前　言

随着化学、化工领域的快速发展，全社会对化学、化工人才的素质尤其是通过英文文献获取和共享信息资源的能力，以及与国外同行进行口语交流的能力，要求也越来越高。为此，华南师范大学化学与环境学院组织相关教师，通过总结多年的专业英语教学经验，联合编写了这部教材。本教材内容选自近年来美国、英国最新出版的大学化学和化工专业教学用书、其它相关正规出版物及 IUPAC（国际纯粹化学和应用化学联合会）化学命名法，主要特点如下：

（1）选材丰富，具有时代感，学生通过学习可以了解到化学、化工专业的新发展和新理念。全书分两个部分，第一部分以无机化学为主，涵盖无机化学、分析化学、无机化学实验等方面的知识；第二部分以有机化学为主，涵盖有机化学、高分子化学、金属有机化学、化学热力学、杂环化学、绿色化学、不对称合成化学、离子液体化学、有机化学实验等方面的知识。

（2）专业词汇量大。书中涵盖专业英语词汇3000个左右，掌握这些词汇以后，可较熟练地阅读各类化学、化工英语期刊图书和其它文献，对于撰写英语论文也有很大帮助。

（3）专业英语单词配有相应音标。专业英语词汇特别是有机化学（化工）专业英语词汇，难发音，音标可以帮助词汇的记忆和掌握。

（4）每课除正文外，还附有词汇、词组和练习题，练习题设计恰当，实用易学。书后还附有英语常用词头和词尾、化学化工常用英文缩写与符号、总词汇表，便于读者查阅和自学。

本书由杨定乔、龙玉华、王升富合编。蓝葆春教授主审了全部稿件，有机合成课题组研究生王欢、张振明、罗人仕、胡萍、梁丽华、夏泽中、张刚对本书的编排做了大量工作，特此表示衷心的感谢。另外，本书的编写和出版得到了化学工业出版社的大力支持，同样表示衷心的感谢。由于编者水平有限，书中疏漏与不妥之处在所难免，恳请读者和同仁提出宝贵意见并批评指正。

编　者

2008年1月于广州

CONTENTS

PART I

1 The Physical Properties of Substances

The study of the properties of substances constitutes an important part of chemistry, because their properties determine the uses to which they can be put.

The properties of substances are their characteristic qualities.

The physical properties are those properties of a substance that can be observed without changing the substance into other substances.

Let us again use sodium chloride, common salt, as an example of a substance. We have all seen this substance in what appear to be different forms—table salt, in fine grains; salt in the form of crystals a quarter of an inch or more across. Despite their obvious difference, all of these samples of salt have the same fundamental properties. In each case the crystals, small or large, are naturally bounded by square or rectangular crystal faces of different sizes, but with each face always at right angles to each adjacent face. The cleavage of the different crystals of salt is the same: when crushed, the crystals always break (cleave) along planes parallel to the original faces, producing smaller crystals similar to the larger ones. The different samples, dissolved in water, have the same salty taste. Their solubility is the same: at room temperature 36 g of salt can be dissolved in 100 g of water. The density of the salt is the same, $2.16 \mathrm{g} \cdot \mathrm{cm}^{-3}$. The density of a substance is the mass (weight) of a unit volume (1 cubic centimeter) of the substance.

There are other properties besides density and solubility that can be measured precisely and expressed in numbers. Such another property is the melting point, the temperature at which a solid substance melts to form a liquid. On the other hand, there are also interesting physical properties of a substance that are not so simple in nature. One such property is the malleability of a substance—the ease with which a substance can be hammered out into thin sheets. A related property is the ductility—the ease with which the substance can be drawn into a wire. Hardness is a similar property: we say that one substance is less hard than the second substance when it is scratched by the second substance. The color of a substance is an important physical property.

It is customary to say that under the same external conditions all specimens of a particular substance have the same physical properties (density, hardness, color, melting point, crystalline form, etc). Sometimes, however, the word substance is used in referring to a material without regard to its state. For example, ice, liquid water, and water vapor may be referred to as the same substance. Moreover, a specimen containing crystals of rock salt and crystals of table salt may be called a mixture, even though the specimen may consist entirely of one substance, sodium chloride. This lack of definiteness in usage seems to cause no confusion in practice.

Vocabulary

property [ˈprɔpəti] *n.* 性质；特性
cleave [kliːv] *vt.* 劈开；裂开
constitute [ˈkɔnstitjuːt] *vt.* 构成；组成
plane [plein] *n.* 平面
characteristic [ˈkæriktəˈristik] *a.* 特有的；*n.* 特性
parallel [ˈpærəlel] *a.* 平行的
original [əˈridʒənl] *a.* 原来的
quality [ˈkwɔliti] *n.* 质量；品质
dissolve [diˈzɔlv] *vt.* 溶解
observe [əbˈzəːv] *vt.* 观察
taste [teist] *vt.* 尝味道；*n.* 滋味
sodium [ˈsəudjəm] *n.* 钠
solubility [sɔljuˈbiliti] *n.* 溶解度
chloride [ˈklɔːraid] *n.* 氯化物
sodium chloride 氯化钠
density [ˈdensiti] *n.* 密度
volume [ˈvɔljum] *n.* 体积
salt [sɔːlt] *n.* 盐
cubic [ˈkjuːbik] *a.* 立方（体）的
appear [əˈpiə] *vt.* 出现；看来（好像）
precisely [priˈsaisli] *a.* 精确地
fine [fain] *a.* 细的
melt [melt] *vt.* & *vi.* 熔化，熔解
grain [grein] *n.* 颗粒
melting point 熔点
crystal [ˈkristl] *n.* 结晶；晶体
malleability [mæliəˈbiliti] *n.* 可锻性；展性
diameter [daiˈæmitə] *n.* 直径
freeze [friːz] (froze [frəuz], frozen [ˈfrəuzn]) *v.* 结冰；*n.* 凝固
sheet [ʃiːt] *n.* 薄片
related [riˈleitid] *a.* 有联系的；相关的
ductility [dʌkˈtiliti] *n.* 延性；延度
across [əˈkrɔs] *ad.* 横过；宽
draw [drɔː] (drew [druː], drawn [drɔːn]) *vt.* 拉
despite [disˈpait] *prep.* 不管；尽管
wire [waiə] *n.* 金属线
obvious [ˈɔbviəs] *a.* 明显的
scratch [skrætʃ] *vt.* 搔；抓；*n.* 刮痕
sample [ˈsæmpl] *n.* 样品；实例
customary [ˈkʌstəməri] *a.* 通常的；惯常的
fundamental [fʌndəˈmentl] *a.* 基本的
bound [baund] *vt.* 邻接；*n.* [常用复数] 界限
external [eksˈtəːnl] *a.* 外部的；外界的
square [skwεə] *n.* 正方形
specimen [ˈspesimin] *n.* 样品；品种
rectangular [rekˈtæŋgjulə] *a.* 矩形的
particular [pəˈtikjulə] *a.* 特别的
size [saiz] *n.* 大小；尺寸
crystalline [ˈkristəlain] *a.* 结晶的
angle [æŋgl] *n.* 角；角度
right angle 直角
vapor [ˈveipə] *n.* （蒸）气
moreover [mɔːˈrəuvə] *ad.* 再者；此外
adjacent [əˈdʒeisənt] *a.* 临近的
contain [kənˈtein] *vt.* 含有；包括
cleavage [ˈkliːvidʒ] *n.* 分裂；分解、裂开
entirely [inˈtaiəli] *ad.* 完全地
crush [krʌʃ] *vt.* 压碎；压扁

definiteness ['definitnis] *n.*	明确
usage ['juːzidʒ] *n.*	用法
substance ['sʌbstəns] *n.*	物质
mixture ['mikstʃə] *n.*	混合物

Phrases

(to) put to use	使用
parallel to	与……平行的
(to)change...into...	把……改变成……
similar to	与……相似的
in the form of	以……形式
on the other hand	另一方面
a quarter of	四分之一
without regard to	不考虑；不顾到
in each case	在每一种情况下
even though	即使
be bounded by	被……限制；与……相邻接

Exercises

1. Put the following into English.

a. 物理性质
b. 溶解度
c. 密度
d. 硬度
e. 展性
f. 熔点
g. 沸点

2. Translate the following into Chinese.

There are other properties besides density and solubility that can be measured precisely and expressed in numbers. Such another property is the melting point, the temperature at which a solid substance melts to form a liquid. On the other hand, there are also interesting physical properties of a substance that are not so simple in nature. One such property is the malleability of a substance—the ease with which a substance can be hammered out into thin sheets. A related property is the ductility—the case with which the substance can be drawn into a wire. Hardness is a similar property: we say that one substance is less hard than the second substance when it is scratched by the second substance. The color of a substance is an important physical property.

2 The Chemical Properties of Substances

2.1 The Chemical Properties of Substances

The chemical properties of a substance are those properties that relate to its participation in chemical reactions.

Chemical reactions are the processes that convert substances into other substances.

Thus sodium chloride has the property of changing into a soft metal, sodium, and a greenish-yellow gas, chlorine, when it is decomposed by passage of an electric current through it. It also has the property, when it is dissolved in water, of producing a white precipitate when a solution of silver nitrate is added to it, and it has many other chemical properties.

Iron has the property of combining readily with the oxygen in moist air to form iron rust; whereas an alloy of iron with chromium and nickel (stainless steel) is found to resist this process of rusting. It is evident from this example that the chemical properties of materials are important in engineering.

Many chemical reactions take place in the kitchen. When biscuits are made with use of sour milk and baking soda there is a chemical reaction between the baking soda and a substance in the sour milk, lactic acid, to produce the gas carbon dioxide, which leavens the dough by forming small bubbles in it. And, of course, a great many chemical reactions take place in the human body. Foods that we eat are digested in the stomach and intestines. Oxygen in the inhaled air combines with a substance, hemoglobin, in the red cells of the blood, and then is released in the tissues, where it takes part in many different reactions. Many biochemists and physiologists are engaged in the study of the chemical reactions that take place in the human body.

Most substances have the power to enter into many chemical reactions. The study of these reactions constitutes a large part of the study of chemistry. Chemistry may be defined as the science of substances-their structure, their properties, and the reactions that change them into other substances.

2. 2 Chemical Changes and Physical Changes

Different kinds of matter have different physical and chemical properties. The properties of a substance are its characteristics. We know one substance from another by their physical and chemical properties. In a physical change the composition of a substance is not changed. Ice can be changed into water. This is a physical change because the composition of water is not changed. In a chemical change the composition of a substance is changed. One or more new substances are formed.

Iron rusts in moist air. When iron rusts, it unites with the oxygen from the air. A new substance is formed. It is iron oxide. It has other different properties. Wood will burn if it is heated in air. When wood burns, it reacts with the oxygen from the air. New substances are formed. They are carbon dioxide and water. Carbon dioxide and water have different properties. Heat is given off if the combustion of any fuel takes place.

The above two cases are chemical changes.

Chemical changes are very common. They are going on around us all the time. Whenever anything burns, there is a chemical change. When iron rusts, the change is a chemical change. A chemical change goes on when things decay.

Physical changes are very common, too. Tearing a piece of paper in two is a physical change. The paper is still paper.

We all know that this is not a chemical change. But we do not always know with ease whether a change is a chemical change or a physical change.

If you dissolve sugar in water， the sugar disappears. You may think that a new material has been formed. But really there is no new material. The sugar is still sugar. You can still taste it. Dissolving anything is a physical change.

When water freezes， the change is a physical change. The water changes from a liquid to a solid. Its chemical formula is still H_2O. The freezing of any liquid is a physical change.

In a word， any change in state is a physical change. When anything melts， it changes from a solid to a liquid. When it evaporates， it changes from a solid or a liquid to a gas. When it condenses， it changes from a gas to a liquid or a solid. But it is the same material still.

Now we see that a chemical change is different from a physical change in that the chemical change causes a change of matter in chemical composition， but the physical change does not.

Vocabulary

participation [paːtisiˈpeiʃən] *n.* 参与
silver [ˈsilvə] *n.* 银； *a.* 银（白）色的
reaction [riˈækʃən] *n.* 反应
nitrate [ˈnaitreit] *n.* 硝酸盐
silver nitrate 硝酸银
process [ˈprəuses] *n.* 过程
convert [kənˈvəː t] *vt.* 转换；转化
add [æd] *vt.* （添）加
greenish-yellow [ˈgriːniʃˈjeləu] *a.* 黄绿色的
iron [ˈaiən] *n.* 铁
chlorine [ˈklɔːriːn] *n.* 氯（气）
combine [kəmˈbain] *vt.* &*vi.* （使）结合
decompose [diːkəmˈpəuz] *vi.* 分解；分析
readily [ˈredili] *ad.* 容易地
passage [ˈpæsidʒ] *n.* 通过
oxygen [ˈɔksidʒən] *n.* 氧
current [ˈkʌrənt] *n.* 电流
moist [mɔist] *a.* 潮湿的
precipitate [priˈsipiteit] *vt.* &*vi.* （使）沉淀； *n.* 沉淀物
rust [rʌst] *n.* 铁（锈）
alloy [ˈælɔi] *n.* 合金
solution [səˈljuːʃən] *n.* 溶液
chromium [ˈkrəumiəm] *n.* 铬
nickel [ˈnikl] *n.* 镍
release [riːˈliːs] *vt.* 放出
stainless [ˈsteinlis] *a.* 不锈的
tissue [ˈtisjuː] *n.* 组织
resist [riˈzist] *vt.* 抵抗；阻挡
biochemist [baiəuˈkemist] *n.* 生物化学家
evident [ˈevidənt] *a.* 明显的
engineering [endʒiˈniəriŋ] *n.* 工程（学）
physiologist [fiziˈɔlədʒist] *n.* 生理学家
biscuit [ˈbiskit] *n.* 饼干
engage [inˈgeidʒ] *vt.* [in] 使从事
sour [ˈsauə] *a.* 酸的
define [diˈfain] *vt.* 规定；下定义
bake [beik] *vt.* 烘；烤
boil [bɔil] *vt.* 煮沸
soda [ˈsəudə] *n.* 苏打；碳酸水
burn [bəːn] *vt.* 燃烧
lactic [læktik] *a.* 乳汁的
lactic acid 乳酸
syrup [ˈsirəp] *n.* 糖浆
formation [fɔːˈmeiʃən] *n.* 形成
leaven [ˈlevən] *vt.* 使发酵

manufacture [mænjuˈfæktʃə] *n.* 制造
dough [dəu] *n.* 生面团
evaporation [ivæpəˈreiʃən] *n.* 蒸发
bubble [ˈbʌbl] *n.* 气泡
human [ˈhjuːmən] *a.* 人类的
unit [juːˈnait] *v.* 结合；化合；团结
digest [diˈdʒest] *vt.* 消化
oxide [ˈɔksaid] *n.* 氧化物
stomach [ˈstʌmək] *n.* 胃
iron oxide 氧化铁；三氧化二铁
intestine [inˈstestin] *n.* （常用复）肠
carbon [ˈkaːbən] *n.* 碳
inhale [inˈheil] *vt.* 吸入
dioxide [daiˈɔksaid] *n.* 二氧化物
hemoglobin [hiːməuˈgləubin] *n.* 血红蛋白
carbon dioxide 二氧化碳
cell [sel] *n.* 细胞
combustion [kəmˈbʌstʃən] *n.* 燃烧
blood [blʌd] *n.* 血液
formula [ˈfɔːmjulə] *n.* 公式；分子式

Phrases

(to) convert…into… 把……转化成
unit…with… 使……同……化合
unit with… 与……化合（或结合、联合）
(to) add to 增加；加入
(to) combine with 与……化合（或联合）
react with… 与……起反应
(to) take place 发生
tear…in two 把……撕成两（块）
be engaged in 正做着；正忙于
in a word 总而言之；总之
(to) enter into 进入
(to) define… as 把……解释为；给……下定义为……
a large part of 大部分的

Exercises

1. **Put the following into English.**
   a. 化学性质
   b. 化学反应
   c. 燃烧
   d. 分子式
   e. 乳酸
   f. 硝酸银
   g. 二氧化碳
   h. 氧化铁
2. **Which of the following processes would you class as chemical reactions?**
   a. The boiling of water.
   b. The burning of paper.
   c. The preparation of sugar syrup by adding sugar to hot water.
   d. The formation of rust on iron.
   e. The manufacture of salt by evaporation of sea water.
3. **Translate the following into Chinese.**

Thus sodium chloride has the property of changing into a soft metal, sodium, and a greenish-yellow gas, chlorine, when it is decomposed by passage of an electric current through it. It also has the property, when it is dissolved in water, of producing a white precipitate when a solution of silver nitrate is added to it, and it has many other chemical properties.

3

Oxidation Numbers of Atoms

The nomenclature of inorganic chemistry is based upon the assignment of numbers (positive or negative) to the atoms of the elements. These numbers, called oxidation numbers, are defined in the following way.

The oxidation number of an atom is a number that represents the electric charge that the atom would have if the electrons in a compound were assigned to the atoms in a certain conventional way.

The assignment of electrons is somewhat arbitrary, but the conventional procedure, described below, is useful because it permits a simple statement to be made about the valences of the elements in a compound without considering its electronic structure in detail and because it can be made the basis of a simple method of balancing equations for oxidation-reduction reactions.

An oxidation number may be assigned to each atom in a substance by the application of simple rules. These rules, though simple, are not completely unambiguous. Although their application is usually a straight-forward procedure, it sometimes requires considerable chemical insight and knowledge of molecular structure. The rules are given in the following statements.

(1) The oxidation number of a monatomic ion in an ionic substance is equal to its electric charge.

(2) The oxidation number of a atom in an elementary substance is zero.

(3) In a covalent compound of known structure the oxidation number of each atom is the charge remaining on the atom when each shared electron pair is assigned completely to the more electronegative of the two atoms sharing it. An electron pair shared by two atoms of the same element is usually split between them.

(4) The oxidation number of an element in a compound of uncertain structure may be calculated from a reasonable assignment of oxidation numbers to the other elements in the compound.

The application of the first three rules is illustrated by the following examples; the number by the symbol of each atom is the oxidation number of that atom:

$Na^{+1}Cl^{-1}$

H_2^0

H^{+1} (hydrogen cation)

$N^{-3}(H^{+1})_3$

$C^{+2}O^{-2}$

$Mg^{+2}(Cl^{-1})_2$

O_2^0

$Cl^{+1}F^{-1}$

$C^{-4}(H^{+1})_4$

$(B^{+3})_2(O^{-2})_3$

C^0 (diamond or graphite)

$(O^{-2}H^{+1})^-$ (hydroxide ion)

$C^{+4}(O^{-2})_2$

$K^{+1}Mn^{+7}(O^{-2})_4$

Fluorine, the most electronegative element, has the oxidation number -1 in all of its compounds with other elements.

Oxygen is second only to fluorine in electronegativity，and in its compounds it usually has oxidation number -2；examples are $Ca^{+2}O^{-2}$，$(Fe^{+3})_2(O^{-2})_3$，$C^{+4}(O^{-2})_2$. Oxygen fluoride，OF_2，is an exception；in this compound，in which oxygen is combined with the only element that is more electronegative than it is，oxygen has the oxidation number $+2$. Oxygen has oxidation number -1 in hydrogen peroxide，H_2O_2，and other peroxides.

Hydrogen when bonded to a nonmetal has oxidation number $+1$，as in $(H^{+1})_2O^{-2}$，$(H^{+1})_2S^{-2}$，$N^{-3}(H^{+1})_3$，$(P^{-2})_2(H^{+1})_4$. In compounds with metals，such as $Li^{+1}H^{-1}$ and $Ca^{+2}(H^{-1})_2$，its oxidation number is -1，corresponding to the electronic structure $H:^{-1}$ for a negative hydrogen ion with completed K shell (helium structure).

Vocabulary

oxidation [ɔksiˈdeiʃən] *n.* 氧化
oxidation number 氧化值
considerable [kənˈsidərəbl] *a.* 相当的；不少的
nomenclature [nəuˈmenklətʃə] *n.* 命名法
insight [ˈinsait] *n.* 见识；见解
monatomic [mɔnəˈtɔmik] *a.* 单原子的
inorganic [inɔː ˈgænic] *a.* 无机的
ionic [aiˈɔnik] *a.* 离子的
assignment [əˈsainmənt] *n.* 指定；分配
elementary [eliˈmentəri] *a.* 基本的；初等的
represent [riːpriˈzent] *vt.* 说明；代表
compound [ˈkɔmpaund] *n.* 化合物
covalent [kəuˈveilənt] *a.* 共价的
assign [əˈsain] *vt.* 指定；分配
share [ʃɛə] *vt.* 共有；分担
conventional [kənˈvenʃənl] *a.* 常规的；惯例的
electron pair [iˈlektrənˈpɛə] 电子对
electronegative [iˈlektrəuˈnegətiv] *a.* 电负性的
somewhat [ˈsʌmwɔt] *ad.* 有点；稍微
arbitrary [ˈaː bitrəri] *a.* 任意的；武断的
split [split] *vt.* 割裂；分裂
procedure [prəˈsiːdʒə] *n.* 程序
reasonable [ˈriːznəbl] *a.* 合理的
describe [disˈkraib] *vt.* 描述；叙述
illustrate [ˈiləstreit] *vt.* 说明
permit [pəˈmit] *vt.* 准许
symbol [ˈsimbəl] *n.* 记号；符号
valence [ˈveiləns] *n.* 价（如原子价，化合价，效价）
fluorine [ˈflu(ː)əriːn] *n.* 氟
peroxide [pəˈrɔksaid] *n.* 过氧化物
detail [ˈdiːteil] *n.* 详情；细节
bond [bənd] *n.* 链；*v.* 连接；结合
application [æpliˈkeiʃən] *n.* 应用
nonmetal [ˈnɔnˈmetl] *n.* 非金属
unambiguous [ˈʌnæmˈbigjuəs] *a.* 清楚的；明确的
shell [ʃel] *n.* 壳；层
straightforward [streitˈfɔːwəd] *a.* 直截了当的；简单的；容易的

Phrases

(be) based (up)on 以……为根据
in detail 详细地
corresponding to 符合；与……一致

Exercises

1. Write the oxidation number of each atom in the following compounds.

a. KCl
b. $CaCl_2$
c. Al_2O_3
d. N_2
e. Fe
f. Na_2O_2
g. $K_2Cr_2O_7$
h. CaF_2
i. Fe_3O_4
j. $LiAlH_4$

2. Translate the following into Chinese.

Oxygen is second only to fluorine in electronegativity, and in its compounds it usually has oxidation number -2; examples are $Ca^{+2}O^{-2}$, $(Fe^{+3})_2(O^{-2})_3$, $C^{+4}(O^{-2})_2$. Oxygen fluoride, OF_2, is an exception; in this compound, in which oxygen is combined with the only element that is more electronegative than it is, oxygen has the oxidation number $+2$. Oxygen has oxidation number -1 in hydrogen peroxide, H_2O_2, and other peroxides.

4 Chemical Calculations

Importance to industry of chemical calculation. To the industrial chemist the chemical equation is of the greatest importance. By means of it he calculates just how much material he needs for a given reaction and how large an amount of product he may hope to get. In actual practice, however, he very seldom gets the full amount of the product as calculated from the equation. Therefore he computes the efficiency of his industrial process, i. e. what fraction the actual yield is of the theoretical yield as computed from the chemical equation. These computations are all based on the chemical equations of the reactions and require only the simplest arithmetical work. They can be classified into several typical cases.

Type 1. molecular weight of a compound from its formula. A formula represents not only the name of the compound but also the weight of a molecule referred to the oxygen atom as 16. To compute the molecular weight of a compound from its formula, we have only to add the weights of all the atoms in the molecule. But since the atomic weights are only relative weights, the molecular weight must be relative also.

For example, the molecular weight of calcium carbonate ($CaCO_3$) is $40+12+(16\times3)$, or 100. Again, the molecular weight of copper sulfate ($CuSO_4$) is $63.6+32+(16\times4)$, or 159.6.

Another example. Find the molecular weight of gypsum ($CaSO_4 \cdot 2H_2O$). Now gypsum is crystallized into calcium sulfate, and each molecule of calcium sulfate carries along two molecules of water. This so-called *water of hydration* or of crystallization is chemically united with the calcium sulfate, as is indicated by the dot in the formula, which means in this place *plus*. The molecular weight then of $CaSO_4 \cdot 2H_2O$ is $40+32+(16\times4)+2(2+16)$, or 172.

Perhaps a better term for molecular weight is formula weight because it more accurately describes what it actually is.

Type 2. Percentage composition of a compound from its formula. If the chemist knows the formula of a compound and has a table of atomic weights, he can easily work out the percentage of each element present in the compound.

For example, he wishes to find the percentage composition of calcium carbonate ($CaCO_3$). The atomic weight of calcium is 40, of carbon is 12, and of oxygen is 16; $40+12+(16\times3)$ make the formula weight 100. Therefore calcium carbonate contains 40/100, or 40 percent calcium, 12/100, or 12 percent carbon, and 48/100, or 48 percent oxygen. This problem is especially easy because the formula weight is equal to 100.

Another example. Find the percentage composition of potassium chlorate ($KClO_3$). The atomic weight of potassium is 39, of chlorine 35.5, and of oxygen 16, then the formula weight is $39+35.5+(16\times3)$, or 122.5. Therefore potassium chlorate contains

$$\frac{39}{122.5}=0.318, \text{ or } 31.8\% \text{ potassium,}$$

$$\frac{35.5}{122.5}=0.290, \text{ or } 29.0\% \text{ chlorine, and}$$

$$\frac{48}{122.5}=0.392, \text{ or } 39.2\% \text{ oxygen}$$

Check. Total is 100.0%.

Still another example. How much metallic copper can be got from a ton (2000 lbs.) of crystallized copper sulfate? Given the formula of copper sulfate crystals as $CuSO_4 \cdot 5H_2O$. The formula weight of this compound is $63.6+32+(16\times4)+5(2+16)$, or 249.6.

The percentage of copper is $63.6/249.6=0.255$, or 25.5 percent, and the weight of copper in a ton of copper sulfate crystals is 0.255×2000, or 510 lbs.

In general, to find the percentage composition of a compound from its formula, first calculate the formula weight, then divide the atomic weight of each element by this formula weight, and express the quotient as a decimal. Keep three significant figures. The first two decimals express the percentage.

Type 3. Problems involving weight only. For example, what weight of iron will be just enough to unite with 10 grams of sulfur to form iron sulfide (FeS)?

To avoid mistakes it is well to arrange the work very clearly and to do it methodically.

We first write the equation:

$$Fe+S \longrightarrow FeS$$

Then we write under each symbol and formula the weight it represents:

$$\underset{56}{Fe}+\underset{32}{S}\longrightarrow\underset{88}{FeS}$$

This means that 56 parts by weight of iron combine with 32 parts by weight of sulfur to give 88 parts by weight of iron sulfide. We have here quantitative meaning of the equation.

Next, we again read the problem and place above the symbol for sulfur the actual weight given, which is 10g, and above the formula for iron X g, which is the weight we wish to find:

$$\underset{56}{\overset{X\text{ g}}{Fe}}+\underset{32}{\overset{10\text{g}}{S}}\longrightarrow\underset{88}{FeS}$$

Finally we state the equation between the ratios of the actual to the formula weights thus:

$$\frac{X}{56}=\frac{10}{32}$$

Hence $X=\frac{56\times10}{32}$, or 17.5 grams of iron

Now we shall check up the reasonableness of our answer by roughly estimating what it ought to be. In this case we know that 56 parts of iron will unite with 32 parts of sulfur. Therefore we shall need about seven-fourths as much iron as the sulfur with which we started. Hence our answer 17.5 is reasonable. In this way we may quickly detect such a mistake as the misplacing of a decimal point or the inverting of a fraction.

Another example. Suppose we want to calculate what weight of iron sulfide (FeS) can be made from 10 grams of sulfur, assuming that the necessary iron is available.

$$Fe+\underset{32}{\overset{10\text{g}}{S}}\longrightarrow\underset{88}{\overset{X\text{ g}}{FeS}}$$

$$\frac{X}{88}=\frac{10}{32}$$

$$X=\frac{88\times10}{32}=27.5\text{ grams of iron sulfide}$$

Check. Wt. of iron(17.5)+ wt. of sulfur (10g)=wt. of iron sulfide (27.5g)

Another method of attack. We know that 32 grams of sulfur yield 88 grams of iron sulfide (FeS) when properly combined with sufficient iron. Then 1 gram of sulfur would yield 1/32 of 88 grams of iron sulfide and 10 grams of sulfur would yield 10 times 1/32 of 88 grams i. e., $\frac{88\times10}{32}$, or 27.5 grams.

The arithmetical computation amounts to the same as that given above, but the method of reasoning is perhaps more direct.

Quantitative meaning of equations. As we have seen, an equation when properly balanced gives us a good deal of valuable information. It tells us what substances react and what the products are. It likewise gives us the number of molecules of each substance involved. And finally, by using the formula weights, we learn the relative weights of the different substances in the equation.

For example, in the equation for preparing oxygen by heating potassium chlorate, we may compute the relative weights of potassium chlorate, potassium chloride, and oxygen thus:

$$\begin{array}{ccccc} 2KClO_3 & \longrightarrow & 2KCl & + & 3O_2 \\ (2\times 122.5) & & (2\times 74.5) & & (3\times 32) \\ 245 & & 149 & & 9.6 \end{array}$$

The formula weight of each molecule may be found by adding the atomic weight of the elements involved:

$$\text{formula wt. of } KClO_3 = 39 + 35.5 + (16\times 3) = 122.5$$

$$\text{formula wt. of } KCl = 39 + 35.5 = 74.5$$

$$\text{formula wt. of } O_2 = 2\times 16 = 32$$

Since there are two molecules of potassium chlorate and of potassium chloride in the equation, we multiply their formula weights by two. And as there are three molecules of oxygen, we multiply its formula weight by three.

We can now read this equation as follows: 245 parts by weight of potassium chlorate give 149 parts by weight of potassium chloride and 96 parts by weight of oxygen.

Significant figures. The atomic weights that are to be used in solving chemical problems are the approximate values in the periodic table. These are not the most accurate values which have been determined, but they are close enough for practical purposes. It is only in very accurate chemical work that we use the most precise values that have been obtained. It will be seen that these numbers have not more than three figures in them; the fourth, fifth, or sixth figure counting from the left has been rounded off. For example, the precise atomic weight of barium is 137.37. We call this 137. In the same way, in carrying out arithmetical processes we should express the answer in the nearest three figures, since we have used atomic weights that have not more than three figures in them, the fourth, fifth, or sixth figures in a possible answer will have no significance. We therefore say that chemical problems should be carried to but three significant figures. Zeros which occur before a set of numbers, as for example in 0.00672, are not considered as significant figures; the three significant figures here are 6, 7 and 2.

Five steps in solving weight problems. Experience has shown that it is quicker and that there is less chance for error if we proceed in the solution of chemical problems in a systematic way. The following steps are suggested:

(1) Write the complete equation for the reaction in question.

(2) Write the formula weight under the formula of each substance involved in the problem.

(3) Write above the formula of the substance the actual weight which is given place X (g. or lbs.) above the formula of the substance the weight of which we wish to find.

(4) Make an equation of two fractions. One should be the actual weight over the formula weight of the substance given, and the other has the X over the formula weight of the substance required. The actual weights are the numerators and the formula weights the denominators.

(5) Solve this equation and decide whether the answer is reasonable by making a rough calculation as to what the answer should be.

An illustrative problem. How many grams of potassium chlorate are necessary to prepare 10 grams of oxygen?

Let us proceed according to the following five steps:

(1) Write the complete equation.

$$2KClO_3 \longrightarrow 2KCl + 3O_2$$

(2) Underwrite the formula weights.

$$\begin{array}{lcl} 2KClO_3 & \longrightarrow & 2KCl + 3O_2 \\ (2\times122.5) & & \qquad(3\times32) \\ \quad 245 & & \qquad\quad 96 \end{array}$$

(3) Write in the actual weights.

$$\begin{array}{lcl} \quad X\text{ g} & & \qquad\quad 10\text{g} \\ 2KClO_3 & \longrightarrow & 2KCl + 3O_2 \\ (2\times122.5) & & \qquad(3\times32) \\ \quad 245 & & \qquad\quad 96 \end{array}$$

(4) Make the fractional equation.

$$\frac{X}{245} = \frac{10}{96}$$

(5) Solve. $96X = 10\times245$

$$X = \frac{245\times10}{96} = 25.5 \text{ grams. Answer.}$$

Check. Since 245 is about 2.5 times 96, we should expect the answer to be about 25g.

Vocabulary

seldom [ˈseldəm] *ad.* 不经常；很少
ton [tʌn] *n.* 吨
compute [kəmˈpjuːt] *vt.* 计算
quotient [ˈkwəuʃənt] *n.* 商
efficiency [iˈfiʃənsi] *n.* 效率
decimal [ˈdesiməl] *n.* 小数
theoretical [θiəˈretikəl] *a.* 理论上的
significant [sigˈnifikənt] *a.* 有意义的
significant figure 有效数字
arithmetical [æriθˈmetikəl] *a.* 算术的
classify [ˈklæsifai] *vt.* 分类
involve [inˈvɔlv] *vt.* 涉及
relative [ˈrelətiv] *a.* 相对的；有关的
gram [græm] *n.* 克
calcium [ˈkælsiəm] *n.* 钙
calcium carbonate 碳酸钙
sulfur [ˈsʌlfə] *n.* 硫
avoid [əˈvɔid] *vt.* 避免

copper [ˈkɔpə] *n.* 铜
copper sulfate 硫酸铜
arrange [əˈreidʒ] *vt.* 排列；安排
methodically [miˈθɔdikəli] *ad.* 有条不紊
gypsum [ˈdʒipsəm] *n.* 石膏
quantitative [ˈkwɔntitətiv] *a.* 数量的
crystallize [ˈkristəlaiz] *vt.* 使结晶
meaning [ˈmiːniŋ] *n.* 意义
hydration [haiˈdreiʃən] *n.* 水合作用
ratio [ˈreiʃiəu] *n.* 比率；比例
indicate [ˈindikeit] *vt.* 指出；表示
hence [hens] *ad.* 因此
dot [dɔt] *n.* 点
reasonableness [ˈriːzənəblnis] *a.* 合理性
perhaps [pəˈhæps] *ad.* 或许
estimate [ˈestimeit] *vt.* 估计
accurately [ˈækjuritli] *ad.* 准确地
detect [diˈtekt] *vt.* 觉察；发觉
percentage [pəˈsentidʒ] *n.* 百分数
misplace [ˈmisˈpleis] *vt.* 错放
composition [kɔmpəˈziʃən] *n.* 构成；组成
decimal point 小数点
potassium [pəˈtæsjəm] *n.* 钾
potassium chlorate 氯酸钾
invert [inˈvəːt] *vt.* 颠倒
assume [əˈsjuːm] *vt.* 假定；假设
check [tʃek] *v.* 核对；检验
available [əˈveiləbl] *a.* 可供利用的
accurate value (= available value) 精确值
wt. =weight [weit] *n.* 重量
attack [əˈtæk] *vt.* & *n.* 着手（工作等）
barium [ˈbæriəm] *n.* 钡
reason [ˈriːzn] *vt.* 推理
experience [iksˈpiəriəns] *n.* 经验
properly [ˈprɔpəli] *ad.* 适当地
chance [tʃaːns] *n.* 机会
valuable [ˈvæljuəbl] *a.* 有价值的
error [ˈerə] *n.* 错误
information [ˈinfəmeiʃən] *n.* 情报；知识
proceed [prəˈsiːd] *vt.* 进行
likewise [ˈlaikwaiz] *ad.* 同样地
systematic [sistiˈmætik] *a.* 系统的
multiply [ˈmʌltiplai] *vt.* & *vi.* 乘
numerator [ˈnjuːməreitə] *n.* 分子
value [ˈvæljuː] *n.* 价值；值
denominator [diˈnɔmineitə] *n.* 分母
periodic [piəriˈɔdik] *a.* 周期的
periodic table 周期表
illustrative [ˈiləstreitiv] *a.* 说明的；示范的
accurate [ˈækjurit] *a.* 正确的；精确的
suggest [səˈdʒest] *vt.* 提议；建议
close [kləus] *a.* 接近的；靠近的
underwrite [ˈʌndərait] *vt.* 把……写在下面
precise [priˈsais] *a.* 精确的
fractional [ˈfrækʃənl] *a.* 分数的
expect [iksˈpekt] *vt.* 期望；预期

Phrases

by mean of 借助于……
(to) multiply A by B 以 B 乘 A
in actual practice of 在实际操作中
as follows 如下
have to 必须
(to) round off 圈掉；舍去
(to) carry along 带有
in the same way 同样
(to) divide A by B 以 B 除 A
(to) carry out 进行；实行
the ratio of A to B A 与 B 之比
in question 讨论中的；谈到的

(to) check up	核对；检验	according to	根据……；按照……
as to	关于	(to) amount to	相当于；等于
in this way	这样	a good deal of	许多

Exercises

1. **Find the molecular weight of each compound.**
   a. aluminium sulfate
   b. carbon dioxide
   c. aluminium potassium sulfate
2. **Find the percentage composition of carbon dioxide.**
3. **How much metallic tungsten can be got from a kilogram of tungsten trioxide?**
4. **How many grams of potassium chlorate are necessary to prepare 48 grams of oxygen?**

5 The Classification of Inorganic Compounds

5.1 The Classes of Compounds

Thousands and tens of thousands of compounds are known to the chemists today. It would be impossible to learn properties and behavior of even a fraction of this number if it had to be done on the basis of individual compounds. Fortunately, most chemical compounds can be grouped together in a few classes. Then, if we can properly classify a compound, we are at once aware of the general properties of the compound from knowledge of the properties of that class or group of compounds. For example, HCl is classed as an acid, and by becoming familiar with the behavior of acids as a distinct class, we are at once aware of the general properties of the compound. A great many of the compounds we are to study may be classified as acids, bases, salts, metallic oxides, or nonmetallic oxides, of these five classes of compounds, the first three—acids, bases, and salts—are by far, the most important.

When an acid, base, or salt is dissolved in water the resulting solution is a conductor of the electric current and is termed an electrolyte. If no conduction of current occurs, the compound is known as a nonelectrolyte. Classification of common compounds.

By looking at the chemical formulas we may classify many common compounds in the following way:

(1) Acid, in the conventional sense, may be recognized by noting that the H is written first in the formula and that the rest of the compound is generally nonmetallic. Ex., HCl, H_2SO_4, $HClO$.

(2) Conventional bases have OH radicals written last in the formula. The first part of the formula is usually a metal. Ex., $NaOH$, $Ca(OH)_2$, $Fe(OH)_3$.

(3) A salt consists of a metal, written first, combined with a non-metal or radi-

cal written last in a formula. Ex., $NaCl$, $Fe_2(SO_4)_3$, $Ca(ClO)_2$.

(4) Oxides are compounds containing oxygen and only one other element.

If the element other than oxygen is a nonmetal, the oxide is classed as a nonmetal oxide or an acidic anhydride. The latter name comes about because water added to nonmetal oxides under certain conditions produces acids. Likewise, if water is removed from an acid containing oxygen, the acid anhydride (without water) results.

The other class of oxides, metallic oxides or basic anhydrides, consist of oxygen combined with a metal. When water is added under proper conditions to basic anhydrides, bases result and vice versa.

5.2 Acids

All acids in the conventional sense contain hydrogen, which may be replaced by metals. The negative portion of the acid molecule if composed of a nonmetal or a radical (negative valence group). These negative valence groups (except oxide and hydroxide) are often referred to as acid radicals. All acids are covalent compounds in which the atoms are held together by a sharing of electrons. When an acid is dissolved in water, ions are formed as a result of the transfer of a hydrogen ion (proton) from the acid molecule to the water molecule—for example.

$$H:\underset{\cdot\cdot}{\ddot{Cl}}: + H:\underset{\cdot\cdot}{\ddot{O}}:H \longrightarrow [H:\underset{H}{\ddot{O}}:H]^+ + [\,:\underset{\cdot\cdot}{\ddot{Cl}}:\,]^-$$

This is a case of coordinate valence, in which an unused pair of electrons from the water molecule combines with a hydrogen ion to form a hydronium ion. The hydronium ion is a hydrated hydrogen or proton ($H^+ \cdot H_2O$) and, while the ionization of acids in aqueous solution depends on its formation, we shall ordinarily use the simple H^+ in writing equations. Such equations are thereby simplified and easier to balance.

The chief characteristic of an acid is its ability to furnish hydrogen ions (proton), therefore, an acid is usually defined as a substance which may furnish protons.

PROPERTIES OF ACIDS. In general, aqueous solutions of acids are characterized by the following properties:

(1) They have a sour taste. Lemons, oranges, and other citrus fruits owe their sour taste to the presence of citric acid; the taste of sour milk is due to the presence of lactic acid.

(2) They turn blue litmus paper red. Litmus is a dye which has a red color in acid solution and a blue color in basic solution; paper which has been soaked in litmus is referred to as litmus paper. Substances of this type, which enable us to determine whether a given solution is acid or basic, are called indicators. Methyl orange and phenolphthalein are other indicators frequently used by chemists.

(3) They react with certain metals to produce hydrogen. Reactions of this type were studied in connection with the preparation of hydrogen.

(4) They react with bases to produce salts and water.

Common strong acids are H_2SO_4, HNO_3, HCl, HBr, and HI. Most other acids are generally only partially ionized and consequently only moderately strong or weak.

5.3 Bases

All metallic hydroxides are classed as conventional bases. Of the common bases only NaOH, KOH, $Ca(OH)_2$ and $Ba(OH)_2$ are appreciably soluble in water. If these compounds are dissolved in water, the OH^- is common to all of their solutions.

An aqueous solution of NH_3 is also classed as a base, since OH^- ions are present in the solution.

In each of these compounds we find a combination of a metal (or NH_4) with the hydroxide group. Just as the characteristic part of an acid is hydrogen ion, so the characteristic part of a base in water solution is the hydroxide ion, OH^-. Later the concept of a base will be extended to include substances which do not furnish hydroxide ions in solution.

PROPERTIES OF BASES. In general, water solutions of metallic hydroxides (bases) exhibit the following properties:

(1) Bitter taste.

(2) Soapy or slippery feeling.

(3) Turn red litmus paper blue.

(4) React with acids to form salts and water.

(5) Most metallic hydroxides are insoluble in water. Of the common ones, only NaOH, KOH, $Ca(OH)_2$, $Ba(OH)_2$ and NH_3 are soluble.

The common strong bases are NaOH, KOH, $Ca(OH)_2$ and $Ba(OH)_2$.

5.4 Salts

An acid reacts with a base to produce a salt and water. Hydrogen from the acid combines with hydroxide from the base to form water molecules.

The reaction of an acid with a base is called neutralization. If all the water is removed by evaporation from the solution after the reaction, the positive ions from the base and the negative ions from the acid form a crystal lattice of solid salt.

It was shown that the compound sodium chloride, a salt, is an electrovalent compound and is ionized in the solid or crystalline state. The crystal is made up of positive sodium ions and negative chloride ions oriented in a definite pattern. In general, most salts in the crystalline state are electrovalent and are composed of ions oriented in a definite way.

Vocabulary

chemist [ˈkemist] *n.* 化学家
acid radical 酸根
individual [indiˈvidjuəl] *a.* 个别的；单独的

share [ʃɛə] *v.* 共享；分享
classify [ˈklæsifai] *vt.* 分类
transfer [ˈtrænsfəː] *n.* [trænsˈfəː] *v.* 转移
conventional [kənˈvenʃənl] *a.* 传统的；通常的
coordinate [kəuˈɔːdinit] *v.* 配位
hydronium [haiˈdrəuniəm] ion 水合氢离子
become [biˈkʌm] *vt.* 变成；*vt.* 适合，与……相称
ionization [aiənaiˈzeiʃən] *n.* 离子化；电离
radical [ˈrædikəl] *n.* 基；根；原子团
acidic [əˈsidik] *a.* 酸的；酸性的
aqueous [ˈeikwiəs] *a.* 水的
anhydride [ænˈhaidraid] *n.* 酐
equation [iˈkweiʃən] *n.* 方程式
likewise [ˈlaikwaiz] *ad.* 同样
simplify [ˈsimplifai] *v.* 简化
basic anhydride 碱酐
balance [ˈbæləns] *n.* 天平，平衡；*v.* 平衡
vice versa [ˈvaisiˈvəːsə] 反之亦然
chief [tʃiːf] *a.* 主要的
negative [ˈnegətiv] *a.* 负的；阴的
ability [əˈbiliti] *n.* 能力
furnish [ˈfəːniʃ] *vt.* 提供；供给
react [ri(ː)ˈækt] *vi.* 反应(with，on)
reaction [ri(ː)ˈækʃən] *n.* 反应
substance [ˈsʌbstəns] *n.* 物质
sour [ˈsauə] *a.* 酸的，酸味的；*v.* 变酸
strong acid 强酸
taste [teist] *n.* 味道；气味；味觉
ionize [ˈaiənaiz] *vt.* 离子化；电离
lemon [ˈlemən] *n.* 柠檬
moderately [ˈmɔdəritli] *ad.* 中等地；适度地
orange [ˈɔrindʒ] *n.* 柑，橘；橙色
citric [ˈsitrik] *a.* 柠檬的
appreciably [əˈpriːʃiəbli] *ad.* 明显地；可看到地
citric acid 柠檬酸
bitter [ˈbitə] *n.* 苦味
citrus [ˈsitrəs] *n.* 柑橘属
soapy [ˈsəupi] *a.* 肥皂般地；滑腻地
lactic [ˈlæktik] *a.* 乳的
lactic acid 乳酸
slippery [ˈslipəri] *a.* 滑的
neutralization [njutrəlaiˈzeiʃə] *n,* 中和
litmus [ˈlitməs] *n.* 石蕊
litmus paper 石蕊试纸
evaporation [iˈvæpəˈreiʃən] *n.* 蒸发
positive [ˈpɔzətiv] *a.* 正的；阳的
positive ion 正离子
dye [dai] *n.* 染料
soak [səuk] *v.* *n.* 浸泡，浸渍
negative ion 负离子
enable [iˈneibl] *vt.* 使……能够
lattice [ˈlætis] *n.* 格子；点阵
indicator [ˈindikeitə] *n.* 指示剂
crystal lattice 晶格
methyl [ˈmeθil] *n.* 甲基
methyl orange 甲基橙
electrovalent [ilektrəuˈveilənt] *a.* 电价的
phenolphthalein [fiːnɔlˈfθæleiːn] *n.* 酚酞
orient [ˈɔː riənt] *vt.* 定向；取向
pattern [ˈpætən] *n.* 模型；形式

Phrases

thousand and tens of thousands 成千上万
in the conventional sence 按传统的观念（常识）
be known to... 被……所知
come about 发生；出现
a fraction of 一小部分
other than... 与……不同的；除……以外的

on the basis of...	根据……；在……基础上
hold together	结合在一起
at once	立即；立刻
define as	定义为……
aware of...	知道；意识到……
enable to （+ing）	使……能够(……)
familiar with...	熟悉；通晓
(have) in connection with	与……有关；在……方面
a great (good) many of...	很多；大量
look at...	考察；注视

Exercises

1. Can you properly classify the following compounds?

a. ammonium hydroxide
b. ammonium chloride
c. nitric acid
d. sodium phosphate
e. calcium chloride
f. carbon dioxide
g. calcium carbonate
h. calcium oxide
i. silicon dioxide
j. potassium hydroxide

2. Translate the following into Chinese.

If the element other than oxygen is a nonmetal, the oxide is classed as a nonmetal oxide or an acidic anhydride. The latter name comes about because water added to nonmetal oxides under certain conditions produces acids. Likewise, if water is removed from an acid containing oxygen, the acid anhydride (without water) results.

6 Acids and Bases

6.1 Historical Background

Acids as a class of compounds were well known to the alchemists, who noted their sour taste (Latin acids, "sour"), their ability to dissolve many water-insoluble substances, and their action on various vegetable dyes. When Priestly announced his discovery of "dephlogisticated air" in 1775, Lavoisier, whose experiments on combination had started the overthrow of the phlogiston theory, concluded that in combination. Accordingly, he named the new substance oxygen (French oxys, "sharp" or "acid", plus genesis). The German name Sauerstoff is a translation of the French name. Davy proved that not all acids contain oxygen and proposed that hydrogen was the common constituent of acids. Liebig firmly established the protonic concept of acids and described an acid as a substance composed of a replaceable hydrogen and an acid radical.

Arrheniue and Ostwald's theory of electrolytic dissociation led to the present-day view of acid-base equilibria in water. Here the theory focuses on the self-dissociation or autoprotolysis of water.

$$HOH \rightleftharpoons H^+(aq) + OH^-(aq)$$

At 25℃ about one in every half-billion water molecules is dissociated into a hydrogen ion and a hydroxide ion. An aqueous solution is said to be neutral when the concentrations of hydrogen ions and hydroxide ions are equal, acidic when there are more hydrogen ions, and basic when there are more hydroxide ions. We can increase the hydrogen ion concentration either by adding a substance that provides additional hydrogen ions for the system, such as hydrogen chloride, or by adding a substance that will remove hydroxide ion from the system, such as boric acid.

$$B(OH)_3 + OH^- \rightleftharpoons B(OH)_4^-$$

Such substances are termed acids. Similarly, the hydroxide ion concentration may be increased by direct dissociation to produce hydroxide ions, as in the case of sodium hydroxide, or by combination with hydrogen ions in solution, as in the case of ammonia. Combination processes of the latter type often are referred to as hydrolysis. Neutralization reactions in water consist of combining hydrogen ions and hydroxide ions to form water.

Many solvents other than water undergo autoprotolysis, and acid-base equilibrium in these solvents may be treated on a conceptual basis similar to the Arrhenius-Ostwald picture. Thus in liquid ammonia, a substance producing ammonium ions would be an acid, a substance producing amide ions would be a base, and a neutralization reaction would consist of the reaction of ammonium ion and amide ion to produce ammonia. A more general solvent theory defines an acid as a substance that produces positive solvent ions and a base as a substance that produces a negatively charged solvent ion. Neutralization consists of combining these ions to produce solvent.

A protonic picture that does not require solvent participation was presented by Brönsted and Lowry in 1923. According to their views, an acid is a proton donor and a base is a proton acceptor. In an acid-base reaction, a proton is transferred from an acid to a base to produce another acid, termed the conjugate acid of the original base, and another base, termed the conjugate base of the original acid.

$$\begin{array}{llllll} HCl & + NH_3 & \longrightarrow & NH_4^+ & + & Cl^- \\ \text{acid} & \text{base} & & \text{conjugate} & & \text{conjugate} \\ & & & \text{acid} & & \text{base} \end{array}$$

A general theory of acids and bases covering all the preceding cases and extending the definition to some substances not included above was set forth by G. N. Lewis, who defined an acid as an electron pair acceptor and a base as an electron pair donor. Neutralization in the Lewis theory consists of the formation of a new covalent bond between an electron pair donor and an electron pair acceptor.

$$\begin{array}{llll} BF_3 & +(CH)_3N: & \longrightarrow & (CH_3)_3N:BF_3 \\ \text{acid} & \text{base} & & \end{array}$$

This chapter deals mainly with the factors that affect the relative of acids and bases. Protonic acids are treated first since there are fewer factors involved than with other Lewis acids and, in the case of protonic acids; these factors are more easily isolated. The pK_a—that is, $-\lg K_a$—will be used often here; the higher the numerical value of the pK_a, the weaker the acid under discussion. For the acid HA, the dissociation constant, K_a, is defined by the activity quotient $K_a=[H^+_{aq}][A^-]/[HA]$.

Usanovitch has given the most general definition of an acid: "An acid is any material which forms salts with bases through neutralization, gives up cations, combines with anions, or electrons." All of these characterizations are useful: the one selected should be the one simplest to apply to the system under study. Thus in aqueous solutions of protonic acids, chemists use the dissociation constant as a measure of acid strength. The bulk of the data currently available are such K_a values. By emphasizing proton transfer as the acid-base reaction, the Brönsted-Lowry picture makes acid-base reactions analogous to oxidation-reduction reactions, in which the electron transfer is the essential defining process. Just as a total oxidation-reduction can be split into half-reactions involving the oxidized and reduced form of a giving reagent, a proton transfer reaction can be broken into half-reactions involving the protonated and unprotonated form of a given base: $B + H^+ \longrightarrow BH^+$. The heat released in such a gas phase reaction is referred to as the proton affinity (PA) of B.

The choice of the appropriate acid-base model depends on the intended use. The Ostwald dissociation picture serves for most situations involving hydrogen ion equilibria in aqueous solution. The Brönsted-Lowry picture sets limits on the intrinsic protonic acidity or basicity through the proton affinity scale and suggests the degree of attenuation of protonic acidity scales in different solvents. Dissection of factors influencing the strength of acids and bases is best carried out using proton affinity data. Comparison with solution data then permits us to assess solvation effects. The many parallelisms between protonic acids and Lewis acids allow us to extend our picture of protonic acids to a broader range of systems, such as coordination complexes. However, such an increase in generality requires that greater care be exercised with regard to the possible changes in multiple-bond character, steric effects, chelate effects, etc, that may accompany the acid-base reaction. Finally, the Usanovitch definition' s extreme generality allows us to use knowledge about any one of the factors covered, such as the ability to combine with electrons, to reveal something about acidity in a "more conventional" —that is, a Lewis-sense.

6.2 Bronsted's and Lewis' Acid-base Concepts

(1) Brönsted-Lowry concept

According to this concept, an acid is a substance that releases protons(a proton donor) and a base is a substance that combines with protons(a proton acceptor). Neutralization reactions involve the transfer of protons. Salts are merely aggregates of ions that are produces in some but not all neutralization reactions.

Upon loss of a proton, an acid forms a base, since by the reverse reaction the substance formed can gain a proton. In the same way a base forms an acid upon gaining a proton. These relationships can be represented by equations.

$$\text{Acid}(1) \rightleftharpoons H^+ + \text{Base}(1)$$

$$\text{Base}(2) + H^+ \rightleftharpoons \text{Acid}(2)$$

The acid and base represented are a conjugate pair; that is an acid forms its conjugate base upon loss of a proton and a base forms its conjugate acid when it gains a proton.

(2) Lewis concept

G. N. Lewis proposed another acid-base concept in the same year(in 1923) that the Brönsted-Lowry concept appeared. Lewis defined an acid as a molecule or ion that can accept an electron pair from another molecule or ion, and a base as a substance that can share its electron pair with an acid. Thus, an acid is an electron-pair acceptor and a base is an electron-pair donor.

It is evident that the Lewis concept applies not only to the chemical behavior correlated by the Brönsted-Lowry concept, but also to many chemical reactions that do not involve proton transfer, and for this reason it is most useful.

Vocabulary

sour [ˈsauə] *a.* 酸的；酸味的
donor [ˈdəunə] *n.* 给（予）体
alchemist [ˈælkimist] *n.* 炼金术士
acceptor [əkˈseptə] *n.* 接受体
neutralize [ˈnjuːtrəlaiz] *vt.* 使中和
aggregate [ˈægrigit] *n.* & *a.* 聚集（体）
[ˈægrigeit] *v.* 总计；聚集
neutralization [ˌnjuːtrəlaiˈzeiʃən] *n.* 中和
dissociate [diˈsəuʃieit] *vt.* 使分解
electron pair [iˈlektrənpεə] 电子对
conjugate [ˈkɔndʒugit] *a.* 共轭的
attenuation [əˌtenjuˈeiʃən] *n.* 变薄；稀薄化；变细；衰减
Lavoisier 拉瓦锡（Antoine Laurent, 1743—1794），法国化学家，氧发现者

Phrases

depend (up) on... 取决于……
for this reason 为此；因此之故
lose out 输掉；失败
not only... but also 不但……而且

Exercises

1. Indicate the conjugate bases of the following substances.

a. NH_3
b. H_2O
c. HI
d. HSO_4^-

2. Indicate the conjugate acids of the following substances.

a. NH_3
b. H_2O

c. HSO_4^-
d. CH_3^-

7 Neutralization—Acids Reacts with Bases

The reaction of an acid with a base is called neutralization. This type of chemical reaction is very important. For example, if you allow a solution of Drano or oven cleaner(both of which contain lye, NaOH) to remain in contact with your skin or fabrics or floor covering, it will cause damage. The first thing to do is to wash away, with a lot of water, as much lye as possible. Then remaining lye can be neutralized by adding vinegar, an acid.

A simple type of neutralization involves the reaction between acids and hydroxides. One example is the reaction between: hydrochloric acid and sodium hydroxide:

$$HCl + NaOH \longrightarrow H_2O + NaCl$$

Hydrochloric acid + sodium hydroxide ⟶ water + sodium chloride

In this equation and others in this article, we write the formulas for the substances in as simple a manner as possible. You now should recognize that writing hydrochloric acid as HCl is a shortcut for 'H^+ attached to water molecules $+Cl^-$ ions'. The formula NaCl really means 'Na^+ ions + Cl^- ion in water solution'.

The words we have written beneath this example provide a generalization: Acid + hydroxide ⟶ water + salt. The term salt is broader in meaning than only NaCl. A salt is a compound formed by the anion from an acid(the negative ion combined with H^+) and the cation from the hydroxide(the positive ion combined with OH^-). A completely general equation for this type of neutralization reaction is

$$H(\text{anion}) + (\text{cation})OH \longrightarrow H_2O + (\text{cation})(\text{anion})$$

For example,

HNO_3	+	NaOH	⟶	H_2O	+	$NaNO_3$
nitric acid		sodium hydroxide		water		sodium nitrate
HCl	+	$NH_3 \cdot H_2O$	⟶	H_2O	+	NH_4Cl
hydrochloric acid		ammonium hydroxide		water		ammonium chloride

In these examples, note that in nitric acid, HNO_3, the anion is the group of atoms NO_3^-, called the nitrate anion, with an electric charge of -1. One of the products of its neutralization reaction with NaOH is the salt $NaNO_3$, the combination of Na^+ cations with NO_3^- anions. The appropriate name for this combination of ions is sodium nitrate. If you follow the same systematic interpretation for the third example, you will recognize the ammonium ion, NH_4^+, as a group of atoms that stay together as a cation, that reaction forms the salt ammonium chloride, NH_4Cl.

We are illustrating here another of the ways a generalization greatly simplified chemistry. Learning one additional feature of this generalization enables you to write correct chemical equations to predict literally thousands of neutralization reactions. We can illustrate this additional idea by writing equations for reactions that involve water solutions of sulfuric acid, H_2SO_4.

$$\begin{array}{lllllll} H_2SO_4 & + & 2NaOH & \longrightarrow & 2H_2O & + & Na_2SO_4 \\ \text{sulfuric acid} & & \text{sodium hydroxide} & & \text{water} & & \text{sodium sulfate} \end{array}$$

The acid H_2SO_4 consists of two H^+ ions and one sulfate anion, SO_4^{2-}. Note that, because the formula H_2SO_4 must represent an electrically neutral substance, the charge of the SO_4^{2-} anion must be -2. This means that the salt, sodium sulfate, must contain two Na^+ in place of the two H^+ of the acid. The correct formula for sodium sulfate is Na_2SO_4. The equation then is balanced by using the correct coefficients 2 in front of the formulas NaOH and H_2O. For every H^+ from the acid, an OH^- from the hydroxide must be added to form a molecule of H_2O. If a neutralization reaction involves phosphoric acid H_3PO_4, the equation must show that three OH^- are added for every H_3PO_4, used in the equation. The formula for the salt sodium phosphate is Na_3PO_4.

A water solution of lime contains the base calcium hydroxide, $Ca(OH)_2$. Here the Ca^{2+} cation combines with two OH^- anions. Calcium, atomic number 20 in the periodic table, is in family 2A. As we all know, atoms of this family tend to lose two outermost electrons to become ions with a charge of $+2$. The neutralization reaction of $Ca(OH)_2$ with hydrochloric acid, HCl, is written as follows:

$$\begin{array}{lllllll} 2HCl & + & Ca(OH)_2 & \longrightarrow & 2H_2O & + & CaCl_2 \\ \text{hydrochloric acid} & & \text{calcium hydroxide} & & \text{water} & & \text{calcium chloride} \end{array}$$

The salt, calcium chloride, has the formula $CaCl_2$; the equation is balanced by using the coefficient 2 in front of HCl and H_2O.

Vocabulary

oven [ˈʌvən] *n.* 炉；烤炉
phosphate [ˈfɔsfeit] *n.* 磷酸盐
lye [lai] *n.* 碱液
lime [laim] *n.* 石灰
fabric [fæbrik] *n.* 织品；织物；布
periodic [piəriˈɔdik] *a.* 周期的
vinegar [ˈvinigə] *n.* 醋
family [ˈfæmili] *n.* 族
anion [ˈænaiən] *n.* 阴离子
outermost [ˈautəməust] *a.* 最外层的
cation [ˈkætaiən] *n.* 阳离子
drano [ˈdreinouə] *n.* 下水道除堵剂
charge [tʃaːdʒ] *n.* 电荷
sulfate [ˈsʌlfeit] *n.* 硫酸盐
coefficient [kəuiˈfiʃənt] *n.* 系数

Phrases

oven cleaner	炉灶除污剂
periodic table	周期表
remain in contact with	与……保持接触
family 2A	ⅡA 族元素
general equation	通式
outermost electron	最外层电子，价电子

Exercises

Indicate the general equation for the type of neutralization reaction and give examples.

8 Nomenclature of Inorganic Compounds (Ⅰ)

8.1 Formulas

The molecular formula is used for compounds that exist as discrete molecules. For example, S_2Cl_2, not SCl; $Co_2(CO)_8$, not $Co(CO)_4$. If the molecular weight varies with changes in conditions, the simplest formula may be used unless it is desired to indicate the molecular complexity for given conditions, for example S, P, and NO_2 may be used instead of S, P, and N_2O_4.

The electropositive constituent is placed first in the formula, for example NaCl, $MgCO_3$. If the compound contains more than one electropositive or more than one electronegative constituent, the sequence within each class is in alphabetical order of their symbols (Table 8.1). Acid are treated as hydrogen salts. In case of binary compounds between nonmetals, that constituent should be placed first which appears earlier in the sequence.

Rn. Xe. Kr. B. Si. C. Sb. As. P. N. H. Se. S. At. I. Br. Cl. O. F.

This sequence roughly follows the order of electronegativities without overlap of periodic groups.

Examples NH_3, H_2, Te, BrCl, Cl_2O, OF_2, XeF_2

Exceptions to the above order are encountered in compounds in which the sequence of symbols is used to indicate the order in which the atoms are bonded in the molecule or ion, for example, HOCN (cyanic acid), HONC (fulminic acid), HNCO (isocyanic acid).

If two or more different atoms or groups are attached to a single central atom, the symbol of the central atom is placed first followed by the symbols of the remaining atoms or groups in alphabetical order.

Parentheses ( ) or brackets [ ] are used to improve clarity, for example $[Co(NH_3)_6]_2(SO_4)_3$. Hydrates are written as follows: $Na_2SO_4 \cdot 10H_2O$.

The prefixes *cis* and *trans* are italicized and separated from the formula by a hyphen, for example, *cis*-$[PtCl_2(NH_3)_2]$.

