

THE INDUSTRIAL CHEMISTRY

Conceptual Linkage

Before reading this chapter, the student must know the:

- Importance of chemistry.
- Different uses of chemical compounds.
- Basic characteristics of metals.
- Basic organic chemistry.

Time Allocation

Teaching periods	= 13
Assessment periods	= 03
Weightage	= 09%

LEARNING OUTCOMES

Students will be able to:

- Describe some metallurgical operations. (Applying)
- Make a list of raw materials for Solvay process. (Applying)
- Outline the basic reactions of Solvay process. (Analyzing)
- Develop a flow sheet diagram of Solvay process. (Creating)
- Describe the composition of urea. (Understanding)
- Develop a flow sheet diagram for the manufacture of urea. (Creating)
- List of uses of urea. (Remembering)
- Define petroleum. (Remembering)
- Describe the formation of petroleum and natural gas. (Understanding)
- Describe the composition of petroleum. (Remembering)
- Describe briefly the fractional distillation of petroleum. (Applying)

Introduction

The Subject of chemistry (and also the others) would have no importance if it remains only in texts or in laboratories. It must be utilized in our daily life and should have a place in more than the labs and texts. This is done by the industries, which put a project to be used at home and in our daily life. For example, the researchers study a reaction, say the anti-inflammatory

Aspirin, prepared in factories in some specialized manner. These processes through which the chemical compounds are prepared in bulk in factories are discussed in the head of Industrial chemistry.

The industrial chemistry, as it seems is of great value, because all actions of science knowledge come true for a user by such operations in industries.

Following are some examples to show how the industry uses the chemical processes.

16.1 Basic Metallurgical Operations:

Metallurgy is the study of the structure and properties of metals, with special reference to their extraction from the ground. The procedures for refining, alloying, and making things from the metals.

An Ore is the raw mineral which is found in earth crust and from which some specific metal is extracted.

There is no common process available for the extraction of all the metals because different metals differ in their chemical and physical properties and also the impurities associated with them is different. So each metal requires characteristic techniques for separation and purification from its ore. However, there are certain operations or procedures common in the metallurgy of all metals. These operations or procedures are called Metallurgical Operations. The various steps involved in metallurgical operations are;

1. Crushing and Grinding of Ore (Pulverisation)

Most of the metals found in nature in the ores which are present in hard lumps. So in order to separate the metal, it has to be vulnerable for chemical procedures. The first step involved in the metallurgy is grinding and crushing of the ore into small pieces by using proper mill.

2. Concentration of Ore

The grinded ores are then concentrated by removing the major impurities present in the ore, this step is called concentration. This step is

different for different types of metals which are to be purified.

3. Extraction of Metal from Oxide Ore.

In this step the ores which are usually in the form of metal oxides are extracted using specific technique for different types of metals chemically.

4. Refining of Crude Metal.

The process of purifying the crude metal is called as refining. There are various methods for the refining process which depends upon the physical as well as chemical properties of metal. For example; distillation, electrolytic refining, zone refining, vapour-phase refining and chromatography are the common methods used for the refining.

16.1.1 Metallurgy of Copper

Copper is an important element and finds many uses in our daily life. The value of electricity is well known by every one. Due to the excellent electric conduction properties and high resistive power to corrode almost every electrical instrument uses copper in some ways. Copper is also used in utensils and in alloys (e.g brass and bronze) formation.

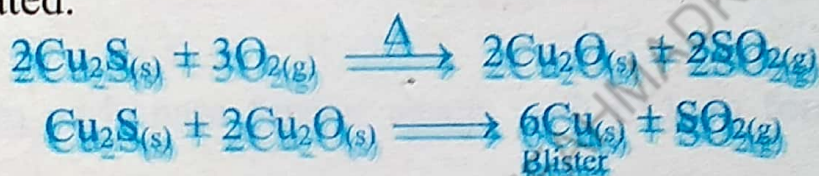
The earth crust contains 0.007% copper, but remember that the concentration is not uniform every where. Copper is found in many mineral ores e.g chalcopyrite (CuFeS_2), bornite (Cu_5FeS_4), covellite (CuS), chalcocite (Cu_2S) azurite ($\text{Cu}_3(\text{CO}_3)_2(\text{OH})_2$), malachite ($\text{Cu}_2\text{CO}_3(\text{OH})_2$), cuprite (Cu_2O) and some others. The first step is to mine the copper from the area that contains rich copper source. The process for the separation of Cu varies for different types of ores. Generally the sulphides which are more abundant pass from the following procedure to get pure Cu.

The First step is to **Concentrate** the ore in Cu content. This is done by crushing the ore to increase the surface area of the ore for subsequent processing. The powdered ore is mixed with some chemicals and introduced to a water bath (aeration tank) containing surfactant. Air is constantly forced through the slurry and the hydrophobic copper sulfides particles catches onto and rides the air bubbles to the surface, where it forms froth and is skimmed

off. These skimmings are generally re-processed to reach a high purity copper concentrate. The remainder is discarded as tailings. After concentration process CuS is obtained free from other impurities and this contains about 40% Cu. The next step is the **Extraction** of pure Cu from the concentrate. In this process the other impurities e.g the FeS are separated by treating the concentrate with SiO₂ and lime, at 1200°C.



The FeO.SiO₂ or slag is discarded, and the remainings that contain almost 70% Cu is called copper matte. Air is blown through this copper matte at high temperature. As a result of which pure copper up to 98% purity (called blister) is separated.



For further purity, the **electro refining** of the blister is carried out. For this purpose the blister is placed into an aqueous solution of 3-4% copper sulfate and 10-16% sulphuric acid in an electrolytic cell. The Cathodes are made up of highly pure copper. A potential of only 0.2-0.4 volts is required for the process to start. At the anode, copper and less noble metals dissolve. The impurities like silver, gold, selenium and tellurium settle at the bottom of the cell as anode mud, which forms a valuable byproduct.

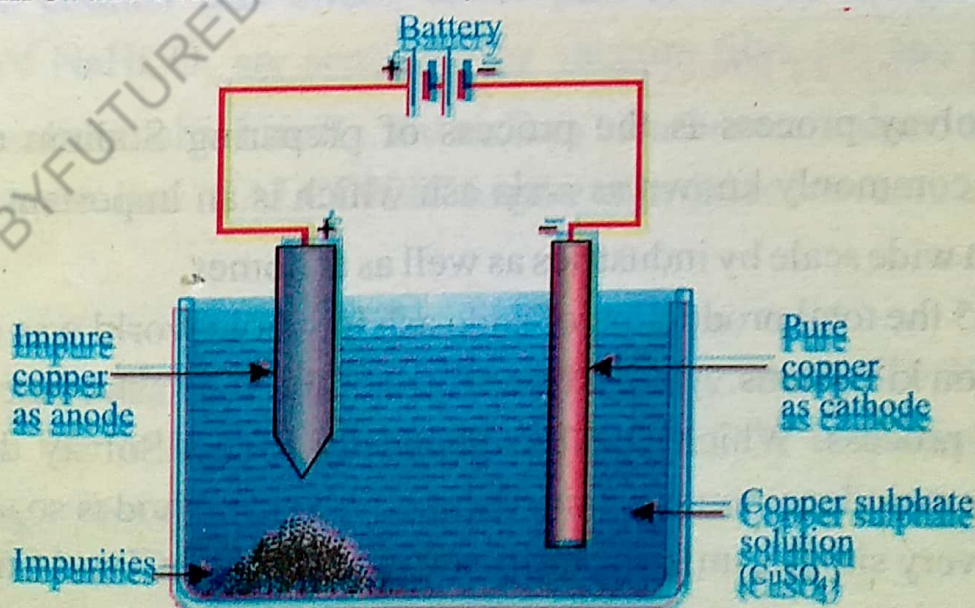
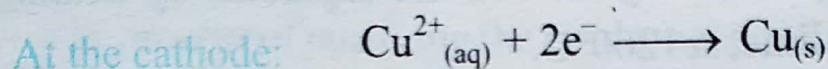
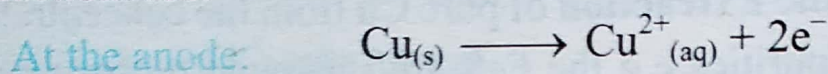


Fig. 16.1: Experimental set up for the electrolytic refining of copper

Copper ions migrate through the electrolyte to the cathode. At the cathode, copper metal plates out and can be collected easily. Some constituents such as arsenic and zinc remain in solution. The reactions are:



After electro refining, the Cu produced is 99.9% pure and can be used in any installation comfortably.

