10. The Chemical Industry

10.1 Raw materials of the chemical industry

The chemical industry plays a vital role in the technological development of nations and in raising the general standard of living of citizens. The chemical industry is made up of those industries which depend on the application of the principles of chemistry and chemical technology.

In general, the chemical industry deals with processes in which materials are converted from one chemical form into another desired chemical form. Such a process is of the form:

$$\text{Reactant(s)} \xrightarrow[\text{process}]{\text{conversion/treatment}} \text{Product(s)} \quad + \quad \text{energy change}$$

The starting materials (the reactants) for the process are covered by the term â€˜**raw materials**â€™. Appropriate treatment of the raw materials yield the desired products. In the chemical industry raw materials range from simple elements such as sulphur, graphite, etc to complex materials such as rubber, palm oil, petroleum etc. The chemical industry operates as a chain of activities so that what one manufacturer regards as his finished product or even waste product, may in fact form the raw material for another manufacturing process.

The success of a particular chemical industry depends on the availability and costs of its raw materials and energy resources. Where the raw materials and energy supply are readily available and cheap, prices of the products are moderate or low, and uninterrupted production is assured. If on the other hand these items are scarce and expensive, the prices of the finished products are high and production is not regular.

All chemicals used in the chemical industry have to be obtained directly or indirectly from materials already available in nature. These materials in nature thus form the basic (primary) raw materials of the chemical industry. Based on their chemical nature these basic raw materials may be classified into two broad types, namely:

(i) Inorganic materials such as air, sea, water, and mineral ores,

(ii) Organic raw materials, such as agricultural (animal and vegetable) products, wood, coal, petroleum and natural gas.

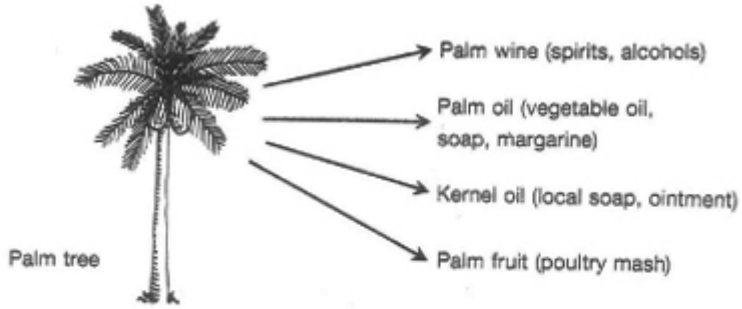


Figure 10.1(a) Agricultural raw materials from palm tree

Plate 10.1(b) Farming for raw materials: an oil palm plantation

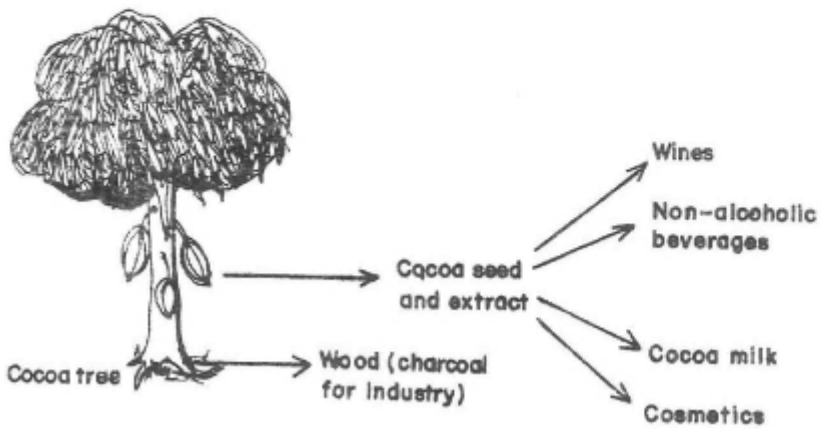


Figure 10.2 Agricultural raw materials from a cocoa tree

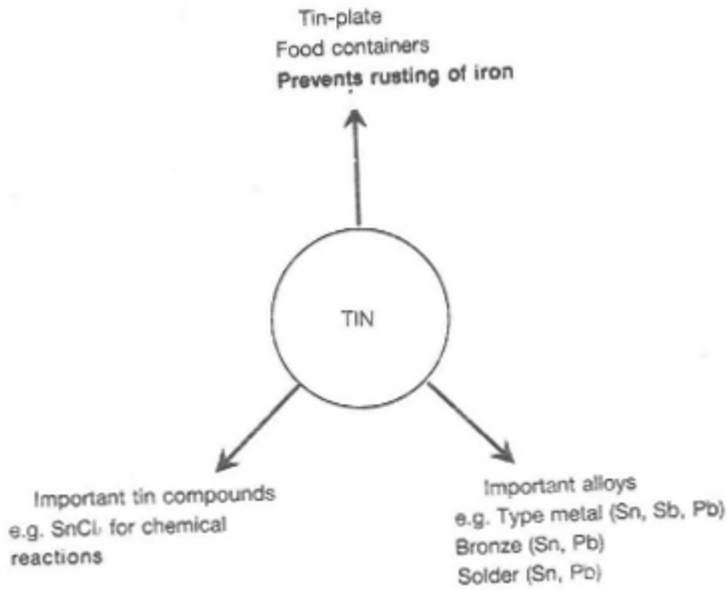


Figure 10.3 Uses of Tin

Plate 10.2 A tin mine in Jos Plateau Nigeria

10.2 Inorganic raw materials

The various types of inorganic raw materials are listed in Table 10.1.

TABLE 10.1 Types of Basic Inorganic Raw Materials

Basic Inorganic Raw Materials	Source
Air	Atmospheric air
Industrial gases	Liquefied air
Mineral salts	Sea water, minerals
Minerals, metals	Minerals and ores
Inorganic non-metals	Minerals and ores

Raw Materials from air

Air is an important source of various industrial gases â€” principally oxygen, nitrogen and the noble gases. Large volumes of air are used in the chemical industry in order to provide the oxygen required in oxidative combustion processes. Such processes include:

(i) The combustion of carbon and carbon-containing compounds to provide energy.

(ii) The production of sulphur(IV) and sulphur(VI) oxides for the manufacture of tetraoxosulphate(VI) acid.

Liquefied air is the principal source of industrial oxygen, nitrogen and. some quantities of the noble gases. Nitrogen is used in the Haber Process for the manufacture of ammonia while the oxygen is used mostly in the oxy-acetylene flame for welding.

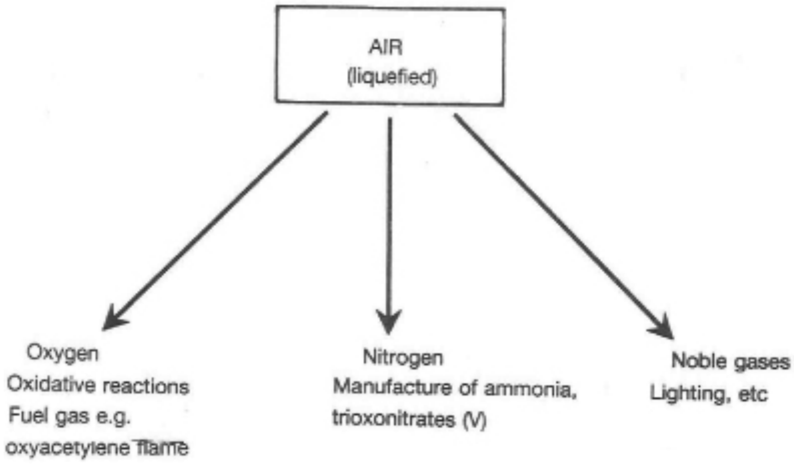


Figure 10.4 Air as an industrial raw material

Raw materials from sea water

The principal mineral content of sea water is common salt, NaCl. It constitutes about 3.4% of sea water, or about 75% of the salts dissolved in the water. Sea water also contains other useful mineral salts among which are magnesium and calcium salts, and sodium bromide.

The sodium chloride in sea water is recovered by evaporating water and then crystallizing out the salt. The remaining solution is further concentrated and then treated with chlorine which displaces bromine from the sodium bromide.

$$Cl_2(g) + 2NaBr(aq) \rightarrow 2NaCl(aq) + Br_2(l)$$

This is the most important source of the element bromine, which is used to prepare such useful compounds as silver bromide used for photographic films and paper, and dibromoethane used for preventing the deposition of tetracthyl lead in engine cylinders.

TABLE 10.2 Order in which the Mineral constituents of Sea Water crystallize out

Order of Crystallizing out	Salts
1st to crystallize out ↓ Last to crystallize out	$CaCO_3$ $CaSO_4,2H_2O$ $NaCl_2$ NaBr $MgCl_2$ $MgSO_4$, KC1. $MgBr_2$.

To extract magnesium from sea water, the liquor obtained after the extraction of common salt is concentrated. Lime is then added to precipitate magnesium hydroxide. The hydroxide is treated with hydrochloric acid thus converting it to magnesium chloride. The fused chloride is electrolysed to yield magnesium metal.

Common salt is the basic material for the production of many other very important chemicals such as sodium hydroxide, chlorine, bleaching powder etc. Sodium metal is obtained by the electrolysis of fused sodium chloride.

Sodium hydroxide is a very important industrial chemical being a source of both sodium and hydroxide ions. It is a vital chemical in the alkali and soap industries. Sodium hydroxide is prepared by the electrolysis of brine using either the diaphragm cell or the mercury cathode cell. Hvdrogen and chlorine which are produced in the electrolysis of brine have several industrial uses.

The importance of sodium chloride as a raw material of the chemical industry is illustrated in Figure 10.5.

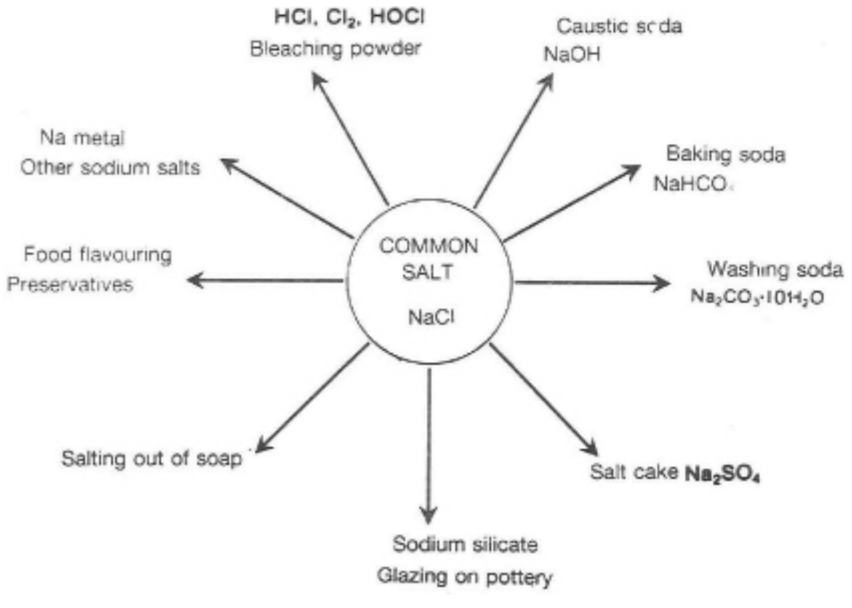


Figure 10.5 Uses of common salt

Mineral Ores

An ore is a mixture of minerals containing one or more useful metallic compounds. An ore always contains impurities most of which are useless, but some of which are very valuable. For example, the noble metals gold and silver are impurities in copper ores. Mineral ores occur as oxides, sulphides, tetraoxpsulphates(VI), trioxocarbonates(IV) or trioxonitrates(V).

