**SS1 Chemistry Lesson Note (Third Term) [year]**

**SCHEME OFWORK**

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**WEEK 1**

**Introduction**

**Growing up, we used to think that any substance that burns is an acid, until we learnt about acids, bases and salts in our foundational chemistry class. It was then clear to us that there is more to acids than corrosivity, and not every substance that is corrosive, is an acid.**

**Definition**

**The definitions of an acid is based on three different concepts of acid-base reactions, namely the Lewis, Brønsted-Lowry and Arrhenius concepts.**

**Acids: The word 'Acid' came from Latin word 'Acidus or Acere' which means sour.**

**Sour taste is the most common characteristic of acid. Acid turns blue litmus paper red. There are many substances which contain acid and hence taste sour, such as curd, tamarind, lemon, etc.**

## Lewis Acids

According to G. N. Lewis, in acid-base reactions, the reactants undergo co-ordinate covalent bonding, in which one reacting species has the ability to accept a lone pair of electrons, while the other can readily donate a lone pair of electrons. A Lewis acid is an electron pair acceptor, because it has an empty orbital. Examples are $H^+$, $H_3O^+$, $Cu^{2+}$, $Fe^{3+}$.

## Brønsted-Lowry Acids

According to J. H. Brønsted and M. Lowry, an acid-base reaction involves the transfer of proton from one of the reactants to the other. A Brønsted-Lowry acid is a proton donor. For instance,

$HA \longrightarrow H^+ + A^-$

$HNO_3 \longrightarrow H^+ + NO_3^-$

Our focus on this topic will be the Arrhenius concept of acid-base reactions, which gives the basic definition of acids.

## Arrhenius Acids

According to Arrhenius, an acid is any substance that produces hydrogen ion, $H^+$ or hydroxonium ion, $H_3O^+$ as the only positive ion, when dissolved in water.

Example, hydrogen chloride gas dissolves in water to form hydroxonium and chloride ions.

$HCl(g) + H_2O(l) \longrightarrow H_3O^+(aq) + Cl^-(aq)$

Other examples include:

$H_2SO_4(l) + 2H_2O(l) \longrightarrow 2H_3O^+(aq) + SO_4^{--}(aq)$

$HNO_3(l) + H_2O(l) \longrightarrow H_3O^+(aq) + NO_3^-(aq)$

$H_3PO_4(l) + 3H_2O(l) \longrightarrow 3H_3O^+(aq) + PO_4^{---}(aq)$

The above equations can be rewritten in the abbreviated form as follows:

$HCl(aq) \longrightarrow H^+(aq) + Cl^-(aq)$

$H_2SO_4(aq) \longrightarrow 2H^+(aq) + SO_4^{--}(aq)$

$HNO_3(aq) \longrightarrow H^+(aq) + NO_3^-(aq)$

$H_3PO_4(aq) \longleftrightarrow 3H^+(aq) + PO_4^{---}(aq)$

**The presence of the $H_3O^+$ or the $H^+$ in the above equations is what accounts for the acidity of the substances.**

**Organic Acids & Source**

**Acid Source**

**Acetic acid Vinegar**

**Ascorbic acid Guava, amla**

**Citric acid Lemon, orange and other citrus fruits**

**Lactic acid Sour milk, curd**

**Methanoic acid Ant sting, nettle sting**

**Oxalic acid Tomato**

**Tartaric acid Tamarind**

**Classification by Nature**

**There are also two types of acids by nature. These are the organic and inorganic acids.**

**Organic Acids: These are acids, which occur naturally in plant and animal matters. Some examples of organic acids are ethanoic (acetic) acid from vinegar, amino acids from protein, lactic acid from milk, ascorbic acid (Vit. C) from oranges, citric acid from lime and lemon, palmitic acid from palm oil, ethanedioic (oxalic) acid, etc.**

**Inorganic Acids: These are acids synthesized from mineral elements. They are also known as mineral acids. Examples include hydrochloric acid, trioxocarbonate (IV) acid, tetraoxosulphate (VI) acid, trioxonitrate (V) acid etc.**

**Examples of some acids are:**

| **Formula** | **IUPAC Name** |
|---|---|
| **HCl** | **Hydrochloric acid** |
| **$HNO_3$** | **Trioxonitrate (V) acid** |

| | |
|---|---|
| $HCN$ | Hydrocyanic acid |
| $CH_3COOH$ | Ethanoic acid |
| $HClO_3$ | Trioxochlorate (V) acid |
| $H_2SO_3$ | Trioxosulphate (IV) acid |
| $H_2SO_4$ | Tetraoxosulphate (VI) acid |
| $H_2CO_3$ | Trioxocarbonate (IV) acid |
| $H_2C_2O_4$ | Ethanedioic acid |
| $H_3PO_4$ | Tetraoxophosphate (V) acid |

**Basicity of Acids**

**The basicity of an acid is the number of replaceable hydrogen or hydroxonium ions present in one molecule of the acid when it dissociates in water.**

**The following equations show the dissociation of some acids in solution, and the accompanying table shows a summary of their basicity.**

$HCl(aq) \longrightarrow H^+(aq) + Cl^-(aq)$

$HCN(aq) \longrightarrow H^+(aq) + CN^-(aq)$

$HNO_3(aq) \longrightarrow H^+(aq) + NO_3^-(aq)$

$HClO_3(aq) \longrightarrow H^+(aq) + ClO_3^-(aq)$

$CH_3COOH(aq) \longleftrightarrow CH_3COO^-(aq) + H^+(aq)$

$H_2SO_4(aq) \longrightarrow 2H^+(aq) + SO_4^{--}(aq)$

$H_2SO_3(aq) \longleftrightarrow 2H^+(aq) + SO_3^{--}(aq)$

$H_2CO_3(aq) \longleftrightarrow 2H^+(aq) + CO_3^{--}(aq)$

$H_2C_2O_4(aq) \longleftrightarrow 2H^+(aq) + C_2O_4^{--}(aq)$

$H_3PO_4(aq) \longleftrightarrow 3H^+(aq) + PO_4^{---}(aq)$

| Basicity (No of $H^+$/molecule) | Acids |
|---|---|
| 1 (monobasic) | $HCl$, $HCN$, $HNO_3$, $CH_3COOH$ |
| 2 (dibasic) | $H_2SO_4$, $H_2SO_3$, $H_2CO_3$, $H_2C_2O_4$ |
| 3 (tribasic) | $H_3PO_4$ |

**EVALUATION**

1. **Define an acid based on the three concepts of acid-base reactions, and give one example each.**
2. **Give the natural sources of the following organic acids:**

**(a) Ascorbic acid**

**(b) Acetic acid**

**(c) Palmitic acid**

**(d) Citric acid**

3. **A strong dilute $H_2SO_4$ ionizes**
4. **slowly but contains more water than acid**
5. **fast but contain more acid than water**
6. **fast but contain more water than acid**
7. **slowly but contains more acid than water**
8. **Acid anhydride is the same as**
9. **dry acid b. acid that increase its volume when exposed to air**
10. **acid made by drying the reactants first**

**24.**

**THEORY**

**ATTEMPT ANY THREE**

**1a.How would you prove that a given colourless liquid is an acid?**

1. **Sulphur(iv) oxide is described as an acid anhydride. Elaborate on this statement.**

**c.Give the natural sources of the following organic Acids.**

1. **Lactic acid   ii Ascorbic  acid   iii  Amino acids**

**2a. Give four general methods of preparing salts and use chemical equations for the examples.**

**2b. How would you prove that sodium Hydroxide is a base without using litmus paper to test? Equation of reaction required.**

**2c. The concentration of H+ in a solution is 1x10-3 mol/dm3,what is the PH  of the solution.**

**3a.Explain why Graphite is a good conductor of electricity while Diamond is not.**

**3b.**

**4a.Name four products obtained in the destructive distillation of coal.**

**4b**

**WEEK 2**

**TYPES OF ACIDS**

**Acids can be classified based on two major categories - their strength and nature.**

**Classification by Strength**

**There are two types of acids based on their strength. These are strong acids and weak acids.**

**Strong Acids: These are acids that dissociate or ionize completely when dissolved in water. Some examples of strong acids are hydrochloric acid, trioxonitrate (V) acid and tetraoxosulphate (VI) acid**

**$HCl(aq) \longrightarrow H^+(aq) + Cl^-(aq)$**

**$HNO_3(aq) \longrightarrow H^+(aq) + NO_3^-(aq)$**

**$H_2SO_4(aq) \longrightarrow 2H^+(aq) + SO_4^{2-}(aq)$**

Weak Acids: These are acids that undergo partial or incomplete ionization in water. Examples include $H_2CO_3$, $H_2SO_3$, $CH_3COOH$, $H_3PO_4$.

$CH_3COOH(aq) \longleftrightarrow CH_3COO^-(aq) + H^+(aq)$

$H_2CO_3(aq) \longleftrightarrow 2H^+(aq) + CO_3^{--}(aq)$

$H_2SO_3(aq) \longleftrightarrow 2H^+(aq) + SO_3^{--}(aq)$

$H_3PO_4(aq) \longleftrightarrow 3H^+(aq) + PO_4^{---}(aq)$

The backward and forward arrows in the equations indicate an incomplete ionization. Actually, only 4 out of every 1000 molecules of ethanoic acid in solution are ionized. Generally, all organic acids like ethanoic acid and ethanedioic acids are weak acids.

## Concentration of Acids

The concentration of an acid is the amount of the acid in moles present in a given volume of water. If a little volume of water is added to a large amount of acid, then the solution is said to be a concentrated acid solution. Conversely, when a large volume of water is added to a small amount of acid, a dilute acid solution will be obtained.

For instance, given two solutions A and B of $H_2SO_4$, of concentrations 10 mol $dm^{-3}$ and 0.1 mol $dm^{-3}$ respectively; the former contains 10 moles or 980g of the acid in 1$dm^3$ (1000 $cm^3$) of distilled water, while the latter contains 0.1 mole or 9.8g of the acid in 1 $dm^3$ of distilled water. Hence, solution A is a concentrated solution, while solution B is a dilute solution, because the amount of $H_2SO_4$ present in 1 $dm^3$ of water is greater in A than in B.

## Physical Properties of Acids

1. They turn blue litmus paper red.
2. The dilute acids possess a sour taste. The presence of acids accounts for the sour taste of unripe fruits, vinegar and rancid (stale) milk.
3. The strong acids are good electrolytes, while the weak acids are weak electrolytes.
4. The concentrated forms of strong acids are corrosive.

Precaution: You are NEVER expected to add water to a concentrated acid, as it may cause severe acid burns. If you must dilute a concentrated acid, ALWAYS ADD THE ACID TO A LARGER VOLUME OF WATER.

Remember, when cooking you DO NOT add water to hot oil, rather the reverse is done. The same principle is applicable when dealing with concentrated acids and water.

**Chemical Properties of Acids**

**There are three major properties that all acids exhibit, irrespective of their nature, and these include:**

**(a) Action on active metals: Active metals displace the hydrogen atoms in acids to form salts with the liberation of hydrogen gas.**

**acid + active metal ----> salt + hydrogen**

**Examples:**

**$2HCl(aq) + Zn(s) \longrightarrow ZnCl_2(aq) + H_2(g)$**

**$H_2SO_4(aq) + 2Na(s) \longrightarrow Na_2SO_4(aq) + H_2(g)$**

**$H_2SO_4(aq) + Mg(s) \longrightarrow MgSO_4(aq) + H_2(g)$**

**It is important to note that unlike other acids, trioxonitrate (V) acid does not undergo this reaction with the metals, except in the action of very dilute trioxonitrate (V) acid (about 1%) on calcium, magnesium or manganese.**

**$2HNO_3(aq) + Ca(s) \longrightarrow Ca(NO_3)_2(aq) + H_2(g)$**

**This is due to its highly oxidizing nature, which causes the hydrogen to be oxidized to water, while the acid, itself, is reduced to nitrogen (IV) oxide or nitrogen (II) oxide gas, depending on the reaction conditions, as shown in its reaction with copper.**

**$4HNO_3(aq) + Cu(s) \longrightarrow Cu(NO_3)_2(aq) + 2NO_2(g) + 2H_2O(l)$ (hot concentrated $HNO_3$)**

**$8HNO_3(aq) + 3Cu(s) \longrightarrow 3Cu(NO_3)_2(aq) + 2NO(g) + 4H_2O(l)$ (cold concentrated $HNO_3$)**

**(b) Action on bases: All acids react with a base to form salt and water. This is known as a neutralization reaction.**

**acid + base ----> salt + water**

**Examples:**

**$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$**

**$H_2SO_4(aq) + CaO(s) \longrightarrow CaSO_4(aq) + H_2O(l)$**

**$HNO_3(aq) + KOH(aq) \longrightarrow KNO_3(aq) + H_2O(l)$**

**$CH_3COOH(aq) + NaOH(aq) \longrightarrow CH_3COONa(aq) + H_2O(l)$**

**The products are formed by the exchange of negative ions and radicals between the acids and the bases.**

**(c) Action on trioxocarbonate (IV), ($CO_3^{--}$): All acids react with trioxocarbonate (IV) salts to produce salt and water, and liberate carbon (IV) oxide.**

**acid + trioxocarbonate (IV) ----> salt + water + $CO_2$**

**Examples:**

**$2HCl(aq) + Na_2CO_3(aq) \longrightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$**

**$H_2SO_4(aq) + CaCO_3(s) \longrightarrow CaSO_4(aq) + H_2O(l) + CO_2(g)$**

**$2HNO_3(aq) + K_2CO_3(aq) \longrightarrow 2KNO_3(aq) + H_2O(l) + CO_2(g)$**

**$CH_3COOH(aq) + PbCO_3(s) \longrightarrow (CH_3COO)_2Pb(s) + H_2O(l) + CO_2(g)$**

**Methods of Acids Preparation**

**The following are some of the methods employed in preparing acids in the laboratory:**

1. **Dissolving an acid anhydride in water. Acid anhydrides are nonmetallic oxides, mostly gases, which dissolve in water to form acids. Examples include $CO_2$, $SO_2$, $P_4O_{10}$ etc**

**Examples:**

**(a) Carbon (IV) oxide dissolves in water to form trioxocarbonate (IV) acid.**

**$CO_2(g) + H_2O(l) \longrightarrow H_2CO_3(aq)$**

**(b) Sulphur (IV) oxide dissolves in water to form trioxosulphate (IV) acid.**

**$SO_2(g) + H_2O(l) \longrightarrow H_2SO_3(aq)$**

**(c) Sulphur (VI) oxide dissolves in water to produce tetraoxosulphate (VI) acid.**

**$SO_3(g) + H_2O(l) \longrightarrow H_2SO_4(aq)$**

**(d) Phosphorus (V) oxide dissolves in water to produce tetraoxophosphate (V) acid.**

**$P_4O_{10}(s) + 6H_2O(l) \longrightarrow 4H_3PO_4(aq)$**

**(e) Nitrogen (V) oxide and nitrogen (III) oxide dissolve in water to form trioxonitrate (V) acid and dioxonitrate (III) acids respectively.**

**$N_2O_5(g) + H_2O(l) \longrightarrow 2HNO_3(aq)$**

**$N_2O_3(g) + H_2O(l) \longrightarrow 2HNO_2(aq)$**

2. **Using a strong acid to displace a volatile or weak acid from its salts.**

**(a) Concentrated tetraoxosulphate (VI) acid is used to displace a volatile gas like hydrogen chloride from a chloride salt.**

**$H_2SO_4(aq) + NaCl(s) \longrightarrow Na_2SO_4 + HCl(g)$**

**The hydrogen chloride produced, dissolves readily in water to form hydrochloric acid.**

**(b) Concentrated tetraoxosulphate (VI) acid can also be used to displace weak trioxocarbonate (IV) acid from a trioxocarbonate (IV) salt.**

**$H_2SO_4(aq) + CaCO_3(s) \longrightarrow CaSO_4(aq) + H_2CO_3(aq)$**

**The trioxocarbonate (IV) acid, which is not stable, readily decomposes to water and carbon (IV) oxide.**

**$H_2CO_3(aq) \longrightarrow H_2O(l) + CO_2(g)$**

**(c) Concentrated tetraoxosulphate (VI) and hydrochloric acids are used to displace trioxonitrate (V) acid from excess trioxonitrate (V) salts.**

**$H_2SO_4(aq) + 2KNO_3(s) \longrightarrow K_2SO_4(aq) + 2HNO_3(g)$**

**$HCl(aq) + NaNO_3(s) \longrightarrow NaCl(aq) + HNO_3(g)$**

3. **Direct combination of elements. Most acids that are binary compounds, such as the hydrogen halides can be prepared by combining the constituent elements at appropriate conditions.**

**Examples:**

**(a) Hydrogen burns rapidly in chlorine in the presence of activated charcoal as a catalyst to form hydrogen chlorine gas, which then dissolves in water to produce hydrochloric acid.**

**$H_2(g) + Cl_2(g)$ + activated charcoal + heat $\longrightarrow 2HCl(g)$**

**$HCl(g) + H_2O(l) \longrightarrow H_3O^+(aq) + Cl^-(aq)$**

**(b) Hydrogen combines with bromine vapour in the presence of platinum and heat to form hydrogen bromide gas, which then dissolves readily in water to form hydrobromic acid.**

**$H_2(g) + Br_2(g)$ + platinum + heat $\longrightarrow 2HBr(g)$**

**$HBr(g) + H_2O(l) \longrightarrow H_3O^+(aq) + Br^-(aq)$**

**The hydrogen bromide gas produced, dissolves readily in water to form hydrobromic acid.**

**Uses of Acids**

**Some uses of acids include:**

1. **Manufacture of textiles, paints, fertilizers, drugs and other chemicals. E.g. $H_2SO_4$, HCl, $HNO_3$.**
2. **As drying and dehydrating agents. E.g. $H_2SO_4$**
3. **In food preservation and dyeing of textiles. E.g. $CH_3COOH$**
4. **As solvents in qualitative analysis. E.g. Dilute HCl, dilute $HNO_3$**
5. **As an oxidizing agent. E.g. Conc. $HNO_3$**
6. **In oil refineries for refining of some petroleum products. E.g. $H_2SO_4$**
7. **In the manufacture of baking soda, soft drinks and health salts. E.g. $H_2CO_3$.**

**EVALUATION**

1. **What is common to both hydrochloric acid and trioxonitrate v acid?**
2. **both are used for fountain experiment. b. both are monobasic c. both are used to prepare hydrogen gas from zinc granules. D. both attack rubber.**
3. **Differentiate between acid and acidic solution.**

**3 . (a) How would you prove that a given colourless liquid is an acid?**

**(b) State three chemical properties of acids.**

4. **(a) Differentiate between a strong acid and a concentrated acid.**

**(b) Carbon (IV) oxide is described as an acid anhydride. Explain.**

**(c) State four uses of acids.**

## WEEK 3

## BASES

In a layman's term, a base is the opposite of an acid. In other words, a base is everything an acid is not.