Table 8. 1 The elements

Name	Symbol	Atomic Number	Name	Symbol	Atomic Number
Actinium	Ac	89	Carbon	C	6
Aluminium	Al	13	Cerium	Ce	58
Amcricium	Am	95	Cesium	Cs	55
Antimony	Sb	51	Chlorine	Cl	17
Argon	Ar	18	Chromium	Cr	24
Arsenic	As	33	Cobalt	Co	27
Astatine	At	85	Copper	Cu	29
Barium	Ba	56	Curium	Cm	96
Berkelium	Bk	97	Dysprosium	Dy	66
Beryllium	Be	4	Einsteinium	Es	99
Bismuth	Bi	83	Erbium	Er	68
Boron	B	5	Europium	Eu	63
Bromine	Br	35	Fermium	Fm	100
Cadmium	Cd	48	Fluorine	F	9
Calcium	Ca	20	Francium	Fr	87
Californium	Cf	98	Gadolinium	Gd	64
Gallium	Ga	31	Potassium	K	19
Germanium	Ge	32	Praseodymium	Pr	59
Gold	Au	79	Promethium	Pm	61
Hafnium	Hf	72	Protactinium	Pa	91
Helium	He	2	Radium	Ra	88
Holmium	Ho	67	Radon	Rn	86
Hydrogen	H	1	Rhenium	Re	75
Indium	In	49	Rhodium	Rh	45
Iodine	I	53	Rubidium	Rb	37
Iridium	Ir	77	Ruthenium	Ru	44
Iron	Fe	26	Samarium	Sm	62
Krypton	Kr	36	Scandium	Sc	21
Lanthanum	La	57	Selenium	Se	34
Lawrencium	Lr	103	Silicon	Si	14
Lead	Pb	82	Silver	Ag	47
Lithium	Li	3	Sodium	Na	11
Lutetium	Lu	71	Strontium	Sr	38
Magnesium	Mg	12	Sulfur	S	16
Manganese	Mn	25	Tantalum	Ta	73
Mendelevium	Md	101	Technetium	Tc	43
Mercury	Hg	80	Tellurium	Te	52
Molybdenum	Mo	42	Terbium	Tb	65
Neodymium	Nd	60	Thallium	Tl	81
Neon	Ne	10	Thorium	Th	90
Neptunium	Np	93	Thulium	Tm	69
Nickel	Ni	28	Tin	Sn	50
Niobium	Nb	41	Thanium	Ti	22
Nitrogen	N	7	Tungsten	W	74
Nobelium	No	102	Uranium	U	92
Osmium	Os	76	Vanadium	V	23
Oxygen	O	8	Xenon	Xe	54
Palladium	Pd	46	Ytterbium	Yb	70
Phosphorus	P	15	Yttrium	Y	39
Platinum	Pt	78	Zinc	Zn	30
Plutonium	Pu	94	Zirconium	Zr	40
Polonium	Po	84			

8. 2 Introduction

Mastering chemical nomenclature is little different from learning a new language, such as German. In order to understand the German scientific literature, you must, e. g. , learn that the compound H_2 is called Wasserstoff. English-speaking chemists call it hydrogen. Your task now is to memorize the names of enough compounds and become sufficiently familiar with the several systems of naming compounds that chemistry ceases to be a "foreign language".

The first thing to learn about naming chemical compounds is that there is usually more than one way to do it. We begin with the simplest system, in which a trivial name, i. e. , one that has no sensible origin, is assigned to a compound. Some examples are

H_2O	water
NH_3	ammonia
Hg_2Cl_2	calomel

Some names, such as quicklime for CaO, derive from the origin of the compound in this case, limestone, $CaCO_3$. Such word origins are often remembered only by etymologists, but the names have persisted for so long that they are an established part of the language. Can you imagine anyone seriously asking for a drink of dihydrogen oxide? The word water serves the purpose much better.

As we come to less common and more complex compounds, the use of trivial names gives way to a more systematic approach. If there are only two elements in the compound, it is customary to name the more metallic element first and the less metallic, or more electronegative, element second, with the suffix "-ide". Some examples are

KCl	potassium chloride
NaBr	sodium bromide
CaO	calcium oxide
HI	hydrogen iodide
BaS	barium sulfide

For compounds containing still only two elements but more than two atoms, the pre fixes "mono-", "di-", "tri-" etc. , become necessary. Some examples of such compounds are the oxides of nitrogen. Another such series is that of the oxide of chlorine. Because chlorine, like nitrogen, is slightly less electronegative than oxygen, the word chlorine comes first:

Cl_2O	dichlorine monoxide
ClO	chlorine monoxide
ClO_2	chlorine dioxide
ClO_3	chlorine trioxide
Cl_2O_7	dichlorine heptoxide
ClO_4	chlorine tetroxide

If no confusion can result, the prefixes "mono-" and "di-" are sometimes dropped.

A class of compounds in which such prefixes are seldom used is that in which the metal atom usually exhibits only one oxidation state. Depending on the oxidation state of the other element, the number of anions per cation is then fixed. Some examples are

$ZnBr_2$	zinc bromide
CaH_2	calcium hydride
Na_2O	sodium oxide
Al_2S_3	aluminum sulfide

The next level of complexity in naming inorganic compounds arises when there are three elements present. Very often, one of these elements is oxygen. Such compounds are named by combining the suffix "-ate" with the name of the less electronegative of the two nonmetallic elements. For example, $NaNO_3$ is sodium nitrate. The problem with this is that there is a similar compound with nitrogen in the +3 oxidation state, $NaNO_2$. Such compounds with the element in a lower oxidation state use the suffix "-ite", so $NaNO_2$ is sodium nitrite. But the number of chemical compounds is not bounded by the chemists' vocabulary, and there are several such examples entailing more than two oxidation states. To solve this problem, the prefix "hypo-" (meaning "below") is used in the name of the compound in which the less electronegative element is in the lowest oxidation state, and the prefix "per-" (meaning "highest") is used when it is in the highest oxidation state. Some examples of the use of this system are shown in the following table (Table 8. 2).

Table 8. 2 Some examples

Formula	Oxidation State	Name of Salt	Formula	Corresponding Acid
KNO_2	+3	potassium nitrite	HNO_2	nitrous acid
KNO_3	+5	potassium nitrate	HNO_3	nitric acid
Rb_2SO_3	+4	rubidium sulfite	H_2SO_3	sulfurous acid
Rb_2SO_4	+6	rubidium sulfate	H_2SO_4	sulfuric acid
$CsClO$	+1	cesium hypochlorite	$HClO$	hypochlorous acid
$CsClO_2$	+3	cesium chlorite	$HClO_2$	chlorous acid
$CsClO_3$	+5	cesium chlorate	$HClO_3$	chloric acid
$CsClO_4$	+7	cesium perchlorate	$HClO_4$	perchloric acid

In the inorganic acids, the suffixes "-ous" and "-ic" are used to denote the lower and higher oxidation states, respectively. These same suffixes are also used with the names of a number of metals, namely, those that usually exhibit more than one oxidation state. Some examples are cobaltous and cobaltic, and mercurous and mercuric. The nomenclature is complicated slightly by the fact that, for a few such metals, these terms are derived from the Latin name of the element rather than the English name.

All but eleven of the elements are given a symbol corresponding to one or two letters in the English name of the compound. (The first letter is always capitalized and the second letter is never capitalized.) One of these exceptions is tungsten, whose symbol (W) is derived from the German name of the element, Wolfram. The other ten have symbols derived from their Latin names. These are: stibium (Sb) for antimony, cuprum (Cu) for copper, aurum (Au) for gold, ferrum (Fe) for iron, plumbum (Pb) for lead, hydrargyrum (Hg) for mercury, kalium (K) for potassium, argentum (Ag) for silver, natrium (Na) for sodium, and stannum (Sn) for tin. The use of the suffixes "-ous" and "-ic" with three of these metals is illustrated below.

CuI	cuprous iodide
CuI_2	cupric iodide
$FeBr_2$	ferrous bromide
$FeBr_3$	ferric bromide
$SnCl_2$	stannous chloride
$SnCl_4$	stannic chloride

The system works well as long as there are only two major oxidation states of the metal atom, as in these examples.

The most rational and self-consistent system of nomenclature of inorganic compounds is that adopted in 1957 by the ultimate authority in such matters, the International Union of Pure and Applied Chemistry. These rules, popularly called the IUPAC Rules, are the model for chemists throughout the world to follow, and are becoming ever more dominant in the chemical literature. Note that the oxidation state of the metal atom is specified by a Roman numeral whenever there could be some doubt about it, but not otherwise. Let us see how the examples shown above are named according to this system.

CuI	copper (Ⅰ) iodide
CuI_2	copper (Ⅱ) iodide
$FeBr_2$	iron (Ⅱ) bromide
$FeBr_3$	iron (Ⅲ) bromide
$SnCl_2$	tin (Ⅱ) chloride
$SnCl_4$	tin (Ⅳ) chloride

Vocabulary

master [ˈmaːstə] *vt.* 掌握
ammonia [əˈməunjə] *n.* 氨；氨水
nomenclature [nəuˈmenklətʃə] *n.* 命名法
calomel [ˈkæləməl] *n.* 甘汞；氯化亚汞
German [ˈdʒəːmən] *n.* 德语；德国人
quicklime [ˈkwiklaim] *n.* 生石灰
scientific literature [saiənˈtifikˈliteritʃə] *n.* 科学文献
derive [diˈraiv] *vi.* 得来
approach [əˈprəutʃ] *n.* 接近；方法
memorize [ˈmeməraiz] *vt.* 记住
etymologist [etiˈmələdʒist] *n.* 词源学
cease [siːs] *vt.* 停止

persist [pə'sist] *vi.* 坚持
trivial ['triviəl] *a.* 平常的；通俗
imagine [i'mædʒin] *vt.* 想象
sensible ['sensəbl] *a.* 能觉察到的
complex ['kɔmpleks] *a.* 复杂的
origin ['ɔridʒin] *n.* 起源；来历
systematic [ˌsisti'mætik] *a.* 有次序的；系统的
suffix ['sʌfiks] *n.* 后缀
perchloric acid [pə'klɔːrikæsid] *n.* 高氯酸
bromide ['brəumaid] *n.* 溴化物
denote [di'nəut] *vt.* 指示；表示
iodide ['aiədaid] *n.* 碘化物
respectively [ris'pektivli] *ad.* 分别地
barium ['bɛəriəm] *n.* 钡
namely ['neimli] *ad.* 即；也就是
prefix ['priːfiks] *n.* 前缀
cobaltous [kəu'bɔːltəs] *a.* 钴的；二价钴的
nitrogen ['naitridʒən] *n.* 氮
cobaltic [kəu'bɔːltik] *a.* 钴的；高钴的
series ['siəriːz] *n.* （单复同）系列
mercurous ['məːkjurəs] *a.* 亚汞的
exhibit [ig'zibit] *vt.* 表示；显示
mercuric [məː'kjuərik] *a.* 汞的
anion ['ænaiən] *n.* 阴离子；负离子
term [təːm] *n.* 术语；字眼
cation ['kætaiən] *n.* 阳离子；正离子
Latin ['lætin] *n.* &*a.* 拉丁语（的）
fix [fiks] *v.* 固定
but [bʌt] *prep.* 除了……
zinc [ziŋk] *n.* 锌
symbol ['simbəl] *n.* 符号；记号
aluminum [ə'ljuːminəm] *n.* 铝
capitalize ['kæpitəlaiz] *vt.* 用大写字母
complexity [kəm'pleksiti] *n.* 复杂性
exception [ik'sepʃən] *n.* 例外
vocabulary [və'kæbjuləri] *n.* 词汇表
antimony ['æntiməni] *n.* 锑
entail [in'teil] *vt.* 需要
lead [led] *n.* 铅
potassium nitrite [pə'tæsjəm'naitrait] 亚硝酸钾
mercury ['məːkjuri] *n.* 汞
tin [tin] *n.* 锡
potassium nitrate [pə'tæsjəm'naitreit] *n.* 硝酸钾
stannous chloride ['stænəs'klɔːraid] *n.* 氯化亚锡
rubidium sulfite [ruː'bidiəm'sʌlfait] *n.* 亚硫酸铷
stannic chloride ['stænic'klɔːraid] *n.* 氯化锡
rubidium sulfate [ruː'bidiəm'sʌlfeit] 硫酸铷
major ['meidʒə] *a.* 主要的
rational ['ræʃənl] *a.* 合理的
cesium hypochlorite ['siːzjəm haipə'klɔːrait] 次氯酸铯
cesium chlorite ['siːzjəm'klɔːrait] 亚氯酸铯
cesium chlorate ['siːzjəm'klɔːrit] 氯酸铯
cesium perchlorate ['siːzjəm'klɔːreit] 过氯酸铯
self-consistent ['self-kən'sistənt] *a.* 自相一致的
adopt [ə'dɔpt] *vt.* 采纳；通过
authority [ɔː'θɔriti] *n.* 权威
ultimate ['ʌltimit] *a.* 最后的
nitrous acid ['naitrəs æsid] 亚硝酸
pure [pjuə] *a.* 纯粹的
nitric acid ['naitrik æsid] 硝酸
sulfurous acid ['sʌlfərəs æsid] 亚硫酸
sulfuric acid [sʌl'fjuərik æsid] 硫酸
hypochlorous acid ['haipə'klɔːrəsesid] 次氯酸
chlorous acid ['klɔːrəs æsid] 亚氯酸
chloric acid ['klɔːrik æsid] 氯酸
otherwise [ʌðəwaiz] *ad.* 其他
various ['vɛəriəs] *a.* 不同的；各种各样的
popularly ['pɔpjuləli] *ad.* 通俗地；普通地

dominant ['dɔminənt] *a.* 支配的；统治的
specify ['spesifai] *vt.* 指定；详细说明
Roman ['rəumən] *a.* 罗马的
numeral ['njuːmərəl] *n.* 数字
doubt [daut] *n.* 怀疑
designate ['dezigneit] *vt.* 指定；指出
envision [in'viʒən] *vt.* 想象；预想
principle ['prinsəpl] *n.* 原理；原则

Phrases

in order to 为了……
give way to 让路；(给……) 让步
(be) familiar with 熟悉
a number of 若干；许多
(to) begin with 以……开始
rather than 而不是
(to) derive from 来自
as long as 只要
in this case 在本例中
throughout the world 全世界

Exercises

1. Write formulas of the following compounds.

a. cyanic acid
b. fulminic acid
c. isocyanic acid
d. ferric rhodanate
e. ferric sulfate
f. ferricyanic acid

2. Name the following compounds.

a. KCl
b. CuI
c. CuI_2
d. CuO
e. $CuSO_4$
f. $Cu(OH)_2$
g. H_3PO_4

3. Translate the following into Chinese.

All but eleven of the elements are given a symbol corresponding to one or two letters in the English name of the compound. (The first letter is always capitalized and the second letter is never capitalized.) One of these exceptions is tungsten, whose symbol (W) is derived from the German name of the element, Wolfram. The other ten have symbols derived from their Latin names. These are: stibium (Sb) for antimony, cuprum (Cu) for copper, aurum (Au) for gold, ferrum (Fe) for iron, plumbum (Pb) for lead, hydrargyrum (Hg) for mercury, kalium (K) for potassium, argentum (Ag) for silver, natrium (Na) for sodium, and stannum (Sn) for tin.

9 Nomenclature of Inorganic Compounds (Ⅱ)

Systematic names—The name of the electropositive constituent is not modified and is placed first. The name of the electronegative constituent[or the element later in sequence (1) for compounds of nonmetals] is modified to end in -ide if it is monoatomic or homopolyatomic. Elements other than those in sequence (1) are taken in order of the elements in the long form of the periodic table starting with Rn(Group 0) and going upward in each family(from Group Ⅰ on the left) before starting the next, thus ending with fluorine, sequence (2).

Examples: Sodium chloride, magnesium sulfide, lithium nitride, nickel arsenide, silicon carbide, sulfur hexafluoride, oxygen difluoride, potassium triiodide, and sodium plumbide.

If the electronegative constituent is heteronuclear, it should be designated by the termination -ate. Exceptions include OH^-, hydroxide ion; NH^{2-}, imide ion; NH_2^-, amide ion; and CN^-, cyanide ion.

In case of two or more electronegative constituents their sequence should be in alphabetical order. This order might differ in names and formulas.

Complex anions can be named using the name of the characteristic or central atom modified to end in -ate. Ligands attached to the central atom are indicated by the termination -o. The oxidation number of the central atom should be indicated by a Roman numberal(Stock system) or by making the charge on the anion clear by the use of prefixes.

Examples

Na_2SO_4	sodium tetraoxosulfate(Ⅵ) disodium tetraoxosulfate	or	$Na[SO_3F]$	sodium trioxofluorosulfate(Ⅵ)
$Na_2[SO_3]$	sodium trioxosulfate(Ⅳ) disodium trioxosulfate	or	$Na[ICl_4]$	sodium tetrachloroiodate(Ⅲ)
$Na_2[S_2O_3]$	disodium trioxothiosulfate		$Na[PCl_6]$	sodium hexachlorophosphosphate(Ⅴ)

Common names of oxo anions and oxo acids may be used.

Stoichiometric proportions may be denoted by the use of Greek numerical prefixes (mono, di, tri, tetra, penta, hexa, hepta, octa, ennea, deca, hendeca, dodeca) preceding without hyphen the names of the elements to which they refer. The Latin prefixes nona (9) and undeca (11) are also used. The prefix mono may be omitted. Beyond 10, Arabic numerals may be used. The end vowels of numerical prefixes should not be elided, for example, tetraoxide.

Examples

N_2O	dinitrogen oxide	Fe_2O_3	triiron tetraoxide
N_2O_4	dinitrogen tetraoxide	U_2O_8	triuraniun octaoxide
S_2Cl_2	disulfur dichloride		

The proportions of the constituents may also be indicated indirectly by the Stock system, in which Roman numerals are used to represent the oxidation number of an element or central atom. For zero the Arabic 0 is used. Latin names of the elements or Latin stems may be used with the Stock system; such usage is common for complex anions. The charge on the aggregate can be shown by an Arabic numeral followed by the charge in parentheses(Ewens and Bassett system) instead of giving the oxidation number of the central atom.

$FeCl_2$	iron(Ⅱ)chloride
$FeCl_3$	iron(Ⅲ)chloride
$SnSO_4$	tin(Ⅱ)sulfate
MnO_2	manganese(Ⅳ)oxide
BaO_2	barium(Ⅱ)peroxide
$Pb_2{}^{II}Pb^{IV}O_4$	dilead(Ⅱ)lead(Ⅳ)oxide or trilead tetraoxide
$K_4[Ni(CN)_4]$	potassium tetracyanonickelate(0)or potassium tetracyanonickelate(4−)
$K_4[Fe(CN)_6]$	potassium hexacyanoferrate(Ⅱ)

The use of the endings -ous and -ic for cations is not recommended and should not be used for elements exhibiting more than two oxidation numbers.

9.1 Hydrides

The following names are acceptable:

H_2O	water	PH_3	phosphine
NH_3	ammonia	P_2H_4	diphosphane
N_2H_4	hydrazine	AsH_3	arsine
BH_3	borane	SbH_3	stibine
B_2H_6	diborane	BiH_3	bismuthine
SiH_4	silane (Si_2H_6 disilane, etc.)	H_2S_5	pentasulfane
GeH_4	germane		

9.2 Names for Ions and Radicals

9.2.1 Cations

Names of monatomic cations are the same as the names of the elements. Oxidation numbers are designated by use of the Stock system.

Examples Cu^+, copper (Ⅰ) ion; Cu^{2+}, copper (Ⅱ) ion.

Polyatomic cations formed from radicals which have special names use those names without change. Complex cations are discussed later.

Examples

NO^+	nitrosyl cation		
NO_2^+	nitryl cation	UO_2^{2+}	uranyl (Ⅵ) ion

Polyatomic cations derived by the addition of protons to monatomic anions are named by adding the ending -onium to the root of the name of the anion.

Examples: Phosphonium, arsonium, stibonium, oxonium, sulfonium, selenonium, telluronium, and iodonium ions.

Exceptions NH_4^+, ammonium ion; $HONH_3^+$, hydroxylammonium ion; $NH_2NH_3^+$; hydrazinium ion; $C_6H_5NH_3^+$; anilinium ion; $C_5H_5NH^+$, pyridinium; $HO_2CCH_2NH_3^+$, glycinium, etc.

The H_3O^+ ion is the oxonium ion. Hydrogen ion may be used for the indefinitely solvated proton or when the hydration is of no particular importance to the matter under consideration.

9.2.2 Anions

Monatomic anions are named by adding the ending -ide to the stem of the name of the element.

Examples: H^-, hydride ion; F^-, fluoride ion; Cl^-, chloride ion; Te^{2-}, telluride ion; N^{3-}, nitride ion; Sb^{3-}, antimonide ion, etc.

Certain polyatomic anions have names ending in -ide. These are:

OH^-	hydroxide ion	CN^-	cyanide ion	N_3^-	azide ion
O_2^{2-}	peroxide ion	C_2^{2-}	acetylide ion	NH^{2-}	imide ion
O_2^-	hyperoxide ion	I_3^-	triiodide ion	NH_2^-	amide ion
O_3^-	ozonide ion	HF_2^-	hydrogendifluoride ion	$NHOH^-$	hydroxylamide ion
S_2^{2-}	disulfide ion	$N_2H_3^-$	hydrazide ion		

Ions such as HS^- and HO_2^- are named hydrogensulfide ion and hydrogenperoxide ion respectively. The names of other polyatomic anions consist of the name of the central atom with the termination -ate in accordance with the naming of complex anions.

Examples $[Sb(OH)_6]^-$ hexahydroxoantimonate(V)ion.

Certain anions have names using prefixes (hypo-, per-, etc.) that are well established. These are in accord with the name of the corresponding acids. The termination -ite has been used to denote a lower oxidation state and may be retained in trivial names in the following case:

NO_2^-	nitrite	SO_3^{2-}	sulfite	ClO_2^-	chlorite
$N_2O_2^{2-}$	hyponitrite	$S_2O_5^{2-}$	disulfite	ClO^-	hypochlorite
NOO_2^-	peroxonitrite	$S_2O_4^{2-}$	dithionite	AsO_3^{3-}	arsenite
$S_2O_2^{2-}$	thiosulfite	SeO_3^{2-}	selenite		

Other anions that have used the -ite ending for example, antimonite, should be named according to the general rule, that is, antimonate (Ⅲ).

9.2.3 Radicals

The names ending in -yl of the following radicals are approved:

HO	hydroxyl	SO	sulfinyl (thionyl)	ClO	chloroxyl
CO	carbonyl	SO_2	sulfonyl (sulfuryl)	ClO_2	chloryl
NO	nitrosyl	S_2O_5	disulfuryl	ClO_3	perchloryl
NO_2	nitryl	SeO	seleninyl	SeO_2	selenonyl
PO	phosphoryl	CrO_2	chromyl	NpO_2	neptunyl
UO_2	uranyl	PuO_2	plutonyl, etc		

The prefixes thio-, seleno-, ect, are used for other chalcogens in place of oxygen.

Examples: PS, thiophosphoryl; CSe, selenocarbonyl, etc. The oxidation number of the characteristic element is denoted by the Stock system or the charge on the ion is indicated by the Ewens-Bassett system. UO_2^{2+} may be uranyl (Ⅵ) or uranyl (2+) and UO_2^+ may be uranyl (Ⅴ) or uranyl (1+).

Radicals are treated as the positive part of a compound. For example $COCl_2$, carbonyl chloride; NOS, nitrosyl sulfide; POCl, phosphoryl (Ⅲ) chloride; IO_2F, iodyl (Ⅴ) fluoride, etc.

9.3 Acids

Acids giving rise to -ide anions are named as binary and pseudobinary compounds of hydrogen, for example, hydrogen chloride, hydrogen cyanide, hydrogen azide, etc.

Other acids may be named as pseudobinary compounds of hydrogen, for example, H_2SO_4, hydrogen sulfate; $H_4Fe(CN)_6$, hydrogen hexacyanoferrate (Ⅲ).

9.3.1 Oxoacids

Most of the common acids are oxoacids commonly named using the -ic and -ous endings in place of the anion endings -ate and -ite, respectively. The acids using the -ous ending should be restricted to those listed above for the -ite anions.

The prefix hypo- is used to denote a lower oxidation state and the prefix per- is used to denote a higher oxidation state. These prefixes should be limited to the following cases:

$H_2N_2O_2$	Hyponitrous acid	HClO	Hypochlorous acid (Also HBrO and HIO)
$H_4P_2O_6$	Hypophosphoric acid	$HClO_4$	Perchloric acid (Also $HBrO_4$ and HIO_4)

$(HO)_2PHO$ is phosphonic acid rather than phosphorous acid in order to reserve the name phosphate for organic derivatives of $P(OH)_3$. Phosphinic acid is the name for $HOPH_2O$, rather than hypophorous acid.

The prefixes ortho- and meta- may be used to distinguish acids differing in the "content of water" in the following cases:

H_3BO_3	orthoboric acid	$(HBO_2)_n$	metaboric acids
H_4SiO_4	orthosilicic acid	$(H_2SiO_3)_n$	metasilicic acids
H_3PO_4	orthophosphoric acid	$(HPO_3)_n$	metaphosphoric acids
H_5IO_6	orthoperiodic acid		
H_6TeO_6	orthotelluric acid		

Acids obtained by removing water from H_5IO_6 or H_6TeO_6 and other acids not covered by specific names should be given systematic names, for example, H_2ReO_4, tetraoxorhenic (Ⅵ) acid; H_2NO_2, dioxonitric (Ⅱ) acid; and H_2MnO_4, tetraoxomanganic (Ⅵ) acid.

The prefix di- is preferred to the prefix pyro- for $H_2S_2O_7$, disulfuric acid; $H_2S_2O_5$, disulfurous acid; and $H_4P_2O_7$, diphosphoric acid.

The names germanic acid, stannic acid, molybdic acid, etc, may be used for substances with indefinite "water content" and degree of polymerization.

9.3.2 Peroxoacids

The perfix peroxo- indicates the substitution of —O—by—O—O— (see coordination compounds)

Examples

HNO_4	dioxoperoxonitric acid or peroxonitric acid
H_3PO_5	trioxoperoxophosphoric acid or peroxophosphoric acid
$H_4P_2O_3$	μ-peroxo-bis-trioxophosphoric acid or peroxodiphosphoric acid
H_2SO_3	trioxoperoxosulfuric acid or peroxosulfuric acid
$H_2S_2O_8$	μ-peroxo-bis-trioxosulfuric acid or peroxodisulfuric acid

9. 3. 3 Thioacids

The prefix thio- indicates the replacement of oxygen by sulfur. The prefixes seleno- and telluro- may be used in a similar manner.

Examples

$H_2S_2O_2$	thiosulfurous acid	H_3PO_3S	monothiophosphoric acid
$H_2S_2O_3$	thiosulfuric acid	$H_3PO_2S_2$	dithiophosphoric acid
HSCO	thiocyanic acid	H_2CS_3	trithiocarbonic acid

Acids containing ligands other than O and S are generally named as complexes.

9. 4 Salts

9. 4. 1 Salts and Saltlike Compounds

Simple salts are named as binary compounds using the names as prescribed for ions.

Salts that contain acidic hydrogens are named by treating hydrogen as a positive constituent.

Examples

$NaHCO_3$	sodium hydrogencarbonate
NaH_2PO_4	sodium dihydrogenphosphate

9. 4. 2 Double Salts, etc.

(1) Cations

Cations other than hydrogen are cited in alphabetical order, which may be different in formulas and names.

Examples

$KMgF_3$	magnesium potassium fluoride
$NaTl(NO_3)_2$	sodium thallium(Ⅰ)nitrate
$KNaCO_3$	potassium sodium carbonate
$MgNH_4PO_4 \cdot 6H_2O$	ammonium magnesium phosphate hexahydrate(or 6-water)
$Na(UO_2)_3[Zn(H_2O)_6](C_2H_3O_2)_9$	hexaaquazinc sodium triuranyl(Ⅵ)nonaacetate
$NaNH_4HPO_4 \cdot 4H_2O$	ammonium sodium hydrogenphosphate tetrahydrate
$AlK(SO_4)_2 \cdot 12H_2O$	aluminum potassium sulfate 12-water

(2) Anions

Anions are to be cited in alphabetical order which may be different in names and formulas.

Examples

$NaCl \cdot NaF \cdot 2Na_2SO_4$ or $Na_6ClF(SO_4)_2$	hexasodium chloride fluoride bis (sulfate)
$Ca_5F(PO_4)_3$	pentacalcium fluoride tris (phosphate)

Basic salts should be treated as double salts, not as oxo or hydroxo salts.

Examples

MgCl (OH)	magnesium chloride hydroxide
BiClO	bismuth chloride oxide
$ZrCl_2O \cdot 8H_2O$	zirconium dichloride oxide octahydrate
$CuCl_2 \cdot 3Cu(OH)_2$ or $Cu_2Cl(OH)_3$	dicopper chloride trihydroxide
$VO(SO_4)_2$	vanadium （Ⅳ） oxide sulfate

Vocabulary

lithium [ˈliθiəm] *n.* 锂
nickel [ˈnikl] *n.* 镍，镍币；*vt.* 镀镍于
plumb [plʌm] *n.* 铅锤；铅弹
elide [iˈlaid] *vt.* 取消；省略
hydrazine [ˈhaidrəziːn] *n.* 肼；联氨
borane [ˈbəurein] *n.* 硼烷
silane [ˈsilein] *n.* 硅烷
arsine [ˈaːsin] *n.* 砷化（三）氢；胂
stibine [ˈstibiːn] *n.* 锑化（三）氢
germane [dʒəːˈmein] *n.* 锗
radical [ˈrædikəl] *a.* 自由基
pseudobinary [(p)sjudə ˈbainəri] *n.* 伪；假
vanadium [vəˈneidiəm] *n.* 钒；铅矿

Exercises

Name the following compounds.

a. PH_3
b. H_2S
c. PO_4^{3-}
d. H_2SO_4
e. H_2SO_3
f. K_2HPO_4
g. KH_2PO_4
h. $Cu_2(OH)_2CO_3$
i. Na_2O_2
j. $Na_2S_2O_3$

10 Nomenclature of Inorganic Compounds（Ⅲ）

10.1 Coordination Compounds

The symbol for the central atom is placed first in the formula of coordination compounds. The ligands are written in the alphabetical order of the symbols of the ligating atoms. The formula for the complex molecule or ion is enclosed in square brackets [ ]. In names the central atom is placed after the ligands. The ligands are listed in alphabetical order regardless of the number of each. Thus diammine is listed under "a" and dimethylamine under "d".

The oxidation number of the central atom is indicated by the Stock notation. Alternatively, the proportion of constituents may be given by means of stoichiometric prefixes, or the charge on the entire ion can be designated by the Ewens-Bassett number. Formulas and names may be supplemented by italicized prefixes cis, trans, fac, mer, etc. Names of complex anions end in -ate. Complex cations and neutral molecules are given no distinguishing ending.

10. 1. 1 Names of Ligands

The names for anionic ligands end in -o (-ido, -ito, and -ato commonly).

Examples

$Li[AlH_4]$	lithium tetrahydroaluminate
$K_2[OsCl_5N]$	potassium pentachloronitridoosmate(Ⅵ)or potassium pentachloronitridoosmate(2−)
$Na_3[Ag(S_2O_3)_2]$	sodium bis(thiosulfato)argentite(Ⅰ)or(3−)
$[Ni(C_4H_7O_2N_2)_2]$	bis(2,3-butanedione dioximato)nickel(Ⅱ)or omit(Ⅱ)
$[Cu(C_5H_7O_2)_2]$	bis(2,4-pentanedionato)copper(Ⅱ)or omit(Ⅱ)
$K_2[Cr(CN)_2O_2(O_2)NH_3]$	potassium amminedicyanodioxoperoxochromate(Ⅵ)or(2−)

The following exceptions are recognized:

H^-	hydrido (or hydro)	HS^-	mercapto
F^-	fluoro	S^{2-}	thio
Cl^-	chloro	CN^-	cyano
Br^-	bromo	CH_3O^-	methoxo or methanolato
I^-	iodo	$C_6H_5^-$	phenyl
OH^-	hydroxo	Other hydrocarbon anions are also given	
O_2^{2-}	poroxo	radical names without the -o ending.	

Neutral and cationic ligands are given no special endings. Water and ammonia are called aqua and ammine, respectively, in complexes. Groups such as NO and CO are named as radicals and treated as neutral ligands.

Examples

$Ba[BrF_4]_2$	barium tetrafluorobromate(Ⅲ)or(1−)
$K[CrF_4O]$	potassium tetrafluorooxochromate(Ⅴ)or(1−)
$Na[BH(OCH_3)_3]$	sodium hydrotrimethoxoborate(Ⅲ)or(1−)
$[CuCl_2(CH_3NH_2)_2]$	dichlorobis(methylamine)copper(Ⅱ)or omit(Ⅱ)
$[Pt(py)_4][PtCl_4]$	tetrakis(pyridine)platinum(Ⅱ)tetrachloroplatinate (Ⅱ)or(2+)and(2−)
$[Co(en)_3]_2(SO_4)_3$	tris(ethylenediamine)cobalt(Ⅲ)sulfate or(3+)
$K[PtCl_3(C_2H_4)]$	potassium trichloro(ethylene)palatinate(Ⅱ)or(1−)
$[Al(OH)(H_2O)_5]^{2+}$	pentaaquahydroxoaluminum(Ⅲ)ion or(2+)
$K_3[Fe(CN)_5NO]$	potassium pentacyanonitrosylferrate(Ⅱ)or(3−)
$[CoCl_3(NH_3)_2\{(CH_3)_2NH\}]$	diamminetrichloro(dimethylamine)cobalt(Ⅲ)or omit(Ⅲ)
$K[SbCl_5C_6H_5]$	potassium pentachloro(phenyl)antimonate(Ⅴ)or(1−)
$Fe(C_6H_5)_2$	bis(cyclopentadienyl)iron(Ⅱ)or omit(Ⅱ)
$[Cr(C_6H_5)_2]$	bis(benzene)chromium(0)or omit(0)
$[Ru(NH_3)_5N_2]Cl_2$	pentaammine(dinitrogen)ruthenium(Ⅱ)chloride or(2+)

10. 1. 2 Alternative Modes of Linkage

A ligand that may be attached through different atoms, for example SCN^-, may be distinguished as follows:

M—SCN thiocyanato —S or M—NCS thiocyanato —N

Where special names are recognized for alternative modes of linkage, these may be used, for example, thiocyanato (—SCN), isothiocyanato (—NCS), nitro (—NO_2), and nitrito(—ONO).

Examples

$[Co(NO_2)_3(NH_3)_3]$	triamminetrinitrocobalt(Ⅲ)or omit(Ⅲ)
$[Co(ONO)(NH_3)_5]SO_4$	pentaaminenitritocobalt(Ⅲ)sulfate or(2+)
$[CO(NCS)(NH_3)_5]Cl_2$	pentaammineisothiocyanatocobalt(Ⅲ)chloride or(2+)

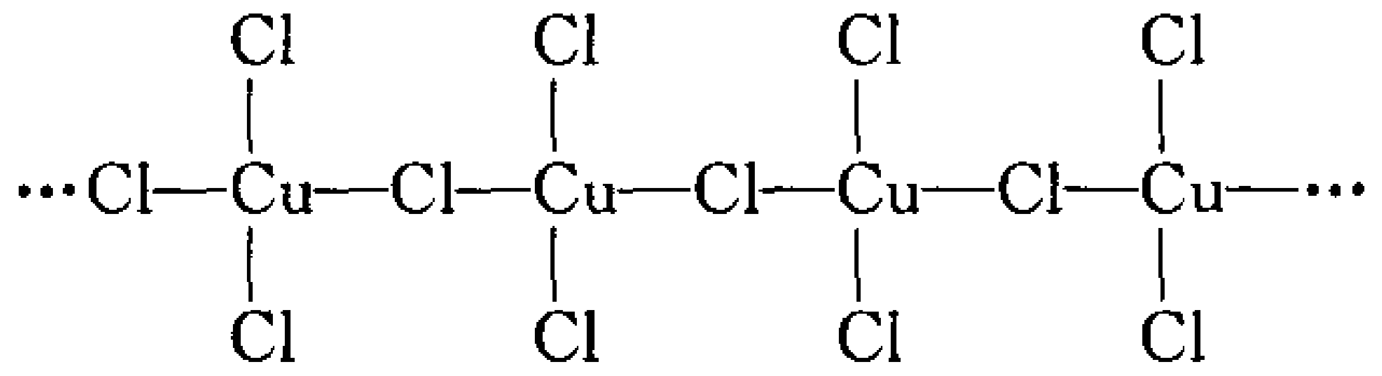
10.2 Di- and Polynuclear Compounds

Bridging groups are indicated by adding the Greek letter μ immediately before the names of the groups. Two or more bridging groups of the same kind are indicated by di-, μ-, etc. If a bridging group bridges more than two metals, use μ_3, μ_4, etc. Bridging groups are listed with other groups in alphabetical order unless the symmetry of the molecule permits a simpler name(first example). If the same ligand is present in bridging and nonbridging roles, it is cited first as a bridging ligand.

Examples

$[(NH_3)_5Cr\text{-}OH\text{-}Cr(NH_3)_5]Cl_5$	μ-hydroxo-bis[pentaamminechromium(Ⅲ)chloride or(5+)]
$[(CO)_3Fe(CO)_3Fe(CO)_3]$	tri-μ-carbonyl-bis(tricarbonyliron)
$[\{Au(CN)(C_3H_7)_2\}_4]$	cyclo-tetra-μ-cyano-tetrakis(dipropylgold)
$[Be_4O(CH_3COO)_6]$	hexa-μ-acetate(*O*,*O*′)-μ_4-oxo-tetra beryllium(Ⅱ) or omit(Ⅲ)
$[(CH_3Hg)_4S]^{2+}$	μ_4-thio-tetrakis[methylmercury(Ⅱ)ion or(2+)]

Extended structures may be indicated by the prefix catena -μ, for example, $CsCuCl_3$ contains the anion



$$\cdots Cl-\underset{Cl}{\overset{Cl}{Cu}}-Cl-\underset{Cl}{\overset{Cl}{Cu}}-Cl-\underset{Cl}{\overset{Cl}{Cu}}-Cl-\underset{Cl}{\overset{Cl}{Cu}}-\cdots$$

The compound may be named cesium catena -μ-chloro-dichlorocuprate (Ⅱ). If the structure were in doubt, however, the substance would be called cesium copper (Ⅱ) chloride(as a double salt).

10.2.1 Compounds Without Bridging Groups

Symmetrical compounds such as those containing metal-metal bonds are named by the use of multiplicative prefixes. When unsymmetrical, one central atom and its attached ligands are treated as a ligand on the other central atom. The one considered as the primary central atom is the first encountered in sequence (2). The ligating atom is named as a radical.

Examples

$[(CO)_5Mn\text{-}Mn(CO)_5]$	bis(pentacarbonylmanganese)
$[(CO)_4Co\text{-}Re(CO)_5]$	pentacarbonyl(tetracarbonylcobaltio)rhenium

$[(C_6H_5)_3AsAuMn(CO)_5]$ pentacarbonyl[(triphenylarsine)aurion]manganese

10.2.2 Metal Cluster Compounds

The geometrical shape of the cluster is designated by triangulo, quadro, tetrahedron, octahedron etc.

Examples

$Os_3(CO)_{12}$	dodecacarbonyl-triangulo-triosmium
$Cs_3[Re_3Cl_{12}]$	cesium dodecachloro-triangulo-trihenate(3−)
$[Nb_6Cl_{12}]^{2-}$	dodeca-μ-chloro-octahedro-hexaniobium(2+)ion
$[Mo_6Cl_8]^{4+}$	octa-μ_3-chloro-octahedro-hexamolybdenum(4+)ion
$[Cu_4I_4(PFt_3)]_2$	tetra-μ_3-iodo-tetrakis(triethylphosphine)-tetrahedro-tetracopper

The best way for you to become familiar with the various systems of nomenclature is to practice. Each time you see the name of a compound, try to envision the formula and structure that it designates. Each time you see a new chemical formula, try to name it, using one or more of the principles described above.

Vocabulary

coordinate [kəu'ɔːdinit] *a.* 同等的；并列的；坐标的

cluster ['klʌstə] *n.* 一串；一束；一簇；一小群

dimethylamine [daiˌmeθilə'miːn] *n.* 二甲胺

ammine ['æmiːn] *n.* 氨络物

cuprate ['kjuːpreit] *n.* 铜酸盐

cesium ['siːzjəm] *n.* 铯

Exercises

1. Name the following compounds.

a. $K_2[SiF_6]$
b. $K[PtCl_5(NH_3)]$
c. $[Zn(NH_3)_4]Cl_2$
d. $[Co(ONO)(NH_3)_5]SO_4$
e. $PtCl_2(NH_3)_2$
f. $Co(NO_2)_3(NH_3)_3$
g. $[Cu(NH_3)_4]SO_4$
h. $Na[Co(CO)_4]$

2. Write formula of the following compounds.

a. magnesium cyanoplatinate
b. magnesium fluosilicate
c. magnesium chlorostannate
d. cobaltic chloropentammine salt

11 Hydrogen

Hydrogen, the lightest substance known to man, does not occur as a gas on the earth, except in minute quantities. It is abundant, however, in the sun. Combined with oxygen as water, it is found almost everywhere.

To make the tremendous quantity of hydrogen required for the industrial users several methods are employed. One of the most important during the last war, and one which was stepped up considerably, was the action of steam on red-hot iron. This method, called the steam-iron process, preceded by stages. Water gas (hydrogen and carbon monoxide prepared by passing water over hot coke) streams over a spongy iron ore (Fe_3O_4) at a high temperature. The iron ore is reduced to a lower oxide, and both the carbon monoxide and hydrogen take part in the reaction as follows:

$$CO + Fe_3O_4 = CO_2 + 3FeO$$
$$H_2 + Fe_3O_4 = H_2O + 3FeO$$

After a time the water gas is shut off. Super-heated steam is then passed through the reduced iron ore to give hydrogen, and at the same time the iron ore reverts to its original condition. The reaction is:

$$H_2O + 3FeO = Fe_3O_4 + H_2$$

The crude hydrogen may contain some impurities such as steam (removed by cooling the gasses) and hydrogen sulphide and carbon dioxide which are removed by pumping the gases through a purifying system.

Another method is to separate out the hydrogen in water gas from the carbon monoxide. This is done by freezing the water gas when the carbon monoxide and other impurities such as oxygen will liquefy first and can then be removed while the hydrogen will remain as a gas. The boiling point of hydrogen is about −253℃, while that of oxygen is −183℃ and carbon monoxide −190℃. A somewhat similar process has been used for separating hydrogen from coke-oven gas, which consists of hydrogen, carbon monoxide and certain hydrocarbons, such as methane, which are not very difficult to liquefy.

Hydrogen gas is also a by- product in several industrial operations and until comparatively recently had little value. In the processes for the manufacture of caustic soda by the electrolysis of brine, and in the large scale method for making metallic sodium, by electrolysis of fused caustic soda, hydrogen is given off. But these two methods are necessarily associated with the caustic soda and sodium which are of greater value, and to collect the gas a compressing plant is necessary.

Another process is to get the hydrogen from ammonia. The ammonia gas is passed through a special 'cracking' apparatus containing a heated metal catalyst. The gas breaks up into hydrogen and nitrogen in the proportion of three to one. At first sight it may seem uneconomic to make ammonia from hydrogen and then subsequently split it to get back the hydrogen. But the explanation lies in the cheaper transport costs of ammonia over hydrogen gas. One 100 pound, cylinder of ammonia produces 4500 cu. ft. 1cu. ft. $=0.0283168m^3$ of hydrogen. To transport this amount of hydrogen in cylinder it would be necessary to have sixteen times the weight of the ammonia cylinder.

In the United States hydrogen is made from the methane gas from petroleum wells. The methane is mixed with steam and passed over a catalyst, iron or cobalt together with aluminium oxide supported on clay, at a temperature of about 1000℃. The reaction is:

$$CH_4 + H_2O = CO + 3H_2$$

The resulting gas, containing abundant steam, is then passed over another catalyst at a lower temperature, to give the following reaction.

$$CO + H_2O = CO_2 + H_2$$

The carbon dioxide is easily removed by dissolving it out in water under pressure, while the hydrogen is left as a gas. Traces of carbon monoxide which may remain are absorbed by a solution of copper salt containing ammonia.

The 'atomic hydrogen' blow pipe is very interesting. When a stream of hydrogen gas is blown through an electric arc the molecules of the gas are split up into atoms. If the gas then hits any surface the atoms are recombined to molecules and in so doing give out tremendous heat, so that the object is usually melted by the heat. This 'atomic hydrogen' flame will even melt tungsten(m. p. 3,370℃). It is thought that any surface acts as a catalyst in the reformation of the hydrogen molecules. Apart from this special way of melting substances, hydrogen can also be used with oxygen in the oxy-hydrogen flame for melting such things as platinum and working fused quartz into special apparatus.

Until 1932 it was thought that there was only one kind of hydrogen, but in that year Professor Harold Urey in America gave out his discovery of deuterium, an isotope of hydrogen which is twice the weight of the latter. This discovery, which was of vital importance, shook the scientific world. It gave a fillip to the investigations into the structure of the nucleus because the deuterium nucleus, the deuteron, could be used as a missile to split the atomic nucleus. Being twice the weight of the proton (hydrogen nucleus) it was, of course, much more powerful its effect.

The oxide if deuterium was called heavy water (D_2O) and it was found to have peculiar properties. There is a small percentage of heavy water in water of all kinds. But when water is electrolysed until only a small part of residual water is left, this part contains a much higher proportion of heavy water than did the original mass of liquid. This is because ordinary water splits up into its constituent hydrogen and oxygen much more easily than does the heavy water. By continual electrolysis, and by adding more and more water as necessary, a liquid can finally be obtained which is almost pure heavy water. Of course cheap electric power has to be available, otherwise the process is too costly.

Heavy water has a higher boiling point than ordinary water, and freezes at 3. 8℃ (i. e. earlier than ordinary water during a freezing process). A whole range of new compounds is envisaged by the replacement of the hydrogen in organic compounds by the heavy isotope, deuterium.

Heavy water is of great importance in atomic energy work. Its importance is shown by the fact that several atomic piles now in operation are heavy water piles, in which heavy water takes the place of the carbon bricks in other piles for the absorption or lowering down of neutrons given out by splitting uranium atoms.

A further isotope of hydrogen, tritium (symbol T), which is three times as heavy as hydrogen, has been discovered, and this, too, is of great importance in the production of the hydrogen bomb.

Vocabulary

monoxide	[mə'nɔksaid]	*n.*	一氧化碳
quartz	[kwɔːts]	*n.*	石英
spongy	['spʌndʒi]	*a.*	多孔的；海绵状的
deuterium	[dju'tiəriəm]	*n.*	氘；重氢
deuteron	['djuːtərɔn]	*n.*	氘核；重氢核
super-heat	[ˌsuːpə'hiːt]	*vt.*	使过热
revert	[ri'vəːt]	*vi.*	回复；恢复原状
isotope	['aisəutəup]	*n.*	同位素
crude	[kruːd]	*a.*	粗制的；原始的；天然的
fillip	['filip]	*n.* & *v.*	刺激；刺激因素；弹指
sulphide	['sʌlfaid]	*n.*	硫化物
missile	['misail]	*n.*	导弹；发射物
hydrocarbon	['haidrə'kaːbən]	*n.*	烃
peculiar	[pi'kjuːliə]	*a.*	特殊的
comparatively	[kəm'pærətivli]	*ad.*	比较地
percentage	[pə'sentidʒ]	*n.*	百分比
fused	[fjuːzd]	*a.*	熔融的
electrolyse	[i'lektrəlaiz]	*vt.*	电解
compress	[kəm'pres]	*vt.*	压缩
envisage	[in'vizidʒ]	*vt.*	展望；预计
subsequently	['sʌbsikwəntli]	*ad.*	随后；其次；接着
pile	[pail]	*n.*	反应堆；堆
cubic	['kjuːbik]	*a.*	立方的
brick	[brik]	*n.*	砖
clay	[klei]	*n.*	黏土
uranium	[juə'reiniən]	*n.*	铀
arc	[aːk]	*n.*	电弧
tritium	['tritiəm]	*n.*	氚；超重氢
recombine	['riːkəm'bain]	*vt.*	重新结合

Phrases

step up	升高；促进；加速
at first sight	乍看起来；一见就
shut off	关掉；关闭；切断
give a fillip to	促进……的发展
give off	放出
take the place of	代替

Exercises

1. Write physical and chemical properties about hydrogen in English.

2. Translate the following into Chinese.

A further isotope of hydrogen, tritium (symbol T), which is three times as heavy as hydrogen, has been discovered, and this, too, is of great importance in the production of the hydrogen bomb.

12 Nitrogen: A Lazy Element with Lively Compounds

Do you recall what happens to the oxygen you inhale? Much of it is chemically changed into carbon dioxide, which you exhale. What happens to the nitrogen you breathe? Practically nothing. Unlike oxygen, the nitrogen you inhale is not chemically changed in the body. (Perhaps a tiny bit of nitrogen does get absorbed into the blood, but it simply stays in the blood as uncombined nitrogen.) Virtually all the nitrogen you inhale, you exhale again.

From what we know about the chemical make-up of the human body, this is a strange fact, for proteins, which make up the greatest part of the body's tissues muscle, blood, skin, nerve, and so on, are compounds of nitrogen. Of course your food contains proteins that were built in the bodies of plants or animals that depend on plants. But this seems a round-about way for the body to get its essential nitrogen when there is such a plentiful supply of nitrogen in the air. Our bodies do, after all, take in and use the free oxygen of the air.

Oxygen in the air easily combines with many substances, as you know. Think of the rusting of iron, the burning of fuel gas, and other oxidation reactions you have observed. Because oxygen combines readily with other elements, chemists say it is an active element.

Nitrogen, however, does not combine easily with other elements. We've called it a 'lazy' element: the chemist would say nitrogen is relatively inactive. But this does not mean nitrogen never combines with other elements. Suppose, for example, we lower a burning wood splint into one jar of nitrogen and a burning strip of magnesium into another jar of nitrogen. The wood splint goes out, but the magnesium continues to burn. How do we explain this? Recall how magnesium reacts with oxygen. The reaction is exothermic; that is, it given off energy.

$$\text{magnesium} + \text{oxygen} \longrightarrow \text{magnesium oxide} + \text{energy}$$
$$2Mg + O_2 \longrightarrow 2MgO + \text{energy}$$

Once the burning of magnesium is started in the oxygen of the air, a great deal of energy is set free. The temperature of the magnesium rises high enough for the magnesium to combine with nitrogen. So if burning magnesium is thrust into pure nitrogen, the reaction continues, but the magnesium is now combining with nitrogen rather than with oxygen.

$$\text{magnesium} + \text{nitrogen} \longrightarrow \text{magnesium nitride}$$
$$3Mg + N_2 \longrightarrow Mg_3N_2$$

A few other metals will react with nitrogen as magnesium does, but most substances will not react with nitrogen of the air.

Why is nitrogen so inactive and oxygen so active? As we often do when we want to explain the behavior of elements, let's look at their molecular structures for a clue. Nitrogen and oxygen both exist in the air as diatomic molecules—formulas are N_2 and O_2. The two atoms in a molecule of nitrogen are held together by a triple chemical bond—three pairs of shared electrons. But the two atoms in a molecule of oxygen are held together by just a single chemical bond—one pair of shared electrons.

Much more energy is needed to break the triple bond of the N_2 molecule than is needed to break the single bond of the O_2 molecule. To start magnesium burning in oxygen, for instance, takes much les heat than to start magnesium burning in nitrogen. When enough energy is supplied to break apart the nitrogen molecule, nitrogen atoms can enter into combination with atoms of other elements. The compounds that can be made, once nitrogen atoms react, are of such value and importance that chemists have a special name for the combining of the air’s nitrogen to form compounds—nitrogen fixation. The combining of nitrogen with magnesium to make magnesium nitride is one example of nitrogen fixation. Let’s take a look at some other ways by which nitrogen can be fixed.

Do you know it can—and sometimes does— rain nitric acid? True, there is only a little of the acid in a great deal of rainwater. Still, it does happen. Whenever there is a thunderstorm, a little nitric acid may come down with the rain.

How does this happen? Ordinarily the nitrogen and oxygen in the air do not react with one another. There isn’t enough energy available to break apart the triple bonds of the nitrogen molecules. However the lightning in a thunderstorm may furnish enough energy, in the form of electricity, to break apart some of the nitrogen molecules. Then a nitrogen fixation reaction can take place between nitrogen and oxygen in the air. The product is nitric oxide(NO). The nitric oxide formed in a thunderstorm combines with more oxygen and with some of the rainwater to make a weak solution of nitric acid(HNO_3). This acid falls to the earth along with the rain, and when it reaches the ground, the nitric acid combines with minerals in the soil to form nitrates. Plants absorb nitrates and build them into complex molecules of proteins. Thus, strange as it seems, lighting actually helps fertilize the soil.

Suitable catalysts(those substances that can help a reaction along but remain unchanged at the end of the reaction) also bring about nitrogen fixation. Catalysts in the cells.of living things are called enzymes. Certain bacteria, known as nitrogen-fixing bacteria, have enzymes that can catalyze nitrogen fixation. These bacteria can take free nitrogen from air mixed in the soil, and change this nitrogen into compounds. Nitrogen-fixing bacteria live in nodules on the roots of plants such as clover, peanuts, and beans. A plant that has these nodules has a sort of built-in nitrogen—fixing factory that furnishes the plant with the nitrates it needs to build proteins.

There are, as you have seen, two main ways in which nitrates are formed by nitrogen fixation in nature. These nitrates are of vital importance to the plants we grow for food. But the amount of natural nitrogen fixation is not enough to supply all the nitrates needed by all the world’s food crops. So man has to add nitrate fertilizers, and the manufacture of the fertilizers depends on man-made processes of nitrogen fixation.

Vocabulary

lazy [ˈleizi] *a.* 懒惰的；惰性的
diatomic [daiæˈtɔmic] *a.* 双原子的
lively [ˈlaivli] *a.* 活泼的
fixation [fikˈdeiʃən] *n.* 固定
inhale [inˈheil] *vt.* 吸入
rainwater [ˈreinwɔːtə] *n.* 雨水

exhale [iksˈheil] *vt.* 呼入
thunderstorm [ˈθʌndəstɔːm] *n.* 雷阵雨
virtually [ˈvəː tʃuli] *ad.* 实际上；实质上
lightning [ˈlaitniŋ] *n.* 闪电
tissue [ˈtisjuː] *n.* 组织
furnish [ˈfəːniʃ] *vt.* 提供；供给
nerve [nəːv] *n.* 神经
fertilize [ˈfəːtilaiz] *vt.* 使肥沃；施肥
round-about [ˈraudəbaut] *n.* 绕道的；拐弯抹角的
cell [sel] *n.* 细胞
plentiful [ˈplentiful] *a.* 大量的；丰富的
enzyme [ˈenzaim] *n.* 酶
thrust [θrʌst] *vt.* 推入；插入
catalyze [ˈkætəlaiz] *vt.* 催化
jar [dʒaː] *n.* 广口瓶；罐；缸
nodule [ˈnɔdjuːl] *n.* 根瘤；瘤状物
inactive [inˈæktiv] *a.* 不活泼的
clover [ˈkləuvə] *n.* 苜蓿；三叶草
strip [strip] *n.* 条；带；片
peanut [ˈpiːnʌt] *n.* 花生
exothermic [eksəuˈθəːmik] *a.* 放热的
bean [biːn] *n.* 豆
nitride [ˈnaitraid] *n.* 氮化物
built-in [ˈbilˈtin] *a.* 嵌入的；内在的

Phrases

break apart 使分裂开
set free 释放出来

Exercises

Put the following into English.

a. 游离氧
b. 固氮作用
c. 稀硝酸溶液
d. 副产品
e. 蛋白质含量
f. Mg_3N_2
g. NO

13 Oxygen

The air we breathe is a mixture of several gases including nitrogen, oxygen, carbon dioxide, argon, water vapor and in urban environments sulphur dioxide. The two main gases nitrogen and oxygen, occupy between them about 99 percent of any given volume of air, the remaining constituents being present only in very small proportions. Oxygen occupies about 21 percent by volume and 23 percent by weight of the atmosphere and is the commonest of all elements in the Earth's crust as a whole making up almost half of it in one form or another.

Oxygen was discovered as a separate element, but not named as such, by two scientists working independently in 1774, Joseph Priestley in England and C. W. Scheele in Sweden who was investigating what happens during heating or burning of materials. The modern theory of burning is attributed to Antoine Lavoisier, a

Frenchman, who, after meeting Priestley in Paris in 1774, confirmed that oxygen is the part of air which combines with burning materials to cause an increase in weight. It was Lavoisier who gave it the name oxygen.

Before 1774, scientists had been at odds over what actually happens what something is burnt. Some materials, such as paper, wood and coal, appear to lose weight when they burn and others, such as copper magnesium and iron filings, gain weight after heating. One explanation was based on the supposition that there existed in all matter an imaginary material called 'phlogiston' that could be burnt to a greater or lesser extent. On burning, the phlogiston escaped and the substance lost weight. The idea of phlogiston did not, however, explain an increase in weight and to get round this it was even assumed that sometimes phlogiston could have negative weight! We now know that in fact all material when they are heated or burned in air absorb oxygen and gain in weight. The apparent loss of weight when wood coal or other materials are burnt is because of the smoke given off and lost. Controlled heating where no smoke is lost has shown conclusively that these materials too absorb oxygen from the air. All materials require the presence of oxygen to a greater or lesser degree for burning to take place. (The observation that gunpowder will burn apparently without oxygen is explained by the fact that there is a certain amount of oxygen present in saltpeter, which is one of the constituents of gunpowder.) One of the tests of oxygen is its ability to relight a glowing splint, so if relighting occurs on insertion of a splint into a gas we know oxygen is present.

Oxygen is a most important element. It is colorless, odorless and tasteless, slightly soluble in water (which is essential for water life), can be liquefied at −183℃ and has approximately the same density as air. The industrial uses of oxygen are in chemical processing and, together with acetylene, in oxy-acetylene cutting and welding of metals. Medical use is made of oxygen to assist breathing in high altitude flying and climbing, submarines and mines.

When a material is heated in air it absorbs oxygen and a chemical reaction takes place resulting in the formation of the oxide of the material. Some examples are copper to form copper oxide, magnesium to form magnesium oxide, carbon to form carbon dioxide (in this case each molecule of carbon dioxide contains two atoms of oxygen, hence the prefix 'di-' in dioxide), and phosphorus to form phosphoric oxide, and so on.

Oxide formation, especially on metals, may or may not be advantageous. In some cases the oxide once formed protects the metal underneath, but in others, where the metal is being used as a conductor of electricity, for example, and oxide of the metal is a non-conductor, had electrical connections may ensue. Another everyday example of oxide formation being distinctly disadvantageous is the process of rusting. We are all familiar with the changes that take place on the surface of iron or iron-based metals which are left out of doors unprotected by paint or other material. The reddish-brown flakes of rust which form are in fact hydrated iron oxide. Rusting is a similar process to burning in that the iron absorbs oxygen from the atmosphere.

However，in this case heat is not required but water must be present as well as traces of carbon dioxide. Rusting is quite a complicated process，in which ferrous carbonate is first formed，then oxidized to ferric carbonate，which absorbs water to give hydrated ferric oxide (rust) and some carbon dioxide. Rust is a major problem in industry and also in domestic surroundings since much of our construction work in machines and buildings uses iron or iron based materials. Left to itself the rusting process continues until all or most of the iron in the vicinity is consumed and holes or major areas of weakened metal are left behind. Any suitable material to prevent the metal remaining in close contact with air and water may be used as a rust preventative.

Vocabulary

breathe [briːð] *v.* 呼吸
apparent [əˈpærənt] *a.* 表面上的；明显的
apparently [əˈpærəntli] *ad.* 表面上看来像；显然
argon [ˈaːgɔn] *n.* 氩
urban [ˈəːbən] *a.* 城市的；市区的
constituent [kənˈstitjuənt] *n.* 组成部分；*a.* 组成的
conclusively [kənˈkluːsivli] *ad.* 结论性地
gunpowder [ˈgʌnpaudə] *n.* 火药
Sweden [ˈswiːdn] *n.* 瑞典
saltpeter [sɔːltˈpiːtə] *n.* 硝酸钾；硝石
investigate [inˈvestigeit] *vt.* 调查研究
relight [ˈriːˈlait] *vt.* 重新点燃（relighted，relighted 或 relit，relit)
confirm [kənˈfəːm] *vt.* 证实；证明
odds [ɔdz] *n.* (用作单或复)不等；差异
glowing [ˈgləuiŋ] *a.* 灼热的；通红的
magnesium [mægˈniːzjəm] *n.* 镁
splint [splint] *n.* 薄板的；薄木条；薄金属片
filings [ˈfailiŋz] *n. pl.* 锉屑；金属屑
insertion [inˈsəːʃən] *n.* 插入；嵌入
phlogiston [flɔˈdʒistən] *n.* 燃素
colorless [ˈkʌləlis] *n.* 无色的
extent [iksˈtent] *n.* 程度；范围
odorless [əudəlis] *n.* 没有气味的；无臭的
absorb [əbˈsɔːb] *vt.* 吸收
tasteless [ˈteistlis] *n.* 无味的
taste [teist] *n.* 味道
everyday [ˈevridei] *a.* 日常的；每日的
liquefy [ˈlikwifai] *vt.* 使液化
distinctly [disˈtiŋktli] *ad.* 明显地；有特色地
approximately [əprɔksiˈmətli] *ad.* 近似地
rust [rʌst] *v.* 生锈；*n.* 锈；铁锈
density [ˈdensiti] *n.* 密度
familiar [fæˈmiljə] *a.* 熟悉的
process [prəˈses] *vt.* 加工；处理；*n.* 过程；工艺；方法
unprotected [ˈʌnprəˈtektid] *a.* 无保护的；未加保护层的
protect [prəˈtekt] *vt.* 保护
processing [prəuˈsesiŋ] *n.* 处理；加工
acetylene [əˈsetiliːn] *n.* 乙炔
reddish-brown [ˈrediʃbraun] *a.* 红棕的；红褐色的
oxy-acetylene [ɔksiəˈsetliːn] *a.* 氧炔的；*n.* 氧乙炔
flake [fleik] *n.* 片；薄片
weld [weld] *v.* 焊接
hydrated [ˈhaidreitid] *v.* 使水合；使成水合物
welding [ˈweldiŋ] *n.* & *a.* 焊接；焊接的
assist [əˈsist] *vt.* 帮助
hydrated [ˈhaidreitid] *a.* 水合的

altitude [ˈæltitjuːd] *n.* 高度；海拔高度
trace [treis] *n.* 微量；痕量
submarine [sʌbməˈriːn] *n.* 潜水艇
ferrous [ˈferəs] *a.* 亚铁的；二价铁的
mine [main] *n.* 矿
ferric [ˈferik] *a.* 正铁的；三价铁的
oxide [ˈɔksaid] *n.* 氧化物
major [ˈmeidʒə] *a.* 主要的；重要的
oxidize [ˈɔksidaiz] *v.* 氧化
domestic [dɔˈmestik] *a.* 家庭的；国产的；本地的
prefix [ˈpriːfiks] *n.* 前缀；词头
phosphorus [ˈfɔsfərəs] *n.* 磷
surroundings [səˈraundiŋz] *n. pl.* （周围）环境
phosphoric [fɔsˈfɔrik] *a.* 磷的
advantageous [ædvənˈteidʒəs] *a.* 有利的
vicinity [viˈsiniti] *n.* 附近
disadvantageous [disædvaːnˈteidʒəs] *a.* 不利的
preventative [priˈventətiv] *n.* 预防方法；预防措施
underneath [ʌndəˈniːθ] *ad.* 在……下面
conductor [kənˈdʌktə] *n.* 导体
non-conductor [ˈnɔnkənˈdʌktə] *n.* 非导体
ensue [inˈsjuː] *vi.* 接着发生

Phrases

be at odds over 在……进行争论
in that 在于；因为；既然；在这点上
对……有分歧意见
leave behind 留下
to a greater or lesser extent (degree) 或多或少地
leave out of doors 置于露天中；置于户外

Exercises

1. Put the following into English.

a. 单体元素
b. 化学处理
c. 水合氧化铁
d. $FeCO_3$
e. $Fe_2(CO_3)_3$
f. 防锈剂
g. MgO
h. CuO

2. From the two words indicated, in each item, choose the right one and insert it into its proper place.

a. I am odds with him over the matter.
(a) in (b) at

b. It will expand rapidly heating.
(a) at (b) on

c. The discovery of oxygen as a separate element is attributed both Joseph Priestley and C. W. Scheele.
(a) to (b) in

d. This chemical reaction will result the formation of a salt.
(a) from (b) in

e. This book is written for readers familiar the French Language.
(a) with (b) to

f. There seems to be no way of getting the difficulty of removing the impurities from it.