Metals and their ores can be classified on the basis of the reactivity of the metal. The reactivity of the metal determines the nature of its ores as follows:

A: â€” Very reactive metals such as sodium and potassium occur as ionic, often simple and soluble salts, e.g. NaCl and KCl.

B: â€” Metals ores of calcium and magnesium, usually occur as insoluble trioxocarbonates(IV) and tetraoxosulphates(VI), e.g. $CaCO_3$ and $MgSO_4$.

C: â€” Fairly reactive metals such as aluminium, chromium and manganese form ions of large charge. Some of these compounds have covalent characters, e.g. Al_2O_3.

D: â€” Less reactive metals like iron, copper, lead, tin and zinc are found as the oxides or combined compounds of sulphur c.g. Fe_2O_3, PbS, $CuFeS_2$.

E: â€” Very unreactive metals like gold, silver and platinum are found uncombined or as compounds which are easily reduced.

Some common oxide ores are: Cassiterite (tin ore â€“ SnO_2), haematite (iron ore â€” $Fe_2O_3.xH_2O$), and bauxite (aluminium ore â€“ $Al_2O_3.H_2O$). Sulphide ores are called pyrites. Examples are iron pyrites (FeS_2) and copper pyrites or chalcopyrite (Copper ore â€“ $CuFeS_2$).

The percentage by mass of a metal which has to be present in an ore for the ore to be worked commercially varies a great deal as indicated in Table 10.3.

TABLE 10.3 Minimum percentage by mass of metal in ore for it to be exploited commercially

Metal	% by Mass
Iron	30â€“70%
Lead	2â€“12%
Nickel	1%
Gold	0.001%

When minerals are mined, they are concentrated by removing most of the impurities. This is done before the extraction of the metal so as to increase the percentage of the mineral in a given mass of the ore. Steps in ore processing are:

1. Mining â€” removal from the earthâ€™s crust.
2. Enrichment â€” removal of impurities and concentration of the ore.
3. Extraction of metal-chemical processes of reduction to obtain the metal.
4. Purification â€” further treatment to attain desired level of purity.

Extraction of the metals is done by either chemical or electrolytic reduction or by thermal decomposition. The method used for any mineral depends on the reactivity of the metal. The most common reducing agents are carbon and carbon(II) oxide. They are used for the less reactive metals, while electrolysis is used for the more reactive and fairly reactive metals. Each step in the processing of an ore is a complex one and the detailed procedures used depend on the properties of the metals being extracted and the nature of the ores.

Nigeria has rich deposits of minerals (Figure 10.6). Exploitation of some of these such as the tin in Jos Plateau, is already in progress.

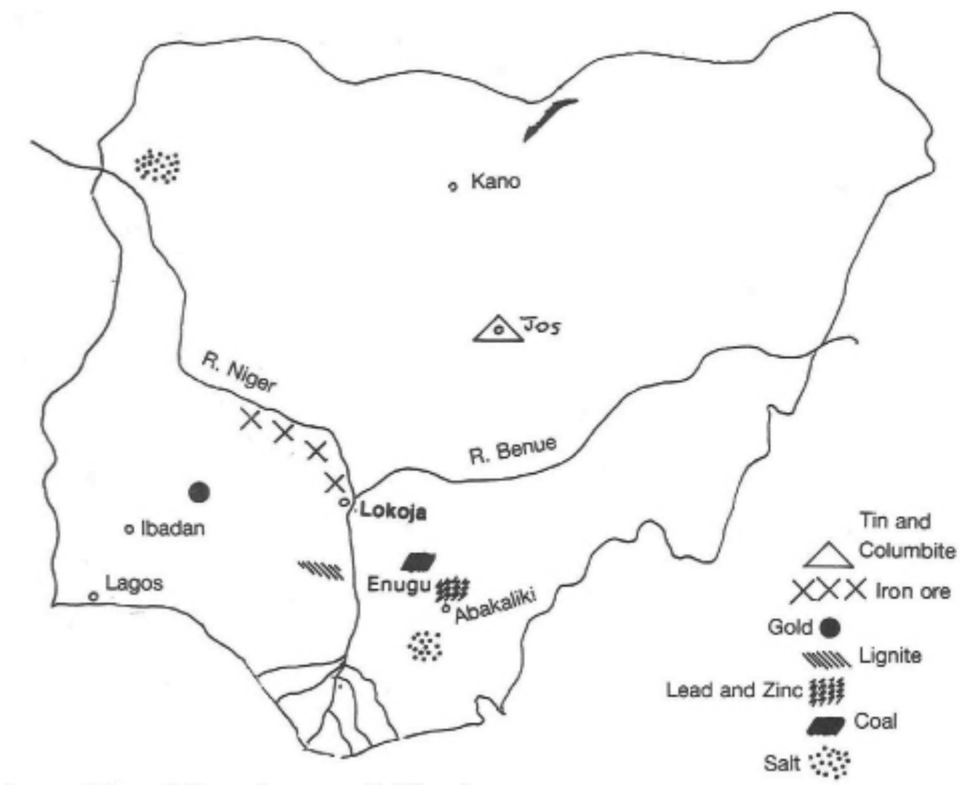


Figure 10.6 Mineral map of Nigeria

Sulphur

Sulphur is a very important raw material. Its largest use is for the manufacture of tetraoxosulphate(VI) acid. Other uses include the preparations of ointments for skin infections, gun-powder, and vulcanization of rubber. The worldâ€™s largest deposits of sulphur are in Mexico where it occurs in a relatively pure form as elemental sulphur. It is mined by a rather simple and economic technique called the **Frasch process**.

Sulphur deposits in the world are not widespread. Where such deposits are not available, alternative sources of sulphur are used to obtain sulphur. Sulphur may be obtained as a by-product of the extraction of metals from ores. These sulphide ores (pyrites) are first â€˜roastedâ€™ before smelting. This converts the metal sulphide to the oxide and sulphur(IV) oxide gas which is collected.

Another important source of sulphur is the desulphurization of crude oil. Crude oil from many parts of the world contain substantive amounts of sulphur compounds. Desulphurization processes convert the sulphur compounds to hydrogen sulphide. The hydrogen sulphide is burnt in plentiful supply of air to form sulphur(IV) oxide.

$$2H_2S(g) + 3O_2(g) \rightarrow 2SO_2(g) + 2H_2O(g)$$

The sulphur(IV) oxide is mixed with excess hydrogen sulphide and the mixture passed over alumina at 400Â°C.

$$2H_2S(g) + SO_2(g) \rightarrow 3S(g) + 2H_2O(g)$$

When the mixture is cooled sulphur condenses to liquid which is pumped away to solidify.

Chalk and Limestone

Chalk and limestone are relatively pure forms of calcium trioxocarbonate(IV) minerals. They are among the commonest minerals and constitute important and cheap raw materials of the chemical industry.

On heating, chalk undergoes decomposition according to the equation:

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

The by-product of the decomposition reaction is carbon(IV) oxide which is useful as a refrigerant and also for making â€˜softâ€™ or aerated drinks.

The principal product is lime which has very important uses as a very cheap alkali and a source of calcium. It has wide uses in agriculture as a soil conditioner for the reduction of soil acidity and in promoting the activity of nitrogen fixing bacteria. Lime is also used in water works to adjust the pH (acidity) of water. It is used extensively in the Solvay Process to produce sodium trioxocarbonate(IV), which is used in glass-making.

Chalk or lime reacts with carbon at very high temperatures (above 3000Â°C) to yield calcium carbide (CaC_2). The calcium carbide liberates ethyne (C_2H_2) on treatment with water.

Limestone is used directly as a building stone. Powdered limestone (or chalk) when mixed with other substances such as alumina, silica and magnesia, and heated in high temperature kilns, yield cement which is an important building material. Limestone is also used in the blast furnace for the extraction of iron. The lime produced by decomposition in the blast furnace reacts with the earth) portion of the iron ore to produce slag which is mainly calcium trioxosilicale(IV). The importance of chalk and limestone as industrial raw materials are illustrated in Figure 10.7.

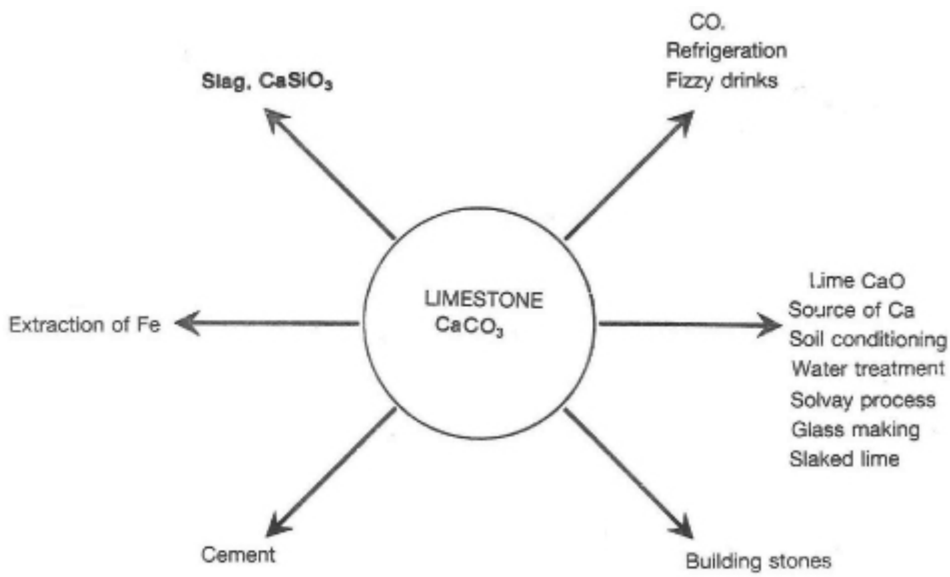


Figure 10.7 Importance of Limestone

10.3 Organic raw materials

Coal

Until recently, coal was the most important source of fuel and organic materials for the chemical industry.

Coal occurs beneath the earthâ€™s surface at depths which range from a few metres to several tens of metres. It is therefore obtained either by surface (open-cast) or by underground mining.

Coal is widely distributed throughout the world but it is not so common in Africa. In West Africa, large deposits occur around the Udi

Hills in Nigeria where they are mined. Nigeriaâ€™s output of coal attained a peak of about 900,000 tonnes in 1959 and is now on the decrease. However, coal still makes a very important contribution to the energy resources of countries such as South Africa, Zimbabwe and Zambia.

The major uses of coal are:

(i) as an industrial fuel â€” to supply heat when burnt.

(ii) as home fuel â€” for cooking and heating in cold climates during winter.

(iii) as a source of chemicals.

(iv) for conversion into petrol by a process called coal gasification. This usage is of particular importance in Sasolburg, South Africa, where coal is used to supply about 50% of the countryâ€™s need of petrol.

Coal occurs, in various stages of formation giving rise to several grades: peat, lignite, bitumenous coal and anthracite. The best type of coal for heating and cooking is bitumenous coal.

Coal contains a high percentage of carbon, along with various other elements and their compounds. The constituents of coal are readily converted into useful products by heating coal in the absence of air, a process known as â€˜destructive distillationâ€™. The details of the destructive distillation of coal and its products have been dealt with in Chapter 8.

Wood and Charcoal

The solid product from the destructive distillation of wood is wood charoal. The volatile matter includes wood alcohol (methanol), propanone and ethanoic acid.

Charcoal is a black, fibrous solid. It is porous (i.e. its structure contains numerous spaces), and burns with a clean, non-smoky flame.