This whole process is summarized in following flow chart diagram.

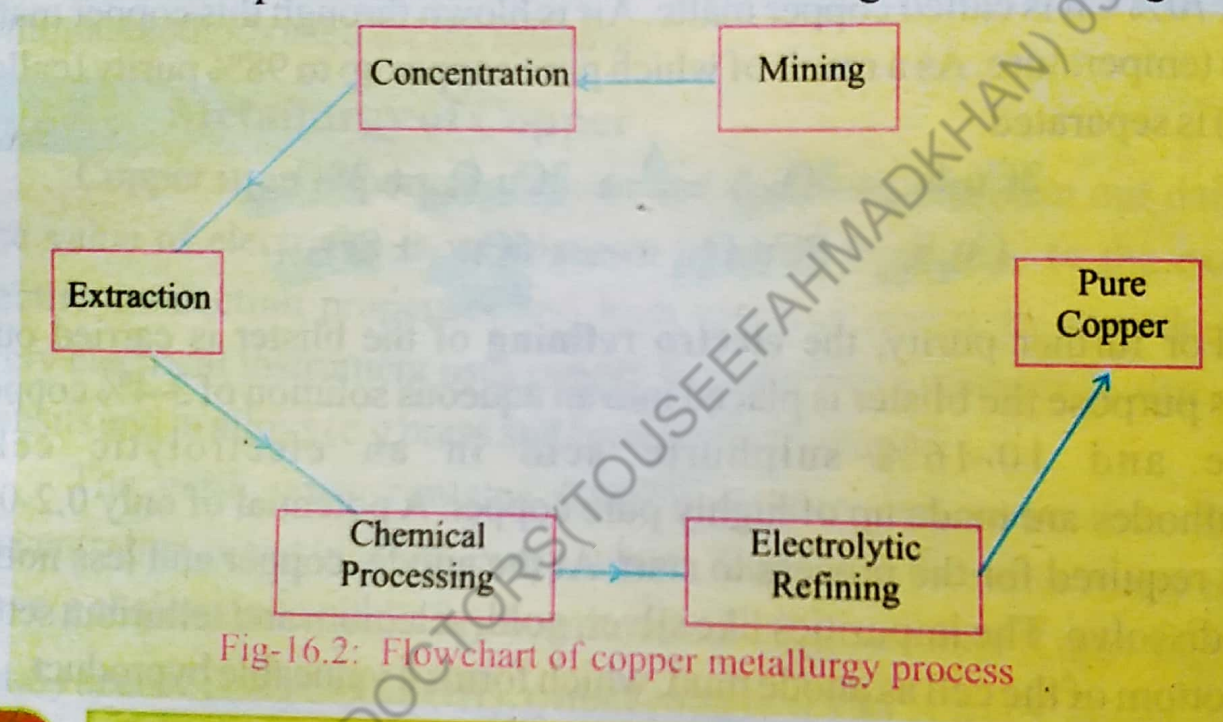


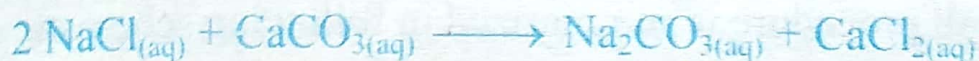
Fig-16.2: Flowchart of copper metallurgy process

16.2 The Solvay Process

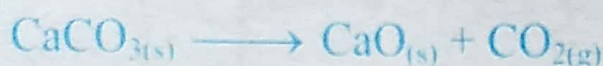
The Solvay process is the process of preparing Sodium carbonate (Na_2CO_3) or commonly known as soda ash which is an important chemical and is used on wide scale by industries as well as at homes.

In 2005 the total production of soda ash in whole world was estimated about 42 billion kilograms. Almost three fourth of the soda ash comes through the Solvay's process. Which was developed by Ernest Solvay during the 1860's, and remainder amount is mined directly. The method is so successful because it is very simple, utilizes cheap raw materials, NaCl and CaCO_3 , and yields a good purity soda ash product. The overall process is summarized by

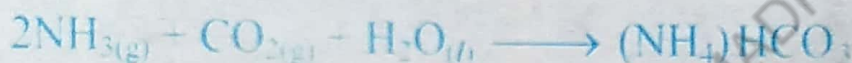
the reaction.



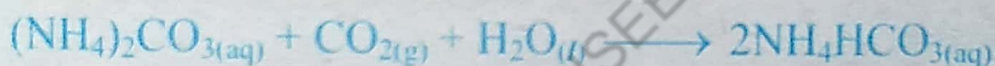
But in practice, the process is carried out by the following manner. In the first step, a saturated solution of NaCl (brine) is allowed to flow down an ammoniating tower. Here NH_3 gas is mixed with brine. In the second step, ammoniated brine is allowed to trickle down a carbonating tower known as solvay tower. Here brine is mixed with carbon dioxide gas, which is produced by heating lime stone in a separate chamber called "kiln".



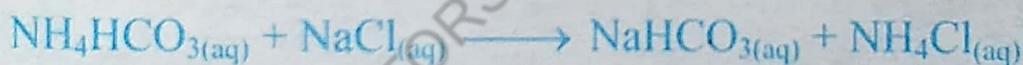
In the Solvay tower, the CO_2 reacts with ammonia to form ammonium carbonate.



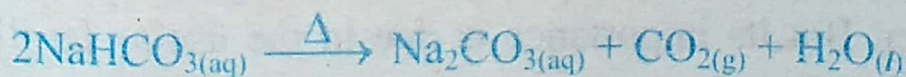
Ammonium carbonate further reacts with CO_2 to form ammonium bicarbonate.



Ammonium bicarbonate then react with NaCl to form sodium bicarbonate.



Due to exothermic nature of above reactions, solubility of NaHCO_3 increases. To counter this effect, lower part of solvay tower is cooled; precipitates of NaHCO_3 are separated by vacuum filtration and washed to remove ammonium salts. Finally, the sodium bicarbonate is dried and heated in rotary furnace called "CALCINER" to give anhydrous sodium carbonate or soda ash.



Carbon dioxide is re circulated to carbonating tower. The NH_3 is also recovered by the following procedure. When CaCO_3 is heated, CaO is obtained along with CO_2 . CaO is treated with water to form Ca(OH)_2 .



Ca(OH)_2 is heated with NH_4Cl to form NH_3 and calcium chloride.



The overall procedure is summarized in following schematic diagram in figure-16.3.