(a) off (b) round

g. Oxygen occupies about 23 percent weight of the atmosphere.

(a) by (b) to

h. His mistake is a great extent due to carelessness.

(a) in (b) to

14 Halogens

14. 1 Occurrence

The halogens occur in combined form in the earth's crust in the approximate amounts F, 0. 08%; Cl, 0. 05%; Br, 0. 001%; and I, 0. 001%. Chlorides and bromides are concentrated in the oceans by the leaching processes of natural waters. Large deposits of NaCl and, to a lesser extent, calcium, potassium, and magnesium chlorides are found in the dried up beds of landlocked lakes, where calcium and magnesium sulfate and mixed salts of KBr and $MgBr_2$ also occur. Because of difference in concentrations and temperature during deposition, the different salts often are well separated. Limiting the fluoride content of sea water is the large concentration of calcium ion present and the very low solubility of CaF_2. CaF_2's low solubility compared with the other calcium halides stems from the high lattice energy of the fluoride, which in turn results from the small radius of F^-. Natural deposits of calcium fluoride, called fluorspar or fluorite, serve as the primary source of fluorine. Cryolyte, Na_3AlF_6, another commercially important fluoride mineral, is used as the electrolyte in the production of Al.

Although the concentration of iodine in the ocean is small, it is absorbed selectively by and can be obtained from seaweed. A more important source is sodium iodate and sodium periodate, which occur in deposits in Chile. The natural occurrence of these oxo anions for iodine contrasts sharply with the lack of natural deposit of oxo salts of Cl and Br and illustrates the greater ease with which it attains the higher oxidation states, compared with the lighter halogens.

Astatine occurs naturally in very small amounts as the beta decay product of ^{216}Po, and ^{218}Po. As polonium itself is rather rare, and α decay is the usual decay route, At has not been isolated from natural sources; it has been prepared by a bombardment of bismuth, $^{209}Bi\ [\alpha,\ 2n]^{211}At$. Astaine itself is radioactive: its longest-lived isotope has a half-life of 8. 3 hr.

14. 2 Preparation of the Elements

Since F, Cl and Br occur in natural as halides, preparing the elements involves suitable oxidation reactions. Electrolytic oxidation of fused KF-HF adducts is used to produce F_2. HF is removed from the F_2 by reaction with NaF. The cells are constructed of copper, mond, or steel with amorphous carbon anodes. Graphite electrodes cannot be used because of the graphite compounds formed. Chlorine is produced by electrolysis of either fused NaCl or concentrated aqueous solutions of NaCl, the latter being the more commonly used method.

$$Na^+Cl^- + H_2O \xrightarrow[\text{electrolysis}]{} Na^+ + OH^- + \frac{1}{2}Cl_2 + \frac{1}{2}H_2$$

In the laboratory, Cl_2 can be made by the action oxidizing agents such as MnO_2 on HCl. Bromine is produced commercially from bromides in sea water by the oxidation of action of chlorine. After the pH of the sea water is adjusted to a value between 1 and 4 with sulfuric acid and then treated with chlorine, the liberated Br_2 is blown out by an air stream and the bromine concentrated by a sequence of reactions, such as absorption in a carbonate solution and subsequent acidification.

$$Cl_2 + 2Br^- \longrightarrow Br_2 + 2Cl^-$$
$$3Br_2 + 3CO_3^{2-} \longrightarrow 5Br^- + BrO_3^- + 3CO_2$$
$$5Br^- + BrO_3^- + 6H^+ \longrightarrow 3Br_2 + 3H_2O$$

Cl_2 is removed from the Br_2 produced by reaction with a bromide such as iron (Ⅲ) bromide.

Sulfite reduction of iodate yields I_2 which is purified by sublimation.

$$2NaIO_3 + 5NaHSO_3 \xrightarrow[\text{aq. sol.}]{} 3NaHSO_4 + 2Na_2SO_4 + H_2O + I_2$$

Vocabulary

landlocked	[ˈlændlɔkt] *a.*	为陆地围住的；生活在与海隔绝的水中的
seaweed	[ˈsiːwiːd] *n.*	海藻；海草
Chile	[ˈtʃili] *n.*	智利
commercial	[kəˈməːʃəl] *n.*	商业的；可获利的；用来出售的
amorphous	[əˈmɔːfəs] *a.*	无定形的
iodate	[ˈaiədeit] *n.*	碘酸盐
sodium iodate		碘酸钠
periodate	[peˈraiədeit] *n.*	高碘酸盐
sodium periodate		高碘酸钠
polonium	[pəˈləuniəm] *n.*	钋
halogen	[ˈhælədʒən] *n.*	卤素
astatine	[æstətiːn] *n.*	砹
bombardment	[bɔmˈbaːdmənt] *n.*	炮击；轰击
acidification	[əˌsidifiˈkeiʃən] *n.*	使发酸；酸化

Phrases

compare with	与……比较

Exercises

1. Write balanced equations for the following preparations.

a. Cl_2 (from NaCl)

b. Br_2 (recovery from seawater)

c. I_2 (from $NaIO_3$)

d. HF(from CaF_2)

e. HCl(from NaCl)

2. **Indicate reactions which might be suitable for the preparation of.**
   a. Anhydrous tetramethylammonium fluoride.
   b. Aluminum bromide
   c. Barium iodide.
3. **Draw the structures of the following species, indicating the approximate bond angles:**
   a. IF_2^+ b. IF_4^+ c. IF_6^+

15 Aluminium

15.1 Introduction

This is probably the most abundant metal on the earth, as the oxide, alumina Al_2O_3, makes up the chief part of all clays and many other rocks. The metal was first isolated as a powder by Wohler. It was not until about 1854 that it was obtained on a manufacturing scale.

Aluminum is a very light metal, weighing only about 2.7 times that of water, and it is therefore only about one-third the weight of iron. It is good conductor of electricity, and although inferior to copper it is replacing copper for the long distance transmission of electric power owing to its lightness and lower cost. It forms a valuable alloy with copper, known as aluminum bronze. To obtain the bronze a mixture of corundum (alumina), charcoal and granulated copper is heated in an electric furnace. The carbon takes up the oxygen of the alumina, while the copper unites with the aluminum to form a golden-colored alloy which has great strength and elasticity.

The development of the motor and aircraft industries led to the introduction of a number of aluminum alloys of great value owing to their lightness and strength. The most important of these are 'magnalium', containing magnesium, and 'duralumin', which is aluminum with about 4 percent of copper and a little magnesium. Other alloys with copper, nickel and zinc are used in the construction of motor-car and aeroplane parts. Alloys of aluminum and silicon, with small amounts of other substances, are used in shipbuilding, as after heat treatment they are very strong and resist the corrosive action of sea water.

Aluminum has been made for many years by the electrolysis of alumina (prepared bauxite, $Al_2O_3 \cdot 2H_2O$) dissolved in fused cryolite (sodium aluminum fluoride Na_3AlF_6). The operation is carried out in an iron pot lined with carbon which forms the cathode. The current is brought in by thick carbon rods forming the anode which dip into the mixture. The metal sinks to the bottom and is tapped off at intervals while carbon monoxide gas escapes. As the metal is removed the supply of alumina is kept up by adding more bauxite to the molten mixture.

In the production of aluminum, as in so many other processes, the source of power is the energy of falling water. Factories have been built near many of the great waterfalls of the world such as Niagara, the Falls of the Rhine at Schaffhausen and in England at Kinlochleven in Argyllshire, and in North Wales. The bauxite used is chiefly from the south of France, but useful deposits occurring in the southern part of the United States, and Antrim, Northern Ireland.

The remarkable increase in the use of aluminum during the past half century is shown by the following figures for the total world output of the metal.

World output of aluminum

1907	30,000 tons
1919	136,000 tons
1924	171,000 tons
1929	270,000 tons
1934	171,000,000 tons
1950	1,417,000 tons

The increasing use of aluminum is well shown by the above figures. Of this amount of nearly one and a half million tons produced in 1950s, the American output was 718, 000 tons, while British production has increased from 15, 000 tons in 1936 to 33, 000 tons in 1959.

Aluminum is valuable not only for its lightness but on account of its peculiar behavior towards acids and alkalis. It dissolves rapidly in dilute hydrochloric acid, but is only slowly attacked by sulphuric and nitric acids, and even less by vegetable acid. On other hand, it is dissolved by alkaline solutions. Hence, although aluminum is used for making cooking vessels and for storage of many foodstuffs, it is well to remember that saucepans or pots of aluminum must not be cleaned by soda.

In the air aluminum soon becomes covered with a thin, almost invisible, film of oxide, which protects the metal from further corrosion. This process of self-protection can be hastened and made more effective by 'anodic treatment.' The metal is made the positive pole in the electrolysis of a suitable solution, and when oxidation occurs the resulting surface is immune to atmospheric corrosion. This anodic process is used for the treatment of aeroplane parts.

Aluminum melts below a red head, and when heated in air it oxidizes readily. A thin piece of aluminum foil in a bottle of oxygen gas if touched with a red-hot wire disappears instantly with a brilliant flash, leaving a white oxide behind. When aluminum combines with oxygen more heat is given off than by any other burning metal. The readiness of aluminum to take up oxygen and the heat thus given off during the combination is used commercially to obtain metals which are difficult to get by other means. A mixture of aluminum heated with the oxide of another metal gives a violent chemical reaction. The aluminum is converted into oxide while the other metal is left in the metallic state. The action is so violent in some cases, copper oxide for example; that a kind of explosion occurs and part of the metal is volatilized. Chromium is obtained in this way in a pure state, as also manganese which previously had been known only in combination with carbon or iron.

An ingenious application of this property of aluminum is found in the 'thermit' process. A mixture of ferric oxide with aluminum powder is put in a crucible with a removable bottom. When a fuse is lit the whole mass glows and in few minutes a layer of molten iron sinks to the bottom of the pot and can be run off into a mould. The method is used for the repair of broken castings or to join the ends of rails without removing them. A mould around the rail-end holds the melted metal, and after solidifying the excess iron can be cut or ground away. The temperature produced in the mixture is about 3, 500℃, and is sufficiently high to melt every known metal. The thermit process is used in many incendiary bombs, as once the reaction is started it cannot be stopped, as many fire-fighters discovered during the air-raids on London and other cities in the last war.

15. 2 Preparation of Aluminum

In 1827 Friedrich Wohler of Germany secured aluminum in sufficient quantity by reduction with potassium to study its properties. By 1852 aluminum sold for $545 a pound. In 1859, Deville of France had perfected a method for extracting aluminum which reduced its price to $17 a pound. But it remained for Charles Martin Hall, in 1886, to perfect a satisfactory commercial method for extracting aluminum from its ore. Just nine months after graduating from Oberlin College, Hall obtained metallic aluminum by the electrolysis of a solution of alumina, Al_2O_3, in molten cryolite, Na_3AlF_6. Most of you already know that young Hall worked in a crude laboratory set up in his father' s woodshed. At about the same time Paul Heroult in France perfected an identical process for producing metallic aluminum. Today, using refinements of the process, aluminum is produced at somewhat less than twenty cent a pound.

The ore used in the electrolytic process is bauxite, a mixture of $Al_2O_3 \cdot H_2O$ and $Al_2O_3 \cdot 3H_2O$. Its main impurities are iron oxide, silicon oxide, and titanium oxide, each of which must be removed before the electrolytic process. These oxides are removed by screening and washing, by magnetic devices and recently by froth floatation. Even this concentration or 'ore dressing' does not yield aluminum oxide sufficiently pure for use in the electrolytic cells. The aluminum oxide used must contain neither iron nor titanium compounds when it is placed in the electrolytic cell. If either of these metals is present, it is reduced along with the aluminum, and an alloy results. The remaining impurities must be removed chemically. Sodium hydroxide, which reacts with neither iron nor titanium oxides, is added. It reacts with the aluminum oxide, forming soluble sodium aluminum. The impurities are filtered out and the solution is cooled. Aluminum hydroxide crystals are added. Under these conditions the sodium aluminate decomposes to $Al(OH)_3$ and NaOH. The sodium hydroxide is removed to be used again, and the aluminum hydroxide, $Al(OH)_3$, is then heated in a rotary kiln. Heating decomposes it to aluminum oxide and water. Thus purified, the aluminum oxide, also called alumina, is ready for use in the electrolytic cell.

$$2Al(OH)_3 \xrightarrow{\triangle} Al_2O_3 + 3H_2O$$

The metallurgy of aluminum required large quantities of electric current, so the factories are generally located near sources of hydroelectric power. The cell used for preparing aluminum consists of a rectangular iron box lined with carbon which becomes the cathode. The anode consists of carbon rods which are suspended from bus bars above the iron box. Long rows of these cells are used, each cell producing about 500 pounds of the metal a day.

Cryolite, Na_3AlF_6, is melted in the cell by the heat from an arc between the anode rods and the carbonlined box. The molten cryolite then dissolves aluminum oxide, which is added in amounts to make about 5 percent of the weight of the cryolite. Additional batches of the oxide are added at regular intervals. Theoretically, the cryolite serves only as a solvent and as a conductor of electric current, but actually there are small losses which must be replaced from time to time. The cell operates at from 950℃ to 1000℃.

Aluminum goes to the cathode during electrolysis and being heavier than the cryolite electrolyte it collects on the bottom. It is drawn off in a molten state and cast in ingots weighing about 50 pounds. Aluminum ingots are 99.0 to 99.9 percent pure metals. Oxygen is liberated from the alumina at the carbon anode bars and unites with the carbon producing CO_2. The rodes must, therefore, be continuously lowered into the cell.

Originally only natural cryoliute from Greenland was used in the electrolytic cells; but for many years much synthetic cryolite has been used in such cells.

During World War Ⅱ, when great quantities of aluminum were required, chemists devised a method of profitably using ores containing high percentages of silica. Soda ash, Na_2CO_3, and limestone are sued for removing silica.

Vocabulary

isolate ['aisəleit] *vt.* 分离；离析

alkaline ['ælkəlain] *a.* 碱的；强碱的

inferior [in'fiəriə] *a.* 较差的

foodstuff ['fuːdstʌf] *n.* 食品

transmission [trænz'miʃən] *n.* 输出；送电；传递

saucepan ['sɔːspən] *n.* 长柄有盖的深平底锅

corundum [kə'rʌndəm] *n.* 刚玉；金刚砂

self-protection ['self-prə'təkʃən] *n.* 自我保护

charcoal ['tʃaːkəul] *n.* 木炭

granulate ['grænjuleit] *vt.* 轧碎；使成粒状

hasten ['heisn] *vt.* 加速

granulated ['grænjuleitid] *a.* 粒状的；成粒的

anodic [æ'nɔdik] *a.* 阳极的；正极的

pole [pəul] *n.* 极；电极

magnalium [mæg'neiliəm] *n.* 镁铝合金

immune [i'mjuːn] *a.* 免疫的；不受影响的

resist [ri'zist] *vt.* 抵抗；耐；抵制

brilliant ['briljənt] *a.* 极明亮的；光辉的

bauxite ['bɔːksait] *n.* 铝土矿；铝矾土

volatilize [vəˈlætilaiz] *vt.* 使挥发
fluoride [ˈfluəraid] *n.* 氟化物
ingenious [inˈdʒiːniəs] *a.* 巧妙的；有创造才能的
pot [pɔt] *n.* 锅
sink [siŋk] *vi.* 沉下；降下（sank 或 sunk，sunk 或 sunken；sinking）
thermit [ˈθəːmit] *n.* 铝热剂
crucible [ˈkruːsibl] *n.* 坩埚
waterfall [ˈwɔːtəfɔːl] *n.* 瀑布
removable [riˈmuːvəbl] *a.* 可取下的
falls [fɔːlz] *n. pl.* 瀑布
fuse [fjuːz] *n.* 引火线
output [ˈautput] *n.* 产量
glow [gləu] *vi.* 灼热；无焰燃烧；发光
vegetable [ˈvedʒitəbl] *a.* & *n.* 植物（的）；蔬菜
dressing [ˈdresiŋ] *n.* 选矿；精选
rail [reil] *n.* 铁轨
aluminate [əˈljuːmineit] *n.* 铝酸盐
solidify [səˈlidifai] *vi.* 凝固
rotary [ˈrəutəri] *a.* 旋转的
incendiary [inˈsendjəri] *a.* 纵火的
hydroelectric [haidrəiˈlektrik] *a.* 水电的；水力发电的
fire-fighter [ˈfaiəfaitə] *n.* 消防队员
air-raid [ˈɛəreid] *n.* 空袭
rectangular [rekˈtæŋgjulə] *a.* 长方形的；矩形的
secure [siˈkjuə] *vt.* 获得
sell [sel] *v.* 卖；销售（sold，sold，selling）
suspend [səsˈpend] *vt.* 悬挂；吊
remain [riˈmein] *vi.* 尚须；有待于
row [rəu] *n.* 排；行
woodshed [ˈwudʃed] *n.* 柴间；木料间
batch [bætʃ] *n.* 批
refinement [riˈfainmənt] *n.* 经改进的设计或装置；精制；提炼
replace [riˈpleis] *vt.* 补充；复原；取代
devise [diˈvaiz] *vt.* 设计
cent [sent] *n.* 分；美分
profitably [ˈprɔfitəbli] *ad.* 有利可图地
titanium [taiˈteinjəm] *n.* 钛
fusion [ˈfjuːʃən] *n.* 熔融体；熔化
screen [skriːn] *v.* 筛分；筛选
silica [ˈsilikə] *n.* 二氧化硅；硅石
magnetic [mægˈnetik] *a.* 磁力的
froth [frɔθ] *n.* 泡沫

Phrases

at intervals 间隔；有时
at regular intervals 定期地
be immune to 不受……的影响
from time to time 不时地

Exercises

1. Put the following into English.

a. 铝青铜
b. 铝热法
c. 磁力选矿装置
d. 浮沫选矿

2. In each case, choose one of the four word that best matches the definition given.

a. A vessel made of heat-resistant material and used at high temperatures for melting metals, fusing etc.

(a) container
(b) furnace
(c) crucible
(d) flask

b. Give off light and heat, especially without flame.

(a) glow
(b) burn

(c) boil (d) melt

c. A mixture of aluminum powder and iron oxide which give out a large amount of heat when ignited.

(a) alumina (b) thermit

(c) explosive (d) bauxite

d. Change to a gas or vapour ; evaporate.

(a) solidify (b) liquefy

(c) volatilize (d) melt

e. Atoms of an element which differ in atomic weight.

(a) deuterium (b) isotopes

(c) tritium (d) ions

f. An aluminium-base alloy containing some magnesium, used for aircraft part.

(a) duralumin (b) cryolite

(c) magnalium (d) alumina

16 Quantitative Inorganic Analysis Introduction

16.1 Quantitative and Quantitative Analysis

Analytical chemistry comprises qualitative and quantitative analysis. The aim of qualitative analysis is the detection and identification of the constituents of a compound or mixture of compounds or elements, whereas the determination of the percentage or molecular composition of a sample is the province of quantitative analysis.

Many of the reactions of quantitative analysis can be and are, by refinement and regulation of conditions, made the basis of quantitative processes. However, a procedure which has proved to be quite useful in quantitative analysis is not always applicable to quantitative analysis. In quantitative analysis it is often immaterial whether in a separation part of the constituent to be sought in the filtrate is retained in the precipitate. Therefore separations which have been found useful in qualitative analysis must be critically tested before application to quantitative analysis.

A quantitative analysis is of the greatest aid in deciding the method to be followed in quantitative analysis. Many quantitative procedures for a given element will yield erroneous results when certain other elements are present in the sample analyzed; and they must therefore be modified to eliminate, or at least reduce, the interference caused by other constituents. The determination of an element in a pure solution, i. e. , a solution free from other substances, is a relatively simple matter; but the case is entirely different when the element in question is associated with others, as so often happens in practical analysis when complex natural materials and artificial products must be analyzed. In such cases, then a qualitative analysis which reveals the constituents present and which indicates the relative amounts of these is often an indispensable preliminary to proper quantitative analysis.

16. 2 The Importance of Quantitative Analysis and the Scope of the Subject

A true understanding of any natural phenomenon is impossible without acknowledge of the quantitative relationships involved. Quantitative analysis has rendered most valuable services in the development of the science of chemistry and other sciences as well which make use of chemistry. The formulation of the fundamental laws of chemistry has been based largely on the results of quantitative analysis. For our knowledge of the composition of the earth and all it contains, and even of extraterrestrial matter, we indebted to chemical analysis.

Apart from its fundamental position in the science, quantitative analysis occupies a most important place in human activities because of its utilitarian character. The value of raw materials such as ores, the suitability of a manufactured product for a given use, the control of a process of manufacture these and many other problems require the application of quantitative chemical analysis for solution.

16. 3 The Methods of Quantitative Analysis

The determination of a substance in quantitative chemical analysis is based on the measurement of a physical or chemical property of the substance, the magnitude of which is a function of the amount present.

All methods of analysis are physical in the strict meaning of the term; in as much as the final step in a determination must involve the measurement of some physical property. However, in a broader sense it is possible to divide all methods into two great classes:

(1) Chemical methods. As the name implies, the methods of this class depend on the application of a chemical reaction involving the constituent being determined. They are distinguished from others by being theoretically based on a stoichiometric reaction:

$$\underset{x}{m\mathrm{C}}+\underset{v}{n\mathrm{R}}\longrightarrow\underset{w}{\mathrm{C}_m\mathrm{R}_n}$$

Where C is the constituent and R is the chemical reagent. As this equation shows, we can find the amount, x, of C from the amount, w, of the product C_mR_n formed, or from the amount, v, of R required to react with the constituent. When the amount of the reaction product is found by weighting we speak of gravimetric analysis. Usually the reaction product is isolated in the from of a very slightly soluble compound which is separated from the solution by filtration, washed free from soluble substances, and weighed after drying or conversion into another compound of definite composition. Since the atomic weights of the elements involved are known, the weight of C is readily calculated.

When the amount of the constituent is found from the amount of the reagent required reacting with it we usually speak of volumetric analysis; because the reagent is added in the form of a solution of known concentration (standard solution). By methods to be described later, the point at which an equivalent amount of the reagent has been added is determined. The quantity of the constituent can then be calculated from the volume of the standard solution used in the titration.

If the reaction product is a gas, its amount can be found from the volume of the gas at known temperature and pressure. This is gasometrical analysis.

(2) Physical and physicochemical methods. If no chemical reaction is revolved in a determination, the method is plainly physical. There are many physical properties which are function either of the mass of a substance or of its concentration. For example, the color intensity of a solution of permanganate is proportional to the concentration. Therefore, by measuring the intensity in a suitable way we can determine the concentration of manganese and therefrom its quantity. Usually the manganese would be present originally in the divalent state and it would be necessary to oxidize it to permanganate. This is a physicochemical method. A chemical reaction is an essential part of the method but the final measurement is purely physical.

A feature of almost all physical and physicochemical methods is the actual comparison of the unknown against standards. If a chemical reaction is involved it need not be stoichiometric, although this is always desirable. Physical methods are concerned largely with energy, in contrast to chemical methods which are concerned with mass. The most important physical and physicochemical methods are those based on emission and absorption of radiation.

16.4 Macro, Micro, and Meso Analysis

Ordinarily the size of sample taken in a quantitative analysis lies in the range 0.1g to 1g. This is a macro sample. It may be advantageous or necessary, because of scarcity of material to work with sample about one one-hundredth as large as this, i. e. , 1mg to 10mg. this is a micro sample and its use requires the application of micro methods. The difference between macro and micro analysis lies essentially in the scale of operations. Gravimetric, volumetric, and other types of methods have all been adapted to micro analysis. In gravimetric micro analysis a micro balance is used, which will weight approximately 0.001mg as compared to 0.1mg with the ordinary analytical balance.

Sometimes it is desirable to work with a sample of a size intermediate between a macro and micro sample, i. e. , about one-tenth that of a macro sample. Such a sample is meso (semi-micro) sample.

The aim in macro, micro and meso analysis is to determine with accuracy a major (>1 percent) or minor (0.01～1 percent). Such an analysis has the characteristics of both the macro and micro analysis. It may require the taking of a large sample as in macro analysis, but the final determination usually involves quantities smaller than those dealt with in micro analysis. Physical and physicochemical methods are of special importance in trace analysis.

Vocabulary

comprise [kəmˈpraiz] *vt.* 包含
procedure [prəˈsiːdʒə] *n.* 程序；处置
detection [diˈtekʃən] *n.* 检出；觉察出
applicable [ˈæplikəbl] *a.* 适用的
constituent [kənˈstitjuənt] *n.* 构分；组分；成分
immaterial [iməˈtiəriəl] *a.* 不重要的
whether [ˈweðə] *conj.* 不管；是否
whereas [wɛərˈæz] *conj.* 而
separation [sepəˈreiʃən] *n.* 分离
province [ˈprɔvins] *n.* 领域
filtrate [ˈfiltreit] *n.* 滤出液
refinement [riˈfainmənt] *n.* 改善；净化
retain [riˈtein] *vt.* 保留
regulation [regjuˈleiʃən] *n.* 调节
gravimetric [græviˈmetrik] analysis 重量分析
precipitate [priˈsipiteit] *n.* 沉淀
critically [ˈkritikəli] *ad.* 批判地；精密地
filtration [ˈfiltreiʃən] *n.* 过滤
follow [ˈfɔləu] *vt.* 遵循；使用
wash [wɔʃ] *vt.* 洗涤
aid [eid] *n.* 帮助
conversion [kənˈvəːʃən] *n.* 转变
yield [jiːld] *vt.* 产生
volumetric [vɔljuˈmetrik] analysis 容量分析；滴定分析；体积分析
erroneous [iˈrəunjəs] *a.* 错误的
modify [ˈmɔdifai] *vt.* 变更；修改
concentration [kɔnsenˈtreiʃən] *n.* 浓度
eliminate [iˈlimineit] *vt.* 消除
titration [taiˈtreiʃən] *n.* 滴定法
reduce [riˈdjuːs] *vt.* 减少；减轻
gasometric [gæsəuˈmetrik] analysis 量气分析
interference [intəˈfiərəns] *n.* 干涉
associate [əˈsəuʃieit] *vt.* 使发生联系；结合；缔合
physicochemical [ˈfizikəuˈkemikəl] *a.* 物理化学的
reveal [riˈviːl] *vt.* 透露；暴露
plainly [ˈpleinli] *ad.* 单纯地
preliminary [priˈliminəri] *a.* 预备的；初步的；准备的
color intensity [ˈkʌləinˈtensiti] 颜色强度
indispensable [indisˈpensəbl] *a.* 必不可少的
permanganate [pəːˈmæŋgənit] *n.* 高锰酸盐
scope [skəup] *n.* 范围
therefrom [ðɛəˈfrɔm] *ad.* 从那里；从而
subject [sʌbdʒikt] *n.* 题目；学科；科目
divalent [ˈdaiveilənt] *a.* 二价的
relationship [riˈleiʃənʃip] *n.* 关系
feature [ˈfiːtʃə] *n.* 特点；特征
involve [inˈvɔlv] *vt.* 牵涉
actual [æktjuəl] *a.* 实际的
render [ˈrendə] *vt.* 提供；给予
desirable [diˈzaiərəbl] *a.* 值得想望的；合意的
service [ˈsəːvis] *n.* 服务
extraterrestrial [ˈekstrətəˈrestriəl] *a.* 地球以外的
macro [ˈmækrəu] analysis 常量分析
micro [ˈmaikrəu] analysis 微量分析
meso [ˈmiːsəu] analysis 半微量分析
fundamental [fʌndəˈmentl] *n.* 根本的；重要的
advantageous [ˈædvənˈteidʒəs] *a.* 有利的，方便的
human [ˈhjuːmən] *a.* 人（类）的
activity [ækˈtiviti] *n.* 活动
scarcity [ˈskɛəsiti] *n.* 缺乏；稀少；不足
utilitarian [juːtiliˈtɛəriən] *a.* 实用的
mg. = milligram 毫克

character [ˈkæriktə] *n.* 性质
essentially [iˈsenʃəli] *ad.* 基本上；主要地
raw [rɔː] *a.* 生的；天然的；未处理的
raw material 原料
scale [skeil] *n.* 规模
suitability [sjuːtəˈbiləti] *n.* 适宜性
balance [ˈbæləns] *n.* 天平
magnitude [ˈmægnitjuːd] *n.* 量；大小
adapt [əˈdæpt] *vt.* 适应
function [ˈfʌŋkʃən] *n.* 函数
major [ˈmeidʒə] *a.* 主要的
strict [strikt] *a.* 严格的
minor [ˈmainə] *a.* 次要的
imply [imˈplai] *vt.* 含有……的意思；暗指
trace [treis] analysis 痕量分析
stoichiometrie [stɔikiəˈmetrik] *a.* 化学计量的
object [ˈɔbdʒikt] *n.* 目的

Phrases

(to) make use of 利用
in a broader sense 在更广泛的意义上来讲
at least 至少
(be) free from 没有
proportional to 与……成正比例
in question 讨论中的（文中意为“测定中的”）
in a suitable way 以适宜的方法
comparison of... against... 与……的比较
as well 同样的；也
(be) indebted [inˈdetid] to 感谢
(be) concerned largely with 大半与……有关
apart from 除……之外
inasmuch [inəzˈmʌtʃ] as 因为；由于
in contrast to... 对比
intermediate [intəˈmiːdiət] between... and... 介于……和……之间
lie in 在于

Exercises

Put the following into English.

a. 定性分析和定性分析方法
b. 定量分析和定量分析方法
c. 常量分析
d. 微量分析
e. 半微量分析
f. 容量法和重量法

17 Use of Burettes

17.1 General

It is necessary for the student to distinguish carefully between the volume that a vessel holds and the volume that it delivers. If exactly one liter of liquid is poured into a clean dry flask, the amount of liquid which can be poured from the flask will be less than one liter since an appreciable quantity of the liquid will cling to the sides of the flask. The quantity of liquid delivered by the flask is held, as well as other factors. If it is desired that the flask deliver exactly one liter, the neck of the flask must be marked at points which will vary depending upon the characteristics of the fluid in the flask. The neck, however, may be marked at a point which shows that the flask contains exactly one liter irrespective of the liquid in the flask. Volumetric flasks are marked in this way to show the amount which is contained by the flask, not the amount which the flask will deliver. Burettes and transfer (volumetric) pipettes, on the other hand, are marked so that they will deliver a definite volume of liquid.

17.2 Burettes

Usually two 50ml burettes are furnished each student in quantitative analysis. One of these will be a Geissler burette with a glass or Teflon stopcock, and the other will be a Mohr burette which is fitted with a glass bead in rubber tubing to control the flow of liquid. The Mohr burette is used for basic titrants such as sodium hydroxide, and the Geissleris used for practically all other titrant.

During titrations, the burette stopcock is normally operated with the left hand. This leaves the right hand free for stirring the liquid or rotating the titration flask. Left-handed students should reverse this and use the right hand for operating the stopcock. Proper control of the stopcock to ensure delivery of small or large volumes accurately requires relaxed muscular control and extensive practice. Muscular tension often causes the student to push the stopcock out of the burette and thus ruin the titration.

There are many errors which can be involved in the used of burette, especially by the beginning student in quantitative analysis:

(1) Dirty burettes can cause an error because the volume of a liquid which clings to a dirty glass surface is different from the volume which clings to a clean surface. Water and dilute solutions form a smooth unbroken surface on clean glassware but will form droplets on a dirty surface. Burette should be cleaned periodically whenever it appears that they are not draining evenly. Usually cleaning with a detergent and a burette brush is satisfactory, but at times it is necessary to use dichromate cleaning solution (concentrated sulfuric acid saturated with potassium dichromate) to get the burette really clean. The student should practice the utmost in the use of dichromate cleaning solution since it is very corrosive and will cause serious burns if allowed to remain on the skin for an appreciable length of time. It can also cause almost immediate deterioration of certain types of cloth, which may lead to embarrassing situations if other clothing is not available.

(2) If the liquid is allowed to flow out of the burette rapidly, the student should wait at least 1 min. before estimating the position of the meniscus to allow for proper drainage. An error of as much as 0. 20 m. can result from reading the position of the meniscus too soon.

(3) In filling the burette, care must be taken to ensure that no bubble of air re-

mains in the tip. If a bubble is entrapped there and dislodged when the liquid is delivered, the reading will be in error by the volume of the bubble.

(4) If a solution of known concentration is poured into a clean burette which is wet with water, the solution is diluted, and the concentration is no longer known exactly. The burette should either be dried before it is filled with the solution or else it should be rinsed at least three times with small volumes of the solution before filling. This rinsing procedure is usually necessary since the burette is seldom dry just before use.

(5) An error due to parallax is encountered whenever the eye is not at the exact level of the meniscus. To offset this error, the student should position his eye so that the back of the milliliter mark above the meniscus appears to be below the front portion and the back of the milliliter mark below the meniscus appears to be above the front portion.

(6) Actually any part of the meniscus may be utilized as long as it is reproducible, but the same portion of meniscus is estimated or an error will be involved. A piece of white paper or piece of white paper upon which a large black mark (with smooth upper edge) is made may be placed behind the burette to sharpen the bottom of the meniscus and to aid in the estimation of the correct reading. With intensely colored solution such as potassium permanganate, the upper part of the meniscus is read.

(7) The relative error in measuring the volume of liquid delivered by a burette decreases as the volume increases. Since an error of 0. 02 ml is liable in each estimation of the meniscus, an error of 0. 04ml is possible. This represents a relative error of 1 part per thousand for 40. 00 ml, an error of 2 parts per thousand for 20. 00 ml, and an error of 40 parts per thousand for a volume of 1. 00 ml. The delivery of more than one burette—full for any one titration is to be avoided since this requires refilling the burette and consequently two additional readings.

(8) It is often necessary when approaching the end point of a titration to add a partial drop of titrant. To do this allows the partial drop to form on the tip of the burette and then touch the tip to the side of the titration flask. The flask can then be tilted so that the added amount is mixed with the solution or it can be washed down with water from the wash bottle. The burette tip should revere be rinsed since this may dilute the titrant in the tip and cause an error.

(9) Burette will often leak slowly through the stopcock if the stopcock is not greased and inserted properly. The use of a large quantity of grease to offset a leak is not advisable since it can plug the bore of the stopcock or the tip of the burette. The burette is usually wet when the stopcock is cleaned and replaced but the stopcock plug and walls must be dry to ensure a satisfactory seal. As a consequence, the burette is always held in a horizontal position during the removal, cleaning, regreasing, and reinsertion of the stopcock plug to ensure that the walls remain dry. The most common error other than getting water between the plug and walls is to use too much stopcock grease, with consequent clogging of the burette during later operation. A

satisfactory seal will be transparent, will have no grease in the bore of the stopcock or tip of the burette, and will allow the plug to be rotated easily. A cloudy seal ordinarily indicates that the walls or plug were not dry or else that too much grease was put on the plug.

Vocabulary

burette [bjuə'ret] *n.* 滴定管；量管
ruin ['ruːin] *vt.* 破坏；毁灭
distinguish [dis'tiŋgwiʃ] *vi.* 区别；区分
burn [bəːn] *n.* 烧伤；灼伤；烫伤
cling [kliŋ] *vi.* 附着；黏附
(clung, clung, clinging)
deterioration [ditiəriə'reiʃn] *n.* 损坏；损伤；腐败；变质
cleanliness ['klenlinis] *n.* 洁净度；清洁度
clothing ['kləuðiŋ] *n.* 衣服
drainage ['dreinidʒ] *v.* 排放；倾倒
embarrass [im'bærəs] *vt.* 使……困窘；使……感到困难
drain [drein] *v.* 排放；倾倒
viscosity [vis'kɔsiti] *n.* 黏度
meniscus [mi'niskəs] *n.* 液面；弯月面
tension ['tenʃən] *n.* 紧张；绷紧；张力
care [kεə] *n.* 注意；小心
neck [nek] *n.* 颈；颈部
tip [tip] *n.* 尖端
irrespective [iris'pektiv] *a.* 不顾的；不考虑的
entrap [in'træp] *vt.* 夹住；裹住
dislodge [dis'lɔdʒ] *vt.* 移走；移位
volumetric [vɔlju'metrik] *a.* 容量的；容积的；测量容积的
rinse [rins] *vt.* 刷洗；冲洗
parallax ['pærəlæks] *n.* 视差
pipette [pi'pet] *n.* 吸量管；吸移管
encounter [en'kauntə] *vt.* 遇见；碰见
quantitative ['kwɔntitətiv] *a.* 数量的
position [pə'ziʃən] *vt.* 定位；安放
teflon ['teflɔn] *n.* 聚四氟乙烯；特氟隆
utilize ['juːtilaiz] *vt.* 使用；利用
stopcock ['stɔpkɔk] *n.* 活栓；活塞
reproducible [riːprə'djuːsəbl] *a.* 可重复的；可再现的
bead [biːd] *n.* 珠；小珠
tubing ['tjuːbiŋ] *n.* 管子
portion ['pɔːʃən] *n.* 部分
titrant ['taitrənt] *n.* 滴定剂
mark [maːk] *n.* 标志；记号；痕迹
titration [tai'treiʃn] *n.* 滴定
sharpen ['ʃaːpən] *vt.* 加深；磨快
delivery [di'livəri] *n.* 输送；交付
estimation [esti'meiʃən] *n.* 估计
relax [ri'læks] *vt.* 放松；使松弛
permanganate [pəː'mæŋgənit] *n.* 高锰酸盐
muscular ['mʌskjulə] *a.* 肌肉的
error ['erə] *a.* 误差；差错
liable ['laiəbl] *a.* 有……倾向的
dirty ['dəːti] *a.* 脏的；不洁的
partial ['paːʃəl] *a.* 部分的；不完全的
unbroken ['ʌn'brəukən] *a.* 完整的；未破损
tilt [tilt] *vt.* 使倾斜；使翘起
leak [liːk] *vi.* 漏出；渗漏
refill [ri'fil] *vt.* 再装满
insert [in'səːt] *vt.* 插入
glassware ['glaːswεə] *n.* 玻璃器皿
reinsertion [riːin'səːʃən] *n.* 重新插入
droplet ['drɔplit] *n.* 小滴
grease [griːz] *vt.* 润滑；*n.* 润滑脂
regrease [riː'griːz] *vt.* 重新润滑
evenly ['iːvənli] *ad.* 均匀地；平稳地
detergent [di'təːdʒənt] *n.* 洗涤剂；去垢剂

offset ['ɔːfset] *vt.* 补偿；弥补；抵消
brush [brʌʃ] *n.* 刷子
plug [plʌg] *vt.* 塞住；堵住
dichromate [dai'krəumeit] *n.* 重铬酸盐
bore [bɔː] *n.* 镗孔；内径
utmost ['ʌtməust] *a.* 最大限度的
seal [siːl] *n.* 密封；封闭
caution ['kɔːʃən] *n.* 小心；谨慎；注意
clogging ['klɔgiŋ] *n.* 阻塞
clog [klɔg] *vt.* 堵塞；阻塞
transparent [træns'pɛərənt] *a.* 透明的

Phrases

irrespective of 不管；不顾；不考虑
at times 有时
or else 否则

Exercises

Put the following into English.

a. 表面张力
b. 量瓶
c. 移液吸管
d. 吸移管
e. 肌肉放松
f. 肌肉紧张
g. 习惯于左手的学生（左撇子）
h. 深色溶液
i. 不到一滴的滴定剂
j. 不很透明的密封（雾状密封）
k. 盖斯勒滴定管

18 Classification of Methods Used in Gravimetric Analysis

In any direct gravimetric analysis， the constituent being determined is separated from the other constituent of the sample in the form of a pure phase which may be the constituent itself or a compound of know and definite composition； from the weight if the later， the weight of the constituent sought is found. The separation， which must always precede the weighing of the constituent or a compound containing it， may be effected in a number of ways. The classification of gravimetric methods is based fundamentally on the methods of separation employed. In the following classification， which is a rough but convenient one practically， the methods are arranged in the order of their importance.

（1） Precipitation methods. In a precipitation process the constituent being determined is precipitated as a very slightly soluble compound （or sometimes element）， and its weight is found.

For example， in determining chloride， a solution of the sample is treated with an excess of silver nitrate to precipitate silver chloride； the precipitate is filtered off， washed free of soluble substances dried， and weighted as silver chloride. From the weight of the dried precipitate, the weight and percentage of chlorine as chloride are easily found. Not infrequently the constituent in question is weighed in a form other than the form in which it was precipitated. Thus, calcium is precipitated as calcium oxalate monohydrate but is preferably weighed as calcium oxide or calcium carbonate for reasons that need not be considered at this point. Electrolytic determinations also belong in the class of precipitation processes.

Precipitation methods are of the greatest importance because often they are more or less specific for the constituent being determined and are of general applicability.

(2) Volatilization or evolution methods. Here one or more of the constituent of the sample is volatile or can be transformed into a volatile compound.

① Direct method. In this subclass, the volatilized or evolved constituent is absorbed in a suitable medium, and the gain in weight of the latter is determined. The method is specific if no other volatile compounds which are absorbed by the medium are present. For example, water in a solid can be determined by heating the sample to the proper temperature and absorbing the volatilized water in a suitable desiccant such as anhydrous magnesium perchlorate. Even if a carbonate were present in the sample, the carbon dioxide evolved on heating would not interfere, since this gas is not retained by magnesium perchlorate (but would be by such basis desiccants as calcium oxide, which naturally could not be used in this case). Analogously, carbon dioxide present as carbonate or bicarbonate can be determined by treating the sample with an excess of acid and absorbing the gas in a suitable substance, after the gas stream has been led through a desiccant to remove water vapor. Hence we are dealing here with a case of chemical separation of two volatile constituents. Separations of volatile constituents are sometimes effects by physical methods such as fractional condensation. Evidently it is easy to arrange matters so that water and carbon dioxide can be determined simultaneously. Such a procedure finds an important application in the elementary analysis of organic compounds, in which the sample is burned in a stream of oxygen and the water and carbon dioxide formed from the oxidation of hydrogen and carbon respectively are absorbed separately in an appropriate absorption train.

② Indirect (difference) methods. Here the weight of the residue remaining after the volatilization of a constituent is determined, and the amount of the constituent sought (which may either be volatilized or remain alone in the residue) is found from the change in weight of the residue (oxidation, for example). As a simple illustration of the method there may be taken the case in which it is desired to find the amount of a dissolved salt (or salts) in an aqueous solution. This can be done very simple by evaporating the water, drying the residue at suitable temperature, and weighing.

The method is of great practical importance in the indirect determination of water. If the sample does not decompose in heating, its water content can be determined by heating a weighed sample to a sufficiently high temperature to expel all the water and then weighing the residue. If the substance decomposes and gives off volatile products at the temperature required to expel the water, it is sometimes possible to add to the weighed sample a weighed amount of a nonvolatile solid which combines with and retains the volatile decomposition products.

Vocabulary

phase [feiz] *n.* 相；状态
desiccant ['desikənt] *n.* 干燥剂
preceed [pri'siːd] *vt.* 在……之前；先于
interfere [intə'fiə] *vt.* 干涉；妨碍
effect [i'fekt] *vt.* 实现；到达
analogously [ə'næləsli] *ad.* 相似地；
fundamentelly ['fʌndə'mentəli] *ad.* 基本上
fractional condensation 分凝
convert [kən'vəːt] *vt.* 转变
simultaneously [siməl'teinjəsli] *ad.* 同时
filter ['filtə] *vt.* 过滤
seperately ['sepəritli] *ad.* 分别地
infrequently [in'friqwəntli] *ad.* 不经常
appropriate [ə'pəupriit] *ad.* 适当的；适宜的
calcium oxalate ['ɔksəleit] *n.* 草酸钙
volatolization [vɔlætilai'zeiʃən] *n.* 挥发
absorption train 吸收序列
volatile ['vɔlətail] *a.* 挥发性的
difference methods 差值法
subclass [sʌbklaːs] *n.* 小分类
residue ['rezidjuː] *n.* 残余物；残渣
medium ['miːdjəm] *n.* 媒介质
content ['kɔntent] *n.* 含量
gain [gein] *n.* 增加
expel [iks'pel] *vt.* 驱除
retain [ri'tein] *vt.* 保留

Phrases

(to) filter off 滤出
other than 不同于（ = different from ）
more or less 或多或少
at this point 在此刻，在这里

Exercises

Put the following into English.

a. 沉淀法
b. 挥发法
c. 残渣
d. 分布冷凝
e. 难溶化合物

19 Melting and Freezing

Melting points. Others, such as manganese and iron, are hard and have high melting point. (Their extra electrons seem to lead to stronger forces between atoms.) These metals are malleable: they can be hammered or rolled into sheets.

Many metals are ductile: they can be drawn or pulled into wire.

EXAMPLE

Describe differences and give an example for each of the following.

(a) crystalline amorphous solids

(b) molecular and network solids

SOLUTION

(a) Crystalline solids such as NaCl have discrete arrangements of atoms, ions, or molecules in a lattice system. Particles in amorphous solids such as glass or rubber have no definite arrangement.

(b) Both molecular and network solids have covalent bonds, but there are no discrete, individual molecules in network solids. Molecular solids such as camphor and iodine have low melting points. Network solids such as diamond are extremely hard and have high melting points.

Melting and Freezing

When a crystalline solid is heated, its particles vibrate more vigorously. As the temperature increases, the substance turns from a solid to a liquid when the attractive forces within the solid are overcome by vigorous vibration. This process is called melting. The temperature at which the soled and liquid exist in dynamic equilibrium is called the melting point. That is, at the melting point, particles move from the solid to the liquid state at the same rate they move from the liquid to the solid state. This equilibrium is often represented as follows

$$\text{Solid} \rightleftharpoons \text{Liquid}$$

As the temperature of a liquid drops, the substance turns from a liquid to a solid. This process is called freezing. The freezing point is the temperature at which the liquid and solid are in dynamic equilibrium.

The temperature at the melting point of a solid is precisely the same as the temperature at the freezing point of the liquid—the distinction is the direction from which we approach this equilibrium temperature. We would give the melting point for tin or lead; they are solids at room temperature. On the other hand, we would give the freezing point of water or alcohol; they are liquids at room temperature. The freezing point of water is the same as the melting point of ice; the distinction depends on the original state.

Although water is an exception, nearly all substances expand when they melt. Substances that have weak intermolecular forces have low melting points; substances with strong intermolecular forces have higher melting points. Pure crystalline solids have sharp melting points while amorphous materials like glass and plastic soften over a wider temperature range.

EXAMPLE

The melting point of tin is 232℃. What is the freezing point of the freezing point of mercury is -39 ℃. What is its melting point?

SOLUTION

The melting point is the same temperature as the freezing point. The freezing point (or melting point) of tin is 232℃. The melting point (or freezing point) of mercury is −39℃.

Heat of fusion

The amount of heat required to convert 1 mol of a solid to a liquid at its melting point is called the molar heat of fusion. The molar heat of fusion of water is 5. 89 kJ. The intermolecular forces of attraction within liquids are not as great as those present in solids; the difference in energy between the two is the heat of fusion. For comparison, the intermolecular forces of attraction within gases are quite small compared to those present in liquids; the difference in energy between the two is the heat of vaporization. Water has a molar heat of vaporization of 40. 7kJ, a value that is considerably larger than its molar heat of fusion, 5. 98kJ.

At the molecular level we can explain why the molar heat of fusion is much smaller than the molar heat of vaporization for a substance: When a sample is melted, energy is required to disrupt the crystal lattice to allow the particles to move around freely in the liquid state, but the particles remain in contact with one another under mutual attractions. This is much less energy than is required during vaporization where nearly all intermolecular forces must be overcome.

EXAMPLE

How much heat (kilojoules) would be required to melt 425g of ice?

SOLUTION

Begin with the quantity of ice in grams, convert this to moles, and use the heat of fusion to determine the heat in kilojoules.

$$425\text{g}\times\frac{1\text{mol}}{18.0\text{g}}\times\frac{5.98\text{kJ}}{\text{mol}}=141\text{kJ}$$

Vocabulary

manganese [mæŋgəˈniːz] *n.* 锰
distinction [disˈtiŋkʃən] *n.* 区别；差别；级别；特性；声望；显赫
malleable [ˈmæliəbl] *a.* 有延展性的；可锻的
exception [ikˈsepʃən] *n.* 除外；例外；反对；异议
hammer [ˈhæmə] *v.* 锤击；锤打
ductile [ˈdʌktail] *a.* 易延展的；易教导的；柔软的
original [əˈridʒənəl] *a.* 最初的；原始的；独创的；新颖的；*n.* 原物；原作
amorphous [əˈmɔːfəs] *a.* 无定形的；无组织的
intermolecular [intə (ː) məˈləkjulə] *a.* 分子间的；存在（或作用）于分子间的
discrete [disˈkriːt] *a.* 不连续的；离散的
mercury [ˈməːkjuri] *n.* 水银；汞
lattice [lætis] *n.* 格子
fusion [ˈfjuːʒən] *n.* 熔化；熔解；熔合
particle [paːtikl] *n.* 粒子；点；微粒
vaporization [veipəraiˈzeiʃən] *n.* 汽化器；喷雾器；蒸馏器
definite [ˈdefinit] *a.* 明确的；一定的
arrangement [əˈreindʒmənt] *n.* 排列；安排
considerably [kənˈsidərəbəli] *adv.* 相当地
camphor [ˈkæmfə] *n.* 樟脑
vibrate [vaiˈbreit] *v.* （使）振动；（使）摇摆

disrupt [disˈrʌpt] *v.* 使中断；使分裂

vigorously [vigərəsli] *ad.* 精神旺盛地

mutual [ˈmjuːtjuəl] *a.* 相互的；共有的

equilibrium [iːkwiˈlibriəm] *n.* 平衡；平静；均衡；保持平衡的能力

kilojoulə [ˈkilədʒuːl] *n.* 千焦耳

kilocalory [ˈkiləukæləri] *n.* 千卡

dynamic [daiˈnæmik] *a.* 动力的；动力学的；动态的

Phrases

be drawn or pulled into... 被拉成……

at the same rate 以同样的速率

for comparison 与……相比

in contact with 与……保持联系

Exercises

Giving the answers to the following questions.

a. What is the freezing point of water or what is the melting point of ice?

b. How much kilojoules would be required to melt 360g of ice?

PART Ⅱ

1 Classification and Nomenclature of Organic Compounds

Organic compounds are classified into three major groups:

(1) Aliphatic and alicyclic compounds.

(2) Aromatic compounds.

(3) Heterocyclic compounds.

1. 1 Aliphatic Compounds

Early chemists saw a formal analogy between alkali halides, such as NaCl, KBr, KI, and organic halides of the type CH_3Cl, C_2H_5Br, and C_2H_5I and named the latter "alkali-like" halides or alkyl (alkali + yl) halides. The name has been retained, and the symbol RX is uses as a general formula for any alkyl halide, X stands for any halogen (F, Cl, Br, I), and R represent any hydrocarbon group such as methyl, ethyl, or propyl. If RX represents any alkyl halide, then ROH represents any alcohol, for example, methyl alcohol, CH_3OH, or ethyl alcohol, C_2H_5OH. Methane and ethane can be thought of as combinations of the methyl and ethyl groups with hydrogen, $CH_3—H$ and $C_2H_5—H$, and the general formula for such a hydrocarbon is RH, where the generic name (class name) alkane. Ethylene and acetylene are the common names of the first members of series of hydrocarbons characterized by having double and triple bonds, respectively, and hence, in a systematic nomenclature worked out at an international congress at Geneva in 1892, these series are designated as alkenes (from ethylene) and alkynes (from acetylene). Alkenes are also known as olefins.

Compounds of this group, identifiable as being derived from methane or other alkane, are called aliphatic. The name aliphatic arises from the fact that the first compound of this class to be studied where the fatty acids (Greek: aliphos, fat). The term aliphatic is now reserved for any compound. That has an open-chain structure.

1. 2 Alicyclic Compounds

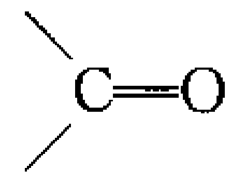
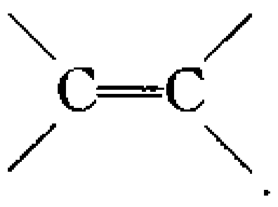
Nonbenzenoid compounds containing rings of carbon atoms are called alicyclic. These are carbocyclic compounds which resemble aliphatic compounds in many ways.

1.3 Aromatic Compounds

The second group is composed of compounds derived from or related to benzene, C_6H_6. Because the first-known derivatives of benzene were natural products extracted from balsams and impressed the discovers because of their fragrant aromas, the group as a whole came to be known as aromatic compounds. The derivatives of benzene are C_6H_5OH, C_6H_5Cl, $C_6H_5NH_2$, etc. The group $C_6H_5—$ is called a phenyl group; the corresponding group derived from naphthalene, $C_{10}H_8$ is called a naphthyl group, $C_{10}H_8—$. The general name for groups of this type is aryl, from aromatic, and the symbol is Ar.

1.4 Heterocyclic Compounds

Heterocyclic compounds are cyclic compounds with the ring containing carbon and other elements, the commonest being oxygen, nitrogen and sulfur. There are a number of heterocyclic rings which are easily opened and do not possess any aromatic properties, e. g. , ethylene oxide, γ-and δ-lactones, etc. These are not considered to be heterocyclic compounds. Heterocyclic ring which are stable, contain conjugated double bonds, and exhibit aromatic character.

In addition, organic compounds are usually classified according to the functional groups they contain, e. g. aldehydes (—CHO group), ketone ( group), carboxylic acids (—COOH group), olefins or alkene ( group), alkyne (—C≡C— group), primary amines ($—NH_2$ group). etc.

1.5 Nomenclature of Organic Compounds

The names of organic substituent form an important part of the language in which organic chemists communicate with one another. Year by year, more and more new organic compounds are prepared, and organic nomenclature must be used continually to supply names for these new compounds.

We should all be familiar with the basic rules of the International Union of Pure and Applied Chemistry (IUPAC) System. In addition, we must know a considerable number of common names and understand the general principles of nomenclature.

The system of nomenclature developed by the IUPAC is based upon the following principles for assignment of substitutive names:

(1) The longest sequence of carbon atoms containing the principle function is the parent structure of acyclic compounds.

(2) The common names of familiar cyclies are frequently chosen as parent structure of compounds containing cyclic structures.

(3) An order of preference is assigned to various functional groups. The groups higher in the order are given preference in the definition of parent structures. Some

functional groups are always considered as substituents.

The fact that the language of science consists of written, rather than spoken words increases the difficulty of any attempt to standardize pronunciation. The choice can never be between right and wrong, but only between more acceptable or less acceptable pronunciations.

Vocabulary

aliphatic [æliˈfætik] *a.* 脂肪（族）的
nonbenzenoid [ˈnɔnˈbenziːnɔid] *a.* 非苯（环）型的
alicyclic [æliˈsaiklik] *a.* 脂环（族）的
aromatic [ˈærəuˈmætik] *a.* 芳香（族）的 *n.* 香料
carbocyclic [ˈkaːbəˈsaiklik] *a.* 碳环的
benzene [ˈbenziːn] *n.* 苯
heterocyclic [ˈhetərəuˈsaiklik] *a.* 杂环（族）的
balsam [ˈbɔːlsəm] *n.* 香油；香脂
fragrant [ˈfreigrənt] *a.* 芳香的
formal [ˈfɔːməl] *a.* 形式上的
aroma [əˈrəumə] *a.* 芳香的
analogy [əˈnælədʒi] *n.* 类似；相似性
derivative [diˈrivətiv] *a.* 衍生的；*n.* 衍生物
alkali [ˈælkəlai] *n.* 碱
halide [ˈhælaid] *n.* 卤化物
phenyl [ˈfiːnil] group 苯基
alkalihalide 碱金属卤化物
naphthalene [ˈnæfθəliːn] *n.* 萘
naphthyl [ˈnæfθil] group 萘基
retain [riˈtein] *vt.* 保持；保留
alkyl [ˈælkil] *n.* 烷基
aryl [ˈæril] *n.* & *a.* 芳基（的）
halogen [ˈhælədʒən] *n.* 卤素
conjugate [ˈkɔndʒugit] *vt.* 共轭
methyl [ˈmeθil] *n.* 甲基
exhibit [igˈzibit] *vt.* 呈现
ethyl [ˈeθil] *n.* 乙基
functional [ˈfʌŋkʃənl] group 官能团
propyl [ˈprəupil] *n.* 丙基
carboxylic [ˈkaːbɔkˈsilik] acid 羧酸
alcohol [ˈælkəhɔl] *n.* （乙）醇；酒精
aldehyde [ˈældihaid] *n.* （乙）醛
whence [hwens] *ad.* 由此；为什么
amine [ˈæmiːn] *n.* 胺
generic [dʒiˈnerik] *a.* 类的；属的
primary amine 伯胺
alkane [ˈælkein] *n.* 烷烃；链烷
ketone [ˈkiːtəun] *n.* 酮
ethylene [ˈeθiliːn] *n.* 乙烯
nomenclature [nəuˈmenklətʃə] *n.* 命名法；专门术语
acetylene [əˈsetiliːn] *n.* 乙炔
alkene [ˈælkiːn] *n.* 烯烃；链烯
assignment [əˈsainmənt] *n.* 指定
alkyne [ˈælkain] *n.* 炔烃；链炔
substitutive [ˈsʌbstitjuːtiv] *a.* 取代的
Geneva [dʒiˈniːvə] *n.* 日内瓦（地名）
sequence [ˈsiːkwəns] *n.* 序列；链
olefin [ˈəuləfin] *n.* （链）烯烃
acyclic [eiˈsaiklik] *a.* 无环的；非环的
identifiable [aiˈdentifaiəbl] *a.* 可识别的
preference [ˈprefərəns] *n.* 优先；选择
Greek [griːk] *n.* 希腊文
assign [əˈsain] *vt.* 指定
reserve [riˈzəːv] *vt.* 保留
substituent [səbˈstitjuənt] *n.* 取代基

Phrases

stand for 代表
work out 创立；制订

in many ways	在许多方面	as a whole	就整体而言
general name	通名	more and more	愈来愈
arise from	由……而引起；由……而产生	derive from	由……得来
		be assigned to	被指定给
be thought of as...	可以被认为是……	in addition	此外（还）

Exercises

1. Name each of the following compounds in English.

a. $HC\equiv CH$
b. $CH_2=CH_2$
c. CH_4
d. CH_3Cl
e. CH_3Br
f. CH_3CH_2Cl
g. CH_3CH_2OH
h. NaCl

2. Translate the following into English.

a. 酒精
b. 共轭体系
c. 杂环化合物
d. 官能团
e. 脂肪族化合物

2 Alkanes

2.1 IUPAC Nomenclature of Alkanes

The formal system of nomenclature used today is one proposed by the International Union of Pure and Applied Chemistry (IUPAC) System. This system was first developed in 1892 and been revised at irregular interval to keep it up to date. Underlying the IUPAC system of nomenclature for organic compounds is a fundamental principle: each different compound should have a different name thus through a systematic set of rules. The IUPAC System provides different names for the more than 7 million known organic compounds, and names can be devised for any one of million of other compound yet to be synthesized. In addition, the IUPAC System is simple enough to allow any chemist familiar with the rules (or with the rules at hand) to write the name for any compound that might be encountered, in the same way, one is also able to derive the structure of a given compound from its IUPAC name.

The IUPAC System for naming alkanes is not difficult to learn, and the principles involved are used in naming compounds in other familiar as well. For these reasons we begin our study of the IUPAC System with the rules for naming alkanes, and then study the rules for alkyl halide, and alcohols.

The names for several of the unbranched alkanes are listed in Table 2.1. The ending for all of the names of alkanes is-ane. The stems of the names of most of the alkanes (above C_4) are of Greek and Latin origin. Learning the stem is like learning to count in organic chemistry. Thus, one, two, three, four, five, becomes meth-, prop-, but-, pent-.

Table 2. 1 The unbranched alkanes

Name	Number of carbon atoms	Structure	Name	Number of carbon atoms	Structure
methane	1	CH_4	heptadecane	17	$CH_3(CH_2)_{15}CH_3$
ethane	2	CH_3CH_3	octadecane	18	$CH_3(CH_2)_{16}CH_3$
propane	3	$CH_3CH_2CH_3$	nonadecane	19	$CH_3(CH_2)_{17}CH_3$
butane	4	$CH_3(CH_2)_2CH_3$	eicosane	20	$CH_3(CH_2)_{18}CH_3$
pentane	5	$CH_3(CH_2)_3CH_3$	heneicosane	21	$CH_3(CH_2)_{19}CH_3$
hexane	6	$CH_3(CH_2)_4CH_3$	docosane	22	$CH_3(CH_2)_{20}CH_3$
heptane	7	$CH_3(CH_2)_5CH_3$	tricosane	23	$CH_3(CH_2)_{21}CH_3$
octane	8	$CH_3(CH_2)_6CH_3$	triacontane	30	$CH_3(CH_2)_{28}CH_3$
nonane	9	$CH_3(CH_2)_7CH_3$	hentriacontane	31	$CH_3(CH_2)_{29}CH_3$
decane	10	$CH_3(CH_2)_8CH_3$	tetracontane	40	$CH_3(CH_2)_{38}CH_3$
undecane	11	$CH_3(CH_2)_9CH_3$	pentacontane	50	$CH_3(CH_2)_{48}CH_3$
dodecane	12	$CH_3(CH_2)_{10}CH_3$	hexacontane	60	$CH_3(CH_2)_{58}CH_3$
tridecane	13	$CH_3(CH_2)_{11}CH_3$	heptacontane	70	$CH_3(CH_2)_{68}CH_3$
tetradecane	14	$CH_3(CH_2)_{12}CH_3$	octacontane	80	$CH_3(CH_2)_{78}CH_3$
pentadecane	15	$CH_3(CH_2)_{13}CH_3$	nonacontane	90	$CH_3(CH_2)_{88}CH_3$
hexadecane	16	$CH_3(CH_2)_{14}CH_3$	hectane	100	$CH_3(CH_2)_{98}CH_3$

2. 2 Nomenclature of Unbranched Alkyl Groups

If we remove one hydrogen atom from an alkane, we obtain what is called an alkyl group. These alkyl groups have names that end in-yl, when the alkane is unbranched, and the hydrogen atom that is removed is a terminal hydrogen atom, the names are straight forward:

Alkane		Alkyl Group	Abbreviation
CH_3—H Methane	becomes	CH_3— Methyl	Me—
CH_3CH_2—H Ethane	becomes	CH_3CH_2— Ethyl	Et—
$CH_3CH_2CH_2$—H Propane	becomes	$CH_3CH_2CH_2$— Propyl	Pr—
$CH_3CH_2CH_2CH_2$—H Butane	becomes	$CH_3CH_2CH_2CH_2$— butyl	Bu—

2. 3 Nomenclature of Branched-Chain Alkanes

Branched-chain alkanes are named according to the following rules:

(1) Locate the longest continuous chain of carbon atom; this chain determines the parent name for the alkane.

We designate the following compound, for example, as a hexane because the longest continuous chain contains six carbon atoms.

$$CH_3CH_2CH_2CH_2CH(CH_3)_2$$

The longest continuous chain may not always be obvious from the way the formula is written. Notice, for example, that the following alkane is designated as a heptane because the longest chain contains seven carbon atoms:

$$CH_3CH_2CH_2CH_2CH(CH_3)CH_2CH_3$$

(2) Number the longest chain beginning with the end of the chain nearer the substituent.

Applying this rule, we number the two alkanes that we illustrated previously in the following way.

$$CH_3CH_2CH_2CH_2CH(CH_3)CH_3 \qquad CH_3CH_2CH_2CH_2CH(CH_3)CH_2CH_3$$

(3) Use the numbers obtained by application of rule (2) to designate the location of the substituent group.