Charcoal of special characteristics is used for removing odours and colour in liquids and is employed in gas masks for absorbing poisonous gases. The specially prepared charcoal is called **activated charcoal**.The impurities stick to the surface of the charcoal. This process of surface bonding is called **adsorption.** It is greatly aided by the very large surface provided by the numerous pores in the activated charcoal.

Animal Charcoal (Bone Black)

Bone black is also known as animal charcoal. It is prepared by the destructive distillation of animal bones. Bone charcoal consists of about 80% calcium trioxophosphate(V) which is the mineral constituent of bones. The mineral portion is in form of a porous mass and the calcium is deposited on it. Thus it has a high surface area and is an active adsorber of gases and colouring matter. It is used in the decolourization of brown sugar to white sugar, and in making paints and inks.

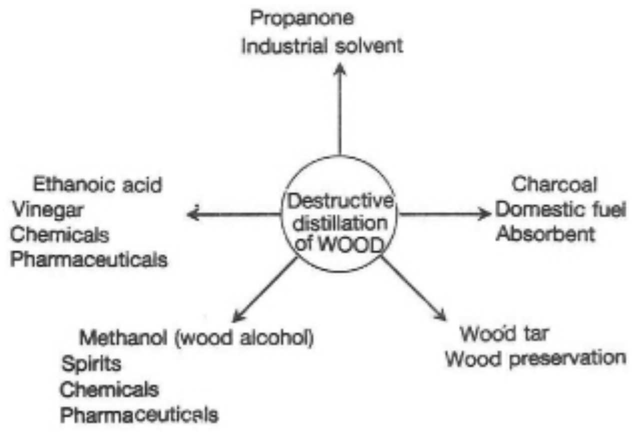


Figure 10.8 Products of the destructive distillation of wood and their uses.

Experiment 10.1 Preparation of Activated Charcoal

Take a raffia palm bamboo (better if dry) and cut it up into 3-4 cm pieces. Remove the outer cover from each piece, then put the pieces into a retort flask and cork it so that air does not enter.

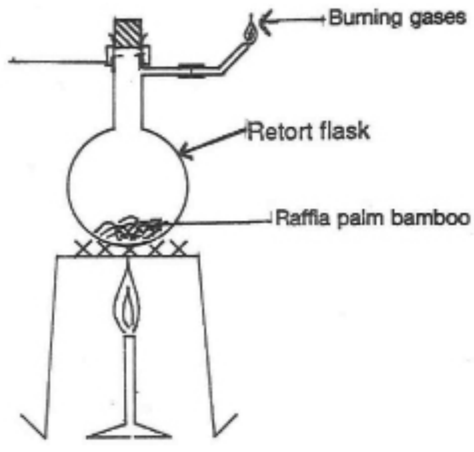


Figure 10.9 Preparation of activated charcoal

Alternatively a pyrex round-bottomed flask with a long neck may be used. Heat the container gently while burning escaping gases at a jet (Figure 10.9). Gradually heat more strongly, and continue until no more gas escapes from the flask (the flame at the jet burns out).

The black residue in the retort is activated charcoal.

Petroleum

Petroleum has now replaced coal as the principal source of organic chemicals. Over 80% of the organic chemicals required by the chemical industry are obtained from oil and natural gas. Those chemicals which are directly derived from petroleum are called petrochemicals.

We learnt earlier that crude oil distillation produces various oil fractions; petroleum (refining) gas, gasoline, kerosene, diesel oils and fuel oils. Each of these fractions may be further processed in order to obtain various desirable chemical products which are either used directly or serve as raw materials or intermediates for chemical manufacturing processes. The most important petroleum fraction for the production of petrochemicals are:

(a) $\left.\begin{array}{l}\text{Petroleum gases} \\ (C_3H_8 \text{ and } C_4H_{10}) \\ \text{naphtha}\end{array}\right\} \xrightarrow[\text{cracking}]{\text{thermal}} \text{ethene} + \text{propene} + H_2 \xrightarrow[\text{treatment}]{\text{further}} \begin{array}{l}\text{various} \\ \text{other} \\ \text{chemicals}\end{array}$

(b) $\left.\begin{array}{l}\text{Kerosene} \\ \text{fraction} \\ \text{reformate}\end{array}\right\} \longrightarrow \text{benzene and homologues (alkyl benzenes)}$

(c) Bottom distillates (waxes ....) $\xrightarrow[\text{combustion}]{\text{incomplete}}$ carbon black and coke

The most important process for the conversion of petroleum gases into chemicals is thermal cracking. The first products of the conversion of petroleum fractions into chemicals are: ethene, propene, butene, hydrogen, benzene and its homologues and carbon.

Until recently the Nigerian refineries located at Port Harcourt, Kaduna and Warri, produced mainly LPG (liquefied petroleum gas or bottled gas), gasoline and some kerosene. The refineries were designed in such a way that any fractions produced in excess of its demand was converted to gasoline.

The first phase of Nigeriaâ€™s petrochemical industry is being set up within the Kaduna and Ekpan refineries. In Kaduna the kerosene reformate fraction is fractionated to give an aromatics-rich fraction which is converted to linear alkyl benzene (C_6H_5â€“R) used for making detergents.

Location	**Fraction**		**Base product**		**Intermediate product**		**Ultimate use**
Kaduna operation	Kerosene	→	Benzene (aromatics)	→	Laboratory chemicals	→	Detergent
		→	Propene	→	Polypropene	→	Plastics
Warri	Bottom distillates (Heavy fraction)	→	Carbon black		——————→		Motor tyres
		→	Propene	→	Polypropene	→	Plastics
Port Harcourt	Petroleum gas Natural gas	→	Ethene	→	Polyethene	→	Plastics

Figure 10.10 Flow chart for the manufacture of some petrochemicals using petroleum as raw material

Natural Gas

Like petroleum, natural gas is a rich source of raw materials for the petrochemical industry. Natural gas consists mainly of methane gas (CH_4). This can be converted into useful petrochemicals such as ethene from which plastics are ultimately made. Nigeria is rich in natural gas, and plans are under way for a major liquefied natural gas (L.N.G.) project.

Agricultural (Vegetable) Products

Many products of plant and animal origin are used in the chemical industry. These products may be grouped into:

a) Bulk products such as

(i) Natural oils, which include tallow (beef or mutton oils), castor oil. olive oil, red palm oil and coconut oil. These are important raw materials for the manufacture of soaps and margarine.

(ii) Sugar and molasses â€” fermented to yield ethanol. The fermentation of sugar to yield alcohol has become a highly commercialized process in countries such as Brazil where alcohol is used as gasoline fuel. Ethanol is also a solvent and may serve as a base product in the manufacture of various other chemicals.

(iii) Bones and starch â€” used in the preparation of gums and glues.

(b) Special plant extracts e.g. dyes, latexes such as rubber and gums, perfumes and medicinal products.

Experiment 10.2 Preparation of Soap

Measure out 12g of coconut, groundnut or palm oil into a 150 cm^3 beaker. Record your weighings. Then measure out 10 cm^3 of 5M (about 20%) sodium hydroxide. Using a dropper, add about 3-5 drops of the sodium hydroxide solution to the oil and stir the mixture vigorously with a glass rod to ensure that a smooth creamy emulsion is formed. Describe the appearance of the mixture.

Then add a few more drops of the sodium hydroxide solution and continue the stirring. Continue with this procedure until all the sodium hydroxide solution has been added to the coconut oil. Note that this experiment succeeds only if you stir up the mixture so well that there is no separation of the oil from the aqueous mixture.

Allow the mixture to stand in your locker until the next laboratory class. Observe the product.

The solid in the beaker is soap. Describe its appearance. Test your soap as follows:

Wash your hands with a small piece of your soap. Comment on (i) the consistency of your soap (ii) its ability to form a lather (iii) its feel (harsh or smooth) on your body (iv) its ability to remove dirt.

You may repeat the preparation using 5 M KOH in place of the 5 M NaOH, but this time stirring should be more vigorous than for the preparation with NaOH.

Compare the sodium and the potassium soaps in terms of the properties (i)-(iv) given above.

The method used in this preparation is the cold method of soap making The reaction in soap making is generally of the form.

Glyceryl ester (fatty acid oil) + Caustic alkali (soda or potash) → Sodium salt of organic fatty acid + Glycerol

In the â€˜cold methodâ€™ the glycerol remains with the soap.

10.4 Divisions of the chemical industry

The entire range of the chemical industry may be classified into 12 divisions: heavy chemicals, fine chemicals, fertilizers, plastics, metallurgy, food and beverages, pharmaceuticals, glass, ceramics, paints, cement, soaps and detergent.

Heavy chemicals

The heavy chemicals industries produce chemicals which find large usage in nearly all areas of the chemical industry. These chemicals are manufactured in very large quantities, of the order of thousands of tonnes per annum.

Principal among these are tetraoxosuiphate (VI) acid and sodium hydroxide. Others include sodium trioxocarbonate(IV) potassium hydroxide, lime and bleaching powder. Some of the major uses of these chemicals are in the petroleum industry and in the manufacture of soap, glass, fertilizers, textiles, dyes, drugs and paints.

The use of heavy chemicals in Nigeria has grown considerably in recent times as a result of the increase in manufacturing activity. It is bound to increase with the commissioning of the various petrochemical and fertilizer plants in Warri, Kaduna and Port Harcourt which will produce alkyl benzenes, detergents and fertilizers among others. An increase in demand for heavy chemicals will also result from the pulp and paper industry in Oku-Iboku (Akwa Ibom State of Nigeria).

The raw material for the manufacture of tetraoxosuiphate(VI) acid, H_2SO_4, is sulphur. Sources of sulphur are highly limited in Africa. Consequently the demand for tetraoxosulphate(VI) acid is satisfied by direct import. The small local output of the product depends largely on imported sulphur. A little sulphur is obtained also from Algerian natural gas fields. Tunisia and Libya have jointly agreed to produce tetraoxosulphate(VI) acid from sulphur recovered from their oil. For the rest of Africa, the only significant source of sulphur is sulphide ores, especially of copper. This accounts for only about 17% of Africaâ€™s H_2SO_4 needs.

Almost all the tetraoxosulphate(VI) acid used in Nigeria is imported. Some manufacturers import sulphur to produce acid for their own internal use. One major plant located at Inyigba (Abakaliki) uses sulphur recovered from the lead and zinc ores found in the area as its raw material.

Other heavy chemicals such as sodium hydroxide are equally in large demand for the soap and detergent industries. Some other industries also have need for sodium hydroxide. Some major projects for the manufacture of chlor-alkali chemicals have reached advanced stages. One such plant located at Uburu-Okposi in Abia State is based on the large salt (NaCl) deposits in the area.

10.5 Fine chemicals

Fine chemicals are special chemicals which are used in relatively small quantities, of the order of tens of tonnes to a few kilogrammes per annum. They are of higher purity than the heavy chemicals, and relatively more expensive. Such chemicals include various cosmetics and perfumes, dyes, photographic chemicals, analytical reagents and additives to fuels and paints.

The cosmetics industry in Nigeria is a fast growing one. The manufactured products include cleansing and cold creams, hand lotions, shaving lotions, face powders, dusting and talcum powders, tooth pastes, nail polishes and removers, hair treatment chemicals, perfumes and deodorants. A number of the small scale industries manufacturing these products are based in Ikeja, Kaduna, Aba and elsewhere.

10.6 Fertilizers

Fertilizers form an essential tool of modern agriculture. Soil fertility depends in part on the chemicals present in the soil. The addition of fertilizers is aimed at ensuring the proper balance of chemicals in the soil. Thus fertilizers make it possible not only to get more food from the soil in a given year but also to cultivate on the same piece of land every year.