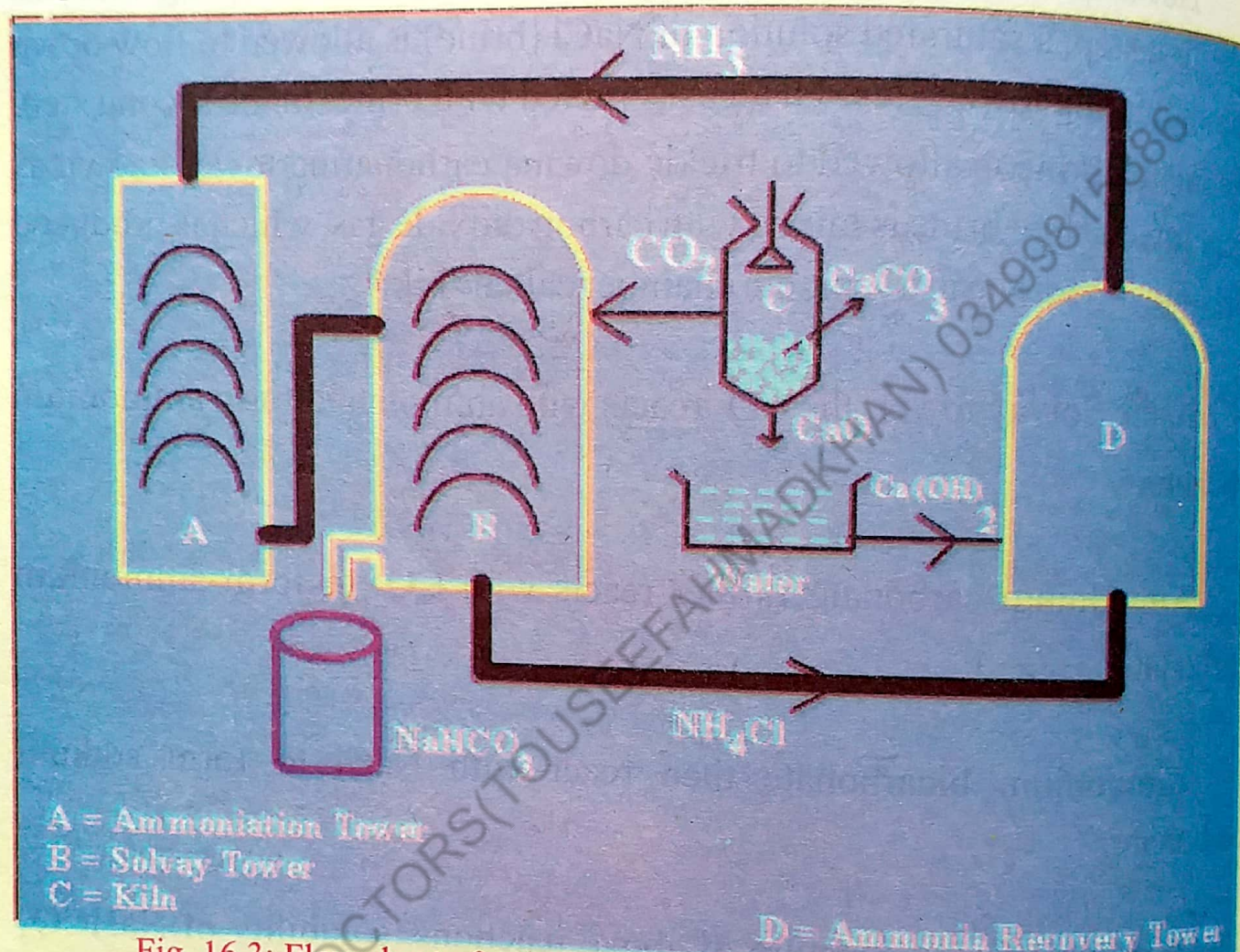


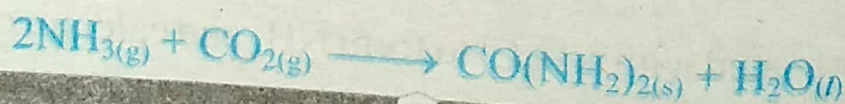
Fig. 16.3: Flow sheet of solving process for preparation of soda ash.

16.3

Urea

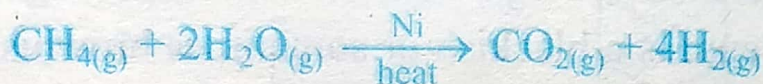
Urea or Carbamide is a well known fertilizer and is widely used throughout the world and as well in Pakistan. It has the molecular formula $\text{CO}(\text{NH}_2)_2$. It is regarded as the first organic compound to be synthesized in 1828 by Wohler. But its importance is due to the use as fertilizer for the nitrogen source for the plant, moreover due to its slight basic nature it also reduces the acidity of the soil produced by the decaying action of organic matter.

On commercial scale urea is prepared using CO_2 and NH_3 . Which react to give urea.



The procedure in an industry is carried out through a series of steps. These steps are discussed here in the following.

First of all CO_2 and H_2 are prepared by the action of steam and natural gas over Ni catalyst.



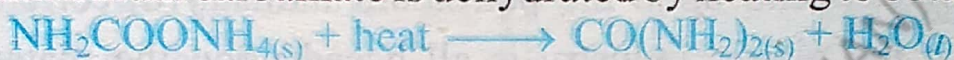
The H_2 produced is treated with N_2 at 500°C over Fe_2O_3 to obtain the NH_3 .



Both CO_2 and NH_3 are combined to get the ammonium carbamate.



The ammonium carbamate is dehydrated by heating to obtain the Urea.



The water present here along with the urea is evaporated by heat. The molten urea obtained by heating is sprayed in a cooled tower. Hence, the urea drops solidify as small prills, which are then filled in bags and send to market.

The whole operation is described by the following flow sheet diagram in figure-16.4.

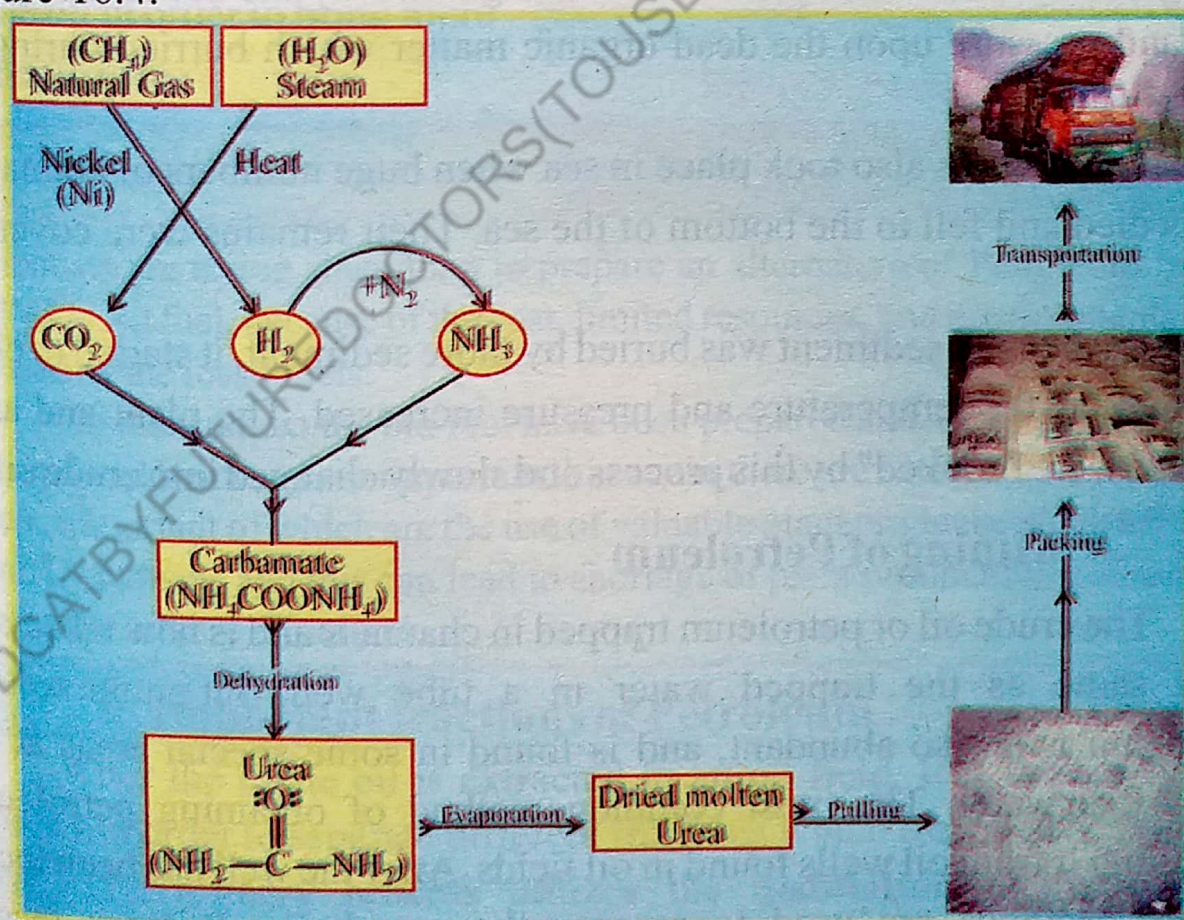


Fig. 16.4: Flow chart of Industrial preparation of Urea

The word petroleum has been originated from two Greek words, i.e: "Petra" which means "Rock" and "Oleum" meaning "Oil".

Petroleum is a blackish or sometimes brownish black, viscous liquid found under the earth, from where it is drilled out. The Petroleum is a complex mixture of thousands of organic compounds. For different uses these compounds are separated in fractions at oil refineries. The petroleum is very important and vital for today's world, as it fulfills almost all energy requirements of the human beings today directly, moreover there are many industries that depend upon the petroleum industry directly for their raw material, e.g the plastic industry is all based upon the material which is obtained through petroleum. You can imagine the types and quantity of plastic products around yourself.