The parent name is placed last, and the substituent group, preceded by the number designating its location on the chain, is placed first. Numbers are separated from words by a hyphen. Our two examples are 2-methylhexane and 3-methylheptane, respectively.

$$CH_3CH_2CH_2CH_2CH(CH_3)CH_3 \qquad CH_3CH_2CH_2CH_2CH(CH_3)CH_2CH_3$$

2-methylhexane 3-methylheptane

(4) When two or more substituents are present, give each substituent a number corresponding to its location on the longest chain. For example, we designate the following compound as 4-ethyl-2-methylhexane.

$$CH_3CH(CH_3)CH_2CH(CH_2CH_3)CH_2CH_3$$

4-ethyl-2-methylhexane

The substituent groups should be listed alphabetically. i. e. ethyl before methyl. Some handbooks also list the groups in order of increasing size or complexity. i. e. methyl before ethyl. Alphabetical listing, however, is now by far the most widely used system. In deciding on alphabetical order disregard multiplying prefixes such as "di" and "tri".

(5) When two substituents are present on the same carbon atom, use that number twice.

$$(CH_3CH_2)_2C(CH_3)CH_2CH_2CH_3$$

3-ethyl-3-methylhexane

(6) When two or more substituents are identical, indicate this by the use of the prefixes di-, tri-, tetra-, and so on. Then make certain that each every substituent has a number. Commas are used to separate numbers from each other.

$$CH_3CH(CH_3)CH(CH_3)CH_3 \qquad CH_3CH(CH_3)CH(CH_3)CH(CH_3)CH_3$$

2,3-dimethylbutane 2,3,4-trimethylpentane

$$CH_3C(CH_3)_2CH_2C(CH_3)_3$$

2,2,4,4-tetramethylpentane

Application of these six rules allows us to name most of the alkanes that we shall encounter. Two other rules, however, may be required occasionally.

(7) When two chains of equal length compete for selection as the parent chain,

choose the chain with the greater number of substituent.

$CH_3CH_2CH(CH_3)CH(CH_2CH_2CH_2CH_3)CH(CH_3)CH(CH_3)CH_3$

2,3,5-trimethyl-4-propylheptane

(four substituents)

(not 4-*sec*-butyl-2,3-dimethylheptane)

(three substituents)

(8) When branching first occurs at equal distance from either end of the longest chain, choose the same that gives the lower number at the first point of difference.

$CH_3CH(CH_3)CH_2\ CH(CH_3)CH(CH_3)CH_3$

2,3,5-trimethylhexane

(not 2,4,5-trimethylhexane)

2.4 Nomenclature of Branched Alkyl Groups

In above section, you learned the names for the unbranched alkyl groups such as methyl, ethyl, propyl, butyl, and so on. Groups are derived by removing terminal hydrogen from an alkane. For alkanes with more than two carbon atoms, more than one derived group is possible. Two groups can be derived from propane, for example, the propyl group, is derived by removal of a terminal hydrogen, and the 1-methylethyl or isopropyl group is derived by removal of a hydrogen from the central carbon:

Three-carbon group

$CH_3CH_2CH_3$	propane	$CH_3CH_2CH_2$—	propyl group
		$CH_3CH(CH_3)$—	methylethyl(isopropyl)group

1-methylethyl is the systematic name for this group, isopropyl is a common name. Systematic nomenclature for alkyl groups is similar to that for branched-chain alkane, with the provision that numbering always begins at the point where the group is attached to the main chain. There are four C_4 groups. Two are derived from butane and two are derived from isobutane (isobutane is a common name for 2-methylpropane that is approved by the IUPAC).

Four-carbon groups

$CH_3CH_2CH_2CH_3$	butane	$CH_3CH_2CH_2CH_2$—	butyl
		$CH_3CH_2CH(CH_3)$—	1-methylpropyl or *sec*-butyl
$CH_3CH(CH_3)CH_3$	isobutane	$CH_3CH(CH_3)CH_2$—	2-methylpropyl or isobutyl
		$CH_3C(CH_3)_2$—	1,1-dimethylethyl or *tert*-butyl

The following examples show how the names of these groups are employed.

$CH_3CH_2CH_2CH(CH_2CH_2CH_3)CH(CH_3)_2$

4-(1-mehtylethyl)heptane or 4-isopropylheptane

$CH_3CH_2CH_2CH[C(CH_3)_3]CH_2CH_2CH_2CH_3$

4-(1,1-dimethylethyl)octane or 4-*tert*-butyloctane

The common names, isopropyl, isobutyl, *sec*-butyl, and *tert*-butyl are approved by the IUPAC for the unsubstituent groups, and they are still very frequently used. You should memorize these groups so well that you will recognize them anyway that they are written. In deciding on alphabetical order for these groups you should disregard structure defining prefixes that are written in italics and separated from the name by a hyphen. Thus *tert*-butyl precedes ethyl, but ethyl precedes isobutyl.

There is one five-carbon group with an IUPAC approved common name that you should also know: the 2, 2-dimethylpropyl group, commonly called the neopentyl group.

$$(CH_3)_3CCH_2—$$

2,2-dimethylpropyl or neopentyl group

Vocabulary

isomer ['aisəumə] *n.* 异构体；同分异构体
alkane [ælkein] *n.* 烷烃
methane ['meθein] *n.* 甲烷
ethane [eθein] *n.* 乙烷
propane ['pəupein] *n.* 丙烷
butane ['bjuːtein] *n.* 丁烷
pentane ['pentein] *n.* 戊烷
hexane [hek'sein] *n.* 己烷
heptane ['heptein] *n.* 庚烷
octane ['ɔktein] *n.* 辛烷
nonane ['nɔnein] *n.* 壬烷
decane ['dekein] *n.* 癸烷
undecane [ʌn'dekein] *n.* 十一烷
dodecane [dəu'dekein] *n.* 十二烷
tridecane [traidekein] *n.* 十三烷
eicosane ['aikəsein] *n.* 二十烷
heneicosane [he'neikəsein] *n.* 二十一烷
docosane ['dɔkəsein] *n.* 二十二烷
tricosane ['traikəsein] *n.* 二十三烷
triacontane [traiə'kɔntein] *n.* 三十烷
hentriacontane ['hentraiə'kɔntein] *n.* 三十一烷
dotriacontane [dəutriə'kɔntein] *n.* 三十二烷
tritriacontane [traitraiə'kɔntein] *n.* 三十三烷
tetriacontane [tetrətraiə'kɔntein] *n.* 四十烷
pentacontane [pentə'kɔntein] *n.* 五十烷
hexacontane [heksə'kɔntein] *n.* 六十烷
octacontane [ɔktə'kɔntein] *n.* 八十烷
nonacontane [nɔnə'kɔntein] *n.* 九十烷
hectane ['hektein] *n.* 一百烷
derive [di'raiv] *vi.* 衍生；派生
neopentane [niːəu'pentein] *n.* 新戊烷
locant ['ləukənt] *n.* 位次
substituent [səb'stitjuənt] *n.* 取代基
tert. = tertiary ['təːʃəri] *a.* 叔的；第三的
sec. = secondary ['sekəndəri] *a.* 仲的；第二的
revise [ri'vaiz] *vt.* 修订；校正
provision [prə'viʒn] *n.* 供应；规定
hyphen ['haifən] *n.* 连字号
commas [kɔməs] *n.* 逗号
italic [i'tælik] *a.* 斜体字
abbreviation [ə'briːvi'eiʃən] *n.* 缩写

Phrases

separate from ... 从……分离出来；和……分离

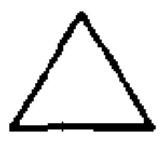
Exercises

1. **Write a structure formula for each of the following compounds.**
   - a. 3-ethylpentane
   - b. 2,3,4-trimethyldecane
   - c. 4-isopropylnonane
   - d. 4-isopropylheptane
   - e. 2,2,4,4-tetramethyloctane
   - f. 2,2-dimethylpropane
   - g. 2,3,5-trimethyl-4-propylheptane
2. **Name each of the following compounds by the IUPAC system.**
   - a. $CH_3CH(CH_2CH_3)CH\ CH_2CH_3$
   - b. $CH_3CH(CH_3)CH_2CH_3$
   - c. $(CH_3)_2CHCH_2CH(CH_3)_2$
   - d. $CH_3CH_2CH(CH_2CH_3)CH_3$
   - e. $CH_3CH_2CH_2CH_2C(CH_3)_2CH(CH_3)_2$
3. **Give correct IUPAC names for all the C_5H_{12} isomers.**

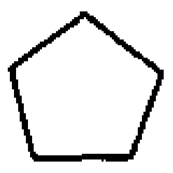
3 Nomenclature of Cycloalkanes

3.1 Monocyclic Compounds

Cycloalkanes with only one ring are named by attaching the prefix cyclo to the names of the alkanes possessing the same number of carbon atom. For example:

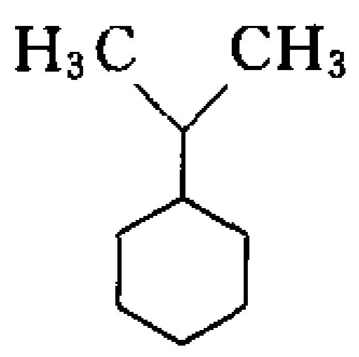


cyclopropane

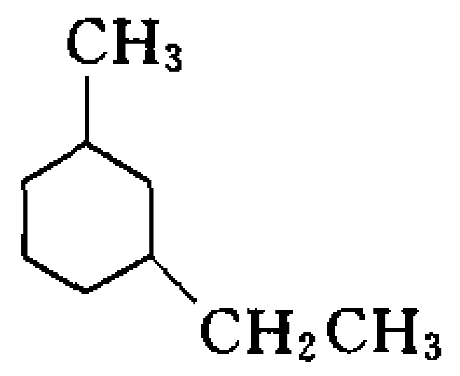


cyclopentane

Naming substituted cycloalkanes is straightforward: we name them as alkylcycloalkanes, if only one substituent is present, it is not necessary to designate its position. When two substituents are present, we number the ring beginning with the substituent first in the alphabet, and number in the direction that gives the next substituent the lower number possible, when three or more substituent are present, we begin at the substituent that leads to the lowest set of locates.

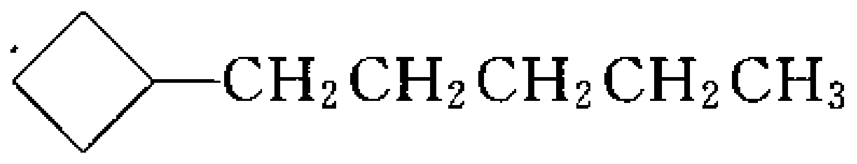


isopropylcyclohexane

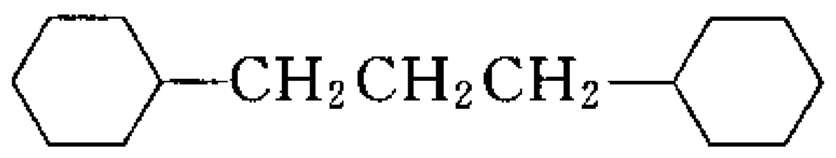


1-ethyl-3-methylcyclohexane
(not 1-ethyl-5-methylcyclohexane)

When a single ring system is attached to a single chain with a greater number of carbon atoms, or when more than one ring system is attached to a single chain, then it is appropriate to name the compounds are cycloalkanes. For example:



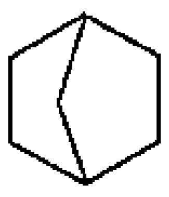
1-cyclobutylpentane



1,3-dicyclohexylpropane

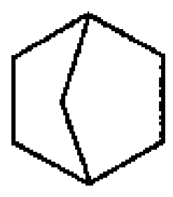
3.2 Bicyclic Compounds

We name compounds containing two fused or bridged rings as bicycloalkanes and we use the name of the alkanes corresponding to the total number of carbon atoms in the rings as the parent name. The following compound, for example, contains seven carbon atoms and is, therefore, a bicycloheptane. The carbon atoms common to both rings are called bridgehead, and each bond, or chain if atoms connecting the bridgehead atoms, is called bridge.

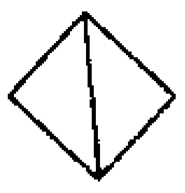


a bicycloheptane

Then we interpose in the name an expression in brackets that denotes the number of carbon atoms in each bridge (in order of decreasing length). For example:

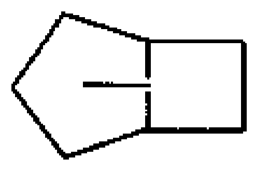


bicyclo[2. 2. 1]heptane
(also called norbornane)

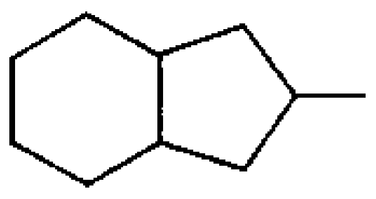


bicyclo[1. 1. 0]butane

If substituents are present, we number the bridged ring system beginning at one bridgehead, proceeding first along the longest bridge to the other bridge head then along the next longest bridge back to the first bridgehead. The shortest bridge is numbered last.



8-methylbicyclo[3. 2. 1]octane



8-methylbicyclo[4. 3. 0]nonane

Vocabulary

cycloalkane	['saikləu'ælkein]	*n.*	环烷烃
designation	['dezig'neiʃən]	*n.*	名称
designate	['dezigneit]	*v.*	指出；把……叫做
bicyclic	[bai'siklik]	*a.*	双环的
interpose	['intəː'pəuz]	*vt.*	插入

Phrase

be attached to ...	连到……上；附上
be appropriated to ...	适于；合乎

Exercises

1. **Write the structure of a bicyclic compound that is an isomer of bicycle [2. 2. 1] heptane and give its name.**

2. Write a structural for each of the following compounds:

a. 1-cyclohexylpentane
b. 1,4-dicyclohexylbutane
c. bicyclo [2. 2. 0] hexane
d. bicyclo [1. 1. 0] butane
e. methylcyclopropane
f. methylcyclopropane
g. 1,2-dimethylcyclohexane
h. 1-ethyl-4-methylcyclohexane
i. 8-methylbicyclo [3. 2. 1] octane
j. 8-methylbicyclo [4. 3. 0] nonane

4 Alkenes

Alkenes are hydrocarbons whose molecules contain the carbon-carbon double bond. An old name for this family of compounds that is still often used is the name olefins. Ethane, the simplest olefin (alkene), was called olefiant gas (Latin: oleum, oiltfacere, to make) because gaseous ethane (C_2H_4) reacts with chlorine to form $C_2H_4Cl_2$, a liquid (oil).

Hydrocarbons whose molecules contain the carbon-carbon triple bond are called alkynes. The common name for this family is acetylenes, after the first member, $HC\equiv CH$.

Nomenclature of Alkenes and Cycloalkenes

Many older names for alkenes are still in common use. Propene is often called propylene, and 2-methylpropane frequently bears the name isobutylene.

$CH_2{=}CH_2$	$CH_3CH{=}CH_2$	$(CH_3)_3C{=}CH_2$
IUPAC: ethene	IUPAC: propene	IUPAC: 2-methylpropene
or ethylene	or propylene	common: isobutylene

The IUPAC rules for naming alkenes are similar in many respects to those for naming alkanes:

(1) Determine the base name by selecting the longest chain that contain the double bond and change the ending of the name of the alkane of identical length from ane to ene.

Thus, if this longest chain contains five carbon atoms, the base name for the alkene is pentene: if it contains six carbon atoms, the base name is hexane, and so on.

(2) Number the chain so as to include both carbon atoms of the double bond, and begin numbering at the end of the chain nearer the double bond. Designate the location of the double bond by using the number of the first atom of the double bond as a prefix:

$CH_2{=}CHCH_2CH_3$	$CH_3CH{=}CHCH_2CH_2CH_3$
1-butene	2-hexene
(not 3-butene)	(not 4-hexene)

(3) Indicate the locations of the substituent groups by the numbers of the carbon atoms to which they are attached.

$(CH_3)_2C{=}CHCH_3$

2-methyl-2-butene

(not 3-methyl-2-butene)

$(CH_3)_2C{=}CHCH_2CH(CH_3)_2$

2,5-dimethyl-2-hexene

(not 2,5-dimethyl-4-hexene)

$CH_3CH{=}CHCH_2C(CH_3)_3$

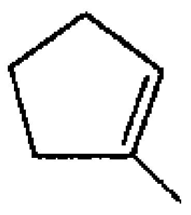
5,5-dimethyl-2-hexene

$CH_3CH{=}CHCH_2Cl$

1-chloro-2-butene

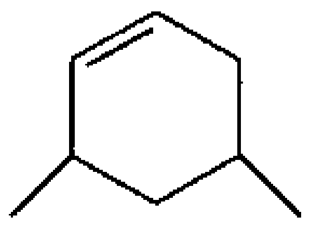
(4) Number substituted cycloalkanes in the way that gives the carbon atoms of the double bond the 1- and 2-positions and also gives the substituent groups the lower numbers at the first point of difference.

With substituted cycloalkanes it is not necessary to specify the position of the double bond since it will always begin with C-1 and C-2. The two examples listed here illustrate the application of these rules.



1-methylcyclopentene

(not 2-methylcyclopentene)



3,5-dimethylcyclohexene

(not 4,6-dimethylcyclohexene)

(5) Two frequently encountered alkenyl groups are the vinyl group and the allyl group.

$CH_2{=}CH—$

the vinyl group

$CH_2{=}CHCH_2—$

the allyl group

The following examples illustrate how these names are employed:

$CH_2{=}CHBr$

bromoethene

or vinyl bromide

(common)

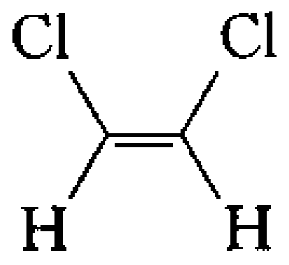
$CH_2{=}CHCH_2Cl$

3-chloropropene

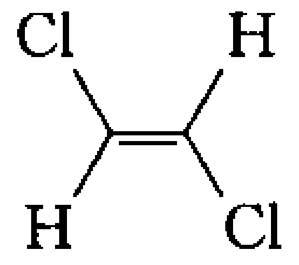
or allyl chloride

(common)

(6) Designate the geometry of a double bond of a disubstituted alkene with the prefixes *cis*- and *trans*-. If two identical groups (usually hydrogen atoms) are on the some side of the double bond, it is *cis*; if they are on opposite, it is *trans*.



cis-1,2-dichloroethene



trans-1,2-dichloroethene

Vocabulary

alkene [ˈækiːn] *n.*	烯烃
olefin [ˈəuləfin] *n.*	烯烃
allyl [ˈælil] *n.*	烯丙基
allyl bromide	烯丙基溴
alkyne [ˈælkain] *n.*	炔烃
cycloalkene [ˈsaikləˈælkiːn] *n.*	环烯烃
geometry [dʒiˈɔmitri] *n.*	几何学
cis-	顺式
trans-	反式
illustrate [ˈiləstreit] *vt.*	说明
double bond	双键

vinyl ['vainil] *n.*	乙烯基
triple bond	叁键
vinyl bromide	溴代乙烯

Phrases

so as to ...	如此……以便
be necessary to ...	为……所必需

Exercises

1. **Write structure formulas for each of the following compounds.**
   - a. *cis*-3-hexene
   - b. *trans*-2-pentene
   - c. 3-ethylcyclohexene
   - d. vinylcyclohexane
   - e. 4,4-dimethyl-1-hexane
   - f. 3-methylcyclopentene
   - g. 3-chloro-1-octane
   - h. 1,2-dimethylcyclohexene
   - i. 1,3-dimethylcyclopentene
   - j. 1,5-dibromocyclohexene
   - k. bromoethane
   - l. allyl chloride
2. **Give names for each of the following alkenes.**
   - a. $CH_2{=}CH_2$
   - b. $CH_3CH{=}CH_2$
   - c. $(CH_3)_2C{=}CH_2$
   - d. $CH_3\ CH_2\ CH{=}CH_2$
   - e. $(CH_3)_2C{=}C(CH_3)_2$
   - f. $CH_2{=}CHCH_2Cl$
   - g. $CH_2{=}CHCl$
   - h. $ClCH{=}CHCl$
3. **Each of the following names is incorrect. Tell how and give the correct name.**
   - a. *cis*-3-pentene
   - b. 1,1,2,2-tetramethylethene
   - c. 2-methylcycloheptene
   - d. 1-methyl-1-heptene
   - e. 3-methyl-2-butene
   - f. 4,5-dichlorocyclopentene

5 Alkynes

5.1 Nomenclature of Alkynes

Alkynes are named in much the same way as alkenes. Unbranched alkynes, for example, are named by replacing the -ane of the name of the corresponding alkane with the ending -yne. The chain is numbered in order to give the carbon atoms of the triple bond the lower possible numbers. The lower number of the two carbon atoms of the triple bond is used to designate the location of the triple bond. The IUPAC names of three unbranched alkynes are shown here

ethyne or acetylene	$HC{\equiv}CH$
propyne	$CH_3C{\equiv}CH$
1-butyne	$CH_3CH_2C{\equiv}CH$

2-butyne	$CH_3C\equiv CCH_3$
1-pentyne	$CH_3(CH_2)_2C\equiv CH$
2-pentyne	$CH_3CH_2C\equiv CCH_3$
1-hexyne	$CH_3(CH_2)_3C\equiv CH$
2-hexyne	$CH_3(CH_3)_2C\equiv CCH_3$
3-hexyne	$CH_3CH_2C\equiv CCH_2CH_3$

The location of substituent groups of branched alkynes and substituted alkynes are also indicated with numbers.

$ClCH_2C\equiv CH$	$CH_3C\equiv CCH_2Cl$
3-chloropropyne	1-chloro-2-butyne
$CH_3CH(CH_3)CH_2CH_2C\equiv CH$	$(CH_3)_3CCH_2C\equiv CH$
5-methyl-1-hexyne	4,4-dimethyl-1-pentyne

5.2 Hydrogenation of Alkynes

Depending on the conditions and the catalyst employed, one or two molar equivalents of hydrogen will add to a carbon-carbon triple bond. when a platinum catalyst is used, the alkyne generally reacts with two molar equivalents of hydrogen to give an alkane.

$$CH_3C\equiv CCH_3 \xrightarrow{H_2,Pt} [\,CH_3CH{=}CHCH_3\,] \xrightarrow{H_2,Pt} CH_3CH_2CH_2CH_3$$

However, hydrogenation of an alkyne to an alkene can be accomplished through the use of special catalysts or reagents. Moreover, these special methods allow the preparation of either (*E*) or (*Z*) alkenes from disubstituted alkynes.

5.2.1 Syn Addition of Hydrogen: Synthesis of *cis*-alkenes

A catalyst that permits hydrogenation of an alkyne to an alkene is the nickel boride compound called p-2 catalyst. This catalyst can be prepared by the reduction of nickel acetate with sodium borohydride.

$$(CH_3COO)_2Ni \xrightarrow[C_2H_5OH]{NaBH_4} Ni_2B\ (p\text{-}2)$$

Hydrogenation of alkynes in the presence of p-2 catalyst cause *syn* addition of hydrogen to take place and the alkene that is formed from an alkyne with an internal triple bond has the (*Z*) or *cis*-configuration. The hydrogenation of 3-hexyne illustrates this method. This reaction takes place on the surface of the catalyst accounting for the *syn* addition.

$$CH_3CH_2C\equiv C{-}CH_2CH_3 \xrightarrow[(syn\text{-addition})]{H_2,\,Ni_2B(p\text{-}2)} CH_3CH_2CH{=}CHCH_2CH_3$$

3-hexyne

(*Z*)-3-hexene
(*cis*-3-hexene)

Other specially conditioned catalysts can be used to prepare *cis*-alkenes from disubstituted alkynes. Metallic palladium deposited on calcium carbonate can be used in this way after it has been conditioned with lead acetate and quinoline. This special catalyst is know as Lindlar's catalyst.

$$RC\equiv CR \xrightarrow[\text{quinoline } syn\text{-addition}]{H_2\text{, Pd. }CaCO_3\text{ (Lindlar's catalyst)}} RCH{=}CHR$$

5.2.2 Anti Addition of Hydrogen: Synthesis of *trans*-alkenes

An *anti* addition of hydrogen atoms to the triple bond occurs when alkynes are reduced with lithium or sodium metal in ammonia or ethylamine at low temperatures. This reaction called a dissolving metal reduction produces an (*E*) or *trans*-alkene.

$$\underset{\text{4-octyne}}{CH_3(CH_2)_2C\equiv C(CH_2)_2CH_3} \xrightarrow[\text{2. }NH_4Cl]{\text{1. Li, }C_2H_5NH_2\text{, }-78℃} \underset{\substack{(E)\text{-4-octene} \\ (trans\text{-4-octene})}}{CH_3(CH_2)_2CH{=}CH(CH_2)_2CH_3}$$

5.2.3 Other Metal Acetylides

Ethyne and terminal alkynes also form metal derivatives with silver and copper (Ⅰ) ions.

$$RC\equiv CH + Cu(NH_3)_2^+ + OH^- \xrightarrow{H_2O} RC\equiv CCu + H_2O + 2NH_3$$

$$RC\equiv CH + Ag(NH_3)_2^+ + OH^- \xrightarrow{H_2O} RC\equiv CAg + H_2O + 2NH_3$$

Silver and copper alkynides differ from sodium alkynides in several ways. The metal-carbon bond in sliver and copper alkynides is largely covalent. As a result, sliver and copper alkynides are poor bases and poor nucleophiles. Sliver and copper alkynides can be prepared in water, whereas sodium alkynides react vigorously with water.

$$RC\equiv CNa + H_2O \longrightarrow RC\equiv CH + NaOH$$

Silver and copper alkynides are also quite insoluble in water and precipitate when they are prepared. This is the basis for an ole and still convenient test for terminal alkynes as well as a method for separating terminal alkynes from alkynes that have an internal triple bond.

$$RC\equiv CR + Ag(NH_3)_2^+OH^- \longrightarrow \text{no precipitate}$$

$$RC\equiv CH + Ag(NH_3)_2^+OH^- \longrightarrow R{-}C\equiv CAg\downarrow$$

Once a separation has been carried out, the terminal alkyne can be regenerated by treating the alkynide with sodium cyanide (or with a strong acid)

$$RC\equiv CAg + 2CN^- + H_2O \longrightarrow RC\equiv CH + Ag(CN)_2^- + OH^-$$

Silver and copper alkynides must be handled cautiously; when dry they are likely to explode.

Vocabulary

alkyne	[ˈælkain]	*n.*	炔烃
acetylene	[əˈsetiliːn]	*n.*	乙炔
ethyne	[eˈθain]	*n.*	乙炔
nucleophile	[ˈnjuːkliəfail]	*n.*	亲核试剂
ethynyl	[eˈθainil]	*n.*	乙炔基
palladium	[pəˈleidiəm]	*n.*	钯
propyne	[ˈprəupain]	*n.*	丙炔
quinoline	[ˈkwinəliːn]	*n.*	喹啉；氮杂萘
equivalent	[iˈkwivələnt]	*a.*	等价的；当量的
cyanide	[ˈsaiənaid]	*n.*	氰化物
configuration	[kənˈfigjuˈreiʃən]	*n.*	结构；构造；构形

deposit [di'pɔzit] *vt.* 放置；安置；使沉淀

boride ['bɔːraid] *n.* 硼化物

Phrases

depend (up) on... 取决于；随……而定

account for... 说明，解释；是……的原因；计算出

as a result... 结果；因此；从而

in the presence of... 在……的面前；在有……参加的情况下

syn addition... 顺式加成

anti addition... 反式加成

Exercises

1. Write a structural formula for each of the following.

a. propyne
b. 1-butyne
c. *cis*-2-butene
d. 2-hexyne
e. (*Z*)-3-methyl-2-hexen-5-yne
f. 4-methyl-2-hexyne
g. 3-chloropropyne
h. 3,3-dimethyl-1-pentyne

2. Give the names of all of the alkyne isomers of the following.

a. C_4H_6　b. C_5H_8　c. C_6H_{10}

6 Alcohols, Phenols and Ethers

6.1 Nomenclature of Alcohols

In substitutive and conjunctive nomenclature of alcohols the hydroxyl group (—OH) as principal group is indicated by a suffix "-ol", with elision of terminal "e" (if present) from the name of the parent compound.

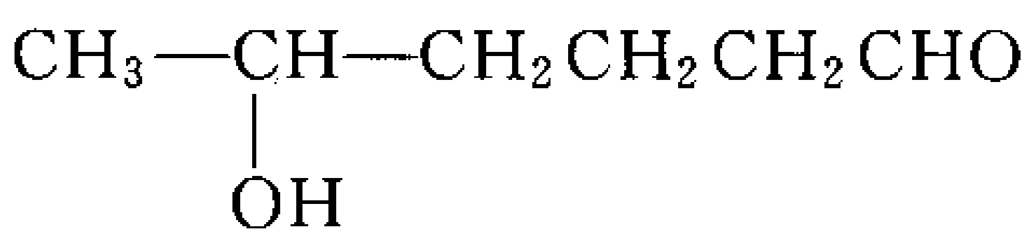
Examples:

methanol	(methyl alcohol)	CH_3OH
ethanol	(ethyl alcohol)	CH_3CH_2OH
2-propanol	(isopropyl alcohol)	$(CH_3)_2CHOH$
2-methyl-2-propanol	(*tert*-butyl alcohol)	$(CH_3)_3COH$
butanol	(butyl alcohol)	$CH_3CH_2CH_2CH_2OH$
2-methyl-1-propanol	(isobutyl alcohol)	$CH_3CH_2(CH_3)CH_2OH$
2-butanol	(*sec*-butyl alcohol)	$CH_3CH(OH)CH_2CH_3$
pentanol	(pentyl alcohol)	$CH_3(CH_2)_3CH_2OH$
1,4-butanediol		$HOCH_2(CH_2)_2CH_2OH$
1,3-propanediol	(propylene glycol)	$HOCH_2CH_2CH_2OH$
glycerol		$HOCH_2CH(OH)CH_2OH$
triphenylmethanol		$(C_6H_5)_3COH$

2-propenol	(allyl alcohol)	$CH_2{=}CHCH_2OH$
2-propynol		$CH{\equiv}CCH_2OH$
2-phenethylalcohol		$C_6H_5CH_2CH_2OH$
pinacol		$(CH_3)_2C(OH)C(OH)(CH_3)_2$

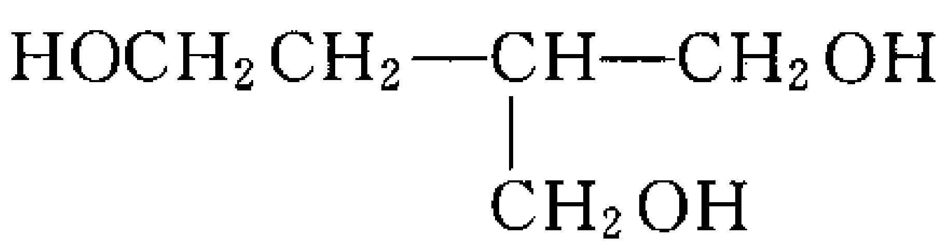
Hydroxyl groups are indicated by the prefix "hydroxyl-" when a group having priority for citation as principal group is also present or when the hydroxyl group is present in a side chain.

Examples:



$CH_3-\underset{\displaystyle OH}{\underset{|}{CH}}-CH_2CH_2CH_2CHO$

5-hydroxyhexanal

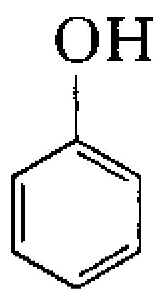


$HOCH_2CH_2-\underset{\displaystyle CH_2OH}{\underset{|}{CH}}-CH_2OH$

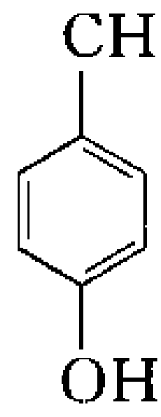
2-hydroxymethyl-1,4-butanediol

6.2 Nomenclature of Phenols

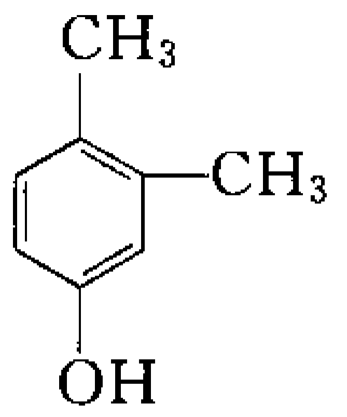
Compounds that have a hydroxyl group directly attached to a benzene ring are called phenols. Thus, phenol is the specific name for hydroxybenzene and it is the general name for the family of compounds derived from hydroxybenzene:



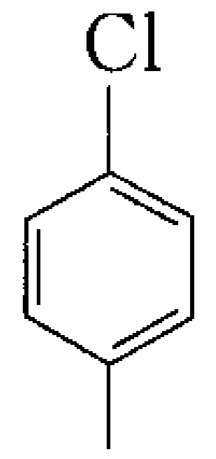
phenol



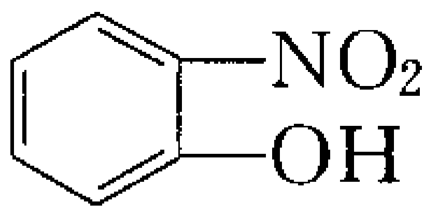
4-methyl-phenol



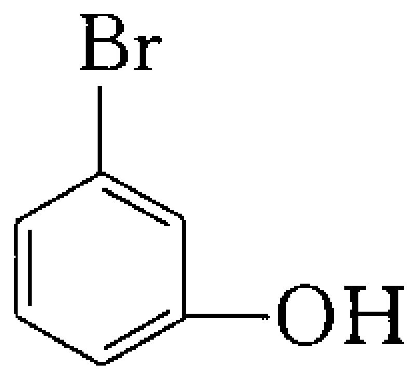
3,4-dinethyl-phenol



4-chloro-phenol
(p-chlorophenol)

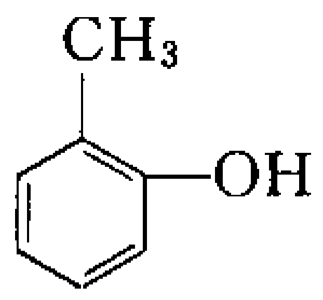


2-nitro-phenol
(o-nitriophenol)

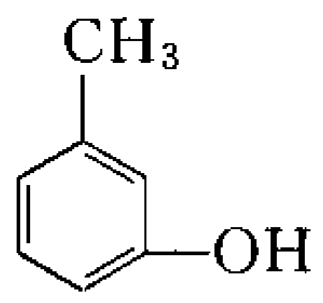


3-bromo-phenol
(m-bromophenol)

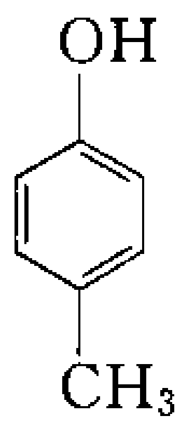
The methylphenols are commonly called cresols.



2-methyl-phenol
(o-cresol)

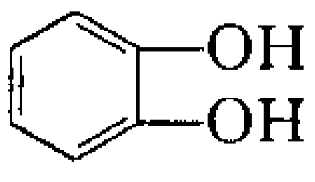


3-methyl-phenol
(m-cresol)

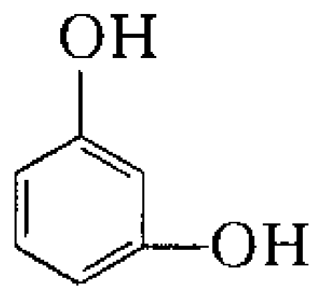


4-methyl-phenol
(p-cresol)

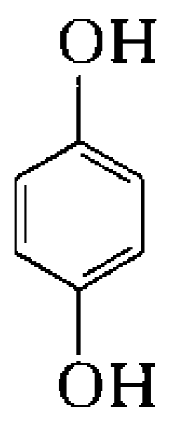
The benzenediols also have common names.



1,2-benzenediol
(catechol)



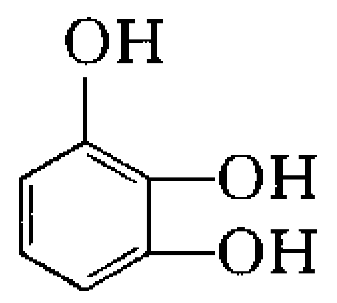
1,3-benzenediol
(resorcinol)



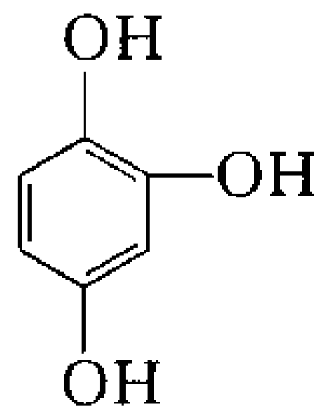
1,4-benzenediol
(hydroquinone)

Hydroxy derivatives of benzene and other aromatic carbocyclic system are named by adding the suffix "-ol", "-diol" and so on , to the name of the hydrocarbon, with elision of terminal "e" (if present) before "ol".

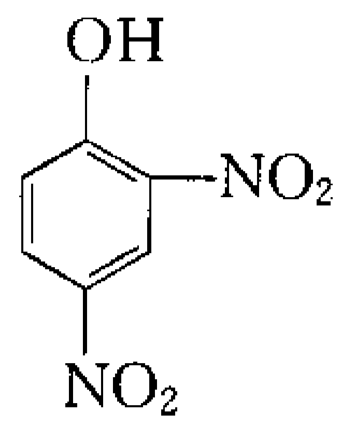
Examples:



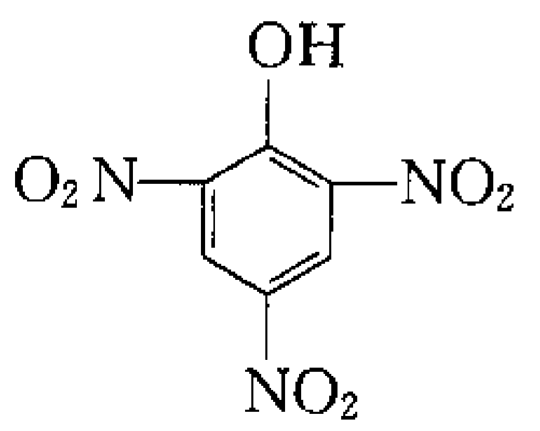
1,2,3-benzenetriol



1,2,4-benzenetriol (pyrogallol)

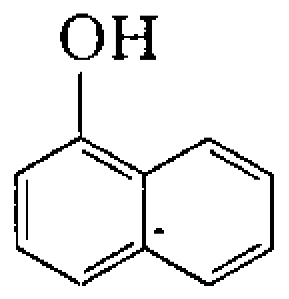


2,4-dinitrophenol

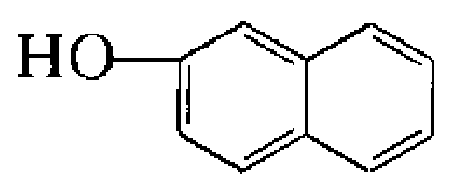


2,4,6-trinitrophenol (picric acid)

Compounds that have a hydroxyl group attached to a polycyclic benzenoid ring are chemically similar to phenols, but they are called naphthols and phenanthrols, for example:



1-naphthol
(α-naphthol)



2-naphthol
(β-naphthol)

6.3 Nomenclature of Radicals

Radicals RO— are named by adding "oxy" as a suffix to the name of the radical R.

Examples:		
	pentyloxy	$CH_3(CH_2)_3CH_2O$—
	allyloxy	$CH_2{=}CHCH_2O$—
	benzyloxy	$C_6H_5CH_2O$—

Only the following contractions for oxygen-containing radical names are recommended as exceptions to rule:

methoxy	CH_3O—	isopropoxy	$(CH_3)_2CHO$—
ethoxy	CH_3CH_2O—	isobutoxy	$(CH_3)_2CHCH_2O$—
propoxy	$CH_3CH_2CH_2O$—	*sec*-butoxy	$CH_3CH_2CH(CH_3)$—O—
butoxy	$CH_3(CH_2)_2CH_2O$—	*tert*-butoxy	$(CH_3)_3C$—O—
phenoxy	C_6H_5O—		

Except when forming part of a ring system, bivalent radicals of the form —O—X—O— are named by adding "dioxy" to the name of the bivalent radical —X— .

Examples:		
	methylenedioxy	—O—CH_2—O—
	ethylenedioxy	—O—CH_2—CH_2—O—
	trimethylenedioxy	—O—$(CH_2)_3$—O—

6.4 Nomenclature of Salts

Anions derived from alcohols are named by changing the final "-ol" of the name of the alcohol or phenol to "olate". This applies to substitutive, radicofunctional , and trivial names.

Examples:

sodium	methanolate	CH_3ONa
magnesium	di(1-propanolate)	$(CH_3CH_2CH_2O)_2Mg$
aluminium	tri(2-propanolate)	$[(CH_3)_2CHO]_3Al$
sodium	phenolate	C_6H_5ONa

Salts composed of an anion RO and a cation (usually a metal) ate named by citing , first , the cation and then the RO anion; the latter has the unabbreviated name used for the RO^- radical but with the ending "-yloxy-" changed to "-yl oxide"

Example: sodium benzyl oxide $C_6H_5CH_2ONa$

When the radical RO^- has an abbreviated name, the ending "-oxy" of this name is changed to "-oxide".

Examples:

sodium methoxide	CH_3ONa
potassium phenoxide	C_6H_5OK
potassium *tert*-butoxide	$(CH_3)_3COK$

6.5 Nomenclature of Ethers

Simple ethers are frequently given common radicofunctional names. One simply lists (in alphabetical order) both groups that are attached to the oxygen atom and adds the word ether.

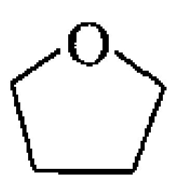
Examples:

$CH_3CH_2OCH_3$	$CH_3CH_2OCH_2CH_3$	$CH_2{=}CHOCH_2CH_3$
ethyl methyl ether	diethyl ether	ethyl vinyl ether(ethoxyethylene)
$CH_2{=}CHCH_2OCH_3$	$CH_2{=}CHOCH{=}CH_2$	$C_6H_5OC(CH_3)_3$
ally methyl ether	divinyl ether	*tert*-butyl phenyl ether
$C_6H_5OCH_3$	$(CH_3CH_2CH_2)_2O$	$(CH_3)_2CHOCH(CH_3)_2$
methyl phenyl ether	dipropyl ether	diisopropyl ether

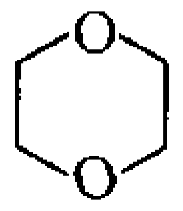
IUPAC Substitutive names should be used for complicated ethers, however, and for compounds with more than one ether linkage. In this IUPAC style, ethers are named as alkoxyalkanes , alkoxyalkenes, and alkoxyarenes. The RO— group is an alkoxy group.

$CH_3CH(OCH_3)CH_2CH_2CH_3$	$CH_3CH_2OC_6H_4CH_3$	$CH_3OCH_2CH_2OCH_3$
2-methoxypentane	1-ethoxy-4-methylbenzene	1,2-dimethoxyethane

Two cyclic ethers that are frequently used as solvents have the common names tetrahydrofuran (THF) and 1,4-dioxane.



tetrahydrofuran
(oxacyclopentane)



1,4-dioxane
(1,4-dioxacyclohexane)

Vocabulary

hydroxyl [hai'drɔksil] *n.* 羟基；氢氧
a hydroxyl group 羟基
hydroxyl radical 氢氧根
conjuctive [kən'dʒʌŋktiv] *a.* 连接的；*n.* 连接词
methanol [meθənəul] *n.* 甲醇
2-propanol ['prəupənɔl] *n.* 2-丙醇
triphenylmethanol ['traifinil'meθənəl] *n.* 三苯甲醇
5-hydroxyhexanal [hai'drɔksi'hekʃənəl] *n.* 5-羟基己醛
radicofunctional ['rædikə'fʌŋkʃənl] *a.* 官能团的
hexyl alcohol ['heksil'ælkəhɔl] *n.* 己醇
allyl ['ælil] alcohol 烯丙（基）醇
benzyl ['benzil] alcohol 苯甲醇
phenethyl ['fenəθil] *n.* 苯乙醇
ethylene glycol ['eθiliːn'glaikɔl] *n.* 乙二醇
glycerol ['glisəˌrɔl] *n.* 甘油；丙三醇
pinacol ['pinəkɔl] *n.* 频哪醇；2,3-二甲基-2,3-丁二醇
1,2,4-benzenetriol ['benziːn'traioul] *n.* 1,2,4-苯三酚
cresol ['kriːsɔl] *n.* 甲酚
naphthol ['næfθɔl] *n.* 萘酚
catechol ['kætəkoul] *n.* 邻苯二酚
resorciniol [re'zɔːsinɔl] *n.* 间苯二酚
pyeogallol ['paiərə'gælɔl] *n.* 1,2,3-三酚；连苯三酚
picric acid ['pikrik'æsid] *n.* 苦味酸；2,4,6-三硝基苯酚
contraction [kən'trækʃən] *n.* 缩短；省略
sodium methanolate [meθə'nɔleit] 甲醇钠
magnesium di(1-propanolate) [dai-wʌn-prooupə'nɔleit] 二正丙醇镁
sodium benzyl alcoholate ['ælkə'hɔleit] 苯甲醇钠
aluminium tri(2-propanolate) 三异丙醇铝
sodium phenolate ['fiːnəleit] 酚钠
unabbreviated ['ʌnə'briːvieitid] *a.* 未缩写的；未简缩的
sodium benzyl oxide 苯甲醇钠
sodium methoxide [me'θɔksaid] 甲醇钠
potassium phenoxide [fi'nɔksaid] 苯酚钾
potassium *tert*-butoxide [bju'tɔksaid] 叔丁醇钾
ethoxyethylene [e'θɔksi'eθiliːn] *n.* 乙氧基乙烯
2-methoxyanthracene [mə'θɔksi'ænθrəsiːn] *n.* 2-甲氧基蒽
ethyl methyl ether ['eθil'miθil'iːθə] 甲乙醚
ethyl vinyl ether ['eθil'vainil'iːθə] 乙基乙烯基醚
tetrahydrofuran ['tetrə'haidrə'fjuərən] *n.* 四氢呋喃
1,4-dioxane [dai'ɔksein] *n.* 二噁烷；1,4-二氧杂环己烷
methoxy [mə'θɔksi] 甲氧基
ethoxy [e'θɔksi] 乙氧基
propoxy [prə'pɔksi] 丙氧基
butoxy [bju'tɔksi] 丁氧基
phenoxy [fi'nɔksi] 苯氧基
benzyloxy ['benzi'lɔksi] 苯甲氧基
isopropoxy ['aisəpre'pɔksi] 异丙氧基
isobutoxy ['aisəu'bjuː tɔksi] 异丁氧基
2-naphthyloxy ['næfθi'lɔksi] 2-萘氧基
methlenedioxy ['meθiliːn, dai'ɔksi] 亚甲基二氧基
ethyenedioxy ['eθiliːn, dai'ɔksi] 亚乙基二氧基
-olate [ɔ(ə)leit] ……醇

Exercises

1. Write structural formulas for each of the following.

a. 2-buten-1-ol
b. 2-chlorl-3-hexyn-l-ol
c. 2-butanol
d. diisopropyl ether
e. 2-ethoxyethanol
f. isobutyl methyl ether
g. 2-phenylethanol
h. tetrahydrofuran
i. 3,3-dimethyl-1-butanol
j. *tert*-butyl ethyl ether
k. picric acid
l. catechol
m. *m*-cresol
n. β-naphthol

2. Give an IUPAC substitutive name for each of the following.

a. $(CH_3)_3CH_2CH_2OH$
b. $CH_2{=}CHCH_2{-}CH{-}OH$
c. $C_6H_5CH_2CH_2OH$
d. $HO{-}C_6H_5{-}OH$
e. $CH_2{=}CHCH_2CHCH_3$
f. $C_6H_5OCH_3$
g. CH_3CH_2ONa
h. C_6H_5OK
i. $(CH_3)_3CONa$
j. $(CH_3)_2CHOCH_2OCH(CH_3)_2$
k. $CH_2CHOCHCHOCHCH_2$
l. $CH_3CH_2CH(OCH_3)CH_2CH_3$
m. $[(CH_3)_2CHO]_3Al$
n. $CH{\equiv}CCH_2OH$
o. $(C_6H_5)_3COH$
p. $HOCH_2CH(OH)CH_2OH$

7 Aldehydes and Ketones

Except for formaldehyde the simplest aldehyde all aldehydes have a carbonyl group, bonded on one side to a carbon, and on the other side to a hydrogen, In ketones , the carbonyl group, bonded on one side to a carbon and on the other side to a carbon, in ketones the carbonyl group is situated between two carbon atoms.

7.1 Nomenclature of Aldehydes

In the IUPAC system aliphatic aldehydes are named substitutively by replacing the final e of the name of the corresponding alkane with al. Since the aldehyde group must be at the end of the chain of carbon atoms, there is no need to indicate its position. When other substituents are present, however, the carbonyl group carbon is assigned position I. Many aldehydes also have common names: these are given here in parentheses . These common names are derived from the common names for the corresponding carboxylic acids and some of them are retained by the IUPAC as acceptable names.

$H_2C{=}O$	CH_3CHO
methanal(formaldehyde)	ethanal(acetaldehyde)

CH_3CH_2CHO

propanal(propionaldehyde)

$CH_3(CH_2)_2CHO$

butanal

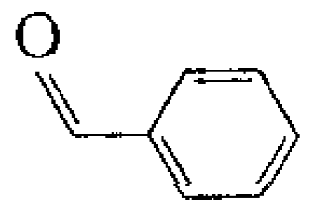
$ClCH_2CH_2CH_2CH_2CHO$

5-chloropentanal

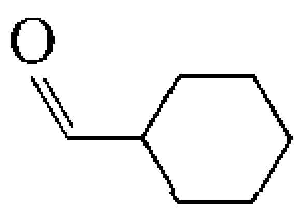
$C_6H_5CH_2CHO$

phenylethanal(phenylacetaldehyde)

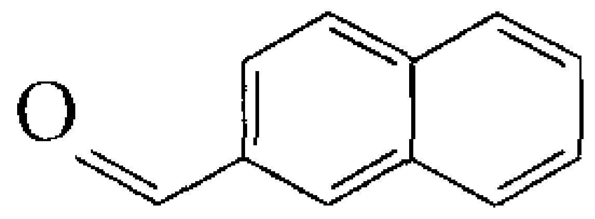
Aldehydes in which the —CHO group is attached to a ring system are named substitutively by adding the suffix carbaldehydes several examples follow:



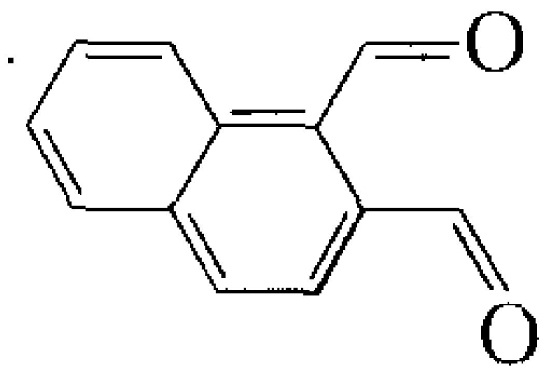
benzenecarbaldehyde
(benzaldehyde)



cyclohexanecarbaldehyde



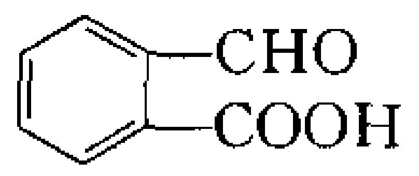
2-naphthalenecarbaldehyde



1,2-naphthalenedicarbaldehyde

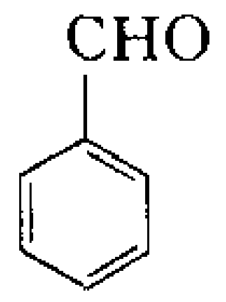
The common name benzaldehyde is far more frequently used than benzenecarbaldehyde for C_6H_5CHO.

When it is necessary to name the —CHO group as a prefix, it is the methanoyl or formyl group.

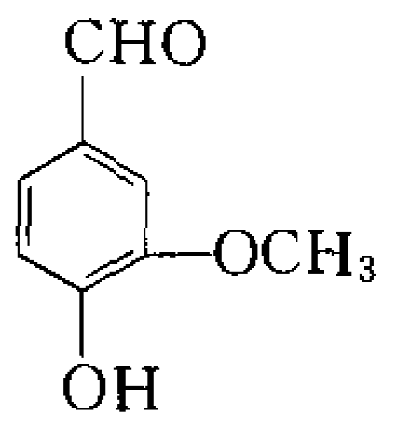


2-methanoylbenzoic acid
(*o*-formylbenzoic acid)

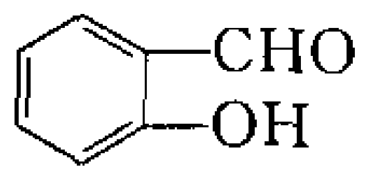
Some aromatic aldehydes obtained from natural sources have very pleasant fragrances some of these are the following:



benzaldehyde
(from bitter almonde)



vanillin
(from vanilla beans)



salicylaldehyde
(from meadowsweet)

$C_6H_5CH{=}CHCHO$

cinnamaldehyde
(from cinnamon)

7.2 Nommenclature of Ketons

Aliphatic ketones are named substitutively by replacing the final e of the name of the corresponding alkane with one. The chain is then numbered in the way that gives the carbonyl carbon atom the lower possible number, and this number is used to designate its position.

$CH_3CH_2COCH_3$
2-butanone
(ethyl methyl ketone)

$CH_3COCH_2CH_2CH_3$
2-pentanone
(methyl propyl ketone)

$CH_3COCH_2CH{=}CH_2$
4-penten-2-one
(not 1-penten-4-one)

$CH_3CH_2COCH_2CH_3$
3-pentanone
(diethyl ketone)

Common radicofunctional names for ketones (in parentheses above) are obtained simply by separately naming the two groups attached to the carbonyl group and adding the word ketone as a separate word.

Some ketones have common names that are retained in the IUPAC system.

CH_3COCH_3 (2-propanone or dimethyl phenyl ketone) acetone
$C_6H_5COCH_3$ acetophenone (1-phenylethanone or methyl phenyl ketone)
$C_6H_5COC_6H_5$ benzophenone (diphenylmethanone or diphenyl ketone)

When RCO— groups are named as substituents they are called alkanoyl or acyl groups.

$CH_3COC_6H_5SO_3H$
4-ethanoyl benzenesulfonic acid
(or *p*-acetyl benzenesulfonic acid)

Vocabulary

formaldehyde [fɔːˈmældihaid] *n.* 甲醇
ethanal [ˈeθənæl] *n.* 乙醇
acetaldehyde [ˈæsiˈtældəhaid] *n.* 乙醛
propionaldehyde [ˈprəupiəˈnældihaid] *n.* 丙醛
carbonyl group 羰基
parentheses [pəˈrenθisiːz] *n.* 圆括号
butanal [ˈbjuːtənæl] *n.* 丁醛
benzene [ˈbenziːn，benˈziːn] *n.* 苯
benzaldehyde [benˈzældiˈhaid] *n.* 苯甲醛
formyl group＝methanoyl 甲醛基
benzoic [benˈzəuik] *a.* 安息香的
benzoic acid 安息香酸；苯甲酸
almond [ˈaːmənd] *n.* 杏仁
vanillin [vəˈnilin，ˈvænilin] *n.* 香草醛；香兰素
vanillic [vəˈnilik] *a.* 香子兰的；香草醛的
meadowsweet [ˈmedəuswiːt] *n.* 珍珠花；麻叶绣球
cinnamon [ˈsinəmən] *n.* 肉桂；桂皮；肉桂树
cinnamaldehyde 肉桂醛
piperonal [ˈpipərənæl] *n.* 胡椒醛
safrole [ˈseifrəul] *n.* 黄樟脑；黄樟素
heliotrope [ˈheljətrəup] *n.* 向日性植物；天芥菜花的气味
aliphatic [ˈæliˈfætik] *a.* 脂肪的；脂肪族的
aliphatic ketones 脂肪族酮
2-butanone [ˈbjuːtənəun] *n.* 2-丁酮
ethyl methyl ketone 甲乙酮
diethyl ketone 二乙酮
acetone [ˈæsitəun] *n.* 丙酮
acetophenone [æsitəˈfenəun] *n.* 苯乙酮
1-phenylethanone 1-苯基乙酮

benzophenone [ˈbenzəufiːnəun] *n.* 二苯甲酮；苯酮；苯酰苯
acyl group 酰基
benzenesulfonic acid *n.* 苯磺酸
p-acestyl benzenesulfonic acid 对乙酰基苯磺酸

Phrases

at the end of... 在……末端；在……的结尾

Exercises

1. **Give a structural formula and another acceptable name for each of the following compounds.**
   a. formaldehyde
   b. acetaldehyde
   c. phenylacetaldehyde
   d. acetone
   e. ethyl methyl ketone
   f. acetophenone
   g. benzophenone
   h. diethyl ketone
   i. ethyl isopropyl ketone
   j. diisopropyl ketone
   k. dibutyl ketone
   l. cinnamaldehyde
   m. vanillin
   n. salicylaldehyde
   o. benzaldehyde
   p. cyclohexanone
2. **Give IUPAC substitutive for the seven isomeric aldehydes and ketones with the formula $C_5H_{10}O$.**

8 Carboxylic Acids and Their Derivatives (Ⅰ)

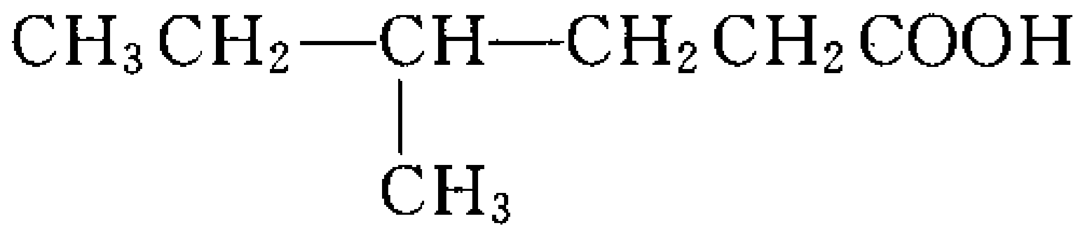
The carboxyl group (abbreviated $-CO_2H$ or $-COOH$), is one of the most widely occurring functional group in chemistry and biochemistry. Not only are carboxylic acids themselves important, but also the carboxyl group is the parent of a large family related compounds.

All of theses carboxylic acid derivatives contain the acyl group, $RCO-$, as a result they are often called acyl compounds. They are called carboxylic acid derivatives because they are derived from a carboxylic acid by replacing the $-OH$ of $RCOOH$ by some other group.

acyl (or acid) chloride	$RCOCl$
acid anhydride	$RCOOOCR$
ester	$RCOOR$
nitrile	$RC\equiv N$
amide	$RCONH_2$

Nomenvlature of Carboxylic Acids

IUPAC systematic or substitutive names for carboxylic acids are obtained by dropping the final e of the name of the alkane corresponding to the longest chain in the acid and by adding -oic acid. The carboxyl carbon atom is assigned number I. The examples listed here illustrate how this done.



$$CH_3CH_2-\underset{\underset{\displaystyle CH_3}{|}}{CH}-CH_2CH_2COOH$$

4-methylhexanoic acid

$CH_3CH{=}CHCH_2CH_2COOH$

4-hexenoic acid

Many carboxylic acids have common names that are derived from Latin or Greek words that indicate one of their natural sources. Methanoic acid is called formic acid (from the Latin, formica, or ant). Ethanoic acid is called acetic acid (from the Latin, acetum, or vinegar). Butanoic acid is one compound responsible for the odor of rancid butter, thus its common name is butyric acid (from the Latin, butyrum, or butter). Pentanoic acid, as a result of its occurrence in valerian, a perennial herb, is named valeric acid. Hexanoic acid is one compound associated with the odor of goats, hence its common name, caproic acid (from the Latin caper, or goat). Octadecanoic acid takes its common name, stearic acid, from the Greek word stear, for tallow.

Most of these common names have been with us for a long time and some are likely to remain in common usage for even longer, so it is helpful to be familiar with them. In this text we shall always refer to methanoic acid and ethanoic acid as formic acid and acetic acid. However, in almost all other instances we shall use IUPAN systematic or substitutive names, for examples:

hexanoic acid	(caproic acid)	$CH_3(CH_2)_4CO_2H$
octanoic acid	(capryic acid)	$CH_3(CH_2)_6CO_2H$
decanoic acid	(caprin acid)	$CH_3(CH_2)_8CO_2H$
dodecanoic acid	(lauric acid)	$CH_3(CH_2)_{10}CO_2H$
hexadecanoic acid	(palmitic acid)	$CH_3(CH_2)_{14}CO_2H$
octadecanoic acid	(stearic acid)	$CH_3(CH_2)_{16}CO_2H$
chloroethanoic acid	(chloroacetic acid)	$ClCH_2CO_2H$
trichloroethanoic acid	(trichloroacetic acid)	Cl_3CO_2H
benzoic acid	(benzic acid)	$C_6H_5CO_2H$
4-nitro benzoic acid	(*p*-nitrobenzoic acid)	$p\text{-}NO_2C_6H_4CO_2H$
4-methylbenzoic acid	(*p*-toluic acid)	$p\text{-}CH_3C_6H_4CO_2H$
1-naphthoic acid	(α-naphthoic acid)	$C_{10}H_7CO_2H$
2-naphthoic acid	(β-naphthoic acid)	$C_{10}H_7CO_2H$

Dicarboxylic acids are named as alkanedioic acids in the IUPAC systematic or substitutive system. Most simple dicarboxylic acids have common names.

oxalic acid	HO_2C-CO_2H	malonic acid	$HO_2CCH_2CO_2H$
succinic acid	$HO_2C(CH_2)_2CO_2H$	glutaric acid	$HO_2C(CH_2)_3CO_2H$

adipic acid $HO_2C(CH_2)_4CO_2H$ maleic acid *cis*-$HO_2CCH{=}CHCO_2H$
fumaric acid *trans*-$HO_2CCH{=}CHCO_2H$ phthalic acid *m*-$HO_2C{-}C_6H_4{-}CO_2H$

Vocabulary

anhydride [æn'haidraid] *n.* 酐
acid anhydride 酸酐
ester ['estə] *n.* 酯
nitrile ['naitrail] *n.* 腈
amide ['æmaid] *n.* 酰胺
hexanoic ['heksei'nəuik] acid 己酸
4-hexenoic ['heksi'nɔik] acid. 4-己烯酸
methanoic [meθə'nɔik] acid 甲酸
phthalic ['θælik] acid 邻苯二甲酸
tollow ['tæləu] *n.* 牛脂
lauric ['lɔːrik] acid 月桂酸；十二酸
palmitic [pæl'mitik] acid 软脂酸；十六酸
formic ['fɔːmik] acid 甲酸；蚁酸
ethanoic [eθə'nɔik] acid 乙酸
propanoic ['prəupə'nɔik] acid 丙酸
butanoic [bjuːtə'nɔik] acid. 丁酸
valeric [və'lərik] acid 戊酸
fumaric [fjuː'mærik] acid 反丁二酸
adipic [ə'dipik] acid 己二酸
maleic [mə'liːik] acid 顺丁烯二酸；马来酸
stearic ['sti'ærik] acid 硬脂酸；十八酸
naphthoic ['næfθɔik] acid 萘甲酸
toluic [tə'ljuːik] acid 甲基苯甲酸
caprylic [kə'prilik] acid 辛酸；羊脂酸
capric ['kæprik] acid 癸酸；羊蜡酸
oxalic [ɔk'sælik] acid 草酸；乙二酸
malonic [mə'lɔnik] acid 丙二酸
succinic [sək'sinik] acid 丁二酸；琥珀酸
glutaric [gluːtæric] acid 戊二酸

Exercises

1. Write a structural formula for each of the following compounds.

a. hexanoic acid
b. 3-hexenoic acid
c. 2-methyl-4-hexenoic acid
d. hexanedioic acid
e. phthalid acid
f. 2-naphthoic acid
g. maleic acid
h. fumaric acid
i. succinic acid
j. malonic acid
k. *m*-toluic acid
l. phenylacetic acid
m. 2,2-dimethylpentanoic acid
n. 4-methylbenzoic acid
o. 2-chlorobutanic acid
p. 4-hydroxybutonoic acid
q. 4-hydroxybutonoic acid
r. palmitic acid
s. capric acid
t. oxalic acid
u. stearic acid
v. formic acid

2. Give an IUPAC systematic or common name for each of the following compounds.

a. $C_6H_5CO_2H$
b. $ClCH_2COOH$
c. CH_2BrCO_2H
d. HO_2CCO_2H
e. $HO_2CCH_2CO_2H$
f. $HO_2C(CH_2)_3CO_2H$
g. $(CH_3)_2CHCH_2CO_2H$
h. *trans*-$HO_2CCH{=}CHCO_2H$

9 Carboxylic Acids and Their Derivatives (Ⅱ)

9.1 Nomenclature of Esters

The names of esters are derived from the names of the alcohol (with the ending -yl)and the (with the ending -ate or -oate). The portion of the name derived from the alcohol comes first.