The principal fertilizers manufactured in a large scale are the nitrogenous, potash and phosphate fertilizers. They provide the essential elements for proper plant growth, which are nitrogen, phosphorus and potassium (N. P. K). Subsidiary agro-chemicals such as pesticides and plant-growth chemicals are also manufactured in addition.

The importance of fertilizers in the Nigerian economy will continue to increase in view of the greater emphasis being placed on modern agriculture.

It is hoped that the need for large scale importation of fertilizers will be eliminated when the local fertilizer plants become fully operational. A full-scale fertilizer manufacturing plant has taken off in Port Harcourt. It uses natural gas for the production of nitrogeneous fertilizers (and sea water for potash). A superphosphate fertilizer plant is also located in Kaduna.

10.7 Plastics

All substances and materials that are easily moulded or shaped by heat and pressure are called plastics. The materials to be moulded are formed by linking small molecules to form giant molecules, such as occur in the manufacture of synthetic rubbers.

The manufacture of plastics has now grown into a very large industry. This growth is accounted for by two factors:

(i) the large growth in the demand for plastic goods in the homes and for industrial use.

(ii) the continued introduction of new varieties of plastics through the results of chemical research.

Plastics form important items in our households where they are found as plastic kitchen wares, baths, furniture, mattresses, pillows, toys, tyres, wearing apparel, shopping bags and woven sacks.

In industry, plastics form materials of construction such as in making water pipes and fittings, car body and machine parts, roofing sheets and ceiling boards, and for containers of various sizes. The use to which any plastic product is put is determined by the characteristics of the plastic. There are therefore many types of plastics with specific individual properties. Some of the common plastics are polythene, polypropene, polyethers, polychloroethenes, polyesters and polyvinyl chloride (PVC).

The raw materials for the manufacture of plastics are all organic and are obtained mostly from petroleum products.

Plate 10.3 A variety of plastic products

All plastics fall into two main classes:

(i) Those which set into a rigid form on cooling, but can still be softened by the application of heat and reformed on cooling. Such plastics are called **thermoplastics**. They can be welded together by application of gentle heat and softened at even fairly low temperatures and pressure. Examples of thermoplastics are polythene, sealing wax, nylon and polystyrenes.

(ii) Those which set into a permanent rigid form on cooling. They cannot be subsequently made to soften by application of heat or pressure, and are extremely difficult to dissolve. They are called **thermosetting plastics**. Examples are terylene and dacron.

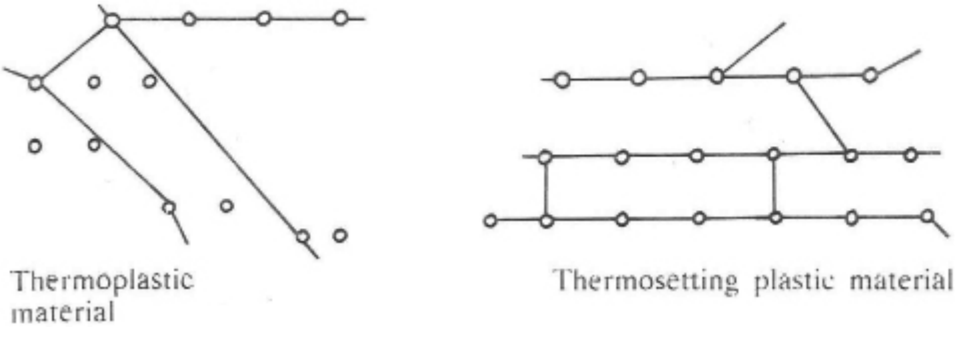


Figure 10.11 Structure of molecules in plastics

10.8 Foods and beverages

The food and beverage industry in Nigeria is heavily dominated by industries engaged in the manufacture of alcoholic drinks.

Alcoholic drinks

There are three main categories of alcoholic drinks:

(i) Wines: an example is palm wine which is common in West Africa. It contains about 10 â€” 20% alcohol.

(ii) Beer: this has an alcohol content of about 4 â€“ 5%.

(iii) Spirits: these have alcohol contents of about 40% or more.

The principal chemical process in the manufacture of alcoholic drinks involves the conversion of carbohydrate to alcohol in the presence of a catalyst (enzyme).

$$\text{Carbohydrate} \xrightarrow{\text{enzyme in yeast}} \text{alcohol} + CO_2 + \text{energy liberated.}$$

$$\text{e.g. } C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g) + \text{energy.}$$

This process is called **fermentation**. Wines and beers result directly from fermentation. Spirits are however prepared by the distillation of a fermented drink, which then increases its alcoholic content considerably.

The starting material for the preparation of alcoholic drinks vary considerably from country to country and from one process type to another.

Experiment 10.3 Preparation of alcohol from sugar

Place 50 cm^3 of 10 percent solution of sucrose (cane sugar) in a conical flask. Place a plug of cotton wool in the mouth of the flask. Then add 5g of powdered brewerâ€™s yeast. Shake the flask and allow it to stand in a warm atmosphere for 2 days. The required approximate temperature of about 35Â°C may be maintained by placing the flask in a cupboard in which a bunsen flame burns gently.

After two days filter the aqueous solution to remove the yeast. The product is a dilute solution of ethanol. The solution may however be fractionally distilled to produce a more concentrated alcoholic solution.

In this process, one of the enzymes, invertase, present in yeast hydrolyses the sucrose to glucose and another enzyme in yeast called zymase hydrolyses the glucose to ethanol.

$$\underset{\text{sucrose}}{C_{12}H_{22}O_{11}(aq)} + H_2O(l) \xrightarrow{\text{invertase}} \underset{\text{glucose}}{C_6H_{12}O_6(aq)} + \underset{\text{fructose}}{C_6H_{12}O_6(aq)}$$

$$\underset{\text{glucose}}{C_6H_{12}O_6(aq)} \xrightarrow{\text{zymase}} \underset{\text{ethanol}}{2C_2H_5OH(aq)} + 2CO_2(g)$$

Sugar is the raw material for the manufacture of alcohol in the Carribeans. In many parts of the world, including West Africa, the raw material for alcoholic drinks is not sugar, but starch obtained from:

(i) fruits such as banana or fruit juice such as pineapple and oil or raffia palm saps (palm wine);

(ii) grains such as maize, millet, guinea corn and barley;

(iii) roots such as cassava and potatoes.

The starch-containing material is first crushed. The starch is extracted by treating the material with steam; malt is then added. Malt contains the enzyme diastase which converts starch by hydrolysis to maltose.

$$\underset{\text{starch}}{2(C_6H_{10}O_5)n(aq)} + nH_2O(l) \xrightarrow{\text{diastase}} \underset{\text{maltose}}{nC_{12}H_{22}O_{11}(aq)}$$

To convert the maltose present to ethanol, yeast is then added. Yeast contains the enzymes, maltase and zymase. Maltase catalyses the conversion of maltose to glucose. The glucose is converted to alcohol by the enzyme zymase.

$$\underset{\text{maltose}}{C_{12}H_{22}O_{11}(aq)} + H_2O(l) \xrightarrow{\text{maltase}} \underset{\text{glucose}}{2C_6H_{12}O_6(aq)}$$

$$C_6H_{12}O_6(aq) \xrightarrow{\text{zymase}} 2C_2H_5OH(aq) + 2CO_2(g)$$

A common alcoholic beverage in Nigeria and a number of other West African countries is the traditional palm wine. It is a sap tapped off the apical bud of oil palm or raffia palm trees. When freshly obtained, palm wine contains sugar and yeast. If allowed to stand for two to three days, the sugar in the wine is fermented by the yeast. The alcohol content can reach a level of about 10-20%. Since yeast is inactive at alcohol levels of above 17%, increasing the alcohol content is achieved through fractional distillation.

In Nigeria and many other African countries there are local industries based on the traditional distillation of fermented palm wine to produce spirits usually termed â€˜illicitâ€™ gin (Plate 10.4).

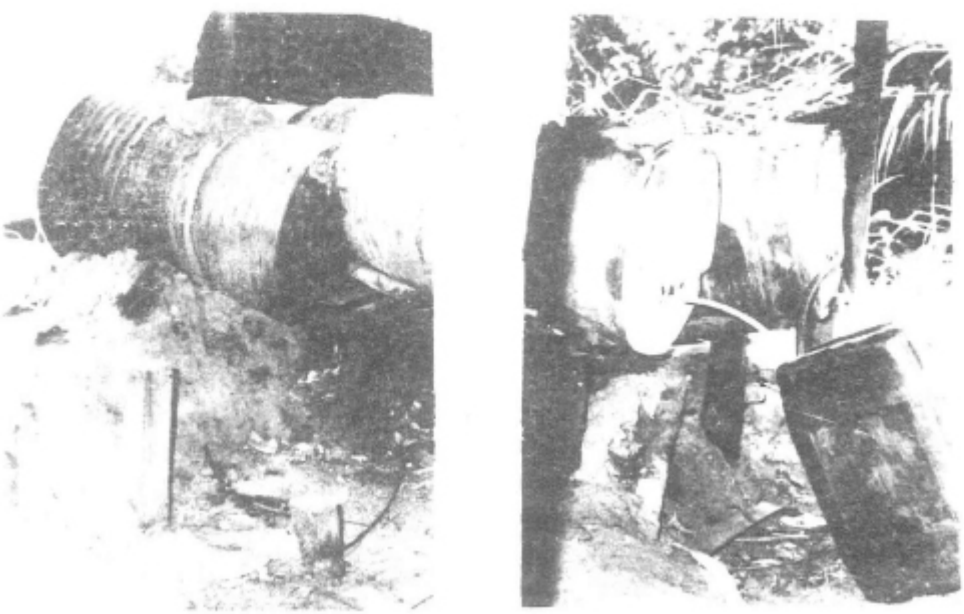


Plate 10.4 A local distillery

A large number of industries have now been set up in many African countries to manufacture beer, wines and spirits. The basic raw materials for hese processes consist of wheat, barley and maize.