### Definition

### Lewis Bases

According to G. N. Lewis, a base is any species that can readily donate a pair of electrons. The availability of lone pair(s) of electrons increases a substance's ability to behave as a base. Examples include $H_2\ddot{O}$, $\tilde{N}H_3$, $Cl^-$, $F^-$ etc. They are also considered to be nucleophiles. Any species with an electron-rich centre is said to be a nucleophile.

### Brønsted-Lowry Bases

According to Brønsted and Lowry, an acid is a proton donor, while a base is a proton acceptor. In other words, any substance that has the ability to accept a proton (hydrogen ion, $H^+$) by donating a pair of electrons to it, is said to be a base. Examples are $H_2\ddot{O}$, $\tilde{N}H_3$, $Br^-$ etc.

$H_2\ddot{O}(l) + H^+(aq) \longleftrightarrow H_3\ddot{O}^+(aq)$

$\tilde{N}H_3(l) + H^+(aq) \longrightarrow NH_4^+(aq)$

$Cl^-(aq) + H^+(aq) \longrightarrow HCl(aq)$

### Arrhenius Bases

Recall that an Arrhenius acid produces hydrogen ion as the only positive ion, when dissolved in water. Similarly, a base is any substance, which produces hydroxide ion, $OH^-$ when dissolved in water. For example, sodium hydroxide dissolves in water to produce sodium ion, $Na^+$ and $OH^-$ as follows:

$NaOH(aq) \longrightarrow Na^+(aq) + OH^-(aq)$

Also, potassium hydroxide dissolves in water to produce potassium ion, $K^+$ and $OH^-$.

$KOH(aq) \longrightarrow K^+(aq) + OH^-(aq)$

A base can also be defined as any substance that neutralizes an acid, or a substance that reacts with an acid to form salt and water. This is because not all bases produce hydroxide ions in water, as some of them are oxides and hydroxides of certain metals, which are insoluble in water.

### Classification of Bases

From the aforementioned, bases can be classified into two major categories based on their solubility in water. These are the soluble and insoluble bases.

Soluble Bases: These comprise of oxides of Group I metals and calcium; and hydroxides of sodium, potassium, calcium and ammonium. These soluble hydroxides are known as alkalis.

Insoluble Bases: These are the oxides and hydroxides of other metals not mentioned above.

Examples of alkalis and insoluble bases are:

| Alkalis | Names |
|---|---|
| NaOH | Sodium hydroxide (Caustic Soda) |
| KOH | Potassium hydroxide (Caustic Potash) |
| $Ca(OH)_2$ | Calcium hydroxide (Slaked Lime/Lime Water) |
| $NH_4OH$ | Ammonium hydroxide (Liquid Ammonia) |

| Insoluble Bases | Names |
|---|---|
| MgO | Magnesium oxide |
| CuO | Copper (II) oxide |
| FeO | Iron (II) oxide |
| $Mg(OH)_2$ | Magnesium hydroxide |
| $Fe(OH)_2$ | Iron (II) hydroxide |
| $Cu(OH)_2$ | Copper (II) hydroxide |
| $Zn(OH)_2$ | Zinc hydroxide |
| $Al(OH)_3$ | Aluminium hydroxide |

Classification of Alkalis

Alkalis are classified based on their strength, which is their degree of ionization in water. These are strong and weak alkalis.

Strong Alkalis: These are those, which ionize completely when dissolved in water. Examples are sodium hydroxide and potassium hydroxide.

$NaOH(aq) \longrightarrow Na(s) + OH^-(aq)$

$KOH(aq) \longrightarrow K^+(aq) + OH^-(aq)$

Weak Alkalis: These are those hydroxides which undergo incomplete dissociation in water. Examples are calcium hydroxide and liquid ammonia.

$Ca(OH)_2(aq) <----> Ca^{2+}(aq) + 2OH^-(aq)$

$NH_4OH(aq) <----> NH_4^+(aq) + OH^-(aq)$

$NH_4OH$ was was initially known as ammonium hydroxide, but was later changed to liquid ammonia ($NH_3.H_2O$), because unlike other hydroxides, it decomposes in the presence of heat to liberate ammonia gas.

$NH_4OH(aq) + heat ----> NH_3(g) + H_2O(l)$

## Physical Properties of Alkalis

1. They possess a bitter taste.
2. They are slippery to touch because of their soapy feel.
3. They turn red litmus paper blue.
4. They change the colour of phenolphthalein paper from colourless to pink.
5. Their concentrated forms are corrosive.
6. They are electrolytes.

## Chemical Properties of Bases

1.Neutralization Reactions: All bases react with acids to form salts and water. This is known as neutralization reaction.

base + acid ----> salt + water

Examples

(a) Potassium hydroxide reacts with hydrochloric acid to form potassium chloride and water.

$KOH(aq) + HCl(aq) ----> KCl(aq) + H_2O(l)$

Ionically,

$K^+(aq).OH^-(aq) + H^+(aq).Cl^-(aq) ----> K^+(aq).Cl^-(aq) + H_2O(l)$

$H^+(aq) + OH^-(aq) ----> H_2O(l)$

(b) Copper (II) oxide reacts with tetraoxosulphate (VI) acid to produce copper (II) tetraoxosulphate (VI) and water.

**$CuO(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + H_2O(l)$**

**(c) Insoluble magnesium hydroxide reacts with dilute trioxonitrate (V) acid to form magnesium trioxonitrate (V) and water.**

**$Mg(OH)_2(s) + 2HNO_3(aq) \longrightarrow Mg(NO_3)_2(aq) + 2H_2O(l)$**

**(d) Sodium hydroxide combines with ethanoic acid to produce sodium ethanoate and water.**

**$NaOH(aq) + CH_3COOH(aq) \longrightarrow CH_3COONa(aq) + H_2O(l)$**

**Ionically,**

**$Na^+(aq).OH^-(aq) + CH_3COO^-(aq).H^+(aq) \longrightarrow CH_3COO^-(aq).Na^+(aq) + H_2O(l)$**

**$H^+(aq) + OH^-(aq) \longrightarrow H_2O(l)$**

**From (a) and (d) above, we can see that the actual species that 'partake' in a neutralization reaction are hydrogen/hydroxonium ions, and hydroxide ions.**

**Hence a neutralization reaction can be redefined as the reaction between hydrogen/hydroxonium ions and hydroxide ions to produce water molecules.**

**$H^+(aq) + OH^-(aq) \longrightarrow H_2O(l)$**

**$H_3O^+(aq) + OH^-(aq) \longrightarrow 2H_2O(l)$**

2. **Reaction with Ammonium Salts: All alkalis, except liquid ammonia, react with ammonium salts to liberate ammonia gas when heated. This reaction is used in qualitative analysis for the identification of salts that contain ammonium ions.**

**$NH_4^+(aq) + NaOH(aq) \longrightarrow NH_4OH(aq) + Na^+(aq)$**

**$NH_4OH(aq) + heat \longrightarrow NH_3(g) + H_2O(l)$**

**Methods of Preparation of Bases**

**The following are some of the ways bases can be prepared in the laboratory:**

1. **Burning metals in air. Metals burn in air to form basic oxides.**

**$4Na(s) + O_2(g) \longrightarrow 2Na_2O(s)$**

**$2Ca(s) + O_2(g) \longrightarrow 2CaO(s)$**

**$2Fe(s) + O_2(g) \longrightarrow 2FeO(s)$**

2. **Dissolving soluble basic oxides in water. Some metallic oxides dissolve in water to form alkalis. For instance, sodium oxide and potassium oxide dissolve in water to form sodium hydroxide and potassium hydroxide respectively.**

**$Na_2O(s) + H_2O(l) \longrightarrow 2NaOH(aq)$**

**$K_2O(s) + H_2O(l) \longrightarrow 2KOH(aq)$**

**Calcium oxide dissolves sparingly in water to form calcium hydroxide (lime water).**

**$CaO(s) + H_2O(l) \longrightarrow Ca(OH)_2(aq)$**

3. **Dissolving some metals in water. The very reactive Group 1 metals like potassium and sodium, and a few Group 2 metals such as calcium and barium react with water to form alkalis with the liberation of hydrogen.**

**$2K(s) + 2H_2O(l) \longrightarrow 2KOH(aq) + H_2(g)$**

**$2Na(s) + 2H_2O(l) \longrightarrow 2NaOH(aq) + H_2(g)$**

**$Ca(s) + 2H_2O(l) \longrightarrow Ca(OH)_2(aq) + H_2(g)$**

4. **Dissolving some metallic hydrides in water. Sodium, potassium and calcium hydrides dissolve in water to form alkalis, with the evolution of hydrogen gas.**

**$NaH(s) + H_2O(l) \longrightarrow NaOH(aq) + H_2(g)$**

**$KH(s) + H_2O(l) \longrightarrow KOH(aq) + H_2(g)$**

**$CaH_2(s) + 2H_2O(l) \longrightarrow Ca(OH)_2(aq) + 2H_2(g)$**

5. **Thermal decomposition of some trioxocarbonate (IV) and trioxonitrate (V) salts. Heating some trioxocarbonate (IV) and trioxonitrate (V) salts will produce the oxides of the metallic cations in the salt.**

**Examples**

**(a) Copper (II) trioxocarbonate (IV) salt undergoes decomposition when heated to form copper (II) oxide, with the liberation of carbon (IV) oxide.**

**$CuCO_3(s) + heat \longrightarrow CuO(s) + CO_2(g)$**

**Other examples are:**

**$ZnCO_3(s) + heat \longrightarrow ZnO(s) + CO_2(g)$**

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

(b) Calcium trioxonitrate (V) salt decomposes on heating to form calcium oxide. Oxygen and brown fumes of nitrogen (IV) oxide are also given off.

2Ca(NO3)2(s) + heat ----> 2CaO(s) + 4NO2(g) + O2(g)

Other examples include:

2Pb(NO3)2(s) + heat ----> 2PbO(s) + 4NO2(g) + O2(g)

2Zn(NO3)2(s) + heat ----> 2ZnO(s) + 4NO2(g) + O2(g)

6. Double decomposition. Some insoluble hydroxides can be prepared through the process of double decomposition by reacting a soluble salt containing the metallic cation of the intended hydroxide with an alkali.

For instance, copper (II) hydroxide can be prepared by reacting copper (II) trioxonitrate (V) solution with sodium hydroxide.

Cu(NO3)2(aq) + 2NaOH(aq) ----> Cu(OH)2(s) + 2NaNO3(aq)

Uses of Bases

The following are some of the important uses of bases:

1. They are used for making soaps. E.g. NaOH, KOH
2. They are used in the manufacture of fertilizer. E.g. NaOH, liquid ammonia.
3. Calcium hydroxide is used for reducing the level of acidity in acidic soils, and for the production of cement, mortar and Plaster of Paris (POP) etc.
4. Magnesium hydroxide is used for making antacid (milk of magnesia), laxatives and toothpaste.
5. Liquid ammonia is used in laundries as a solvent for removing grease and oil stains.
6. They are used in the petroleum industry for the refining of some petroleum products. E.g. NaOH
7. They are used as dyes in tanning industry. E.g. KOH
8. Alkalis like KOH, NaOH and liquid ammonia are used in water treatment, and in qualitative analysis for the identification of some cations.

The alkali ammonia NH3 is a component in some oven cleaners and will react with fatty acids.

Citric acid is found in citrus fruits and is used as a food and drink flavouring, as is tartaric acid.

**Table salt, used in preserving food and sprinkling over your fish and chips as a flavouring etc. is the chemical sodium chloride NaCl.**

**Hydrochloric acid HCl and phosphoric acid H3PO4 are components of limescale removers.**

**Salts are used to produce the colours in fireworks e.g. sodium chloride a yellow flame, calcium chloride makes a red flame and copper chloride can produce green and blue effects.**

**Antacid indigestion tablets are mild alkalis that react by neutralising excess stomach acid which is the 'strong' hydrochloric acid which your delicate stomach lining and upper gut can only take so much of. The antacids must be weak bases i.e. mild alkalis or harmless insoluble bases like calcium carbonate or magnesium hydroxide which readily react with hydrochloric acid. However, strong alkalis are not to be recommended as a suitable medication for 'heartburn' afflictions, since they can be just as irritating as strong acids! See hazard warning signs further down the page and also "Investigation of Indigestion Tablets".**

**Bicarbonate or (sodium hydrogencarbonate NaHCO3, sodium bicarbonate, baking powder) can be used with sour milk (acidic) for raising action in baking. The acidic milk reacts with 'Bicarb' to form carbon dioxide gas giving the rising action. You can easily demonstrate this by adding any common laboratory acid to baking powder or any other carbonate!**

**Acidic bee stings (pH 5.0–5.5) can be soothed, i.e. neutralised by calomine lotion, which is a mild alkali and antiseptic and anti–itching agent based on zinc oxide. You can also use baking soda ('bicarb of soda' or sodium hydrogen carbonate), another mild alkali.**

**Wasp stings are supposed to be alkaline, but apparently not so! they are almost neutral at pH 6.8–6.9 but are 'traditionally' treated with vinegar which is a weak acid (and then perhaps you need the calomine too!). I've come across references on the web to say that wasp stings are not alkaline so 'English folklore' and mild–weak acid treatment has no real scientific basis. It should be pointed out that sting venom is a complex mixture, including many protein–enzymes, which, with other 'foreign' substances, might well trigger a response from the bodies immune system, so, in all honesty, I'm not quite sure what the truth is! However, what is known is that (i) bees and wasps have glands that can secrete either acids or alkalis with other substances and (ii) ants sting venom often contains methanoic acid ('formic acid') which can have a pH of 3 and is presumably 'soothed' by mild alkalis and just to confuse matters more, (iii) many people claim the 'folklore' remedies work! and maybe they do!**

**Ammonium salts, phosphate salts and magnesium/potassium sulfate salts are used in fertilisers for the garden.**

**Soluble aspirin is made by neutralising the acidic form of the medication with sodium hydroxide to make a soluble salt, or its made in situ with a bicarbonate 'fizzing' mixture.**

Acids and alkalis are useful in your body! Your stomach produces hydrochloric acid to help in digestion of proteins. Certain digestive enzymes only function properly in very acid conditions i.e. a low pH <2. Pancreatic fluids are alkaline to suit the conditions required by enzymes breaking down starches, fats and proteins. The hydrochloric acid in your stomach kills a large % of potentially harmful bacteria, minimising the risk of food poisoning and irritation of the gut system. However, as mentioned above, if you produce too much acid you get indigestion and need to take an antacid indigestion tablet to neutralise the excess. More body chemistry, preferably to be avoided!

The strong alkali sodium hydroxide $NaOH$ is used bleaches and other cleaning products.

The equally strong alkali potassium hydroxide $KOH$ is used in alkaline batteries.

In the chemical INDUSTRY

Alkalis like lime (calcium oxide, $CaO$) and limestone (calcium carbonate, $CaCO_3$) are used to reduce the acidity in soil, the neutralisation reaction produces the optimum pH for crops to grow.

Sodium hydroxide $NaOH$, one of the most commonly used alkalis, is used to neutralise aspirin making 'soluble aspirin'. Aspirin is an organic acid and not very soluble in water, but, its sodium salt is much more soluble and is absorbed faster by the body for more effective treatment.

Ammonia $NH_3$ gas is a weak alkali and neutralised by sulphuric acid or nitric acid to form ammonium sulphate or ammonium nitrate salts. These are important agri–chemical fertilisers supplying nitrogen to the soil for better plant growth. Of course some people prefer organic growing using good old muck and compost, but it doesn't involve neutralisation, but it does involve my wife, who is a member of the Soil Association! NPK fertilisers for agriculture contain potassium, ammonium and phosphate salts.

Neutralising harmful sulphur dioxide gas (acidic, irritating and toxic $SO_2$) in power station smoke from burning fossil fuels, by absorbing it in alkaline calcium hydroxide solution (limewater) to absorb it. Eventually harmless calcium sulphate solution is formed.

Acids can be used to clean corroded metal surfaces because of their reactivity to metals and metal oxides to form soluble salts which can be washed away to leave a cleaner metal surface. Concentrated acid solutions are used to remove limescale from the ceramic (unreactive) sides of toilets. Limescale is the build–up of a limestone like deposit in areas of hard water.

Alkalis are important chemicals in many industrial processes e.g.