16.4.1 Origin of Petroleum

The Petroleum is believed to be originated by the action of Bacteria, heat and pressure upon the dead organic matter which buried during time course.

The process also took place in sea when huge numbers of animals and plants died and fell to the bottom of the sea. Their remains were covered by mud.

As the mud sediment was buried by more sediment, it started to change into rock as the temperature and pressure increased. The plant and animal remains were "cooked" by this process and slowly changed into crude oil.

16.4.2 Mining of Petroleum

The crude oil or petroleum trapped in channels and is now taken out by tubes same as the trapped water in a tube well. But unlike water the petroleum is not so abundant, and is found in some special areas at more depths than water. The most common method of obtaining petroleum is extracting it from oil wells found in oil fields. After the well has been located, various methods are used to recover the petroleum. Primary recovery

methods are used to extract oil that is brought to the surface by underground pressure. This generally recovers about 20% of the oil present. After the oil pressure has depleted to the point that the oil is no longer brought to the surface, secondary recovery methods draw another 5 to 10% of the oil in the well to the surface. Finally, when secondary oil recovery methods are no longer viable, tertiary recovery methods reduce the viscosity of the oil in order to bring more to the surface.

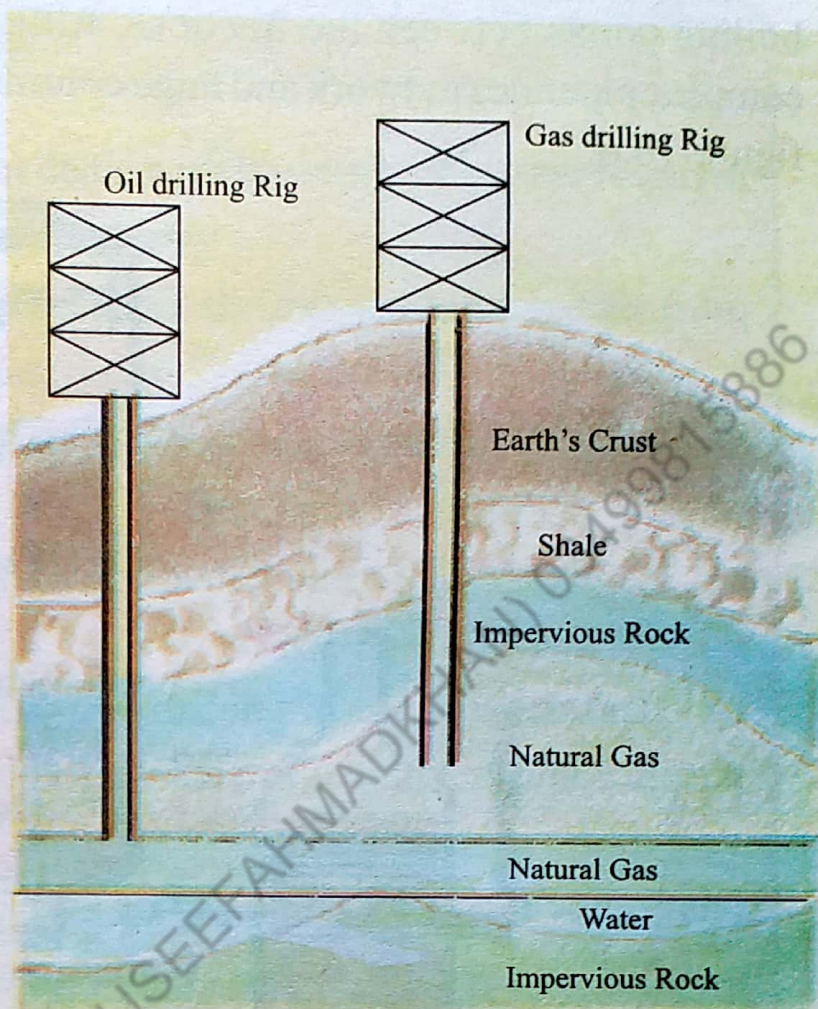


Fig. 16.5: Petroleum Mining

Interesting Information

Scientists are trying since long to prepare an alternative of Petroleum fuel also called fossil fuel, because of the cost, limited resources, and environmental issues caused by the fossil fuels.

In this context the bio fuel have been prepared and are in use, of these the ethanol and biodiesel are important, but again there are reservations for these bio fuels, important of which are the use of valuable plant products which are used as food by humans and this can lead to shortage of plant product food of which the vegetable oils are important.

16.4.3 Important fractions of Petroleum

After the crude oil is extracted in an oil field. It is brought in an oil refinery in order to separate different fractions which can be used in different ways. The refinery process utilizes the **distillation technique** which separates the different fractions of the crude oil due to the difference of

boiling points between the fractions. Although, an oil refinery consists of a complex pipelines network and huge columns, but simply it is described in the figure-16.6.

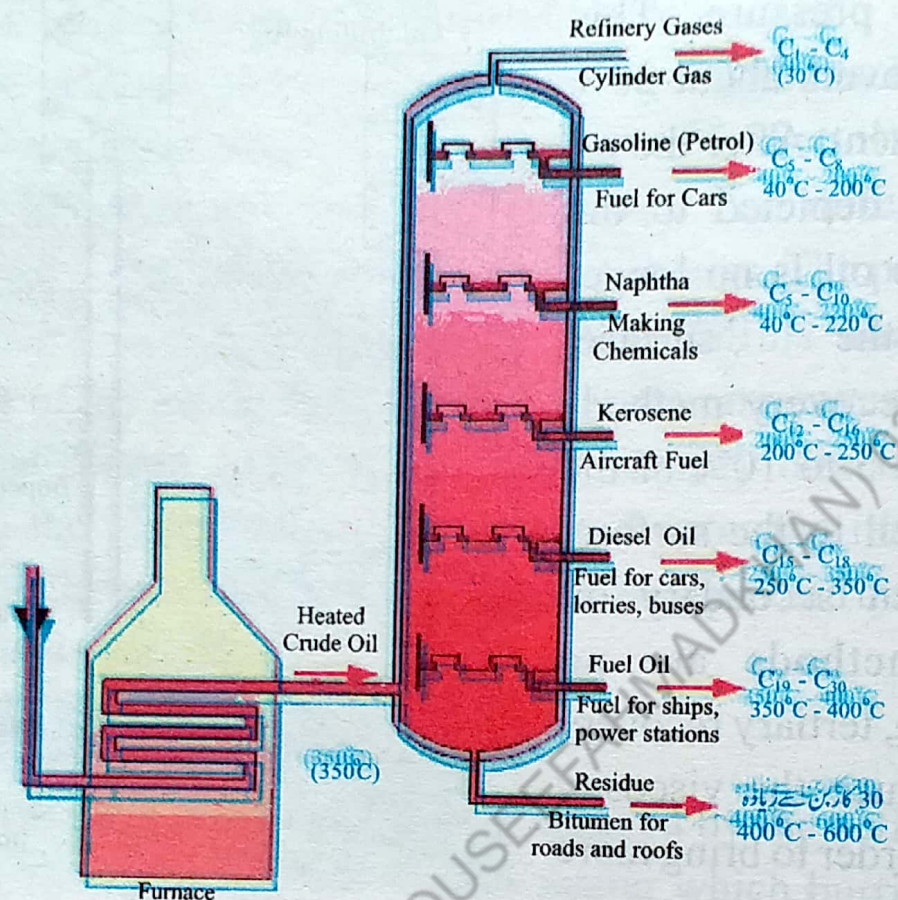


Fig. 16.6: Fractions obtained by refining of petroleum and their uses

Notice that the different fractions collected are used in different types of engines. Actually these fractions differ in the number of carbon atoms per molecule, as the number of carbon atoms in a molecule increase, the boiling point and density both increase and even the fractions that contain more than 40 atoms may be solid or semi solids.

Interesting Information

The quality and rating of petroleum fuels are measured by a number called "**Octane number**". Higher the octane number higher will be the performance of the fuel. The standard octane number is the "100", but in Pakistan the petrol pumps sell the gasoline of "80" octane number. The octane number of fuel is increased by adding TEL (tetra ethyl lead), but this also causes environmental problems. Another substance that is used to increase octane number is BTX, which is actually a mixture of three compounds, the Benzene, Toluene and xylene. The BTX is also environmental pollutant increasing substance but relatively less than the TEL.