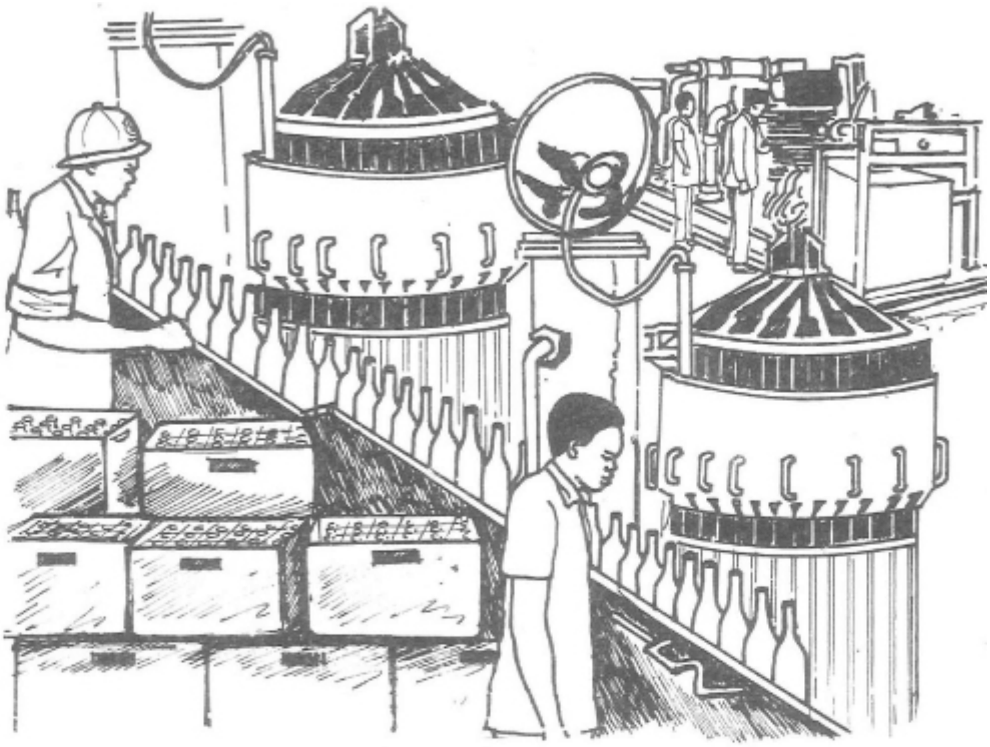


Figure 10.12 The brewing of beer

The brewing of beer

Three principal processes involved in the production of beer are:

(i) Conversion of starch in the grains by diastase (present in the malt) to maltose.

$$\underset{\text{Starch}}{(C_6H_{10}O_5)n(aq)} + \frac{n}{2} H_2O(l) \xrightarrow{\text{diastase}} \frac{n}{2} \underset{\text{Maltose}}{C_{12}H_{22}O_{11}(aq)}$$

The maltose is dissolved in water and the impurities separated from the liquid by filtration. Solution of the malt sugar is called **wort.**

(ii) Hydrolysis of maltose by the enzyme, maltase, (present in yeast) to glucose.

$$\underset{\text{maltose}}{C_{12}H_{22}O_{11}(aq)} + H_2O(l) \xrightarrow{\text{maltase}} \underset{\text{glucose}}{2C_6H_{12}O_6(aq)}$$

(iii) Conversion of glucose by zymase (present in the yeast) to ethanol.

$$C_6H_{12}O_6(aq) \xrightarrow{\text{zymase}} 2C_2H_5OH(aq) + 2CO_2(g)$$

The yeast for beer making is either of the types â€” *Saccharomyces cerevisiae* or *Saccharomyces carlsbergensis.* The type to be used is determined by the nature of the beer to be brewed. The fermented liquor contains 6-10 per cent alcohol. Distilling the liquor several times yields whisky.

European wines are prepared by the fermentation of grape juice. Grapes are grown in temperate climates, especially the Mediterranean zone. Red wines are made from black grapes while white wines are made from white grapes. The fermentation is brought about by the enzymes contained in a microscopic yeast, *Saccharomyces ellipsoideus* which is found in the skin of the grapes. Virtually any fruit juice may be fermented to produce a wine.

A description of the nature of various alcoholic beverages is given in Table 10.4.

TABLE 10.4 Types of Alcoholic Beverages

Type	How Prepared
Beer â€“	Made by fermentation of starch-containing substances, such as barley or barley-like cereals. No distillation. Hop added to improve taste and flavour.
Whisky â€“	Prepared by distilling solution formed after beer is brewed.
Wine â€“	**By fermentation of fruit/plant juice; no distillation. The wine may be red or white** depending on starting material.
Cognac â€“	By distillation of fermented grape fruit juice.
Gin â€“	By fermenting and distilling rye or palm wine.
Rum â€“	By distilling the fermentation product of sugar solution.
â€˜Illicitâ€™ gin â€“	Locally prepared alcoholic liquor obtained by distillation of fermented solution of palm wine.

Margarine

The first margarine was made in 1869 by Mege-Mouries a French Chemist, as a â€˜cheap butterâ€™ for the French armed forces. However margarine as we know it today is prepared by the addition of hydrogen to animal and vegetables oils to produce solid fat. This process is called **hydrogenation**.

Margarine was first made from animal fats such as beef tallow, but now the principal raw material for its manufacture is vegetable oils, especially cotton seed, groundnut, palm oil, maize and sunflower oils and other cooking oils. To extract the oils from the oil-bearing seed, the seeds are crushed and the oils extracted either mechanically by applying pressure to squeeze out the oil, or by the use of a suitable organic solvent which dissolves the oil. The oil is then purified before it is hydrogenated.

During hydrogenation, hydrogen is bubbled through the vegetable oil in which is suspended finely divided nickel catalyst. The oil is maintained at a temperature of about 140Â°C. Some of the double bonds in the oil are hydrogenated during this process. The liquid vegetable oil becomes solid as a result of the hydrogenation. Colouring, vitamins and flavouring materials are then added to obtain the margarine. Margarines, and soaps are often made by the same manufacturers because both require the same raw materials, edible oils.

10.9 Pharmaceuticals

One area in which chemistry has contributed most to man is in promoting health and longevity. Chemistry has done much to keep off the agents of illness and disease, and to help us get well when we become sick. To make this possible the chemist has worked in conjunction with the pharmacist, physician and surgeon, by providing numerous varieties of medicines and drugs which reduce pain and help cure diseases.

The various medicines such as antiseptics, anaesthetics, antibiotics, sedatives, hormones, laxatives, ointments, nose sprays, mouth washes, serums, antitoxins, etc, are prepared by established methods of chemical technology under the careful control of chemists.

Disinfectants are used to arrest the growth of harmful germs, and preventing them from attacking the body. However, some of these germs do get into the body, causing disease. We use drugs to kill germs when they attack the body. The use of chemicals (drugs) to treat disease is called **chemotherapy.** Chemicals used in medicinal preparations fall into various classes according to the roles they play in the body. Some of these are as follows:

Disinfectants

Disinfectants are a group of chemicals which act to kill or stop the growth of germs. Some disinfectants are capable of stopping bacterial growth but are too strong to be used on the body. These are called **germicides.** Disinfectants which arrest the growth of bacteria and are mild enough to be used on human tissues are called **antiseptics.** Most antiseptics in use are actually dilute solutions of germicides.

Common antiseptics and disinfectants are iodine (used as iodine tincture) hydrogen peroxide, trioxoborate(III) acid and mercury(II) iodide. Other disinfectants in common use include carbolic acid, sodium oxochlorate(I), cresols and formalin.

Plate 10.5 A chemist (drugist) store

Antibiotics

The first set of drugs used for treatment were sulphur-containing compounds. Examples are sulphathiazole, sulphanilamide, sulphapyridine, etc. These drugs stop bacteria from spreading, allowing the body defence agents (white blood cells) to attack and destroy the bacteria.

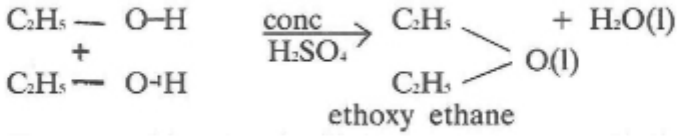
Penicillin was discovered in 1929 by Sir Alexander Fleming and was subsequently used as an effective chemical (antibiotic) against many types of bacteria. Since then a wide range of other antibiotics have been developed. Examples are streptomycin, auromycin, terramycin, erythromycin. These antibiotics are obtained as products from moulds cultured under sterile conditions in the laboratory.

The disease malaria which is common in Nigeria and most other West African countries, is caused by a protozoan which multiplies in the blood of its victim. The drug, quinine has been used with great success for treating malaria. It was initially obtained from the bark of a tree called *Chinchona.* Quinine is now manufactured synthetically by a process developed in 1944 by the American chemists, Robert Woodward and William Doering.

Anaesthetics

The use of antiseptics was a great contribution to surgery as it has now made surgery safer. The introduction of anaesthetics however represents a vital development in the practice of surgery. Anaesthetics are those chemicals (drugs) which when used on parts of the body cause temporary numbness, unconsciousness or loss of feeling. Anaesthetics have thus made surgery painless, thus reducing shock and other dangerous after-effects of surgical operations.

The first known anaesthetic was ethoxyethane (diethyl ether) which was first used in 1842 by Dr Crawford W Long. Ethoxyethane was then used in an operation to remove a tumour. It is readily prepared by treating ethanol with concentrated tetraoxosulphate(VI) acid.



Dinitrogen(I) oxide (N_2O) is used as an anaesthetic particularly in dentistry and occasionally in childbirth. It is usually administered to a patient as a mixture with carbon(IV) oxide and oxygen. Because when patients are recovering from its effect they tend to be hysterical, it is called â€˜laughing gasâ€™. Trichloromethane, $CHCl_3$, was until recently a common anaesthetic. It is no longer in use. Ethene (C_2H_4) mixed with oxygen also serves as an anaesthetic. Methoxyethane, dinitrogen oxide, trichloromethane, cyclopropane and ethene are **general anaesthetics**. This means that they produce total unconsciousness of the body. Another general anaesthetic, sodium pentothal, is administered by injection into the arm.

Some other anaesthetics deaden pain in some restricted parts of the body. They are called *local anaesthetics.* Examples are dichloromethane, CH_2Cl_2, monochloroethane, C_2H_5Cl, and novocaine. They are used for minor surgical operations.

Sedatives, Stimulants and Narcotics

Drugs which reduce nervous tension and depress the action of the brain are called sedatives. They may also be called depressants. One common depressant is aspirin which is used to suppress headaches. Aspirin is a relatively simple organic compound called acetylsalicylic acid. You can readily prepare samples of aspirin in your laboratory (see projects).

Stimulants produce some momentary increase in physical and mental activity. Alcoholic beverages fall into this category. They are stimulants when taken in small amounts; in large amount however they have an opposite effect i.e. they depress mental and physical activity.

Narcotics are drugs which are used in special medical cases but which have been abused by unauthorized users. These drugs when taken will first excite and stimulate all body activities, and then cause extreme depression of the bodyâ€™s actions. Narcotics such as cocaine, codeine, heroin and morphine are derived from plants. They belong to a class of chemicals called alkaloids. The narcotics are used in the management and treatment of cancer patients. However, their use is carefully regulated because they are habit-forming and may cause detrimental changes in physical and mental behaviour in people when used in wrong doses.

Synthetic Hormones

Hormones are chemicals secreted by ductless (endocrine) glands in the body and they regulate body activities. These include substances such as insulin, adrenalin, cortisone, oestrogen and testosterone, a good number of which are now produced synthetically (i.e. by laboratory techniques). Thus, insulin used in treating diabetic patients is essentially synthetically produced. Most contraceptive pills are also hormones and are produced synthetically.

10.10 Glass

Glass making is one of the high-temperature processes of chemical technology, i.e. it uses temperatures higher than are normally encountered in the normal laboratory. Other high-temperature processes are ceramics and cement manufacture.

The necessary high temperatures are achieved in furnaces which are capable of producing temperatures of up to 1000Â°C and above. The furnace in which glass is made is a high tank heated by gas or oil and capable of holding several tonnes of material.

Ordinary glass such as those used for making bottles, window panes and laboratory glass tubings is known as soda-lime glass or soda glass. It is prepared by heating together a mixture of sand ($Si\ O_2$) limestone ($CaCO_3$) and soda ash (sodium trioxocarbonate(IV), Na_2CO_3), in a furnace.

At the temperatures of the furnace the following reactions take place:

$$CaCO_3(s) + SiO_2(s) \longrightarrow CaSiO_3(s) + CO_2(g)$$
$$Na_2CO_3(s) + SiO_2(s) \longrightarrow Na_2SiO_3(s) + CO_2(g)$$

Glass is a mixture of silica (sand) with sodium and calcium trioxosilicate(IV) salts. The molten mass is cooled and solidifies without first forming crystals. Glass is therefore a **supercooled solution.**

During glass making the raw materials are fed together with scraps of glass at one end of the furnace; the molten product is drawn off at the other end.