**Heating natural oils and fats with strong alkalis like sodium hydroxide produces soaps.**

**Alkalis are used either directly, or to make other chemicals that bind natural dyes to cloth and other fabrics.**

**The alkali sodium carbonate is used in making glass.**

**In the past alkalis have been obtained from burnt wood, burnt seaweed and stale urine, but they are now may made on a huge bulk scale from industrial processes e.g. sodium chloride is manufactured from the electrolysis of brine (sodium chloride solution) and is then used to make many other products. Sodium carbonate is made from calcium carbonate (limestone) and common salt (sodium chloride) by the Solvay Process.**

**So all of this is still pretty important chemistry even for the 21st century, with strong links to agriculture, the environment and leading a stressful life!**

**Of course there are 'downsides' to some of this 'acidic' chemistry: Acid rain increases the rate of corrosion of stonework (particularly limestone) and metal structures. Acid rain makes water too acid for some aquatic organisms to live and this in turn affects food chains e.g. salmon do not like water with a pH below 4.5! Living on Venus could be hard going, its atmosphere is mainly sulphuric acid, mind you, you should be ok in a plastic suit because plastics don't usually react with acids, which is why, as well as being cheaper, plastics are replacing water pipes, drain pipes and gutters etc.**

**EVALUATION**

**1.(a) What is a base?**

**(b) What is a neutralization reaction?**

**(c) Aqueous solution of trioxonitrate (V) acid neutralizes a solution of sodium hydroxide. Write the ionic equation for this reaction.**

**(d) In what other way, can it be shown that potassium hydroxide is a base without using litmus or phenolphthalein paper?**

**2.Answer True (T) or False (F)**

**A base**

**(a) is a proton donor according to Brønsted and Lowry.**

**(b) produces hydroxide ions in water.**

**(c) accepts a pair of electrons based on Lewis Theory.**

**(d) is an electrolyte.**

**(e) does not have the ability to change the colour of an indicator.**

**(f) forms an aqueous solution with pH6.**

**(g) is neutralized by a salt.**

**(h) reacts with ammonium tetraoxosulphate (VI) to liberate ammonia when heated.**

**3.(a) Elaborate on the statement: "All alkalis are bases, but all bases are not alkalis".**

**(b) Using appropriate examples, state five methods of preparing bases in the laboratory.**

**(c) List four uses of bases**

4. **Drop the odd one out from $Cu(OH)_2$, $Al(OH)_3$, $Mg(OH)_2$ and $Zn(OH)_2$**
5. **$Cu(OH)_2$ b. Al(OH) c. $Mg(OH)_2$ d. $Zn(OH)_2$**

**5.Which of the following oxides is basic?**

1. **$NO_2$ B. $Al_2O_3$ C. $SO_2$ D. CaO**

**WEEK 4**

**SALTS**

**Salts are formed when acids reacts with bases .**

**Characteristics of salt:**

**a.Most of the salts are crystalline solid**

**b.Salts may be transparent or opaque**

**c.Most of the salts are soluble in water**

**d.Solution of salts conducts electricity. Salts conduct electricity in their molten state also**

**e.The salt may be salty, sour, sweet, bitter and umami (savoury)**

**f.Neutral salts are odourless**

**g.Salts can be colourless or coloured**

**Family of Salt:**

**Salts having common acidic or basic radicals are said to belong to same family.**

**Example: Sodium chloride ($NaCl$) and Calcium chloride ($CaCl_2$) belong to chloride family.**

**Calcium chloride ($CaCl_2$) and calcium sulphate ($CaSO_4$) belong to calcium family.**

**Zinc chloride ($ZnCl_2$) and Zinc sulphate ($ZnSO_4$) belong to zinc family.**

**Acidic, Basic and Neutral Salts**

**Neutral Salt: Salts produced because of reaction between strong acid and strong base are neutral in nature. The pH of value of such salts is equal to 7, i.e. neutral. Example; Sodium chloride, sodium sulphate, potassium chloride, etc.**

**Sodium chloride ($NaCl$) is formed after the reaction between hydrochloric acid (a strong acid) and sodium hydroxide (a strong base).**

**$NaOH + HCl \Rightarrow NaCl + H_2O$**

**Sodium sulphate ($Na_2SO_4$): It is formed after the reaction between sodium hydroxide (a strong base) and sulphuric acid (a strong acid).**

**$2NaOH + H_2SO_4 \Rightarrow Na_2SO_4 + 2H_2O$**

**Potassium chloride ($KCl$): It is formed after the reaction between potassium hydroxide (a strong base) and hydrochloric acid (a strong acid).**

**$KOH + HCl \Rightarrow KCl + H_2O$**

**Acidic salt:**

**Salts which are formed after the reaction between a strong acid and weak base are called acidic salt. The pH value of acidic salt is lower than 7. Example: ammonium sulphate, ammonium chloride, etc.**

**Ammonium chloride is formed after reaction between hydrochloric acid (a strong acid) and ammonium hydroxide (a weak base).**

**$NH_4OH + HCl \Rightarrow NH_4Cl + H_2O$**

**Ammonium sulphate is formed after reaction between ammonium hydroxide (weak base) and sulphuric acid (a strong acid).**

**$2NH_4OH + H_2SO_4 \Rightarrow (NH_4)_2SO_4 + 2H_2O$**

**Basic Salt: Salts which are formed after the reaction between weak acid and strong base are called basic salt. For example; sodium carbonate, sodium acetate, etc.**

**Sodium carbonate is formed after the reaction between sodium hydroxide (a strong base) and carbonic acid (a weak base).**

**$H_2CO_3 + 2NaOH \Rightarrow Na_2CO_3 + 2H_2O$**

**Sodium acetate is formed after the reaction between a strong base, sodium hydroxide and a weak acid, acetic acid.**

**$CH_3COOH + NaOH \Rightarrow CH_3COONa + H_2O$**

**Cause of formation of acidic, basic and neutral salt:**

**When a strong acid reacts with a weak base, the base is unable to fully neutralize the acid. Due to this an acidic salt is formed in this case.**

**When a strong base reacts with a weak acid, the acid is unable to fully neutralize the base. Due to this a basic salt is formed in this case.**

**When equally strong acid and base react they fully neutralize each other. Due to this a neutral salt is formed in this case.**

**pH value of salt:**

- **Neutral salt: The pH value of a neutral salt is almost equal to 7.**
- **Acidic salt: The pH value of an acidic salt is less than 7.**
- **Basic salt: The pH value of a basic salt is more than 7.**

**Common Salt (Sodium Chloride)**

**Sodium chloride (NaCl) is also known as common or table salt. It is formed after the reaction between sodium hydroxide and hydrochloric acid. It is a neutral salt. The pH value of sodium chloride is about 7. Sodium chloride is used to enhance the taste of food. Sodium chloride is used in manufacturing of many chemicals.**

**Important chemicals from sodium chloride:**

**Sodium Hydroxide (NaOH): Sodium hydroxide is a strong base. It is also known as caustic soda or Iye. It is obtained by the electrolytic decomposition of solution of sodium chloride (brine). In the process of electrolytic decomposition of brine (aqueous solution of sodium chloride), brine decomposes to form sodium hydroxide. In this process, chlorine is obtained at anode and hydrogen gas is obtained at cathode as byproducts. This whole process is known as Chlor-Alkali process.**

**$2NaCl + 2H_2O \Rightarrow 2NaOH + Cl_2 + H_2$**

**Use of products after the electrolysis of brine:**

**a.Hydrogen gas is used as fuel, margarine, in making of ammonia for fertilizer, etc.**

**b.Chlorine gas is used in water treatment, manufacturing of PVC, disinfectants, CFC, pesticides. It is also used in manufacturing of bleaching powder and hydrochloric acid.**

**c.Sodium hydroxide is used for de-greasing of metals, manufacturing of paper, soap, detergents, artificial fibres, bleach, etc.**

**Bleaching Powder ($CaOCl_2$ ):**

**Bleaching powder is also known as chloride of lime. It is a solid and yellowish white in colour. Bleaching powder can be easily identified by the strong smell of chlorine.**

**When calcium hydroxide (slaked lime) reacts with chlorine, it gives calcium oxychloride (bleaching powder) and water is formed.**

**$Ca(OH)_2 + Cl_2 \Rightarrow CaOCl_2 + H_2O$**

**Aqueous solution of bleaching powder is basic in nature. The term bleach means removal of colour. Bleaching powder is often used as bleaching agent. It works because of oxidation. Chlorine in the bleaching powder is responsible for bleaching effect.**

**Use of bleaching powder:**

- **Bleaching powder is used as disinfectant to clean water, moss remover, weed killers, etc.**

- **Bleaching powder is used for bleaching of cotton in textile industry, bleaching of wood pulp in paper industry.**
- **Bleaching powder is used as oxidizing agent in many industries, such as textiles industry, paper industry, etc.**

**Baking Soda ($NaHCO_3$ )**

**Baking soda is another important product which can be obtained using byproducts of chlor-alkali process. The chemical name of baking soda is sodium hydrogen carbonate ($NaHCO_3$ ) or sodium bicarbonate. Bread soda, cooking soda, bicarbonate of soda, sodium bicarb, bicarb of soda or simply bicarb, etc. are some other names of baking soda.**

**Baking soda is obtained by the reaction of brine with carbon dioxide and ammonia. This is known as Solvay process.**

**$NaCl + CO_2 + NH_3 + H_2O \Rightarrow NH_4Cl + NaHCO_3$**

**In this process, calcium carbonate is used as the source of $CO_2$ and the resultant calcium oxide is used to recover ammonia from ammonium chloride.**

**Properties of sodium bicarbonate:**

- **Sodium bicarbonate is white crystalline solid, but it appears as fine powder.**
- **Sodium hydrogen carbonate is amphoteric in nature.**
- **Sodium hydrogen carbonate is sparingly soluble in water.**
- **Thermal decomposition of sodium hydrogen carbonate (baking soda).**
- **When baking soda is heated, it decomposes into sodium carbonate, carbon dioxide and water.**

**$2NaHCO_3 + heat \Rightarrow Na_2CO_3 + CO_2 + H_2O$**

**Sodium carbonate formed after thermal decomposition of sodium hydrogen carbonate; decomposes into sodium oxide and carbon dioxide on further heating.**

**$Na_2CO_3 \Rightarrow Na_2O + CO_2$**

**This reaction is known as dehydration reaction.**

**Use of Baking Soda:**

- **Baking soda is used in making of baking powder, which is used in cooking as it produces carbon dioxide which makes the batter soft and spongy.**

- **Baking soda is used as antacid.**
- **Baking soda is used in toothpaste which makes the teeth white and plaque free.**
- **Baking soda is used in cleansing of ornaments made of sliver.**
- **Since, sodium hydrogen carbonate gives carbon dioxide and sodium oxide on strong heating, thus it is used as fire extinguisher.**

**Baking powder:**

**Baking powder produces carbon dioxide on heating, so it is used in cooking to make the batter spongy. Although baking soda also produces carbon dioxide on heating, but it is not used in cooking because on heating; baking soda produces sodium carbonate along with carbon dioxide. The sodium carbonate; thus produced; makes the taste bitter.**

**$2NaHCO_3$ + heat ⇨ $Na_2CO_3 + CO_2 + H_2O$**

**Baking powder is the mixture of baking soda and a mild edible acid. Generally, tartaric acid is mixed with baking soda to make baking powder.**

**$NaHCO_3 + C_4H_6O_6$ ⇨ $CO_2 + H_2O + Na_2C_4H_4O_6$**

**When baking powder (mixture of baking soda and an edible acid) is heated, the sodium carbonate formed because of heating of baking soda neutralizes after reacting with tartaric acid and sodium tartarate salt is formed. The smell of sodium tartarate is pleasant and taste is good. This makes the cake or any other food tasty.**

**Washing Soda (Sodium carbonate)**

**Sodium carbonate is manufactured by the thermal decomposition of sodium hydrogen carbonate obtained by Solvay process.**

**$NaCl + CO_2 + NH_3 + H_2O$ ⇨ $NH_4Cl + NaHCO_3$**

**$NaHCO_3 + C_4H_6O_6$ ⇨ $CO_2 + H_2O + Na_2C_4H_4O_6$**

**The sodium carbonate obtained in this process is dry. It is called soda ash or anhydrous sodium carbonate. Washing soda is obtained by rehydration of anhydrous sodium carbonate.**

**$Na_2CO_3 + 10H_2O$ ⇨ $Na_2CO_3.10H_2O$**

**Since there are 10 water molecules in washing soda, hence it is known as Sodium bicarbonate decahydrate.**

**Sodium carbonate is a crystalline solid and it is soluble in water when most of the carbonates are insoluble in water.**

**Use of sodium carbonate:**

- **It is used in cleaning of cloths; especially in rural areas.**
- **In making of detergent cake and powder.**
- **In removing permanent hardness of water.**
- **It is used in glass and paper industries.**

**Water of crystallization: Many salts contain water molecule and are known as hydrated salts. The water molecule present in salt is known as water of crystallization.**

**Examples:**

**Copper sulphate pentahydrate ($CuSO_4.5H_2O$):Blue colour of copper sulphate is due to presence of 5 molecules of water. When copper sulphate is heated, it loses water molecules and turns into grey-white colour, which is known as anhydrous copper sulphate. After adding water; anhydrous copper sulphate becomes blue again.**

**$CuSO_4.5H_2O$ + heat ⇨ $CuSO_4$**

**Ferrous Sulphate heptahydrate ($FeSO_4.7H_2O$): The green colour of Ferrous sulphate heptahydrate; commonly known as ferrous sulphate; is due to the presence of 7 molecules of water in it.**

**Plaster of Paris**

**Plaster of Paris is obtained by heating of gypsum, a hydrated salt of calcium.**

**$CaSO_4.2H_2O$ + Heat ⇨ $CaSO_4.(0.5)H_2O + (1.5)H_2O$**

**After addition of water Plaster of Paris is again converted into gypsum.**

**$CaSO_4.(0.5)H_2O + (1.5)H_2O$ ⇨ $CaSO_4.2H_2O$**

**Plaster of Paris is used in making of toys, designer false ceiling, etc. Doctors use Plaster of Paris to set the fractured bone.**

**Salt solubility affects the method you choose to make a salt, the table below will help you decide on the method**

**A solubility guide for salts and other compounds**

**Information required to decide on the method used to prepare a salt**

**salts and other compounds solubility?**

**common salts of sodium, potassium and ammonium ions usually soluble in water**

**common sulfates (sulphates) usually quite soluble except for calcium sulfate (slightly soluble), lead sulfate and barium sulfate are both insoluble**

**common chlorides (similar rule for bromides and iodides) usually soluble except for insoluble lead(II) chloride and silver chloride**

**common nitrates all soluble**

**common carbonates most metal carbonates are insoluble apart from sodium & potassium carbonate.  Ammonium carbonate is also soluble**

**common hydroxides most metal hydroxides are insoluble apart from soluble sodium, potassium and ammonium hydroxide**

**6a. A Method of Making a Water Soluble Salt**

**6a. METHOD (a) Neutralising a soluble acid with a soluble base (alkali) to give a soluble salt**

**One important point is to recognise that all the reactants are soluble here, which is why you need a titration procedure to work out how much of the acid is to be added to a given volume of alkali.**

**e.g. the hydroxide of an alkali metal like sodium hydroxide, potassium hydroxide or ammonia solution (wrongly called )ammonium hydroxide. Steps (1) to (3) below is called a titration.**

**Typical common soluble bases (alkalis) used for preparing soluble salts:**

**NaOH sodium hydroxide, KOH potassium hydroxide and some soluble carbonates**

**Typical examples shown by the word and symbol equations below include ...**

**sodium hydroxide + hydrochloric acid ==> sodium chloride + water**

**NaOH(aq) + HCl(aq) ==> NaCl(aq) + H2O(l)**

**sodium hydroxide + sulphuric acid ==> sodium sulphate + water**

**$2NaOH(aq) + H_2SO_4(aq) \Rightarrow Na_2SO_4(aq) + 2H_2O(l)$**

**potassium hydroxide + sulphuric acid ==> potassium sulphate + water**

**$2KOH(aq) + H_2SO_4(aq) \Rightarrow K_2SO_4(aq) + 2H_2O(l)$**

**sodium hydroxide + nitric acid ==> sodium nitrate + water**

**$NaOH(aq) + HNO_3(aq) \Rightarrow NaNO_3(aq) + 2H_2O(l)$**

**ammonia + nitric acid ==> ammonium nitrate**

**$NH_3(aq) + HNO_3(aq) \Rightarrow NH_4NO_3(aq)$**

**potassium hydroxide + hydrobromic acid ==> potassium bromide + water**

**$KOH(aq) + HBr(aq) \Rightarrow KBr(aq) + H_2O(l)$**

**sodium carbonate + hydrochloric acid ==> sodium chloride + water + carbon dioxide**

**$Na_2CO_3(s) + 2HCl(aq) \Rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$**

**METHOD (b) Procedure for making a soluble salt from an insoluble base, carbonate or metal**

**(1) The required volume of acid is measured out into the beaker with a measuring cylinder. The excess of insoluble metal, oxide, hydroxide or carbonate is weighed out (*) and the solid added in small portions to the acid in the beaker with stirring. Doing the weighing will minimise trial and error especially if the reaction is slow, as long as you know how to do the theoretical calculation and add on a little excess!**

**(*) You can avoid doing a calculation and weighing of the insoluble solid reactant by adding small quantities to the hot acid until no more apparently dissolves.**

(2) The mixture may be heated to speed up the reaction. When no more of the solid dissolves it means ALL the acid is neutralised and there should be a little excess solid. You should see a residue of the solid (oxide, hydroxide, carbonate) left at the bottom of the beaker. On filtration, only a solution of the salt is left.

(3) The hot solution (with care!) is filtered to remove the excess solid metal/oxide/carbonate, into an evaporating dish.

(4) You may need to carefully heat the solution to evaporate some of the water. Then hot solution is left to cool and crystallise. After crystallisation, you collect and dry the crystals with a filter paper.

Note (i) Apparatus used: (1) balance, measuring cylinder, beaker and glass stirring rod. (2) beaker/rod, bunsen burner, tripod and gauze; (3)-(4) filter funnel and filter paper, evaporating (crystallising) dish.

(ii) A measuring cylinder is adequate for measuring the acid volume, you do not need the accuracy of a pipette or burette required in method (a).

METHODS of MAKING SALTS - salt preparation procedures

Making a salt by direct combination of elements

Sometimes it isn't appropriate to prepare a soluble salt by reacting an acid with an insoluble base or alkali, so it may be possible to prepare the salt by directly combining the metal and the non-metal elements. Two such examples are the preparation of anhydrous aluminium chloride and anhydrous iron(III) chloride (anhydrous here means without any water of crystallisation).

Preparation of aluminium chloride $AlCl_3$

Preparation of iron(III) chloride $FeCl_3$

How can we make aluminium chloride? How do we prepare iron(III) chloride?

METHOD (d) both preparations illustrated above.

These compounds can be made by direct combination of the elements to form anhydrous salts e.g. if dry chlorine gas $Cl_2$ is passed over heated iron or aluminium, the chloride is produced. These experiment preparations (shown above) should be done very carefully by the teacher in a fume cupboard.

