**CHEMISTRY SS 1**

**THIRD TERM**

**SCHEME OF WORK**

**WEEK**  **TOPIC**

1. Revision /Acids: Properties, Preparation and Uses. pH Scale

2-3. Bases: Properties, Preparation. Salts: Classification, Methods of preparation, Types and Characteristics

4.        Carbon- Allotropes and their Structures, Properties, Differences between Diamond and Graphite.

5.    Carbon (ii) Oxide (CO), Carbon (iv) Oxide (CO2): their Preparation, Properties and Uses.

6. Coal: Types of Coal, Destructive Distillation of Coal, Uses of the Products, Coke: Gasification and Uses.

7. Metallic Carbonate: Occurrences, Preparation and Uses, Test for Trioxocarbonate ion. Trioxocarbonate (iv) acid: Preparation, Properties and Uses.

8-9. Introduction to Hydrocarbons: Sources of Hydrocarbons, Classification of Aliphatic Hydrocarbons. Petroleum and Natural gases: Refining of Petroleum by Fractional Distillation, Uses of different Fractions, Cracking of Petroleum (Thermal and Catalytic), Anti-knock and Octane rating.

10.    Applied Chemistry: Raw material used in Chemical industries and their Sources. Division of the Chemical Industries: Heavy chemicals, Fine chemicals, Fertilizers, Plastics, Metallurgy, Pharmaceutical, Glass, Ceramics, Cements, Soap and Detergents.

11. Revision.

12-13. Examination

**WEEK ONE**

**TOPIC: REVISION/ACIDS**

**CONTENT**

* Definition.
* Properties.
* Preparation and uses.
* pH.

**ACIDS**

Definition: An acid is substance which in aqueous solution produces hydroxonium ion (H3O+) or hydrogen ion (H+) as the only positive ion. Also, acids can be referred to as proton donor.

**CLASSES OF ACIDS**

There are two classes of acids:

(1). Organic acids occur as natural products in plants and animal material.

|  |  |
| --- | --- |
| Organic acids | Source |
| Ethanoic acids | Vinegar |
| Lactic acids | Milk |
| Citric acids | Lime, Lemon |
| Amino acids | Proteins |
| Fatty acids | Fats and oils |
| Ascorbic acids (Vitamin C). | Oranges |

(2). Inorganic acid: Inorganic acid can be prepared from mineral elements or inorganic matter.

|  |  |  |
| --- | --- | --- |
| Inorganic acid | Formula | Constituents |
| Hydrochloric acid | HCl | Hydrogen, Chlorine |
| Tetraoxosulphate(VI) acid | H2SO4 | Hydrogen, Sulphur & Oxygen |
| Trioxonitrate(VI) acid | HNO3 | Hydrogen, Nitrogen & Oxygen |

An acid is also defined as a substance which produces hydroxonium ion as the only positive ion when dissolved in water.

H+(aq)  + H2O(l) H3O+(aq)

Acid can be dilute or concentrated depending on the amount of water added. A dilute acid is acid produced when a large amount of water is added to a small amount of acid. A concentrated acid is acid produced when only a little amount of water is added to a relatively large amount of acid.

**STRENGTH OF AN ACID**

The strength of an acid can either be weak or strong.

(1) Strong acids: are acids which ionize completely in aqueous solution and such acid solution having a high concentration of H+. Examples are HCl, H2SO4 and HNO3.

H2SO4 2H+ + SO42-

HNO3 H+ + NO3-

HCl H+ + Cl-

(2) Weak acids: are acids which ionize or dissociate slightly or partially in aqueous solution and such acid solution have a low concentration of hydrogen ions. Examples are ethanoic acid (CH3COOH), H2CO3, H3PO4, H2SO3.