$CH_3COOCH_2CH_3$
ethyl acetate or
ethyl ethanoate
$CH_3CH_2OOCCH_2COOCH_2CH_3$
diethyl malonate
HCO_2CH_3
methyl formate
$CH_3CO_2CH_3$
methyl acetate
$CH_3CO_2CH_2CH_2CH_2CH_3$
butyl acetate
$CH_3(CH_2)_3CO_2CH_2CH_3$
ethyl pentanoate
$CH_3(CH_2)_4CO_2CH_2CH_3$
ethyl hexanoate
$CH_3CO_2C_6H_5$
phenyl acetate

$CH_3CH_2COOC(CH_3)_3$
tert-butyl propanoate
$HCO_2CH_2CH_3$
ethyl formate
$CH_3CO_2CH_2CH_2CH_3$
propyl acetate
o-$HOC_6H_4CO_2CH_3$
methyl salicylate

$CH_3COOCH{=}CH_2$
vinyl acetate or
ethenyl ethanoate
$C_6H_5CO_2CH_3$
methyl benzonate

Esters are polar compounds but lacking hydrogen attached to oxygen, their molecules can not from strong hydrogen bonds to each other. As a result, esters hare boiling points that are lower than those of acids and alcohols of comparable molecular weight. The boiling points of esters are about the same as those of comparable aldehydes and ketones.

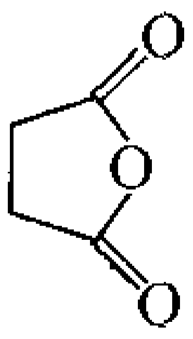
Unlike the low molecular weight acids, esters usually have pleasant odors, some resembling those of fruits, and these are used in the manufacture of synthetic flavors:

$CH_3CO_2CH_2CH_2CH(CH_3)_2$
isopentyl acetate (used in synthetic banana flavor)
$CH_3(CH_2)_3CO_2CH_2CH_2CH(CH_3)_2$
isopentyl pentanoate (used in synthetic apple flavor)

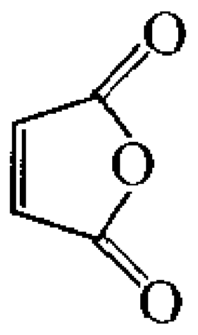
9. 2 Nomenclature of Carboxylic Anhydrides

Most anhydrides are named by dropping the word acid from the named of the carboxylic acid and then adding the word anhydride.

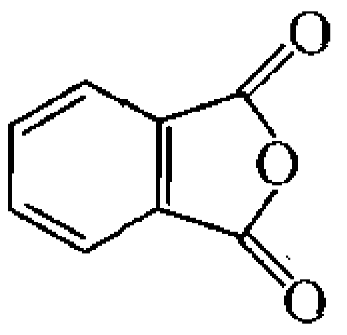
$(CH_3CO)_2O$	$(CH_3CH_2CO)_2$
acetic anhydride (ethanoic anhydride)	propanoic anhydride



succinic anhydride



maleic anhydride



phthalic anhydride

9. 3 Nomenclature of Acyl Chlorides

Acyl chlorides are also called chlorides. They are named by dropping -ic acid from the named of the acid and then adding -yl chloride. Examples are

CH_3COCl	CH_3CH_2COCl
acetyl chloride (ethanoyl choride)	propanoyl chloride
C_6H_5COCl	
benzoyl chloride	

Acyl chlorides and carboxylic anhydride have boiling points in the same range as esters of comparable molecular weight.

9. 4 Nomenclature of Amides

Amides that have no substituent on nitrogen are named by dropping -ic acid from the common name of the acid (or -oic from the substitutive name) and then adding -amide. Alkyl groups on the nitrogen atom of amides are named as substituents and the named substituent is prefaced by *N*-, or *N*,*N*-. Examples are

acetamide (ethanamide)	CH_3CONH_2
N,*N*-dimethylacetamide	$CH_3CON(CH_3)_2$
N-ethyl acetamide	$CH_3CONHCH_2CH_3$
benzamide	$C_6H_5CONH_2$
N,*N*-dimethyl benzamide	$C_6H_5CON(CH_3)_2$

Molecules of amides with one (or no) substituent on nitrogen are able to form strong hydrogen bonds to each other and, consequently, such amides have high melting points and boiling points. Molecules of *N*,*N*-disubstituted amide cannot form strong hydrogen bonds to each other; they have lower melting points and boiling points.

9. 5 Nomenclature of Nitriles

In IUPAC substitutive nomenclature acyclic nitriles are named by adding the suffix nitrile to number 1. The named acetonitrile is an acceptable common name for CH_3CN and acrylonitrile is an acceptable common name for $CH_2{=}CHCN$.

Examples:

ethanenitrile (acetonitrile)	CH_3CN
butanenitrile	$CH_3(CH_2)_2CN$
propeneniteile (acrylonitrile)	$CH_2{=}CHCN$
4-pentenenitrile	$CH_2{=}CH(CH_2)CN$

Cyclic nitriles are named by adding the suffix carbonitrile to the name of the ring system to which the —CN group is attached. Benzonitrile is an acceptable common name for C_6H_5CN.

C_6H_5CN	$C_6H_{11}CN$
benzenecarbonitrile (benzonitrile)	cyclohexanecarbonitrle

Vocabulary

acetate ['æsiteit] *n.* 醋酸盐; 乙酸盐
ethyl acetate 醋酸乙酯; 乙酸乙酯
phthalic ['θælik] anhydride 邻苯二甲酸酐
salicylate [sæ'lisileit] 水杨酸酯(盐)
amide ['æmaid] *n.* 酰胺
salicylate aldehyde 水杨醛
amine ['æmiːn] *n.* 胺
ester ['estə] *n.* 酯
nitrile ['naitrail] *n.* 腈
succinic [sək'sinik] anhydride 丁二酸酐
benzamide ['benziːmaid] *n.* 苯甲酰胺
benzoyl chloride 苯甲酰氯
maleic [ma'liːik] anhydride 马来酸酐; 顺丁烯二酸酐
acetyl chloride ['æsitil'klɔːraid] 乙酰氯

Exercises

1. Write structural formulas for the following.

a. methyl propanoate
b. ethyl *p*-nitrobenzoate
c. dimethyl malonate
d. *N*,*N*-dimethylbenzamide
e. pentanenitrile
f. dimethyl phthalate
g. dipropyl maleate
h. *N*,*N*-dimethylformamide
i. 2-bromopropanoyl bromide
j. diethyl succinate
k. succinimide
l. maleic anhydride
m. *N*,*N*-diethylhexanamide
n. diethyl oxalate
o. isobutyl propanoate
p. benzonitrile

2. Give IUPAC names for the following.

a. $HO_2C(CH_2)_5CO_2H$
b. $CH_3(CH_2)_2CO_2CH_3$
c. $CH_3CH_2CHClCO_2H$
d. $(CH_3CH_2CO)_2O$
e. $CH_3CH_2CH_2COCl$
f. $CH_3CH_2CONH_2$
g. $CH_3CH_2CH_2CONHCH_3$
h. $C_6H_5CH_2CH_2CH_2COCl$
i. $CH_2{=}CHCN$
j. CH_3CN
k. $(CH_3)_2NCOCH_3$
l. C_6H_5COCl
m. o-$HOC_6H_4CO_2CH_3$
n. $CH_3CO_2C_6H_5$

10 Qualitative Organic Analysis

Although the subject of the identification of organic compounds by application of a systematic of qualitative organic analysis is covered in a full course at the senior or graduate student level in most schools, there is much to be gained by making a preliminary study of this phase of organic chemistry in the first course in the subject. Furthermore, of all of the laboratory assignments in the first year course in organic chemistry, this is the one that students usually enjoy the most. You will find that the identification of an unknown poses a real challenge to you in the application of your skill in laboratory manipulations and your knowledge of the subject of organic chemistry.

The analysis of a chemical substance is generally performed for one of reasons: (1) To assign unambiguously a structure to a new molecule which has not been described previously in the chemical literature. (2)To characterize the properties of the compound for comparison purposes. Thus, an investigator who isolates a product as a result of some chemical reaction has two options by which he can determine the identity of this product. He can first characterize the molecule as discussed below and search the literature for a known molecule which has identical properties. Should the literature search provide such a compound, then the investigator can safely argue that he has succeeded in identifying his substance. On the other hand, if such data are not available in the literature, his remaining alternative is to carry out a full structure determination.

10. 1 A Structure Determination Involves the Following Steps:

(1) Determination of the empirical formula by quantitative analysis of all elements present in the compound.

(2) Determination of the molecular weigh by any of several methods, i. e. freezing point depression, osmometry, mass spectrometry.

(3) Point(1)and(2)taken together yield knowledge of the molecular formula.

(4) Qualitative and, possibly, quantitative determination of the functionality present in the molecule. This may be accomplished by the use of molecular spectra, particularly, IR, or by any of several chemical tests.

(5) Determination of the spatial arrangement of the atoms which constitute the molecular structure. This implies a determination of stereo chemistry as well. Such determinations are best done by instrumental methods such as NMR, MS, UV, etc.

(6) Structure determination can be aided by chemical reactions which unambig-

uously transform the unknown compound into compounds of known structure.

The above steps may not be necessary if an X-ray diffraction study can be performed on the unknown molecule. This powerful method will give the absolute structure directly, but is only applicable to nicely crystalline compounds and is very expensive and time consuming as well.

10. 2 Characierization of a Compound Involves the Following Steps:

(1) Determination of all physical properties of the compound, including spectra.

(2) Qualitative determination of the elements other than carbon, hydrogen, and oxygen present in the molecule.

(3) Qualitative determination of the functionality present.

(4) Conversion to solid derivatives.

Notice that there is an overlap of information between structure determination and characterization. However, the characterization procedures are designed to supply the requisite information quickly and simply with the use of a minimal amount of sample.

An important part of the characterization scheme is step (4). Once the number of possible structures for the unknown has been reduced by the application of the first three characterization procedures, derivatives are prepared so as to distinguish further among the remaining possibilities, all of which will posses similar at this point due to the availability of several sets of physical data (those of the unknown as well as those of its derivatives), rather than just one such set (for the unknown only). Solid derivatives are used because of their ease of purification and the fact the melting point is the most reproducible of the readily measured physical properties of such derivatives.

In this series of experiments you will concentrate on the characterization of a compound whose identity is unknown to you. The purpose is to identify the compound positively by deducing the elements and functionality present and by comparing its physical properties. This approach will emphasize chemical rather than spectral methods.

The laboratory instructor will furnish you with 10-15 g. Samples of the unknown compound, either liquid or solid, which are to be identify during the course of the prescribed number of periods. The unknown will belong to one of the following classes of monofunctional compounds: alkenes, alkynes, aromatic hydrocarbons, alkyl and arylhalides, alcohols, phenols, aldehydes, ketones, carboxylic acids or their salts, ester, anhydrides, acyl chlorides, amides, nitriles, ethers, and aliphatic nitro compounds.

The unknowns are all monofunctional in the sense that only one type of functional group is represented in the molecule. However, the unknown may be multifunctional in that more that one of the same type of functional group may be multifunctional in that more than one of the same type of functional group may be present, e. g. dicarboxylic acids.

(The only exceptions to this statement are certain phenols which may also contain other functionality, e. g. *p*-nitrophenol.)

Vocabulary

qualitative ['kwɔlitətiv] *a.* 性质的；定性的
spatial ['speiʃəl] *a.* 空间的
systematic ['sisti'mætik] *a.* 系统的
graduate student 研究生
resonance NMR/nuclear magnetic 核磁共振
graduate ['grædjueit] *a.* 研究院的；已取得学士学位的
possess [pɔ'zes] *vt.* 有；具有
X-ray diffraction ['eks'reidi'frækʃən] X射线衍射
nicely ['naisli] *ad.* 精确地；恰好地
UV/ultraviolet ['ʌltrə'vaiəlit] *a.* & *n.* 紫外线（的）；紫外光谱
phase [feiz] *n.* 时期；阶段
option ['ɔpʃən] *n.* 选择
preliminary [pri'liminəri] *a.* & *n.* 初步（的）；开端；开始
characterization ['kæriktərai'zeiʃən] *n.* 鉴定；鉴别
minimal ['miniməl] *a.* 最小的；最低的
equisite ['rekwizit] *a.* 需要的；必要的
manipulation [mə'nipju'leiʃən] *n.* 操作；操纵
deduce [di'djuːs] *vt.* 推论；推断
approach [ə'prəutʃ] *n.* 方法；步骤
quantitative ['kwɔntitətiv] *a.* 量的；定量的
positively ['pɔzitivli] *ad.* 确实地；毫无疑问地
freezing point depression ['friːziŋ pɔintdi'preʃən] 冰点降低（法）测定（法）
instructor [ins'trʌktə] *n.* 教师；导师
MS/mass spectrometry [mæs spek'trɔmitri] 质谱
molecule spectra ['mɔlikjuːl'spektrə] *n.* 分子光谱
osmometry [ɔz'mɔmitri] *n.* 渗透压；渗透压测定法

Phrases

furnish sb. with. sth. 给……提供……
applicable to 适应于；对……很合适；可应用
in the sense that 在某种意义上
concentrate (up) on 集中于；专心于

Exercises

Translate the following into English.

a. 有机定性分析
b. 有机定量分析
c. 红外光谱
d. 核磁共振谱
e. 紫外光谱
f. X射线衍射的研究
g. 研究生
h. 冰点降低法
i. 质谱分析
j. 有机物的鉴定
k. 分子光谱
l. 原子的空间排列
m. 化学物质的分析
n. 未知物的测定

11 Polymer Chemistry

11.1 Introduction

When polymers are fabricated into useful articles they are referred to as plastics, rubbers, and fibers. Some polymers, for example, cotton and wool, occur naturally, but the great majority of commercial products are synthetic in origin. A list of the names of the better known materials would include bakelite, melmac, dacron, nylon, silicones, lucite, celanese, orlon, styron, polythene, and teflon.

Previous to 1930 the use of synthetic polymers was not widespread. However, they should not be classified as new materials for many of them were known in the latter half of the nineteenth century. The failure to develop them during this period was due, in part, to a lack of understanding of their properties; in particular, the problem of the structure of polymers was the subject of much fruitless controversy.

Two events of the twentieth century catapulted polymers into a position of worldwide importance. The first of these was the successful commercial production of the plastic now known as bakelite. Its industrial usefulness was demonstrated in 1912 and in the next few succeeding years. Today bakelite is high on the list of important synthetic products. Before 1912 materials made from cellulose were available, but their manufacture never provide the incentive for new work in the polymer field such as occurred after advent of bakelite. The second event was concerned with fundamental studies of the nature of polymers by staudinger in Europe and by carothers, who worked with the du pont company in Delaware. A greater part of the studies were made during the 1920's. Staudinger's work was primarily fundamental. Carother's achievements led to the development of our present huge plastics industry by causing an awakening of interest in polymer chemistry, an interest which is still strongly apparent today.

11.2 Definitions

A polymer is a substance of high molecular weigh, well above the size of the compounds considered so far. There is no agreement as to the minimum molecular weigh of a substance in order for it to be classified as a polymers; however, a practical figure would be about 1,000. Many commercial polymers are found in the range of 10,000 to 50,000 although some of them have much higher molecular weights. A polymer is formed by the reaction of many low-molecular-weight molecules combining into a high-molecular-weight compound. A compound capable of conversion into a polymer, as ethylene is into polyethylene, is called a monomer (mono, one; mer, unit). A polymer then is a molecule of many units, and the process involved in the formation of one is termed polymerization.

11.3 Classifiction of Polymers

(1) Addition polymers

An addition polymer results form the self-combination of many monomer units into a substance with a molecular weight about one thousand. The empirical formula of the polymer is the same as that of the monomer:

$$n\text{CH}_2{=}\text{CH}_2 \xrightarrow{\text{catalyst}} \left[\text{CH}_2-\text{CH}_2\right]_n$$

ethylene polyethylene

(2) Condensation polymers

Bakelite is an example of a polymer formed by a condensation process. The reaction involved a general one in organic chemistry, will be discussed later, but for the present it may be said that self-addition of monomers is not involved. Instead, as the polymer forms, there is an elimination of by-product, usually water. The following simplified equation illustrates the formation of a polymer link, and the dotted lines indicate the further reaction is occurring in the directions indicated:

$$\text{HO}-\text{R}-\text{O}-\text{H} + \text{H}-\text{O}-\text{R}-\text{O}-\text{H} \longrightarrow -\text{O}-\text{R}-\text{O}-\text{R}-\text{O}- + \text{H}_2\text{O}$$

11.4 Polythene

When ethylene is heated under pressure, with oxygen as a catalyst, it is converted to a polymeric form known as polyethylene or polythene. The product is a mixture of high-molecular-weight alkanes (if the one double bond at the end of the chain is ignored) and may be classified as a polyalkane. A formula representing the mixture was given under classification of polymers. Under one set of experimental conditions the value of n may vary from 50 to 700 with the average for the mixture being about 500, since the repeating unit of the polymer $\left[\text{CH}_2-\text{CH}_2\right]$ has a value of 28, the average molecular weight for it is about 14, 000. At this point the student should make a special note of the fact that most polymers are not pure compounds but are complex mixture of compounds.

The polythene of industry is a thermoplastic solid, i. e. , it will soften and flow when heated. Most thermoplastic materials soften at relatively low temperature; polythene is plastic at about 115℃; like other polymers, it may be deposited as a thin film or sheet. The film-forming property of thermoplastic polymers is important and, because of it many useful products are possible: raincoats, tablecloths, shower curtain, paints, etc. It may be molded into a variety of solid articles such as the flexible, nonbreakable bottles used for drug store products and other material. Perhaps its most important use has been in electrical insulation where the nonconducting property of alkane hydrocarbon is employed in a useful way.

Thermoplastic polymers are, as a rule, hard and brittle so for practical purposes various softening agents known as plasticizers are blended with the polymer before it is fabricated. Plasticizers are often pure organic compounds relatively simple in structure and soluble in the polymer. A good quality plasticizer will remain in the plastic indefinitely; a poor one will slowly volatilize and leave behind the original hard, brittle polymer. The behavior may be noted sometimes in the home in an inexpensive apron or shower curtain.

Vocabulary

polymer [ˈpɔlimə] *n.* 聚合物
carothers [kəˈrʌðəz] W. H. 卡罗瑟
article [ˈaːtikl] *n.* 制品；物件；文章
condensation [kɔndenˈseiʃən] *n.* 综合
synthetic (al) [sinˈθetik] *a.* 合成的
elimination [ilimiˈneiʃən] *n.* 消除
melmac [ˈmelmæk] *n.* 三聚氰胺-甲醛合成树脂和黏合剂；蜜胺树脂
mold/mould [məuld] *vt.* 模塑
flexible [ˈfleksəbl] *a.* 柔软的；柔性的
fabricate [ˈfæbrikeik] *vt.* 制造；二次加工
insulation [insjuˈleiʃən] *n.* 绝缘
plastic [ˈplæstik] *n.* 塑料/*a.* 可塑的
plasticizer [ˈplæstisaizə] *n.* 增塑剂
blend [blend] / blended [ˈblendid] *vt.* & *n.* 掺和（物）
bakelite [ˈbeikəlait] *n.* 酚醛树脂；电木
dacron [ˈdeikrən] *n.* 聚对苯二甲酸
silicones [ˈsilikəuns] *n.* 聚硅氧烷；乙二醇酯纤维；涤纶
apron [ˈeiprən] *n.* 围巾
nylon [ˈnailən] *n.* 尼龙；聚酰胺纤维
celanese [seləˈniːz] *n.* 奥纶；聚丙烯腈
lucite [ˈluːsait] *n.* 有机玻璃
catapult [ˈkætəpʌlt] *vt.* 弹射；突然出名
styron [ˈstairɔn] *n.* 聚苯乙烯
succeeding [səkˈsiːdiŋ] *a.* 连续的
advent [ˈædvənt] *n.* 到来；出现
teflon [ˈteflɔn] *n.* 特氟隆
empirical [emˈpirikəl] *a.* 经验的
fruitless [ˈfruːtlis] *a.* 无效果的；无益的
controversy [ˈkɔntrəvəːsi] *n.* 争论；辩论
cellulose [ˈseljuləus] *n.* 纤维素
empirical [emˈpirikəl] formula 实验式
paint [peint] *n.* 油漆；涂料
fruitless [fruːtlis] *a.* 无效果的；无益的
incentive [ˈinˈsentiv] *n.* & *a.* 刺激（的）
staudinger [ˈstaudiŋgə] H. 史滔丁格
cellulose [ˈseljuləus] *n.* 纤维素

Phrases

(be) referred to as （被）叫做
well above 高出很多；大大超过
previous to 在……之前
as to 到于；关于
in particular 特别（地）
(be) capable of 能够……的
(to) subject to 使受（影响，作用等）
result in 导致；结果是
(be) concerned with 与……有关；牵涉到
a variety of 各种各样的
for the present 目前；暂时
as a rule 通常；一般

Exercises

1. Translate the following into English.

a. 塑料
b. 橡胶
c. 纤维
d. 高分子化学

e. 涤纶
f. 尼龙
g. 聚乙烯
h. 奥纶
i. 聚苯乙烯
j. 酚醛塑料
k. 增塑剂
l. 邻苯二甲酸丁酯

2. Translate the following into Chinese.

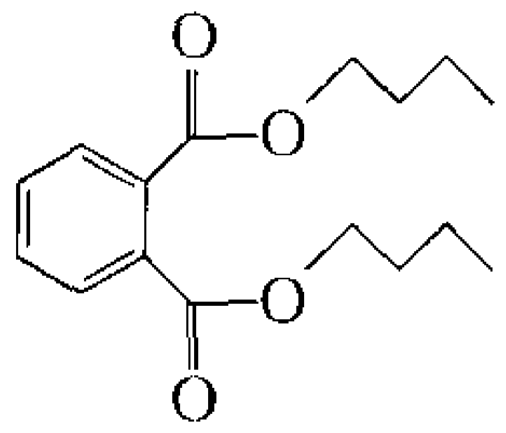
When ethylene is heated under pressure, with oxygen as a catalyst, it is converted to a polymeric form known as polyethylene or polythene. The product is a mixture of high-molecular-weight alkanes (if the one double bond at the end of the chain is ignored) and may be classified as a polyalkane. A formula representing the mixture was given under classification of polymers. Under one set of experimental conditions the value of n may vary from 50 to 700 with the average for the mixture being about 500, since the repeating unit of the polymer $-\!\!\left[CH_2-CH_2\right]\!\!-$ has a value of 28, the average molecular weight for it is about 14, 000. At this point the student should make a special note of the fact that most polymers are not pure compounds but are complex mixture of compounds.

12 Polymer Structure and Physical Properties

Classification of synthetic polymers according to their physical properties is a useful exercise because it allows us to make a rough correlation between structure and property. In general, we can divide polymers into four major categories: thermoplastics, fibers, elastomers, and thermosetting resins.

12.1 Thfrmoplastics

Thermoplastics are the polymers most people think of when the word plastic is mentioned. These polymers are hard at room temperature but become soft and viscous when heated. As a result, they can be modeled into toys, beads, telephone housings, or into any one of thousands of other items. Because thermoplastics have little or no cross-linking, the individual chains can slip past one another on heating. Some thermoplastic polymers such as poly (methylmethacrylate), used in plexiglas, are amorphous (i. e. noncrystalline); Others, such as polyethylene and nylon, are partially crystalline. Plasticizers—small organic molecules that act as lubricants between chains—are usually added to plastics to keep them from becoming brittle at room temperature. Dialkyl phthalates are commonly used for this purpose and, in the past few decades, have become among the most widely dispersed of all environmental pollutants. Phthalate plasticizers have even been m-$CH_3(CH_2)_3OOCC_6H_4COO(CH_2)_3CH_3$ detected in the fat of antarctic penguins.



dibutyl phthalate (a plasticizer)

12. 2 Fibers

Fibers are thin threads produced by extruding a molten polymer through small holes in a die or spinneret. The fibers are then cooled and drawn out. Drawing has the effect of orienting the crystallite regions along the axis of the fiber, a process that adds considerable tensile strength. Nylon, dacron, and polyethylene all have the semicrystalline structure necessary for drawing into oriented fibers.

12. 3 Elastomers

Elastomers are amorphous polymers that have the ability to stretch out and spring back to their original shapes. These polymers must have a modest amount of cross-linking to prevent the chains from slipping over one another, and the chains must have an irregular shape to prevent crystallite formation. When stretched, the randomly coiled chains straighten out and orient along the direction of the pull. Van Der Waals forces are too weak and too few to maintain this orientation, however, and the elastomer therefore revert to its random coiled state when the stretching force is released.

Natural rubber is one example of an elastomer. Rubber has the long chains and occasional cross-links needed for elasticity, but its irregular geometry prevents close packing of the chains into crystallites. Guttapercha, by contrast, is highly crystalline and is not an elastomer.

12. 4 Thermosetting Resins

Thermosetting resins are polymers that become highly cross-linked and solidify into a hard, insoluble mass when heated. We have not paid particular attention to such polymers up to this point, but one example should suffice. Bakelite, a thermosetting resin that was first produced in 1907 by leo Bakeland has been in commercial use longer than any other synthetic polymer. It is widely used for molded parts for adhesive, for coatings, and even for high-temperature applications such as missile nose cones. Chemically, bakelite is a phenolic resin produced by reaction of phenol and formaldehyde. On heating, water is eliminated, many cross-links form, and the polymer sets into a stable, rock-like mass.

The crosslinking in bakelite and thermosetting resins is three-dimensional and is so extensive that we cannot speak of polymer "chains". Bakelite is essentially one large molecule.

12. 5 Summary

Synthetic polymers can be classified as either chain-growth polymers or step-growth polymers. Chain-growth polymers are prepared by chain reaction polymerization of unsaturated monomers，in the presence of a radical，an anion，or a cation initiator. Radical polymerization is the most commonly used method，but alkenes such as 2-methylpropene that have electron-donating substituents on the double bond polymerize easily by a cationic route. Similarly，monomers such as methyl α-cyanoacrylate that have electron-withdrawing substituents on the double bond polymerize by an anionic（Michael-type reaction）pathway. Conjugated dienes such as 1，4-butadiene，isoprene，and the products have double bonds in their chains，still another possibility is the copolymerization of two monomers to give a product that has properties different from those of either homopolymer.

Alkene polymerization can be carried out in a much more controlled fashion if Ziegler-natta catalysts are used. Ziegler-natta polymerization minimizes the amount of chain branching in the polymer and leads to stereoregular chain-either isotactic（substituents on the same side of the chain）or syndiotactic（substituents on alternate sides of the chain），rather than atactic（subtituents randomly disposed）.

Step-growth polymers，the second major class of polymers，are prepared by reactions two different difunctional molecules；the individual bonds in the polymer are formed independently of one another；polyamides（nylons）are formed by step-growth polymerization between a diamine；polyesteres are formed from a diester and diol；and polyurethanes are formed from a diisocyanate and a diol.

The chemistry of synthetic polymers is similar to the chemistry of small molecules with the same functional groups，but the physical properties of polymers are greatly affected by size. Polymers can be classified by physical property into four groups：thermoplastics，fibers，elastomers，and thermosetting resins. The properties of each group can be accounted for by the structure，the degree of crystalline，the geometry，and the amount of cross-linking in specific polymers.

Vocabulary

elastomer [iˈlæstəmə] *n.* 弹性体；合成橡胶
lubricant [ˈluːbrikənt] *a.* 润滑的；润滑剂
thermosetting [θəːməuˈsetiŋ] *a.* & *n.* 热固；热硬性的
resins [ˈrezin] *n.* 树脂
antarctic [æntˈaːktik] *a.* 南极的
bead [biːd] *n.* 有孔小珠；玻璃珠
penguin [ˈpeŋgwin] *n.* 企鹅
methacrylate [meˈθækrəleit] *n.* 异丁烯酸盐（酯）；甲基丙烯酸酯树脂
extrude [eksˈtruːd] *vt.* 挤压；模压
spinneret [spinəˈret] *n.* 吐丝器；吐丝头
amorphous [əˈmɔːfəs] *a.* 无定形
revert [riˈvəːt] *vi.* 恢复原状；回复
monomer [ˈmɔnəmə] *n.* 单体；单聚物

Phrases

in general 一般；大体上
by contrast 相反
act as 充当；作为；起……的作用
pay attention to 注意；关心

add to	增加
in the presence of	在……的面前；在有……参加的情况下
keep from	使不；阻止

Exercises

Translate the following into English.

a. 无定形
b. 热塑性树脂
c. 热固性树脂
d. 天然橡胶
e. 三维空间
f. 合成高聚物
g. 自由基聚合
h. 控电子取代基
i. 交错连接

13 Specialist Heterocyclic Nomenclature

13.1 Extension of Hantzsch-Widman System

13.1.1 Monocyclic compounds containing one or more hetero atoms in a three-to ten-membered ring are named by combining the appropriate prefix or prefixes from Table 13.1 (eliding "a" where necessary) with a stem from Table 13.1. The state of hydrogenation is indicated either in the stem, as shown in Table 13.2, or by the prefixes "dibydro-", "tetrahydro-" etc.

Table 13.1 In Decreasing Order of Priority

Element	Valence	Prefix	Element	Valence	Prefix
oxygen	Ⅱ	oxa	antimony	Ⅲ	stiba
sulfur	Ⅱ	thia	bismuth	Ⅲ	bisma
selenium	Ⅱ	selena	silicon	Ⅲ	sila
tellurium	Ⅱ	tellure	germanium	Ⅳ	germa
			tin	Ⅳ	stanna
phosphorus	Ⅲ	phospha	lead	Ⅳ	plumba
arsenic	Ⅲ	arsa	boron	Ⅲ	bora
nitrogen	Ⅲ	aza	mercury	Ⅱ	mercura

When immediately followed by "-in" or "-ine", "phospha-" should be replaced by "phospher-", "arsa-" should be replaced by "arsen-" and "stiba-" should be replaced by "antimon-". In addition, the saturated six-membered rings corresponding to phosphorin and arsenin are named phosphorinane and arsenane. Further exceptions: Borin is replaced by borinane.

Table 13. 2 Nomenclature of Heterocyclic Compounds

No. of members in the ring	Rings containing unsaturation(a)	Nitrogen saturation	Rings containing unsaturation(a)	No nitrogen saturation
3	-rine	-iridine	-irene	-irane(e)
4	-ete	-etidine	-ete	-etane
5	-ole	-olidine	-ole	-olane
6	-ine(b)	(c)	-in(b)	-ane(d)
7	-epine	(c)	-epin	-epane
8	-ocine	(c)	-ocin	-ocane
9	-onine	(c)	-onin	-onane
10(f)	-ecine	(c)	-ecin	-ecane

(1) Corresponding to the maximum number of non-cumulative double bonds, the hetero elements having the normal valences shown in Table 13. 1.

(2) For phosphorus, arsenic, antimony and boron, see the special provisions of Table 13. 1.

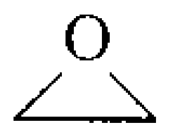
(3) Expressed by prefixing "perhydro" to the name of the corresponding unsaturated compound.

(4) Not applicable to silicon, germanium, tin and lead. In this case, "perhydro-is prefixed to the name of the corresponding unsaturated compound".

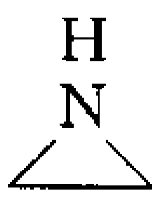
(5) The syllables denoting the size of rings containing 3,4 or 7-10 members are derived as follows: "ir" from tri, "et" from tetra, "ep" from hepta, "oc" from octa, "on" from nona, and "ec" from deca.

(6) Rings with more than ten members are named by replacement nomenclature. It is necessary to elide the final "a" of the prefix when followed immediately by a vowel. e. g. ox(a)azole.

Examples:



oxirane



aziridine

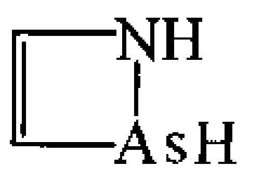
2*H*-azepine

13. 1. 2 Heterocyclic systems whose unsaturation is less than the one corresponding to the maximum number of non-cumulative double bonds are named by using the prefixes "dihydro-" "tetrahydo-", etc.

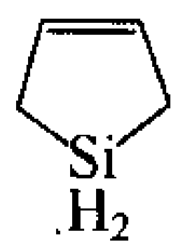
In the case of 4-and 5-membered rings, a special termination is used for the structures containing one double bond. When there can be more that one non-cumulative double bond.

No. of members of the partly saturated rings	Rings containing nitrogen	Rings containing no nitogen
4	-etine	-etene
5	-oline	-olene

Examples:



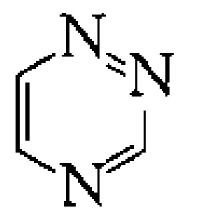
Δ^3-1,2-azarsetine



3-silolene

13.1.3 Multiplicity of the same hetero atom in indicated by to prefix "di-", "tri-" etc., placed before the appropriate "a" term (Table 13.1).

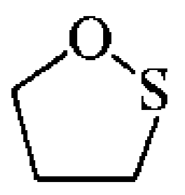
Example:



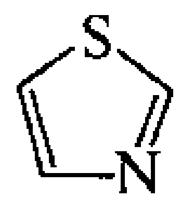
1,3,5-triazine

13.1.4 If two or more kinds of "a" terms occur in the same name, their order of citation is in order of their appearance in Table 13.1.

Example:



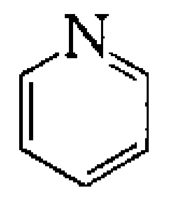
1,2-oxathiolane



1,3-thiazole

13.1.5 The position of a single hetero atom determines the numbering in a mono-cyclic compound.

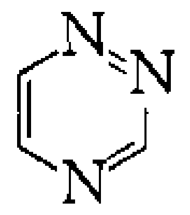
Example:



azocine

13.1.6 When the same hetero atom occurs more than one in a ring, the numbering is chosen to give the lowest locants to the hetero atoms.

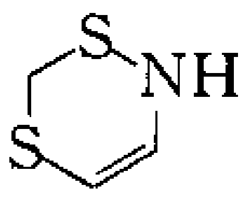
Example:



1,2,4-triaxine

13.1.7 When hetero atoms of different kinds are present, the locant 1 is given to a hetero atom which is as high as possible in Table 13.1. The numbering is then chosen to give the lowest locants to the hetero atoms.

Example:



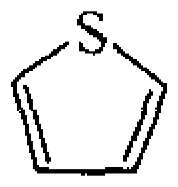
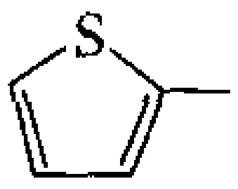
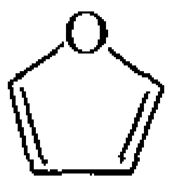
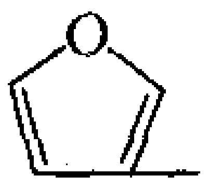
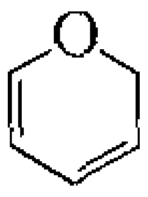
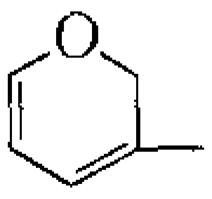
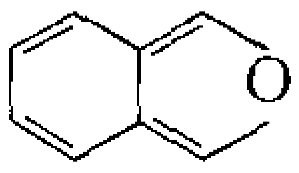
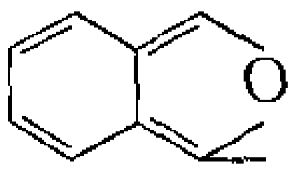
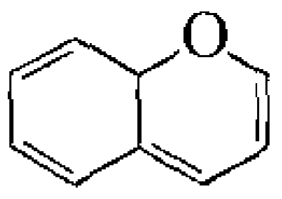
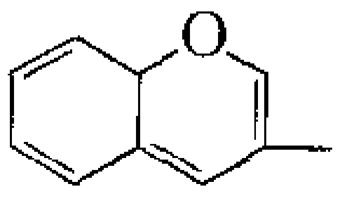
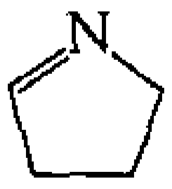
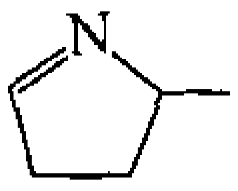
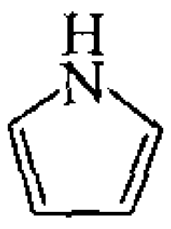
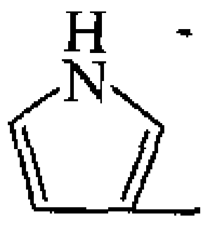
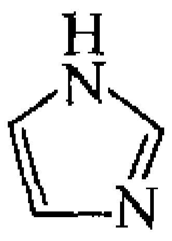
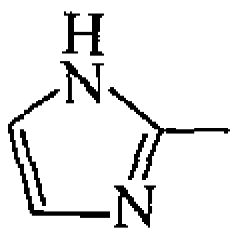
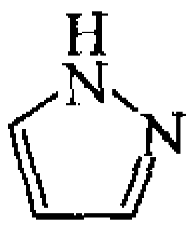
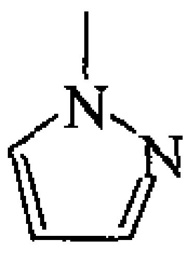
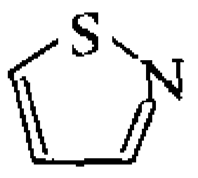
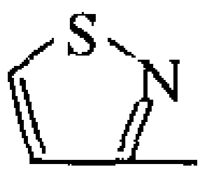
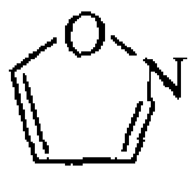
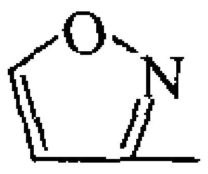
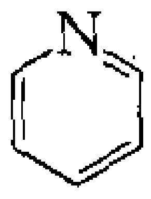
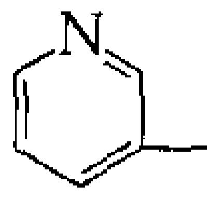
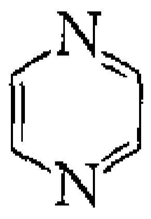
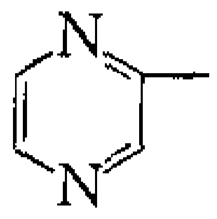
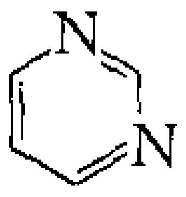
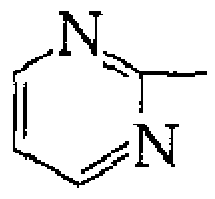
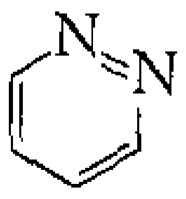
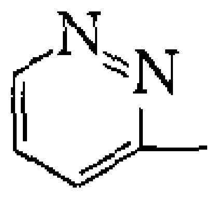
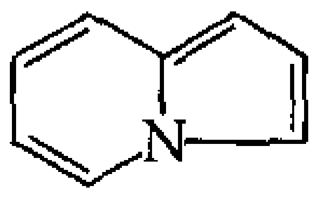
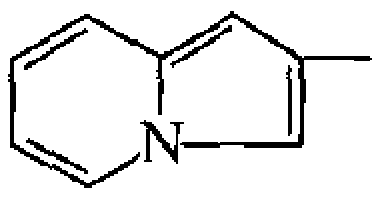
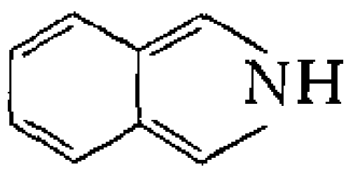
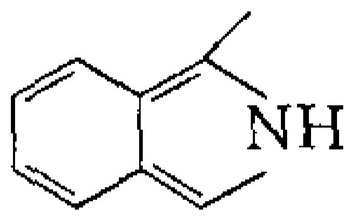
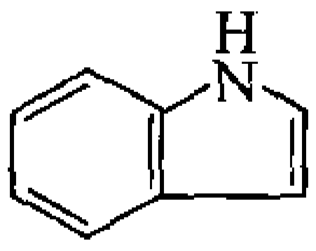
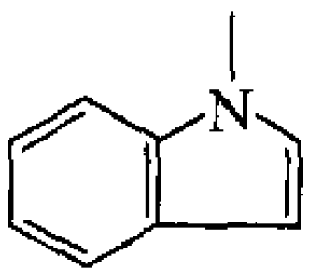
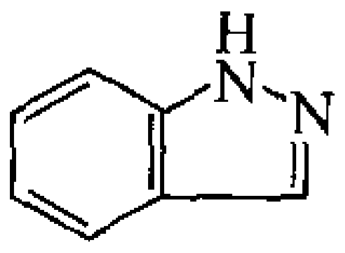
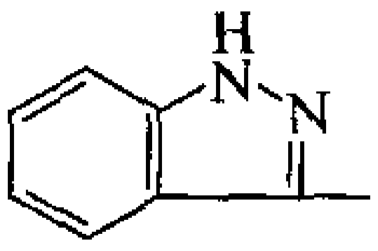
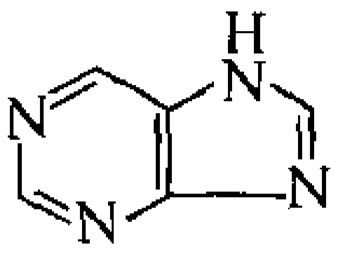
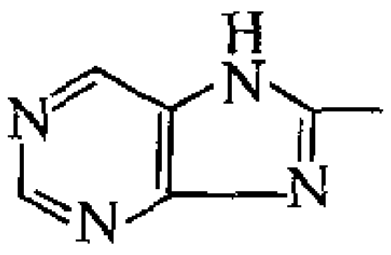
2*H*,6*H*-1,5,2-dithiazine
(not: 1,3,4-dithiazine)
(not: 1,3,6-dithiazine)
(not: 1,5,4-dithiazine)

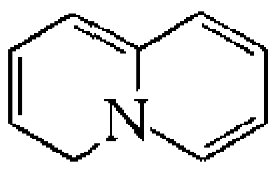
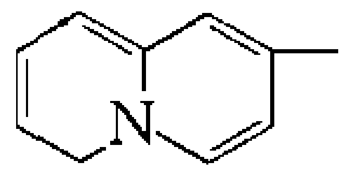
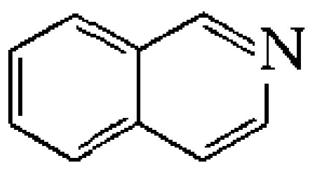
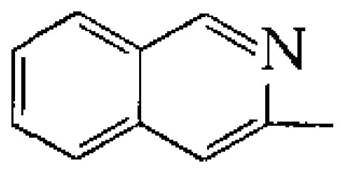
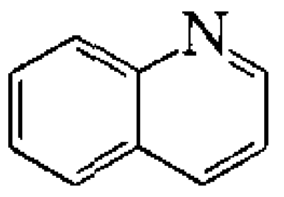
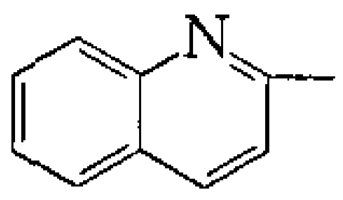
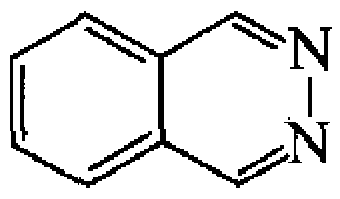
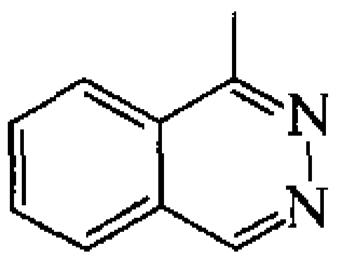
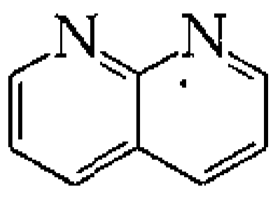
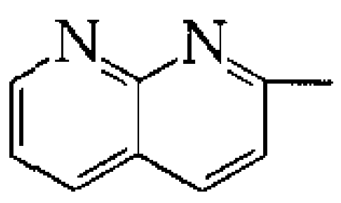
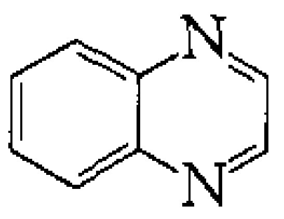
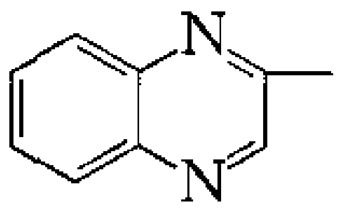
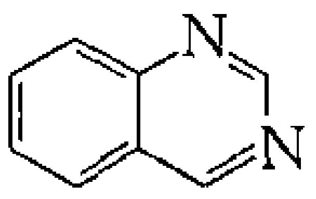
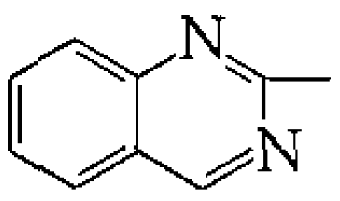
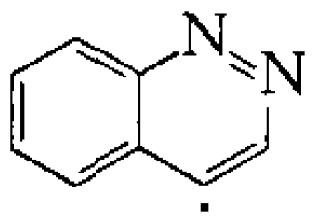
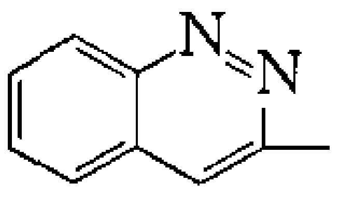
The numbering has to begin with a sulfur atom. The choice of this atom is determined by the set of locants which can be attributed to the remaining hetero atoms of any kind.

As the set 1,2,5 is lower than 1,3,4 or 1,5,4 in the usual sense, the name is 1,5,2-dithiazine.

13.2 Trivial and Semi-Trivial Names

The following trivial and semi-trivial names constitute a partial list of such names which are retained for the compound and as a basis of fusion names.

Compound	Parent Compound Name	Compound	Radical Name
	thiophene		thienyl (2-shown)
	furan		furyl (3-shown)
	pyran (2*H*-shown)		pyranyl(2*H*-pyran-3-shown)
	isobenzofuran		isobenzofuranyl (1-shown)
	chromene(2*H*-shown)		chromenyl(2*H*-cheromen-3-yl shown)
	2*H*-pyrrole		2*H*-phrroly(2*H*-pyrrol-3-yl shown)
	pyrrole		pyrrolyl (3-shown)
	imidazole		imidazolyl (2-shown)
	pyrazole		pyrazolyl (1-shown)
	isothiazole		isothiazolyl (3-shown)
	isoxazole		isoxazolyl (3-shown)
	pyridine		pyridinyl (3-shown)
	pyrazine		pyrazinyl
	pyrimidine		pyrimidinyl (2-shown)
	pyridazine		pyridazinyl (3-shown)
	indolizine		indolizinyl (2-shown)
	2*H*-indole		2*H*-indolyl (2- shown)
	indole		indolyl (1-shown)
	1*H*-indazole		indazolyl (1*H*-indazoe-3-yl shown)
	purine		purinyl (3-shown)

Compound	Parent Compound Name	Compound	Radical Name
	4*H*-quinolizine		4*H*-quinolizinyl(4*H*-quinolizin-2-ylshown)
	isoquinoline		isoquinolyl (3-shown)
	quinoline		quinolyl (2-shown)
	phthalazine		phthalazinyl (1-shown)
	naphthyridine(1,8-shown)		naphthyridinyl(1,8-naphthyridin-2-yl shown)
	quinoxaline		quinoxalinyl (2-shown)
	quinazoline		quinazolinyl (2-shown)
	cinnoline		cinnolinyl (3-shown)

Vocabulary

heterocyclic [ˌhetərəuˈsaiklik] *a.* 杂环的
extension [iksˈtenʃən] *n.* 伸展；扩大
stem [stem] *n.* 词干
phosphorin [ˈfɔsfrin] *n.* 磷杂己因
arsenin [ˈaːzənin] *n.* 砷杂己因
phosphorinane [ˈfɔsfɔrinein] *n.* 磷杂己环
arsenane [aːsənein] *n.* 砷杂己环
borin [ˈbɔrin] *n.* 硼杂己因
borinane [ˈbrinein] *n.* 硼杂己环
provision [prəˈviʒən] *n.* 规定；供应
syllable [ˈsiləbl] *n.* 音节
oxazole [ˈɔksəzəul] *n.* 噁唑
oxirane [ˈɔksirein] *n.* 环氧乙烷；氧杂丙环
aziridine [ˈæziridiːn] *n.* 氮丙啶；氮杂环丙烷
azepine [ˈæzəpiːn] *n.* 吖庚因
azarsetine [æzˈaːzətiːn] *n.* 氮杂砷杂丁亭
silolene [ˈsiləuliːn] *n.* 硅杂咻；硅杂五元环烯
triazine [traiˈæzəul] *n.* 三（吖）嗪；三氮己因
oxathiolane [ɔksəˈθaiəlein] *n.* 噁噻烷
triazole [traiˈæzəul] *n.* 三唑
azocine [ˈæzəusiːn] *n.* 吖辛因
thiadiazine [θaiədaiˈæziːn] *n.* 噻二吖嗪
dithiazine [ˌdaiθaiˈæziːn] *n.* 二噻吖嗪
fusion [ˈfjuːʒən] *n.* 熔化；熔合；合成
parent [ˈpæərənt] *n.* 母体
parent compound 母体化合物
thiophene [ˈθaiəfiːn] *n.* 噻吩
thienyl [ˈθaiəni] *n.* 噻吩基
furan [ˈfjuərən] *n.* 呋喃
furyl [ˈfjuəril] *n.* 呋喃基
pyran [ˈpairæn] *n.* 吡喃
pyranyl [ˈpairænil] *n.* 吡喃基
isobenzofuran [aiθəˌbenzəu ˈfjuərən] *n.* 异苯并呋喃
isobenzofuranyl [aiθəˌbenzəuˈfjuərənil] *n.* 异苯并呋喃基
chromene [ˈkrəumiːn] *n.* 苯并吡喃
chromenyl [ˈkrəumini] *n.* 苯并吡喃基
pyrrole [piˈrəul] *n.* 吡咯

pyrrolyl [pi'rəulil] *n.* 吡咯基

imidazole [ˌimi'dæzəul] *n.* 咪唑

imidazolyl [ˌimi'dæzəul] *n.* 咪唑基

pyrazole ['pairəzəul] *n.* 吡唑

pyrazolyl ['pairəzəulil] *n.* 吡唑基

isothiazole [aisə'θaiəzəul] *n.* 异噻唑

isothiazolyl [aisə'θaiəzəulil] *n.* 异噻唑基

pyridine ['piridine] *n.* 吡啶

pyridinyl ['piridinil] *n.* 吡啶基

pyrazine ['pirəziːn] *n.* 吡嗪

pyrazinyl ['pirəzinil] *n.* 吡嗪基

pyrimidine [pai'rimidiːn] *n.* 嘧啶

pyrimidinyl [pai'rimidini] *n.* 嘧啶基

pyridazine [pairi'dæziːn] *n.* 哒嗪

pyridazinyl [pairi'dæzinil] *n.* 哒嗪基

indolizine [in'dəliziːn] *n.* 中氮茚

indolizinyl [in'dəlizinil] *n.* 中氮茚基；4-*n*-吲哚基

isoindole [aisə'indəul] *n.* 异吲哚

isoindolyl [aisə'indəlil] *n.* 异吲哚基

indole ['indəu(ɔ)l] *n.* 吲哚；氮杂茚

indolyl ['indəlil] *n.* 吲哚基

indazole ['indəzəul] *n.* 吲唑

indazolyl ['indəzəlil] *n.* 吲唑基

purine ['pjuəriːn] *n.* 嘌呤

purinyl ['pjuərinil] *n.* 嘌呤基

quinolizine [kwi'nəliziːn] *n.* 喹嗪

quinolizinyl [kwi'nəlizinil] *n.* 喹嗪基

isoquinoline [aisə'kwinəliːn] *n.* 异喹啉

isoquinoly [aisə'kwinəlil] *n.* 异喹啉基

quinoline ['kwinəliːn] *n.* 喹啉

quinolyl ['kwinəlil] *n.* 喹啉基

phthalazine ['fθləziːn] *n.* 2,3-二氮杂萘

phthalazinyl ['fθæləzini] *n.* 2, 3-二氮杂萘

naphthyridine [ˌnæfθə'ridiːn] *n.* 1,5-二氮杂萘

naphthyridinyl [ˌnæfθə'ridinil] *n.* 1,5-二氮杂萘基

quinoxaline [kwi'nəksəlin] *n.* 1, 4-二氮杂萘

quinazoline [kwi'næzəliːn] *n.* 1,4-二氮杂萘基

quinoxalinyl [kwi'nəksəlinil] *n.* 1,3-二氮杂萘基

quinazoilinyl [kwnə'zəulinil] *n.* 1,3-二氮杂萘基

cinnoline ['sinəliːn] *n.* 1,2-二氮杂萘

cinnolinyl ['sinəlinil] *n.* 1, 2-二氮杂萘基

前缀

oxa- [əksə-] 氧杂，噁

thia- [θaiə-] 硫杂，噻

selina- ['selinə-] 硒杂

tellrua- ['teljuərə-] 碲杂

aza- ['æzə-] 氮杂，吖

phospha- ['fɔsfə-] 磷杂

arsa- ['aːsə-] 砷杂，吡

stiba- ['stibə-] 锑杂

bisma- [bizmə-] 铋杂

sila- ['silə-] 硅杂

germa- ['kəmə-] 锗杂

stana- ['stænə-] 锡杂

plumba- ['plʌmbə-] 铅杂

bora- ['bɔrə-] 硼杂

mercura- ['məkjurə-] 汞杂

后缀

-irine [-iriːn] 丙因（含氮不饱和三元杂环）

-ete [-it] 丁环（四元不饱和杂环）

-ole [-əul] 氮杂戊（含氮五元不饱和杂环）

-ine [-iːn] 己因（含氮六元不饱和杂环）

-epine [-epiːn] 庚因（含氮七元不饱和杂环）

-ocine [-əusiːn] 辛因（含氮八元不饱和杂环）

-ecine [-əuniːn] 癸因（含氮十元不饱和杂环）

-onine [-əuniːn] 壬因（含氮九元不饱和杂环）

-iridine [-iridiːn] 丙啶（含氮三元饱和杂环）

-etidine [-etədiːn] 丁啶（含氮四元饱和杂环）

-olidine [-əulədiːn] 戊啶（含氮五元饱和杂环）

14 Organometallic Compounds

There is a wide range of compounds which contain carbon to metal bonds. In this lesson, only those in which the carbon-metal bond is a simple single covalent bond are discussed, and the word metal is taken to include all elements less electronegative than carbon, such as boron and silicon as well as lithium, copper, thallium, lead, etc.

14.1 Methods of Making Compounds with Carbon-Metal Bonds

There are three major methods of forming carbon-metal bonds: (1) from the metal and an alkyl halide, (2) by substitution of one metal for another or for a proton, and (3) by addition of a compound of the metal to an alkene.

(1) Alkyl metals, such as, methyllithium and ethylmagnesium bromide can be made by reduction of the alkyl halide by the metal, as we saw in this lesson.

$$CH_3I + 2Li \longrightarrow CH_3Li + LiI$$

(2) Treatment of these alkylmetals with different metal exchange. For example, methyllithium can react with Cu (Ⅰ) salts to give methylcopper:

$$CH_3Li + Cu^+ \longrightarrow CH_3Cu + Li^+$$

and Grignard reagents can react with solution halides to form new C—Si bonds:

$$CH_3MgBr + SiCl_4 \longrightarrow CH_3SiCl_3 + MgBrCl$$

It may also be possible to exchange a proton for a metal ion, but since most C—H bonds do not dissociate readily, at is necessary to add a base in order to remove the proton.

$$HC{\equiv}CH + CH_3MgBr \longrightarrow HC{\equiv}CMgBr + CH_4$$

ethyne (acetylene) ethynylamgneium bromide

In the latter example the methyl Grignard reagent provides the base and the new metal atom.

(3) The third important method of making carbon-metal bonds is by addition to alkenes of some simple compounds containing the metal:

$$H_2C{=}CH_2 + BH_3 \longrightarrow [CH_3CH_2BH_2] \xrightarrow{2H_2C=CH_2} (CH_3CH_2)_3B$$

borane triethylborane

The hydride of boron is easily made. It exists as the dimer diborane (B_2H_6), but its reaction can be drawn as if it were simply BH_3. It reacts with alkenes, such as, ethene by adding the double bond. The process is called hydroboration of the alkene. Addition reactions to alkenes are common and are discussed in the later. Although the mechanisms of the reactions discussed there are not the same as the mechanism of the borane addition. The first product still has two BH bonds and so can react with two more ethene molecules to give eventually triethylborane.

14. 2 Properties of Organometallic Compounds

By variations of these routes. It is possible to prepare alkylmetals from almost any metal. The properties of the alkylmetals vary considerably. such as. tetramethyl silicon $(CH_3)_4Si$, are stable. Some, such as trimethylaluminium, $(CH_3)_3Al$ are very easily oxidized or even spontaneously flammable in air. Some are useful commercially, such as tetraethyl lead. , Which is a valuable but toxic additive put into petrol to modify the burning behavior of the hydrocarbons.

In synthetic organic chemistry, the heterolytic reactions of the alkylmetals are useful. In all of these compounds a carbons atom is attached to an atom which is more electropositive than it is. The bonds will all be polarized in the sense and heterolysis of the bond will tend to give rise to a metal cation and a carbanion, which may be stable in solution, in a suitable solvent or may be simultaneously captured by a reagent electrophile:

$$CH_3Li \longrightarrow CH_3^- + Li^+$$

Even if the carbanion can exist as such for some time, It will be able to react with electrophiles. Reactions with electrophiles form the major part of the chemistry of alkylmetals.

The electrophile could be a metal ion:

$$Cu^+ + CH_3Li \longrightarrow CuCH_3 + Li^+$$

This is the process discussed above as a method of making alkylcopper.

14. 3 Grignard Reagents

Orgnomagnesium halides were discovered by the French chemist Victor Grignard in 1900. Grignard received the Nobel Prize for his discovery in 1912, and organomagnesium halides are now called Grignard reagents in his honor. Grignard reagents have great use in organic synthesis.

Grignard reagents are usually prepared by the reaction of an organic halide and magnesium metal in an ether solvent.

$$RX + Mg \xrightarrow{Et_2O} RMgX$$

$$ArX + Mg \xrightarrow{Et_2O} ArMgX$$

Grignard reagents

The order of reactivity of halides with magnesium is also RI>RBr>RCl. Very few organomagnesium fluorides have been prepared. Aryl Grignard reagents are more easily prepared from aryl bromides and aryl iodides than from aryl chlorides which react very sluggishly.

Grignard reagents are seldom isolated but are used for further reactions in ether solution. The ether solutions can be analyzed for the content of the Grignard reagent, however, and the yields of Grignard reagents are almost always very high (85%～95%).

$$CH_3I + Mg \xrightarrow[35℃]{Et_2O} CH_3MgI \quad \text{methylmagnesium iodide (95\%)}$$

$$C_6H_5Br + Mg \xrightarrow[35℃]{Et_2O} C_6H_5MgBr \quad \text{phenylmagnesium bromide (95\%)}$$

Vocabulary

eletronegative [iˈlektrəuˈnegətiv] *a.* 负电性的；阴电性的

thallium [ˈθæliəm] *n.* 铊

thallium hydroxide 氢氧化铊

borane [ˈbəurein] *n.* 甲硼烷；甲硼烷衍生物

hydride [ˈhaidraid] *n.* 氢化物

electropositive [iˌlektrəˈpɔzitiv] *a.* 正电性；阴电性

carbanion [ˈkaːbənaiən] *n.* 碳酸根离子；负碳离子

sluggish [slʌgis] *a.* 偷懒的；不活泼的

Exercises

Translate the following into English.

a. 有机金属化合物
b. 碳金属键
c. 亲电性
d. 亲核性
e. 卤代烷
f. 甲基锂
g. 甲基镁
h. 溴化苯基镁
i. 甲基酮
j. 环戊二烯
k. 三甲基硼烷
l. 烯烃的硼氢化
m. 反应机理
n. 三乙基铅
o. 四甲基铅
p. 碘代烷
q. 格利雅试剂

15 Extractive and Azeotropic Distillation

Extractive and azeotropic distillation have the common feature that a substance not normally present in the mixture to be separated is deliberately introduced into the system in order to increase the difference in volatility of the most hard to separate components. Extractive distillation can be defined as distillation in the presence of a substance which is relatively non-volatile compared to the components to be separated, and which, therefore, is charged continuously near the top of the fractionating tower, so that an appreciable concentration is maintained on all plates in the tower below its entry. Azeotropic distillation can be defined as distillation in which the added substance forms an azeotrope with one or more of the components in the feed, and by virtue of this are present on most of the plates in the tower above its entry at an appreciable level of concentration.

These separation methods find their principal applications in the separation of mixtures whose components boil too close together for the economical use of simple fractionating equipment. These separation methods are particularly applicable when the components to be separated differ in chemical type. The theoretical principles involved are well documented, and will not be further considered here. The processes differ in the means used to maintain be desired solvent concentration on the plates of the tower. In extractive distillation the high concentration of solvent is maintained by virtue of its non-volatility, and by the fact that it is charged at a high point in the tower. The solvent is, necessarily, removed from the base of the principal tower. In azeotropic distillation, most of the solvent is taken off from overhead, with relatively small amounts (ideally, none) drawn off with the bottoms.

Extractive distillation is generally more flexible than azeotropic distillation, a greater variety of solvents and a wider range of operation conditions are available; and the concentration of solvent may be controlled by heat and material balances rather than by the accident of azeotrope composition. Furthermore, since vaporization of the solvent is not required beat loads are usually considerably less. It has been mainly used for the separation of toluene, not benzene. But it is mentioned here for the sake of completeness.

The use of azeotroptc distillation as a means of separation of BTX components from other non-aromatic hydrocarbons has been known and employed for some thirty years. Acetone is used as an entrainer to purify benzene from similar-boiling non-aromatic hydrocarbons. Toluene can be separated by the use of either methanol, or of methyl ethyl ketone. Ethyl benzene may be separated from styrene either by isobutanol, of by 1-nitro-propane.