The aluminium can burn intensely with a violet flame, white fumes of aluminium chloride sublime from the hot reacted aluminium and the white solid forms on the cold surface of the flask.

aluminium + chlorine ==> aluminium chloride

$2Al(s) + 3Cl_2(g) \Longrightarrow 2AlCl_3(s)$

The aluminium chloride is often discoloured yellow from the trace chlorides of copper or iron that may be formed from traces of these metals that might be present in the original aluminum).

The iron (e.g. as steel wool) glows red and brown fumes of iron(III) chloride stream off, the brown solid collects on the cold flask surface.

iron + chlorine ==> iron(III) chloride

$2Fe(s) + 3Cl_2(g) \Longrightarrow 2FeCl_3(s)$

Note (i): Both these chlorides react exothermically and hydrolyse with water to give the metal hydroxide and fumes of hydrogen chloride, and so dry conditions are needed.

Note (ii): Both these chlorides cannot be made in an anhydrous form from aqueous solution neutralisation. This is because on evaporation the compounds contain 'water of crystallisation'. On heating the hydrated salt hydrolyses and decomposes into water, the oxide or hydroxide and fumes of hydrogen chloride, and maybe some impure anhydrous chloride, basically it a mess in terms of trying to make pure $AlCl_3$ and $FeCl_3$ in this way.

## Efflorescences

The property by which certain hydrous crystals lose their water of crystallisation, completely or partially, when exposed to air and crumble into a powder is called efflorescence. Some examples are given below.

Such substances are termed as efflorescent substances.

## Deliquescence

Certain hygroscopic substances, not only absorb moisture from the air, but they themselves dissolve in that moisture, undergoing a change of state. Such substances are called deliquescent substances. The process is called deliquescence.

some Deliquescent substances

Anhydrous calcium chloride $CaCl_2$ Ferric chloride Fecl3

Magnesium chloride $MgCl_2$ Calcium nitrate $Ca(NO_3)_2$

Solid sodium hydroxide $NaOH$ Copper nitrate $Cu(NO_3)_2$

Solid potassium hydroxide $KOH$ Zinc nitrate $Zn(NO_3)_2$

## Hygroscopic

Hygroscopic substances are those substances that absorb water vapour from the air. The process is called Hygroscopicity.

Some Hygroscopic Substances

Concentrated sulphuric acid $H_2SO_4$ Magnesium chloride $MgCl_2$

Anhydrous calcium chloride $CaCl_2$ Ferric Chloride $FeCl_3$

Calcium oxide $CaO$ Phosphorus pentoxide $P_4O_{10}$

Solid Sodium hydroxide $NaOH$ Calcium nitrate $Ca(NO_3)_2$

Solid potassium hydroxide $KOH$ Copper nitrate $Cu(NO_3)_2$

## Hydrolysis of salts

Dissolution of different salts in water does not always result in neutral solutions. For example, aqueous solution of copper sulphate is acidic whereas aqueous solution of sodium acetate is basic and aqueous solution of sodium chloride forms neutral solution. This is due to the dissociation of the salt in water to form ions. This process of the reaction of anion or cation of the salt with water to produce an acidic or an alkaline solution is called hydrolysis. Thus, hydrolysis is reverse of neutralization.

**Colours of salts**

**RECOVERING SALT FROM SOLUTION**

**It is, in many cases, important when recovering salt from salt solutions to obtain the salts in the form of large crystals. Such a case is for example the recovery of sulphate of ammonia from ammonium sulphate solutions, the am- 'monium sulphate salt being intended to serve as fertilizer. It is well-known, that ammonium sulphate in fine crystals is liable to form into lumps and same can only be spread over the fields in a very poor manner. On the other hand, sulphate of ammonia consisting of large crystals, remains always loose and can be readily spread even by hand, without any previous grinding being necessary. Salt in large crystals offers the further advantage when used as a fertilizer in as much as the large grains of the salt are not so easily carried oil? by the wind as is the case of salt in fine crystals.**

1. **The process of recovering large crystals of solid salts from salt solutions, comprising evaporating the salt solution to be treated in such way that crystals are separated out of the salt solution, collecting the crystals separated out of solution in a heap in the fluid undergoing evaporazone the salt crystals removed from the fluid of 40 the evaporation stage with a liquid to swim off therefrom the smaller crystals from the larger crystals, separating out from the larger crystals in the swimming stage the larger part of the swim liquid together with the small crystals swimming in the same from the larger crystals left in the swimming stage, and finally recovering the larger crystals from the swimming stage.**

**EVALUATION**

1. **Explain each of the following with examples.**
2. **Acid salt ii. Basic salt iii. Double salt iv. Normal salt**
3. **Show how each of them can be prepared using chemical equations only.**
4. **Which of these is not a Hygroscopic salt?**
5. **Calcium Oxide b. Magnesium chloride c. Copper(ii)oxide d. Sodium trioxonitrate(v).**

WEEK 5

## pH – Measurement of strength of Acid and Base

The strength of acid or base depends upon the hydrogen ion concentration. If the concentration of hydrogen ion is greater than hydroxide ion, the solution is called acidic. If the concentration of hydrogen ion is smaller than the hydroxide ion, the solution is called basic. If the concentration of hydrogen ion is equal to the concentration of hydroxide ion, the solution is called neutral solution.

### Ph and ph scale

In 1909, Sorensen introduced a term for expressing the concentration of hydrogen ions, which give an idea about the acidic and basic characters of the aqueous solution. This term was called 'pH' which means the 'power of hydrogen ions'..

In pH scale ‘p’ stands for ‘potenz’. Potenz is a German word which means ‘power’ or ‘potential’. Here; ‘H’ stands for hydrogen ion. Thus, pH means the potential of hydrogen or power of hydrogen.

pH is defined as the decimal logarithm of the reciprocal of the hydrogen ion activity (a(H+ )), in a solution.

For neutral solution at 298 K,

$[H_3O^+]$ = $[OH^-]$ = 1.0 x 10-7 mol L-1

so that, pH = -log $[H_3O^+]$ = -log (1.0 x 10-7) = 7

Substituting different values for $[H_3O^+]$ in the above relation we have,

For acidic solution pH <>

For basic solution pH > 7

For neutral solution pH = 7

A scale called as the pH scale is devised to express the acidic and basic properties of solution in terms of the pH value.

Fig: 8.1 - The pH scale

From the scale it is clear that for solutions with

pH between 0 to 2 strongly acidic

pH between 2 to 4 moderately acidic

pH between 4 to 7 weakly acidic

pH between 7 to 10 weakly basic

pH between 10 to 12 moderately basic

pH between 12 to 14 strongly basic.

## Calculating pH

To calculate the pH of an aqueous solution you need to know the concentration of the hydronium ion in moles per liter (molarity). The pH is then calculated using the expression:

pH = - log [H3O+].

Example: Find the pH of a 0.0025 M HCl solution. The HCl is a strong acid and is 100% ionized in water. The hydronium ion concentration is 0.0025 M. Thus:

pH = - log (0.0025) = - ( - 2.60) = 2.60

## Calculating the Hydronium Ion Concentration from pH

The hydronium ion concentration can be found from the pH by the reverse of the mathematical operation employed to find the pH.

[H3O+] = 10-pH or [H3O+] = antilog (- pH)

Example: What is the hydronium ion concentration in a solution that has a pH of 8.34?

8.34 = - log [H3O+]

- 8.34 = log [H3O+]

[H3O+] = 10-8.34 = 4.57 x 10-9 M

On a calculator, calculate 10-8.34, or "inverse" log ( - 8.34).

## Calculating pOH

To calculate the pOH of a solution you need to know the concentration of the hydroxide ion in moles per liter (molarity). The pOH is then calculated using the expression:

pOH =  - log [OH-]

Example:  What is the pOH of a solution that has a hydroxide ion concentration of 4.82 x 10-5 M?

pOH = - log [4.82 x 10-5] = - ( - 4.32) = 4.32

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## Calculating the Hydroxide Ion Concentration from pOH

The hydroxide ion concentration can be found from the pOH by the reverse mathematical operation employed to find the pOH.

[OH-] = 10-pOH   or   [OH-] = antilog ( - pOH)

Example:  What is the hydroxide ion concentration in a solution that has a pOH of 5.70?

5.70 = - log [OH-]

-5.70 = log[OH-]

[OH-] = 10-5.70 = 2.00 x 10-6 M

On a calculator calculate 10-5.70, or "inverse" log (- 5.70).

## Relationship Between pH and pOH

The pH and pOH of a water solution at 25oC are related by the following equation.

pH + pOH = 14

If either the pH or the pOH of a solution is known, the other can be quickly calculated.

Example:  A solution has a pOH of 11.76.  What is the pH of this solution?

pH =  14  -  pOH = 14  -  11.76 =  2.24

**Indicator:**

**Substances which show the acidic or basic behavior of other substance by change in colour are known as indicator.**

**Type of Indicator: There are many types of indicators. Some common types of indicators are**

**1.Natural**

**2.Olfactory Indicator**

**3.Synthetic Indicator**

**4.Universal Indicator**

**Natural Indicator: Indicators obtained from natural sources are called natural indicators. Litmus, turmeric, red cabbage, China rose, etc. are some common natural indicators used widely to show the acidic or basic character of substances.**

**Litmus: Litmus is obtained from lichens. The solution of litmus is purple in colour. Litmus paper comes in two colour – blue and red.**

- **An acid turns blue litmus paper red.**
- **A base turns red litmus paper blue.**

**Turmeric: Turmeric is another natural indicator. Turmeric is yellow in colour. Turmeric solution or paper turns reddish brown with base. Turmeric does not change colour with acid.**

**Red cabbage: The juice of red cabbage is originally purple in colour. Juice of red cabbage turns reddish with acid and turns greenish with base.**

**Olfactory Indicators: Substances which change their smell when mixed with acid or base are known as olfactory indicators. For example onion, vanilla, clove, etc.**

**Onion: Paste or juice of onion loses its smell when added with base. It does not change its smell with acid.**

**Vanilla: The smell of vanilla vanishes with base, but it’s smell does not vanishes with an acid.**

Olfactory indicators are used to ensure the participation of visually impaired students in laboratory.

Synthetic Indicator: Indicators that are synthesized in laboratory are known as synthetic indicators. For example; phenolphthalein, methyl orange, etc.

Phenolphthalein is a colourless liquid. It remains colourless with acid but turns into pink with a base.

Methyl orange is originally orange in colour. It turns into red with acid and turns into yellow with base.

Indicator Original colour Acid Base

Red litmus Red No change Blue

Blue litmus Blue Red No change

Turmeric Yellow No change Reddish brown

Red cabbage juice Purple Reddish Greenish yellow

Phenolphthalein Colourless Colourless Pink

Methyl orange Orange Red Yellow

Onion n/a No change Smell vanishes

Vanilla n/a No change Smell vanishes

Universal Indicator:

Using a litmus paper, phelophthalein, methyl orange, etc. only the acidic or basic character of a solution can be determined, but use of these indicators does not give the idea about the strength of acid or base. So, to get the strength as well as acidic and basic nature of a given solution universal indicator is used.

Universal indicator shows different colour over the range of pH value from 1 to 14 for a given solution. Universal indicator is available both in the form of strips and solution. Universal indicator is the combination of many indicators, such as water, propanol, phelophthalein, sodium salt, sodium hydroxide, methyl red, bromothymol blue monosodium salt, and thymol blue monosodium salt. The colour matching chart is supplied with universal indicator which shows the different colours for different values of pH.

**EVALUATION**

**1.The ph values of three solutions are 4.0,9.0,and 13.5.Predict the colours that these indicators would attain for the different solutions of methyl orange,Litmus,phenolphthalein.**

2. **Calculate the pH value of (i) 0.001 M HCl and (ii) 0.01 M NaOH**
3. **Calculate the pH of a solution whose hydronium ion concentration is 6.2 x 10-9 mol L-1.**
4. **Acid A, B, C and D have the following pKa values: A = 1.5, B = 3.5, C = 2.0, D = 5.0. Arrange these acids in the increasing order of acid strength.**
5. **The value of Kw is 9.55 x 10-14 at a certain temperature. Calculate the pH of water at this temperature.**
6. **What is the pH of a solution whose hydrogen ion concentration is 0.005 x 10-3 kg dm-3?**
7. **The pH of blood is maintained at 7.4 due to the presence of HCO-3 and H2CO3. If Ka of H2CO3 in blood is 8 x 10-7 calculate the ratio [HCO-3]:[H2CO3] in blood.**

**Solution**

**(2) Since HCl is a strong acid, it completely ionizes and therefore, H3O+ ions concentration is equal to that of the acid itself i.e.,**

**[H3O+] = [HCl] = 0.001 M = 1 x 10-3 M**

**now, pH = -log [H3O+]**

**pH = -log [1 x 10-3]**

**= -(-3) log 10 = 3 (log 10 =1)**

**(3) Since NaOH is a strong base, it completely ionizes and therefore, OH- ions concentration is equal to that of the base itself i.e.,**

**[OH-] = [NaOH] = 0.01 M = 1 x 10-2 M**

**Kw = [H3O+] [OH-]**

**pH = -log [H3O+]**

**pH = -log [1 x 10-12]**

**= -(-12) log 10 = 12**

**4.We know that,**

**pKa = -log Ka or Ka = 10-pKa**

**Therefore, for the given acids,**

**Ka (A) = 10-1.5 Ka (B) = 10-3.5**

**Ka (C) = 10-2.0 Ka (D) = 10-5.0**

**Since, 10-5.0<>-3.5<>-2.0<>-1.5**

**Hence, the strength of acids follows the order, D <>**

**5.Kw = 9.55 x 10-14**

**For water [H3O+] = [OH-]**

**If, Kw = [H3O+] [OH-] = 9.55 x 10-14 then,**

**[H3O+] [H3O+] = 9.55 x 10-14**

**[H3O+]2 = 9.55 x 10-14**

**pH = -log [H3O+]**

**pH = -log [3.09 x 10-7]**

**= -(log 3.09 + log 10-7)**

**= -(0.49 - 7) = 6.51**

**6.In the solution [H+] = 0.005 x 10-3 kg dm-3 = 0.005 x 10-3x 103Lm-3**

**= 0.005 g dm-3 = 0.005 mol dm-3**

**7.pH = 7.4= -log[H+]**

**log[H+]= -7.4 = 8.6 [H+]= 3.98 x 10-84 x 10-8 M**

**.**

**EVALUATION**

**1.A solution has a pOH of 11.76. What is the pH of this solution.**

2. **2.24 b.1.32 c .3.43 d.5.6**
3. **An hydroxonium ion is**
4. **H3O B. H3O+ C. H3O- D.2[H+OH]**
5. **pH of a 0.001m acid is**
6. **2 b. 4 c.3 d.1**
7. **A solution whose pH cannot be altered due to accidental addition of acid or base is called**
8. **plasma b. annotated solution c. buffer solution d. deionized solution**
9. **Sodium Hydroxide is added drop by drop to some hydrochloric acid in a beaker. Which of the following occurs in the beaker?**
10. **The PH of the solution decreases.**
11. **The concentration of hydrogen ions increases.**
12. **The concentration of hydroxide ions increases.**
13. **The solution turns pink**

14. **Sodium Chloride Crystals forms**

**WEEK 6**

**ALLOTROPES OF CARBON**

**Carbon forms the largest number of compounds, next only to hydrogen. It ranks seventeenth in the order of abundance in the earth's crust. Carbon occurs in the free native state as well as in the combined state. Carbon and its compounds are widely distributed in nature.**

**In its elemental form, carbon occurs in nature as diamond and graphite. Coal, charcoal and coke are impure forms of carbon. The latter two are obtained by heating wood and coal in the absence of air, respectively. In the combined state, carbon is present as carbonate in many minerals, such as hydrocarbons in natural gas, petroleum etc. In air, carbon dioxide is present in small quantities, (0.03%).**

**Our food also contains carbon in the combined form. All living systems contain carbon compounds. Indeed, life as we know today, would be impossible without such carbon compounds.**

**Carbon is a non-metallic element and the first member of group 14 of the periodic table**

**Symbol: C, Electronic configuration1s2, 2s22p2, Melting point = 800K**

**Atomic mass: 12.01amu, Atomic radius 77pm, Atomic number: 6**

**ALLOTROPES OF CARBON.**

**Allotropy:**

**Allotropy is the property of an element to exist in more than one physical forms having similar chemical properties but different physical properties.**

**Carbon exists both in crystalline and amorphous allotropic forms.**

**Crystalline allotropes of carbon:**

**Diamond**

**Graphite**

**Fullerene**

**Amorphous  allotropes of carbon:**

**Coal**

**Coke**

**Charcoal**

**Lampblack**

**Gas carbon**

**Coke**

**Diamond**

**Diamonds are chiefly found in the Union of South Africa, the Belgian Congo, Brazil, British Guiana, India etc.**

**Diamond was discovered for the first time in India. The famous 'Kohinoor diamond' (186 -carat) and the 'Regent or Pitt' (studded in Napoleon's state sword, 136.2 carat) were found near Kistna river in South India.**

**The 'Cullinan diamond', the largest ever found weighed 3025.75 carat (about 600 g) was mined in South Africa in 1905.**

**Diamonds occur in the form of transparent octahedral crystals usually having curved surfaces and do not shine much in their natural form. To give them their usual brilliant shine they are cut at a proper angle so as to give rise to large total internal reflections.**

**Moissan (1893) prepared the first artificial diamond by heating pure sugar charcoal and iron in a graphite crucible to a temperature of about 3000°C in an electric arc furnace.**

**Graphite**

**Graphite is found widely distributed in nature, viz., in Siberia, Sri Lanka, USA, Canada.**

**Large quantities of graphite are also manufactured from coke or anthracite in electric furnaces.**

**Diamonds and graphite are two crystalline allotropes of carbon. Diamond and graphite both are covalent crystals. But, they differ considerably in their properties.**

**Comparison of the properties of diamond and graphite**

**These differences in the properties of diamond and graphite are due to the differences in their structures.**

**Structure of diamond**

**In diamond, the carbon atoms are arranged tetrahedrally (sp3 hybridisation of C): each C atom is linked to its neighbors by four single covalent bonds. This leads to a three-dimensional network of covalent bond.**