H2CO3 2H+ + CO32-

H3PO4 3H+ + PO43-

CH3COOH H+ + CH3COO-

H2SO3 2H+ + SO32-

**BASICITY OF AN ACID**

The basicity of an acid is the number of replaceable hydrogen ions, H+, in one molecule of the acid.

|  |  |
| --- | --- |
| Acid | Basicity |
| Hydrochloric acid | Monobasic |
| Tetraoxosulphate (vi) acid | Dibasic |
| Tetraoxophosphate(v) acid | Tribasic |
| Ethanoic acid | Monobasic |

**EVALUATION**

1. Define the term acid

2. Differentiate between strong acid and concentrated acid

3. What is the basicity of the following acids: HCl, HNO3, H2SO4

**PHYSICAL PROPERTIES OF ACID**

1. They have a sour taste.

2. They turn blue litmus paper to red.

3. They are corrosive in nature especially the strong acid.

4. In aqueous solution, they conduct electricity.

**CHEMICAL PROPERTIES OF ACID**

Reaction with metals: They react with metals to liberate hydrogen gas and salt of metal i.e

Acid + Metal Salt + Hydrogen gas.

E.g.  2HCl(aq) +Zn(s) ZnCl2(aq) + H2(g)

H2SO4(aq) + Mg(s) MgSO4(aq) + H2(g)

They react with soluble bases to form salt and water only. This reaction is known as neutralization.

Acid + Base salt + water

E.g H2SO4(aq)  + 2KOH(aq) K2SO4(aq) + 2H2O(l)

2HCl(aq) + CaO(s) CaCl2(aq) + H2O(l)

1. They react with trioxocarbonates (iv) salts to liberate carbon (iv) oxide, salt and water i.e. Acid + trioxocarbonate (iv) Salt + Water + CO2

E.g 2HCl (aq) + Na2CO3(aq) 2NaCl(aq) + H2O(l) + CO2(g)

**PREPARATION OF ACIDS**

Acid can be prepared by using the following methods:

1. Dissolving an acid anhydride in water: Acid anhydride is oxides of non-metal that dissolve in water to produce the corresponding acids e.g SO2, CO2, CO, NO2, SO3.

SO2(g) + H2O(l) H2SO3(aq)

CO2(g) + H2O(l) H2CO3(aq)

SO3(g) + H2O(l) H2SO4(aq)

2. Combination of constituent elements.

(a).Burning hydrogen in chlorine, in the presence of activated charcoal as the catalyst, yields HCl gas which dissolves readily in water to give HCl acid.

H2(g) + Cl2(g) activated charcoal 2HCl(g)

(b)Heating hydrogen gas and bromine vapour, in the presence of platinum as the catalyst, produces hydrogen bromide which dissolves readily in water to form hydrobromic acid.

H2(g) + Br2(g)  Platinum 2HBr(g)

(3)By displacement of a weak or more volatile acid from it salt by a stronger or less

volatile acid. For example

(a)Displacement of the more volatile hydrogen chloride from metallic chloride by the less volatile concentrated tetraoxosulphate (vi) acid.

NaCl(s) + H2SO4(aq) NaHSO4(aq) + HCl(aq)

(b)Displacement of weaker trioxoborate (iii) acid from ‘borax’ by tetraoxosulphate (vi) acid.

Na2B4O7(s) + H2SO4(aq) + 5H2O(l) Na2SO4(aq) + 4H3BO3(aq)

Borax Trioxoborate (iii) acid

(4)By precipitating an insoluble sulphide from a metallic salt by hydrogen sulphide

Pb (CH3COO)2(aq) + H2S(g) PbS(s) + CH3COOH(aq)

**Uses of acid**

(1) Acids are useful chemicals which are used in many industries to make other consumer chemicals such as fertilizers, detergent and drugs.

(2) They are used in industrial process as drying agents, oxidizing agents and catalysts.