In a 1966 review paper, further information was made available. Fifty-eight possible entraining agents for separating ethyl benzene (bp. 136.2℃) and para-xylene (bp. 138.4℃) have been examined. It would appear that 2-methyl butanol is the most suceessful agent, requiring a column with only 48 percent of the number of theoretical plates required if no entrainer were used.

The separation of para-and meta-xylenes (bp. 138.2℃ and 139.2℃ respectively) is much more difficult. Of thirty five entrainers examined the best appears to be 2-metbylbutanol, but the change of relative volatility is only from 1.020 to 1.029, and hence it can be safely concluded that azeotropic distillation for the separation of the para-and meta-xylenes is not an economic proposition.

Last, and easiest of the C_8 aromatics is the separation of meta-from ortho-xylene (bp. 139.2℃ and 144.5℃ respectively). Twenty-eight entrainers were examined, the best being formic acid, required a column containing only 70 percent of the theoretical plates required of no entrainer is used.

Two commercial processes have been developed for the separation of toluene using azeotropic distillation. One using an aqueous solution of methyl ethyl ketone and water and the other using methanol. Both processes operate on a narrow boiling range concentrate. The equilibrium relationships are well established. One commercial plant has been built using the methanol azeotrope which was developed by Socony-Vacuum oil Co. The azeotropic system consists of two towers each containing 36 trays operating at 30. p. s. i. g. The toluene concentrate is mixed with 75 vol per cent of anhydrous methanol for a feed containing 25 vol per cent toluene, and charged to the first tower. Cold reflux of 0.6 to 0.7 vols/vol of feed is employed. Practically complete recovery of toluene is obtained in the form of a 70 vol per cent concentrate from the bottom methanol. Cold reflux of the order 4.0 to 4.5 vols/vol of feed is employed, and toluene recovery from this tower averages about 95 per cent, while overall yields of about 80 per cent of the toluene present in the initial feed are obtained. Losses are distributed mainly in the azeotrope overhead and in the acid treating and re-running stages.

The MEK process, developed by Union Oil Company, has had one commercial plant operating, and handles a wide variety of straight-run and cracked stocks. A preconcentrate feedstock with a toluene content in the range 35～85 vol per cent is charged, together with the solvent (90 vol per cent MEK plus 10 vol per cent H_2O), to the 22nd tray of a 50-tray tower. The volumetric ratio of solvent + water/hydrocarbon charge varies between 2.0 to 3.0 to 1 depending upon the boiling range and type of non aromatics present. Cold reflux in the ratio of 0 to 1 reflux / feed is employed. The azeotropic distillate is composed 0 about 75 vol per cent solvent. A small amount of water-rich phase separates from it in the reflux drain (80 vol per cent water, 20 vol per cent MEK) and is recycled back to the feed, 95～97 per cent of the toluene present in the fed is recovered as bottoms from the azeotropic tower as 99 per-cent purity toluene on a solvent-free bases. The removal of MEK from the azeotropic distillate is accomplished by four stages of water-extraction thus reducing the ketone content to approximately 1 vol per cent. The water material is then fractionated in an auxiliary tower to remove the remaining ketone. Recovery of MEK from the water extracts is done by distillation of the MEK-water azeotrope from the excess water in a tower with only a few trays and a low reflux ratio. The azeotrope thus obtained is then fed directly to the primary azeotrope tower together with the toluene pre-concentrate feed. The crude toluene so produced, after removal of MEK is treated with sulphuric acid, and followed by redistillation to produce nitration grade toluene. Overall recover of toluene is around 90 per cent.

Vocabulary

extractive [iks'træktiv] *a.* 抽提的；萃取的
extractive distillation 萃取蒸馏
azeotropic [eziːə'trɔpik] *a.* 共沸的
azeotropic distillation 共沸蒸馏
feed [fiːd] *v.* & *n.* 进料；供料；原料
hard-to-separate 难分离的
equipment [i'kwipmənt] *n.* 设备；装备
document ['dɔkjumənt] *vt.* 证明
overhead ['əuvə'hed] *n.* 塔顶馏出物
flexible ['fleksəbl] *a.* 易操作的；易适应的
material balance 物料平衡
vaporisation = vaporization [ˌveipərai'zeiʃən] *n.* 蒸发

load [ləud] *n.* &*v.* 负荷；负载；装填
p. s. i. g. = pounds per square inch guage [ˈpaunds pəːskwɛə intʃgeidʒ] 磅/平方英寸（表压）
cold reflux 冷回流
overall yield 总产率
recovery [riˈkʌvəri] *n.* 回收；回收率
acid wash 酸洗
charge [tʃaːdʒ] *vt.* 投料；装料；进料
fractionating tower [ˈfrækʃəneitiŋːˈtauə] 精馏塔
bottoms [ˈbɔtəms] *n.* 釜渣；釜（残）液
plate [pleit] *n.* 板；塔板
azeotrope [ˈeiziːətrəup] *n.* 共沸物；共沸蒸馏
bp = boiling point
BTX = benzene-toluene-xylene 苯-甲苯-二甲苯
entrainer [inˈtreinə] *n.* 携带剂；夹带剂
entraining 携带剂
theoretical plate 理论塔板
proposition [ˌprɔpəˈzeiʃən] *n.* 意见；见解；事情
caustic [ˈkɔːstik] *n.* 原料；材料
preconcentrate [ˌpriˈkɔnsentreit] *n.* 预（先）浓缩物
tray tower 盘式塔
drain [drein] *n.* 排水；排放口
auxiliary [ɔːgˈziljəri] *a.* 辅助的；辅的
reflux ratio 回流比

Phrases

by virtue of... 根据；借助于；由于；因为
take off 流出；馏出
draw off... 拿出；排出；移去
a variety of... 多种多样；各种
the ratio of ... to... ……与……之比；……比……
for the sake of ... 为……起见，由于……缘故
feed... into... 把……送入
on... basis 按照；根据
charged with 充有；装满

Exercises

1. Translate the following into English.

a. 有机溶剂提取
b. 共沸蒸馏
c. 精馏塔
d. 物料平衡
e. 苯-甲苯-二甲苯共沸蒸馏
f. 理论塔板
g. 酸洗
h. 碱洗
i. 甲丙醇
j. 盘式塔
k. 回流比
l. 丙醇
m. 非芳香烃
n. 甲苯的回收

2. Translate the following into Chinese.

Extractive distillation is generally more flexible than azeotropic distillation, a greater variety of solvents and a wider range of operation conditions are available; and the concentration of solvent may be controlled by heat and material balances rather than by the accident of azeotrope composition. Furthermore, since vaporization of the solvent is not required beat loads are usually considerably less. It has been mainly used for the separation of toluene, not benzene. But is mentioned here for the sake of completeness.

16 Crystallization

On both large and small scale crystallization is the most important method for the purification of solid organic compounds. A crystalline organic substance is made up of a three-dimensional array of molecules held together primarily by vender wades forces. These intermolecular attractions are fairly weak; most organic solids melt in the range of room temperature to 250℃.

Crystals can be grown from the molten state just as water is frozen into ice, but it is not easy to remove impurities from crystals grade in this way. Thus most purification in the laboratory involves dissolving the material to be purified in the appropriate hot solvent. As the solvent cools, the solution becomes saturated with respect to the substance. Soluble impurities stay in solution because they are not concentrated enough to saturate the solution. The crystals are collected by filtration, the surface of the crystals is washed with cold solvent to remove the adhering impurities, and then the crystals are dried. This process is carried out on an enormous scale in the commercial purification of sugar.

In the organic laboratory, crystallization is usually the most rapid and convenient method for purifying the products of a reaction. Initially you will be told which solvent to use to crystallize a given substance and how much of it to use; Later on you will judge how much solvent is needed, acid finally the choice of both the solvent and its volume will be left to you. It takes both experience and knowledge to pick the correct solvent for a given purification.

The process of crystallization can be broken into seven discrete steps: choosing the solvent, dissolving the solute decolorizing the solution, removing suspended solids, crystallizing the solute. Collecting and washing the crystals and drying the product. The process involves dissolving the impure substance in all appropriate hot solvent, removing some impurities by decolorizing and/or filtering the hot solution, allowing the substance to crystallize as the temperature of the solution falls, removing the crystallization solvent, and drying the resulting purified crystals.

16. 1 Choosing the Solvent

"Like dissolves like", some common solvents are water, methanol, ethanol, ligroin and toluene. When you use a solvent pair, dissolve the solute in the better solvent and add the poorer solvent to be hot solution until saturation occurs. Some common solvent pairs are ethanol-water, diethyl ether-ligroin, and toluene-ligroin.

16. 2 Dissolving the Solute

To the crushed or ground solute in the Erlenmeyer flask or reaction tubes add solvent; heat the mixture to boiling. Add more solvent as necessary to obtain a hot, saturated solution.

16. 3 Decolorizing the Solution

If it is necessary to remove colored impurities, cool the solution to near room temperature and add more solvent to prevent crystallization from occurring. Add decolorizing charcoal in the form of palletized. Norit to the cooled solution, and then heat it to boiling for a few minutes, taking care to swirl the solution to prevent bumping. Remove the norit by filtration, and then concentrate the filtrate.

16. 4 Filtering Suspended Solids

If it is necessary to remove suspended solids, dilute the hot solution slightly to prevent crystallization from occurring during filtration. Filter the hot solution. Add solvent if crystallization begins in the funnel. Concentrate the filtrate to obtain a saturated solution.

16. 5 Crystallizing the Solute

Let the hot saturated solution cool spontaneously to room temperature. Do not disturb the solution. Then cool it in ice. If crystallization does not occur, scratch the inside of the container or add seed crystals.

16. 6 Collecting and Washing the Crystals

Collect the crystals using the pasteur pipet method or by vacuum filtration on a Hirsh funnel or a buchner funnel. If the latter technique is employed, wet the filter paper with solvent, apply vacuum until solvent just disappears, break vacuum, add cold wash solvent, apply vacuum, and repeat until crystals are clean and filtrate cones through clear.

16. 7 Drying the Product

Press the product on the filter to remove solvent. Then remove it from the filter, squeeze it between sheets of filter paper to remove more, and spread at on a watch glass to dry.

Vocabulary

crystalline ['kristəlain] *a.* 水晶的; *n.* 结晶质; 结晶体

crystallization [ˌkristəlai'zeiʃən] *n.* 晶化; 结晶; 结晶体

crystallize ['kristəlaiz] *vt.* 使结晶

array [ə'rei] *vt.* 打扮; 装饰; 排列

purify ['pjuərifai] *vt.* 使纯净; 提纯; 精制; *vi.* 纯净

nucleation [ˌnjuːkliˈeiʃən] *n.* 成核；晶核过程

supersaturation [sjuːpəsætʃəˈreiʃən] *n.* 过饱和

ligroin [ˈligrəuin] *n.* 挥发油；石油醚

charcoal [ˈtʃaːkəul] *n.* 炭；炭笔

activated charcoal 活性炭

purification [pjuərifiˈkeiʃən] *n.* 清洗；净化；提纯

adhere [ədˈhiə] *vi.* 黏附；固着；遵循；坚持

filter [ˈfiltə] *n.* 滤器；滤纸；*vi.* 过滤

filtration [filˈtreiʃən] *n.* 过滤；渗入

discrete [disˈkriːt] *a.* 分离的；不连续的

suspend [səsˈpend] *vt.* 吊起；悬挂

scratch [skrætʃ] *vt.* & *vi.* 抓；刮擦声；刮痕

flask [flaːsk] *n.* 瓶；长颈瓶；烧瓶

pelletize [ˈpelitaiz] *vt.* 使成小球形

filtrate [ˈfiltreit] *vt.* & *vi.* 过滤；*n.* 滤液

bump [bʌmp] *v.* 撞

pipette [piˈpet] *n.* 吸移管；吸量管

squeeze [skwiːz] *vt.* 挤；压；塞

Phrases

on a large scale 大规模地

in the range of ... 在……范围内

on a small scale 小规模的

with respect of [to]... 关于；就……相对于而论

be made up of... 由……组成；由……构成

Exercises

Translate the following into English.

a. 选择溶剂
b. 相似相溶
c. 结晶过程
d. 溶解
e. 分子内吸引
f. 真空过滤
g. 溶剂对
h. 布氏漏斗
i. 干燥产品
j. 表面皿
k. 过滤纸
l. 活性炭

17 Preparation of a Carboxylic Acid by the Grignard Method

17.1 Introduction

Some of the common methods for the preparation of carboxylic acids include the oxidation of alcohols, the carbonation of Grignard reagents, and the hydrolysis of nitriles.

Because a solid carboxylic acid is much easier to isolate and purify than a liquid acid, benzoic acid, mp. 121℃, rather than a liquid aliphatic acid, has been selected for this assignment. It will first be prepared by treatment of phenylmagnsium bromide with solid carbon dioxide (Dry Ice) and subsequent acidification of the reaction mixture by the addition of hydrochloric acid.

The Grignard reagent, phenylmagnsium bromide, is to be prepared at time start of the present period by reaction of bromobenzene with metallic magnesium. The entire sequence of steps employed in this synthesis of benzoic acid is shown in the equations at the beginning of this experiment.

Since most of the common aliphatic carboxylic acids are liquids at room temperature, such acids are purified by distillation. If one were to prepare such an acid by the Grignard method, not only would the purification by distillation have to be carried out, but also it would be necessary to prepare at least one solid derivative of the acid in order to identify the product in a reasonably certain manner. Hence the entire experiment could not conveniently be completed in a regular 3-hour laboratory period.

However in the actual practice of organic chemistry in industrial or institutional laboratories, where there are no arbitrary time limits for completing an experiment, the syntheses of certain aliphatic carboxylic acids can be achieved better by the Grignard process than by other methods. For example, trimethylacetic acid, $(CH_3)_3CCOOH$, is readily prepared from *t*-butyl chloride, $(CH_3)_3CCl$, by the Grignard method, whereas the nitrile route would be of no use; treatment of *t*-butyl chloride with sodium cyanide gives sodium chloride, hydrogen cyanide and isobutylene rather than trimethylacetoniltrile, $(CH_3)_3CCN$.

Anhydrous ether is generally used as the solvent in the preparation of a Grignard reagent. Actually, the ether plays a more important role in the reaction than merely that of solvent. Ether molecules combine with the various components of a Grignard reagent to form complex etherates. For example, one of the components present in phenylmagnesium bromide-ether solution is a complex.

As implied in the previous paragraph, a Grignard reagent is actually an equilibrium mixture of different molecular species. One of the equilibria thought to exist in any Grignard reagent is shown in the following equation, which has been simplified in that the ether molecules coordinate with the magnesium are not shown: .

$$2RMgX \rightleftharpoons R_2Mg + MgX_2$$

Addition of anhydrous dioxide to an ether solution of a Grignard reagent causes RMgX and MgX_2 to precipitate, leaving R_2Mg in solution occasionally, for certain specific reactions, It is preferable to use the filtrate from such a mixture rather than the Grignard mixture itself; i. e. there are certain Grignard reactions in which the use of R_2Mg is preferable to the use of the equilibrium mixture of RMgX, MgX_2, and R_2Mg. However, no such complication exists in today's experiment.

Grignard reagents can be prepared successfully only in a completely anhydrous medium and in an atmosphere that is free of oxygen. The presence of water causes hydrolysis of the reagent and the presence of oxygen causes loss of the reagent by oxidation.

$$RMgX + H_2O \longrightarrow RH + Mg(OH)X$$

$$2RMgX + O_2 \longrightarrow 2ROMgX$$

Therefore, in carrying out a Grignard reaction, one must take care to dry the apparatus and all of the reagents (magnesium metal, ether, and organic halide) and also to provide an inert atmosphere over the reaction mixture. The latter condition is best realized by passing highly purified nitrogen over the surface of the liquid.

However, in today's experiment, the oxygen-free atmosphere will be attained by keeping the ether solution warm during the preparation of the Grignard reagent. Ether is so highly volatile (b. p. 35°C) that a blanket of ether vapors over the warm solution keeps the reagent reasonably well insulated from contact with the air.

17. 2 Experimental

Fit a dry, 200ml, round bottomed flask with a dry water-cooled condenser. A drying tube filled with calcium chloride is attached to the top of the condenser. In the flask place 2. 4g (0. 10 mole) of dry magnesium turnings, a crystal of iodine, 30ml of anhydrous ether, and 10ml (15. 7g, 0. 10mole) of anhydrous bromobenzene. If reaction does not start immediately, warm the flask on the steam bath so that the ether refluxes gently and then remove the bath. This will usually initiate the reaction. The disappearance of the iodine color, the production of a cloudiness the solution and gentle boiling of the ether are all indications that the reaction has started. Once the reaction has begun, it will proceed of its own accord causing the ether to boil gently, 35～40 minutes.

You are now ready for the carbonation of the Grignard reagent by reaction with Dry Ice. Place about 15g of crushed Dry Ice in to 250ml beaker and gradually pour into this mixture the solution of phenylmagnesium bromide. The reaction is vigorous, and the mixture sets to a stiff paste. Continue stirring the mixture until all the excess carbon dioxide has evaporated. Take the beaker to the hood and add 50～60ml of hot water in order to evaporate the small remaining quantity of ether. Acidify the contents of the beaker with dilute hydrochloric acid in order to dissolve the magnesium salts and liberate the benzoic acid. Stir the warm mixture well and set it in a pan of ice so that portion of benzoic acid that is dissolved in the warm water may crystallize. When the solution is cold, collect the benzoic acid on the buchner funnel.

The benzoic acid that you have now obtained is usually contaminated with a little biphenyl that has been formed as a by-product according to the following equation:

$$C_6H_5MgBr + C_6H_5Br \longrightarrow C_6H_5{-}C_6H_5 + MgBr_2$$

In as much as biphenyl is but slightly soluble in hot water, you may purify your sample of benzoic acid by recrystallizing it from that solvent.

Vocabulary

carbonation [ˌkaːbəˈneiʃən] *n.* 碳酸(盐)化；羧基化

Grignard reagent [ˌgriːnjaːdriːˈeidʒənt] 格氏试剂

purify [ˈpjuərifai] *vi.* 纯化；净化
phenylmagnesium bromide [ˈfenilmæˈgniːziəmˈbrəumaid] 溴化苯基镁
dry ice [drai ais] 干冰；固体二氧化碳
acidification [əˌsidifiˈkeiʃən] *n.* 酸化
bromobenzene [ˌbrəuməˈbenziːn] *n.* 溴苯
reasonable [ˈriːznəbl] *a.* 合理的；正当的 -bly，*ad.*
manner [ˈmænə] *n.* 方式；方法
convenient [kənˈviːnjənt] *a.* 方便的；顺利的 -ly，*ad.*
laboratory [ləˈbɔrətəri] *n.* 实验室
institutional [ˌinstiˈtjuːʃənəl] 规定的；学校的
arbitraty [ˈaːbitrəri] *a.* 武断的；随意的
trimethylacetic [traiˈmeθiləˈsiːtik] acid. 三甲基乙酸
t-butyl chloride [ˈtəːʃəriˈbjuːtilˈklɔːraid] 叔丁基氯
whatsoever [ˌwɔtsəuˈevə] *prop.* & *a.* 不管；无论；无论什么样的
hydrogen cyanide [ˈhaidrəudʒənˈsaiənaid] 氰化氢
trimethylacetonitrile [ˈtraiˈmeθilˌæsitəˈnaitril] 三甲基乙腈
etherate [ˈiːθəreit] *n.* 醚化物
dioxane [ˌdaiˈɔksein] *n.* 二噁烷；二氧杂环己烷
filtrate [ˈfiltreit] *v.* 过滤；*n.* 滤液
loss [lɔs] *n.* 损失
blanket [ˈblæŋkit] *n.* 毛毯；掩盖；覆盖层
fit [fit] *vt.* 安装
round bottomed flask [raundˈbɔtəmd flaːsk] 圆底烧瓶
condenser [kənˈdensə] *n.* 冷凝器
mole [məul] *n.* 摩尔；克分子
turning [ˈtəːniŋ] *n.* 旋转
steam bath 蒸汽浴
gentle [ˈdʒentl] *a.* 温和的；轻轻的；-tly. *ad.*
cloudiness [ˈklaudinis] *n.* 阴暗；朦胧
crush [krʌtʃ] *vt.* 压碎；磨细
beaker [ˈbiːkə] *n.* 烧杯
vigorous [ˈvigərəs] *a.* 有力的；活泼的；激烈的
stiff [stif] *a.* 浓黏的；硬的
paste [peist] *n.* 糨糊；膏；*vt.* 粘贴
hood [hud] *n.* 盘
acidify [əˈsidifai] *v.* 酸化
buchenr funnel [ˈbuːknəˈfʌnəl] 瓷器斗；布氏漏斗
biphenyl [ˌbaiˈfenil] *n.* 联苯
recrystallize [riːˈkristəlaiz] *v.* 再结晶；重结晶
pan [pæn] *n.* 盘

Phrases

preferable to... 比……更好；优于
free of (from)... 无……的；除……的
take care to (+ inf.) 一定……；务必……
insulate from... 与……隔离；与……绝缘
of one's (its) own accord 自动地，自然而然地
in as much as ... 因为，由于……缘故

Exercises

Translate the following into English.

a. 联苯的重结晶
b. 圆底烧瓶
c. 蒸汽浴
d. 羧酸的制备
e. 溴化苯基镁
f. 三甲基乙腈

g. 无水乙醚	i. 叔丁基氯
h. 干冰	j. 格氏试剂

18 Chemical Equilibrium and Kinetics

A major objective of chemists is to understand chemical reactions, to know whether under a given set of conditions two substances will react when mixed, to determine whether a given reaction will be exothermic or endothermic, and to predict the extent to which a given reaction will proceed before equilibrium is established an equilibrium state. Produced as a consequence of two opposing reactions occurring simultaneously, is a state in which there is no net change as long as there is no change in conditions. In this lesson it will be shown how one can predict the equilibrium states of chemical systems from thermodynamic data, and conversely how the experimental measurements on equilibrium states provide useful thermodynamic data. Thermodynamics alone cannot explain the rate at which equilibrium is established, nor does it provide details of the mechanism by which equilibrium is established. Such explanations can be developed from considerations of the quantum theory of molecular structure and from statistical mechanics.

To appreciate fully the nature of the chemical equilibrium state, it is necessary first to have some acquaintance with the factors which influence reaction rates. The factors which influence the rates of a chemical reaction are temperature, concentrations of reactants (or partial pressures of gaseous reactants), and presence of a catalyst. In general, for a given reaction, the higher the temperature, the faster the reaction will occur. The concentrations of reactants or partial pressure of gaseous reactants will affect the rate of reactions, an increase in concentration or partial pressure increases the rate of most reactions. Substances which accelerate a chemical reaction but themselves are not used up in the reaction are called catalysts.

18.1 Dynamic Equilibrium

In many cases, direct reactions between two substances appear to cease before all of either starting material is exhausted. Moreover, the products of chemical reactions themselves often react to produce the starting materials. For example, nitrogen and hydrogen combine at 500℃ in the presence of a catalyst to produce ammonia:

$$N_2 + 3H_2 \longrightarrow 2NH_3$$

At the same temperature and in the presence of the same catalyst, pure ammonia decomposes into nitrogen and hydrogen:

$$2NH_3 \longrightarrow 3H_2 + N_2$$

For convenience, there two opposite reactions are denoted in one equation by use of a double arrow:

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

The reaction proceeding toward the right is called the forward reaction; the other is called the reverse reaction.

If either ammonia or a mixture of nitrogen and hydrogen is subjected to the above condition, a mixture of all three gases will result. The rate of reaction between the materials which were introduced into the reaction vessel will decrease after the reaction starts, because their concentrations are decreasing. Conversely, after the start of the reaction the material being produced will react faster, since there will be more of it. Thus the faster forward reaction becomes slower, and the slower reverse reaction speeds up. Ultimately the time comes when the rates of the forward and reverse reactions become equal, and there will be no further net change. This situation is called equilibrium. Equilibrium is a dynamic state because both reactions are still proceeding; but since the two opposing reactions are proceeding at equal rates, no net change is observed.

All chemical reactions ultimately proceed toward equilibrium. In a practical sense, however, some reactions go so far in one direction that the reverse reaction can not be detected, and they are said to go to completion. The principles of chemical equilibrium apply even to these, and it will be seen that for many of them, the extent of reaction can be expressed quantitatively.

18.2 Equilibrium Constants

Equilibrium is a state of dynamic balance between two opposing processes. For a general reaction at a given temperature.

$$A + B \rightleftharpoons C + D$$

at the point of equilibrium, the following ratio must be a constant:

$$K = \frac{[C][D]}{[A][B]}$$

The constant, K, is called the equilibrium constant of the reaction. It has a specific value at a given temperature. If the concentration of any of the components in the system at equilibrium is changed, the concentrations of the other components will change in such a manner that the defined ratio remains equal to K as long as the temperature does not change. The equilibrium constant expression quantitatively defines the equilibrium state.

More generally, for the reversible reaction

$$aA + bB \rightleftharpoons cC + dD$$

the equilibrium constant expression is written as follows :

$$K = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

By convention, the concentration terms of the reaction products are always placed in the numerator of the equilibrium constant expression. It should be noted that the exponents of the concentration terms in the equilibrium constant expression are the coefficients of the respective species in the balanced chemical equation.

18.3 Chemical Kinetics

When a system is in the equilibrium state, the rate of the forward reaction is identical to the rate of the reverse reaction. It is important to know just how fast a reactant is being used up in a process, or the speed with which a product is being formed. It is also important to have detailed information about rates of reactants in order to test theories and mechanisms for various kinds of chemical processes.

Experiments show that a number of reaction variables affect reaction rates:

Temperature. The rates of chemical reactions are temperature-dependent. Therefore, it is common practice when studying the rate in the laboratory to carry out reactions at constant temperature (isothermally), thus eliminating one variable.

Pressure and volume. Volume and pressure are important in a kinetic consideration of gas phase reactions. Usually, volume is fixed by running the reaction in a container of fixed dimensions. For solid and liquid state reactions, pressure is usually atmospheric, and the volume of the reacting system is relatively unimportant because there is little change in volume.

Concentration. As any particular temperature, the rates of most chemical reactions are functions of the concentrations of one or more of the components of the system. In practice, it is usually the concentration of the reactants that are used in determining the over-all rates of reaction.

Catalyst any substance that affects the rate of a chemical reaction cannot be identified as a product or reactant is said to be a catalyst. A catalyst may accelerate or decelerate the rate, but we usually refer to decelerating catalysts as inhibitors.

The order of a chemical reaction is given by the number of atomic or molecular species whose concentrations directly determine the reaction rate.

The rate of hydrolysis of ethyl acetate in water in directly proportional to the ethyl acetate concentration. Therefore, the reaction is said to be first order.

Vocabulary

kinetics [kai'netiks] *n.* 动力学
equilibrium state 平衡（状态）
opposing [ə'pəuziŋ] *n.* 相反；相对；反抗
datum ['deitəm]（复 data ['deitə]）*n.* 资料；论据
molecular structure 分子结构
quantum ['kwɔntəm] 量子
quantum theory 量子论
statistical mechanics [stə'tistikəl mi'kæniks] 统计力学
acquaintance [ə'kweintəns] *n.* 熟悉；认识
partial pressure ['pa:ʃəl'preʃə] 分压
affect [ə'fekt] *vt.* 影响
accelerate [æk'seləreit] *vt.* 加速

dynamic [daiˈnæmik] *a.* 动力（学）的
cease [ˈsiːs] *v.* 停止；终止
forward reaction 正反应
reverse reaction 逆反应
subject [sʌbˈdʒekt] *vt.* 遭受；蒙受
ultimately [ˈʌltimətli] *ad.* 最后；最终
specific value 比值
term [təːm] *n.* （比例或方程的）项
numerator [ˈnjuːmareitə] *n.* （分数中的）分子
exponent [eksˈpəunənt] *n.* 指数
coefficient [ˌkəuiˈfiʃənt] *n.* 系数；率
test [test] *vt.* 检验；验证；试验
isothermal [ˈaisəuˈθəməl] *a.* 等温线的
decelerate [diːˈseləreit] *v.* 减速；减慢
order [ˈɔːdə] *n.* 级数
rate law 速度定律

Phrases

as a consequence of... 由于……（结果）
as long as... 只要
not...nor 不……，也不
have acquaintance with... 熟悉；认识
use up 消耗掉；用完
in a practical sense 实验上
in such a manner that... 以上这样的方式，以致……
by convention 按照惯例
it is common practice（＋inf.） 通常的做法是……
over...all 总的；全部的
an educated guess 有根据的推测
refer to...as... 把……称作

Exercises

Translate the following into English.

a. 化学平衡和动力学
b. 平衡状态
c. 量子化学
d. 统计热力学
e. 正反应和逆反应
f. 速度定律
g. 化学反应级数
h. 分子结构的量子理论
i. 平衡常数
j. 作用物的浓度
k. 一级反应
l. 二级反应

19 Green Chemistry（Ⅰ）

It is important that chemistry students at all levels, whether they intend to pursue careers in science or not, be introduced to green chemistry and recognize the impact it can have on human health and the environment. The fresh approach and intriguing concepts presented by green chemistry are likely to appeal to students and enhance their interest in chemistry. Also, among our current chemistry students are future chemists for whom early exposure to green chemistry can provide a frame of reference that will enable them to contribute to the greening of chemical processes in the future.

Chemical manufacturing is the source of many useful and enjoyable products on which we have come to depend. These include

- antibiotics and other medicines;
- plastics;
- gasoline and other fuels;
- agricultural chemicals such as fertilizers and pesticides; and
- a wide array of synthetic fabrics, including nylon, rayon, and polyester.

Although these varied products are important to us, some of the chemicals and processes used to make them have resulted in harm to the environment and to human health. In recent years, as the hazards of some widely used chemicals have come to light, scientists and engineers have begun to incorporate this new knowledge into the processes that we use to make things. Green chemistry is the name given to their efforts to change or reinvent these processes in order to ensure a safer, cleaner environment in the 21st century.

The Twelve Principles of Green Chemistry:

(1) Prevention

It is better to prevent waste than to treat or clean up waste after it has been created.

(2) Atom Economy

Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.

(3) Less Hazardous Chemical Syntheses

Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

(4) Designing Safer Chemicals

Chemical products should be designed to affect their desired function while minimizing their toxicity.

(5) Safer Solvents and Auxiliaries

The use of auxiliary substances (e. g. , solvents, separation agents, etc.) should be made unnecessary wherever possible and innocuous when used.

(6) Design for Energy Efficiency

Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized. If possible, synthetic methods should be conducted at ambient temperature and pressure.

(7) Use of Renewable Feedstocks

A raw material or feedstock should be renewable rather than depleting whenever technically and economically practicable.

(8) Reduce Derivatives

Unnecessary derivatization (use of blocking groups, protection / deprotection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste.

(9) Catalysis

Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.

(10) Design for Degradation

Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.

(11) Real-time Analysis for Pollution Prevention

Analytical methodologies need to be further developed to allow for real-time, in-process monitoring and control prior to the formation of hazardous substances.

(12) Inherently Safer Chemistry for Accident Prevention

Substances and the form of a substance used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions, and fires.

Green chemistry aims to eliminate pollution by preventing it from happening in the first place. In designing a reaction according to green chemistry principles, chemists pay close attention to whatever is known about the possible hazard a chemical presents to health or the environment before using that chemical in a reaction or creating it as a product. In other words, they treat the hazard posed by a substance as a property that must be considered along with other chemical and physical properties and select substances that minimize harm. Thus, green chemistry processes are benign by design. We can characterize some of the key ideas that guide chemists in designing chemical reactions the green way as follows:

- Get off to a safe start.
- Use renewable resources.
- Find safer solvents.
- Economize on atoms.
- Lower energy input.
- Return safe substances to the environment.

- Get off to a safe start

Identify reactions that use nonhazardous starting materials to make a desired product. This minimizes danger to workers in manufacturing plants when they handle the chemicals and also prevents accidental release of harmful chemicals to the environment if leaks or explosions occur. A new way of making an important industrial chemical, adipic acid, illustrates this principle. Almost 2 billion kg of adipic acid are needed each year to make nylon, polyurethane, lubricants, and plasticizers. The standard way of making adipic acid uses benzene, which can cause cancer, as the starting material. In a newly developed process that is aided by biocatalysts (genetically altered bacteria), the simple sugar glucose can be substituted for benzene. Starting with a safe substance like glucose to make adipic acid means that the use of large quantities of a harmful chemical can be avoided if new processes such as this one become widely used.

- Use renewable resources

Place greater emphasis on renewable starting materials, such as substances derived from growing plants, rather than irreplaceable materials like the petroleum and natural gas supplies that are becoming depleted. The glucose mentioned in the example above as a starting material can be derived from cornstarch or the cellulose found in plant materials. Even corncobs, stalks, and fallen leaves (often viewed as waste materials) can yield glucose. In another example, cornstarch is used to produce the small, puffed packaging pellets that prevent damage to materials shipped in containers. These pellets can replace plastic packing materials made from petroleum-based chemicals that will eventually run out.

- Find safer solvents

Eliminate the use of toxic solvents to dissolve the reacting materials. Many of the solvents currently used in large quantities in industry are known to be harmful to health or to create other kinds of dangers like explosions or fire hazards. Examples of widely used solvents that carry health risks include carbon tetrachloride, chloroform, and perchloroethylene. Substitution of safer solvents such as water or liquid carbon dioxide is sometimes possible. For example, new dry-cleaning processes for clothing have recently been developed that dissolve grease and dirt using liquid carbon dioxide rather than the toxic chemical perchloroethylene.

- Economize on atoms

Design reactions in which most or all of the atoms you start with end up in the desired product rather than in waste byproducts. Barry Trost, a chemist at Stanford University, developed this concept, which he termed *atom economy*. One example of the principle in action is an improved process designed in 1991 for making the pain reliever ibuprofen, the active ingredient in the brand name drugs Motrin, Advil, Nuprin, and Medipren. In the former six-step process developed in the 1960s, only 40% of the reactant atoms ended up in the desired product (ibuprofen), and 60% ended up in unwanted byproducts or waste that had to be disposed of. The new process requires only three steps and is designed in such a way that 77% of the reactant atoms end up in the ibuprofen. This green process eliminates millions of pounds of waste chemical byproducts every year, and it reduces by millions of pounds the amount of reactants needed to make ibuprofen.

- Lower energy input

Use methods that minimize the energy required for a reaction to take place. For example, some reactions can be speeded up by using catalysts or microwave radiation so that much less energy is needed overall in the process. Catalysts have the further advantage of being reusable, since they help to bring about a desired reaction without being consumed in the process. Energy can be further conserved by modifying reaction conditions in such a way that the greatest energy efficiency is achieved and minimal energy is wasted.

- Return safe substances to the environment

Produce materials that are benign or rapidly biodegradable (easily digested by microorganisms in the environment to simpler, safer substances) at the end of their use, so that they don't build up to harmful levels in the environment or create mountains of solid waste. Packing pellets made of starch dissolve in water when disposed of outdoors, and microorganisms can easily digest the starch. The more widely used polystyrene plastic packing materials, in contrast, are not easily biodegradable. Attention to these principles not only benefits the environment but also can save companies money in the long run by lowering the cost of pollution control and by using less energy.

Vocabulary

antibiotics *n.* 抗生素；抗生学
fertilizer [fəːtilaizə] *n.* 肥料；[动] 受精媒介物
hazardous ['hæzədəs] *a.* 危险的；冒险的；碰运气的
innocuous [i'nɔkjuəs] *a.* 无害的；无毒的；无伤大雅的；不得罪人的
renewable [ri'nju(ː)bəl] *a.* 可更新的；可恢复的
feedstock ['fiːdstɔk] *n.* 给料（指供送入机器或加工厂的原料）
depleting [di'pliːt] *vt.* 耗尽；使衰竭
catalysis [kə'tælisis] *n.* 催化作用
catalytic [kætə'litik] *a.* 接触反应的
degradation [degrə'deiʃən] *n.* 降级；降格；退化
explosion [iks'pləuʒən] *n.* 爆发；发出；爆炸；[矿] 煤气爆炸
benign [bi'nain] *a.* （病）良性的；（气候）良好的；仁慈的；和蔼的
adipic [ə'dipik] *a.* 脂肪的；油质的；来自脂肪（或油质）的
nylon [nailən] *n.* 尼龙
polyurethane [pɔli'juəriθein] *n.* 聚亚氨酯
lubricants [luːbrikənt] *n.* 滑润剂
plasticizers [plæstisaize] *n.* 可塑剂
benzene ['benziːn] *n.* 苯
glucose ['gluːkəus] *n.* 葡萄糖
cornstarch ['kɔːnsta tʃ] *n.* 玉米淀粉
cellulose ['seljuləus] *n.* 纤维素
corncob ['kɔːnkɔb] *n.* 玉米棒子
tetrachloride [tetrə'klɔːraid] *n.* 四氯化物
chloroform [klɔːrəfɔːm] *n.* 氯仿；*vt.* 用氯仿麻醉
reliever [ri'liːvə] *n.* 救济者
ibuprofen [aibju'prufin] *n.* [药] 异丁苯丙酸；布洛芬（抗炎、镇痛药）
ingredient [in'griːdiənt] *n.* 成分；因素
disposed [dis'pəuz] *v.* 处理；处置；部署；*vt.* 布置；安排；除去

Phrases

green chemistry 绿色化学
have the impact on... 对……有影响
appeal to 吸引
enable... to... 使能够
result in 导致
incorporate... into... 合并；把（一物）合并到已存在的另外某物中
rather than 而非
be superior to... 比……好（优越）
prior to... 优先于……
prevent... from... 阻碍；使（某人）不做某事；阻挠
along with... 陪伴；相关；一起
according to... 根据
pay close attention to... 十分关注
place emphasis on... 强调
be harmful to... 对……有害
in contrast 相反

20 Green Chemistry (Ⅱ)

Fats and oils: sustainable raw material

Using raw materials and feedstock that are renewable rather than depleting is one of those most important green chemistry principles. Renewable feedstock are often made from agricultural products or are the wastes of other processes; depleting feedstock are made from fossil fuels (petroleum, natural gas, or coal) or are mined. Using renewable resources is key step to achieve a sustainable civilization on earth. Vegetable oils and fats are important constituents of human and animal foodstuffs. Certain grades are industrially used and, together with carbohydrates and proteins, are important renewable resources compared to fossil and mineral raw materials, whose occurrence is finite. In concepts for new products, the price, performance, and product safety criteria are equally important and have a correspondingly high importance right at the start of product development. To ensure a high degree of product safety for consumers and the environment, renewable resources have often been shown to have advantages when compared with petrochemical raw materials and can therefore be regarded as being the ideal raw material basis. Results from oleochemistry show that the use of vegetable fats and oils allows the development of competitive, powerful products, which are both consumer-friendly and environment-friendly. Recently developed products, which fit this requirement profile, are the anionic surfactants cocomonoglyceride sulfate and the nonionic sugar surfactant alkyl polyglycoside. These products are used especially as mild surfactants in cosmetic formulations. In polymer applications derivatives of oils and fats, such as epoxides, polyols, and dimerizations products based on unsaturated fatty acids, are used as plastic additives or components for composites or polymers like polyamides and polyurethanes. In the lubricant sector fatty acid based esters have proven to be powerful alternatives to conventional mineral oil products.

The sources of oils and fats are various vegetable and animal raw materials (e. g. , tallow, lard) with the vegetable raw materials soybean, palm, rapeseed and sunflower oil being the most important ones regarding the amounts involved. Of the approximately 101 million tonnes of fats and oils which were produced worldwide in 1998, by far the largest share was used in human foodstuffs. For oleochemistry, 14 million tonnes were available. In recent years, the amounts produced have continuously increased by approximately 3% per year. It is predicted that this trend will continue in the medium and long terms. The composition of the fatty acids contained in the oil (fatty acid spectrum) determines the further use of the oils. Special attention must be given to coconut oil and palm kernel oil (lauric oils) because of their high share of fatty acids with a short or medium chain length (mainly 12 and 14 carbon atoms: C_{12}, C_{14}). For example, these are particularly suitable for further processing to surfactants for washing and cleansing agents as well as cosmetics. Palm, soybean, rapeseed, and sunflower oil, as well as animal fats such as tallow, contain mainly long-chain fatty acids (e. g. , C_{18}, saturated and unsaturated) and are used as raw materials for polymer applications and lubricants. Based on results from cycle analyses and ecological and toxicological studies for selected cases one can assume that products based on renewable resources usually are better ecologically compatible when compared with petrochemical-based substances an important criterion in the development of a new product, just as price and performance are.

Vocabulary

foodstuffs ['fuːdstʌf] *n.* 食品；粮食
carbohydrates [kaːbəu'haidreit] *n.* 碳水化合物；糖类
fossil ['fɔsl] *n.* 化石；僵化的事物；*a.* 化石的；陈腐的；守旧的
mineral ['minərəl] *n.* 矿物；矿石
environment-friendly 环境友好
surfactants [səːfæktənt] *n.* & *a.* 表面活性剂（的）
proteins ['prəutiːn] *n.* 蛋白质；*a.* 蛋白质的
formulation [fɔːmju'leiʃən] *n.* 用公式表示；明确地表达；作简洁陈述
tallow ['tæləu] *n.* 牛脂；动物脂；*vt.* 涂脂油于
lard [laːd] *n.* 猪油

Phrases

be compared to (with)... 与……相比
be regarded as... 被看作……
as well as 和，也，又
based on 根据

21 Ionic Liquid

To date, most chemical reactions have been carried out in molecular solvents. For two millennia, most of our understanding of chemistry has been based upon the behavior of molecules in the solution phase in molecular solvents. Recently, however, a new class of solvent has emerged ionic liquids. These solvents are often fluid at room temperature, and consist entirely of ionic species. They have many fascinating properties which make them of fundamental interest to all chemists.

Ionic liquids are important to chemists for three reasons. (1) They can dissolve a wide range of polar and nonpolar organic and inorganic molecules. (2) Although they are liquids at room temperature, their vapor pressures are negligible. (3) New chemical reactions and industrial processes are being discovered that can only be carried out in these solvents. As opposed to most other organic solvents, these liquids have the potential of being greener reaction media because they are nonvolatile.

Since both the thermodynamics and kinetics of reactions carried out in ionic liquids are different to those in conventional molecular solvents, then the chemistry is different and unpredictable at our current state of knowledge. As they are made up of at least two components which can be varied (the anion and cation), the solvents can be designed with a particular end use in mind, or to possess a particular set of properties.

Hence, the term "designer solvents" has come into common use. At first, the prospect of carrying out chemical reactions in ionic liquids may seem daunting to a chemist who has not worked with them before, but it turns out that carrying reactions out in ionic liquids can be exceptionally easy.

The first room-temperature ionic liquid $[EtNH_3][NO_3]$ (m. p. 12℃) was discovered in 1914, but interest did not develop until the discovery of binary ionic liquids made from mixtures of aluminum (Ⅲ) chloride and *N*-alkylpyridinium or 1,3-dialkylimidazolium chloride. In general, ionic liquids consist of a salt where one or both the ions are large, and the cation has a low degree of symmetry. These factors tend to reduce the lattice energy of the crystalline form of the salt, and hence lower the melting point. Ionic liquids come in two main categories, namely simple salts (made of a single anion and cation) and binary ionic liquids (salts where equilibrium is involved). For example, $[EtNH_3][NO_3]$ is a simple salt whereas mixtures of aluminum (Ⅲ) chloride and 1,3-dialkylimidazolium chlorides (a binary ionic liquid system) contain several different ionic species, and their melting point and properties depend upon the mole fractions of the aluminum (Ⅲ) chloride and 1,3-dialkylimidazolium chloride present. Examples of ionic liquids consisting of a simple salt are given in Fig. 21. 1, and these show simple melting behavior. For the binary systems, the melting point depends upon composition, and this complex behavior has been studied extensively for the archetypal system, .[emim]Cl-$AlCl_3$ ($[emim]^+$ = 1-ethyl-3-methylimidazolium).

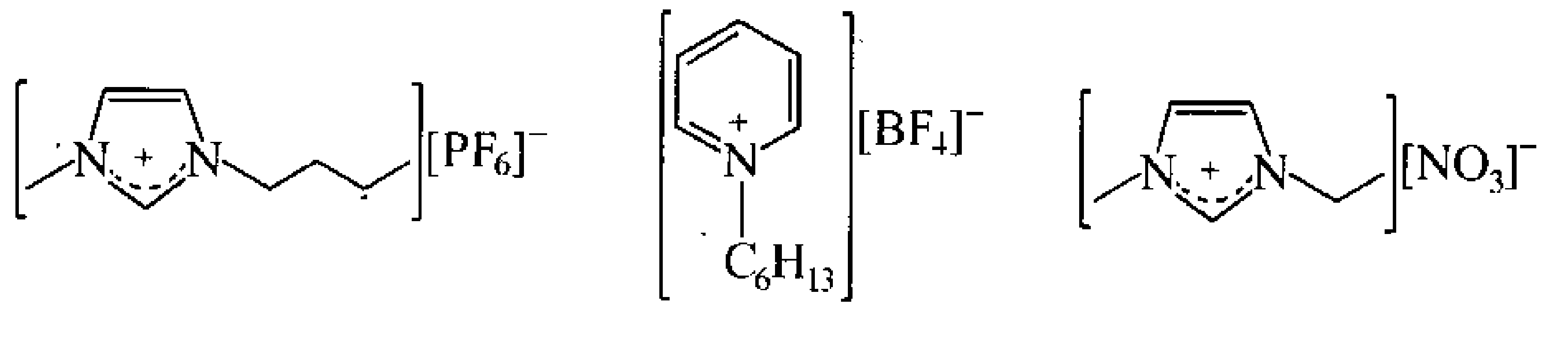


Fig. 21. 1 Examples of simple room-temperature ionic liquids

Ionic liquids have been described as designer solvents, and this means that their properties can be adjusted to suit the requirements of a particular process. Properties such as melting point, viscosity, density, and hydrophobicity can be varied by simple changes to the structure of the ions. For example, the melting points of 1-alkyl-3-methylimidazolium tetrafluoroborates and hexafluorophosphates are a function of the length of the 1-alkyl group, and form liquid crystalline phases for alkyl chain lengths over 12 carbon atoms. Another important property that changes with structure is the miscibility of water in these ionic liquids. For example, 1-alkyl-3-methylimidazolium tetrafluoroborate salts are miscible with water at 25℃ where the alkyl chain length is less than 6, but at or above 6 carbon atoms, they form a separate phase when mixed with water. This behavior can be of substantial benefit when carrying out solvent extractions or product separations, as the relative solubilities of the ionic and extraction phase can be adjusted to make the separation as easy as possible.

Reactions in Chloroaluminate (Ⅲ) Ionic Liquids

The chemical behavior of Franklin acidic chloroaluminate (Ⅲ) ionic liquids (where X ($AlCl_3$) >0.50) is that of a powerful Lewis acid. As might be expected, it promotes reactions that are conventionally promoted by aluminum (Ⅲ) chloride, without suffering the disadvantage of the low solubility of aluminum (Ⅲ) chloride in many solvents. Indeed, chloroaluminate (Ⅲ) ionic liquids are exceptionally powerful solvents, being able to dissolve kerogen, C_{60} and many polymers. The preparation of these ionic liquids is straightforward. Simply by mixing the appropriate organic halide salt with aluminum (Ⅲ) chloride results in the two solids melting together to form the ionic liquid. However, this synthesis must be performed in an inert atmosphere.

A classical reaction promoted by Lewis acids is the Friedel-Crafts reaction, which was found to work efficiently in chloroaluminate (Ⅲ) ionic liquids. A number of commercially important fragrance molecules have been synthesized by Friedel-Crafts acylation reactions in these ionic liquids. Traseolide (5-acetyl-1,1,2,6-tetramethyl-3-isopropylindane) and Tonalid (6-acetyl-1,1,2,4,4,7-hexamethyltetralin) have been made in high yield in the ionic liquid [emim] Cl-$AlCl_3$ ($X=0.67$) (Fig. 21.2). In the acylation of naphthalene, the ionic liquid gives the highest known selectivity for the 1-position. Cracking and isomerization reactions occur readily in acidic chloroaluminate (Ⅲ) ionic liquids. A remarkable example of this is the reaction of polyethylene, which is converted to a mixture of gaseous alkanes with the formula (C_nH_{2n+2}, where $n = 3 \sim 5$) and cyclic alkanes with a hydrogen to carbon ratio of less than two (Fig. 21.3). The distribution of the products obtained from this reaction depends upon the reaction temperature and differs from other polyethylene recycling reactions.

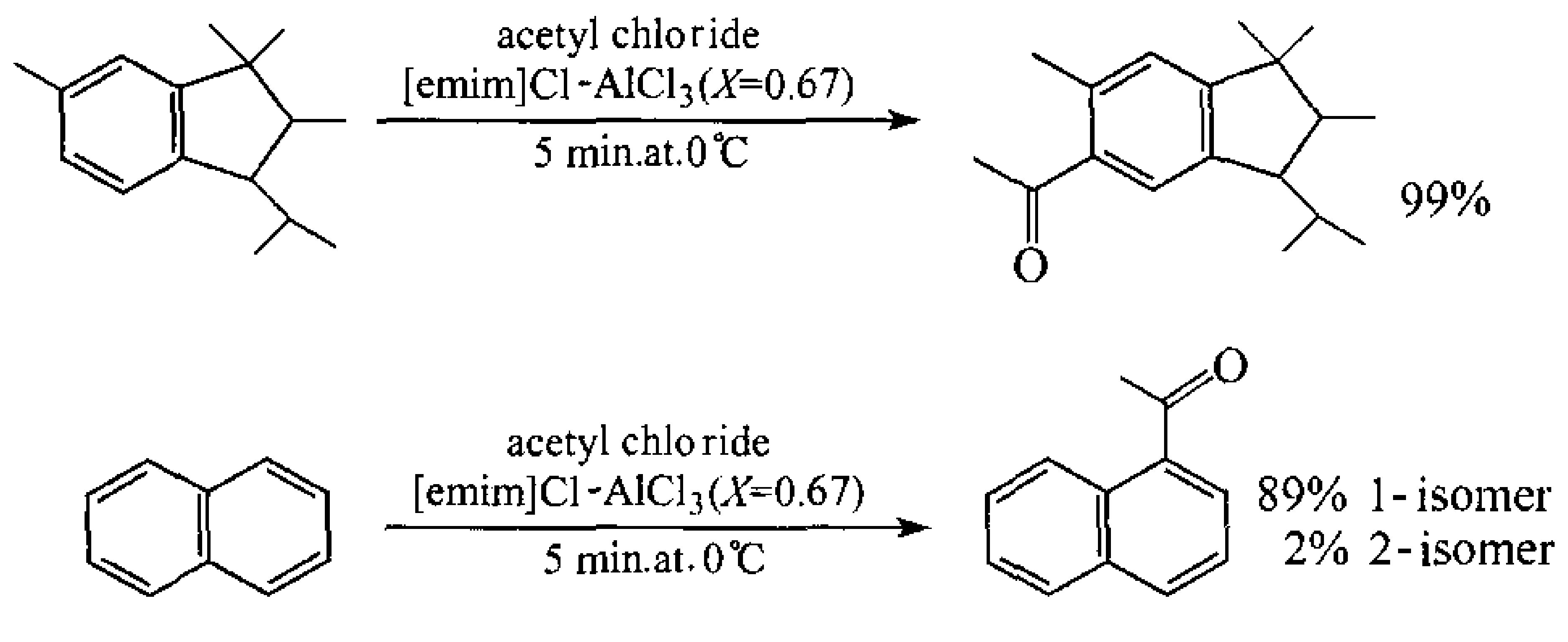


Fig. 21.2 The acetylation of 1,1,2,6-tetramethyl-3-isopropylindane (upper) and naphthalene (lower) in [emim] Cl-$AlCl_3$ ($X = 0.67$)

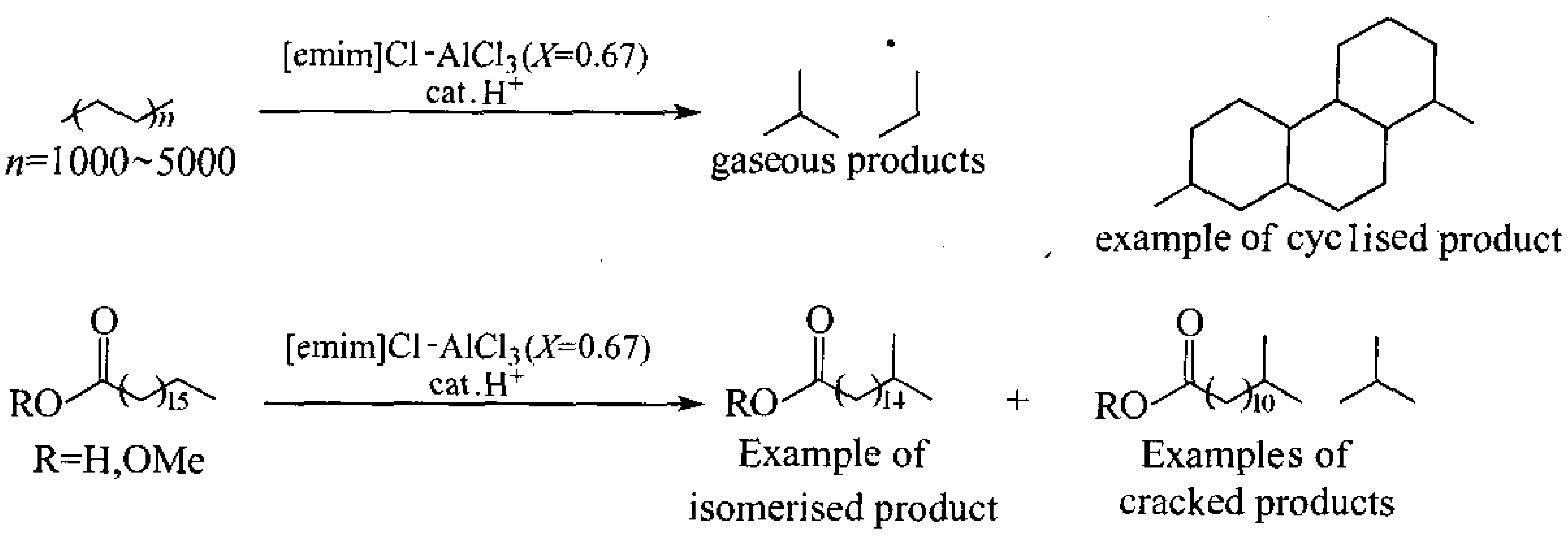


Fig. 21. 3 Isomerization and cracking reactions of alkanes and alkyl chains in chloroaluminate (Ⅲ) ionic liquids

Alkenes are not formed in significant concentrations. Another significant difference is that this ionic liquid reaction occurs at temperatures as low as 90℃, whereas conventional catalytic reactions require much higher temperatures, typically 300～1000℃. A similar reaction occurs with fatty acids such as stearic acid or methyl stearate, which undergo isomerization, cracking, and dimerization reactions. This has been used to convert solid stearic acid into the more valuable liquid, isostearic acid. The isomerization and dimerization of oleic acid and methyl oleate has also been found to occur in chloroaluminate (Ⅲ) ionic liquids. The dimerization and oligomerization of olefins in the presence of homogeneous nickel (Ⅱ) catalysts has been studied extensively in chloroaluminate (Ⅲ) and alkylchloroaluminate (Ⅲ) ionic liquids. Few catalysts are known that catalyze the linear dimerization and oligomerization of C_4-olefins. Linear C_8-olefin dimers are highly desirable intermediates for the production of C_9-plasticizers, exhibiting better thermal properties than those produced from highly branched C_8-olefin dimmer feedstock. This has been developed commercially in the IFP Difasol process. The products of these reactions are insoluble in the ionic liquid and can be separated by decantation, leaving the ionic liquid and catalyst behind, whence the catalyst and solvent can be reused. Polycyclic aromatic hydrocarbons dissolve in chloroaluminate (Ⅲ) ionic liquids to form highly colored paramagnetic solutions. The addition of a reducing agent, such as an electropositive metal, and a proton source results in the selective hydrogenation of the aromatic compound. For example, pyrene and anthracene can be reduced to perhydropyrene and perhydroanthracene at ambient temperatures and pressures; only the thermodynamically most stable isomer of the product is obtained. This contrasts with catalytic hydrogenation reactions, which require high temperatures and pressures, and an expensive platinum oxide catalyst and give rise to an isomeric mixture of products.

By careful monitoring of the reduction in the ionic liquid, a number of intermediate products can be isolated, and the sequence of the chemical reduction process can be determined (Fig. 21. 4). It is also possible to carry out catalytic hydrogenation reactions of cyclohexene using Wilkinson's catalyst, $[RhCl(PPh_3)_3]$, in basic chloroaluminate (Ⅲ) ionic liquids, but neutral ionic liquids are preferred for this type of reaction, for ease of handling and lower moisture sensitivity.

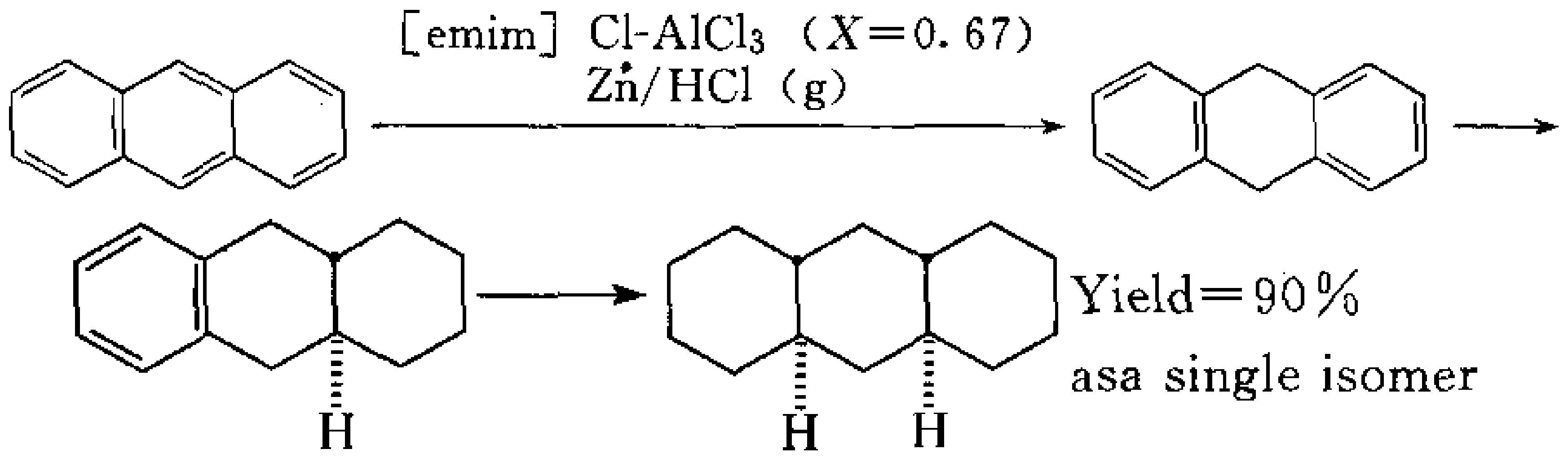


Fig. 21.4 The sequence in the reduction of anthracene to perhydroanthracene

Vocabulary

archetypal [ˈaːkitaipəl] *a.* 原型的
miscibility [misibiliti] *n.* 可混合性
miscible [ˈmisibl] *a.* 易混合的
kerogen [kerədʒən] *n.* [矿] 油母岩质
polymers [ˈpɔlimə] *n.* 聚合体
inert [iˈnəːt] *a.* 无活动的；惰性的；迟钝的
fragrance [ˈfreigrəns] *n.* 芬芳；香气；香味
acylation [æsəleitʃən] *n.* 酰化；酰化（作用）
isomerization [ai. sɔməraiˈzeiʃən] *n.* 异构化（作用）
cracking [krækiŋ] *n* . 破裂；裂化
olefins [əuləfin] *n.* 石蜡
decantation [diːkænˈteiʃən] *n* . 移注
whence [(h) wens] *n.* 来处，根源；*adv.* 从何处，从哪里；*conj.* 拒此；*pron.* 何处
paramagnetic [pærəmægˈnetik] *a.* 顺磁性的
pyrene [ˈpairiːn] *n.* [植] 分核；小坚果
anthracene [ˈænθrə siːn] *n.* 蒽
hydrogenation [haidrədʒˈneinʃən] *n.* 加氢；氢化（作用）

Phrases

ionic liquids 离子液体
consist of 由……组成
turn out 证实；发觉是
in general 普遍地
A number of 许多；大量
be converted into 被转化成……
differ from 与……不同

22 Stereochemistry

22.1 Stereochemistry: Chirality

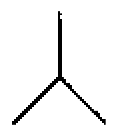
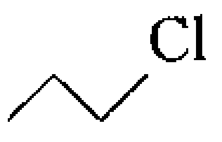
Chirality is a phenomenon that pervades the universe. Achiral object is an object that possesses the property of "handness" (from the Greek word *cheir*, meaning hand). A chiral object, such as each of our hands, is one that cannot be placed on its mirror image so that all parts coincide. In other words, a chiral is not superposable on its mirror image. When you view your left hand in a mirror, for example, the mirror image of your left hand is a right hand. Yet your left hand and your right hand is not identical because they are not superposable, even though they are mirror images.

The human body is structurally chiral, with the heart lying to the left of center and the liver to the right. Helical seashells are chiral and most are spiral, such as a right-handed screw. Many plants show chirality in the way they wind around supporting structures. Honeysuckle winds as a left-handed helix; bindweed winds in a right-handed way. DNA is a chiral molecule. The double helical form of DNA turns in a right-handed way.

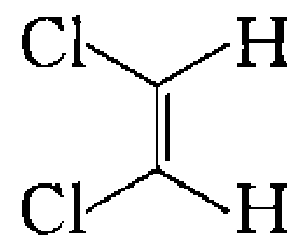
Chirality in molecules, however, involves more than the fact that some molecules adopt left-or right-handed conformations. As we all known, it is the nature of groups bonded at specific atoms that can bestow chirality upon a molecule. Indeed, all but one of 20 amino acids that make up naturally occurring proteins are chiral, and all of these are classified as being left-handed. The molecules of natural sugars are almost all classified as being right-handed. In fact, most of the molecules of life are chiral, and most are found in only one mirror image form.

Let us now consider what causes some molecules to be chiral. To begin, we will return to aspects of isomerism. Isomers are different compounds that have the same molecular formula. In our study thus far, much of our attention has been directed toward isomers we have called constitutional isomers. Constitutional isomers have the same molecular formula but different connectivity, meaning that their atoms are connected in a different order. Examples of constitutional isomers are the following (Table 22. 1):

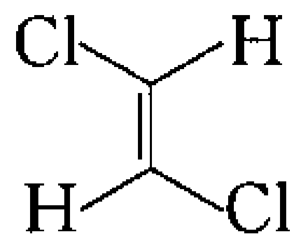
Table 22. 1 Examples of Constitutional Isomers

Molecular Formula		Constitutional Isomers
C_4H_{10}	butane : 	isobutane: 
C_3H_7Cl	2-chloropropane: 	1-chloropropane: 
C_2H_6O	Ethanol: CH_3CH_2OH	Dimethyl ether: CH_3OCH_3

Stereoisomers are not constitutional isomers. Stereoisomers have their atoms connected in the same sequence (the same constitution), but they differ in the arrangement of their atoms in space. Stereoisomers can be subdivided into two general categories: enantiomers and diastereomers. Enantiomers are stereoisomers whose molecules are nonsuperposable mirrors of each other. Diastereomers are stereoisomers whose molecules are not mirror images of each other. The alkene isomers *cis*-and *trans*-1,2-dichloroethene, shown here, are stereoisomers that are diastereomers:



cis-1,2-dichloroethene



trans-1,2-dichloroethene

Enantiomers occur only with compounds whose molecules are chiral. A chiral molecule and its mirror image are called a pair of enantiomers. The relationship between them is defined as enantiomeric.

