# PART 1 CHEMISTRY AND CHEMICAL INDUSTRY

## Lesson One Elements and Compounds

Elements are pure substances that can not be decomposed into simpler substances by ordinary chemical changes. At present there are 109 known elements. Some common elements that are familiar to you are carbon, oxygen, aluminum, iron, copper, nitrogen, and gold. The elements are the building blocks of matter just as the numerals 0 through 9 are the building blocks for numbers. To the best of our knowledge, the elements that have been found on the earth also comprise the entire universe.

About 85% of the elements can be found in nature, usually combined with other elements in minerals and vegetable matter or in substances like water and carbon dioxide. Copper, silver, gold and about 20 other elements can be found in highly pure forms. Sixteen elements are not found in nature; they have been produced in generally small amounts in nuclear explosions and nuclear research. They are man-made elements.

Pure substances composed of two or more elements are called compounds. Because they contain two or more elements, compounds, unlike elements, are capable of being decomposed into simpler substances by chemical changes. The ultimate chemical decomposition of compounds produces the elements from which they are made.

The atoms of the elements in a compound are combined in whole number ratio, not in fractional parts of an atom. Atoms combined with one another to form compounds which exist as either molecule or ions. A molecule is a small, uncharged individual unit of a compound formed by the union of two or more atoms, if we subdivide a drop of water into smaller and smaller particles, we ultimately obtain a single unit of water known as a molecule of water. This water molecule consists of two hydrogen atoms and one oxygen atom bonded together. We cannot subdivide this unit further without destroying the molecule, breaking it up into its elements. Thus, a water molecule is the smallest unit of the compound water.

An ion is a positive or negative electrically charged atom or group of atoms. The ions in a compound are held together in a crystalline structure by the attractive forces of their positive and negative charges. Compounds consisting of ions do not exist as molecules. Sodium chloride is an example of a non-molecular compound. Although this type of compound consists of large numbers of positive and negative ions, its formula is usually represented by the simplest ratio of the atoms in the compound. Thus, the ratio of ions in sodium chloride is one sodium ion to one chlorine ion.

Compounds exist either as molecules which consist of two or more elements bonded together or in the form of positive and negative ions held together by the attractive force of

their positive and negative charges.

The compound carbon monoxide (CO) is composed of carbon and oxygen in the ratio of one atom of carbon to one atom of oxygen. Hydrogen chloride (HCl) contains a ratio of one atom of hydrogen to one atom of chlorine. Compounds may contain more than one atom of the same element. Methane ("natural gas" $CH_4$) is composed of carbon and hydrogen in a ratio of one carbon atom to four hydrogen atoms; ordinary table sugar (sucrose, $C_{12}H_2O_{11}$) contains a ratio of 12 atoms of carbon to 22 atoms of hydrogen to 11 atoms of oxygen. These atoms are held together in the compound by chemical bonds.

There are over three million known compounds, with no end in sight as to the number that can and will be prepared in the future. Each compound is unique and has characteristic physical and chemical properties. Let us consider in some detail two compounds——water and mercuric oxide. Water is a colorless, odorless, tasteless liquid that can be changed to a solid, ice, at 0℃ and to a gas, steam at 100℃. It is composed of two atoms of hydrogen and one atom of oxygen per molecule, which represents 11.2 percent hydrogen and 88.8 percent oxygen by mass. Water reacts chemically with sodium to produce hydrogen gas and sodium hydroxide, with lime to produce calcium hydroxide, and with sulfur trioxide to produce sulfuric acid. No other compound has all these exact physical and chemical properties; they are characteristic of water alone.

Mercuric oxide is a dense, orange-red powder composed of a ratio of one atom of mercury to one atom of oxygen. Its composition by mass is 92.6 percent mercury and 7.4 percent oxygen. When it is heated to temperatures greater than 360℃, a colorless gas, oxygen, and a silvery liquid metal, mercury, are produced. Here again are specific physical and chemical properties belonging to mercuric oxide and to no other substance. Thus, a compound may be identified and distinguished from all other compounds by its characteristic properties.