Summary of the Chapter

- ❖ The branch of chemistry that deals with the study of matter found in industries is called Industrial chemistry.
- ❖ The branch of science that deals with the extraction of metals from its ores is called chemical metallurgy.
- ❖ Mineral is a natural inorganic chemical compound which is found in earth crust.
- ❖ An ore is the substance that is unrefined, impure source of metal and is obtained by mining process.
- ❖ The general metallurgy involves crushing of ore, concentration of ore, extraction of metal from its oxides or sulphides, and refining processes.
- ❖ Sodium carbonate (soda ash) is an important chemical compound and is prepared using solvay's method.
- ❖ The important fertilizer urea is prepared by using the natural gas and steam as starting raw materials.
- ❖ Petroleum is the back bone of economy of any country. The use of petroleum also determines the prosperity of a country.
- ❖ Petroleum is mined from earth and is purified in oil refineries.
- ❖ The fractions of petroleum are separated using the fact that different chemical compounds have different boiling points. This technique is called fractional distillation.

Exercise

Q1: Fill in the blanks with suitable words.

- i) Metallurgy deals with of pure metals from its ores.
- ii) Solvay process is used for the preparation of
- iii) Wohler prepared in 1828.
- iv) Petroleum is believed to be prepared by the action of bacteria upon
- v) Petroleum is found in the earth in more than the water.
- vi) Quality of petroleum fuel is determined using a number called.....
- vii) Chemical formula of Soda ash is
- viii) Ammonium carbamate is the hydrated form of.....
- ix) The first step in metallurgy of a metal is the.....of metal ore.
- x) Petra is a Greek word meaning.....

Q2: Choose the correct answer.

- i) The soda ash is prepared commercially by using:
(a) NaNO_3 and KCO_3 (b) NaNO_3 and NH_3
(c) NaCl and MgCO_3 (d) NaCl and CaCO_3
- ii) The first step in metallurgical operations is to:
(a) Concentrate the ore
(b) Crushing the ore
(c) Extraction of metal from ore
(d) Refining the ore
- iii) Commercially urea is prepared by:
(a) Carbamide (b) Ammonia and carbon dioxide
(c) Cyanogens (d) All of these
- iv) Petroleum is refined by the technique of:
(a) Distillation (b) Crystallization

- (c) Condensation (d) All of above
- v) As the number of carbon atoms increase in petroleum fractions, it also increases the:
- (a) Boiling point (b) Density
(c) Both of these (d) None of these
- vi) Solvay process is used to prepare:
- (a) Urea (b) Soda Ash
(c) Gasoline (d) Iron
- vii) Methane gas is used in preparation of:
- (a) Urea (b) Ammonia gas
(c) Petrol (d) Copper ore
- viii) LPG contains the mixture of:
- (a) Methane and pentane (b) Methane and ethane
(c) Ethane and Pentane (d) Propane and butane
- ix) The Major fraction in the CNG is:
- (a) Methane (b) Ethane
(c) Propane (d) Butane
- x) Octane number is used to measure:
- (a) Number of 'C' atoms in a molecule of a fuel
(b) Number of 'H' atoms in the fuel molecules
(c) Efficiency of fuel
(d) Percentage of Methane in any fuel

Q3: Explain with reasoning.

- i) Why the Petroleum fuels are called Fossil fuels?
- ii) Diesel provides more energy per mole than petrol.
- iii) Extraction of metals from their ore is different for different metals.
- iv) Why Soda ash is essential to prepare on large scale?
- v) Urea is more used in Pakistan rather than ammonia fertilizer.

- Q4: How the industries help in the progress of mankind?
- Q5: Write a brief note on the metallurgical operations? How the copper can be extracted from the earth?
- Q6: Discuss the importance of soda ash. Also explain the solvay process for its preparation.
- Q7: Why the fertilizers are needed for more production of crops? Explain the preparation method for the urea.
- Q8: How the petroleum originated in the earth crust? What are the different fractions obtained from the petroleum, and also describe the utilization of these fractions.

Glossary

acetylene A colourless, highly flammable gas that is explosive when compressed; the simplest compound containing a triple bond; Also known as ethyne. Its formula is C_2H_2 .

acid 1. Any of a class of chemical compounds whose aqueous solutions turn blue litmus paper red, react with and dissolve certain metals to form salts, and react with bases forming salts. 2. A compound capable of transferring a hydrogen ion in solution.

3. A molecule or ion that combines with another molecule or ion by forming a covalent bond with two electrons from the other species.

adsorption The surface retention of solid, liquid, or gas molecules, atoms, or ions by a solid or liquid.

aerosol A suspension of small particles in a gas; the particles may be solid or liquid or a mixture of both; aerosols are formed by the conversion of gases to particles, the disintegration of liquids or solids, or the suspension of powdered material.

air The mixture of a variety of individual gases forming the earth's enveloping atmosphere.

alcohol Any member of a class of organic compounds in which a hydrogen atom of a hydrocarbon has been replaced by a hydroxy (OH) group.

aldehyde One of a class of organic compounds containing the CHO radical.

aldohexose A hexose, such as glucose or mannose, containing the aldehyde group.

alicyclic A cyclic hydrocarbon which is non aromatic

aliphatic organic compound characterized by a straight chain of the carbon atoms;

alkali Any compound having highly basic qualities.

Alkaline earth metals The members of group 2 in the periodic table; (calcium, strontium, magnesium, and barium.)

alkane A member of a series of saturated aliphatic hydrocarbons having the empirical formula C_nH_{2n+2} . Also known as paraffin; paraffinic hydrocarbon.

alkene One of a class of unsaturated aliphatic hydrocarbons containing one or more carbon-to-carbon double bonds.

alkyl An organic group that results from removal of a hydrogen atom from alkane ; It is represented by symbol 'R'.

alkyl halide A compound consisting of an alkyl group and a halogen;

alkyne One of a group of organic compounds containing a carbon to carbon triple bond.

amide One of a class of organic compounds containing the $CONH_2$ radical.

amine One of a class of organic compounds which can be considered to be derived from ammonia by replacement of one or more hydrogen.

amino-, amin- Having the property of a compound in which the group NH_2 is attached

to a radical other than an acid radical.

amphoteric Having both acidic and basic characteristics.

anion An ion that is negatively charged.

anti on the opposite side of a reference plane;

antifreeze A substance added to a liquid to lower its freezing point; the principal automotive antifreeze component is ethylene glycol.

antioxidant A substance that, when present at a lower concentration than that of the oxidizable substrate, significantly inhibits or delays oxidative processes.

aqua Latin for water.

aqua regia A fuming, highly corrosive, volatile liquid with a suffocating odour made by mixing 1 part concentrated nitric acid and 3 parts concentrated hydrochloric acid; It reacts with all metals, including silver and gold.

aromatic A compound characterized by the presence of at least one benzene ring.

atom The basic unit of any chemical element which enters into chemical reactions.

base A substance having the property of turning litmus from red to blue, it donates OH^- , electron pair and accepts H^+ ion during chemical reactions.

biochemistry The study of chemical substances occurring in living organisms.

bond The strong attractive force that holds together atoms or ions in molecules and crystalline salts.

Bronsted acid A chemical species which can act as a source of protons. Also known as proton acid; protonic acid.