The molten glass is plastic in nature and may be drawn into sheets, poured into moulds or blown into desired shapes by a glass blower or machines. Glass is usually cooled slowly, a process called **annealing,** which is carried out in an annealing oven.

Pure glass is colourless. Quite often however impurities of iron compounds contained in the raw materials i.e. limestone and sand may impart a greer colour. These colours may be masked by the addition of manganese(IV) oxide, MnO_2 to the furnace during glass making.

Special types of glass

There are a number of special varieties of glass, some of which are as follows:

Plate glass: This is the type of glass produced by leaving the molten soda lime glass in the hot furnace for several days. This allows all the carbon(IV) oxide evolved during the decomposition of $CaCO_3$ and Na_2CO_3 to escape completely. The molten product is rolled flat, annealed and polished. It is used for making table tops, glass doors and large windows.

Safety (shatterproof) glass: These are used in automobile windscreen. They are made by placing a thin sheet of plastic between two thin sheets of plate glass. By applying heat and pressure the glass sheets are cemented to the plastic sheet. Thus the glass can break but does not shatter as the plastic holds the broken pieces in place.

Bulletproof glass: This is made of many layers of glass and plastic.

Reinforced glass: This is produced by forming a plate glass around a mesh of iron wire.

Lead glass: This is the glass used in light bulbs and for making decorative glass vases. It consists of dense and soft glass which is prepared by using potash (K_2CO_3) in place of soda ash and lead(II) oxide in place of limestone.

Fibreglass: When forced through tiny openings, molten glass on solidifying forms strong and flexible fibres. Some of the strands may be finer than human hair. The product is called glass wool. These glass fibres may be spun or woven to form fabrics. Fibreglass is an excellent heat and electrical insulating material and is completely fire and rot-proof.

Pyrex glass: This is used in producing laboratory glassware, cooking ware etc. It is made from a mixture of sand, sodium heptaoxo-tetraborate(III) ($Na_2B_4O_7$) aluminium oxide (Al_2O_3) and arsenic oxide, AS_2O_3. This glass is thus a mixture of sodium borosilicate and aluminium borosilicate.

Crown glass and flint glass: These types are used to make lenses for telescopes, microscopes and cameras. They are ordinary soda lime glass made with a high degree of purity and free from colour. Flint glass is made from lead and potassium compounds similar to that used in making glass vases.

Foam glass: This is very low density glass with a density similar to that of cork Like glass wool, it is a good heat and electrical insulator. It is also sound proof and can be sawn like wood.

Foam glass is produced by mixing crushed glass and powdered coke in a furnace and heating the mixture to a temperature of about 3600Â°C. The carbon burns and produces gases which swell up the molten mass, giving a porous material. Owing to its lightness, it is used in life rafts and buoys.

Colouring of glass

The normal green colour in glass is indicative of impure and cheap quality glass. However, sometimes glass is intentionally coloured by the addition of small amounts of metallic compounds to the melt. Some such intentionally added colouring matter and the colours imparted are as follows:

Colour	Colouring matter
Green	Cr as Na_2CrO_4
Red	Se
Dark blue	CoO
Purple glass	MnO_2
White glass	CaF_2
Opaque glass	As_2O_3

Plate 10.6 Glass blowing in progress

10.11 Paints

Paints have been in use long before written history. They were initially used for decoration and for primitive art. Prehistoric man for instance, used coloured clay to make drawings on walls of caves. The roles of paints for decoration and art paintings are still important today. The proper selection of colours for homes, schools, hospitals and offices has some influence on the happiness and efficiency of the people in them.

Apart from the aesthetic applications of paints, they also serve a useful function of protecting items. They keep off water, oxygen and carbon(IV) oxide, the. agents of corrosion from materials on which they are coated. In some cases, the paints also prevent the growth of fungi. Thus, paints may protect wood from decay, and iron and steel from rusting. The protective role of paints is very important in buildings, ships, vehicles and furniture.

We may define a paint as any coloured liquid which when spread over a solid surface dries or hardens to form a uniform film. A paint may be as simple as â€˜whitewashâ€™, which is chalk mixed with water. On the other hand, it may be an extremely complex type such as the paints for cars, which are designed to withstand varying and extreme weather conditions.

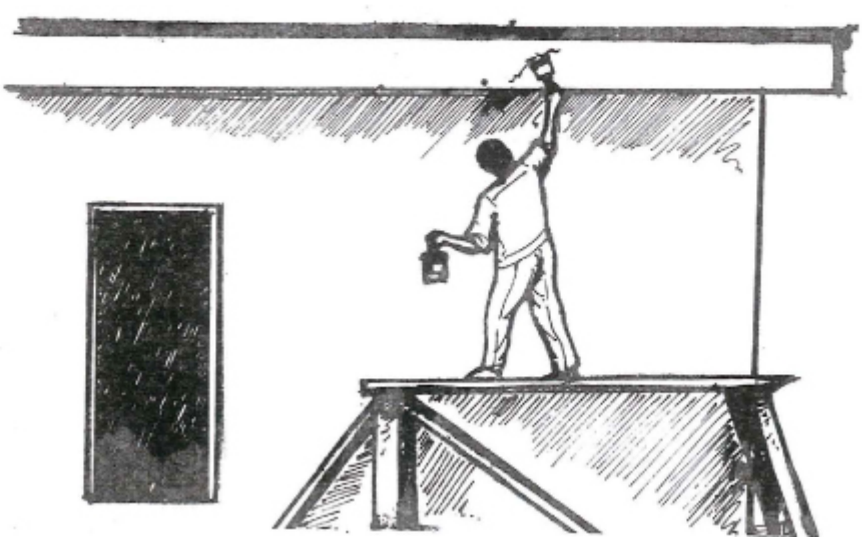
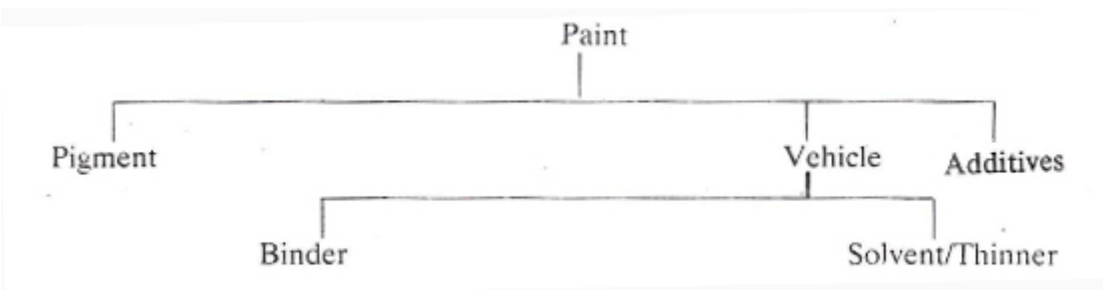


Plate 10.7 A painter at work

The constituents of all paints can be summarised with the diagram shown below:



From the diagram, it could be seen that all paints consist of two main portions: â€”

(a) the pigment; which is a solid composed of fine insoluble particles, and provides the colour of the paint film;

(b) the vehicle, which refers to the liquid portion of the paint along with other materials that may be dissolved in the liquid portion.

The pigment particles are insoluble in the vehicle, but are dispersed in it. Most common pigments are inorganic substances. Some organic pigments are also in use, such as carbon (black) and monastral (blue).

Some common pigments employed in paints include the following:

Colour	Pigment
White	(i) Titanium oxide, TiO_2 which is the most important white pigment. (ii) Zinc oxide, ZnO. (iii) White lead, $2PbCO_3.Pb(OH)_2$.
Red and Brown	(i) Coloured clays; (ii) Hydrated iron oxides; (iii) Red lead (Pb_3O_4).
Prussian blue	$K_4Fe(CN)_6$.
Yellow	(i) Lead tetraoxochromate(VI), $PbCrO_4$; (ii) Zinc tetraoxochromate(VI), $ZnCrO_4$;
Metallic	powdered aluminium metal
Black/Grey	lamp black and bone black; when added to white paint, darkens the paint giving various tones of grey.

Note that lead paints have the disadvantage that when exposed to air contaminated with hydrogen sulphide, they darken and become unsightly.

In some paints, the pigments are mixed with other substances called extenders which are used for a number of purposes such as:

(a) to improve the mechanical strength of the paint film

(b) to assist viscocity of the paint

(c) to improve adhesion to the surface

(d) to reduce the cost of the paint.

Some common extenders are calcium trioxocarbonate(IV) (chalk), barium tetraoxosulphate(VI) and various compounds of silicon, e.g., talc, $3MgO.4SiO_2.H_2O$ and china clay.

The vehicle: The roles of the vehicle are (a) to make it easier to apply the paint and (b) to bind the paint to the surface being painted. The vehicle may have two component parts:

â€” a non-volatile portion which is called the binder and forms part of the final solid film, and

â€” a volatile portion known as the thinner which evaporates during the drying of the paint. The volatile portion is therefore not a part of the dry paint film. Its function is to increase the flow properties of the paint and hence make it easier to apply the paint to the surface. The solvent in emulsion paint is water while that in gloss or oil paints are organic chemicals derived from the petrochemical industries; for example, white spirit (the commonest), xylene, etc.

The binder which is the non-volatile part of the clear film binds the pigments particles together and to the painted surface. When used without pigments, it forms a dry clear film referred to as â€˜varnishâ€™. A number of substances including glue, milk, honey and wax have been used as binders. Drying oils such as linseed oil are more commonly used as binders.

The binder gives the paint necessary properties such as gloss, adhesion, hardness, toughness, durability, flexibility and ease of drying. It is the most important part of the paint.

To make the paint, the finely ground solid pigments are mixed with the oil. The pigment particles remain suspended in the vehicle for long periods of time. Occasionally the mixture may have to be stirred to make it uniform. On application of the paint to the surface, the pigment and the non-volatile vehicle (binder) dry together forming a solid film. The time taken for this change in composition varies from less than an hour to several days, depending on the nature of the binder and the pigment-to-vehicle ratio.

Traces of a number of other constituents may be added to the paint composition to provide certain desirable properties in the paint. One such constituent is the dryer. The dryer is usually an active catalytic agent which promotes the drying process and shortens drying time. The usual dryer consists of a mixture of lead, manganese and cobalt compounds.

Another important additive is silicone, which makes the surface of the film more resistant to marking and scratching.

Types of paints

We may group paints according to their uses. Thus we have exterior and interior building paints, wood paints, industrial coatings, automotive paints, liquid-on-paper paints, etc. It is more common to classify paints according to their composition, especially the nature of the vehicle. Some of the important types of paints are:

Emulsion paints: These are water-based paints; the vehicle is primarily water. They are the commonest paints in the market and are used mainly for residential buildings.

Oil paints (gloss): These are oil-based paints. The vehicle consists primarily of drying oils, such as linseed oil. They dry to a thick, smooth and lustrous finish which is impervious to air and water. They provide protection against the weather and do not wear or scratch easily. They are used for coating the surfaces of storage tanks, metals, windows, doors, etc.

Varnish: A varnish is a surface coating which gives a harder and more lustrous surface than ordinary paints. It is made by mixing a drying oil, a hard resin, a dryer and a volatile solvent with no pigments. The resulting mixture is a clear liquid which when spread on a surface dries to the hard lustrous film.

Enamel paints: These are varnishes which are made opaque by the addition of insoluble pigments.