**It is due to this, that diamond is very hard, and has high melting andboiling points. In diamond, each carbon atom is bonded to the other through regular covalent bonds. The electrons thus are held tightly between the nuclei, and there are no mobile electron to conduct electricity i.e. all the valence electrons of carbon are used up in forming the covalent bonds. Hence diamond does not conduct electricity. Diamond is also denser than graphite (density: Diamond = 3.52 g cm-3 Graphite =2.25 g cm-3 ) as the Diamond structure is a closely packed structure, while the layer-to-layer large distance makes graphite to have an open structure.**

**Diamond are not attacked by acids, bases and other reagents but it can reacts with fluorine to form carbon tetrafluoride at about 1023 K temperature.**

**$C + 2F_2 \rightarrow CF_4$**

**Diamond burns in air at about 1173 K to produce carbon dioxide gas.**

**In diamond carbon atoms are in tetrahedral arrangement.**

**Structure of graphite**

**In graphite, the carbon atoms are arranged in flat parallel layers as regular hexagons. Each layer is bonded to adjacent layers by weak Van der Waals forces. This allows each layer to slide over the other easily. Due to this type of structure graphite is soft and slippery, and can act as a lubricant. Graphite is also a good conductor of electricity. In graphite, carbon atoms in each layer are bonded to three other carbon atoms by special covalent bonds. This gives some double-bond character to the C-C bonds. This gives it the presence of delocalized p-electron system. These mobile electrons explain the electrical conductivity of graphite.**

**Uses of diamond**

- **The unusual brilliant shine of diamond makes it an invaluable precious stone in jewellery.**
- **Making high precision cutting tools for use in medical field.**
- **Because of it's hardness it is used in manufacturing tools/cutting drills for cutting glass and rock.**
- **In making dyes for drawing very thin wires of harder metals. Tungsten wires of thickness 1/6th that of human hair, can be drawn using diamond dyes.**
- **Graphite is used as a moderator in nuclear reactor.**

**Uses of graphite**

- **As a lubricant at higher temperatures.**
- **As a refractory material of making crucibles and electrodes for high temperature work.**
- **In electrotyping and in the manufacture of gramophone records: Graphite is used for making the non-conducting (generally wax) surface, so that electroplating can be done.**
- **For manufacturing lead pencils and stove paints.**

**Amorphous Forms of Carbon**

**Coal is formed in nature by the 'carbonisation' of wood. Conversion of wood to coal under the influence of high temperature, high pressure, and in the absence of air is termed carbonisation.**

**Amongst coal varieties, anthracite is the purest form. It contains about 94 - 95% of carbon. The common variety of coal is bituminous coal; it is black, hard and burns with smoky flame.**

**Uses**

**Coal is mainly used,**

- **As an industrial fuel in steel, power generation plants etc. It is also a domestic fuel to a limited extent.**
- **For manufacture of producer gas and water gas, which are used as fuel gases.**
- **For manufacturing coal tar, coke and coal gas.**
- **Anthracite coal is used for preparing graphite.**
- **For the manufacture of synthetic petrol by catalytic hydrogenation of coal.**

**Wood charcoal**

**When wood is heated strongly in a very limited supply of air, wood charcoal is obtained. This is called destructive distillation of wood. The volatile products are allowed to escape.**

**Charcoal is a black, porous and brittle solid. It is a good adsorbent. Charcoal powder adsorbs coloring matter from solutions and poisonous gases from the air. Charcoal is also a good reducing agent.**

**Uses**

- **As a fuel.**
- **As a deodorant and in gas masks to filter pollution.**
- **As a discoloring agent for decolorizing oils, etc.**
- **In making gun powder.**

**Animal Charcoal**

**Animal charcoal (or Bone charcoal) is obtained by destructive distillation of bones. It contains about 10-12% of amorphous carbon.**

**Sugar Charcoal**

**It is obtained by heating sugar in the absence of air. Sugar charcoal is the purest form of amorphous carbon.**

**Sugar charcoal becomes activated charcoal when it is powdered to particle size of about 5 Âµ and heated at about 1000 K in vacuum. Activated charcoal has an increased adsorption capacity.**

**Lamp Black**

**Lamp black is manufactured when tar and vegetable oils (rich in carbon) are burnt in an insufficient supply of air and the resulting soot is deposited on wet blankets hung in a room. Lamp black is a velvety black powder. It is used in the manufacture of India ink, printer's ink, black paint and varnishes and carbon papers.**

**CarbonBlack**

**When natural gas is burned in limited supply of air, the resulting soot is deposited on the underside of a revolving disc. This is carbon black and it is then scraped off and filled in bags. It differs from lamp black in being not so greasy. Carbon black is added to the rubber mix used for making automobile tyres, and has replaced the use of lampblack for a number of purposes.**

**GasCarbonandPetroleumcoke**

Carbon scraped that is from the walls of the retort used for the destructive distillation of coal in called gas carbon. During refining of crude petroleum, petroleum coke is deposited on the walls of the distillation tower.

Both, gas carbon and petroleum coke are used for making electrodes in dry cells and are good conductors of electricity.

## Fullerenes

Fullerenes are allotropes of carbon that were discovered as recently as 1985. They have been found to exist in the interstellar dust as well as in geological formations on earth. They are large cage like spherical molecules with formulae C32, C50 C60, C70, C76, C84 etc. The most commonly known fullerene is C60 which is named as 'buckminster fullerene after the designer of the geodesic dome, American architect Buckminister.

C60 molecule has marvelously symmetrical structure. It is a fused-ring of aromatic system containing 20 hexagons and 12 pentagons of C atoms. The structure bends around and closes to form a soccer ball shaped molecule. It is therefore, called buckyball also. Fullerene looks different from diamond and graphite. It is a yellow powdery substance, which turns pink on dissolution in solvents like toluene. It polymerizes on exposure to U.V. radiations.

Fullerenes are fascinating because they show unusual characteristics and applications like:

- They are wonderful lubricants because the balls can roll between the surfaces.
- Alkali compounds of C60 (A3C60) are super conducting materials even at high temperatures of the order of 10-40 K.

## Destructive Distillation of Coal

When coal is heated without air, it does not burn but produces many by-products. This process of heating coal in the absence of air is called destructive distillation of coal.

The main by products are:

- coke
- coal tar
- amino acid liquor

- **coal gas**

**The destructive distillation of coal can be carried out in the laboratory. The apparatus is set up as shown in the below figure.**

**Destructive Distillation of Coal**

**Finely powdered coal taken in a test tube is heated. As the coal breaks down coke, coal tar, ammonia and coal gas are produced. Coal tar collects at the bottom of the second test tube and coal gas escapes out through the side tube. The ammonia produced is absorbed in the water forming ammoniacal liquor (ammonium hydroxide). The black residue left in the 1st tube is called coke.**

**Coke is a fuel in its own right which can be used in homes and factories. But it is largely used as a reducing agent in the extraction of metals from their ores. It is also used in making fuel gases like water gas which is a mixture of carbon monoxide and hydrogen.**

**Another by product namely coal tar which is a mixture of different carbon compounds can be used to make soap, fats, dyes plastics perfumes, drugs, pesticides, explosives etc.**

**The other by product, ammonia is used for making fertilizers such as ammonium sulphate, ammonium superphosphate etc.**

**The coal gas, also called as a town gas is a mixture of hydrogen, methane and carbon monoxide which are combustible making the coal gas an excellent fuel having high calorific values.**

**EVALUATION**

**1.Explain why graphite is a good conductor of electricity while diamond is not,although both are true allotropes of carbon. Compare the other properties of graphite and diamond.**

**2.Write short notes on the preparations and uses of**

1. **Charcoal ii Coke iii. lamp-black iv. Animal charcoal.**

**3.When graphite is subjected to a very high temperature and pressure for several hours in the presence of catalysts nickel, the product is a. soot b. quartz**

1. **artificial diamond d. graphite flakes.**

**4..Acheson process is a process of producing**

1. **graphite from coke at high temperature b. producing coke using graphite at high temperature c. anthracite from carbon d. wood-charcoal from coal.**

**WEEK 7**

**OXIDES OF CARBON**

**Carbon Monoxide**

**The various names of Carbon Monoxide (CO) are carbonous oxide, carbon (II) oxide, carbonyl etc. It is an odorless, colorless gas which is less dense than air.**

**The higher concentration of carbon monoxide can be toxic to humans and animals due to the great combining affinity of carbon monoxide with hemoglobin. It is a short lived and spatially variable gas in atmosphere which can be easily combined with oxygen to form carbon dioxide and ozone.**

**Carbon monoxide is a flammable and highly toxic gas. It is a neutral oxide of carbon element and burns in air to give carbon dioxide. For several chemical reaction, it acts as a good reducing agent. For example, to reduce cupric oxide to copper metal and to convert carbon dioxide to C and O2.**

**$CuO + CO \rightarrow Cu + CO_2$**

**It is also an important industrial gas and widely used as a fuel and as an important reducing agent in the chemical industry.**

**Laboratory preparation, properties and uses of carbon monoxides**

**Carbon monoxide was first prepared in the laboratory in 1776 by J.M.F. de Lassone, a French chemist. As carbon monoxide is extremely poisonous, its preparation should be carried out only in a fume chamber. Under no circumstances must the gas be inhaled or smelled.**

**Preparation of carbon monoxide by dehydrating oxalic acid with hot concentrated sulphuric acid**

**Experiment 1**

**Carbon monoxide is prepared with the help of oxalic acid and concentrated sulphuric acid as shown in figure 11.2.**

**Oxalic acid has the formula . Sulphuric acid reacts with oxalic acid and removes from it one molecule of water (both the hydrogen atoms, along with an oxygen atom). The product left behind due to this reaction, is a molecule of carbon dioxide and a molecule of carbon monoxide. The carbon dioxide can be removed by passing it through a concentrated solution of potassium hydroxide.**

**Preparation of carbon monoxide by dehydrating formic acid**

**Experiment 2**

**Formic acid has the formula HCOOH. Formic acid can also be dehydrated in a similar way by hot concentrated sulphuric acid. Sulphuric acid removes two atoms of hydrogen and one atom of oxygen as a molecule of water from it, and leaves behind one molecule of carbon monoxide (Fig.11.3).**

**Physical properties of carbon monoxide**

1. **a) Nature**

**Carbon monoxide is colorless, almost odorless and tasteless gas.**

1. **b) Density**

**It is very slightly lighter than air.**

**Vapor Density=14 [Vapor density of air =14.4].**

1. **c) Solubility**

**Carbon monoxide is only very slightly soluble in water.100 volumes of water can dissolve only 3.5 volumes of the gas at S.T.P**

1. **d) Poisonous nature**

**This is a highly poisonous gas. Air containing even less than 1% of carbon monoxide, can be fatal, if breathed in for about 10 to 15 minutes.**

**Chemical properties of carbon monoxide**

1. **a) Nature**

**Carbon monoxide is a neutral oxide. It is neither acidic nor basic.**

1. **b) Stability**

**It is very stable and cannot be decomposed by heat.**

1. **c) Combustibility**

**It is a combustible gas. It burns well in air or oxygen to form carbon dioxide. The formation of carbon dioxide is tested by passing it through a solution of lime water. (Fig.11.4).**

**This is a highly exothermic reaction. Hence it is a very good fuel.**

**However, it is not a supporter of combustion,**

**d)**

**Combination with chlorine**

**Carbon monoxide combines with chlorine in presence of sunlight and charcoal as catalyst, to form carbonyl chloride, commonly called as phosgene.**

1. **e) Combination with sodium hydroxide**

**Carbon monoxide when heated under a pressure of six atmosphere, combines with sodium hydroxide and flakes to form sodium formate.**

1. **f) Reducing property**

**Carbon monoxide is a powerful reducing agent.**

**Experiment 3**

**When CO is passed over heated metallic oxides, it takes away the oxygen to form carbon dioxide and reduces the oxides to their respective metals (Fig.11.5).**

1. **g) As a synthetic reagent**

**Carbon monoxide acts as the staring material for the synthesis of many important organic substances. For e.g., the synthesis of methyl alcohol, or methanol, (CH3OH) takes place by the reaction of carbon monoxide and hydrogen.**

1. **h) Combination with metals**

**When carbon monoxide is passed over heated metals under pressure, metal carbonyls are formed.**

1. **i) Combination with cuprous chloride**

**Carbon monoxide is absorbed by ammonical cuprous chloride to form an addition compound.**

**Uses of carbonmonoxide**

1. **Carbon monoxide is used as a fuel by itself, or in the form of producer gas (mixture of carbon monoxide and nitrogen), or water gas (mixture of carbon monoxide and hydrogen). It is also present in fuel gases like coal gas.**
2. **It is used as a reducing agent in the extraction of metals. Carbon monoxide reduces the metal oxides to metals. Usually coke is used to generate this gas. In this process coke combines with oxygen to form carbon dioxide, which gets reduced to carbon monoxide due to the lack of oxygen.**
3. **Carbon monoxide is used in the manufacture of methyl alcohol, sodium formate, phosgene, etc.**

**Effects of Carbon Monoxide**

**The main product of complete combustion of any organic compound is carbon dioxide and water. However the incomplete combustion of organic compounds in the limited amount of oxygen yields carbon monoxide.**

**Once the gas is inhaled, it becomes very harmful. Since carbon monoxide is easily absorbed through the lungs, it's easy for gas to circulate in body. Carbon monoxide has more binding affinity with hemoglobin compared to oxygen.**

**Hence, it can easily replace oxygen and can bound with hemoglobin. In the deficiency of oxygen, tissue becomes starved for it.**

**Due to high binding affinity of carbon monoxide, it forms carboxyheamoglobin (HbCO) which starved oxygen supplies in cell.**

**Exposure to carbon monoxide is most commonly accompanied by the following symptoms.**

- **Headache, dizziness, nausea, shortness of breath on exertion, impaired judgment, chest pain and depressionetc.**
- **The low supply of oxygen to the blood leads to hypoxia myoglobin and mitochondrial cytochrome oxidase are thought to be adversely affected.**
- **For the treatment of poisoning due to carbon monoxide, oxygen acts as the best medicine. Supply of oxygen provides hyperbaric oxygen therapy.**
- **Oxygen acts as an antidote because the high concentration of oxygen forces to remove carbon monoxide from hemoglobin and turn the body with normal levels of oxygen.**
- **Domestic carbon monoxide can be detected by using carbon monoxide detectors.**

**CARBON (IV)OXIDE**

**Carbon dioxide occurs in free state in the atmosphere, and accounts for 0.03 to 0.04 % of its total volume. It is also found in mines and caves in the form of minerals, such as limestone, magnesite and dolomite.**

**Carbon dioxide is released into the atmosphere during respiration by living organisms, combustion of fuels, and fermentation.**

**Preparation of Carbon dioxide**

**In the laboratory, carbon dioxide is prepared by the action of calcium carbonate with dilute hydrochloric acid.**

**$CaCO_3$ + dil $2HCl$ → $CaCl_2$ + $CO_2$↑ + $H_2$↑**

**Test for carbon dioxide**

**The presence of carbon dioxide can be tested by bringing a burning splinter near the mouth of the cylinder containing carbon dioxide – it gets extinguished.**

**If carbon dioxide is passed through limewater, it turns milky white.**

**Methods of preparation of Carbon dioxide**

**The combustion of carbon or methane produce carbon dioxide**

**$C + O_2$ → $CO_2$ + Heat**

**$CH_4 + 2O_2$ → $CO_2 + 2H_2O$**

**The decomposition of carbonate salts like calcium carbonate or magnesium carbonate produces carbon dioxide.**

**When metallic carbonates or metallic bicarbonates react with sulphuric acid, they form carbon dioxide.**

**Carbon dioxide is also formed in the process of fermentation as a by product.**

**Physical properties**

- **Colourless and odourless gas with a sour taste.**
- **Slightly soluble in water.**
- **Heavier than air.**
- **Solidifies at room temperature and 70 atmospheres pressure.**
- **Solid $CO_2$ is called Dry ice**
-

**Chemical properties**

**$CO_2$ Reacts with water to form carbonic acid.**

**$CO_2 + H_2O \rightarrow H_2CO_3$**

**$CO_2$ Reacts with sodium hydroxide to form sodium carbonate. Excess carbon dioxide produces sodium bicarbonate.**

**$CO_2 + 2NaOH \rightarrow Na_2CO_3 + H_2O$**

**$Na_2CO_3 + H_2O + CO_2 \rightarrow 2NaHCO_3$**

**$CO_2$ Reacts with calcium hydroxide to form calcium carbonate and water.**

**$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$**

**$CO_2$ Reacts with metals to form metallic oxides.**

**$2Mg + CO_2 \rightarrow 2MgO + C$**

**$CO_2$ Reacts with non-metals to form carbon monoxide.**

**$C + CO_2 \rightarrow 2CO$**

**Uses**

**To prepare soft drinks and soda, in fire extinguishers, as a refrigerating agent, to prepare several chemicals like urea, washing soda and baking soda, to preserve food.**

**Helps to maintain the temperature of the earth's surface. Used in welding to control corrosion**

**.**

**CARBON (IV)OXIDE VERSUS CARBONMONOXIDE**

**Carbon monoxide and carbon dioxide are both colorless and odorless gases.**

- **Carbon monoxide has a molecular formula of CO while carbon dioxide is CO2.**
- **Carbon monoxide is composed of one carbon atom and one oxygen atom while carbon dioxide is composed of one carbon atom and two oxygen atoms.**
- **Carbon monoxide is produced from the incomplete combustion of fossil fuels like gas, coal, oil, and solid fuel appliances while carbon dioxide is produced from the exhalation of people and animals and from the combustion of organic materials like leaves and wood.**
- **Carbon dioxide is important in the process of respiration and photosynthesis.**
- **Carbon monoxide at increased levels is poisonous which will likely result in death.**
-

**Carbon Dioxide**

**There are two tests for carbon dioxide. Firstly it will extinguish a flame, however, as any oxygen free gas will also extinguish a flame this is a poor gas test and may result in misidentification.**

**The best way of testing for Carbon dioxide is to bubble it through lime water. A positive test will result in the lime water turning milky. Lime water turns milky as the Calcium hydroxide (chemical name for limewater) reacts with carbon dioxide to form Calcium Carbonate which is insoluble in water and thus forms a milky white precipitate.**

**EVALUATION**

1. Differentiate between carbon (ii )oxide and carbon (iv) oxide in terms of preparation, properties ,uses and test.
2. Why is carbon(ii)oxide poisonous?
3. Which properties of carbon(iv)oxide account for its use in fire extinguishers?
4. Write a short note on the preparation and uses of producer Gas.