Bronsted-Lowry theory A theory that all acid-base reactions consist simply of the transfer of a proton from one base to another. Also known as Bronsted theory.

catalyst Substance that speeds up the velocity of a chemical reaction but is not consumed in the reaction.

cation A positively charged atom or group of atoms

caustic soda The sodium hydroxide.

chemical equilibrium A condition in which a chemical reaction is occurring at equal rates in its forward and reverse directions, so that the concentrations of the reacting substances do not change with time.

chemical kinetics The branch of physical chemistry concerned with the mechanisms and rates of chemical reactions.

chemical reaction A change in which a substance (or substances) is changed into one or more new substances;

concentration In solutions, the mass, volume, or number of moles of solute present in proportion to the amount of solvent or total solution.

condensation Transformation from a gas to a liquid.

covalent bond A bond in which each atom of a bound pair contributes one electron to form a pair of electrons.

cyclic compound A compound that contains a ring of atoms.

dehydration Removal of water from any substance.

derivative A substance that is made from another substance or it is the product formed from parent compound.

dilute To make less concentrated

distillation The process of producing a gas or vapour from a liquid by heating the liquid in a vessel and collecting and condensing the vapours back into liquids.

distilled water Water that has been freed of dissolved or suspended solids and organisms by distillation.

double bond A type of linkage between atoms in which two pair of electrons are shared equally.

double salt 1. A salt that upon hydrolysis forms two different anions and cations. 2. A salt that is a molecular combination of two other salts.

dry ice Carbon dioxide in the solid form,

empirical formula A chemical formula that indicates the composition of a compound in terms of the relative numbers and kinds of atoms in the simplest ratio.

fractional distillation A method to separate a mixture of several volatile components of different boiling points; the mixture is distilled at the lowest boiling point, and the distillate is collected as one fraction until the temperature of the vapour rises, showing that the next higher boiling component of the mixture is beginning to distill; this component is then collected as a separate fraction.

free radical An atom or a diatomic or polyatomic molecule which possesses one unpaired electron. Also known as radical.

freezing point The temperature at which a liquid and a solid may be in equilibrium.

green chemistry The use of chemical products and processes that reduce or eliminate substances hazardous to human health or the environment.

halogen 1. A family of elements (in the periodic table) of Group-18. 2. Any of the elements of the halogen family (Group-17), consisting of fluorine, chlorine, bromine, iodine, and astatine.

halogenation A chemical process or reaction in which a halogen element is introduced into a substance, generally by the use of the element itself.

hard water Water that contains certain salts, such as phosphates or sulphates of calcium or magnesium, which form insoluble deposits in boilers and form precipitates with soap.

heat of combustion The amount of heat released in the oxidation of 1 mole of a substance at constant pressure, or constant volume.

heat of decomposition The change in enthalpy accompanying the decomposition of 1 mole of a compound into its elements at constant pressure.

heat of dissociation The change in enthalpy at constant pressure, when molecules break apart.

heat of formation The increase in enthalpy resulting from the formation of 1 mole of a

substance from its elements at constant pressure.

heat of hydration The increase in enthalpy accompanying the formation of 1 mole of a hydrate from the anhydrous form of the compound and from water at constant pressure.

heat of reaction Change in enthalpy accompanying a chemical reaction at constant pressure.

heavy water A compound of hydrogen and oxygen containing a higher proportion of the hydrogen isotope. Also known as deuterium oxide.

hydrate A form of a solid compound which has water in the form of H_2O molecules associated with it; for example, hydrated copper sulfate having formula $CuSO_4 \cdot 5H_2O$.

hydration The incorporation of molecular water into a complex molecule with the molecules or units of another species; the complex may be held together by relatively weak forces or may exist as a definite compound.

hydrocarbon One of a very large group of chemical compounds composed only of carbon and hydrogen; the largest source of hydrocarbons is from petroleum crude oil.

hydrogen bond A type of intermolecular force where a linkage is formed between 'H' and strongly electronegative element like 'O' or 'F'.

hydrolysis Decomposition or alteration of a chemical substance by water.

hydronium ion H_3O^+ An oxonium ion consisting of a proton combined with a molecule of water; found in pure water and in all aqueous solutions.

Hydrosphere The water layer of the earth surface is called hydrosphere e.g. ocean.

Amino acid Organic acid in which the NH_2 group is attached to carbon; for example, NH_2CH_2COOH .

ion An isolated electron or positron or an atom or molecule which by loss or gain of one or more electrons has acquired a net electric charge.

ionization A process by which a neutral atom or molecule loses or gains electrons, thereby acquiring a net charge and becoming an ion; occurs as the result of the dissociation of the atoms of a molecule in solution ($NaCl \longrightarrow Na^+ + Cl^-$).

iso- A prefix indicating a single branching at the end of the carbon chain.

isomer One of two or more chemical substances having the same elementary percentage composition and molecular weight but differing in structure, and therefore in properties; there are many ways in which such structural differences occur; for example *n*-butane, $CH_3(CH_2)_2CH_3$, and isobutane, $CH_3CH(CH_3)_2$ are the isomers of butane (C_4H_{10}).

isomerism The phenomenon whereby certain chemical compounds have structures that are different although the compounds possess the same elemental composition.

IUPAC Abbreviation for International Union of Pure and Applied Chemistry.

ketone One of a class of chemical compounds of the general formula $RCOR'$, where R and R' are alkyl or aryl radicals; the groups R and R' may be the same or different.

law of mass action The law stating that the rate at which a chemical reaction proceeds is

directly proportional to the molecular concentrations of the reacting compounds.

Lewis acid A substance that can accept an electron pair from a base; e.g. AlCl_3 , BF_3 and SO_3 are Lewis acids.

Lewis base A substance that can donate an electron pair; examples are the hydroxide ion, OH^- , and ammonia, NH_3 .

Lewis structure A structural formula in which electrons are represented by dots; two dots between atoms represent a covalent bond. Also known as electron-dot formula; Lewis formula.

ligand The molecule, ion, or group bound to the central atom in a chelate or a coordination compound; an example is the NH_3 in $[\text{Co}(\text{NH}_3)_6]^{3+}$.

line-formula method A system of notation for hydrocarbons showing the chemical elements, functional groups, and ring systems in linear form; an example is acetone, CH_3COCH_3 .

lipophilic 1. Having a strong affinity for fats. 2. Promoting the solubilization of lipids

lipophobic Lacking an affinity for, repelling, or failing to absorb or adsorb fats.

macromolecule A large molecule in which there is a large number of one or several relatively simple structural units, each consisting of several atoms bonded together.

methyl red $(\text{CH}_3)_2\text{NC}_6\text{H}_4\text{NNC}_6\text{H}_4\text{COOH}$. A dark red powder or violet crystals; soluble in alcohol, ether, and glacial acetic acid; used as an acid-base indicator.

molality Concentration given as moles per 1000 grams of solvent.

monomer A molecule which is capable of combining with like or unlike molecules to form a polymer; it is a repeating structure unit within a polymer.

neutralization The process of making a solution neutral (pH 7) by adding a base to an acid solution, or adding an acid to an alkaline (basic) solution. Also known as neutralization reaction.

orbital overlap The overlapping of two electron orbitals, one from each of two different atoms, such that each orbital obtains a share in the electron of the other atom, forming a chemical bond.

organic Of chemical compounds, based on carbon chains or rings and also containing hydrogen with or without oxygen, nitrogen, or other elements.

organic chemistry The study of the structure, preparation, properties, and reactions of carbon compounds, or the **hydrocarbons** and their derivatives.

organic salt The reaction product of an organic acid and an inorganic base, for example, sodium acetate (CH_3COONa) from the reaction of acetic acid (CH_3COOH) and sodium hydroxide (NaOH).

phase Portion of a physical system (liquid, gas, solid) that is homogeneous throughout, has definable boundaries, and can be separated physically from other phases.

pH A term used to describe the hydrogen-ion activity of a system;

precipitate A substance separating, in solid particles, from a liquid as the result of a chemical or physical change;

rate of reaction A measurement based on the mass of reactant consumed in a chemical reaction during a given period of time.

reactivity The relative capacity of an atom, molecule, or radical to combine chemically with another atom, molecule, or radical

Single bond: a covalent bond in which one pair of electrons is shared between two atoms.

Solubility: the amount of solute that dissolves in a given quantity of solvent (normally 100ml) at a specific temperature.

Standard pressure: A pressure of 1 atmosphere which is equal to 760mmHg.

Standard temperature: A temperature of 0.0 °C, or 273.16 K.

S.T.P. S.T.P. is the abbreviation of standard temperature pressure.(273.16 K and a pressure of 1 atmosphere).

Structural formula: A formula which defines the bonding and arrangement of the atoms present in a compound.

Temperature: The temperature of a sample of matter is a measure of the average kinetic energy of the molecules in that sample.

Unsaturated compound: A compound in which double or triple bonds are present.

Valence electrons: Electrons in the outer electronic shell of an atom, and which are involved in chemical reactions.

Vapour pressure: The pressure exerted by a vapour. At the boiling point, the vapour pressure of a liquid is equal to the pressure exerted on the liquid by the atmosphere.