Lacquer: Lacquers are quick-drying paints specially used in the machinery industry for coating objects such as automobiles, refrigerators, dryers, etc. The vehicle in lacquers is cellulose (as nitrate(V) or ethanoate) or ethyl ethanoate. A component called plasticizer is added to give proper flexibility to the paint.

10.12 Cement

Cement is used extensively all over the world for various types of civil construction works.

The ancient Egyptians used mixtures of lime and Plaster of Paris for binding stones while the Romans used cement as a mortar and plaster for walls. Cement, as we know it today is called Portland cement. Portland cement was first prepared by Aspden in 1824. Todayâ€™s Portland cement is still similar in many respects to the original product.

Portland cement could be prepared from a variety of raw materials, two of which are calcium trioxocarbonate(IV) (in the form of chalk or limestone), and aluminium trioxosilicate(IV) (in the form of clay, shale or slate). Cement works are therefore sited near large deposits of these bulky raw materials in order to avoid huge transportation costs.

There are a number of different ways of making cement, all of which involve the same basic procedure. In making cement, the raw materials are thoroughly ground and mixed, fired in a kiln and finally ground to a fine powder. The processes involved are of two types â€” the wet and the dry processes. The choice of method depends on whether the calcium trioxocarbonate(IV) is in the form of hard limestone or as soft chalk. The wet method is used in the case of chalk while the dry method is used for limestone.

The wet process

In the wet process the raw materials, chalk and clay, are ground with water to obtain a thick slurry. This slurry is blended until a correct chemical composition is obtained; it is then transferred to a rotary kiln which is a large cylindrical vessel ranging in diameter from about 5m to 180m. The kiln is maintained at temperatures of about 1400Â°C.

In the kiln, the water is boiled off and carbon(IV) oxide is liberated due to the decomposition of trioxocarbonate(IV). The clay and limestone undergo reaction, forming a mixture of calcium aluminatc(III), calcium trioxosilicate(IV) salts with some free lime, which make up the cement.

Under the great heat inside the kiln, the product is fused. It forms small pieces of the size of fine gravels referred to as cement clinker. The clinker is cooled and gypsum is added. The mixture is then ground to a very fine powder in large mills and stored in cement silos.

The dry process

The raw materials are limestone and shale. Both materials are ground to a fine dry powder, and any moisture present is removed by passing the hot waste gases from the kilns over the mixture. The mixture (raw meal), is blended to the correct chemical constitution and then transferred to a pre-heater where the materials are heated to about 800Â°C. They are then transferred to a shorter kiln â€” a Humbolt kiln where clinker forms. After cooling, gypsum is added, and the mixture ground to a powder and stored in silos.

Plate 10.8 A cement factory

Note that the manufacture of cement is associated with two major problems:

(1) it emits large quantities of dust which is dangerous to health.

(2) the quarries which are left after mining the raw materials require proper disposal, otherwise they are unpleasant to the sight.

Nigeria now manufactures a large proportion of her requirements of cement. Manufacturing industries are located at Nkalagu, Okene, Ukpilla, Ewekoro, Sokoto and Gboko.

10.13 Ceramics

The term ceramics includes all the range of products or objects which are made from clay. Building bricks, earthenware such as cooking and storage pots, vases and breakable plates are products of the ceramics industry.

The art and craft of ceramics in Nigeria has now grown from the handicraft stage into a fully mechanized industry. Thus, the native pottery industry exists side by side with such establishments as the Ceramics Industries at Umuahia in Abia State, or the Clay Products Company at Ezinachi, in Imo State.

Clay is represented by the formula $H_4Al_2Si_2O_9$. and is one of the most abundant substances in the earthâ€™s crust. Mixed with water, it becomes plastic and can therefore be formed into any desired shape, On heating this plastic material, the water is driven out, leaving a hard product.

Building bricks

They are prepared from impure clay. The clay is mixed with sand and water and then cut into shape. It is then dried and baked in a kiln. At the high temperatures of the kiln, the constituents fuse together into a very hard mass.

To give the product a smooth non-porous surface, it is treated to a process called glazing. During glazing, salt is added to the kiln and the temperature further raised. The salt vapourizes forming a glassy coating over the brick. The red colour of the brick is due to the salt in the clay. If the finished brick is to be given special colours, then colouring glazing salts are used.

Plate 10.9 Different types of ceramic products

Earthenware

Earthenware such as jars, flower pots and roofing tiles are also prepared from impure clay. The clay is first moistened and shaped. It is then baked in a kiln until it hardens. It may then be glazed. All objects prepared by shaping and firing of clay are regarded as **pottery**.

Chinaware and porcelain

These are types of pottery products made from pure clay. Such a pure form of clay is called **kaolin**. Chinaware and porcelain are produced by mixing the kaolin with powdered quartz SiO_2, the mineral feldspar, $KAlSi_3O_8$ and water. The mixture which is first made into a heavy plastic mass is shaped as desired either on a rotating wheel (**potterâ€™s wheel**) or in a mould. It is then placed in a kiln and fired. The product at this stage is hard but porous.

To glaze it, a paste which consists of quartz, feldspar and metallic oxides (to provide colour if desired) is applied. It is then fired a second time. The glazing produces a non-porous surface which is highly resistant to chemical attack. A design is painted or inscribed on the surface, then a final coat of glazing is put on the object and it is finally fired to fix the design on the object.

10.14 Soaps and detergents

Soap is probably the most important commercial product derived from animal and vegetable fats. Soap is a metallic salt of long chain alkanoic acid such as hexadceanoic (palmitic) acid and octadecanoic (stearic) acid. The alkanoic acids of interest are those of C_{12} to C_{18}. Soaps prepared from acids with carbon chain less than C_{12} irritate the skin while those above C_{18} are very insoluble.

Soap is prepared locally in Nigeria by heating together a mixture of palm oil and an aqueous extract of wood ash which contains potash, K_2CO_3. The product is soft and dark. Although this soap is not exactly as attractive as the commercially made soap, the manufacturing procedure for commercial soap applies the same chemical principles.

Commercially, soap is made from animal and vegetable oils, such as tallows (beef or other animal fat), palm oil and coconut oil. In the preparation of soap the oil or a mixture of oils is heated with sodium hydroxide (caustic soda) solution. The sodium hydroxide hydrolyses the oil. This reaction is called **saponification.**

The fats and oils used for soap making are esters of propan-l,2,3-triol (glycerol) and three alkanoic acid units (triglyceryl esters). During saponification the esters are converted to propan-l,2,3-triol and alkanoic acid salt which is the soap.

Example:

$CH_3(CH_2)_{16}CO\text{-}OCH_2$

$CH_3(CH_2)_{16}CO\text{-}OCH(l)$

$CH_3(CH_2)_{16}CO\text{-}OCH_2 + 3NaOH(aq) \rightarrow 3CH_3(CH_2)_{16}COONa(aq)$ (soap) + CH_2OH–$CHOH(l)$–CH_2OH

Propan-1,2,3-trioctadecanoate (stearate)

Propan-1,2,3-triol (glycerol)

Soaps made from sodium hydroxide are usually **hard soaps.** The hydrolysis of fats and oil could also be carried out using potassium hydroxide. Potassium soaps are soft solids or liquids and are used in toilet soaps and shampoos. Potassium soaps are called **soft soaps.**

Commercially, soap making may be carried out either as a batch process i.e. prepared one batch at a time or as a continuous process (i.e. as an unbroken chain of events). The batch process is much more established than the continuous process.

The batch process

In the batch process, the oil, water and some salt are placed in a reaction vessel called a kettle with a diameter of about 8.5m and a depth of about 10m. The mixture is then heated with steam from open tubes. A solution of sodium hydroxide is then run in, and the mixture is carefully boiled. As saponification proceeds, further additions of sodium hydroxide, fats and salt are made. Saponification is complete after several hours.

Common salt is then added with stirring to the boiling mixture. This causes the soap to separate out and stay as a frothy layer on the surface. This process is known as â€˜**salting out**â€™.

The solution beneath the soap layer is called **lye** and contains the glycerol and salt. It is run off and the glycerol which is an important by-product is recovered while the salt is re-used for making more soap.

The soap left behind is called **grained soap**. This soap undergoes a number of washing stages to remove remaining glycerol. Perfumes or colours are added. It is then conditioned to give it a proper texture. This process is called **fitting**. The soap is then dried to reduce its water content from about 25% water to about 10% water.

The whole process may take from 4 to 11 days. Batches are however started at different times to ensure uninterrupted production.

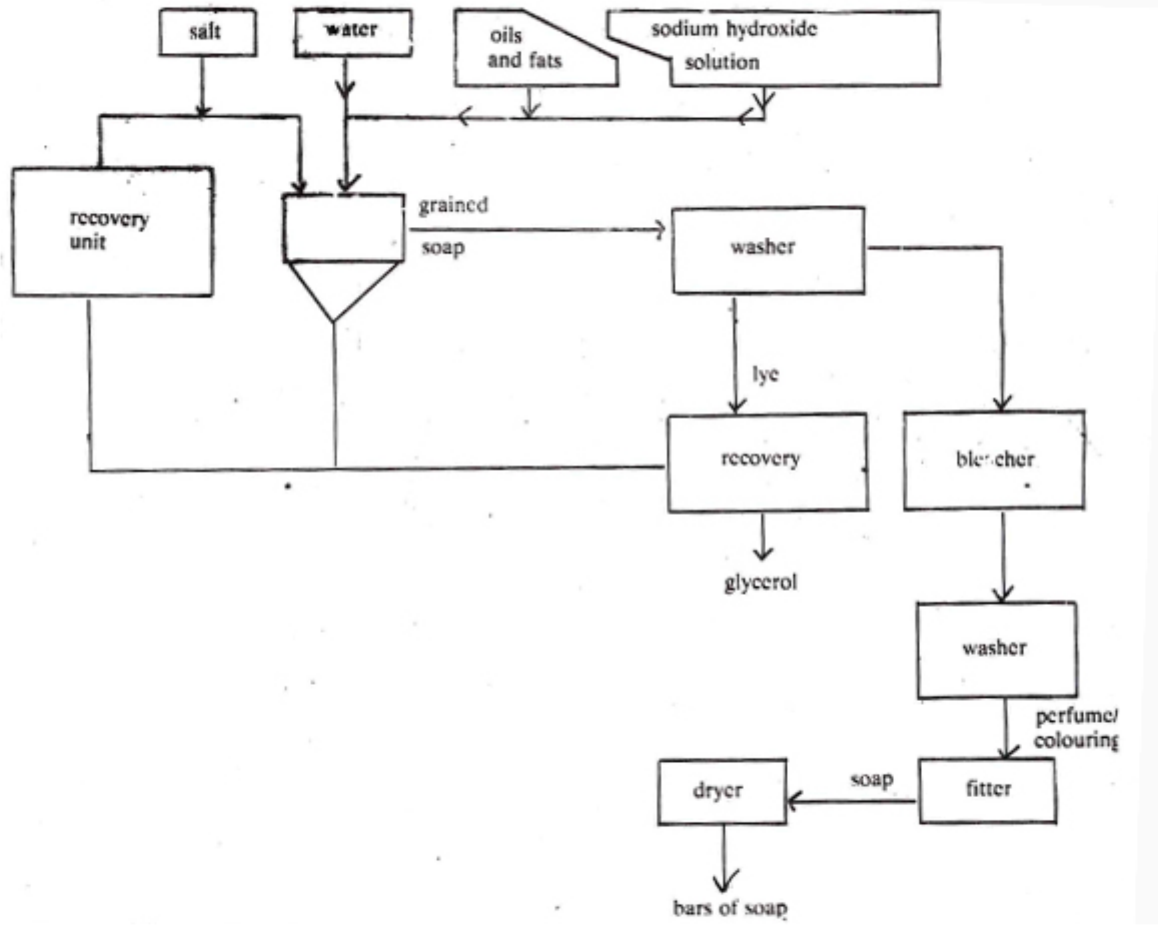


Figure 10.13 The batch process for the manufacture of soap

The Continuous Process

A number of continuous processes have been devised in order to reduce the time taken up by the batch process. One of these processes uses three reaction vessels connected together. Fats and oils and sodium hydroxide are measured into these vessels where saponification occurs. The soap is salted by pumping hot brine in a direction opposite to the flow of the soap mixture.