## New Words

compound [kɔmpaund] *n.* 化合物
decompose [di:kəm'pəuz] *vt.* 分解
carbon [kɑ:bən] *n.* 碳
oxygen ['ɔksidʒən] *n.* 氧
aluminum [ə'lju:minəm] *n.* 铝
nitrogen [naitridʒən] *n.* 氮
copper [kɔpə] *n.* 铜
silver [silvə] *n.* 银
gold [gəuld] *n.* 金
nuclear ['nju:kliə] *a.* 核的，核能的
ion [aiən] *n.* 离子
positive [pɔzətiv] *a.* 正的，阳性的
negative ['negətiv] *a.* 负的，阴性的

bond [bɔnd] *n.* 键；*vt.* 结合
chlorine ['klɔ:ri:n] *n.* 氯
methane ['meθein] *n.* 甲烷，沼气
mercury ['mə:kjuri] *n.* 汞
mercuric [mə:'kjuərik] *a.* 汞的　水银的
sodium ['səudjəm] *n.* 钠
calcium ['kælsiəm] *n.* 钙
sulfur ['sʌlfə] *n.* 硫

## Expressions and Technical Terms

be composed of　由……组成
be decomposed into　被分解成
whole number ratio　整数比
percent by mass　质量百分比
identified and distinguished　鉴别和区别
ratio of　比率
carbon dioxide　二氧化碳
positive and negative charges　正电荷和负电荷
ordinary table sugar　普通方糖

## Notes

① The ultimate chemical decomposition of compounds produces the elements from which they be made. 化合物化学分解的最终产物为组成它们的元素。

② No end in sight as to the number that can and will be prepared in the future. 在未来能够和将要被制造（化合物）的数目是数不清的。 as to对于……，关于……， that…引出定语从句修饰 number。

③ Water is a colorless, odorless, tasteless liquid that can be changed to a solid, ice, at 0℃ and to a gas, steam, at 100℃. 水是无色、无嗅、无味的液体，它在 0℃变成冰， 100℃变成水蒸气。

④ Water reacts chemically with sodium to produce hydrogen gas and sodium hydroxide, with lime to produce calcium hydroxide, and with sulfur trioxide to produce sulfuric acid. 水与钠反应生成氢氧化钠和氢气，与石灰反应生成氢氧化钙，与三氧化硫反应生成硫酸。with…, with…表示并列关系。

## Exercises

1. Put the following into Chinese

Magnesia (MgO) is generally derived from the mineral magnesite (magnesium carbonate, $MgCO_3$) or from magnesium salts in seawater and some naturally occurring brines. Magnesite deposits account for approximately 80% of total magnesia production. Two types of magnesia are used by industry: caustic calcined magnesia and refractory magnesia.

Caustic calcined magnesia is produced by calcining magnesite in furnaces , typically at temperatures of 800 - 900℃. Global production is estimated at around 1.6 - 1.7Mt/a, of which China accounts for 35% - 40%. It has a variety of agricultural, environmental, chemical and industrial applications and is also the precursor for refractory magnesias.

2. Put the following into English

硫酸 硝酸 盐酸 硫酸铜 氧化铁 氯化钠

## Reading Material

# Chemical Equilibrium

Recognizing equilibrium systems

1. They can be approached from either end.

e. g. chromate ions can be changed into dichromate ions by adding acid, and dichromate ions can be turned into chromate ions by adding hydroxide ions, which remove the hydroxonium ions.

$$2CrO_4^{2-} + 2H_3O^+ \rightleftharpoons Cr_2O_7^{2-} + 3H_2O$$

2. If the temperature is changed, an equilibrium system will change, but if the original temperature is restored, the system will go back to its original state.

**Proving the dynamic nature of an equilibrium system**

This is done using radioactive tracers.

1. Set up an equilibrium system and allow it to reach equilibrium.
2. By sampling and measuring, find the exact composition of the whole system.
3. Now set up an identical system by adding the exact amount you have just measured, but with one component made of a radioactive isotope, say one of the reactants.
4. Leave the system for a time and sample them again and show that there are radioactive products, thus proving that even at equilibrium matter is being converted either way.

**Reversible reactions**

Reversible reactions make products which themselves react to give back the products. These reactions never stop because once some product is made, it can regenerate the reactants from which it came.

e. g. acid reacts with alcohol to make ester and water , but ester reacts with water to make acid and alcohol.

To show a system, like this the equilibrium sign $\rightleftharpoons$ is used

$$\text{acid} + \text{alcohol} \rightleftharpoons \text{ester} + \text{water}$$

Look at the way concentration and rate change with time here.

After time $t$, products are being made at exactly the same rate as they are reacting to make reactants. Because the two opposite rates are exactly equal, there is no external change and the system is said to be in dynamic equilibrium.

**The equilibrium law**

The equilibrium law states that for any systems in equilibrium, there is a numerical relationship between the concentrations of the products, raised to the power of their stoichiometric numbers, and the concentrations of the reactants, raised to the powers of their stoichiometric numbers. This relationship is called the equilibrium constant, $K_c$ (when trying to explain this in an answer you must give an example like this).

e. g. for the system $N_2+3H_2 \rightleftharpoons 2NH_3$

The equilibrium law states that:

$$K_c=\frac{[NH_3]^2}{[N_2]\,[H_2]^3}$$

Square brackets, [ ], mean concentration of whatever is inside them.