Water of crystallization: Water molecules which form an integral part of the lattice of ionic crystals. The water of crystallization is normally included in the formula for the substance, i.e., $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$.

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TABLE OF ELEMENTS

Element	Symbol	At.No	At.mass	Element	Symbol	At.No	At.mass
Hydrogen	H	1	1.0079	Selenium	Se	34	78.96
Helium	He	2	4.0026	Bromine	Br	35	79.904
Lithium	Li	3	6.941	Krypton	Kr	36	83.798
Beryllium	Be	4	9.0122	Rubidium	Rb	37	85.4678
Boron	B	5	10.811	Strontium	Sr	38	87.62
Carbon	C	6	12.01	Yttrium	Y	39	88.9058
Nitrogen	N	7	14.0067	Zirconium	Zr	40	91.224
Oxygen	O	8	15.9994	Niobium	Nb	41	92.906
Fluorine	Fr	9	18.9984	Molybdenum	Mo	42	95.94
Neon	Ne	10	20.1797	Technetium	Tc	43	98.9063
Sodium	Na	11	22.9898	Ruthenium	Ru	44	101.07
Magnesium	Mg	12	24.305	Rhodium	Rh	45	102.9055
Aluminium	Al	13	26.9815	Palladium	Pd	46	106.42
Silicon	Si	14	28.0855	Silver	Ag	47	107.8682
Phosphorus	P	15	30.9738	Cadmium	Cd	48	112.411
Sulphur	S	16	32.065	Indium	In	49	114.818
Chlorine	Cl	17	35.453	Tin	Sn	50	118.71
Argon	Ar	18	39.948	Antimony	Sb	51	121.76
Potassium	K	19	39.0983	Tellurium	Te	52	127.6
Calcium	Ca	20	40.078	Iodine	I	53	126.9045
Scandium	Sc	21	44.9559	Xenon	Xe	54	131.293
Titanium	Ti	22	47.867	Caesium	Cs	55	132.9054
Vanadium	V	23	50.9415	Barium	Ba	56	137.327
Chromium	Cr	24	51.9961	Lanthanum	La	57	138.9055
Manganese	Mn	25	54.938	Cerium	Ce	58	140.116
Iron	Fe	26	55.845	Praseodymium	Pr	59	140.9076
Cobalt	Co	27	58.933	Neodymium	Nd	60	144.242
Nickel	Ni	28	58.6934	Promethium	Pm	61	146.9151
Copper	Cu	29	63.546	Samarium	Sm	62	150.36
Zinc	Zn	30	65.409	Europium	Eu	63	151.964
Gallium	Ga	31	69.723	Gadolinium	Gd	64	157.25
Germanium	Ge	32	72.64	Terbium	Tb	65	158.925
Arsenic	As	33	74.9216	Dysprosium	Dy	66	162.5

Element	Symbol	At.No	At.mass	Element	Symbol	At.No	At.mass
Holmium	Ho	67	164.93	Neptunium	Np	93	237.0482
Erbium	Er	68	167.259	Plutonium	Pu	94	244.0642
Thulium	Tm	69	168.93	Americium	Am	95	243.0614
Ytterbium	Yb	70	173.04	Curium	Cm	96	247.0703
Lutetium	Lu	71	174.967	Berkelium	Bk	97	247.0703
Hafnium	Hf	72	178.49	Californium	Cf	98	251.0796
Tantalum	Ta	73	180.9479	Einsteinium	Es	99	252.0829
Tungsten	W	74	183.84	Fermium	Fm	100	257.0951
Rhenium	Re	75	186.207	Mendelevium	Md	101	258.0986
Osmium	Os	76	190.23	Nobelium	No	102	259.1009
Iridium	Ir	77	192.217	Lawrencium	Lr	103	260.1053
Platinum	Pt	78	195.084	Rutherfordium	Rf	104	261.1087
Gold	Au	79	196.9665	Dubnium	Db	105	262.1138
Mercury	Hg	80	200.59	Seaborgium	Sg	106	263.1182
Thallium	Tl	81	204.283	Bohrium	Bh	107	262.1229
Lead	Pb	82	207.2	Hassium	Hs	108	265
Bismuth	Bi	83	208.98	Meitnerium	Mt	109	266
Polonium	Po	84	208.98	Darmstadtium	Ds	110	269
Astatine	At	85	209.98	Roentgenium	Rg	111	272
Radon	Rn	86	222.176	Copernicium	Cn	112	285
Francium	Fr	87	223.0197	Ununtrium	Uut	113	284
Radium	Ra	88	226.0254	Ununquadium	Uuq	114	289
Actinium	Ac	89	227.278	Ununpentium	Uup	115	288
Thorium	Th	90	232.0381	Ununhexium	Uuh	116	292
Protactinium	Pa	91	231.0359	Ununseptium	Uus	117	unknown
Uranium	U	92	238.0289	Ununoctium	Uuo	118	294

IUPAC Periodic Table of the Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H hydrogen [1.007 94]	4 Be beryllium [9.012 1618]											5 B boron [10.811 700]	6 C carbon [12.010 700]	7 N nitrogen [14.006 422]	8 O oxygen [15.999 422]	9 F fluorine [18.998 422]	10 Ne neon [20.179 700]
3 Li lithium [6.941 159]	12 Mg magnesium [24.304 670]											13 Al aluminum [26.981 538]	14 Si silicon [28.085 509]	15 P phosphorus [30.973 762]	16 S sulfur [32.065 500]	17 Cl chlorine [35.453 762]	18 Ar argon [39.948 762]
11 Na sodium [22.989 768]																	
19 K potassium [39.098 310]	20 Ca calcium [40.078 310]																
37 Rb rubidium [85.468 310]	38 Sr strontium [87.62 310]																
55 Cs caesium [132.905 450]	56 Ba barium [137.327 450]																
87 Fr francium	88 Ra radium																
		21 Sc scandium [44.955 912]	22 Ti titanium [47.88 912]	23 V vanadium [50.941 912]	24 Cr chromium [51.996 912]	25 Mn manganese [54.938 912]	26 Fe iron [55.845 912]	27 Co cobalt [58.933 912]	28 Ni nickel [58.69 912]	29 Cu copper [63.546 912]	30 Zn zinc [65.38 912]	31 Ga gallium [69.723 912]	32 Ge germanium [72.63 912]	33 As arsenic [74.921 912]	34 Se selenium [78.96 912]	35 Br bromine [79.904 912]	36 Kr krypton [83.80 912]
		39 Y yttrium [88.905 840]	40 Zr zirconium [91.224 840]	41 Nb niobium [92.906 840]	42 Mo molybdenum [95.94 840]	43 Tc technetium [98 840]	44 Ru ruthenium [101.07 840]	45 Rh rhodium [102.905 840]	46 Pd palladium [106.367 840]	47 Ag silver [107.868 840]	48 Cd cadmium [112.411 840]	49 In indium [114.818 840]	50 Sn tin [118.710 840]	51 Sb antimony [121.757 840]	52 Te tellurium [127.6 840]	53 I iodine [126.905 840]	54 Xe xenon [131.29 840]
		57-71 lanthanoids	72 Hf hafnium [178.49 840]	73 Ta tantalum [180.948 840]	74 W tungsten [183.84 840]	75 Re rhenium [186.207 840]	76 Os osmium [190.23 840]	77 Ir iridium [192.222 840]	78 Pt platinum [195.084 840]	79 Au gold [196.967 840]	80 Hg mercury [200.59 840]	81 Tl thallium [204.383 840]	82 Pb lead [207.2 840]	83 Bi bismuth [208.980 840]	84 Po polonium	85 At astatine	86 Rn radon
		89-103 actinoids	104 Rf rutherfordium	105 Db dubnium	106 Sg seaborgium	107 Bh bohrium	108 Hs hassium	109 Mt meitnerium	110 Ds darmstadtium	111 Rg roentgenium	112 Cn copernicium						