The soap produced is then fitted and dried as earlier described.

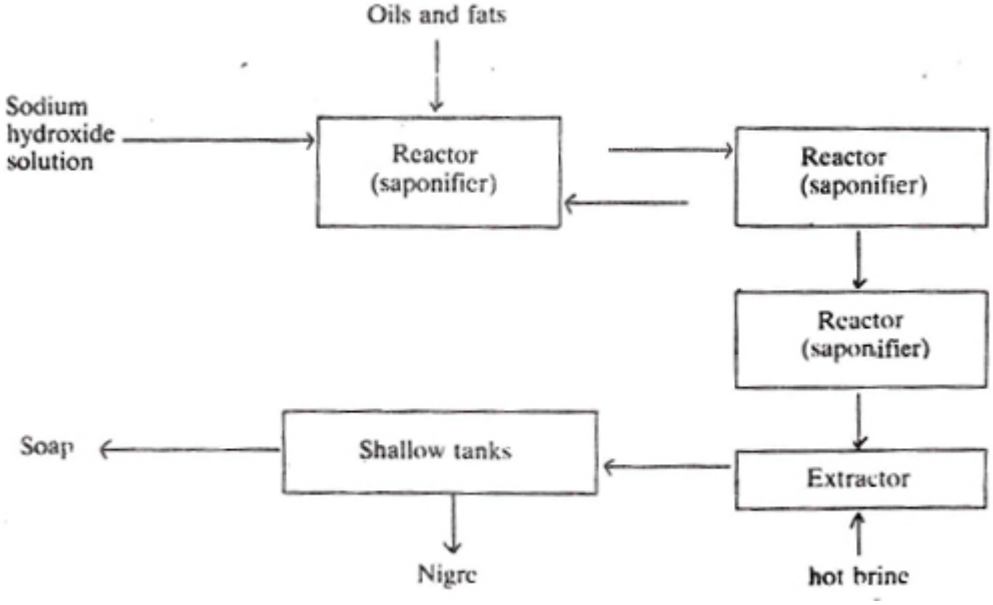


Figure 10.14 The continuous process for the manufacture of soap

Non-soapy detergents

Synthetic detergents have now been developed to provide substitutes for soaps. The most important of the synthetic detergents are those referred to as anionic detergents. They have soap-like molecular structures but the alkanoate group, (COO-), of soap is replaced by SO_2O- group or â€”OSO_2O â€” group. Sulphonated branched alkyl benzenes such as the tetrapropane,

$CH_3\text{-}(\overset{CH_3}{\overset{|}{C}}H.CH_2)_2.\overset{CH_3}{\overset{|}{C}}H.C_6H_4SO_2ONa$ is a commercial synthetic detergent.

However they were not easily broken down (degraded) by bacteria. They produced a lot of foam which persisted for long periods and polluted soils, seas, rivers and lakes as well as sources of drinking water.

Synthetic detergents for laundry purposes are nowadays made from linear (straight-chain) alkenes. These are usually obtained by the cracking of waxes. The preferred alkenes are those of C_{10} to C_{14}. They are reacted with benzene at 300Â°C in the presence of hydrogen fluoride, HF.

$$\underset{\text{alkene}}{R\text{-}CH = CH_2(g)} + \underset{\text{benzene}}{C_6H_6(g)} \xrightarrow[300^\circ C]{HF} \underset{\text{alkyl benzene}}{R - \overset{CH_3}{\overset{|}{C}}H \,.\, C_6H_4(g)}$$

The alkyl benzene are then sulphonated with oleum or sulphur (VI) oxide.

$$R-\overset{CH_3}{\overset{|}{C}}H - C_6H_5(l) + SO_3(g) \rightarrow R.\overset{CH_3}{\overset{|}{C}}H.C_6H_4SO_2OH(s)$$

alkyl benzene — an alkylbenzenesulphonic acid.

The sulphonic acids are then neutralized with sodium hydroxide solution to obtain the detergent.

$$R-\overset{CH_3}{\overset{|}{C}}H - C_6H_4SO_2OH(s) + NaOH(aq) \rightarrow R\overset{CH_3}{\overset{|}{C}}H.C_6H_4SO_2ONa(aq) + H_2O(l)$$

Detergents produced from linear alkyl benzenes are more readily broken down by bacteria. Only about 20 percent of the contents of a packet of detergent powder is made up of the active agent itself; the remainder is made up of various other substances called â€˜bindersâ€™ and â€˜additivesâ€™.

Soaps versus non-soap detergents

Soaps have a disadvantage as laundry detergents. The calcium and magnesium salts of soap are insoluble in water. When soap is used with hard water which contains calcium or magnesium ions, precipitates of the insoluble salts are formed. This precipitate is called a **scum**. It is not only unsightly, but is also deposited on clothes, baths and other laundry vessels. The deposit accumulates, and after some time is attacked by bacteria, to produce unpleasant colour and odour.

The calcium and magnesium salts of non-soapy detergents are soluble. Thus detergents can be effectively used for washing, even in hard water. They have very good cleaning power, and are much more soluble in water than soaps.

Local production of soaps and detergents

Most African countries produce soaps and detergents in nearly self-sufficient quantities. However, production is essentially controlled by a few multinational organizations. Nigeriaâ€™s production of soaps was estimated at about 80,700 tonnes in 1980, while in the same year 81,200 tonnes of non-soapy detergents were produced. This output is likely to increase considerably when the petrochemical plants begin full-scale production at Kaduna and Ekpan. These plants are designed to produce the important raw materials, linear alkyl benzenes.

Chapter Summary

Raw materials for industries fall into two categories â€” inorganic and organic.

Sources of inorganic raw materials â€”

(a) AIR â€“ (i) nitrogen for Haber process â†’ trioxonitrate(V) acid â†’ fertilizers.

(ii) Oxygen for conversion of sulphur to sulphur(IV) oxide â†’ sulphur(VI) oxide â†’ tetraoxosulphate(VI) acid.

(iii) Noble gases â†’ argon for filling electric bulbs, neon for lamps.

(b) SEA WATER â€“ (i) Common salt, from which sodium, chlorine, sodium hydroxide, bleaching powder are made.

(ii) Sodium bromide from which silver bromide for photography is made.

(iii) Iodine, from sea weeds for drugs.

(c) Minerals (ores)

1. Sulphur from (i) Frasch method of extraction.

(ii) metal sulphides

(iii) sulphur-rich petroleum.

Major use of sulphur is in the manufacture of tetraoxosulphate(VI) acid.

2. Metal ores

Reactive metals (Na,K) occur as chloride ores; moderately reactive metals (Ca, Mg) occur as CO_3^{2}, SO_4^{2} ores. Fairly reactive metals (Al, Cr, Mn, Fe) occur as oxide ores.

Slightly reactive metals (Cu, Pb, Sn, Zn) also occur as oxide ores.

Unreactive metals (Hg, Au, Ag) occur as the elements or easily decomposed compounds

Extration processes involve:

Mining, concentrating the ore, reduction, purification.

Organic raw materials.

(a) Agricultural products

(i) Natural oils (olive oil, palm oil, etc) raw materials for soap.

(ii) Sugar and mollases â€" fermentation yields ethanol for alcoholic drinks, solvent, fuel and starting material for other chemicals.

(iii) Bone and starch for glue, gum.

(iv) Plant extracts â€" dye, rubber latex, gum, perfumes, medicinal products.

(b) Coal-based raw materials â€" see Chapter 8 for products of destructive distillation of coal.

(c) Petroleum-based raw materials: see Chapter 9 for products of fractional distillation of petroleum. Refinery gases and naphtha fractions on cracking yield ethene, propene, hydrogen, etc. Kerosene on reforming produces benzene and alkyl benzenes. Bottom distillates undergo incomplete combustion producing carbon black and coke.

From these and other petrochemicals the chemical industries manufacture:

(i) Plastics, used in kitchen wares, furniture, toys, wearing apparels, etc.

(ii) Pharmaceuticals â€” synthesis of antibiotics, analgesics, anaesthetics, sedatives, hormones, etc.

(iii) Synthetic glass for car windscreens, etc.

(iv) Paints (both pigments and vehicles)

Assessment

1. Draw the nitrogen cycle. Show diagramatically how nitrogenous fertilizers are manufactured from air. Why does the % of N_2 in air remain constant?
2. Explain why air is regarded as an industrial gas
3. What type of raw materials are regarded as heavy and what type are light? Give examples. What factors will change a light raw material into a heavy one?
4. Name five petrochemical raw materials and list their final products. Show the reactions occuring as one of the named petrochemical is converted to its final product.
5. How are (i) water gas and

(ii) producer gas made from coke?

What is the advantage of making both gases in the same furnace?

Why is the calorific value of water gas higher than that of producer gas?

Experimental Projects: Analysis of Materials

1. Distillation of a sample of locally made alcohol

Collect at least $500cm^3$ of a sample of local wine from various sources. Your samples should include: palm wine from raffia palm, palm wine from oil palm, burukutu, etc.

Place each sample in a large flat-bottomed or conical flask. Plug it up with cotton wool and allow it to ferment for three or four days. During this period work out how you will obtain the alcohol from the wine by distillation. Show your proposal to your teacher for his approval.

Set up the distillation apparatus and carry out the distillation of each wine sample separately. Use $300cm^3$ of each sample for the distillation. Measure the volume of each distillate and record. Dry your distillate by adding a small quantity of calcium oxide to each sample and filter. The quantity of calcium oxide added should be equal. Measure the volume of the dry distillate. Compare the yields of the different sources.

2. Analysis of industrial products

Consult several textbooks from your school library, public library, etc, and make a list of the chemical composition of many common industrial products like paint, lime, cement, fertilizers, bleach, tooth paste, shaving powder, etc.

Devise a procedure which will enable you to test if the elements and compounds you have read in textbooks are present in each item.

In performing a test note the following points:

(a) First, the test may be carried out on the dry solid. For example, the presence of some acid radicals e.g. $CO_3^{2\text{â€″}}$, $HCO_3^{\text{â€″}}$, $SO_3^{2\text{â€″}}$, and $S^{2\text{â€″}}$ may be shown by simply adding dilute HCl, the presence of a chloride may also be shown by mixing the solid with MnO_2 and cone H_2SO_4 and heating.

(b) Metal ions are tested by using their solutions. It is necessary therefore to dissolve the sample in water, dilute or concentrated HNO_3. or a mixture called aqua regia. Some materials are hard to dissolve, e.g. certain paints: your teacher should guide you on how to dissolve these.

(c) Certain metals such as zinc, lead and aluminium if present in the sample solution may be readily detected by using dilute NaOH. Lead may be detected with dilute HCl because it forms a white precipitate with dilute HCl the precipitate disappears on warming and reappears on cooling.

(d) There are specific tests which confirm the presence of any particular metal ion or anion.
Using samples of the industrial products, conduct tests to determine the metal ions and the anions present.
Prepare a record of all your results.