5.One of these is not a reaction of charcoal

a.$C + O_2 \rightarrow CO_2$ b.$CO_2 + C \rightarrow 2CO$ c.$2CO + O_2 \rightarrow 2CO_2$ d.$CO_2 + 2CO \rightarrow 2CO$

6. Kipp's apparatus is an instrument for preparing intermittent supply of gases by reacting a. liquid with gas b. liquid with solid c. solid with gas d.liquid with liquid
7. Gas which dissolves in ammoniacal copper I chloride but insoluble in water is a. $NH_3$ b.CO c.$N_2O$ d.$CO_2$

**WEEK 8**

**TRIOXOCARBONATES .**

**INTRODUCTION**

You might have seen the effervescence when lime juice is dropped on the floor, leaving a white mark. Or you might have observed the use of baking soda as a leavening agent to rise cookies, cakes etc.,. You may wonder about the fizz when club soda or coke bottles are opened. It is a known fact that our favorite bakery items are rendered tasty by adding baking powder. The use of washing soda in laundries, in softening hard water; and the use of lime stone and lime water in making construction materials like Portland cement, lime mortar etc., - all of these involve carbonates or bicarbonates.

Carbonates and bicarbonates find their way from household things to metallurgical processes and even biological reactions. They are present in tooth pastes, black board chalks etc.

**FORMULAE & STRUCTURES OF CARBONATES AND BICARBONATE ANIONS**

**So after all, what are carbonates & bicarbonates? These are the salts of carbonic acid. The anions are represented as:**

- **Carbonate ion: CO32-**
- **Bicarbonate or hydrogencarbonate ion: HCO3-**

**These anions are formed from carbonic acid, H2CO3 as follows:**

**H2CO3 <-------> HCO3- + H+ <--------> CO32- + H+**

**The structural relationships can be represented as:**

**Their shape is trigonal planar with 120o of bond angles. The central carbon atom undergoes sp2 hybridization.**

## COMPOUNDS CONTAINING CARBONATE OR BICARBONATE ANIONS

**Usually metal ions with bigger atomic size form stable carbonates and bicarbonates. Some of the bicarbonates can only be detected in aqueous medium. Some important carbonates and bicarbonates are listed below.**

**Carbonates & Bicarbonates**

**Group compound General formula Examples**

**Group-1 (alkali metals) carbonates M2CO3 Li2CO3, Na2CO3, K2CO3 etc.,**

**bicarbonates MHCO3 LiHCO3, NaHCO3, KHCO3 etc.,**

**Group-2 (alkaline earth metals) carbonates MCO3 MgCO3, CaCO3, BaCO3 etc.,**

**bicarbonates M(HCO3)2 Mg(HCO3)2, Ca(HCO3)2 etc.,**

**p-block elements carbonates _ Tl2CO3 and PbCO3**

**Transition elements carbonates _ ZnCO3, CuCO3, Ag2CO3, FeCO3 etc.,.**

## OCCURRENCE

**There are several carbonate minerals present in the nature. A few of them are listed below.**

**Carbonate minerals**

Formula Name of the mineral

$Na_2CO_3$ Soda ash or Natrite

$CaCO_3$ Lime stone or Calcite or Aragonite or Chalk

$MgCO_3$ Magnesite

$CaCO_3.MgCO_3$ Dolomite

$SrCO_3$ Strontianite

$BaCO_3$ Witherite

$PbCO_3$ Cerrusite

$FeCO_3$ Siderite

$CuCO_3.Cu(OH)_2$ Malachite

$2[CuCO_3].Cu(OH)_2$ Azurite

$ZnCO_3$ Smithsonite (in the old literature it is known as calamine)

$CdCO_3$ Otavite

## PREPARATION

Carbonic acid is formed when carbon dioxide gas is dissolved in water.

$H_2O + CO_2 \longleftrightarrow H_2CO_3$

Though looking simple, this reaction is the basic principle involved in the manufacture of club soda, coca cola, Pepsi etc.,. These beverages are made by dissolving carbon dioxide gas in water at high pressures. Of course, some other ingredients are also added to improve the taste of the product. That is another story. When you open the bottle, the carbon dioxide gas will come out with effervescence (you call it fizz).

It is possible to get either carbonate or bicarbonate by passing carbon dioxide into alkaline solutions. Usually carbonates are formed when small amounts of carbon dioxide are passed through alkaline solutions.

E.g.

$2NaOH + CO_2 \longleftrightarrow Na_2CO_3 + H_2O$

small amount fairly soluble in water

**$Ca(OH)_2$ + $CO_2$ <------> $CaCO_3$↓ + $H_2O$**

**small amount insoluble in water**

**But bicarbonates are eventually formed when excess of carbon dioxide is passed into the solution.**

**E.g.**

**$NaOH$ + $CO_2$ <------> $NaHCO_3$**

**excess sparingly soluble**

**in cold water**

**$Ca(OH)_2$ + $2CO_2$ <------> $Ca(HCO_3)_2$**

**excess soluble in water**

**Application-1: It is observed that lime water, $Ca(OH)_2$ turns milky initially when carbon dioxide is passed through it and becomes clear after passing excess of carbon dioxide. Initially an insoluble white solid, $CaCO_3$ is formed. Hence lime water turns milky. It is then converted to water soluble bicarbonate, $Ca(HCO_3)_2$ upon passing excess of carbon dioxide by making the solution clear again.**

**The reactions are summarized below.**

**$Ca(OH)_2$ + $CO_2$ ----------> $CaCO_3$↓ + $H_2O$**

**Slaked lime small amount white solid**

**$CaCO_3$ + $H_2O$ + $CO_2$ ----------> $Ca(HCO_3)_2$**

**excess soluble**

**Note: The formation of calcium carbonate is one of the reaction that occurs during setting of lime mortar, which was used in the construction of old buildings**

**Application-2: It has been observed that a white precipitate is formed when aqueous solution of sodium hydroxide is preserved for longer times in the containers which are not closed properly. It is because of the formation of insoluble $NaHCO_3$ when NaOH reacts with excess of carbon dioxide in air.**

**$NaOH$ + $CO_2$ <------> $NaHCO_3$**

**excess sparingly soluble**

**in cold water**

**GENERAL PROPERTIES**

**Physical state:**

*** Carbonates and bicarbonates are solids at room temperature. Carbonates of group-1 and group-2 elements are colorless. Whereas, the carbonates of transition elements may be colored.**

*** The polarizing power of the group-1 metal ions ($M^+$) is less than the polarizing power of group-2 metal ions ($M^{2+}$). Hence group-2 carbonates are more covalent than the carbonates of group-1.**

**Whereas the polarizing power decreases down the group with increase in the size of metal ion. Hence the ionic nature increases down the group.**

*** $NaHCO_3$ and $KHCO_3$ can exist in the solid state. But the bicarbonates of group-2 elements are only known in aqueous solutions.**

**Solubility in water:**

*** Except $Li_2CO_3$, The group-1 carbonates are fairly soluble in water. The solubility increases down the group as the ionic nature nature increases.**

*** Group-2 carbonates are sparingly soluble in water as their lattice energies are higher (it is due to increase in covalent nature). There is no clear solubility trend observed down this group.**

**But group-2 carbonates are soluble in a solution of $CO_2$ due to formation of $HCO_3^-$.**

**Thermal stability:**

*** Carbonates are decomposed to carbon dioxide and oxide upon heating. Whereas bicarbonates give carbonate, water and carbon dioxide.**

*** Thermal stability of group-1 and group-2 carbonates (also of bicarbonates) increases down the group as the polarizing power of the metal ion decreases.**

*** Due to same reason, carbonates of group-1 are more stable than those of group-2.**

*** Small and highly charged metal ions possess more polarizing power and hence facilitates the decomposition of carbonate ion into carbon dioxide and oxide ion.**

**CHEMICAL REACTIONS**

**The most important reaction shown by these anions is 'decomposition' by liberating carbon dioxide either upon heating or by adding acids. Water or oxide are the other products.**

**$2HCO_3^-$ --------> $CO_3^{2-}$ + $CO_2$ + $H_2O$ (upon heating)**

**$HCO_3^-$ + $H^+$ --------> $CO_2$ + $H_2O$ (in acidic medium)**

**$CO_3^{2-}$ --------> $CO_2$ + $O^{2-}$ (upon heating)**

**$CO_3^{2-}$ + $2H^+$ ---------> $CO_2$ + $H_2O$ (in acidic medium)**

**Illustrations:**

1. **i) $2NaHCO_3$ --------> $Na_2CO_3$ + $CO_2$ + $H_2O$ (upon heating)**
2. **ii) $NaHCO_3$ + $H^+$ --------> $Na^+$+ $CO_2$ + $H_2O$**

**Application: That is why baking soda ($NaHCO_3$) is used as leavening agent to raise cookies, cakes etc.,. It is decomposed to $CO_2$ and water upon heating. This makes the cookies porous and palatable.**

**iii) $Ca(HCO_3)_2$ --------> $CaCO_3$ + $CO_2$ + $H_2O$ (upon heating)**

**$Mg(HCO_3)_2$ --------> $MgCO_3$ + $CO_2$ + $H_2O$ (upon heating)**

**Application: Temporary hardness of water is due to presence of bicarbonates of Ca and Mg. It is possible to remove temporary hardness by boiling water. Upon boiling, the soluble bicarbonates are decomposed to insoluble carbonates, which can be filtered off.**

1. **iv) $CaCO_3$ --------> $CaO$+ $CO_2$ (upon heating)**

**Application: This reaction is used to get quick lime (CaO), in lime kilns, which is further used in the preparation of slaked lime, $Ca(OH)_2$. This is also one of the reaction occurring in the manufacture of Portland cement. Technically this type of reaction is called calcination.**

1. **v) $CaCO_3$ + 2HCl --------> $CaCl_2$ + $H_2O$ + $CO_2$**
2. **vi) $MgCO_3$ + 2HCl --------> $MgCl_2$ + $H_2O$ + $CO_2$**

**or in general**

**$CO_3^{2-}$ + $2H^+$ ---------> $CO_2$ + $H_2O$**

**Comment: This reaction is the principle involved in the detection of carbonate ion present in a given salt.**

**Calcium carbonate is present in the marble stone. This is decomposed to carbon dioxide when come into contact with acids. Hence the effervescence is observed when acids are dropped on the floor. Lime juice contains citric acid, which liberates carbon dioxide and forms insoluble calcium citrate, which appears as white marking.**

**Note: Effervescence is observed sometimes on granite floor which may rarely contain carbonates. This may be originated from lichens lived on them.**

**STUDY OF SOME INDIVIDUAL CARBONATES AND BICARBONATES**

**$Li_2CO_3$:**

*** Lithium carbonate is a colorless salt with polymeric nature.**

*** It is sparingly soluble in water and its solubility decreases with increase in temperature. But it dissolves in presence of carbon dioxide due to the formation of $LiHCO_3$.**

*** It is used in psychiatry to treat mania. The lithium ions interfere the sodium pump and inhibit the activity of protein kinase C (PKC).**

*** It is also used in the preparation of lithium cobalt oxide - which is present in lithium ion battery cathodes.**

**$Na_2CO_3$:**

*** Sodium carbonate is a colorless salt.**

*** It is fairly soluble in water.**

*** It is also called as washing soda.**

*** It is used mainly in laundries and in softening hard water.**

*** It is also used in making glass.**

**EVALUATION**

**1.Describe the effect of the following on trioxocarbonates. Use chemical equations where necessary.**

**i .Acid ii .Water iii. Heat**

2. **State 2 uses of trioxocarbonates with examples.**

**3.What happens when dilute acids reacts with trioxocarbonates. Use chemical equations to support your answer.**

**4.Describe the test for trioxocarbonates.**

**WEEK 9**

**HYDROCARBONS**

**Organic compounds entirely made up of carbon and hydrogen are called as hydrocarbons. This category includes saturated and unsaturated compounds as well as open, cyclic and benzenoid aromatic compounds. Hydrocarbons are classified as saturated and unsaturated based on the nature of the bond between carbon atoms.**

**Similarly depending upon the nature of chain/ring structure hydrocarbons are classified as chain, branched and cyclic hydrocarbons. In cyclic hydrocarbons there is special category of benzene and benzene ring containing hydrocarbons called as aromatic hydrocarbons. Hence the classification of hydrocarbons can be explained by the following chart.**

**Aliphatic Hydrocarbon**

**Hydrocarbons that don't have a benzene ring in their structure are called as aliphatic compounds. Aliphatic can be simply understand as non-aromatic. This is broad category contains many hydrocarbons like linear, branched, cyclic, saturated and unsaturated hydrocarbons.**

**Butane a common constituent of LPG and octane a common constituent in petrol are some of the aliphatic hydrocarbons.**

**CH3-CH2-CH2-CH3 CH3-(CH2)6-CH3**

**Butane Octane**

**Cyclic Hydrocarbon**

**Aliphatic hydrocarbons whose carbon chain is closed end to end to form a ring structure is called as cyclic hydrocarbons. For example cyclobutane and cyclopropane are cyclic hydrocarbons. This category includes both saturated and unsaturated compounds like cyclobutene.**

**Saturated Hydrocarbons**

**Aliphatic hydrocarbons where there is single bond between all the carbon atom are called as saturated hydrocarbons. They are called so because all the valence of carbon atom is completely filled in it. In the saturated hydrocarbons the carbon atom is sp3 hybridized.**

**The structure of saturated hydrocarbon is tetrahedral with respect to each carbon atom. They are less reactive and they cannot undergo addition reaction, where some atoms of groups are added to a compound. Methane, hexane, cyclopentane are examples for saturated hydrocarbons.**

**Unsaturated Hydrocarbons**

**Aliphatic hydrocarbons where there is double/triple bond between carbon atoms are called as unsaturated hydrocarbons. They are called as unsaturated because the valence of carbon is not completely filled.**

**Hence they can undergo addition reaction with atoms or groups to give saturated molecules. The carbon atom is sp2/sp hybridized in alkenes/alkynes. This category includes alkenes, alkynes. The structure of alkene is trigonal while the structure of alkyne is linear. Ethylene, isobutene, acetylene are examples of unsaturated hydrocarbons.**

**$CH_2=CH_2$ CH=CH**

**Ethylene Acetylene**

**Aromatic Hydrocarbon**

**Benzene is a ring hydrocarbon made with three double bonds. But it is unusually stable and will not show any properties for three double bond. Hence the compounds containing benzene ring are classified separately as aromatic compounds.**

**In aromatic hydrocarbons the root word 'aroma' means perfume. All the aromatic compounds have characteristic smell and many of them are used as perfumes. Benzene, naphthalene are example for aromatic hydrocarbon.**

**Polyaromatic Hydrocarbons**

**Polyaromatic hydrocarbons are also otherwise called as polycyclic aromatic hydrocarbons. They are hydrocarbons made up of two or more benzene rings fused together without any other substituents. Naphthalene, anthracein are some examples of polyaromatic hydrocarbons.**

**They posses more threat to environment as a major pollutant in soil. They are obtained from petroleum by distillation.**

**Sources of hydrocarbons**

**Until the early years of the nineteenth century, only the plants and animals were the known sources of organic compounds. With the advent of the Industrial Revolution in Europe, fossil fuels like coal and petroleum gained prominence as the sources of organic compounds, particularly hydrocarbons. Today, hydrocarbons are mostly obtained from petroleum. In recent years coal has started gaining prominence, probably due to the uncertain conditions in the world oil market.**

**Origin of coal and petroleum**

**Coal and petroleum have organic origin, being decomposed plant and animal matter buried deep inside the earth. Coal is mined like any other mineral.**

**The chief coal producing countries in the world are China, U.S.A., U.S.S.R., U.K., Germany, Poland, Australia and India. In India, coal is mainly mined in Bihar, West Bengal, Madhya Pradesh and to some extent in Andhra Pradesh.**

**Petroleum occurs deep inside the Earth at depth ranging from a few hundred to few thousand meters. The name petroleum has been given to the crude oil because it occurs under the Earth's crust entrapped in rocks (petra = rocks oleum = oil). Crude oil (petroleum) is pumped out of Earth by drilling oil wells. Petroleum is obtained by drilling a hole through the crust till it reaches the oil reserve. The oil gushes out of its own due to high pressure of the gas over its surface. However, when the pressure falls, it is pumped out with the help of pumps. Large quantity of natural gas is generally associated with petroleum. Petroleum is often referred to as liquid gold, due to its importance in transportation, commerce and industry. Prosperity of any country depends upon its petroleum reserves.**

**The chief petroleum producing countries are, U.S.A., U.S.S.R., Saudi Arabia, Kuwait, Iraq, Iran, Libya, Nigeria, Algeria, Venezuela China and Mexico.**

**Composition of coal and petroleum**

**Coal is mainly composed of carbon. Coal, is classified into different varieties depending upon its carbon content. Common varieties of coal are,**

**Variety of coal: Peat Lignite Bituminous AnthraciteCarbon content:10-15% 40% 60-70% 80-90%**

**Coal also contains arenes or aromatic hydrocarbons like benzene, toluene, xylene, naphthalene and anthracene. It also has some organic compounds of sulphur and nitrogen.**

**Crude oil (or petroleum) is a dark brown viscous liquid sometimes having a greenish tinge. Crude oil is a mixture of about 150 different organic compounds. Crude oil is largely made up of aliphatic hydrocarbons, with much lesser amounts of aromatic compounds and organic compounds of sulphur and nitrogen.**

**Formation of coal and petroleum in nature**

**It is believed that coal in nature was formed from the remains of the trees buried inside the earth some 500 million years ago. Due to the bacterial and chemical action on the wood, it got converted into peat. Then, as a result of high temperature and high pressure inside the earth peat got transformed into coal.**

**It is believed that the petroleum was formed from the partial decomposition of the sea animals and prehistoric forests under high temperature and pressure conditions inside the earth.**

**Hydrocarbon from petroleum**

**Crude oil or petroleum pumped out of an oil well, is a viscous and complex mixture of several hydrocarbons and small amounts of other compounds. It is not useful in this state. The 'refining of (crude) petroleum' involves the process of fractional distillation, whereby petroleum is separated into many useful fractions.**