**The equilibrium constant, $K_c$, for homogeneous liquid systems**

Many equilibrium systems are made up of ions in solution. They are all in the same liquid phase. Here $K_c$ is written in terms of concentration. For example:

$$Fe^{3+}(aq) + SCN^-(aq) \rightleftharpoons FeSCN^{2-}(aq)$$

$$K_c=\frac{[FeSCN^{2-}]}{[Fe^{3+}][SCN^-]}$$

$$Cu^{2+}(aq)+4Cl^-(aq)\rightleftharpoons CuCl_4^{2-}(aq)$$

$$K_c=\frac{[CuCl_4^{2-}]}{[Cu^{2+}][Cl^-]^4}$$

**The equilibrium constant for heterogeneous systems**

Many systems contain more than one phase and so are heterogeneous. If one of the phase is a pure solid or liquid, then although the amount of the solid or liquid may change, its concentration will not. In these cases it is usual to write an equilibrium law expression that does not contain the pure solid or liquid phase's concentration (which is actually included in the modified equilibrium constant). These example show this point:

$$CaCO_3(s)\rightleftharpoons CaO(s)+CO_2(g)$$

$$K_c=[CO_2] \text{ and } K_p=p_{CO_2}$$

$$Fe_2O_3(s)+3CO(g)\rightleftharpoons 2Fe(s)+3CO_2(g)$$

$$K_c=\frac{[CO_2]^3}{[CO]^3} \text{ and } K_p=\frac{p_{CO_2}^3}{p_{CO}^3}$$

**The equilibrium constant, $K_p$, for homogeneous gaseous systems**

For gases it is usually more convenient to measure the pressure of the gas than its concentration. In a mixture of gases the gas is causing only part of the pressure, so the idea of partial pressure is used.

**The partial pressure of a gas in a mixture is the pressure that the gas would exert, if it alone occupied the space containing the mixture.**

The partial caused by a gas is proportional to the number of particle of the gas, so we can write:

$$\frac{\text{partial pressure of the gas, } p_g}{\text{total pressure of the gas mixture, } p_T} \qquad \frac{\text{number of particles of the gas, } n_g}{\text{total number of particles in the mixture, } n_T}$$

which can be rearranged to give $p_g = n_g/n_T \times p_T$

$n_g/n_T$ is the mole fraction of the gas.

So the partial pressure of a gas equals the mole fraction of that gas multiplied by the total pressure.

Using partial pressures, a form of the equilibrium law can be written in terms of a different equilibrium constant $K_p$. For example:

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 \qquad 2SO_2 + O_2 \rightleftharpoons 2SO_3$$

$$K_p = \frac{p^2_{NH_3}}{p_{N_2} p^3_{H_2}} \qquad K_p = \frac{p^2_{SO_3}}{p^2_{SO_2} p_{O_2}}$$

**The equilibrium constant**

**The size of the equilibrium constant**

The value of size of $K_c$ tell us whether there are more reactants or products in the systems at equilibrium. So

If $K_c$ is $>10^2$, there will be far more products than reactants

If $K_c$ is $<10^{-2}$, there will be far more reactants than products

If $K_c$ is between $10^{-2}$ and $10^2$, both reactants and products will be in the system in noticeable amounts.

**The equilibrium position**

The position of an equilibrium system is a term used to describe qualitatively what the equilibrium constant does quantitatively. It gives an indication of whether the reactants or products are more plentiful in the system. Remember, reactants are written on the left, products on the right in an equation, so:

if the position lied to the left then the reactants dominate:

$$CH_3COOH(l) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq) \quad K_c = 1 \times 10^{-5}$$

if the position lied to the right the reactants dominate:

$$HCl(g) + H_2O(l) \rightleftharpoons H_3O^+(aq) + Cl^-(aq) \quad K_c = 5.55 \times 10^8$$

**The units of the equilibrium constant**

Equilibrium constants for different systems can have different units. Just remembers that the units of concentration are mol $dL^{-1}$ and that the units on each side of the equation must balance, so:

For the system: $N_2 + 3H_2 = 2NH_3$ $\qquad K_c = \dfrac{[NH_3]^2}{[N_2][H_2]^3}$

So the units of $K_c$ will be $= \dfrac{\text{mol} \cdot L^{-1} \times \text{mol} \cdot L^{-1}}{\text{mol} \cdot L^{-1} \times \text{mol} \cdot L^{-1}}$