**USES OF ORGANIC AND INORGANIC ACID**

|  |  |
| --- | --- |
| Name | Uses |
| HCl | Needed by industries to make chemicals used to remove rust.  Used to clean the surface of metals before electroplating. |
| H2SO4 | Needed by industries to make chemicals used as a drying and dehydrating agent.  Used as an electrolyte in lead-acid accumulators  Required in oil refineries. |
| HNO3 | Needed by industries for making fertilizers, explosives etc. |
| Boric acid | Used as mild antiseptic or germicide. |
| Tartaric acid | Used in making baking soda, soft drinks and health salts |
| Acetic acid (ethanoic acid) | Used in preserving food.  Used in dyeing silk and other textiles. |
| Citric acid | Used in making fruits juice. |
| Fatty acid (palmitic and stearic acid) | Used in the manufacture of soap. This process is known as saponification.  Fatty acid + Caustic soda Soap + H2O. |

**EVALUATION**

1. Mention three physical properties of acids

2. Using balanced equations, state the chemical properties of acids

3. State two methods of preparing acids

4. Outline the uses of acids

**pH SCALE**

All acidic solution contains H+ and all alkaline solution contains OH- ions. The PH scale measure the concentration of H+ ions present in a solution and start from 0 to 14

**DEFINITION OF pH**

pH is defined as the negative logarithms of the hydrogen ion [H+] concentration to the base of 10.

i.e. pH = -log [H+].

Thus: If [H+] = 0.00001 or 10-5.

log [H+] = log10-5 = -5

pH= -log [H+] = - (-5) = 5.

If [H+] =10-x

Therefore, pH= -log10-x = - (-x) = x

If [H+] = 10-2, PH = 2

**DEFINITION OF pOH**

POH is defined as the negative logarithms of the hydroxide ion [OH-] concentration to the base of 10.

i.e. pOH= -log [OH-].

PH is the degree of acidity. A solution with PH 7 is neutral. A solution with PH less than 7, i.e. PH 6,5,4, e.t.c, indicate acidity increasing as the numbers decreases. A solution with PH greater than 7, i.e. PH 8,9,10, e.t.c, indicate alkalinity increasing as the numbers increase.

PH 1 2 3 4 5 6 7 8 9 10 11 12 13 14

Increasing acidity Neutral Increasing alkalinity

A solution with PH 1 is very acidic [with high concentration of H+]. A solution with pH 13 is very alkaline [with low concentration of H+, but high concentration of OH-].

Note that: If pH is 1, it has concentration of H+ 10 times greater than pH 2 and 100 times greater than PH 3 e.t.c.

pH 1 > pH 2 > pH 3.

Concentration of H+ 10-1 10-2 10-3.

0.1 0.01 0.001.

**Relationship between pH and pOH.**

H2O H+ + OH-

From conductivity measurement, [H+]=10-7moldm-3, [OH-]=10-7moldm-3.

[H+] [OH-] = Kw=10-7 x 10-7=10-14mol2dm-6.

Taking logarithm of both sides

log ([H+] [OH-]) = logKw

log [H+] + log[OH-] =logKw

Subtracting both sides

-(log[H+] + [OH-]) = -logKw

-log [H+] – log[OH-] = -logKw

-log [H+] + (-log [OH-]) = -logKw

pH + pOH = PKw

pKw = -log10-14 = -(-14) = 14

Therefore, pH + pOH = 14.

Worked examples

1. Find the hydrogen and hydroxide ion concentrations in

(a) 0.01moldm-3 tetraoxosulphate (vi) acid solution.

(b) 0.001moldm-3 potassium hydroxide solution.

Solution

(a). H2SO4(aq)  2H+(aq) + SO42-(aq)

From the equation, 1 moldm-3 H2SO4 ionizes to give 2moldm-3 H+

Therefore, 0.01moldm-3 H2SO4 would ionize to give (2x0.01) moldm-3 H+

[H+] = 2x10-2moldm-3

[H+] [OH-] = 10-14

(2x10-2) [OH-] = 10-14

[OH-] = 10-14

2x 10-2

[OH-] = 0.5x (10-14- -2)

[OH-] =0.5 x10-14+2

[OH-] =0.5x10-12moldm-3.

(b). KOH(aq) K+(aq) + OH-(aq)

From the equation,

1moldm-3 of KOH ionizes to give 1moldm-3 of OH-

10-3moldm-3 of KOH would ionize to give 10-3moldm-3 of OH‑

[OH-]=10-3moldm-3.

[H+] [OH-]=10-14

[H+] (10-3) = 10-14.

[H+] = 10-14

10-3

[H+] = 10-14+3

[H+] = 10-11moldm-3

2. A glass cup of orange juice is found to have a POH of 11.40. Calculate the concentration of the hydrogen ions in the juice.