**Refining of crude oil**

**The refining of petroleum is done in big refineries. Washing it with acidic or basic solution first neutralizes crude oil. A furnace is used to heat up the crude oil to 650 - 675 K and then the pressure reduced. The resulting crude oil vapors are fed into a fractionating column through an inlet near the bottom of the furnace.**

**Fig: 15.4 - Fractional distillation of crude oil**

**The fractionating tower is a tall cylindrical steel structure divided into compartments by horizontal trays fitted into it. Each tray has a number of holes and a short tube with a bubble cap. Due to a regular temperature gradient along the height of the column, the fractions with lower boiling points rise up and get liquefied at different heights in the trays, depending on the boiling. These caps allow the lighter vapors to escape up the column while the progressively less volatile and heavier fraction condense and flow into the respective trays (through tray holes and overflow) in the lower section of the tower. They can then be tapped out. The major products obtained from the fractional distillation of crude oil are listed below. Gasoline obtained by this procedure is called straight run gasoline.**

**ECONOMIC IMPORTANCE OF FRACTIONS**

**Product Chain length Boiling range Uses %**

**Gas C1 to C5 Below room temperature As fuel: in manufacture of gasoline. rubber, carbon black. ammonia and methane black. 2**

**Petroleum ether C5toC7 303 — 363 K As a solvent and in dry cleaning. 2**

**Petrol C7 to C12 343 — 473 K Motor fuel: dry cleaning solvent. 32**

**Kerosene c1 to C16 440 — 540 K As a fuel and illuminant. 18**

**Gas oil Fuel oil diesel C15 to C18 523 — 673 K Furnace fuel: diesel engine fuel: in cracking 20**

**Residue products:-**

**Lubrication oil,greases,petroleum jelly C16 and up 623 and up As lubricant.in medicines and cosmetics(petrol jelly)**

**Paraffin wax C20 and up Melts at 325— 330 K Making candles andwater proofinq.**

**Petroleum coke c30 and up Residue As a fuel for making electrodes.**

**Liquefied petroleum gas (LPG)**

**Petroleum gas a by-product from two sources: natural gas processing and crude oil refining is a mixture of butane, propane and ethane. The main constituent of liquefied petroleum gas is, however, propane, propylene, butane, butylene in various mixtures. These hydrocarbons burn readily, producing a large amount of heat. This makes petroleum gas a very good fuel.**

**Large quantities of propane and butane are now available from gas and petroleum industries. These are often employed as fuel for tractors, trucks, and buses and mainly as a domestic fuel. They are gases under ordinary pressure. Because of the low boiling point (-44 to 0°C) and**

high vapor pressure of these gases, their handling as liquids in pressure cylinders is necessary. Thus, they can be easily liquefied under pressure. The petroleum gas, which has been liquefied under pressure is called Liquefied petroleum gas (LPG).

Petroleum gas is supplied in liquid form so that a cylinder of even small volume may contain an appreciable amount of the gas. A domestic gas cylinder whose main constituent is butane, contains about 14 kg of LPG. A strong smelling substance (Ethyl mercaptan $C_2H_5SH$) is added to LPG gas cylinders to help in the detection of gas leakage. The gas used for domestic cooking is called Liquefied Petroleum Gas (LPG) because it is present in liquid form in the cylinders and is commonly used for domestic heating purposes.

Owing to demand from industry for butane derivatives, LPG sold as fuel for automobiles is made up largely of propane. This is because,

- LPG compares favorably in cost per mile.
- It has a high octane rating making it useful in engines too.
- LPG leaves little or no engine deposit in the cylinders when it burns, a factor of importance in internal combustion engines.
- As it enters the engine as a vapor, it cannot wash down the cylinder walls, remove lubricant, and increase cylinder-wall piston and piston-ring wear.

All these factors reduce engine wear, increase engine life, and maintenance costs low.

Compressed natural gas (CNG) and Liquid natural gas (LNG)

A liquefied form of natural gas usually consists primarily of methane. Its properties are those of liquid methane, slightly modified by minor constituents. One property, which differentiates liquefied natural gas (LNG) from liquefied petroleum gas (LPG), which is principally propane or butane or both, has a much lower critical temperature, about (-73°C). Unlike LPG, natural gas cannot be liquefied at normal ambient temperature by increasing pressure; natural gas must be cooled to cryogenic temperatures to be liquefied and then stored in well-insulated containers. CNG or LNG is stored in high pressure cylinders or special tanks.

The natural gas is compressed or liquefied for ease of storing and transporting. LNG takes up about 1/600 the space that natural gas does in its gaseous form. LNG technology has made it possible to utilize natural gas from remote areas where it previously had no common use and was burned. CNG or LNG are very clean fuels, which cause very little pollution and have very high calorific value.

Cracking and reforming

**Cracking of hydrocarbons**

**The process of breaking higher hydrocarbons with high boiling points into a variety of lower hydrocarbons that are more volatile (low boiling), is called cracking (or pyrolysis). For example, a higher hydrocarbon $C_{10}H_{22}$ splits according to the reaction.**

**$C_{10}H_{22}C_8H_{18} + C_2H_4$**

**higher hydrocarbon lower hydrocarbons**

**The process of cracking, increases the relative amounts of the lower hydrocarbons. During cracking, carbon-carbon bonds get broken in a random manner, leading to various kinds of products being formed.**

**Cracking is generally carried out in the following ways.**

**Types of cracking**

**Thermal cracking**

**Breaking down large molecules by heating at high temperature and pressure is termed as thermal cracking. Thermal cracking is further classified into the following classes.**

- **Liquid phase thermal cracking process: The higher boiling fractions e.g., fuel oil, lubricating oil are converted into low boiling fractions by heating the liquids at a temperature of 750 K, under a pressure of about 10 atmosphere.**
- **Vapor phase thermal cracking process: Low boiling fraction e.g., kerosene is cracked in the vapor phase at a temperature of about 875 K and under a pressure of 3 atmosphere.**

**Catalytic cracking**

**Higher hydrocarbons can also be cracked at lower temperature (600 - 650 K) and lower pressure (2 atm) in the presence of a suitable catalyst. Catalytic cracking produces gasoline of higher octane number and therefore this method is used for obtaining better quality gasoline. A typical catalyst used for this purpose is a mixture of silica ($SiO_2$), 4 parts; alumina ($Al_2O_3$), 1 part, and manganese-dioxide ($MnO_2$), 1 part.**

**Steam cracking**

**Here, higher hydrocarbons are mixed with steam in their vapor phase and heated for a short duration to about 900°C, and cooled rapidly. This process is suitable for obtaining lower unsaturated hydrocarbons.**

**Applications of cracking**

The most important products obtained in straight-run refining are petrol, diesel and kerosene. The demand for these products outstrips that obtained during refining of the petroleum. Conversely, high-boiling fractions find lesser use. So,

- In petroleum industry, the cracking of less useful high boiling fractions is done to increase the yield of low boiling (lower molecular mass) fractions, such as gasoline.
- Cracking always yields low boiling alkenes as the by-products. These unsaturated hydrocarbons are called petrochemicals, that form a variety of useful compounds such as, polyethylene etc.

Reforming or aromatisation

Reforming or aromatisation involves the conversion of open chain (aliphatic) hydrocarbons and/or cycloalkanes in the presence of a catalyst, into aromatic hydrocarbons (arenes) containing the same number of carbon atoms. Aromatisation involves reactions of the type, dehydrogenation, cyclisation, and isomerisation.

In reforming (or aromatisation), cyclic and acyclic alkanes containing six to eight carbon atoms are heated at about 670 K in the presence of palladium, platinum or nickel as catalyst. Platinum seems to be the best catalyst and so the process is sometimes called platforming.

For example,

Hexane when passed over Cr2O3 supported over alumina at 670 K benzene is produced.

n-hexane benzene

Under similar conditions, n-heptane yields toluene.

n-heptane toluene

Cyclohexane gives benzene

cyclohexane benzene

Applications of reforming

- Production of aromatic hydrocarbons (arenes) like benzene, toluene and xylenes. Earlier the bulk of arenes were obtained from coal tar, but now they are derived from petroleum by the process of reforming.

- **Increasing the octane number of straight-run gasoline by increasing the proportion of aromatic hydrocarbons in gasoline.**

**Aromatic hydrocarbons have octane numbers higher than 100, while the straight-run gasoline has the octane number of 55.**

**The straight-run gasoline (octane number 55) is first distilled to obtain a fraction containing n-hexane, cyclohexane and methylcyclopentane. This fraction is then heated with a platinum catalyst to convert the cyclohexanes into benzene and toluene (octane number > 100).**

**Aliphatic and aromatic hydrocarbon form coal**

**Aliphatic hydrocarbon form coal**

**The petrol obtained artificially from coal as a mixture of alkanes resembling petroleum like aliphatic hydrocarbon fuels is called synthetic petrol. Two important methods for producing synthetic petrol are the Fischer-Tropsch process and the Bergius process. These processes were developed in Germany during World War II, when its petroleum supplies were cut off. Germany produced considerable amounts of fuel from coal by the above processes during that period.**

**These processes have once again drawn much attention due to the existing uncertainties in the world oil markets.**

**Bergius process**

**In this process, powdered coal is mixed with heavy oil and heated with hydrogen under high pressure (200-250 atm) at about 748 K in presence of iron oxide as catalyst.**

**The vapours on condensation give a liquid resembling crude oil. This is called synthetic petroleum, which on fractional distillation gives petrol (gasoline).**

**Fischer-Tropsch process**

**In this process, a mixture of water gas and hydrogen under pressure (5-10 atm) is passed over a cobalt catalyst at 450 - 475 K. The water gas required is obtained by passing steam over red-hot coke.**

**C (red hot) + $H_2O(g)CO + H_2$water gas**

**The product so obtained is fractionally distilled to obtain petrol, middle oil and heavy oil. Further hydrogenation of the middle oil fraction then produces petrol.**

## Aromatic hydrocarbon form coal

## Aromatic compounds from coal

Coal is a complex mixture of hydrocarbons. It also contains some organic compounds containing nitrogen and sulphur in small amounts. It can be approximated to the formula $(C_3H_4)_n$.

Coal is a hydrogen-deficient substance. It is assumed that the basic structure of coal is probably built up of a large number of interlocked benzene rings, upto thirty, in bituminous/anthracite coal. Hydrogen is present in the aliphatic side chains. Bituminous coal has to be thermally decomposed, for obtaining organic compounds from coal. This process is called destructive distillation or 'pyrolysis' of coal.

### Destructive distillation of coal

Destructive distillation of coal occurs when coal is heated in the absence of air, at high temperatures. To achieve this, coal is heated in the absence of air in iron retorts, wherein the volatile material evolved is collected as distillate/condensate. The process can be carried out under different temperature conditions, depending upon the nature of the products required.

### Low temperature pyrolysis

Coal when heated in the absence of air at about 723 - 973 K gives a soft solid, smokeless coke called coalite. The yield of coal tar and coal gas is doubled here. Coal tar so obtained contains more of aliphatic compounds.

### High temperature pyrolysis

In this process, coal is heated in the absence of air to about 1273 - 1473 K. The major products of high temperature pyrolysis are,

Coal

The yield per ton of coal on destructive distillation at higher temperature is,

Coke Coal gas Coal tar Ammonium sulphate Light oil 680 kg 30 m3 15 - 22 kg 1 kg 5 - 6 kg

The coal tar obtained is a heavy viscous almost black liquid due to carbon content with an unpleasant odor. It is a valuable by-product in the destructive distillation of coal. Its composition depends upon the nature of coal used during distillation. However, coal tar generally contains the following compounds: Acidic compounds (Phenol and cresols etc.), basic compounds (Pyridine, etc.) and Neutral compounds (Benzene, toluene, naphthalene and anthracene etc.)

**Fractional distillation of coal tar**

The outgoing hot vapors from the main iron still preheat coal tar obtained from the destructive distillation of coal, in a pre-heater. In this process, coal tar loses most of the water it contains, along with some low boiling hydrocarbons. It is then sent to the main iron still (a side retort) heated directly in a furnace. The vapors are condensed to obtain various fractions at different temperatures. Various fractions obtained during fractional distillation of coal-tar are given below.

Various fractions obtained from the fractional distillation of coal tar

**Quality of gasoline, octane member and gasoline additive**

The explosive nature of a hydrocarbon is determined by its volatility. The volatility of any liquid depends upon the temperature.

'The flash point of any liquid is the lowest temperature at which a liquid hydrocarbon gives off enough vapor to form an explosive mixture with air'.

The flash point of any liquid hydrocarbon is so adjusted that it remains safe under the conditions of its use. For example, the minimum flash point permitted in India is 44°C, while in France it is 33°C and in Britain it is 22°C.

**Knocking of fuels**

An internal combustion engine works with a system of pistons. A mixture of air and petrol vapor, is drawn from the carburetor into the cylinder in the down-stroke of the piston. In the upstroke phase, the mixture is compressed. The ratio of the initial volume to final volume is called the compression ratio. At the end of the upstroke of the piston, a spark ignites the compressed air-petrol (gasoline) mixture. As the gases burn, they expand and the flame front moves in a smooth manner and supplies power to the engine.

To achieve maximum efficiency of the engine, a high compression ratio of about seven to eight is required. However the increase in the compression ratio, results in the burning of petrol-air mixture in an explosive manner, that produces a metallic sound. This sound is called knocking, and indicates inefficient performance of the gasoline. High compression ratio engines also require less fuel, so petrol having less knocking tendencies are very valuable.

**It has been found that the knocking tendency of the fuels falls off with the nature of the fuel as follows.**

**Straight chain alkanes > Branched chain alkanes > Alkenes**

**Knocking may also be prevented or minimized by adding compounds such as tetraethyl lead (TEL) to gasoline. Such compounds are called anti-knocking agents. To prevent the deposition of lead inside the cylinder, dibromoethane is added to the gasoline.**

**Quality of petrol (gasoline) - octane number**

**The controlled combustion of fuel in the presence of air, gives an internal combustion engine its power. A low quality fuel does not burn smoothly and causes an occasional explosive sound, which is known as knocking. This greatly reduces the power of the engine.**

**The quality of a fuel is indicated in terms of its octane number. Different hydrocarbons have different knocking tendencies. A fuel that produces minimum knocking is considered as a good fuel.**

**An arbitrary scale of octane number has been set up with n-heptane and 2,2,4-trimethylpentane (iso-octane) as the reference compounds. All fuels are graded in between these two limiting values by comparing with a suitable mixture of the above two compounds. 2,2,4-trimethylpentane (generally called iso-octane) has excellent anti-knocking properties and has been arbitrarily assigned an octane number of 100, whereas n-heptane, which is very prone to knocking is assigned an octane number of zero (0). Therefore, the antiknock property of a fuel increases with the increase in its octane number.**

**Thus, the octane number of any fuel is defined 'as the percentage of iso-octane in a mixture of iso-octane and n-heptane that has the same knocking as the fuel under examination'.**

**A fuel having an octane number of 80 behaves in a manner similar to a mixture having 80% of iso-butane, and 20% of n-heptane. Straight run gasolines may have octane values ranging from 20 to 73. Aviation fuel is rated as 100 octane.**

**The octane number of a hydrocarbon depends upon its structure.**

- **Branched-chain alkanes, alkenes and aromatic hydrocarbons have high octane numbers. Such compounds are added to straight-run gasoline to raise its octane number. These high octane compounds, viz., branched-chain alkanes, alkenes, and aromatic hydrocarbons are prepared by catalytic cracking and catalytic reforming.**

**Straight chain alkanes have low octane numbers, the value of which decreases with the increase in the length of the chain.**
- **Cyclic alkanes have higher octane numbers than the corresponding straight chain alkanes.**
- **The unsaturated hydrocarbons have higher octane numbers than the corresponding straight chain hydrocarbons.**
- **Aromatic hydrocarbons have very high octane numbers.**

**Octane ratings of some compounds are:**

**n-Heptane 0**

**n-Pentane 62**

**tert-butyl alcohol 98**

**neo-octane Benzene 100**

**Ethanol 112**

**Methanol 116**

**Toluene 118**

**Quality of diesel - octane number**

**octane number is defined as the percentage of cetane in a mixture of cetane and -methyl naphthalene, which has the same ignition quality as the fuel under examination at the same conditions.**

**octane is arbitrarily given a octane number of 100 as it ignites rapidly while -methyl naphthalene ignites is given a octane number of zero as it ignites slowly.**

**Gasoline additive**

**Gasoline additives are compounds added to gasoline, which improve the octane number of a fuel. Such substances are called antiknock compound that improve the fuels combustion in an internal combustion engine. Tetraethyl lead ($(C_2H_5)_4Pb$) is a main additive and is a common antiknock compound . A small quantity of tetraethyl lead (TEL) improves the anti-knock quality of the gasoline. Gasoline containing tetraethyl lead is called leaded petrol or ethyl gasoline.**

**A gasoline-engine (internal combustion engine) discharges various substances into the atmosphere. These are carbon dioxide, water, carbon monoxide, nitrogen oxides, unburnt hydrocarbons from leaded gasoline and certain compounds of lead. About 0.1 g of lead per litre of the gasoline burnt escapes into the atmosphere. Most of it finds its way into the soil.**

**Steps to reduce pollution due to automobile exhausts**

**While many compounds present in the exhaust of any automobile are harmful, lead is extremely toxic and poisonous. The increasing emission of such harmful substances into the atmosphere due to the increasing use of automobiles, is a serious pollution problem. Methods adopted to improve this pollution problem are:**

- **Removal of lead from gasoline is done by replacing tetraethyl lead in gasoline by certain aromatics and branched-chain hydrocarbons. The gasoline free from tetraethyl lead is called lead-free gasoline (or lead-free petrol).**
- **Certain devices such as, catalytic converters are now being used to oxidize the un-burnt hydrocarbons and carbon monoxide to carbon dioxide and to decompose nitrogen oxides into nitrogen and oxygen.**

**EVALUATION**

1. **What are Hydrocarbons? Give three examples and three main sources in nature.**
2. **With the aid of a diagram, briefly describe the industrial fractionation of petroleum.**
3. **Write short notes on the following i. cracking ii. octane number and**