## New Words

equilibrium [ˌi:kwi'libriəm] *n.* 平衡

dynamic [dai'næmik] *a.* 动力的，动态的

converted [kən'və:tid] *a*,改装的

regenerate [i'dʒenərit] *a.* 再生的；*n.* 再生；*v.* 再生

ester ['estə] *n.* 酯

## Expressions and Technical Terms

chemical equilibrium 化学平衡
chromate ions and dichromate ions 铬酸根离子和重铬酸根离子
radioactive isotope 放射性同位素
reversible reaction 可逆反应
homogeneous gaseous system 均相气体系统
dynamic equilibrium 动态平衡
stoichiometric number 化学计量数
equilibrium constant 平衡常数

# Lesson Two The Anatomy of a Chemical Manufacturing Process

The basic components of a typical chemical process are shown in Fig. 1, in which each block represents a stage in the overall process for producing a product from the raw materials. Fig. 1 represents a generalized process; not all the stages will be needed for any particular process, and the complexity of each stage will depend on the nature of the process. Chemical engineering design is concerned with the selection and arrangement of the stages, and the selection, specification and design of the equipment required to perform the stage functions.

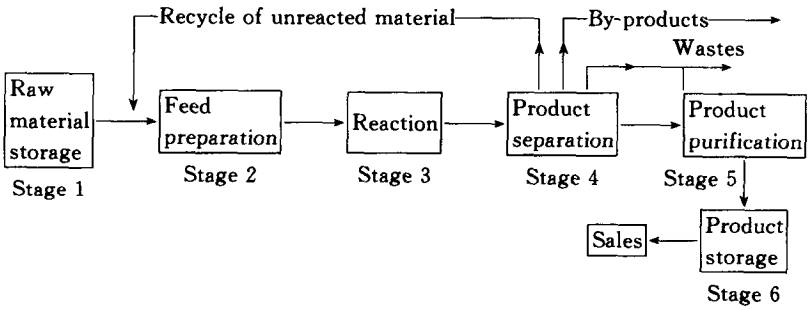


Fig. 1 Anatomy of a chemical process

**Stage 1. Raw material storage**

Unless the raw materials (also called essential materials, or feedstocks) are supplied as intermediate products (intermediates) from a neighboring plant, some provision will have to be made to hold several days, or weeks storage to smooth out fluctuations and interruptions in supply. Even when the materials come from an adjacent plant, some provision is usually made to hold a few hours, or even a few days, supply to decouple the processes. The storage required will depend on the nature of the raw materials, the method of delivery, and what assurance can be placed on the continuity of supply. If materials are delivered by ship (tanker or bulk carrier), several weeks stocks may be necessary; whereas if they are received by road or rail, in smaller lots, less storage will be needed.

**Stage 2. Feed preparation**

Some purification, and preparation, of file raw materials will usually be necessary before they are sufficiently pure, or in the right form, to be fed to the reaction stage. For example, acetylene generated by the carbide process contains arsenical and sulphur compounds, and other impurities, which must be removed by scrubbing with concentrated sulphuric acid (or other processes) before it is sufficiently pure for reaction with hydrochloric acid to produce dichloroethane. Liquid feeds will need to be vaporized before being fed to gas-phase reactors, and solids may need crushing, grinding and screening.

**Stage 3. Reactor**

The reaction stage is the heart of a chemical manufacturing process. In the reactor the raw materials are brought together under conditions that promote the production of the desired product ; invariably , by-products and unwanted compounds (impurities) will also be formed.

**Stage 4. Product separation**

In this first stage alter the reactor the products and by-products are separated from any unreacted material. If in sufficient quantity, the unreacted material will be recycled to the reactor. They may be returned directly to the reactor or to the feed purification and preparation stage. The by-products may also be separated from the products at this stage.

**Stage 5. Purification**

Before sale the main product will usually need purification to meet the product specification. If produced in economic quantities, the by-products may also be purified for sale.

**Stage 6. Product storage**

Some inventory of finished product must be held to match production with sale. Provision for product packaging and transport will also be needed , depending on the nature of the product. Liquids will normally be dispatched in drums and in bulk tankers (road, rail and sea), solids in sacks, cartons or bales.

The stack held will depend on the nature of the product and the market.

1. Ancillary processes

In addition to the main process stages shown in Fig. 1, provision will have to be made for the supply of the services (utilities) needed, such as process water, cooling water, compressed air, steam. Facilities will also be needed for maintenance, firefighting, offices and other accommodation, and laboratories.