Solution

pH + pOH = 14.

pH = 14 – 11.4.

pH = 2.6.

pH = -log [H+]

2.6 =-log [H+].

[H+] = Antilog (-2.6)

[H+] = 0.0025moldm-3

[H+] = 2.5x10-3moldm-3.

**Measuring pH of a solution**.

We use pH meter and a universal indicator to detect PH of a solution.

Universal indicator is a mixture of indicator and can change to several colours corresponding to a particular PH and compared with the standard colour provided by the manufacturer of the universal indicator. Universal indicator measures PH between 3 and 11.

Process:-

Put 10cm3 of test solution in a test tube, add 2 drops of universal indicator and compare with the colour chart or place 2 drops of test solution on universal indicator paper and compare the colour with the chart.

**EVALUATION**

1. Define the term pH.

2. What is the pH of a solution having hydrogen ion concentration of 6x 10-9

mol/dm3

**GENERAL EVALUATION/REVISION**

1. Give the chemical formula of the following acids (a) Tetraoxosulphate (vi) acid

(b) Trioxonitrate (v) acid (c) Oxochlorate (i) acid

2. What is the IUPAC nomenclature of the following (a) HNO2 (b) HOBr (c) H3PO4 (d) H2S

3. Determine the oxidation number of Cl and C in each of the following (a) KClO3

(b) HOCl (c) H2CO3 (d) CO2

4. Mention the laboratory apparatus that are used in for an acid-base titration

What can be used to determine the acidity or alkalinity of a solution?

**WEEKEND ASSIGNMENT**

1. The following acids are monobasic except (a) HNO2 (b) HBr (c) HOCl (d) H2SO3

2. Which of the following ions is acidic? (a) K+ (b) NO3- (c) S2-  (d) H3O+.

3. The number of hydroxonium ions produced by one molecule of an acid in aqueous solution is it (a) acidity (b) basicity (c) concentration (d) pH.

4. The basicity of ethanoic acid CH3COOH is: (a) 0 (b) 1 (c) 2 (d) 3

5. A solution with pH 7 is (a) Acidic (b) dilute (c) neutral (d) saturated

**THEORY**

1**.** What is (i) an acid (ii) basicity of an acid?

2. What is the basicity of tetraoxophosphate (V) acid.

3. The concentrations of H+ in two solutions are (a) 1 x10-4moldm-3and (b) 5 x 10-9moldm-3 . What is the PH of each solution?

**WEEK TWO AND THREE**

**TOPIC: BASES AND SALTS**

**CONTENT**

* Bases
* Salts
* Efflorescence, deliquescence and hygroscopic

**BASES AND ALKALIS**

A base is a substance which will neutralize an acid to yield a salt and water only. Most oxide and hydroxide of metals are bases e.g. Na2O, K2O, MgO, NaOH, KOH e.t.c.

An alkalis is a basic hydroxide which is soluble in water NaOH, KOH, Ca(OH)2. A basic oxide (or hydroxide) is a metallic oxide (or hydroxide) which contains ions (O2‑ or OH‑) and will react with an acid to form a salt and water only.

Note: An exception to this definition is the reaction of lead (IV) oxide with hydrochloric acid to produce lead (ii) chloride (a salt), water and chlorine gas.

PbO2(s) + 4HCl (aq) PbCl2 (aq) + 2H2O (l) + Cl2 (g)

From the equation above, PbO2 is not a base. The nature of the hydroxides of the metals varies according to the position of the metal in the electrochemical series, as illustrated below.

|  |  |  |
| --- | --- | --- |
| Metal | Solubility | Decomposition by heat. |
| K  Na  Ca | The hydroxides of these metals are soluble in water and are alkalis. | Hydroxide of sodium and potassium can  not be decomposed by heat. |
| Mg, Al, Zn  Fe, Pb, Cu | These metals form hydroxides which are insoluble in water. They are amphoteric except the three hydroxides of Magnesium, iron, and copper. | Decomposed on heating to form oxide and water. |
| Hg, Ag, Au. | Hydroxides of these metals do not exist. |  |

**STRENGTH OF BASE**

Like an acid, we have strength of a base. The strength of a base can either be weak or strong.