**iii. petrochemicals.**

4. **State the products of fractional distillation of crude oil in increasing order of boiling points.**

**WEEK 10**

**THE CHEMICAL INDUSTRIES**

**The chemical industry involves the use of chemical processes such as chemical reactions and refining methods to produce a wide variety of solid, liquid, and gaseous materials. Most of these products are used in manufacture of other items, although a smaller number are used directly by consumers. These chemicals are used to produce plastics, synthetic fibers, lightweight automobile parts, fertilizers, cosmetics, household materials, computers, and many more products.- Learn more at www.technofunc.com. Your online source for free professional tutorials.**

**Sectors of Chemical Industry**

**Fundamentally, the chemicals industry can be divided into two sectors; commodity/basic chemicals and specialty chemicals. Commodity chemicals are manufactured by many different companies however the end product is generally the same with very little variations. There exits other segmentations for this industry as well. Understand the main sectors of chemical domain.**

**Sales of the chemical business can be divided into following broad categories/sectors:**

- **Basic or Commodity Chemicals - Approximately 35 to 37 percent of the dollar output**
- **Life Sciences- Approximately 30 percent of the dollar output**
- **Specialty Chemicals - Approximately 20 to 25 percent of the dollar output**
- **Consumer Products- Approximately 10 percent of the dollar output**

**Basic Classification of Chemical Industry Sectors:**

**Fundamentally, the chemicals industry can be divided into two sectors; commodity/basic chemicals and specialty chemicals. Commodity chemicals are manufactured by many different companies however the end product is generally the same with very little variations. Specialty chemicals are typically made to suit the needs of a specific customer, and are generally only available from a few suppliers. These chemicals are often protected by patents.**

**Basic/Commodity Chemicals: They are also called basic chemicals, are typically inexpensive and include polymers, bulk petrochemicals, basic industrial chemicals, inorganic chemicals, and fertilizers. Polymers make up the largest segment of this sector. Commodity chemicals are generally made in large volumes.**

**Specialty Chemicals: They are also called fine chemicals; include industrial gases, adhesives, sealants, industrial cleaning chemicals, coatings, and electronic chemicals. A Specialty Chemical is a chemical produced for a specialized use. They are produced in lower volume**

**than bulk chemicals, of which petrochemicals, made from oil feedstock, are the most common. However, both are produced in a chemical plant. Some examples of specialty chemicals are adhesives, additives, antioxidants, corrosion inhibitors, cutting fluids, dyes, lubricants, pigments, etc. These chemicals are generally more expensive than commodity chemicals. Chemicals are made from elements and every element has a unique set of physical and chemical properties. Specialty chemists understand how to combine certain elements that result in a chemical with the required properties.**

**Advanced Classification of Sectors of Chemical Industry:**

**Further classification of chemicals industry can be done to separate Life Science Chemicals, Science and Technology Chemicals and Commodity Chemicals. Definition of these two sectors is provided below:**

**Life Science Chemicals: These are differentiated biological and chemical substances used to induce specific outcomes in humans, animals, plants and other life forms. The major products of this segment include agrochemicals, pharmaceuticals and biotechnology products. Life sciences (about 30 percent of the dollar output of the chemistry business) include differentiated chemical and biological substances, pharmaceuticals, diagnostics, animal health products, vitamins, and pesticides. Life science products are usually produced with very high specifications and are closely scrutinized by government agencies such as the Food and Drug Administration. Pesticides, also called "crop protection chemicals", are about 10 percent of this category and include herbicides, insecticides, and fungicides.**

**Science and Technology Chemicals: These products include advanced materials that transform current technologies. They enhance the characteristics of traditional specialty chemical products, as listed above.**

**Consumer Products: Consumer products include direct product sale of chemicals such as soaps, detergents, and cosmetics. Typical growth rates are 0.8 to 1.0 times GDP. They include sulfuric acid, nitrogen, ethylene, oxygen, lime, ammonia, propylene, polyethylene, chlorine and phosphoric acid.**

**Sub-Segments of Chemicals Industry:**

**Given below are some of the sub-segments of the chemicals industry. They help the learner to understand the various sub-classifications as well as key products and manufacturing operations in the chemicals domain:**

- **Chemical Wholesaling Industry**
- **Organic Chemicals Industry**

- **Inorganic Chemicals Industry**
- **Fertilizer Manufacturing Industry**
- **Pesticide Manufacturing Industry**
- **Soap & Cleaning Compound Manufacturing Industry**
- **Chemical Product Manufacturing Industry**
- **Dye & Pigment Manufacturing Industry**
- **Generic Pharmaceutical Manufacturing Industry**

**Chemical Wholesaling Industry: As a key intermediary within the supply chain, the Chemical Wholesaling industry plays an important role in overall chemical manufacturing. Because chemical wholesalers have diversified product offerings, no operator holds a dominant share of the market. As a result, this industry is highly competitive, with wholesalers competing on storage efficiency and distribution. This industry wholesales chemicals and related products, including compressed gas, chemical additives and synthetic rubber, to the manufacturing, construction and mining industries. This industry does not wholesale agricultural and medicinal chemicals, paints and varnishes, fireworks or plastics materials. Major industry products are detergents and soaps, alkalies and chlorine, industrial gases, adhesives, sealants and glues, sanitation chemicals, polishes and waxes, synthetic rubber, dyes and pigments.**

**Organic Chemicals Industry: Organic chemicals industry is one of the most significant sectors of the chemical industry. It plays a vital developmental role by providing chemicals and intermediates as inputs to other sectors of the industry like paints, adhesives, pharmaceuticals, dye stuffs and intermediates, leather chemicals, pesticides etc. Methanol, acetic acid, formaldehyde, pyridines, phenol, alkyl amines, ethyl acetate and acetic anhydride are the major organic chemicals produced. Formaldehyde and acetic acid are important methanol derivatives and are used in numerous industrial applications. Phenol is an aromatic compound and derived from cumene, benzene and propylene derivatives. Alkyl amines are used in the manufacture of surfactants. Pyridine derivatives are used in the manufacture of pharmaceuticals. Ethyl acetate is the ester of ethanol and acetic acid and is manufactured for use as a solvent. Acetic anhydride is widely used as a reagent. Natural gas/ naphtha are mainly used as feedstock for the manufacture of these organic chemicals. Alcohol is also an important feedstock for the industry, with sizable production of acetic acid and entire production of ethyl acetate being based on alcohol. Global production of organic chemicals was around 400 million tons during 2010-11. Major producers of organic chemicals are USA, Germany, U.K, Japan, China and India. Few Latin American countries, for example Brazil and Chile are increasing their presence in global organic chemicals market.**

**Inorganic Chemicals Industry: This industry manufactures a variety of basic inorganic chemicals. Inorganic chemicals are generally mineral-based. Most organic chemicals, on the other hand, are carbon-based. Inorganic chemicals are used as inputs in a number of manufacturing and industrial processes. Key identifiable industry segments include chlor-alkali and carbon black products. Major industry products are Chlorine, Caustic soda, Potassium, sodium and other alkali compounds, Chemical catalysts, Inorganic acids, Carbon black and Other inorganic chemicals.**

**Fertilizer Manufacturing Industry: This industry primarily manufactures fertilizer products. These products contain a different mixture of the three vital nutrients essential for plant growth: nitrogen, phosphorous and potassium. The products are distributed via wholesale arrangements with third parties or, in the case of vertically integrated operations, by the manufacturer. Major industry products are phosphate fertilizers, nitrogenous fertilizers and mixed fertilizers. The major activities include manufacturing ammonia, ammonium nitrate, ammonium sulfate and ammonium phosphates, natural organic and animal waste or sewage origin fertilizers, nitric acid and phosphoric acid, nitrogenous fertilizer materials, urea, phosphatic fertilizer materials, potting soil, plant foods and compost etc.**

**Pesticide Manufacturing Industry: This industry formulates and prepares agricultural and household pest control chemicals. Key products include pesticides (herbicides, insecticides and fungicides) and agricultural chemical products (insect repellents, sheep dips, fly sprays and flea powders). Key markets for this industry include the agricultural sector, households and various commercial and industrial users.**

**Soap & Cleaning Compound Manufacturing Industry: This industry produces substances that loosen and remove soil from a surface for personal hygiene, sanitization or cleaning clothes, linens and furnishings. The industry does not include manufacturers of synthetic glycerin, industrial bleaches or shampoos. Major industry products include household soaps and detergents, commercial soaps and detergents, polishes and other sanitation goods and surface active agents.**

**Chemical Product Manufacturing Industry: This industry manufactures a diverse range of chemical products. Key product groups include custom compounding plastic resins and manufacturing toners, toner cartridges, photographic chemicals and sensitized photographic film, paper and plates. Custom compounding of plastic resins includes custom mixing and blending of purchased plastic resins and reformulating plastic resins from recycled plastic products. Major industry products include custom compounding of resins, photographic chemicals and materials and other related products and preparations.**

**Dye & Pigment Manufacturing Industry: This industry manufactures synthetic organic and inorganic dyes and pigments, such as lakes and toners (except: electrostatic and photographic). As such, the industry produces various pigments and dyes, including color, lead, chrome, metallic and zinc-based pigments as well as disperse, vat and direct dyes. A chemical intermediate product, these pigment and dyes are used to impart color to numerous products. Major industry products include inorganic dyes and pigments and synthetic organic dyes and pigments.**

**Generic Pharmaceutical Manufacturing Industry: Generic pharmaceutical and medicine manufacturers develop prescription and over-the-counter drug products that are used to prevent or treat illnesses in humans or animals. Generic drugs are produced and distributed without patent protection, and industry operators are not significantly engaged in the research and development of new drugs. The industry does not include manufacturers of nutritional supplements or cosmetic beauty products. Major products include pharmaceutical preparations for metabolic drugs, cardiovascular drugs, central nervous system drugs, psychotherapeutic drugs and other drugs. It includes medicinal and botanical products, in-vitro diagnostic substance products and biological products (except: diagnostic). The main activities of this industry are to develop and produce drugs, market and distribute them after gaining regulatory approval for respective drugs. Generic firms can be smaller, because the cost of research and development is significantly lower than it is in the brand name industry. Economies of scale exist when increasing the size of a company increases its productivity.**

## IMPORTANCE OF CHEMICAL INDUSTRIES

### Importance of Chemicals Industry in Agriculture:

**The agricultural industry makes use of many different chemicals. Fertilizers, insecticides, fungicides, and pesticides are all used to protect crops. Chemical companies contribute to the development of sustainable crops by producing slow-release fertilizers that plants can use more efficiently. Because smaller amounts of these fertilizers are required, less energy is used. In addition, reduced runoff decreases contamination of water systems and subsequent release of nitrous oxide, a potent greenhouse gas. The end result is a markedly improved means of growing crops. Many chemical companies have also developed crops that are drought tolerant or pesticide resistant, and these properties reduce environmental impact by allowing no-till farming and other “green” practices. These products help sustain higher yields, reduce the loss of crops, and decrease the level of natural toxins produced by bacteria and fungi.**

**All of these products must undergo an approval process and be deemed safe before they can be used on crops. Many chemical companies are pioneers in the development of seeds, both**

traditional and genetically modified. They are involved in the production and delivery of fertilizers and soil conditioners. Development and scale-up of processes for effecting chemical transformations and separations of solids, liquids, and gases are the specialty of many companies engaged in producing commodity and specialty chemicals.

**Impact of Chemicals Industry on Environment:**

Environmental science is the study of the interactions between the physical, chemical and biological elements of the environment. For chemists, this applies to understanding the interactions on a molecular scale. This can involve aspects of climate change, conservation, biodiversity, groundwater and soil contamination, use of natural resources, waste management, air pollution and noise pollution. Chemistry has traditionally been viewed as a scientific tool which could harness natural resources to enhance our lives. However the production, processing, and use of chemicals in modern society have been accompanied by global-scale environmental pollution, natural resource depletion, and health impacts. However, now the focus is shifting to development of less toxic chemical products with specific functional properties. Now, the chemical industry has brought its expertise and capital investment into action for solving environmental problems for over fifty years. The industry is continuing to expand its roles in energy efficiency, trace chemical detection and mitigation, applications of natural biochemical materials and processes, and water and air pollution control technology development and application. The industry expects to be a major contributor to expanding the science and technology that supports life cycle environmental assessment and sustainable development policies.

**Importance of Chemicals Industry in Hygiene & Health:**

Chemical Sciences help us gain understanding on the development reasons of the various diseases like cancer, help us improve care and protection by diagnostics and sensors for the prevention and detection of deadly diseases. The chemical sciences will be able to answer many of challenges of the 21st century including improving the health protection and care. Even the detergents are made up of a combination of ingredients, including soap and other surfactants. They are used for washing fabrics, dishes, kitchen utensils, hard surfaces, and laundry.

**Chemicals Industry and Sustainable Energy Solutions:**

The major cause of global warming is the combustion of fossil fuels and subsequent emission of carbon dioxide and other greenhouse gases and reductions in manmade gas emissions are imperative to halt the rise in global temperatures and the negative impact this will have on our climate. The only way to achieve this is through conservation of current supplies and the development of new technologies. The chemical sciences will play a key role by helping us manage waste products from energy production and help to reduce the energy demand of domestic living.

**Importance of Chemical Sciences on Food:**

**Food chemistry is the study of chemical processes and interactions of all biological and non-biological components of foods. This discipline also encompasses how products change under certain food processing techniques and ways either to enhance or to prevent them from happening. An example of enhancing a process would be to encourage fermentation of dairy products with microorganisms that convert lactose to lactic acid; an example of preventing a process would be stopping the browning on the surface of freshly cut Red Delicious apples using lemon juice or other acidulated water. Similarly, chemicals, such as salt, spices, and sulfides, have been added to food for centuries, both to improve taste and help with preservation. Processed food industry depends on identification of new additives that can help preserve the foods. Similarly, food emulsifiers are used in salad dressings, margarine, and ice cream. Another example could be the use of citric acid to enhance the flavor of lemon or lime soft drinks.**

**Importance of Painting & Coating:**

**The Paint Manufacturing industry plays an important role within specific sectors of the economy because they provide protective and decorative finishes for many products in various end-use markets. Paints and coatings are used to cover a large number of products, from computers, circuit boards, and microchips to buildings, cars, planes, and ships. Construction sector needs paint for the houses and commercial buildings it constructs, and the manufacturing sector requires paint for certain products, particularly cars and boats. Although their primary purpose is to protect products and make them more attractive, they also serve a number of other functions. For example, they can help save resources by making products last longer. They can also be used to absorb or reflect light, conduct electricity, or as anti-skid surfaces. Products include Car paint, Paint and varnish for the construction industry, Emulsion paint, Stoving paint, Wood coating, Plastics coating, Furniture and paper varnish, Powder coating, Anti-corrosion paint and Cement paint etc.**

**Importance of Petro-Chemistry:**

**Petro chemistry involves transforming crude oil and natural gas into basic petrochemicals, such as ethylene, propylene, butadiene, and benzene. The process of refining crude oil leads to the production of a number of by products which are classified as petroleum products. These petrochemicals form the basic building blocks for a large variety of products. These products are present in our daily trivial things to the most significant things available. The uses of these products are so significant that it is simply impossible to live life without it.**

**Some of the most common products which contain these by products include paints, thinners, dry cleaning chemicals, inks, insecticides, charcoal lighters, construction chemicals and so forth. With an endless list it is quite impossible to categorize all the items.**

**These products have a wide variety of uses, wax is widely used to make candles, various types of polishes, cartons and so forth, synthetic is of immense importance and used as a raw material for manufacturing different types of garments, fertilizers are used to protect crops from damage, preservatives used in canned food and for producing different types of vitamins, dyes are used in ink pens and cloth dyes, and majority of the plastic containers, plates and cups contain this by- product of crude oil. Hence petrochemical products are used in varied forms in all fields, ranging from common household items to complex applications; the uses are extensively wide and different. Through the development of new technologies and materials, petro chemistry enables the creation of products like computer chips, cell phones, automobiles, and pharmaceuticals. Petro chemistry is known as an enabling industry. That is, it supports a wide range of essential industries, including health care, construction, telecommunications, and transportation.**

**Importance of Pharmaceuticals:**

**Biological science involves studying the science of life. However, chemistry is important to a variety of sub-disciplines. These can include health science, the discipline of applied science that deals with human and animal health, looking at the how the body functions and using this knowledge to improve health and cure diseases. The study of pharmacology, determines how substances (typically pharmaceuticals) interact with living organisms to produce a change in function. Biochemistry is the study of the chemical substances and vital processes occurring in living organisms, studying biomolecules such as proteins, lipids and carbohydrates. Molecular biology is looking at biology at the molecular level, analyzing the processes that control cells, including replication, transcription and translation of genetic material within cells. This discipline also includes biotechnology, the use of biological systems to modify or derive new products, typically drugs or foodstuffs.**

**Chemicals and Construction Industry:**

**The residential construction market is a major consumer of chemicals. Chemicals comprise approximately 17% of all materials used in new construction. Home construction and buying consumes synthetic materials such as pipes and siding, manufactured from plastics. Construction stimulates demand for appliances, carpeting, furniture, and paints – also produced from chemicals. The strength of the construction industry directly impacts the strength of the chemical industry.**

**Chemicals and Automobile Industry:**

**Car manufacturing consumes a significant amount of chemical products in the form of plastics, rubber, fibers, and paint. Every automobile contains over $2,000 worth of chemical processing and products. Most of the major Diversified chemical firms serve the automotive sector in the areas of specialized coatings and plastics.**

**EVALUATION**

1. **List six divisions of the chemical industry and briefly discuss any two of them.**
2. **Briefly highlight the importance of chemical industries.**
3. **Differentiate between heavy chemicals and fine chemicals and state two examples each**
4. **What are Hydrocarbons. Give 2 examples.**

**5.Fine chemicals have the following characteristics except**

1. **they are chemically pure b. they are produced by batch process c. they are produced in large quantity because of high applicability.**
2. **they are produced in small quantity because of limited applicability.**

**6.Exceptional large number of carbon compounds is essentially due to the ability of a. carbon to catenate liberally b. various groups to catenate**

1. **Nitrogen, Hydrogen, phosphorus and the Halogens to catenate with themselves**
2. **Hydrocarbons to dominate other groups.**