22.2 Asymmetric Synthesis

Reactions carried out with achiral reactants can often lead to chiral products. In the absence of any chiral influence from a catalyst, reagent, or solvent, the outcome of such a reaction is a racemic mixture. In other words, the chiral product is obtained as a 50 : 50 mixture of enantiomers.

Asymmetric synthesis, also called chiral synthesis, enantioselective synthesis or stereoselective synthesis is organic synthesis which introduces one or more new and desired elements of chirality.

To achieve maximum chiral multiplication, chemists must create efficient catalytic systems that permit precise discrimination among enantiotopic atoms, groups, or faces in achiral molecules. The candidates for these enantioselective catalysts are often metal complexes bearing chiral and nonracemic organic ligands, often in enantiopure form. Therefore, tuning the catalyst to achieve the perfect match among chiral ligand, metallic ion, substrate, and so on is a key point for achieving the maximum chiral multiplication. Combinatorial chemistry has been well recognized as a powerful strategy for the discovery and optimization of bioactive drugs, novel coordination complexes, and solid-state materials. High diversity and efficiency can be regarded as two distinguishing advantages of the combinatorial chemistry approach. Successful catalyst optimization requires rational design, intuition, and experience, but also some degree of trial and error. Therefore, the generation of a combinatorial library of chiral metallic complexes and the screening of the set of constituents of the library for the target reaction by taking advantage of its high diversity and efficiency would provide a potentially powerful approach for the discovery of highly efficient and enantioselective catalysts .

Vocabulary

stereochemistry [stiəriə'kemistri] *n.* 立体化学
chirality ['tʃirəliti] *n.* 手征；手性
superposable [sjuːpə'pəuzəbl] *a.* 可置于上面的；[数] 可重合的；可叠合的
helix ['hiːliks] *n.* 螺旋；螺旋状物
helical ['helikəl] *a.* 螺旋状的
spiral [spaiərəl] *a.* 螺旋形的；*n.* 螺旋
bestow [bi'stəu] *vt.* 给予；安放
enantiomer [i'næntiəumə] *n.* 对映体
diastereomer [daiə'stiəriəumə] *n.* 非对映异构体
achiral [ə'tʃirəl] *a.* 非手性的
racemic [rə'siːmik] *a.* 外消旋的
asymmetric [æsi'metrik] *a.* 不均匀的；不对称的
enantioselective 对映选择性的
stereoselective 立体选择性的
enantiopure 对映纯的

Phrases

chiral molecule 手性分子
asymmetric synthesis 不对称合成
take advantage of 利用
racemic mixture 外消旋混合物
combinatorial chemistry 组合化学

23 Grignard Synthesis of Triphenylmethanol

23. 1 Prelab Exercise

Prepare a flow sheet for the preparation of triphenylmethanol. Through knowledge of the physical properties of the solvents, reactants, and products, show how the products are purified. Indicate which layer in separation should contain the product.

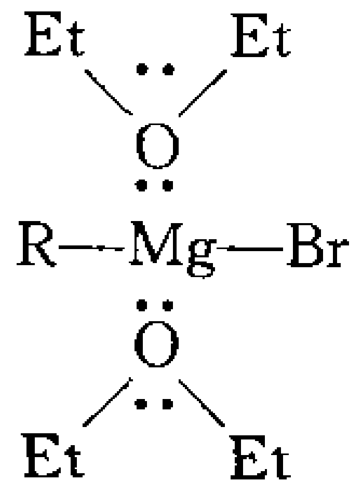
In 1912 Victor Grignard received the Nobel Prize in chemistry for his work on the reaction that bears his name, a carbon-carbon bond-forming reaction by which almost any alcohol may be formed from appropriate alkyl halides and carbonyl compounds. The Grignard reagent is easily formed by reaction of an alkyl halide, in particular a bromide, with magnesium metal in anhydrous ether. Although the reaction can be written and thought of as simply it appears that the structure of the material in solution is rather more complex. There is evidence that dialkylmagnesium is

$$\mathrm{R{-}Br+Mg \longrightarrow R{-}Mg{-}Br}$$

It appears that the structure of the material in solution is rather more complex. There is evidence that dialkylmagnesium is present.

$$\mathrm{2R{-}Mg{-}Br \rightleftharpoons R{-}Mg{-}R+MgBr_2}$$

And that the magnesium atoms, which have the capacity to accept two electron pairs from donor molecules to achieve a four-coordinated state, are solvated by the unshared pairs of electrons on ether:

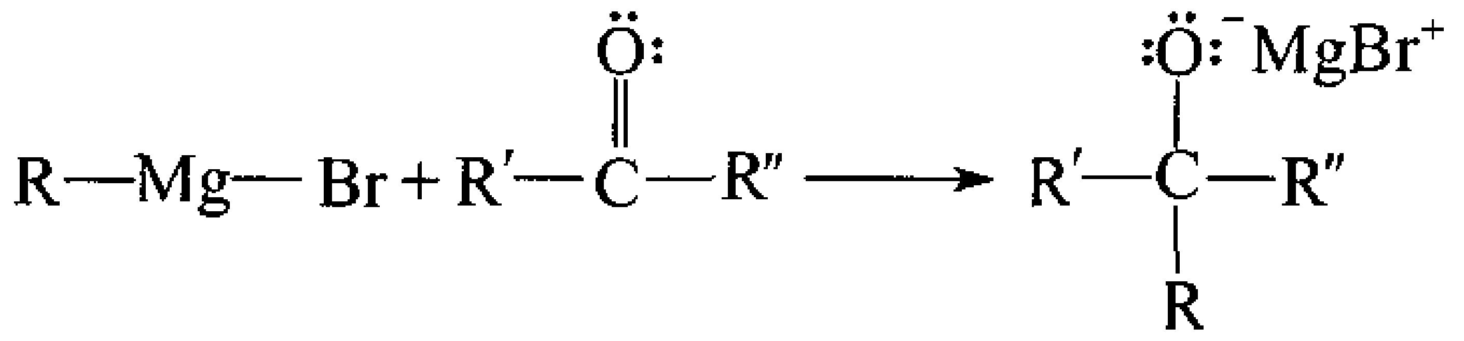


The Grignard reagent is a strong base and a strong nucleophile. As a base it will react with all protons that are more acidic than those found on alkenes and alkanes. Thus Grignard reagents react readily with water, alcohols, amines, thiols, etc. , to regenerate the alkane:

$$\mathrm{R{-}Mg{-}Br+H_2O \longrightarrow R{-}H+MgBrOH}$$
$$\mathrm{R{-}Mg{-}Br+R'HO \longrightarrow R{-}H+MgBrOR'}$$
$$\mathrm{R{-}Mg{-}Br+R'NH_2 \longrightarrow R{-}H+MgBrNHR'}$$

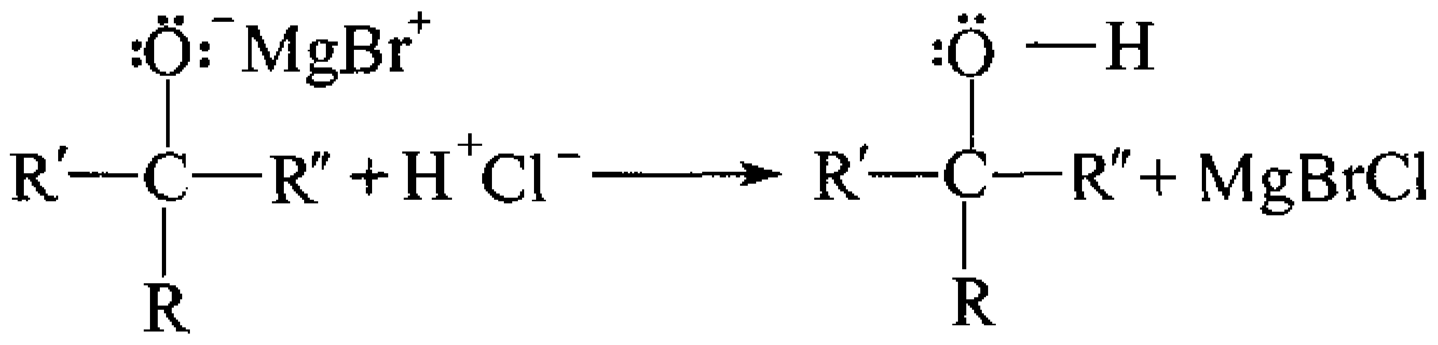
The starting material for preparing the Grignard reagent can contain no acidic protons. The reactants and apparatus must all be completely dry; otherwise the reaction will not start. If proper precautions are taken, however, the reaction proceeds smoothly.

The magnesium metal, in the form of turnings, has a coat of oxide on the out-side. A fresh surface can be exposed by crushing a piece under the absolutely dry ether in the presence of the organic halide. Reaction will begin at the exposed surface, as evidenced by a slight turbidity in the solution and evolution of bubbles. Once the exothermic reaction starts it proceeds easily, the magnesium dissolves, and a solution of the Grignard reagent is formed. The solution is often turbid and gray due to impurities in the magnesium. The reagent is not isolated but reacted immediately with, most often, an appropriate carbonyl compound:



$$R{-}Mg{-}Br + R'{-}\overset{\overset{\ddot{O}:}{\|}}{C}{-}R'' \longrightarrow R'{-}\underset{\underset{R}{|}}{\overset{\overset{:\ddot{O}:^{-}MgBr^{+}}{|}}{C}}{-}R''$$

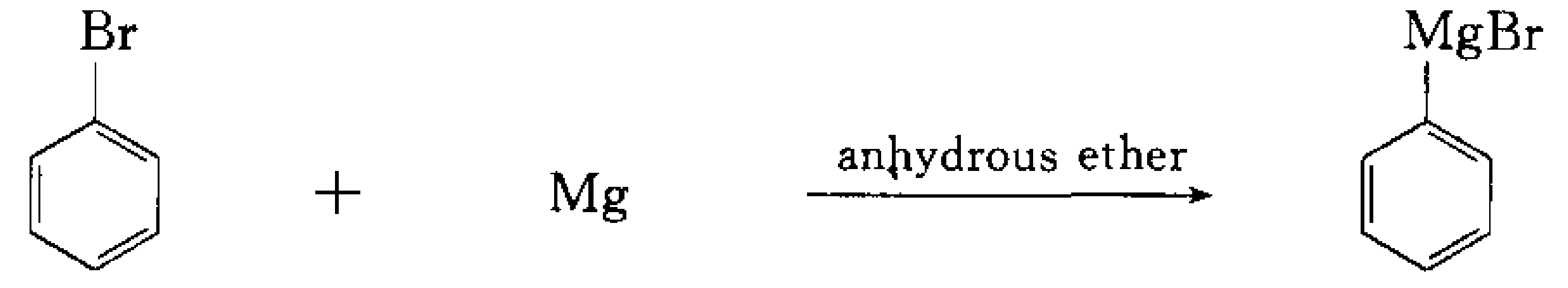
to give, in another exothermic reaction, the magnesium alkoxide. In a simple acid-base reaction this alkoxide is reacted with acidified ice water to give the covalent, ether-soluble alcohol and the ionic water-soluble magnesium salt:



$$R'{-}\underset{\underset{R}{|}}{\overset{\overset{:\ddot{O}:^{-}MgBr^{+}}{|}}{C}}{-}R'' + H^{+}Cl^{-} \longrightarrow R'{-}\underset{\underset{R}{|}}{\overset{\overset{:\ddot{O}{-}H}{|}}{C}}{-}R'' + MgBrCl$$

The great versatility of this reaction lies in the wide range of reactants that undergo the reaction.

23. 2 Phenylmagnesium Bromide (Phenyl Grignard Reagent)



bromobenzene
MW157. 02
bp156℃
denl. 491

magnesium
At. Wt
24. 31

phenyl magnesium bromide
not isolated, used in situ

All apparatus and reagents must be absolutely dry. The Grignard reagent is prepared in a dry 100mL round-bottomed flask fitted with a long reflux condenser. A calcium chloride drying tube inserted in a cork that will fit either the flask or the top of the condenser is also made ready. The flask, condenser, and magnesium (2g = 0. 082 mole of magnesium turnings) should be as dry as possible to begin with, and then should be dried in a 110℃ oven for at least 35 min. Alternatively, the magnesium is placed in the flask, the calcium chloride tube is attached directly, and the flask is heated gently but thoroughly with a cool luminous flame. Do not overheat the magnesium. It will become deactivated through oxidation or, if strongly overheated, can burn. The flask on cooling pulls dry air through the calcium chloride. Cool to room temperature before proceeding! **Extinguish all flames**! Ether vapor is denser than air and can travel along bench tops and into sinks. Use care.

Make an ice bath ready in case control of the reaction becomes necessary, although this is usually not the case. Remove the drying tube and fit it to the top of the condenser. Then pour into the flask though the condenser 15mL of absolute ether (absolutely dry, anhydrous) and 9mL (13.5g = 0.086mole) of bromobenzene are absolutely dry. (More ether is to be added as soon as the reaction starts, but at the outset the concentration of bromobenzene is kept high to promote easy starting.) If there is no immediate sign of reaction, insert a dry stirring rod with a flattened end and crush a piece of magnesium firmly against the bottom of the flask under the surface of the liquid, giving a twisting motion to the rod. When this is done properly the liquid becomes slightly cloudy, and ebullition commences at the surface of the compressed metal. Be careful not to punch a hole in the bottom of the flask. Attach the condenser at once, swirl the flask to provide fresh surfaces for contact, and, as soon as you are sure that the reaction has started, add 25mL more absolute ether through the top of the condenser before spontaneous boiling becomes too vigorous (replace the drying tube). Note the volume of ether in the flask. Cool in ice if necessary to slow the reaction but do not overcool the mixture; the reaction can be stopped by too much cooling. Any difficulty in initiating the reaction can be dealt with by trying the following expedients in succession.

(1) Warm the flask with your hands or a beaker of warm water. Then see if boiling continues when the flask (condenser attached) is removed from the warmth.

(2) Try further mashing of the metal with a stirring rod.

(3) Add a tiny crystal of iodine as a starter (in this case the ethereal solution of the final reaction product should be washed with sodium bisulfite solution to remove the yellow color).

(4) Add a few drops of a solution of phenylmagnesium bromide or of methylmagnesium iodide (which can be made on a test tube).

(5) Start afresh, taking greater care with the dryness of apparatus and reagents, and sublime a crystal or two of iodine on the surface of the magnesium to generate Gattermann's "activated magnesium" before beginning the reaction again.

Once the reaction begins, spontaneous boiling in the diluted mixture may be slow or become slow. If so, mount the flask and condenser on the steam bath (one clamp supporting the condenser suffices) and reflux gently until the magnesium has disintegrated and the solution has acquired a cloudy or brownish appearance. The reaction is complete when only a few small remnants of metal (or metal contaminants) remain. Check to see that the volume of ether has not decreased. If it has, add more anhydrous ether. Since the solution of Grignard reagent deteriorates on standing, the next step should be started at once.

23.3 Triphenylmethanol

Mix 5g (0.037mole) of methyl benzoate and 15 mL of absolute ether in a separatory funnel, cool the flask containing phenylmagnesium bromide solution briefly in an ice bath, remove the drying tube, and insert the stem of the separatory funnel into the top of the condenser. Run in the methyl benzoate solution slowly with only such cooling as is required to control the mildly exothermic reaction, which affords an intermediate addition compound that separates as a white solid. Replace the calcium chloride tube, swirl the flask until it is at room temperature and the reaction has subsided. The reaction is then completed by either refluxing the mixture for one-half hour, or stopping the flask with the calcium chloride tube and letting the mixture stand overnight (subsequent refluxing is then unnecessary).

Pour the reaction mixture into a 250mL Erlenmeyer flask containing 50mL of 10% sulfuric acid and about 25 g of ice and use both ordinary ether and 10% sulfuric acid to rinse the flask. Swirl well to promote hydrolysis of the addition compound; basic magnesium salts are converted into water-soluble neutral salts and triphenylmethanol is distributed into the ether layer. An additional amount of ether (ordinary) may be required. Pour the mixture into a separatory funnel (rinse the flask with ether), shake, and draw off the aqueous layer. Shake the ether solution with 10% sulfuric acid to further remove magnesium salts, and wash with saturated sodium chloride solution to remove water that has dissolved in the ether. The amounts of liquid used in these washing operations are not critical. In general, an amount of wash liquid equal to one-third of the ether volume is adequate.

To effect final drying of the ether solution, pour the ether layer out of the neck of the separatory funnel an Erlenmeyer flask, add about 5g of granular anhydrous sodium sulfate, swirl the flask from time to time, and after 5min remove the drying agent by gravity filtration through a filter paper held in a funnel into a tared Erlenmeyer flask. Rinse the drying agent with a small amount of ether. Add 25mL of 66～77℃ ligroin and concentrate the ether-ligroin solutions (steam bath) in an Erlenmeyer flask under an aspirator tube. Evaporate slowly until crystals of triphenylcarbinol just begin to separate and then let crystallization proceed, first at room temperature and then at 0℃. The product should be colorless and should melt not lower than 160℃. Concentration of the mother liquor may yield a second crop of crystals. A typical student yield is 5.0g. Evaporate the mother liquors to dryness and save the residue for later isolation of the components by chromatography.

Analyze the first crop of triphenylmethanol and the residue from the evaporation of the mother liquors by thin layer chromatography. Dissolve equal quantities of the two solids (a few crystals) and also biphenyl in equal quantities of dichloromethane (1 or 2 drops). Using a microcapillary, spot equal quantities of material on silica gel TLC plates (Eastman No. 13181) and develop the plates in an appropriate solvent system. Try 1 : 3 dichloromethane-petroleum ether first and adjust the relative quantities of solvent as needed. The spots can be seen by examining the TLC plate under a fluorescent lamp or by treating the TLC plate with iodine vapor. From this analysis decide how pure each of the solids is and whether it would be worthwhile to attempt to isolate more triphenylmethanol from the mother liquors.

Turn in the product in a vial labeled with your name, the name of the compound, its melting point, and the overall percent yield from benzoic acid.

Cleaning Up Combine all aqueous layers, dilute with a large quantity of water, and flush the slightly acidic solution down the drain. The ether/ligroin mother liquor from the crystallization goes in the organic solvents container. The thin layer chromatography developer, which contains dichloromethane, is placed in the halogenated organic waste container. Calcium chloride from the drying tube should be dissolved in water and flushed down the drain.

Vocabulary

magnesium [mægˈniːzjəm] *n.* 镁
expedient [iksˈpiːdiənt] *a.* 有利的
capacity [kəˈpæsiti] *n.* 容量；智能；才能；能力
succession [səkˈseʃən] *n.* 连续；继承
mashing [mæʃiŋ] *n.* 捣碎
solvate [ˈsɔlveit] *n.* 溶剂化物
ethereal [iˈθiəriəl] *a.* 轻的；像空气的
thiol [ˈθaiəul] *n.* 硫醇
bisulfite [baiˈsʌlfait] *n.* 重亚硫酸盐；酸性亚硫酸盐
regenerate [riˈdʒenərit] *vt.* 使新生，重建，改革，革新；*vi.* 新生，再生；*a.* 新生的，更新的
sublime [səˈblaim] *v.* 提高；（使）升华
mount [maunt] *vt.* 装上，设置，安放，制作……的标本，上演；*vi.* 爬上，增长
disintegrate [disˈintigreit] *vt.* （使）分解；（使）碎裂
precaution [priˈkɔːʃən] *n.* 预防；防范
turbidity [təːˈbiditi] *n.* 混浊；混乱
brownish [ˈbrauniʃ] *a.* 呈褐色的
exothermic [eksəuˈθəːmik] *a.* 发热的；放出热量的
remnant [ˈremnənt] *n.* 残余，剩余，残迹；*a.* 剩余的，残留的
alkoxide [ælˈkɔksaid] *n.* 醇盐
contaminant [kənˈtæminənt] *n.* 致污物；污染物
acidify [əˈsidifai] *vt.* 使酸化；*vi.* 变酸
versatility [vəːsəˈtiləti] *n.* 多功能性
benzoate [ˈbenzəueit] *n.* 安息香酸盐
oven [ˈʌvən] *n.* 烤箱；烤炉
stopper [ˈstɔpə] *n.* 塞子，制动器，阻塞物，制止者；*v.* 塞住
critical [ˈkritikəl] *a.* 评论的；鉴定的；批评的；危急的；临界的
thoroughly [ˈθʌrəli] *adv.* 十分地；彻底地
deactivate [diːˈæktiveit] *vt.* 使无效，
adequate [ˈædikwit] *a.* 适当的；足够的
ligroin [ˈligrəuin] *n.* 轻石油
extinguish [iksˈtiŋgwiʃ] *vt.* 熄灭；消灭；压制；使黯然失色
microcapillary [maikrəˈkəˈpiləri] *n.* 微型毛细管
twist [twist] *n.* & *vt.* & *vi.* 扭曲；盘旋；曲折歪曲；螺旋状
fluorescent [fluəˈresənt] *a.* 荧光的
halogenate [ˈhælədʒəneit] *v.* 卤化
commence [kəˈmens] *v.* 开始；着手
flush [flʌʃ] *vt.* 淹没；冲洗
swirl [swəːl] *vt.* 使成旋涡；*vi.* 打旋，盘绕

Phrases

in particular 尤其
deal with 处理
in the presence of 在……存在下
in succession 连续
due to 因为，由于
be converted into 被转化成……
in the (wide) range of 在……范围内
in general 总体上
in case 如果，以防万一

Exercises

1. Why does rapid addition of bromobenzene to magnesium favor the formation of the undesirable by-product, biphenyl, over phenylmagnesium bromide?

2. Triphenylmethanol can also be prepared from the reaction of ethylbenzoate with phenylmagnesium bromide and by the reaction of diethylcarbonate with phenylmagnesium bromide. Write stepwise reaction mechanisms for these two reactions.

3. If the ethyl benzoate used to prepare triphenylmethanol is wet, what by-product is formed?

4. Exactly what weight of dry ice is needed to react with 2 mmoles of phenylmagnesium bromide?

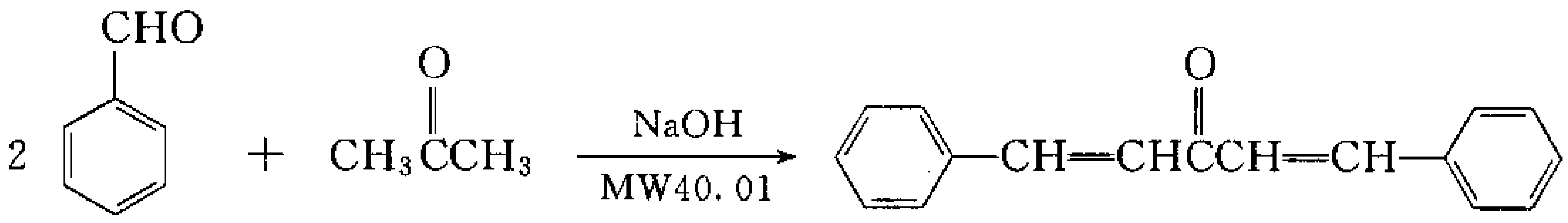
5. In the synthesis of benzoic acid, benzene is often detected as an impurity. How does this come about?

6. The benzoic acid could have been extracted from the ether layer using sodium bicarbonate solution. Give equations showing how this might be done and how the benzoic acid would be regenerated. What practical reason makes this extraction less desirable than sodium hydroxide extraction?

24 Dibenzalacetone by the Aldol Condensation

24.1 Prelab Exercise

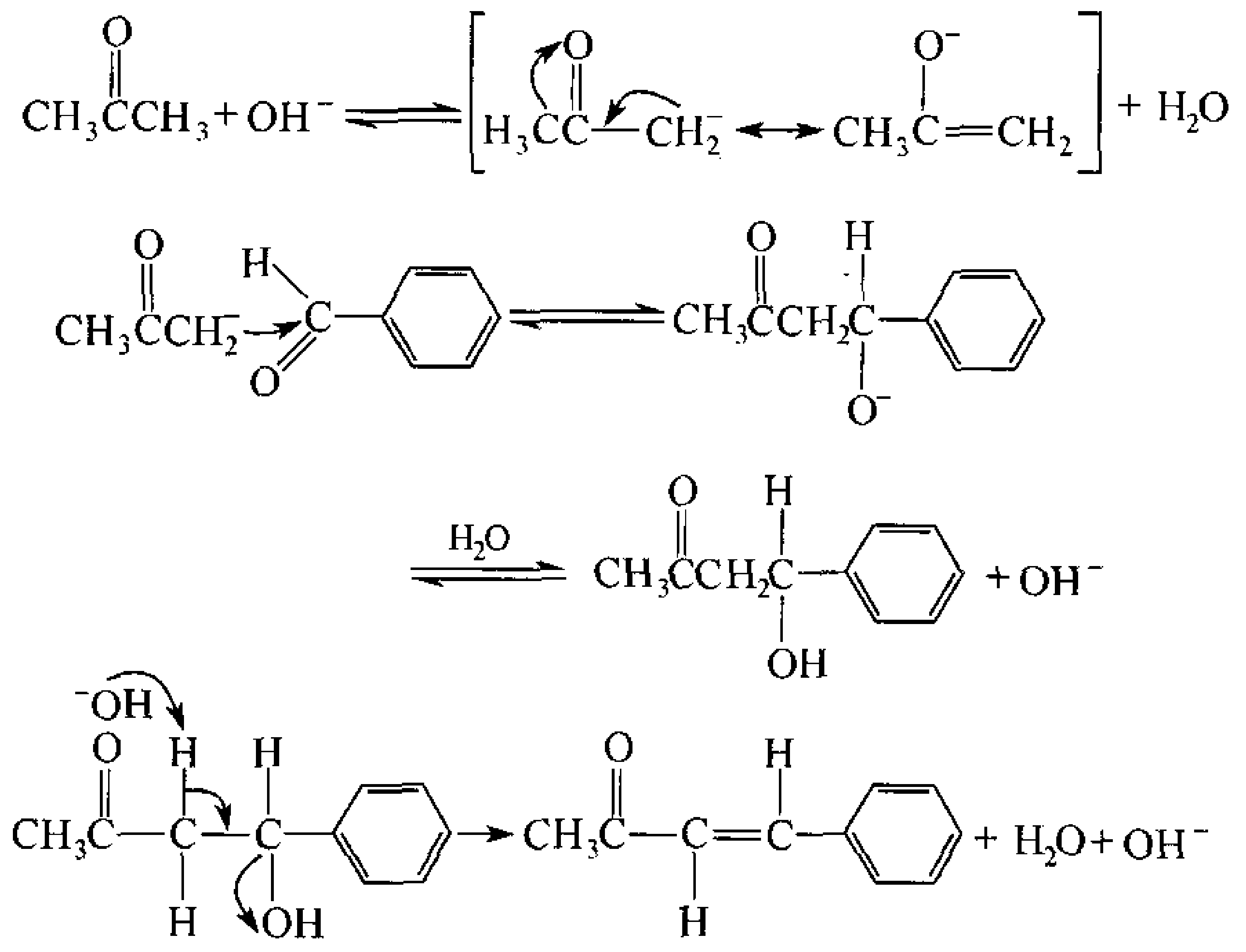
Calculate the volumes of benzaldehydes and acetone needed for the reaction, taking into account the densities of the liquids and the number of moles of each required.



benzaldehyde	acetone	dibenzalacetone
MW106.13	MW58.08	MW243.30
bp. 178℃	bp. 56℃	mp. 110～111℃
den. 1.04	den. 0.790	

The reaction of an aldehyde with a ketone employing sodium hydroxide as the base is an example of a mixed aldol condensation reaction, the Claisen-Schmidt reaction. Dibenzalacetone is readily prepared by condensation of acetone with two equivalents of benzaldehyde. The aldehyde carbonyl is more reactive than that of the ketone and therefore reacts rapidly with the anion of the ketone to give a β-hydroxyketone, which easily undergoes base-catalyzed dehydration. Depending on the relative quantities of the reactants, the reaction can give either mono-or dibenzalacetone.

In the present experiment sufficient ethanol is present as solvent to readily dissolve the starting material, benzaldelyde, and also the intermediate, benzalacetone. The benzaldehyde, once formed, can then easily react with another mole of benzaldehyde to give the product, dibenzalacetone. The detail mechanism for the formation of benzalacetone is:



24. 2 Experiments

(1) Synthesis of Dibenzalacetone

Into a 10×100mm reaction tube place 2mL of 10% sodium hydroxide solution. To this solution add 1. 6mL of 95% ethanol and then, from a 1mL syringe, 0. 204mL of benzaldehyde. Rinse the syringe with a small quantity of acetone and then add 0. 073mL of acetone to the reaction mixture. Alternatively the benzaldehyde (0. 212g) and the acetone (0. 058g) can be weighed out or the instructor may provide a solution that contains 58mg of acetone on each 1. 6 mL of ethanol. Cap the tube immediately and shake the mixture vigorously. The benzaldehyde, initially insoluble, goes into solution and a water-clear, pale yellow precipitate of the product forms. Continue to shake the tube from time to time for the next 30min. If the product fails to crystallize, open the tube and scratch the inside of the tube with a glass rod. Remove the liquid from the tube using a Pasteur pipette by squeezing the bulb of the pipette, pressing the tip against the bottom of the tube, and bringing the liquid into the pipette, leaving the crystals in the tube. Add 3mL of water, cap, and shake the tube vigorously. Remove the wash liquid as before and wash the crystals twice more with water. After the final washing rap the tube sharply on the desk to drive the crystals to the bottom of the tube; remove remaining water with the pipette. It is important to remove as much of the water as possible since water causes the "oiling out" problem during crystallization. Some water might be absorbed into a roll of filter paper forced into the crystals. Alternatively, collect the crystals on a Hirsch funnel using vacuum filtration. Place the slightly damp crystals in a dry reaction tube. Weigh the tube to determine the weight of crude wet product. It should not weigh more than 300mg. Add 2mL of 95% ethanol to the damp crystals and warm the tube in a sand bath. Insert a wooden boiling stick to promote even boiling and heat the mixture until the crystals dissolve.

Remove the tube from the hot sand bath and place it in an insulated container to cool slowly to room temperature. Should the product separate as an oil, try to obtain a seed crystal, heat the solution to dissolve the oil, and add the seed crystal as the solution cools. If it continues to oil out add a bit more ethanol. Collect the product by removing the solvent with a pipette after cooling the tube for several minutes in ice. Wash the crystals once with about 0. 5mL of ice-cold ethanol while the tube is in ice. Dry the product under vacuum by attaching the tube to an aspirator for a few minutes. Determine the weight of the dibenzalacetone, its mp, and calculate the percent yield. In a typical experiment the yield will be 0. 10g, mp 110. 5～112℃.

Cleaning Up Dilute the filtrate from the reaction mixture with water and neutralize it with dilute hydrochloric acid before flushing down the drain. The ethanol filtrate from the crystallization should be placed in the organic solvents container.

(2) Synthesis of Dibenzalacetone

Mix 0. 05mole of benzaldehyde with the theoretical quantity of acetone, add one-half the mixture to a solution of 5g of sodium hydroxide dissolved in 50mL of water and 40mL of ethanol at room temperature (<25℃). After 15 min add the remainder of the aldehyde-ketone mixture and rinse the container with a little ethanol to complete the transfer. After one-half hour, during which time the mixture is swirled frequently, collect the product by suction filtration on a Buchner funnel. Break the suction and carefully pour 100mL of water on the product. Reapply the vacuum. Repeat this process three times in order to remove all traces of sodium hydroxide. Finally, press the product as dry as possible on the filter using a cork, and then press it between sheets of filter paper to remove as much water as possible. Save a small sample for melting point determination and then recrystallize the product from ethanol using about 10mL of ethanol for each 4g of dibenzalacetone. Pure dibenzalacetone melts at 110-111℃, and the yield after recrystallizaion should be about 4g.

Cleaning Up Dilute the filtrate from the reaction mixture with water and neutralize it with dilute hydrochloric acid before flushing down the drain. The ethanol filtrate from the crystallization should be placed in the organic solvents container.

Vocabulary

aldehyde ['ældihaid] *n.* 醛；乙醛
pipette [pi'pet] *n.* 吸液管
aldol ['ældəul] *n.* 丁间醇醛
squeeze [skwiːz] *n.* & *v.* 压榨；挤
condensation [kɔnden'seiʃən] *n.* 浓缩
absorb [əb'sɔːb] *vt.* 吸收；吸引
dibenzalacetone [daibenzə'læsitəun] *n.* 二亚苄基丙酮
filtration [fil'treiʃən] *n.* 过滤；筛选
damp [dæmp] *a.* 潮湿的
equivalent [i'kwivələnt] *n.* 等价物，相等物；*a.* 相等的，相当的
insulate ['insjuleit] *vt.* 使绝缘，隔离
aspirator ['æspəreitə] *n.* 吸气器；吸出器
benzaldehyde [ben'zældihaid] *n.* 安息香；苯甲醛

hydrochloric [haidrəu'klɔːrik] *a.* 氯化氢的；盐酸的

mechanism ['mekənizəm] *n.* 机制；机构；机械装置

theoretical [θiə'retikəl] *a.* 理论的

remainder [ri'meində] *n.* 残余；剩余物

syringe ['sirindʒ] *n.* 注射器，洗涤器；*v.* 注射，冲洗，灌洗

suction ['sʌkʃən] *n.* 抽气；抽水泵

cork [kɔːk] *n.* 软木塞；（用塞子）塞住

rinse [rins] *v.* 刷，冲洗掉；*n.* 漂洗，冲洗

scratch [skrætʃ] *vt.* 乱写；刮擦声，抓痕，擦伤；*vi.* 发刮擦声，搔，抓

Phrases

depend on　依靠，依赖，取决于

from time to time　时时，间或

attach... to...　把……连在……上

Exercises

1. How will you do when sodium hydroxide gets on the skin?

2. What role does sodium hydroxide play in the aldol condensation?

3. Why is it important to maintain equivalent proportions of reagents in this reaction?

4. Why is the aldehyde carbonyl more reactive than that of the ketone when reacting with the anion of the ketone?

附录Ⅰ　英语常用词头和词尾

有许多英语单词是由词的基干部分加上词头或词尾构成的，例如：oxide（氧化物）加上词头 di-（二）成为 dioxide（二氧化物）；work（工作）加词尾-er（者）成为 worker（工人）；polytetrafluoroethylene（聚四氟乙烯）是由 poly-（聚），tetra-（四），fluor-（氟），ethylene（乙烯）构成。学习词头词尾对词义理解和单词的记忆很有帮助，现将常用的词头和词尾列表如下。

表Ⅰ-1　常用词头

词头	附加意义	例　　词
anti-	反抗	anti-imperialism ['æntiim'piəriəlizəm]反帝国主义(imperialism 帝国主义)
bi-	两个	bichloride [bai'klɔːraid]二氯化物(chloride 氯化物)
centi-	百分之一	centimeter ['sentimiːtə]厘米(meter 米,分尺)
co-	共同,联合	cooperation [kəuɔpə'reiʃən]合作(operation 作用)
col-		collocate ['kɔləkeit]排列(locate 安排)
com-		composition [kɔmpə'ziʃən]组成(position 位置)
con-		confirm [kən'fəːm]使坚定(firm 坚定)
de-	脱,除	decomposition [diːkɔmpə'ziʃən]分解(composition 组成)
di-	二	dioxide [dai'ɔksaid]二氧化物(oxide 氧化物)
tri-	三	tributyl amine[trai'bjuːtilːæmine]三丁胺(butyl amine 丁胺)
dis-	分开,除去	discover [dis'kʌvə]发现(cover 覆盖物)
en-	使	enlarge [in'laːdʒ]使扩大(large 大)
hydro-	水	hydrometer [hai'drɔmitə]液体比重计(meter 计,量)
im-	不,无	impossible [im'pɔsəbl]不可能的(possible 可能的)
ir-		irresistible [iri'zistəbl]不可抗拒的(resistible 可抗拒的)
in-		incorrect [inkə'rekt]不正确(correct 正确)
inter-	相互,在……之间	interchange [intə'tʃeindʒ]交换(change 变化)
iso-	异	isobutent ['aisəu'bjuːtiːn]异丁烯(butene 丁烯)
kilo-	千	kilogram [kiləugræm]千克,公斤(gram 克)
milli-	千分之一	millimeter ['milimiːtə]毫米(meter 米)
mis-	错误	misunderstand ['misʌndə'stænd]误解(understand 了解)
multi-	多	multi-purpose ['mʌlti'pəːpəs]多种用途(purpose 目的,用途)
non-	非,不	non-ferrous metal [nɔn'ferəs'metl]非铁金属,有色金属(metal 金属)
poly-	多,聚	polymer 聚合物
		polyoxide ['pɔli'ɔksaid]多氧化物(oxide 氧化物)
pre-	预先	preheat ['priː'hiːt]预热(heat 热)
re-	重复	refit ['riː'fit]重新装配(fit 适合,装配)
sur-	在上,胜	surpass [səː'paːs]胜过(pass 通过)
tele-	过,远	telephone ['telifəun]电话(phone 声)
trans-	反式	trans-addition[an'tiːədiʃən]反式加成(addition 加成)
un-	相反,不	unequal [ʌn'iːkwəl]不等的(equal 相等的)

表 Ⅰ-2　常用词尾

词尾所表示的词类及意义			例　　词
词 类	意　义	词 尾	
构成名词	表示人或物	-er	worker [ˈwəːkə]工人
		-or	indicator [ˈindikeitə]指示剂
		-ist	communist [ˈkɔmjunist]共产主义者
	表示行为、性质、状态等	-ion	revolution [revəˈluːʃən]革命
		-ing	teaching [ˈtiːtʃiŋ]教导
		-ance	importance [imˈpɔːtəns]重要(性)
		-ence	difference [ˈdifərəns]差异
		-ment	movement [ˈmuːvmənt]运动
		-ure	pressure [ˈpreʃə]压力
		-ics	physics [ˈfiziks]物理学
		-age	percentage [pəˈsentidʒ]百分比
		-ness	correctness [kəˈrektnis]正确
		-ity	purity [ˈpjuəriti]纯度
		-y	difficulty [ˈdifikəlti]困难
构成序数词	第……	-th	sixth [siksθ]第六
构成形容词	具有某种性质	-ic	atomic [əˈtɔmik]原子的
		-al	experimental [iksperiˈmentl]实验的
		-ful	careful [ˈkɛəful]小心的
	具有某种特征	-ous	fibrous [ˈfaibrəs]纤维(状)的
		-able	changeable [ˈtʃeindʒəbl]可变的
		-ive	active [ˈæktiv]积极的，活泼的
		-ant	important [imˈpɔːtənt]重要的
		-ent	different [ˈdifrənt]不同的
	不具有某种特征	-less	colourless [ˈkʌləlis]无色的
构成副词	表程度、方式、方向	-ly	carefully [ˈkɛəfuli]小心地
		-ward(s)	eastward [ˈiːstwəd(z)]向东
构成动词	使	-ize	criticize [ˈkritisaiz]批评
		-en	harden [ˈhaːdn]使硬
		-fy	purify [ˈpjuərifai]使纯化
		-ate	separate [ˈsepəreit]使分离

附录Ⅱ　化学化工常用英文缩写与符号

Å	埃(10^{-10} m)	angstrom unit [ˈæŋsrtəmˈjuːnit]
a. c.	交流电	alternative current [ɔːlˈtəːnətivˈkʌrənt]
addn.	加入	addition [əˈdiʃən]
anhydr.	无水的	anhydrous [ænˈhaidrəs]
A. P.	分析纯	analytically pure [ænəˈlitikə pjuə]
atm. pr.	大气压	atomosphere pressure [ætməsfiəˈpreʃə]
av.	平均	average [ˈævəridʒ]
b. p.	沸点	boiling point [ˈbɔiliŋˈpɔint]
℃	摄氏度	Celsirs [ˈselsjəs]
c	浓度	concentration [kɔnsenˈtreiʃən]
cal	卡	calorie [ˈkæləri]
cc	立方厘米	cubic centimetre [ˈkjuːbikˈsentimiːtə]
cL	厘升	centilitre [ˈsentiliːtə]
cm	厘米	centimetre [ˈsentimiːtə]
concd.	浓的	concentrated [ˈkɔnsentreitid]
const.	常数	constant [ˈkɔnstənt]
C. P.	化学纯	chemically pure [ˈkemikəli pjuə]
cpd. (compd.)	化合物	compound [ˈkɔmpaund]
cryst.	结晶	crystalling [ˈkristəlinŋ]
d.	直径	diameter [daiˈæmitə]
d.	密度	density [ˈdensiti]
d-	右旋	dextrorotatory [ˈdekstrəuˈrəutətəti]
D-	D-型	Dextro-configuration
d. c.	直流	direct current [diˈreiktˈkʌrənt]
decomp.	分解	decompose [diːkəmˈpəuz]
deg.	度	degree [diˈgriː]
deriv.	衍生物	derivative [diˈrivətiv]
dil.	稀的	dilute [daiˈljuːt]
distd.	蒸馏的	distilled [disˈtild]
dL	分升	decilitre [ˈdesiliːtə]
e. g.	例如	for example [fɔːigˈzaːmpl]
eq.	方程式	equation [iˈkweiʃən]
equiv.	当量	equivalent [iˈkwivələnt]
eqpt.	设备	equipment [iˈkwipmənt]
℉	华氏度	Fahrenheit [ˈfærənhait]
f.	函数	function [ˈfʌnkʃən]
fig.	图	figure [ˈfigə]
g	克	gram [græm]
g/c. c.	克每毫升	gram (s) per cubic centimetre

h.	高度	height [hait]
HP.	马力	horsepower [hɔːspauə]
hr	时	hour [auə]
hyd.	有水的	hydrous [ˈhaidrəs]
i	不溶的	insoluble [inˈsɔljubl]
i. e.	即	that is [ðætiz]
mL	毫升	milliliter [ˈmililiːtə（r）]
kcal	千卡	kilo-calorie [ˈkiːləˈkæləri]
psi	磅力/英寸^2	pound（s） per square inch
resp.	各自，分别	respectively [riˈspektivli]
sec.	秒	second [ˈsekənd]
sol.	溶液	solution [səˈluːʃən]
sp. gr.	比重（相对密度）	specific gravity [spiˈsifikˈgræviti]
sq.	平方	square [skwɛə]
STP	标准温度与压力	standard temperature and pressuer [ˈstædədˈtempritʃəændˈpreʃə]
t.	时间，时刻	time [taim]
t	吨	ton [tʌn]
tech.	工业的，技术的	technical [ˈteknikəl]
T	热力学温度	absolute temperature [ˈæbsəljuːtˈtempritʃə]
Temp	温度	temperature [ˈtempritʃə]
Tech. p.	工业纯	technically pure [ˈteknikəli pjuə]
V	体积	volume [ˈvɔljuːm]
V	伏特	volt [vəult]
v	（反应）速度	velocity [viˈlɔsiti]
W	瓦（特）	watt（s） [wɔt（s）]
Wt.	重量	weight [weit]
Ph	苯基	phenyl [ˈfiːnil]
→	生成	yields [jiːldz]
=（≈）	等于（约等）	equal [ˈiːkwəl]
°	度	degree [diˈgriː]
π	圆周率	
△	加热	heat [hiːt]
%	百分（比）	percent [pəˈsent]
μ	微米＝$\frac{1}{1000000}$米	miron [ˈmaikrɔn]

附录Ⅲ　总词汇表（Glossary Index）

A

abbreviation [ə'briːvi'eiʃən] *n.* 缩写
ability [ə'biliti] *n.* 能力
absorb [əb'sɔːb] *vt.* 吸收；吸引
absorption train 吸收序列
accelerate [ək'seləreit] *vt.* 加速
acceptor [ək'septə] *n.* 接受体
accurate ['ækjurit] *a.* 正确的；精确的
accurate value（＝available value）精确值
accurately ['ækjuritli] *ad.* 准确地
p-acestyl benzenesulfonic acid 对乙酰基苯磺酸
acetaldehyde ['æsi'tældəhaid] *n.* 乙醛
acetate ['æsiteit] *n.* 醋酸盐
acetone ['æsitəun] *n.* 丙酮
acetophenone [æsitə'fenəun] *n.* 苯乙酮
acetyl chloride ['æsitil'klɔːraid] *n.* 乙酰氯
acetylene [ə'setiliːn] *n.* 乙炔
achiral [ə'tʃirəl] *a.* 非手性的
acid anhydride 酸酐
acid radical 酸根
acid wash 酸洗
acidic [ə'sidik] *a.* 酸的；酸性的
acidification [ə. sidifi'keiʃən] *n.* 发酸；酸化
acidify [ə'sidifai] *vt.* 使酸化；*vi.* 变酸
acquaintance [ə'kweintəns] *n.* 熟悉；认识
across [ə'krɔs] *ad.* 横过；宽
activated charcoal 活性炭
activity [æk'tiviti] *n.* 活动
actual [æktjuəl] *a.* 实际的
acyclic [ei'saiklik] *a.* 无环的；非环的
acyl group 酰基
acylation [æsəleitʃən] *n.* 酰化；酰化（作用）
adapt [ə'dæpt] *vt.* 适应
add [æd] *vt.*（添）加
adequate ['ædikwit] *a.* 适当的；足够的
adhere [əd'hiə] *vi.* 黏附；固着，遵循，坚持
adipic [ə'dipik] acid 己二酸
adipic [ə'dipik] *a.* 脂肪的；油质的；来自脂肪（或油质）的
adjacent [ə'dʒeisənt] *a.* 临近的
adopt [ə'dɔpt] *vt.* 采纳；通过
advantageous [ædvən'teidʒəs] *a.* 有利的
advent ['ædvənt] *n.* 到来；出现
affect [ə'fekt] *vt.* 影响
aggregate ['ægrigit] *n* & *a.* 聚集（体）；['ægrigeit] *v.* 总计；聚集
aid [eid] *n.* 帮助
air-raid ['ɛəreid] *n.* 空袭
alchemist ['ælkimist] *n.* 炼金术士
alcohol ['ælkəhɔl] *n.*（乙）醇；酒精
aldehyde ['ældihaid] *n.* 醛；乙醛
aldol ['ældəul] *n.* 羟醛，醛醇；3-羟基丁醛
alicyclic [æli'saiklik] *a.* 脂环（族）的
aliphatic [æli'fætik] *a.* 脂肪（族）的
aliphatic ketones 脂肪族酮
alkali ['ælkəlai] *n.* 碱
alkalihalide 碱金属卤化物
alkaline ['ælkəlain] *a.* 碱的；强碱的
alkane ['ælkein] *n.* 烷烃；链烷
alkene ['ælkiːn] *n.* 烯烃；链烯
alkoxide [æl'kɔksaid] *n.* 醇盐
alkyl ['ælkil] *n.* 烷基
alkyne ['ælkain] *n.* 炔烃；链炔
alloy ['ælɔi] *n.* 合金
allyl ['ælil] *n.* 烯丙基
allyl alcohol 烯丙（基）醇
allyl bromide 烯丙基溴
almond ['aːmənd] *n.* 杏仁
altitude ['æltitjuːd] *n.* 高度；海拔高度

aluminate [ə'ljuːmineit] *n.* 铝酸盐

aluminium tri (2-propanolate) 三异丙醇铝

aluminum [ə'ljuːminəm] *n.* 铝

amide ['æmaid] *n.* 酰胺

amine ['æmiːn] *n.* 胺

ammine ['æmiːn] *n.* 氨络物

ammonia [ə'məunjə] *n.* 氨；氨水

amorphous [ə'mɔːfəs] *a.* 无定形的；无组织的

analogously [ə'næləsli] *ad.* 相似地；

analogy [ə'nælədʒi] *n.* 类似；相似性

angle [æŋgl] *n.* 角；角度

anhydride [æn'haidraid] *n.* 酐

anion ['ænaiən] *n.* 阴离子；负离子

anodic [æ'nɔdik] *a.* 阳极的；正极的

antarctic [ænt'aːktik] *a.* 南极的

anthracene ['ænθrə siːn] *n.* 蒽

antibiotic ['æntibai'ɔtik] *n.* 抗生素

antimony ['æntiməni] *n.* 锑

apparent [ə'pærənt] *a.* 表面上的；明显的

apparently [ə'pærəntli] *ad.* 表面上看来像；显然

appear [ə'piə] *vt.* 出现；看来（好像）

applicable ['æplikəbl] *a.* 适用的

application [æpli'keiʃən] *n.* 应用

appreciably [ə'priːʃiəbli] *ad.* 明显地；可看到地

approach [ə'prəutʃ] *n.* 方法；步骤

appropriate [ə'pəupriit] *ad.* 适当的；适宜的

approximately [əprɔksi'mətli] *ad.* 近似地

apron ['eiprən] *n.* 围巾

aqueous ['eikwiəs] *a.* 水的

arbitrary ['aːbitrəri] *a.* 任意的；武断的

arc [aːk] *n.* 电弧

archetypal ['aːkitaipəl] *a.* 原型的

argon ['aːgɔn] *n.* 氩

arithmetical [æriθ'metikəl] *a.* 算术的

aroma [ə'rəumə] *a.* 芳香的

aromatic ['ærəu'mætik] *a.* 芳香（族）的；*n.* 香料

arrange [ə'reidʒ] *vt.* 排列；安排

arrangement [ə'reindʒmənt] *n.* 排列；安排

array [ə'rei] *vt.* 打扮；装饰；排列

arsa- ['aːsə-] 砷杂，吡

arsenane [aːsənein] *n.* 砷杂己环

arsenin [aːzənin] *n.* 砷杂己因

arsine ['aːsin] *n.* 砷化（三）氢；胂

article ['aːtikl] *n.* 制品；物件；文章

aryl ['æril] *n.* & *a.* 芳基（的）

aspirator ['æspəreitə] *n.* 吸气器；吸出器

assign [ə'sain] *vt.* 指定；分配

assignment [ə'sainmənt] *n.* 指定；分配

assist [ə'sist] *vt.* 帮助

associate [ə'səuʃieit] *vt.* 使发生联系；结合；缔合

assume [ə'sjuːm] *vt.* 假定；假设

astatine [æstətiːn] *n.* 砹

asymmetric [æsi'metrik] *a.* 不均匀的；不对称的；

attack [ə'tæk] *vt.* & *n.* 着手（工作等）

attenuation [əˌtenju'eiʃən] *n.* 变薄；稀薄化；变细；衰减

authority [ɔː'θɔriti] *n.* 权威

auxiliary [ɔːg'ziljəri] *a.* 辅助的；辅的

available [ə'veiləbl] *a.* 可供利用的

avoid [ə'vɔid] *vt.* 避免

aza- ['æzə-] 氮杂，吖

azarsetine [æz'aːzətiːn] *n.* 氮杂砷杂丁亭

azeotrope ['eiziːətrəup] *n.* 共沸物；共沸蒸馏

azeotropic [eziːə'trɔpik] *a.* 共沸的

azeotropic distillation 共沸蒸馏

azepine ['æzəpiːn] *n.* 吖庚因

aziridine ['æziridiːn] *n.* 氮丙啶；氮杂环丙烷

azocine ['æzəusiːn] *n.* 吖辛因

B

bake [beik] *vt.* 烘；烤

bakelite ['beikəlait] *n.* 酚醛树脂；电木

balance ['bæləns] *n.* 天平，平衡；*v.* 平衡

balsam ['bɔːlsəm] *n.* 香油；香脂

barium ['bɛəriəm] *n.* 钡

basic anhydride 碱酐

batch [bætʃ] *n.* 批

bauxite ['bɔːksait] *n.* 铝土矿；铝矾土

bead [biːd] *n.* 有孔小珠；玻璃珠

beaker ['biːkə] *n.* 烧杯

bean [biːn] *n.* 豆

become [bi'kʌm] *vi.* 变成；*vt.* 适合，与……相称

benign [bi'nain] *a.* （病）良性的；（气候）良好的；仁慈的；和蔼的

benzaldehyde [ben'zældihaid] *n.* 安息香；苯甲醛

benzamide ['benziːmaid] *n.* 苯甲酰胺；琥珀酸酐

benzene ['benziːn，ben'ziːn] *n.* 苯

benzenesulfonic acid *n.* 苯磺酸

1,2,4- benzenetriol ['benziːn'traioul] *n.* 1,2,4-苯三酚

benzoate ['benzəueit] *n.* 安息香酸盐

benzoic [ben'zəuik] *a.* 安息香的

benzoic acid 安息香酸；苯甲酸

benzophenone ['benzəufiːnəun] *n.* 二苯甲酮；苯酮；苯酰苯

benzoyl chloride *n.* 苯甲酰氯

benzyl ['benzil] alcohol 苯甲醇

benzyloxy-['benzi'lɔksi] 苯甲氧基

bestow [bi'stəu] *vt.* 给予；安放

bicyclic [bai'siklik] *a.* 双环的

biochemist [baiəu'kemist] *n.* 生物化学家

biphenyl ['bai'fenil] *n.* 联苯

biscuit ['biskit] *n.* 饼干

bisma- [bizmə-] 铋杂

bisulfite [bai'sʌlfait] *n.* 重亚硫酸盐；酸性亚硫酸盐

bitter ['bitə] *n.* 苦味

blanket ['blæŋkit] *n.* 毛毯；掩盖；覆盖层

blend [blend]/ blended ['blendid] *vt.* & *n.* 掺和（物）

blood [blʌd] *n.* 血液

boil [bɔil] *vt.* 煮沸

bombardment [bɔm'baːdmənt] *n.* 炮击；轰击

bond [bɔnd] *n.* 链；*v.* 连接；结合

bora- ['bɔrə-] 硼杂

borane ['bəurein] *n.* 甲硼烷；甲硼烷衍生物

borane ['bəurein] *n.* 硼烷

bore [bɔː] *n.* 镗孔；内径

boride ['bɔːraid] *n.* 硼化物

borin ['bɔrin] *n.* 硼杂己因

borinane ['brinein] *n.* 硼杂己环

bottoms ['bɔtəms] *n.* 釜渣；釜（残）液

bound [baund] *vt.* 邻接；*n.* [常用复数] 界限

bp=boiling point

breathe [briːð] *v.* 呼吸

brick [brik] *n.* 砖

brilliant ['briljənt] *a.* 极明亮的；光辉的

bromide ['brəumaid] *n.* 溴化物

bromobenzene [ˌbrəumə'benziːn] *n.* 溴苯

brownish ['brauniʃ] *a.* 呈褐色的

brush [brʌʃ] *n.* 刷子

BTX=benzene-toluene-xylene 苯-甲苯-二甲苯

bubble ['bʌbl] *n.* 气泡

buchenr funnel ['buːknə'fʌnəl] 瓷器斗；布氏漏斗

built-in ['bil'tin] *a.* 内装有；内在的

bump [bʌmp] *v.* 撞

burette [bjuə'ret] *n.* 滴定管；量管

burn [bəːn] *n.* 烧伤；灼伤；烫伤；*vt.* 燃烧

but [bʌt] *prep.* 除了

butanal ['bjuːtənæl] *n.* 丁醛

butane ['bjuːtein] *n.* 丁烷

butanoic [bjuːtə'nɔik] *acid* 丁酸

2-butanone ['bjuːtənəun] *n.* 2-丁酮

t-butyl chloride ['təːʃəri'bjuːtil'klɔːraid] 叔丁基氯

butoxy- [bju'tɔksi] 丁氧基

C

calcium ['kælsiəm] *n.* 钙

calcium carbonate 碳酸钙

calcium oxalate ['ɔksəleit] 草酸钙

calomel ['kæləməl] *n.* 甘汞；氯化亚汞

camphor ['kæmfə] *n.* 樟脑

capacity [kə'pæsiti] *n.* 容量；智能；才能；能力

capitalize ['kæpitəlaiz] *vt.* （字母）大写

capric ['kæprik] acid 癸酸；羊蜡酸

caprylic [kə'prilik] acid 辛酸；羊脂酸

carbanion ['kaːbənaiən] *n.* 碳酸根离子；负碳离子

carbocyclic ['kaːbə'saiklik] *a.* 碳环的

carbohydrates [ˌkaːbəu'haidreit] *n.* 碳水化合物；糖类

carbon ['kaːbən] *n.* 碳

carbon dioxide 二氧化碳

carbonation [ˌkaːbə'neiʃən] *n.* 碳酸（盐）化；羧基化

carbonyl group 羰基

carboxylic ['kaːbɔk'silik] acid 羧酸

care [kεə] *n.* 注意；小心

carothers [kə'rʌðəz] W. H. 卡罗毖
catalysis [kə'tælisis] *n.* 催化作用
catalytic [kætə'litik] *a.* 接触反应的
catalyze ['kætəlaiz] *vt.* 催化
catapult ['kætəpʌlt] *vt.* 聚甲基丙烯酸酯类
catechol ['kætəkoul] *n.* 邻苯二酚
cation ['kætaiən] *n.* 阳离子；正离子
caustic ['kɔːstik] *n.* 原料，材料
caution ['kɔːʃən] *n.* 小心；谨慎；注意
cease ['siːs] *v.* & *vt.* 停止；终止
celanese [selə'niːz] *n.* 奥纶；聚丙烯腈
cell [sel] *n.* 细胞
cellulose ['seljuləus] *n.* 纤维素
cent [sent] *n.* 分；美分
cesium ['siːzjəm] *n.* 铯
cesium chlorate ['siːzjəm'klɔːrit] 氯酸铯
cesium chlorite ['siːzjəm'klɔːrait] 亚氯酸铯
cesium hypochlorite ['siːzjəm haipə'klɔːrait] 次氯酸铯
cesium perchlorate ['siːzjəm'klɔːreit] 过氯酸铯
chance [tʃaːns] *n.* 机会
character ['kæriktə] *n.* 性质
characteristic ['kæriktə'ristik] *a.* 特有的；*n.* 特性
characterization ['kæriktərai'zeiʃən] *n.* 鉴定；鉴别
charcoal ['tʃaːkəul] *n.* 炭；炭笔
charge [tʃaːdʒ] *n.* 电荷；*vt.* 投料，装料，进料
check [tʃek] *v.* 核对；检验
chemist ['kemist] *n.* 化学家
chief [tʃiːf] *a.* 主要的
Chile ['tʃili] *n.* 智利
chirality ['tʃirəliti] *n.* 手征；手性
chloric acid ['klɔːrik æsid] 氯酸
chloride ['klɔːraid] *n.* 氯化物
chlorine ['klɔːriːn] *n.* 氯（气）
chloroform [klɔːrəfɔːm] *n.* 氯仿；*vt.* 用氯仿麻醉
chlorous acid ['klɔːrəs æsid] 亚氯酸
chromene ['krəumiːn] *n.* 苯并吡喃
chromenyl ['krəumini] *n.* 苯并吡喃基
chromium ['krəumiəm] *n.* 铬
cinnamon ['sinəmən] *n.* 肉桂；桂皮；肉桂树
cinnamaldehyde 肉桂醛
cinnoline ['sinəliːn] *n.* 1,2-二氮杂萘
cinnolinyl ['sinəlinil] *n.* 1,2 - 二氮杂萘基
cis- 顺式 *trans*- 反式
citric ['sitrik] *a.* 柠檬的
citric acid 柠檬酸
citrus ['sitrəs] *n.* 柑橘属
classify ['klæsifai] *vt.* 分类
clay [klei] *n.* 黏土
cleanliness ['klenlinis] *n.* 洁净度；清洁度
cleavage ['kliːvidʒ] *n.* 分裂；分解，裂开
cleave [kliːv] *vt.* 劈开；裂开
cling [kliŋ] *vi.* 附着；黏附（clung，clung，clinging）
clog [klɔg] *vt.* 堵塞；阻塞
clogging ['klɔgiŋ] *n.* 阻塞
close [kləus] *a.* 接近的；靠近的
clothing ['kləuðiŋ] *n.* 衣服
cloudiness ['klaudinis] *n.* 阴暗，朦胧
clover ['kləuvə] *n.* 苜蓿；三叶草
cluster ['klʌstə] *n.* 一串；一束；一簇；一小群
cobaltic [kəu'bɔːltik] *a.* 钴的；高钴的
cobaltous [kəu'bɔːltəs] *a.* 钴的；二价钴的
coefficient [ˌkəui'fiʃənt] *n.* 系数；率
cold reflux 冷回流
color intensity ['kʌləin'tensiti] 颜色强度
colorless ['kʌləlis] *n.* 无色的
combine [kəm'bain] *vt.* & *vi.* （使）结合
combustion [kəm'bʌstʃən] *n.* 燃烧
commas [kɔməs] *n.* 逗号
commence [kə'mens] *v.* 开始；着手
commercial [kə'məːʃəl] *n.* 商业的；可获利的；用来出售的
comparatively [kəm'pærətivli] *ad.* 比较地
complex ['kɔmpleks] *a.* 复杂的
complexity [kəm'pleksiti] *n.* 复杂性
composition [kɔmpə'ziʃən] *n.* 构成；组成
compound ['kɔmpaund] *n.* 化合物
compress [kəm'pres] *vt.* 压缩
comprise [kəm'praiz] *vt.* 包含
compute [kəm'pjuːt] *vt.* 计算
concentration [kɔnsen'treiʃən] *n.* 浓度
conclusively [kən'kluːsivli] *ad.* 结论性地
condensation [kɔnden'seiʃən] *n.* 综合
condensation [kɔnden'seiʃən] *n.* 浓缩
condenser [kən'densə] *n.* 冷凝器
conductor [kən'dʌktə] *n.* 导体
configuration [kən'figju'reiʃən] *n.* 结构；构造；构型

confirm [kən'fəːm] *vt.* 进一步；证明
conjuctive [kən'dʒʌŋktiv] *a.* 连接的；*n.* 连接词
conjugate ['kəndʒugit] *a.* 共轭的；*vt.* 共轭
considerable [kən'sidərəbl] *a.* 相当的；不少的
considerably [kən'sidərəbəli] *ad.* 相当地
constituent [kən'stitjuənt] *n.* 构分；组分；成分；*a.* 组成的
constitute ['kɔnstitjuːt] *vt.* 构成；组成
contain [kən'tein] *vt.* 含有；包括
contaminant [kən'tæminənt] *n.* 致污物；污染物
content ['kɔntent] *n.* 含量
contraction [kən'trækʃən] *n.* 缩短；省略
controversy ['kɔntrəvəːsi] *n.* 争论；辩论
convenient [kən'viːnjənt] *a.* 方便的；顺利的
conventional [kən'venʃənl] *a.* 常规的；惯例的
conversion [kən'vəːʃən] *n.* 转变
convert [kən'vəːt] *vt.* 转换；转化
coordinate [kəu'ɔːdinit] *v.* 配位
coordinate [kəu'ɔːdinit] *a.* 同等的；并列的；坐标的
copper ['kɔpə] *n.* 铜
copper sulfate 硫酸铜
cork [kɔːk] *n.* 软木塞；(用塞子)塞住
corncob ['kɔːnkɔb] *n.* 玉米棒子
cornstarch ['kɔːnstatʃ] *n.* 玉米淀粉
corundum [kə'rʌndəm] *n.* 刚玉；金刚砂
covalent [kəu'veilənt] *a.* 共价的
cracking [krækiŋ] *n.* 破裂；裂化
cresol ['kriːsɔl] *n.* 甲酚
critical ['kritikəl] *a.* 评论的；鉴定的；批评的；危急的；临界的
critically ['kritikəli] *ad.* 批判地；精密地
crucible ['kruːsibl] *n.* 坩埚
crude [kruːd] *a.* 粗制的；原始的；天然的
crush [krʌʃ] *vt.* 压碎；压扁
crystal ['kristl] *n.* 结晶；晶体
crystal lattice 晶格
crystalline ['kristəlain] *a.* 水晶的；*n* 结晶质；结晶体
crystallization [ˌkristəlai'zeiʃən] *n.* 晶化，结晶；结晶体
crystallize ['kristəlaiz] *vt.* 使结晶
cubic ['kjuːbik] *a.* 立方(体)的
cuprate ['kjuːpreit] *n* . 铜酸盐
current ['kʌrənt] *n.* 电流
customary ['kʌstəməri] *a.* 通常的；惯常的
cyanide ['saiənaid] *n.* 氰化物
cycloalkane ['saikləu'ælkein] *n.* 环烷烃
cycloalkene ['saiklə'ælkiːn] *n.* 环烯烃