2. Continuous and batch processes

Continuous processes are designed to operate 24 hours a day, 7 days a week, throughout the year. Some down time will be allowed for maintenance and, for some processes, catalyst regeneration. The plant attainment, that is, the percentage of the available hours in a year that the plant operates, will usually be 90% to 95%.

$$\text{Attainment}\% = \frac{\text{hours operated}}{24 \times 365} \times 100$$

Batch processes are designed to operate intermittently. Some, or all, the process units being frequently shut down and started up.

Continuous processes will usually be more economical for large scale production. Batch processes are used where some flexibility is wanted in production rate or product specification.

The choice between batch or continuous operation will not be clear cut, but the following rules can be used as a guide.

## Continuous

1. Production rate greater than $5 \times 100$kg /h

2. Single product
3. No severe fouling
4. Good catalyst life
5. Proven processes design
6. Established market

## Batch

1. Production rate less than 5×100 kg/h
2. A range of products or product specifications
3. Severe fouling
4. Short catalyst life
5. New product
6. Uncertain design

## New Words

anatomy [ə'nætəmi] *n.* 解剖，分解，构造，组织
specification [spesifi'keiʃən] *n.* 说明书；(*pl.*) (尺寸) 规格，技术要求
fluctuation [flʌktju'eiʃən] *n.* 波动，脉动，振幅
decouple [di'kʌpl] *v.* 消除……间的影响，分隔，去耦
bulk [bʌlk] *a.* 散装的；大块的
lot [ɔt] *n.* (商品的) 一批，批量，份额
acetylene [ə'setili:n] *n.* 乙炔
carbide ['kɑ:baid] *n.* 碳化物，碳化钙
arsenical [ɑ:'senikəl] *a.* (含) 砷的；*n.* 含砷制剂
sulphur ['sʌlfə] *n.* 硫，硫磺
impurity [im'pjuəriti] *n.* 杂质，夹杂物，不纯，污染
scrub [skrʌb] *v.* 气体洗涤，涤气，洗涤，清洗
vaporize ['veipəraiz] *vt.* (使) 汽化，(使) 蒸发
screen [skri:n] *v.* 筛分，筛选，屏蔽
reactor [ri'æktə] *n.* 反应器，反应堆
inventory ['invəntri] *n.* 库存量；(商品、物资等) 清单
dispatch [dis'pætʃ] *vt.* (迅速地) 发送，派遣，迅速办理，了结
carton ['kɑ:tən] *n.* 纸板箱 (或盒)
bale [beil] *n.* 大包，大捆
regeneration [ri:dʒenə'riʃən] *n.* 再生，更新，新生
attainment [ə'teinmənt] *n.* 开工率
batch [bætʃ] *a.* 间歇的，分批的
intermittently [intə'mitəntli] *ad.* 间歇地，断断续续地，周期性地
foul [faul] *n.* 污物 (垢)；*v.* 结垢，弄脏
dichloroethane *n.* 二氯乙烷

## Expressions and Technical Terms

raw material 原材料
chemical engineering 化学工程
intermediate product 中间产物
hydrochloric acid 盐酸
method of delivery （原料）输送方式
gas-phase reactor 气相反应器
by-product 副产品
process water 生产用水
bulk carrier 散装大船
to meet the product specification 以达到产品的标准
stack held 库存
compressed air 压缩空气
batch processes 间歇生产
continuous processes 连续生产

## Notes

① Some provision will have to be made to hold several days , or weeks storage to smooth out fluctuations and interruptions in supply. 某些原料库存必须满足几天或数周的（生产）之需以免发生供应的中断。 smooth out 意为平息、减少。

② Some purification , and preparation , of file raw materials will usually be necessary before they are sufficient pure , or in the right form , to be fed to the reaction stage. 使用的原料在进入反应阶段之前，一定的纯化和处理是必须的，以使它们有足够的纯度或合适的形式，before 引出时间状语，to be fed to 作补语。

③ If produced in economic quantities , the by-products may also be purified for sale. 如果（考虑）生产的经济效益，副产品也可以提纯后销售。 by-product 为副产品。

④ Some down time will be allowed for maintenance and , for some processes , catalyst regeneration. 将允许一些停机时间进行检修和处理，催化剂的再生。 down time 在此为停机时间。