57 La lanthanum [138.905 450]	58 Ce cerium [140.12 450]	59 Pr praseodymium [140.908 450]	60 Nd neodymium [144.24 450]	61 Pm promethium	62 Sm samarium [150.4 450]	63 Eu europium [152.0 450]	64 Gd gadolinium [157.25 450]	65 Tb terbium [158.925 450]	66 Dy dysprosium [162.5 450]	67 Ho holmium [164.930 450]	68 Er erbium [167.259 450]	69 Tm thulium [168.934 450]	70 Yb ytterbium [173.054 450]	71 Lu lutetium [175.0 450]
89 Ac actinium [227 260]	90 Th thorium [232.037 260]	91 Pa protactinium [231.036 260]	92 U uranium [238.028 260]	93 Np neptunium	94 Pu plutonium	95 Am americium	96 Cm curium	97 Bk berkelium	98 Cf californium	99 Es einsteinium	100 Fm fermium	101 Md mendelevium	102 No nobelium	103 Lr lawrencium

Chapter No.9

Activity: 9.1

- $\text{N}_{2(g)} + 2\text{O}_{2(g)} \rightleftharpoons 2\text{NO}_{2(g)}$
- $\text{N}_{2(g)} + 3\text{H}_{2(g)} \rightleftharpoons 2\text{NH}_{3(g)}$
- $\text{H}_{2(g)} + \text{I}_{2(g)} \rightleftharpoons 2\text{HI}_{(g)}$
- $2\text{NO}_{(g)} + \text{O}_{2(g)} \rightleftharpoons 2\text{NO}_2$
- $\text{CO}_{2(g)} + 4\text{H}_{2(g)} \rightleftharpoons \text{CH}_{4(g)} + 2\text{H}_2\text{O}_{(g)}$

Activity: 9.2

- $$K_c = \frac{[\text{NaNO}_3][\text{AgCl}]}{[\text{NaCl}][\text{AgNO}_3]}$$
- $$K_c = \frac{[\text{Na}_2\text{SO}_4][\text{H}_2\text{O}]^2}{[\text{NaOH}]^2[\text{H}_2\text{SO}_4]}$$
- $$K_c = \frac{[\text{NH}_4\text{Cl}]^2[\text{CaCO}_3]}{(\text{NH}_4)_2\text{O}_3[\text{CaCl}_2]}$$

Q3. ii)
$$K_c = \frac{[\text{NH}_4\text{Cl}]}{[\text{NH}_3][\text{HCl}]}$$

Chapter No.10

Activity: 10.1

- $$\text{NH}_{3(g)} + \text{H}_2\text{O}_{(l)} \rightleftharpoons \text{N}^+\text{H}_{4(aq)} + \text{O}^-\text{H}_{(aq)}$$

NH_3 is a base here
 H_2O is acting as an acid here.
 N^+H_4 is a conjugate acid of reaction
 O^-H is a conjugate base of reaction
- $$\text{HNO}_{3(aq)} + \text{H}_2\text{O}_{(l)} \rightleftharpoons \text{H}_3\text{O}^+_{(aq)} + \text{NO}_3^-_{(aq)}$$

Acid Base Conjugate Acid Conjugate Base
- $$\text{CH}_3\text{COOH}_{(aq)} + \text{H}_2\text{O}_{(l)} \rightleftharpoons \text{CH}_3\text{COO}^-_{(aq)} + \text{H}_3\text{O}^+_{(aq)}$$

Acid Base Conjugate Base Conjugate Acid

Activity: 10.2

Ans. = $[\text{H}^+] = 0.001 \text{ mols/lit}$

Activity: 10.4

- $\text{HCl}_{(aq)} + \text{KOH}_{(aq)} \rightleftharpoons \text{KCl}_{(aq)} + \text{H}_2\text{O}_{(l)}$
- $\text{CH}_3\text{COOH}_{(aq)} + \text{NaOH}_{(aq)} \rightleftharpoons \text{CH}_3\text{COONa}_{(aq)} + \text{H}_2\text{O}_{(l)}$
- $2\text{HNO}_{3(aq)} + \text{Ca}(\text{OH})_{2(aq)} \rightleftharpoons \text{Ca}(\text{NO}_3)_{2(aq)} + 2\text{H}_2\text{O}_{(l)}$

Q17. Ans. is = pH = '2'

Q18. (a) 0.00001M

$1 \times 10^{-5} \text{M}$

(b) $1 \times 10^{-10} \text{M}$

- Q19. (a) 6
(b) 11

Chapter No.11

Activity: 11.3

The products of combustion reaction of hydrocarbons are always CO_2 and water.



Kerosine Oil

Chapter No.12

Activity: 12.3

1.
$$\begin{array}{c} \text{CH}_3-\text{CH}-\text{CH}_2-\text{CH}_2-\text{CH}_3 \\ | \\ \text{CH}_3 \end{array}$$

2-Methyl pentane
2.
$$\begin{array}{c} \text{CH}_3-\text{CH}_2-\text{CH}_2-\text{CH}-\text{CH}-\text{CH}_3 \\ | \quad | \\ \text{CH}_3 \quad \text{CH}_3 \end{array}$$

2,3-Dimethyl hexane
3.
$$\begin{array}{c} \text{CH}_3 \\ | \\ \text{CH}_3-\text{C}-\text{CH}_2-\text{CH}_3 \\ | \\ \text{CH}_3 \end{array}$$

2,2-Dimethyl butane

Q12. Draw structures:

- i)
$$\begin{array}{c} \text{CH}_3 \\ | \\ \text{CH}_3-\text{CH}_2-\text{C}-\text{CH}_2-\text{CH}_3 \\ | \\ \text{CH}_3 \end{array}$$

3,3-Dimethyl pentane
- ii)
$$\begin{array}{c} \text{CH}_3 \\ | \\ \text{CH}_3-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}-\text{CH}_3 \\ | \\ \text{CH}_3 \end{array}$$

2-Methyl hexane
- iii)
$$\text{CH}_3-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_2-\text{CH}_3$$

n-Hexane
- iv)
$$\begin{array}{c} \text{CH}_3-\text{CH}_2-\text{CH}_2-\text{CH}-\text{CH}-\text{CH}_2-\text{CH}_3 \\ | \quad | \\ \text{CH}_3 \quad \text{CH}_3 \end{array}$$

3-4-dimethyl heptane
- v)
$$\begin{array}{c} \text{CH}_3-\text{CH}_2-\text{CH}-\text{CH}_3 \\ | \\ \text{CH}_3 \end{array}$$

Isopentane

Table of Basic S.I units

S/No	Measurement	Unit	Symbol
1	Length	Metre or Meter	m
2	Mass	Kilogram	Kg
3	Time	Second	s
4	Electric current	Ampere	A
5	Temperature	Kelvin	K
6	Amount of substance	Mole	mol
7	Luminous intensity	Candela	cd

Some Prefixes for Multiples / fraction

Factor	Scientific Notation	Prefix	Symbol
1000,000,000	10^9	Giga	G
1000,000	10^6	Mega	M
1000	10^3	kilo	k
100	10^2	hecto	h
10	10^1	deca	da
0.1	10^{-1}	deci	d
0.01	10^{-2}	centi	c
0.001	10^{-3}	milli	m
0.000,001	10^{-6}	micro	μ
0.000,000,001	10^{-9}	nano	n
0.000,000,000,001	10^{-12}	pico	p

Conversion Factors

Length

1 metre = 1.0936 yards

1 centimeter = 0.39370 inch

1 inch = 2.54 centimeters

1 kilometer = 0.62137 mile

1 mile = 1.6093 kilometers

1 angstrom = 10^{-10} meter = 100 pico meter

Mass

1 kilogram = 1000gm = 2.2046 Pounds

1 Pound = 453.5gms = 0.454 kilograms

1 ton = 2000 pounds = 907.185 kilograms

1 metric ton = 1000 kilograms = 2204.6 pounds

1 a.m.u = 1.66054×10^{-27} kilograms = 1.66054×10^{-24} gms

Temperature

0K = -273.15°C = -459.67°F

K = $^{\circ}\text{C} + 273.15$

$^{\circ}\text{C}$ = $\frac{5}{9} (^{\circ}\text{F} - 32)$

$^{\circ}\text{F}$ = $\frac{9}{5} (^{\circ}\text{C}) + 32$

Energy

1 Calorie = 4.184 Joules = 3.965×10^{-3} btu

1 btu = 1055.06 Joules = 252 Calories

Pressure

1 atmosphere = 101325 Pascals = 760 torr

= 760mmHg = 14.70 Pounds per square inch

1 bar = 10^5 Pascals

1 pascal = $1 \text{ N/m}^2 = 1 \text{ Kg m}^{-1} \text{ s}^{-2}$

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