D

dacron ['deikrən] *n.* 聚对苯二甲酸
damp [dæmp] *a.* 潮湿的
datum ['deitəm] (复 data ['deitə]) *n.* 资料；论据
deactivate [diː'æktiveit] *vt.* 使无效
decane ['dekein] *n.* 癸烷
decantation [diːkæn'teiʃən] *n.* 移注
decelerate [diː'seləreit] *v.* 减速；减慢
decimal ['desiməl] *n.* 小数
decimal point 小数点
decompose [diːkəm'pəuz] *vi.* 分解；分析
deduce [di'djuːs] *vt.* 推论；推断
define [di'fain] *vt.* 规定；下定义
definite ['definit] *a.* 明确的；一定的
definiteness ['definitnis] *n.* 明确
degradation [degrə'deiʃən] *n.* 降级；降格；退化
delivery [di'livəri] *n.* 输送；交付
denominator [di'nɔmineitə] *n.* 分母
denote [di'nəut] *vt.* 指示；表示
density ['densiti] *n.* 密度
depleting [di'pliːt] *vt.* 耗尽；使衰竭
deposit [di'pɔzit] *vt.* 放置；安置；使沉淀
derivative [di'rivətiv] *a.* 衍生的；*n.* 衍生物
derive [di'raiv] *vi.* 衍生；派生
describe [dis'kraib] *vt.* 描述；叙述
desiccant ['desikənt] *n.* 干燥剂
designate ['dezigneit] *vt.* 指定；指出
designation ['dezig'neiʃən] *n.* 名称
desirable [di'zaiərəbl] *a.* 值得想望的；合意的
despite [dis'pait] *prep.* 不管；尽管
detail ['diːteil] *n.* 详情；细节
detect [di'tekt] *vt.* 觉察；发觉
detection [di'tekʃən] *n.* 检出；觉察出
detergent [di'təːdʒənt] *n.* 洗涤剂；去垢剂

deterioration [ditiəriəˈreiʃn] *n.* 损坏；损伤；腐败；变质

deuterium [djuˈtiəriəm] *n.* 氘；重氢

deuteron [ˈdjuːtərɔn] *n.* 氘核；重氢核

devise [diˈvaiz] *vt.* 设计

diameter [daiˈæmitə] *n.* 直径

diastereomer [daiəˈstiəriəumə] *n.* 非对映异构体

diatomic [daiæˈtɔmic] *a.* 双原子的

dibenzalacetone [daibenzəˈlæsitəun] *n.* 二亚苄基丙酮

dichromate [daiˈkrəumeit] *n.* 重铬酸盐

diethyl ketone 二乙酮

difference methods 差值法

digest [diˈdʒest] *vt.* 消化

dimethylamine [daiˌmeθiləˈmiːn] *n.* 二甲胺

1,4-dioxane [daiˈɔksein] *n.* 二噁烷；1,4-二氧杂环己烷

dioxide [daiˈɔksaid] *n.* 二氧化物

dirty [ˈdəːti] *a.* 脏的；不洁的

disadvantageous [disædvaːnˈteidʒəs] *a.* 不利的

discrete [disˈkriːt] *a.* 分离的；不连续的

disintegrate [disˈintigreit] *vt.*（使）分解；（使）碎裂

dislodge [disˈlɔdʒ] *vt.* 移走；移位

disposed [disˈpəuz] *v.* 处理，处置，部署；*vt.* 布置，安排，除去

disrupt [disˈrʌpt] *v.* 使中断；使分裂

dissociate [diˈsəuʃieit] *vt.* 使分解

dissolve [diˈzɔlv] *vt.* 溶解

distinction [disˈtiŋkʃən] *n.* 区别；差别；级别；特性；声望；显赫

distinctly [disˈtiŋktli] *ad.* 明显地；有特色地

distinguish [disˈtiŋgwiʃ] *vi.* 区别；区分

dithiazine [ˌdaiθaiˈæziːn] *n.* 二噻吖嗪

divalent [ˈdaiveilənt] *a.* 二价的

docosane [ˈdɔkəsein] *n.* 二十二烷

document [ˈdɔkjumənt] *vt.* 证明

dodecane [dəuˈdekein] *n.* 十二烷

domestic [dɔˈmestik] *a.* 家庭的；国产的；本地的

dominant [ˈdɔminənt] *a.* 支配的；统治的

donor [ˈdəunə] *n.* 给（予）体

dot [dɔt] *n.* 点

dotriacontane [dəutriəˈkɔntein] *n.* 三十二烷

double bond 双键

doubt [daut] *n.* 怀疑

dough [dəu] *n.* 生面团

drain [drein] *v.* 排放；倾倒

drainage [ˈdreinidʒ] *v.* 排放；倾倒

drano [ˈdreinouə] *n.* 下水道除堵剂

draw [drɔː] (drew) [druː], drawn [drɔːn] *vt.* 拉

dressing [ˈdresiŋ] *n.* 选矿；精选

droplet [ˈdrɔplit] *n.* 小滴

dry ice [drai ais] *n.* 干冰，固体二氧化碳

ductile [ˈdʌktail] *a.* 易延展的；易教导的；柔软的

ductility [dʌkˈtiliti] *n.* 延性；延度

dye [dai] *n.* 染料

dynamic [daiˈnæmik] *n.* 动力学；*a.* 动力的，动力学的，动态的

E

-ecine [-əuniːn] 癸因（含氮十元不饱和杂环）

effect [iˈfekt] *vt.* 实现；到达

efficiency [iˈfiʃənsi] *n.* 效率

eicosane [ˈaikəsein] *n.* 二十烷

elastomer [iˈlæstəmə] *n.* 弹性体；合成橡胶

electrolyse [iˈlektrəlaiz] *vt.* 电解

electron pair [iˈlektrənˈpεə] 电子对

electronegative [iˈlektrəuˈnegətiv] *a.* 电负性的

electropositive [iˌlektrəˈpɔzitiv] *a.* 正电性；阳电性

electrovalent [ilektrəuˈveilənt] *a.* 电价的

elementary [eliˌmentəri] *a.* 基本的；初等的

eletronegative [iˌlektrəuˈnegətiv] *a.* 负电性的；阴电性的

elide [iˈlaid] *vt.* 取消；省略

eliminate [iˈlimineit] *vt.* 消除

elimination [ilimiˈneiʃən] *n.* 消除

embarrass [imˈbærəs] *vt.* 使……困窘；使……感到困难

empirical [emˈpirikəl] *a.* 经验的

empirical [emˈpirikəl] formula 实验式

enable [iˈneibl] *vt.* 使……能够

enantiomer [iˈnæntiəumə] *n.* 对映体

enantiopure 对映纯的

enantioselective 对映选择性的
encounter [en'kauntə] *vt.* 遇见；碰见
engage [in'geidʒ] *vt.* [in] 使从事
engineering [endʒi'niəriŋ] *n.* 工程（学）
ensue [in'sjuː] *vi.* 接着发生
entail [in'teil] *vt.* 需要
entirely [in'taiəli] *ad.* 完全地
entrainer [in'treinə] *n.* 携带剂；夹带剂
entraining 携带剂
entrap [in'træp] *vt.* 夹住；裹住
environment-friendly 环境友好
envisage [in'vizidʒ] *vt.* 展望；预计
envision [in'viʒən] *vt.* 想象；预想
enzyme ['enzaim] *n.* 酶
- epine [-epiːn] 庚因（含氮不饱和七元杂环）
equation [i'kweiʃən] *n.* 方程式
equilibrium [iːkwi'libriəm] *n.* 平衡；平静；均衡；保持平衡的能力
equilibrium state 平衡（状态）
equipment [i'kwipmənt] *n.* 设备；装备
equisite ['rekwizit] *a.* 需要的；必要的
equivalent [i'kwivələnt] *n.* 等价物，相等物；*a.* 相等的，相当的
erroneous [i'rəunjəs] *a.* 错误的
error ['erə] *a.* 误差；差错
essentially [i'senʃəli] *ad.* 基本上；主要地
ester ['estə] *n.* 酯
estimate ['estimeit] *vt.* 估计
estimation [esti'meiʃən] *n.* 估计
-ete [-it] 丁环（四元不饱和杂环）
ethanal ['eθənæl] *n.* 乙醇
ethane [eθein] *n.* 乙烷
ethanoic [eθə'nɔik] acid 乙酸
etherate ['iːθəreit] *n.* 醚化物
ethereal [i'θiəriəl] *a.* 轻的；像空气的
ethoxy- [e'θɔksi] 乙氧基
ethoxyethylene [e'θɔksi'eθiliːn] *n.* 乙氧基乙烯
ethyenedioxy- ['eθiliːnˌdai'ɔksi] 亚乙基二氧基
ethyl ['eθil] *n.* 乙基
ethyl acetate 醋酸乙酯；乙酸乙酯
ethyl methyl ether ['eθil'miθil'iːθə] 甲乙醚
ethyl methyl ketone 甲乙酮
ethyl vinyl ether ['eθil'vainil'iːθə] 乙基乙烯基醚
ethylene ['eθiliːn] *n.* 乙烯
ethylene glycol ['eθiliːn'glaikɔl] *n.* 乙二醇
ethyne [e'θain] *n.* 乙炔
ethynyl [e'θainil] *n.* 乙炔基
e-tidine [-etədiːn] 丁啶（含氮四元饱和杂环）
etymologist [eti'mɔlədʒist] *n.* 词源学
evaporation [ivæpə'reiʃən] *n.* 蒸发
evenly ['iːvənli] *ad.* 均匀地；平稳地
everyday ['evridei] *a.* 日常的；每日的
evident ['evidənt] *a.* 明显的
exception [ik'sepʃən] *n.* 除外；例外；反对；异议
exhale [iks'heil] *vt.* 呼入
exhibit [ig'zibit] *vt.* 表示；显示
exothermic [eksəu'θəːmik] *a.* 发热的；放出热量的
expect [iks'pekt] *vt.* 期望；预期
expedient [iks'piːdiənt] *a.* 有利的
expel [iks'pel] *vt.* 驱除
experience [iks'piəriəns] *n.* 经验
explosion [iks'pləuʒən] *n.* 爆发；发出；爆炸；[矿] 煤气爆炸
exponent [eks'pəunənt] *n.* 指数
extension [iks'tenʃən] *n.* 伸展；扩大
extent [iks'tent] *n.* 程度；范围
external [eks'təːnl] *a.* 外部的；外界的
extinguish [iks'tiŋgwiʃ] *vt.* 熄灭；消灭；压制；使黯然失色
extractive [iks'træktiv] *a.* 抽提的；萃取的
extractive distillation 萃取蒸馏
extraterrestrial ['ekstrətə'restriəl] *a.* 地球以外的
extrude [eks'truːd] *vt.* 挤压；模压

F

fabric [fæbrik] *n.* 织品；织物；布
fabricate ['fæbrikeik] *vt.* 制造；二次加工
falls [fɔːlz] *n. pl.* 瀑布
familiar [fæ'miljə] *a.* 熟悉的
family ['fæmili] *n.* 族
feature ['fiːtʃə] *n.* 特点；特征
feed [fiːd] *v.* & *n.* 进料；供料；原料
feedstock ['fiːdstɔk] *n.* 给料（指供送入机器或加工厂的原料）
ferric ['ferik] *a.* 正铁的；三价铁的

ferrous ['ferəs] *a.* 亚铁的；二价铁的
fertilize ['fəːtilaiz] *vt.* 使肥沃；施肥
fertilizer [fəːtilaizə] 肥料；[动] 受精媒介物
filings ['failiŋz] *n.* & *pl.* 锉屑；金属屑
fillip ['fillip] *n.* & *v.* 刺激；刺激因素；弹指
filter ['filtə] *n.* 滤器；滤纸；*vi.* 过滤
filtrate ['filtreit] *vt.* & *vi.* 过滤；*n.* 滤液
filtration [fil'treiʃən] *n.* 过滤；渗入
fine [fain] *a.* 细的
fire-fighter ['faiəfaitə] *n.* 消防队员
fit [fit] *vt.* 安装
fix [fiks] *v.* 固定
fixation [fik'deiʃən] *n.* 固定
flake [fleik] *n.* 片；薄片
flask [flaːsk] *n.* 瓶；长颈瓶，烧瓶
flexible ['fleksəbl] *a.* 易操作的；易适应的
fluorescent [fluə'resənt] *a.* 荧光的
fluoride ['fluəraid] *n.* 氟化物
fluorine ['flu(ː)əriːn] *n.* 氟
flush [flʌʃ] *vt.* 淹没；冲洗
follow ['fɔləu] *vt.* 遵循；使用
foodstuff ['fuːdstʌf] *n.* 食品
formal ['fɔːməl] *a.* 形式上的
formaldehyde [fɔː'mældihaid] *n.* 甲醇
formation [fɔː'meiʃən] *n.* 形成
formic ['fɔːmik] acid 甲酸；蚁酸
formula ['fɔːmjulə] *n.* 公式；分子式
formulations [fɔːmju'leiʃən] *n.* 用公式表示；明确地表达；作简洁陈述
formyl group＝methanoyl 甲醛基
forward reaction 正反应
fossil ['fɔsl] *n.* 化石，僵化的事物；*a.* 化石的，陈腐的，守旧的
fractional ['frækʃənl] *a.* 分数的
fractional condensation 分凝
fractionating tower ['frækʃəneitiŋ'tauə] 精馏塔
fragrance ['freigrəns] *n.* 芬芳；香气；香味
fragrant ['freigrənt] *a.* 芳香的
freeze [friːz] *v.* （使）结冰；（使）冷冻；冻结
freezing point depression 冰点降低（法）测定（法）
froth [frɔθ] *n.* 泡沫
frozen ['frəuzn] *vt.* 凝结；冻结
fruitless ['fruːtlis] *a.* 无效果的；无益的
fumaric [fjuː'mærik] acid 反丁二酸
function ['fʌŋkʃən] *n.* 函数
functional ['fʌŋkʃənl] group 官能团
fundamental [fʌndə'mentl] *a.* 基本的；根本的；重要的
fundamentelly ['fʌndə'mentəli] *ad.* 基本上
furan ['fjuərən] *n.* 呋喃
furnish ['fəːniʃ] *vt.* 提供；供给
furyl ['fjuəril] *n.* 呋喃基
fuse [fjuːz] *n.* 引火线
fused [fjuːzd] *a.* 熔融的
fusion ['fjuːʒən] *n.* 熔化；熔合；合成

G

gain [gein] *n.* 增加
gasometric [gæsəu'metrik] analysis 量气分析
generic [dʒi'nerik] *a.* 类的；属的
Geneva [dʒi'niːvə] *n.* 日内瓦（地名）
gentle ['dʒentl] *a.* 温和的；轻轻的
geometry [dʒi'ɔmitri] *n.* 几何学
germa- ['kəmə-] 锗杂
German ['dʒəːmən] *n.* 德语；德国人
germane [dʒəː'mein] *n.* 锗
glassware ['glaːswεə] *n.* 玻璃器皿
glow [gləu] *vi.* 灼热；无焰燃烧；发光
glowing ['gləuiŋ] *a.* 灼热的；通红的
glucose [gluːkəus] *n.* 葡萄糖
glutaric [gluːtæric] acid 戊二酸
glycerol ['glisəˌrɔl] *n.* 甘油；丙三醇
graduate ['grædjueit] *a.* 研究院的；已得学士学位的
graduate student 研究生
grain [grein] *n.* 颗粒
gram [græm] *n.* 克
granulate ['grænjuleit] *vt.* 轧碎；使成粒状
granulated ['grænjuleitid] *a.* 粒状的；成粒的
gravimetric [grævi'metrik] analysis 重量分析
grease [griːz] *vt.* 润滑；*n.* 润滑脂
Greek [griːk] *n.* 希腊文
greenish-yellow ['griːniʃ'jeləu] *a.* 黄绿色的

Grignard reagent [ˌgriːnjaːd riːˈeidʒənt] 格氏试剂

gunpowder [ˈgʌnpaudə] *n.* 火药

gypsum [ˈdʒipsəm] *n.* 石膏

H

halide [ˈhælaid] *n.* 卤化物

halogen [ˈhælədʒən] *n.* 卤素

halogenate [ˈhælədʒəneit] *v.* 卤化

hammer [ˈhæmə] *v.* 锤击；锤打

hard-to-separate 难分离的

hasten [ˈheisn] *vt.* 加速

hazardous [ˈhæzədəs] *a.* 危险的；冒险的；碰运气的

hectane [ˈhektein] *n.* 一百烷

helical [ˈhelikəl] *a.* 螺旋状的

heliotrope [ˈheljətrəup] *n.* 向日性植物；天芥菜花的气味

helix [ˈhiːliks] *n.* 螺旋；螺旋状物

hemoglobin [hiːməuˈgləubin] *n.* 血红蛋白

hence [hens] *ad.* 因此

heneicosane [heˈneikəsein] *n.* 二十一烷

hentriacontane [ˈhentraiəˈkɔntein] *n.* 三十一烷

heptane [ˈheptein] *n.* 庚烷

heterocyclic [ˌhetərəuˈsaiklik] *a.* 杂环的

heterocyclic [ˈhetərəuˈsaiklik] *a.* 杂环（族）的

hexacontane [heksəˈkɔntein] *n.* 六十烷

hexane [hekˈsein] *n.* 己烷

hexanoic [ˈhekseiˈnəuik] acid 己酸

4-hexenoic [ˈheksiˈnɔik] acid 4-己酸

hexyl alcohol [ˈheksilˈælkəhɔl] *n.* 己醇

hood [hud] *n.* 盘

human [ˈhjuːmən] *a.* 人（类）的

hydrated [ˈhaidreitid] *a.* 水合的；*v.* 使水合；使成水合物

hydration [hai ˈdreiʃən] *n.* 水合作用

hydrazine [ˈhaidrəziːn] *n.* 肼；联氨

hydride [ˈhaidraid] *n.* 氢化物

hydrocarbon [ˈhaidrəˈkaːbən] *n.* 烃

hydrochloric [haidrəuˈklɔːrik] *a.* 氯化氢的；盐酸的

hydroelectric [haidrəiˈlektrik] *a.* 水电的；水力发电的

hydrogen cyanide [ˈhaidrəudʒənˈsaiənaid] 氰化氢

hydrogenation [haidrədʒˈneinʃən] *n.* 加氢；氢化（作用）

hydronium [haiˈdrəuniəm] ion 水合氢离子

5-hydroxyhexanal [haiˈdrɔksiˈhekʃənəl] *n.* 5-羟基己醛

hydroxyl [haiˈdrɔksil] *n.* 羟基；氢氧

hydroxyl group 羟基

hydroxyl radical 氢氧根

hyphen [ˈhaifən] *n.* 连字号

hypochlorous acid [ˈhaipəˈklɔːrəsesid] 次氯酸

I

ibuprofen [aibjuˈprufin] *n.* [药] 异丁苯丙酸；布洛芬（抗炎、镇痛药）

identifiable [aiˈdentifaiəbl] *a.* 可识别的

illustrate [ˈiləstreit] *vt.* 说明

illustrative [ˈiləstreitiv] *a.* 说明的；示范的

imagine [iˈmædʒin] *vt.* 想象

imidazole [ˌimiˈdæzəul] *n.* 咪唑

imidazolyl *n.* 咪唑基

immaterial [iməˈtiəriəl] *a.* 不重要的

immune [iˈmjuːn] *a.* 免疫的；不受影响的

imply [imˈplai] *vt.* 含有……的意思；暗指

inactive [inˈæktiv] *a.* 不活泼的

incendiary [inˈsendjəri] *a.* 纵火的

incentive [inˈsentiv] *n.* & *a.* 刺激（的）

indazole [ˈindəzəul] *n.* 吲唑

indazolyl [ˈindəzɔlil] *n.* 吲唑基

indicate [ˈindikeit] *vt.* 指出；表示

indicator [ˈindikeitə] *n.* 指示剂

indispensable [indisˈpensəbl] *a.* 必不可少的

individual [indiˈvidjuəl] *a.* 个别的；单独的

indole [ˈindəu(ɔ)l] *n.* 吲哚；氮杂茚

indolizine [inˈdɔliziːn] *n.* 中氮茚

indolizinyl [inˈdɔlizinil] *n.* 中氮茚基；4-*n*-吲哚基

indolyl [ˈindəlil] *n.* 吲哚基
- ine [-iːn] 己因（含氮六元不饱和杂环）
inert [iˈnəːt] *a.* 无活动的；惰性的；迟钝的
inferior [inˈfiəriə] *a.* 较差的
information [ˈinfəmeiʃən] *n.* 情报；知识
infrequently [inˈfriqwəntli] *ad.* 不经常
ingenious [inˈdʒiːniəs] *a.* 巧妙的；有创造才能的
ingredient [inˈgriːdiənt] *n.* 成分；因素
inhale [inˈheil] *vt.* 吸入
innocuous [iˈnɔkjuəs] *a.* 无害的；无毒的
inorganic [inɔːˈgænic] *a.* 无机的
insert [inˈsəːt] *vt.* 插入
insertion [inˈsəːʃən] *n.* 插入；嵌入
insight [ˈinsait] *n.* 见识；见解
institutional [ˌinstiˈtjuːʃənəl] 规定的；学校的
instructor [insˈtrʌktə] *n.* 教师；导师
insulate [ˈinsjuleit] *vt.* 使绝缘；隔离
insulation [insjuˈleiʃən] *n.* 绝缘
interfere [intəˈfiə] *vt.* 干涉；妨碍
interference [intəˈfiərəns] *n.* 干涉
intermolecular [intə(ː)məˈlekjulə] *a.* 分子间的；存在（或作用）于分子间的
interpose [ˈintəːˈpəuz] *vt.* 插入
intestine [inˈstestin] *n.* （常用复）肠
invert [inˈvəːt] *vt.* 颠倒
investigate [inˈvestigeit] *vt.* 调查研究
involve [inˈvɔlv] *vt.* 涉及
iodate [ˈaiədeit] *n.* 碘酸盐
iodide [ˈaiədaid] *n.* 碘化物
ionic [aiˈɔnik] *a.* 离子的
ionization [aiənaiˈzeiʃən] *n.* 离子化；电离
ionize [ˈaiənaiz] *vt.* 离子化；电离
-iridine [-iridiːn] 丙啶（含氮三元饱和杂环）
- irine [-iriːn] 丙因（含氮不饱和三元杂环）
iron [ˈaiən] *n.* 铁
iron oxide 氧化铁；三氧化二铁
irrespective [irisˈpektiv] *a.* 不顾的；不考虑的
isobenzofuran [aiθəˌbenzəu ˈfjuərən] *n.* 异苯并呋喃
isobenzofuranyl [aiθəˌbenzəu ˈfjuərənil] *n.* 异苯并呋喃基
isobutoxy- [ˈaisəuˈbjuːtɔksi] 异丁氧基
isoindole [aisəˈindəul] *n.* 异吲哚
isoindolyl [aisəˈindəlil] *n.* 异吲哚基
isolate [ˈaisəleit] *vt.* 分离；离析
isomer [ˈaisəumə] *n.* 异构体；同分异构体
isomerization [aiˌsɔməraiˈzeiʃən] *n.* 异构化（作用）
isopropoxy- [ˈaisəpreˈpɔksi] 异丙氧基
isoquinoline [aisəˈkwinəliːn] *n.* 异喹啉
isoquinoly [aisəˈkwinəlil] *n.* 异喹啉基
isothermal [ˈaisəuˈθəməl] *a.* 等温线的
isothiazole [aisəˈθaiəzəul] *n.* 异噻唑
isothiazolyl [aisəˈθaiəzəulil] *n.* 异噻唑基
isotope [ˈaisəutəup] *n.* 同位素
italic [iˈtælik] *a.* 斜体字

J

jar [dʒaː] *n.* 广口瓶；罐；缸

K

kerogen [kerədʒən] *n.* [矿] 油母岩质；油原
ketone [ˈkiːtəun] *n.* 酮
kilocalory [ˈkiləukæləri] *n.* 千卡
kilojoule [ˈkilədʒuːl] *n.* 千焦耳
kinetics [kaiˈnetiks] *n.* 动力学

L

laboratory [ləˈbɔrətəri] *n.* 实验室
lactic [ˈlæktik] *a.* 乳的
lactic [læktik] *a.* 乳汁的
lactic acid 乳酸
landlocked [ˈlændlɔkt] *a.* 为陆地围住的；生活在与海隔绝的水中的

lard [laːd] *n.* 猪油
Latin [ˈlætin] *n.* & *a.* 拉丁语（的）
lattice [ˈlætis] *n.* 格子；点阵
lauric [ˈlɔːrik] acid 月桂酸；十二酸
lazy [ˈleizi] *a.* 懒惰的；惰性的
lead [led] *n.* 铅
leak [liːk] *vi.* 漏出；渗漏
leaven [ˈlevən] *vt.* 使发酵
lemon [ˈlemən] *n.* 柠檬
liable [ˈlaiəbl] *a.* 有……倾向的
lightning [ˈlaitniŋ] *n.* 闪电
ligroin [ˈligrəuin] *n.* 挥发油；石油醚；轻石油
likewise [ˈlaikwaiz] *ad.* 同样
lime [laim] *n.* 石灰
liquefy [ˈlikwifai] *vt.* 使液化
lithium [ˈliθiəm] *n.* 锂
litmus [ˈlitməs] *n.* 石蕊
litmus paper 石蕊试纸
lively [ˈlaivli] *a.* 活泼的
load [ləud] *n.* & *v.* 负荷；负载；装填
locant [ˈləukənt] *n.* 位次
loss [lɔs] *n.* 损失
lubricant [ˈluːbrikənt] *a.* 润滑的；*n.* 润滑剂
lucite [ˈluːsait] *n.* 有机玻璃
lye [lai] *n.* 碱液

M

macro [ˈmækrəu] analysis 常量分析
magnalium [mægˈneiliəm] *n.* 镁铝合金
magnesium [mæg ˈniːzjəm] *n.* 镁
magnesium di(1-propanolate) [dai-wʌn-proupəˈnɔleit] 二正丙醇镁
magnetic [mægˈnetik] *a.* 磁力的
magnitude [ˈmægnitjuːd] *n.* 量；大小
major [ˈmeidʒə] *a.* 主要的
maleic [maˈliːik] anhydride 马来酸酐；顺丁烯二酸酐
malleability [mæliəˈbiliti] *n.* 可锻性；展性
malleable [ˈmæliəbl] *a.* 有延展性的；可锻的
malonic [məˈlɔnik] acid 丙二酸
manganese [mæŋgəˈniːz] *n.* 锰
manipulation [məˈnipjuˈleiʃən] *n.* 操作；操纵
manner [ˈmænə] *n.* 方式；方法
manufacture [mænjuˈfæktʃə] *n.* 制造
mark [maːk] *n.* 标志；记号；痕迹
mashing [mæʃiŋ] *n.* 捣碎
master [ˈmaːstə] *vt.* 掌握
material balance 物料平衡
meadowsweet [ˈmedəuswiːt] *n.* 珍珠花；麻叶绣球
meaning [ˈmiːniŋ] *n.* 意义
mechanism [ˈmekənizəm] *n.* 机制；机构；机械装置
medium [ˈmiːdjəm] *n.* 媒介质
melmac [ˈmelmæk] *n.* 三聚氰胺-甲醛合成树脂和黏合剂；蜜胺树脂
melt [melt] *vt.* & *vi.* 熔化；熔解
melting point 熔点
memorize [ˈmeməraiz] *vt.* 记住
meniscus [miˈniskəs] *n.* 液面；弯月面
mercura- [ˈməkjurə-] 汞杂
mercuric [məːˈkjuərik] *a.* 汞的
mercurous [ˈməːkjurəs] *a.* 亚汞的
mercury [ˈməːkjuri] *n.* 水银；汞
meso [ˈmiːsəu] analysis 半微量分析
methacrylate [meˈθækrəleit] *n.* 异丁烯酸盐（酯）；甲基丙烯酸酯树脂
methane [ˈmeθein] *n.* 甲烷
methanoic [meθəˈnɔik] acid 甲酸
methanol [meθənəul] *n.* 甲醇
methlenedioxy- [ˈmeθiliːn，daiˈɔksi] 亚甲基二氧基
methodically [miˈθɔdikəli] *ad.* 有条不紊
methoxy- [məˈθɔksi] 甲氧基
2-methoxyanthracene [məˈθɔksiˈænθrəsiːn] *n.* 2-甲氧基蒽
methyl [ˈmeθil] *n.* 甲基
methyl orange 甲基橙
mg. ＝milligram 毫克
micro [ˈmaikrəu] analysis 微量分析
microcapillary [maikrəˈkəˈpiləri] *n.* 微型毛细管
mine [main] *n.* 矿
mineral [ˈminərəl] *n.* 矿物；矿石
minimal [ˈminiməl] *a.* 最小的；最低的

minor [ˈmainə] *a.* 次要的
miscibility [misibiliti] *n.* 可混合性
miscible [ˈmisibl] *a.* 易混合的
misplace [ˈmisˈpleis] *vt.* 错放
missile [ˈmisail] *n.* 导弹；发射物
mixture [ˈmikstʃə] *n.* 混合物
moderately [ˈmɔdəritli] *ad.* 中等地；适度地
modify [ˈmɔdifai] *vt.* 变更；修改
moist [mɔist] *a.* 潮湿的；湿润的
mold/mould [məuld] *vt.* 模塑
mole [məul] *n.* 摩尔
molecular structure 分子结构
molecule spectra [ˈmɔlikjuːlˈspektrə] *n.* 分子光谱
monatomic [mɔnəˈtɔmik] *a.* 单原子的
monomer [ˈmɔnəmə] *n.* 单体；单聚物
monoxide [məˈnɔksaid] *n.* 一氧化碳
moreover [mɔːˈrəuvə] *ad.* 再者；此外
mount [maunt] *vt.* 装上，设置，制作……的标本；*vi.* 爬上，增长
MS/mass spectrometry [mæs spekˈtrɔmitri] 质谱
multiply [ˈmʌltiplai] *vt.* & *vi.* 乘
muscular [ˈmʌskjulə] *a.* 肌肉的
mutual [ˈmjuːtjuəl] *a.* 相互的；共有的

N

namely [ˈneimli] *ad.* 即；也就是
naphthalene [ˈnæfθəliːn] *n.* 萘
naphthoic [ˈnæfθɔik] acid 萘甲酸
naphthol [ˈnæfθɔl] *n.* 萘酚
naphthyl [ˈnæfθil] group 萘基
2- naphthyloxy- [ˈnæfθiˈlɔksi] 2-萘氧基
naphthyridine [ˌnæfθəˈridiːn] *n.* 1,5 - 二氮杂萘
naphthyridinyl [ˌnæfθəˈridinil] *n.* 1,5 - 二氮杂萘基
neck [nek] *n.* 颈；颈部
negative [ˈnegətiv] *a.* 负的；阴的
negative ion 负离子
neopentane [niːəuˈpentein] *n.* 新戊烷
nerve [nəːv] *n.* 神经
neutralization [ˌnjuːtrəlaiˈzeiʃən] *n.* 中和
neutralize [ˈnjuːtrəlaiz] *vt.* 使中和
nicely [ˈnaisli] *ad.* 精确地；恰好地
nickel [ˈnikl] *n.* 镍，镍币；*vt.* 镀镍于
nickel [ˈnikl] *n.* 镍
nitrate [ˈnaitreit] *n.* 硝酸盐
nitric acid [ˈnaitrik æsid] 硝酸
nitride [ˈnaitraid] *n.* 氮化物
nitrile [ˈnaitrail] *n.* 腈
nitrogen [ˈnaitridʒən] *n.* 氮
nitrous acid [ˈnaitrəs æsid] 亚硝酸
nodule [ˈnɔdjuːl] *n.* 根瘤；瘤状物
nomenclature [nəuˈmenklətʃə] *n.* 命名法；专门术语
nomenclature [nəuˈmenklətʃə] *n.* 命名法
nonacontane [nɔnəˈkɔntein] *n.* 九十烷
nonane [ˈnɔnein] *n.* 壬烷
nonbenzenoid [ˈnɔnˈbenziːnɔid] *a.* 非苯（环）型的
non-conductor [ˈnɔnkənˈdʌktə] *n.* 非导体
nonmetal [ˈnɔnˈmetl] *n.* 非金属
nucleation [ˌnjuːkliˈeiʃən] *n.* 成核；晶核过程
nucleophile [ˈnjuːkliəfail] *n.* 亲核试剂
numeral [ˈnjuːmərəl] *n.* 数字
numerator [ˈnjuːməreitə] *n.* 分子
numerator [ˈnjuːməreitə] *n.*（分数中的）分子
nylon [ˈnailən] *n.* 尼龙；聚酰胺纤维

O

object [ˈɔbdʒikt] *n.* 目的
observe [əbˈzəːv] *vt.* 观察
obvious [ˈɔbviəs] *a.* 明显的
-ocine [-əusiːn] 辛因（含氮八元不饱和杂环）
octacontane [ɔktəˈkɔntein] *n.* 八十烷
octane [ˈɔktein] *n.* 辛烷
odds [ɔdz] *n.*（用作单或复）不等；差异
odorless [əudəlis] *n.* 没有气味的；无臭的
offset [ˈɔːfset] *vt.* 补偿；弥补；抵消
-ole [-əul] 氮杂戊（含氮五元不饱和杂环）
olefin [ˈəuləfin] *n.* 烯烃
olefins [əuləfin] *n.* 石蜡

-olidine [-əulədiːn] 戊啶（含氮五元饱和杂环）

-onine [-əuniːn] 壬因（含氮九元不饱和杂环）

opposing [ə'pəuziŋ] *n.* 相反；相对；反抗

option ['ɔpʃən] *n.* 选择

orange ['ɔrindʒ] *n.* 柑，橘；橙色

order ['ɔːdə] *n.* 级数

orient ['ɔːriənt] *vt.* 定向；取向

origin ['ɔ ridʒin] *n.* 起源；来历

original [ə'ridʒənəl] *a.* 最初的，原始的，独创的，新颖的；*n.* 原物，原作

osmometry [ɔz'mɔmitri] *n.* 渗透压；渗透压测定法

otherwise [ʌðəwaiz] *ad.* 其他

outermost ['əutəməust] *a.* 最外层的

output ['autput] *n.* 产量

oven ['ʌvən] *n.* 炉；烤炉

overall yield 总产率

overhead ['əuvə'hed] *n.* 塔顶馏出物

oxa- [ɔksə-] 氧杂，噁

oxalic [ɔk'sælik] acid 草酸；乙二酸

oxathiolane [ɔksə'θaiəlein] *n.* 噁噻烷

oxazole ['ɔksəzəul] *n.* 噁唑

oxidation [ɔksi'deiʃən] *n.* 氧化

oxidation number 氧化值

oxide ['ɔksaid] *n.* 氧化物

oxidize ['ɔksidaiz] *v.* 氧化

oxirane ['ɔksirein] *n.* 环氧乙烷；氧杂丙环

oxy-acetylene [ɔksiə'setliːn] *a.* 氧炔的；*n.* 氧乙炔

oxygen ['ɔksidʒən] *n.* 氧

P

paint [peint] *n.* 油漆；涂料

palladium [pə'leidiəm] *n.* 钯

palmitic [pæl'mitik] acid 软脂酸；十六酸

pan [pæn] *n.* 盘

parallax ['pærəlæks] *n.* 视差

parallel ['pærəlel] *a.* 平行的

paramagnetic [pærəmæg'netik] *a.* 顺磁性的

parent ['pæərənt] *n.* 母体

parent compound 母体化合物

parentheses [pə'renθisiːz] *n.* 圆括号

partial ['paːʃəl] *a.* 部分的；不完全的

partial pressure ['paːʃəl'preʃə] 分压

participation [paːtisi'peiʃən] *n.* 参与

particle [paːtikl] *n.* 粒子；点；微粒

particular [pə'tikjulə] *a.* 特别的

passage ['pæsidʒ] *n.* 通过

paste [peist] *n.* 浆糊，膏；*vt.* 粘贴

pattern ['pætən] *n.* 模型；形式

peanut ['piːnʌt] *n.* 花生

peculiar [pi'kjuːliə] *a.* 特殊的

pelletize ['pelitaiz] *vt.* 使成小球形

penguin ['peŋgwin] *n.* 企鹅

pentacontane [pentə'kɔntein] *n.* 五十烷

pentane ['pentein] *n.* 戊烷

percentage [pə'sentidʒ] *n.* 百分数；百分比

perchloric acid [pə'klɔːrik æsid] *n.* 高氯酸

perhaps [pə'hæps] *ad.* 或许

periodate [pe'raiədeit] *n.* 高碘酸盐

periodic [piəri'ɔdik] *a.* 周期的

periodic table 周期表

permanganate [pəː'mæŋgənit] *n.* 高锰酸盐

permit [pə'mit] *vt.* 准许

peroxide [pə'rɔksaid] *n.* 过氧化物

persist [pə'sist] *vi.* 坚持

phase [feiz] *n.* 时期；阶段；相；状态

phenethyl ['fenəθil] *n.* 苯乙醇

phenolphthalein [fiːnɔl'fθæleiːn] *n.* 酚酞

phenoxy- [fi'nɔksi] 苯氧基

phenyl ['fiːnil] group 苯基

1- phenylethanone 1-苯基乙酮

phenylmagnesium bromide ['fenilmæ'gniːziəm 'brəumaid] 溴化苯基镁

phlogiston [flɔ'dʒistən] *n.* 燃素

phospha- ['fɔsfə-] 磷杂

phosphate ['fɔsfeit] *n.* 磷酸盐

phosphoric [fɔs'fɔrik] *a.* 磷的

phosphorin ['fɔsfrin] *n.* 磷杂己因

phosphorinane ['fɔsfɔrinein] *n.* 磷杂己环

phosphorus ['fɔsfərəs] *n.* 磷

phthalazine ['fθləziːn] *n.* 2,3-二氮杂萘

phthalic ['θælik] anhydride 邻苯二甲酸酐

phthalic ['θælik] acid 邻苯二甲酸

physicochemical ['fizikəu'kemikəl] *a.* 物理化学的

physiologist [fiziˈɔlədʒist] *n.* 生理学家
picric acid [ˈpikrikˈæsid] *n.* 苦味酸；2,4,6-三硝基苯酚
pile [pail] *n.* 反应堆；堆
pinacol [ˈpinəkɔl] *n.* 频哪醇；2,3-二甲基-2,3-丁二醇
piperonal [ˈpipərənæl] *n.* 胡椒醛
pipette [piˈpet] *n.* 吸移管；吸量管
plainly [ˈpleinli] *ad.* 单纯地
plane [plein] *n.* 平面
plastic [ˈplæstik] *n.* 塑料；*a.* 可塑的
plasticizer [ˈplæstisaize] *n.* 增塑剂
plate [pleit] *n.* 板；塔板
plentiful [ˈplentiful] *a.* 大量的；丰富的
plug [plʌg] *vt.* 塞住；堵住
plumb [plʌm] *n.* 铅锤；铅弹
plumba- [ˈplʌmbə-] 铅杂
pole [pəul] *n.* 极；电极
polonium [pəˈləuniəm] *n.* 钋
polymer [ˈpɔlimə] *n.* 聚合物
polyurethane [pɔliˈjuəriθein] *n.* 聚亚氨酯
popularly [ˈpɔpjuləli] *ad.* 通俗地；普通地
portion [ˈpɔːʃən] *n.* 部分
position [pəˈziʃən] *vt.* 定位；安放
positive [ˈpɔzətiv] *a.* 正的；阳的
positive ion 正离子
positively [ˈpɔzitivli] *ad.* 确实地；毫无疑问地
possess [pɔˈzes] *vt.* 有；具有
pot [pɔt] *n.* 锅
potassium [pəˈtæsjəm] *n.* 钾
potassium chlorate 氯酸钾
potassium nitrate [pəˈtæsjəmˈnaitreit] *n.* 硝酸钾
potassium nitrite [pəˈtæsjəmˈnaitrait] 亚硝酸钾
potassium phenoxide [fiˈnɔksaid] *n.* 苯酚钾
potassium *tert*-butoxide [bjuˈtɔksaid] *n.* 叔丁醇钾
precaution [priˈkɔːʃən] *n.* 预防；防范
preceed [priˈsiːd] *vt.* 在……之前；先于
precipitate [priˈsipiteit] *vt.* & *vi.* （使）沉淀；*n.* 沉淀物
precise [priˈsais] *a.* 精确的
precisely [priˈsaisli] *ad.* 精确地
preconcentrate [ˌpriˈkɔnsentreit] *n.* 预（先）浓缩物
preference [ˈprefərəns] *n.* 优先；选择
prefix [ˈpriːfiks] *n.* 前缀；词头
preliminary [priˈliminəri] *a.* & *n.* 初步；开端；开始
preventative [priˈventətiv] *n.* 预防方法；预防措施
primary amine 伯胺
principle [ˈprinsəpl] *n.* 原理；原则
procedure [prəˈsiːdʒə] *n.* 程序；处置
proceed [prəˈsiːd] *vt.* 进行
process [prəˈses] *vt.* 加工；处理；*n.* 过程；工艺；方法
processing [prəuˈsesiŋ] *n.* 处理；加工
profitably [ˈprɔfitəbli] *ad.* 有利可图地
propane [ˈpəupein] *n.* 丙烷
propanoic [ˈprəupəˈnɔik] acid 丙酸
2- propanol [ˈprəupənɔl] *n.* 2-丙醇
properly [ˈprɔpəli] *ad.* 适当地
property [ˈprɔpəti] *n.* 性质；特性
propionaldehyde [ˈprəupiəˈnældihaid] *n.* 丙醛
proposition [ˌprɔpəˈzeiʃən] *n.* 意见；见解；事情
propoxy- [prəˈpɔksi] 丙氧基
propyl [ˈprəupil] *n.* 丙基
propyne [ˈprəupain] *n.* 丙炔
protect [prəˈtekt] *vt.* 保护
protein [ˈprəutiːn] *n.* 蛋白质；*a.* 蛋白质的
province [ˈprɔvins] *n.* 领域
provision [prəˈviʒən] *n.* 规定；供应
pseudobinary [(p) sjudəˈbainəri] *n.* 伪；假
p. s. i. g. =pounds per square inch guage [ˈpaunds pəːskwεə intʃgeidʒ] 磅/平方英寸
pure [pjuə] *a.* 纯粹的
purification [pjuərifiˈkeiʃən] *n.* 清洗；净化；提纯
purify [ˈpjuərifai] *vt.* 使纯净；提纯，精制；*vi.* 纯净
purine [ˈpjuəriːn] *n.* 嘌呤
purinyl [ˈpjuərinil] *n.* 嘌呤基
pyeogallol [ˈpaiərəˈgælɔl] *n.* 1,2,3-三酚；连苯三酚
pyran [ˈpairæn] *n.* 吡喃
pyranyl [ˈpairænil] *n.* 吡喃基
pyrazine [ˈpirəziːn] *n.* 吡嗪
pyrazinyl [ˈpirəzinil] *n.* 吡嗪基
pyrazole [ˈpairəzəul] *n.* 吡唑
pyrazolyl [ˈpairəzəulil] *n.* 吡唑基
pyrene [ˈpairiːn] *n.* [植] 分核；小坚果
pyridazine [pairiˈdæziːn] *n.* 哒嗪
pyridazinyl [pairiˈdæzinil] *n.* 哒嗪基

pyridine ['piridine] *n.* 吡啶
pyridinyl ['piridinil] *n.* 吡啶基
pyrimidine [pai'rimidiːn] *n.* 嘧啶
pyrimidinyl [pai'rimidini] *n.* 嘧啶基
pyrrole [pi'rəul] *n.* 吡咯
pyrrolyl [pi'rəulil] *n.* 吡咯基

Q

qualitative ['kwɔlitətiv] *a.* 性质的；定性的
quality ['kwɔliti] *n.* 质量；品质
quantitative ['kwɔntitətiv] *a.* 量的；定量的
quantum ['kwɔntəm] 量子
quantum theory 量子论
quartz [kwɔːts] *n.* 石英
quicklime ['kwiklaim] *n.* 生石灰
quinazoilinyl [kwnə'zəulinil] *n.* 1,3 - 二氮杂萘基
quinazoline [kwi'næzəliːn] *n.* 1,4 - 二氮杂萘基
quinoline ['kwinəliːn] *n.* 喹啉；氮杂萘
quinolizine [kwi'nɔliziːn] *n.* 喹嗪
quinolizinyl [kwi'nɔlizinil] *n.* 喹嗪基
quinolyl ['kwinəlil] *n.* 喹啉基
quinoxaline [kwi'nɔksəlin] *n.* 1,4 - 二氮杂萘
quinoxalinyl [kwi'nɔksəlinil] *n.* 1,3-二氮杂萘基
quotient ['kwəuʃənt] *n.* 商

R

racemic [rə'siːmik] *a.* 外消旋的
radical ['rædikəl] *n.* 基；根；原子团
radicofunctional ['rædikə'fʌŋkʃənl] *a.* 官能团的
rail [reil] *n.* 铁轨
rainwater ['reinwɔːtə] *n.* 雨水
rate law 速度定律
ratio ['reiʃiəu] *n.* 比率；比例
rational ['ræʃənl] *a.* 合理的
raw material 原料
react [ri(ː)'ækt] *vi.* 反应（with，on）
reaction [ri(ː)'ækʃən] *n.* 反应
readily ['redili] *ad.* 容易地
reason ['riːzn] *vt.* 推理
reasonable ['riːznəbl] *a.* 合理的；正当的
reasonableness ['riːzənəblnis] *n.* 合理性
recombine ['riːkəm'bain] *vt.* 重新结合
recovery [ri'kʌvəri] *n.* 回收；回收率
recrystallize [riː'kristəlaiz] *v.* 再结晶；重结晶
rectangular [rek'tæŋgjulə] *a.* 长方形的；矩形的
reddish-brown ['rediʃbraun] *a.* 红棕的；红褐色的
reduce [ri'djuːs] *vt.* 减少；减轻
refill [ri'fil] *vt.* 再装满
refinement [ri'fainmənt] *n.* 经改进的设计或装置；精制；提炼
reflux ratio 回流比
regenerate [ri'dʒenərit] *vt.* 使新生；*a.* 新生的，更新的
regrease [riː'griːz] *vt.* 重新润滑
regulation [regju'leiʃən] *n.* 调节
reinsertion [riːin'səːʃən] *n.* 重新插入
related [ri'leitid] *a.* 有联系的；相关的
relationship [ri'leiʃənʃip] *n.* 关系
relative ['relətiv] *a.* 相对的；有关的
relax [ri'læks] *vt.* 放松；使松弛
release [riː'liːs] *vt.* 放出
reliever [ri'liːvə] *n.* 救济者
relight ['riː'lait] *vt.* 重新点燃（relighted，relighted 或 relit，relit）
remain [ri'mein] *vi.* 尚须；有待于
remainder [ri'meində] *n.* 残余；剩余物
remnant ['remnənt] *n.* 残余，剩余，残迹 *a.* 剩余的，残留的
removable [ri'muːvəbl] *a.* 可取下的
render ['rendə] *vt.* 提供；给予
renewable [ri'nju(ː)bəl] *a.* 可更新的；可恢复的
replace [ri'pleis] *vt.* 补充；复原；取代
represent [riːpri'zent] *vt.* 说明；代表
reproducible [riːprə'djuːsəbl] *a.* 可重复的；可再现的
reserve [ri'zəːv] *vt.* 保留
residue ['rezidjuː] *n.* 残余物；残渣
resins ['rezin] *n.* 树脂
resist [ri'zist] *vt.* 抵抗；阻挡

resonance NMR/nuclear magnetic ['njuːkliə mæg'netik] NMR 核磁共振

resorciniol [re'zɔːsinɔl] n. 间苯二酚

respectively [ris'pektivli] ad. 分别地

retain [ri'tein] vt. 保持；保留

reveal [ri'viːl] vt. 透露；暴露

reverse reaction 逆反应

revert [ri'vəːt] vi. 恢复原状，回复无晶形；非晶体

revise [ri'vaiz] vt. 修订；校正

right angle 直角

rinse [rins] v. 刷，冲洗掉；n. 漂洗，冲洗

Roman ['rəumən] a. 罗马的

rotary ['rəutəri] a. 旋转的

round-about ['raudəbaut] n. 绕道的；拐弯抹角的

round bottomed flask [raund'bɔtəmd flaːsk] 圆底烧瓶

row [rəu] n. 排；行

rubidium sulfite [ruː'bidiəm'sʌlfait] n. 亚硫酸铷

rubidium sulfate [ruː'bidiəm'sʌlfeit] 硫酸铷

ruin ['ruːin] vt. 破坏；毁灭

rust [rʌst] v. 生锈；n. 锈；铁锈

S

safrole ['seifrəul] n. 黄樟脑；黄樟素

salicylate [sæ'lisileit] n. 水杨酸酯（盐）

salicylate aldehyde 水杨醛

salt [sɔːlt] n. 盐

saltpeter [sɔːlt'piːtə] n. 硝酸钾；硝石

sample ['sæmpl] n. 样品；实例

saucepan ['sɔːspən] n. 长柄有盖的深平底锅

scale [skeil] n. 规模

scarcity ['skεəsiti] n. 缺乏；稀少；不足

scientific literature [saiən'tifik'literitʃə] n. 科学文献

scope [skəup] n. 范围

scratch [skrætʃ] vt. 乱写，抓痕，擦伤；vi. 搔，抓

screen [skriːn] v. 筛分；筛选

seal [siːl] n. 密封；封闭

seaweed ['siːwiːd] n. 海藻；海草

sec. =secondary ['sekəndəri] a. 仲的；第二的

secure [si'kjuə] vt. 获得

seldom ['seldəm] ad. 不经常；很少

self-consistent ['self-kən'sistənt] a. 自相一致的

self-protection ['self-prə'tekʃən] n. 自我保护

selina- ['selinə-] 硒杂

sell [sel] v. 卖；销售（sold，sold，selling）

sensible ['sensəbl] a. 能觉察到的

separation [sepə'reiʃən] n. 分离

seperately ['sepəritli] ad. 分别地

sequence ['siːkwəns] n. 序列；链

series ['siəriːz] n. （单复同）系列

service ['səːvis] n. 服务

share [ʃεə] vt. 共有；分担

sharpen ['ʃaːpən] vt. 加深；磨快

sheet [ʃiːt] n. 薄片

shell [ʃel] n. 壳；层

significant [sig'nifikənt] a. 有意义的

significant figure 有效数字

sila- ['silə-] 硅杂

silane ['silein] n. 硅烷

silica ['silikə] n. 二氧化硅；硅石

silicones ['silikəuns] n. 聚硅氧烷；乙二醇酯纤维；涤纶

silolene ['siləuliːn] n. 硅杂咻；硅杂五元环烯

silver ['silvə] n. 银；a. 银（白）色的

silver nitrate 硝酸银

simplify ['simplifai] v. 简化

simultaneously [siməl'teinjəsli] ad. 同时

sink [siŋk] vi. 沉下；降下（sank 或 sunk，sunk 或 sunken；sinking）

size [saiz] n. 大小；尺寸

slippery ['slipəri] a. 滑的

sluggish [slʌgis] a. 偷懒的；不活泼的

soak [səuk] v. & n. 浸泡；浸渍

soapy ['səupi] a. 肥皂般地；滑腻地

soda ['səudə] n. 苏打；碳酸水

sodium ['səudjəm] n. 钠

sodium benzyl alcoholate ['ælkə'h ɔleit] 醇钠；苯甲醇钠

sodium benzyl oxide 醇钠

sodium chloride 氯化钠

sodium iodate 碘酸钠

sodium methanolate [meθə'nɔleit] 甲醇钠

sodium periodate 高碘酸钠
sodium phenolate [ˈfiːnəleit] 酚钠
solidify [səˈlidifai] *vi.* 凝固
solubility [səljuˈbiliti] *n.* 溶解度
solution [səˈljuːʃən] *n.* 溶液
solvate [ˈsɔlveit] *n.* 溶剂化物
somewhat [ˈsʌmwɔt] *ad.* 有点；稍微
sour [ˈsauə] *a.* 酸的，酸味的；*v.* 变酸
spatial [ˈspeiʃəl] *a.* 空间的
specific value 比值
specify [ˈspesifai] *vt.* 指定；详细说明
specimen [ˈspesimin] *n.* 样品；品种
spinneret [spinəˈret] *n.* 吐丝器；吐丝头
spiral [spaiərəl] *a.* 螺旋形的；*n.* 螺旋
splint [splint] *n.* 薄板的；薄木条；薄金属片
split [split] *vt.* 割裂；分裂
spongy [ˈspʌndʒi] *a.* 多孔的；海绵状的
square [skwɛə] *n.* 正方形
squeeze [skwiːz] *n.* &*v.* 压榨；挤
stainless [ˈsteinlis] *a.* 不锈的
stana- [ˈstænə-] 锡杂
stannic chloride [ˈstænicˈklɔːraid] *n.* 氯化锡
stannous chloride [ˈstænəsˈklɔːraid] *n.* 氯化亚锡
statistical mechanics [stəˈtistikəl miˈkæniks] 统计力学
staudinger [ˈstaudiŋgə] H. 史滔丁格
steam bath 蒸汽浴
stearic [ˈstiˈærik] acid 硬脂酸；十八酸
stem [stem] *n.* 词干
stereochemistry [stiəriəˈkemistri] *n.* 立体化学
stereoselective 立体选择性的
stiba- [ˈstibə-] 锑杂
stibine [ˈstibiːn] *n.* 锑化（三）氢
stiff [stif] *a.* 浓黏的；硬的
stoichiometrie [stɔikiəˈmetrik] *a.* 化学计量的
stomach [ˈstʌmək] *n.* 胃
stopcock [ˈstɔpkɔk] *n.* 活栓；活塞
stopper [ˈstɔpə] *n.* 塞子，制动器，阻塞物，制止者；*v.* 塞住
straightforward [streitˈfɔːwəd] *a.* 直截了当的；简单的；容易的
strict [strikt] *a.* 严格的
strip [strip] *n.* 条；带；片
strong acid 强酸
styron [ˈstairɔn] *n.* 聚苯乙烯
subclass [sʌbklaːs] *n.* 亚纲；子集
subject [sʌbˈdʒekt] *vt.* 遭受；蒙受；*n.* 题目；学科；科目
sublime [səˈblaim] *v.* 提高；（使）升华
submarine [sʌbməˈriːn] *n.* 潜水艇
subsequently [ˈsʌbsikwəntli] *ad.* 随后；其次；接着
substance [ˈsʌbstəns] *n.* 物质
substituent [səbˈstitjuənt] *n.* 取代基
substitutive [ˈsʌbstitjuːtiv] *a.* 取代的
succeeding [səkˈsiːdiŋ] *a.* 连续的
succession [səkˈseʃən] *n.* 连续；继承
succinic [səkˈsinik] anhydride 丁二酸酐
succinic [səkˈsinik] acid 丁二酸；琥珀酸
suction [ˈsʌkʃən] *n.* 抽气；抽水泵
suffix [ˈsʌfiks] *n.* 后缀
suggest [səˈdʒest] *vt.* 提议；建议
suitability [sjuːtəˈbiləti] *n.* 适宜性
sulfate [ˈsʌlfeit] *n.* 硫酸盐
sulfur [ˈsʌlfə] *n.* 硫
sulfuric acid [sʌlˈfjuərik æsid] 硫酸
sulfurous acid [ˈsʌlfərəs æsid] 亚硫酸
sulphide [ˈsʌlfaid] *n.* 硫化物
super-heat [ˈsuːpəˈhiːt] *vt.* 使过热
superposable [sjuːpəˈpəuzəbl] *a.* 可置于上面的
supersaturation [sjuːpəsætʃəˈreiʃən] *n.* 过饱和
surfactant [səːfæktənt] *n.* & *a.* 表面活性剂（的）
surroundings [səˈraundiŋz] *n.* *pl.* （周围）环境
suspend [səsˈpend] *vt.* 吊起；悬挂
Sweden [ˈswiːdn] *n.* 瑞典
swirl [swəːl] *vt.* 使成旋涡；*vi.* 打旋，盘绕
syllable [ˈsiləbl] *n.* 音节
symbol [ˈsimbəl] *n.* 符号；记号
synthetic（al）[sinˈθetik] *a.* 合成的
syringe [ˈsirindʒ] *n.* 注射器，洗涤器；*v.* 注射，冲洗，灌洗
syrup [ˈsirəp] *n.* 糖浆
systematic [ˈsistiˈmætik] *a.* 系统的

T

tallow [ˈtæləu] *n.* 牛脂，动物脂；*vt.* 涂油脂于
taste [teist] *n.* 味道，气味，味觉；*vt.* 尝味道

tasteless ['teistlis] *n.* 无味的

teflon ['teflɔn] *n.* 聚四氟乙烯；特氟隆

tellrua- ['teljuərə-] 碲杂

tension ['tenʃən] *n.* 紧张；绷紧；张力

term [təːm] *n.* （比例或方程的）项；*n.* 术语；字眼

tert. ＝tertiary ['təːʃəri] *a.* 叔的；第三的

test [test] *vt.* 检验；验证；试验

tetrachloride [tetrə'klɔːraid] *n.* 四氯化物

tetrahydrofuran ['tetrə'haidrə'fjuərən] *n.* 四氢呋喃

tetriacontane [tetrətraiə'kɔntein] *n.* 四十烷

thallium ['θæliəm] *n.* 铊

thallium hydroxide 氢氧化铊

theoretical [θiə'retikəl] *a.* 理论的

theoretical plate 理论塔板

therefrom [ðɛə'frɔm] *ad.* 从那里；从而

thermit ['θəːmit] *n.* 铝热剂

thermosetting [θəːməu'setiŋ] *a.* & *n.* 热固；热硬性的

thia- [θaiə-] 硫杂，噻

thiadiazine [θaiədai'æziːn] *n.* 噻二吖嗪

thienyl ['θaiəni] *n.* 噻吩基

thiol ['θaiəul] *n.* 硫醇

thiophene ['θaiəfiːn] *n.* 噻吩

thoroughly ['θʌrəli] *ad.* 十分地；彻底地

thrust [θrʌst] *vt.* 推入；插入

thunderstorm ['θʌndəstɔːm] *n.* 雷阵雨

tilt [tilt] *vt.* 使倾斜；使翘起

tin [tin] *n.* 锡

tip [tip] *n.* 尖端

tissue ['tisjuː] *n.* 组织

titanium [tai'teinjəm] *n.* 钛

titrant ['taitrənt] *n.* 滴定剂

titration [tai'treiʃn] *n.* 滴定

tollow ['tæləu] *n.* 牛脂

toluic [tə'ljuːik] acid 甲基苯甲酸

ton [tʌn] *n.* 吨

trace [treis] *n.* 微量；痕量

trace analysis 痕量分析

transfer ['trænsfəː] *n.* [træns'fəː] *v.* 转移

transmission [trænz'miʃən] *n.* 输出；送电；传递

transparent [træns'pɛərənt] *a.* 透明的

tray tower 盘式塔

triacontane [traiə'kɔntein] *n.* 三十烷

triazine [trai'æzəul] *n.* 三（吖）嗪；三氮己因

triazole [trai'æzəul] *n.* 三唑

tricosane ['traikəsein] *n.* 二十三烷

tridecane ['traidekein] *n.* 十三烷

trimethylacetic [trai'meθilə'siːtik] acid 三甲基乙酸

trimethylacetonitrile ['trai'meθilˌæsitə'naitril] 三甲基乙腈

triphenylmethanol ['traifinil'meθənəl] *n.* 三苯甲醇

triple bond 叁键

tritium ['tritiəm] *n.* 氚；超重氢

tritriacontane [traitraiə'kɔntein] *n.* 三十三烷

trivial ['triviəl] *a.* 平常的；通俗的

tubing ['tjuːbiŋ] *n.* 管子

turbidity [təː'biditi] *n.* 混浊；混乱

turning ['təːniŋ] *n.* 旋屑

twist [twist] *n.* & *vt.* & *vi.* 扭曲；盘旋；曲折歪曲；螺旋状

U

ultimate ['ʌltimit] *a.* 最后的

ultimately ['ʌltimətli] *ad.* 最后；最终

unabbreviated ['ʌnə'briːvieitid] *a.* 未缩写的；未简缩的

unambiguous ['ʌnæm'bigjuəs] *a.* 清楚的；明确的

unbroken ['ʌn'brəukən] *a.* 完整的；未破损

undecane [ʌn'dekein] *n.* 十一烷

underneath [ʌndə'niːθ] *ad.* 在……下面

underwrite ['ʌndərait] *vt.* 把……写在下面

unit [juː'nait] *v.* 结合；化合；团结

unprotected ['ʌnprə'tektid] *a.* 无保护的；未加保护层的

uranium [juə'reiniən] *n.* 铀

urban ['əːbən] *a.* 城市的；市区的

usage ['juːzidʒ] *n.* 用法

utilitarian [juːtili'tɛəriən] *a.* 实用的

utilize ['juːtilaiz] *vt.* 使用；利用

utmost ['ʌtməust] *a.* 最大限度的

UV/ultraviolet [ˈʌltrəˈvaiəlit] *a/n.* 紫外线； 紫外光谱

V

valence [ˈveiləns] *n.* 价（如原子价，化合价，效价）
valeric [vəˈlərik] acid 戊酸
valuable [ˈvæljuəbl] *a.* 有价值的
value [ˈvæljuː] *n.* 价值；值
vanadium [vəˈneidiəm] *n.* 钒；铅矿
vanillic [vəˈnilik] *a.* 香子兰的；香草醛的
vanillin [vəˈnilin，ˈvænilin] *n.* 香草醛；香兰素
vapor [ˈveipə] *n.* （蒸）气
vaporisation＝vaporization [ˌveipəraiˈzeiʃən] *n.* 蒸发；汽化器，喷雾器，蒸馏器
various [ˈvɛəriəs] *a.* 不同的；各种各样的
vegetable [ˈvedʒitəbl] *a.* & *n.* 植物（的）；蔬菜
versatility [vəːsəˈtiləti] *n.* 多功能性
vibrate [vaiˈbreit] *v.* （使）振动；（使）摇摆
vice versa [ˈvaisiˈvəːsə] 反之亦然
vicinity [viˈsiniti] *n.* 附近
vigorous [ˈvigərəs] *a.* 有力的；活泼的；激烈的
vigorously [vigərəsli] *ad.* 精神旺盛地
vinegar [ˈvinigə] *n.* 醋
vinyl [ˈvainil] *n.* 乙烯基
vinyl bromide 溴代乙烯
virtually [ˈvəːtʃuli] *ad.* 实际上；实质上
viscosity [visˈkɔsiti] *n.* 黏度
vocabulary [vəˈkæbjuləri] *n.* 词汇表
volatile [ˈvɔlətail] *a.* 挥发性的
volatilize [vəˈlætilaiz] *vt.* 使挥发
volatolization [vɔlætilaiˈzeiʃən] *n.* 挥发
volume [ˈvɔljum] *n.* 体积
volumetric [vɔljuˈmetrik] *a.* 容量的；容积的；测量容积的
volumetric analysis 容量分析；滴定分析；体积分析

W

wash [wɔʃ] *vt.* 洗涤
waterfall [ˈwɔːtəfɔːl] *n.* 瀑布
weld [weld] *v.* 焊接
welding [ˈweldiŋ] *n.* & *a.* 焊接；焊接的
whatsoever [ˌwɔtsəuˈevə] *prop.* & *a.* 不管；无论；一点儿……也
whence [(h)wens] *n.* 来处，根源；*ad.* 从何处，从哪里
whereas [wɛərˈæz] *conj.* 而
whether [ˈweðə] *conj.* 不管；是否
wire [waiə] *n.* 金属线
woodshed [ˈwudʃed] *n.* 柴间；木料间
wt. ＝weight [weit] *n.* 重量

X

X-ray diffraction [ˈeksˈreidiˈfrækʃən] X射线衍射

Y

yield [jiːld] *vt.* 产生

Z

zinc [ziŋk] *n.* 锌

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