## Exercises

1. Put the following into Chinese

The quality system of the Company is in conformity with ISO 9002. Making comprehensive use of biotechnology , fine chemical technology , the Company specializes in manufacturing and selling C-4 series organic acids and chiral products. These products are widely used in many fields such as food , pharmaceutical and chemical industries , and are well accepted by the domestic and overseas markets. The main products are L-Malic acid , DL-Malic acid , L （+）-Tartaric acid , L-Aspartic acid , Fumaric acid , Maleic acid and other organic acids. Annual productivity amounts to 20 000 tones. The Company has become an

important manufacturer of C-4 series organic acids in the world. All the products of the Company have respectively met the different international advanced standards such as Food Chemicals Codex, U. S. Pharmacopoeia, British Pharmacopoeia, and the products have obtained Star-K Kosher Certificate. Above 70% of the Company's products are exported to Japan, Europe, Australia, the United States and Middle East, and they are renown and well recognized in the international markets. The Company will devote itself to research and development of enzyme technology and organic electrochemistry. It will continuously introduce new food additives, chiral pharmaceutical intermediates, chiral auxiliaries and chiral drugs. Depending on superior quality, good service and high reputation, the Company is willing to establish a long-term mutually beneficial business partnership with overseas customers and continue to contribute to the happy life of humans.

2. Put the following into English

**化学工程化学工业无机产品有机产品反应器市场药品制造**

Reading Material

## Major Sectors of the Chemical Industry

The chemical industry takes a relatively small number of natural raw materials such as oil and natural gas, limestone and salt and converts them (by chemical processing or chemical reactions) into several thousand chemical intermediates. As we have already seen, these are then converted into end or consumer products. It is important to note that value is added at every stage in this process and the final product may have a value many times that of the raw materials which were used at the beginning. Clearly the increase in value added at each stage must exceed the processing costs if the company is to realize a profit on its activities.

The major sectors of the chemical industry are:

- Petrochemicals
- Polymers
- Dyestuffs
- Agrochemicals
- Pharmaceuticals
- Chlor-alkali products
- Sulphuric acid (sulphur industry)
- Ammonia and fertilizers (nitrogen industry)
- Phosphoric acid and phosphates (phosphorus industry)

The petrochemicals sector provides key intermediates or building blocks (derived from oil and natural gas) such as ethylene, propylene, benzene and toluene. These are the starting points for the synthesis of an enormous range of industrial organic chemicals, which are produced in the downstream processing of the key intermediates in some of the other sec-

tors listed.

The polymers sector is the major user of petrochemical intermediates and consumes almost half the total output of organic chemicals which are produced. It covers plastics, synthetic fibers, rubbers, elastomers and adhesives, and it was the tremendous demand for these new materials with their special, and often novel, properties which brought about the explosive growth of the organic chemicals industry between 1950 and 1970.

Although the dyestuffs sector is much smaller than the previous two, it has strong links with them. This arose because the traditional dyestuffs, which were fine for natural fibers like cotton and wool, were totally unsuitable for the new synthetic fibers like nylons and polyesters. A great deal of research and technological effort within the sector has resulted in the amazingly wide range of colors in which modern clothing is available. Along with drugs and plant-protection agents (pesticides) dyestuffs are examples of fine chemicals, i. e. chemicals produced in relatively small tonnages which are of high purity and high value per unit mass.

Agrochemicals (pesticides) in recent years, along with the pharmaceuticals sector have constituted a blue-chip sector of the chemical, i. e. a very profitable one for those companies which can continue to operate on it.

Pharmaceuticals have been the glamorous sector of the industry for some years, because of their high levels of profitability——although this often seems to attract criticism that profits on some drugs are too high. The latter comments have to be set against the very high risks and costs (in excess of $160 million per marketable compound) of discovering and developing new products. This sector is unique in both its relationship with its customers and the fact that demand for its products is little affected by ecónomic recessions, in great contrast to all the other sectors.

The chlor-alkali products sector produces principally the very high-tonnage chemicals chlorine and sodium hydroxide. It is an area which demonstrates very nicely the influence of new technology and energy costs on chemicals production.

Sulphuric acid (sulphur industry) is the most important chemical of all in tonnage terms. Its production can be regarded as having reached maturity some years ago, but even now work is being done to remove the last traces of unreacted $SO_2$ (for environmental reasons).

Ammonia and fertilizers is a sector in which it has been difficult to achieve a balance between capacity and demand, and this has often led to major cost cutting and losses for many companies. In tonnage term it is one of the most important sectors and it is based on the Haber process for ammonia. This is very energy demanding (moderately high temperatures and very high pressures) and a fortune is awaiting anyone who can find a viable alternative route. It will not be easy since no one has yet succeeded despite 70 years of intensive research effort!

Various phosphates are produced from phosphoric acid which is made either by adding sulphuric acid to phosphate rock (wet process) or by burning phosphorus in air to give phos-

phorus pentoxide, which is then hydrated. Major uses of phosphoric acid are the production of phosphate and compound fertilizers, formation of sodium tripolyphosphate (which is used as a builder in detergents where it forms stable water-soluble complexes with calcium and magnesium ions) and the production of organic derivatives like triphenyl and tricresyl phosphate. These are used as plasticizers for synthetic polymers and plastics.

Soaps and detergents represent an interesting and rather different sector. Interesting in that early production of soap, with its demand for alkali, can be viewed as the beginnings of the modern chemical industry. Different from the other sectors in that its products are sold directly to the public and market share probably has more to do with packaging and marketing than the technical properties of the product. Many of its products can be derived from both petrochemical intermediates and from animal and vegetable oils and fats, e. g., alkyl and aryl sulphonate.

Although some chemicals, such as organic solvents, are used directly, most require further processing and formulating before they can be put to their end uses. In some cases, where novel materials have been discovered, major technological advances were required before they could be processed and their unique properties utilized. Such a material is polytetrafluoroethylene, which is better known as PTFE or under its trade names Fluon (ICI) and Teflon (Dupont). When this was first made its special properties of great chemical stability, excellent electrical insulation, very low coefficient of friction (hence its non-stick applications) and very wide working temperature range were quickly recognized. However, its use was delayed for several years because it could not be processed by conventional techniques and it had to await the development of powder metallurgy techniques.

In order to appreciate the downstream processing and technology, let us take as an example polyvinyl acetate and one of its applications as a binder in such that a homogeneous film is produced on evaporation of the water base. What processing steps are involved in making the polyvinyl acetate and in finally formulating the paint?

The story starts with crude oil or natural gas fractions, e. g., naphtha, which are cracked to give principally ethylene. The ethylene is then reacted with acetic acid and oxygen over a supported palladium catalyst to produce the vinyl acetate. Finally this is polymerized to polyvinyl acetate which is then mixed with the other ingredients to produce the emulsion paint.

## New Words

limestone [laimstəun] *n.* 石灰石
intermediate [ntə'midjət] *a.* 过渡的，中间的； *n.* 中间体，半成品
petrochemical [petrəu'kemikəl] *a.* 石油化学的；*n.* 石油化学品
polymer ['pɔlimə] *n.* 聚合物，聚合体
dyestuff ['daistʌf] *n.* 染料，着色剂
polyester [pɔli'estə] *n.* 聚酯
agrochemical [ægrəu'kemik] *n.* 农用化学品

pharmaceutical [ˌfɑːməˈsjuːtikəl] *a.* 药物的，制药的； *n.* 药物
ethylene [ˈeθiliːn] *n.* 乙烯
propylene [ˈprəupiliːn] *n.* 1，2-亚丙基，丙烯
benzene [ˈbenziːn] *n.* 苯
plastic [ˈplæstik] *n.* 塑胶，塑料
rubber [ˈrʌbə] *n.* 胶皮，天然橡胶，橡胶，橡皮
elastomer [iˈlæstəmə] *n.* 弹胶体，弹性体，合成橡胶
adhesive [ədˈhiːsiv] *n.* 胶合剂，胶黏剂，黏结剂
dyestuff [ˈdaistʌf] *n.* 染料，着色剂
glamorous [ˈglæmərəs] *a.* 迷人的
detergent [diˈtədʒənt] *n.* 除垢剂，清洁剂，洗涤剂
phosphate [ˈfɔsfeit] *n.* 磷酸盐，磷酸脂，磷酸酯
pentoxide [penˈtɔksaid] *n.* 五氧化物
builder [ˈbildə] *n.* 助洗剂，组分
derivative [diˈrivətiv] *n.* 衍化物
tri-phenyl [ˌtraiˈfiːnil] *n.* 三苯基
plasticizer [ˈplæstisaizə] *n.* 可塑剂，塑化剂，增韧剂，增塑剂
alkyl [ælkil] *n.* 烷基
sulphate [ˈsʌlfeit] *n.* 硫酸盐
formulate [ˈfɔːmjuleit] *vi.* 用公式表示； *vt.* 公式化，公式化表示，制定
insulation [ˌinsjuˈleiʃən] *n.* 隔离，绝热，绝缘，绝缘座
coefficient [ˌkəuiˈfiʃənt] *n.* 共同作用系数
binder [baində] *n.* 绷带，夹子，胶黏剂，铺路沥青
homogeneous [ˌhɔməuˈdʒiːnjəs] *a.* 均一的，均质的，同类的
palladium [pəˈleidiəm] *n.* 钯

## Expressions and Technical Terms

synthetic fiber 合成纤维
fine chemicals 精细化学品，精细化工产品
blue-chip 行业中最赚钱的，第一流的，（股票等）热门的
economic recession 经济衰退
chlor-alkali products 氯碱产品
phosphoric acid and phosphate 磷酸和磷酸盐
tripolyphosphate 三聚磷酸盐
phosphorus pentoxide 五氧化二磷
polytetrafluoroethylene 聚四氟乙烯
powder metallurgy technique 粉末冶金技术
aryl group *n.* 芳基
tricresyl phosphate *n.* 磷酸三甲苯酯

# PART 2 CHEMICAL ENGINEERING

## Lesson Three Heat Transfer

Heat, as a form of energy, cannot be created or destroyed. Heat can be transferred from one substance to another.

Heat always tends to pass from warmer objects to cooler ones. When a warm substance comes in contact with a cold substance, the molecules of the warm substance collide with the molecules of the cold substance, giving some of its energy to the cold molecules. This is only one way to transfer heat.

In a chemical plant, for example, in a refinery, transfer of heat is very important. The successful operation of most processes is dependent on correct application of the principles of heat transfer. Where we are handling a hot material, we may insulate the system to hold the heat in; where the material is cold, we may insulate to keep the heat out. Efficient equipment, designed to take full advantage of processing heat, is in use in almost all chemical plants.

Three methods of heat transfer are conduction, convection, and radiation. Conduction is the transfer of heat that occurs by direct contact between two objects at different temperatures, or the transfer from one part of an object to another part of the same object, without movement or mixing of particles.

If a silver spoon is placed in a cup of hot coffee, the handle of the spoon will get hot. Due to the molecular collisions, heat is transferred from the coffee to the spoon. The spoon becomes hot since it gains heat, and the coffee gets a little cooler since it loses some heat. Similarly, when one end of an iron poker is placed in a fire, the other end will get too hot to touch, if, however, one end of a wooden rod is placed in a fire the other end will be warmed hardly at all.

Convection is the transfer of heat from one place to another within a liquid or gas by mixing one part of liquid or gas with the other. It could be defined as the process by which gases and liquids move about, due to changes in temperature and pressure. A gas or liquid expands when heated. It becomes lighter and moves upward as gravity pulls the heavier, less heated gas or liquid downward. The transfer of heat by convection is used both in heating and in cooling our homes.

A steam radiator is a good example of heating by convection. Air in contact with the radiator warms and rises because it is lighter than the other air in the room. It is displaced by cooler air.

Radiation is the transmission of heat from a heated body to a cooler body by heat waves

or the transfer of heat by electromagnetic waves. Similar to radio signals , radiation can transfer energy through empty space. Unlike conduction and convection , radiation does not require a substance to transfer heat.

The heat we get from the sun is an example of radiation. Another example is warming one's self by an open fire. The side next to the fire gets warm while the opposite side remains cool. Turn around and the cool side warms up and the warm side cools off. Since you are not actually touching the fire , this warming cannot be by conduction. Likewise, it cannot be heat transmission by convection for only the side next to the fire is warmed. If it had been heat by convection the both sides would have been warmed.

## New Words

transfer [trænsfə] *n./v.* 调动，转移，迁移
tend [tend] *v.* 倾向，趋向
contact ['kəntækt] *v.* 接触，联系
substance ['sʌbstəns] *n.* 物质
collide [kə'laid] *n./v.* 碰撞，冲突
molecule ['mɔlikju:l] *n.* 分子
refinery [ri'fainəri] *n.* 炼油厂
operation [ɔpə'reiʃən] *n.* 操作，作用，运转
dependent [di'pendənt] *a./n.* 依靠的，取决的
application [æpli'keiʃən] *n.* 应用，申请
principle [prinsəpl] *n.* 原理，原则
insulate [insjuleit] *n./v.* 使绝缘，使隔离
handle ['hændl] *n./v.* 处理，操作
efficient ['fiʃənt] *a.* 有效的
equipment [i'kwipmənt] *n.* 设备
material [mə'tiəriəl] *n.* 材料，原料，物质
conduction [kən'dʌkʃən] *n.* 传导，输送
convection [kən'vekʃən] *n.* 对流
radiation [reidi'eiʃən] *n./v.* 辐射
occur [ə'kə:] *n./v.* 发生，存在，想到
particle ['pɑ:tikl] *n.* 颗粒，粒子
silver ['silvə] *a./n.* 银，银的
collision [kə'liʒən] *n.* 碰撞，冲突
similarly ['similəli] *a.* 相似地，类似地
rod [rɔd] *n.* 杆，棒
define [di'fain] *n./v.* 下定义，说明
process [prəuses] *n.* 过程，工艺
upward ['ʌpwəd] *a./ad.* 向上
gravity ['græviti] *n.* 重力