Weak base: Weak base are base that ionizes slightly in aqueous solution to produce positively charged metallic ion and negatively charged hydroxide ion e.g. CaO, NH3.

NH3 (g) + H2O (l) NH4+(aq) OH-(aq)

Strong bases: Strong base are base that ionizes completely in aqueous solution to produce positively charged metallic ion and negatively charged hydroxide ion e.g. Na2O, K2O.

Na2O(s) + H2O (l) 2NaOH(aq)

K2O(s) + H2O (l) 2KOH(aq)

NaOH (aq) Na+(aq) + OH-(aq)

KOH (aq) K+(aq) + OH-(aq)

**PHYSICAL PROPERTIES OF ALKALIS**

1. Alkalis have a bitter taste.

2. Alkalis are soapy to the touch.

3. Alkalis turn red litmus blue.

4. Concentrated form of the caustic alkalis of NaOH and KOH are corrosive.

**CHEMICAL PROPERTIES OF ALKALIS**

1. Reaction with acid: All base react with acid to form salt and water only.

NaOH(aq) + HCl(aq) NaCl(aq) + H2O(l)

MgO(s) + 2HNO3(aq) Mg(NO3)2(aq) + H2O(l)

2. Displacement of volatile ammonia from ammonium salt by a non volatile alkali: if an ammonium salt is warmed with an alkali (in the presence of water) ammonia gas is liberated

NaOH (aq) + NH4Cl (aq) NaCl (aq) + H2O(l) + NH3(g)

Ca (OH)2(aq) + (NH4)2SO4(aq) CaSO4(aq) + 2H2O(l) + 2NH3(g)

**USES OF ALKALIS/BASE**

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| --- | --- |
| Names | Uses |
| NaOH | Used in the manufacture of soap, Na salts and plastic  Used in petrol refining. |
| KOH | Used in the manufacture of liquid soap  Used in dyeing and electroplating. |
| Ca(OH)2 | Used in manufacture of mortar, cement and plaster  Used in dissolving acidic soil. |
| Mg(OH)2 | Used in the manufacture of toothpaste  Used as a laxative. |
| Aqueous NH3 | Used for bleaching cloth  Used as detergent. |

**EVALUATION**

1. Define alkali giving examples

2. State three physical properties of alkalis

3. Using balanced equations, state two chemical properties of bases

4. State the uses of bases

**NEUTRALIZATION REACTION**

Neutralization reaction can be defined in three major ways.

1. In terms of acid and the base present.

2. In terms of H+ ion and OH- present in the acid and base.

3. In terms of oxonium ions (H3O+) and hydroxide ion (OH-).

Neutralization is the process whereby an acid react completely with an alkalis/bases to form salt and water.

HCl(aq) + NaOH(aq) NaCl(aq) + H2O(l)

Neutralization is the combination of hydrogen ion (H+) and hydroxide ions (OH-) to form water molecules. A salt is also form at the same time.

H+(aq) + OH- H2O(l)

Neutralization can also be defined as the combination of oxonium ions (H3O+) and hydroxide ions (OH-) to form water molecule. A salt is also formed at the same time.

H3OCl(aq) + KOH(aq) KCl(aq) + H2O(l)

(H3O)2SO4(aq) + 2NaOH(aq) Na2SO4(aq) + 4H2O(l)

H3O+(aq) + OH-(aq) 2H2O(l)

**OXONIUM ION**

In aqueous solution, the hydrogen ion become associated with a water molecule to form oxonium ion (H3O+).This is an example of a coordinate covalent combination.

H+ + H2O H3O+

During neutralization, oxonium ion H3O+ behaves as hydrogen ion and thus reacts with hydroxide ion (OH-) to form water molecules.

**EVALUATION**

1. Define the term neutralization.

2. Write TWO balanced equations to show neutralization reactions.

**SALTS**

A salt is referred to as the compound formed when all or part of the ionisable hydrogen ion in an acid is replaced by a metallic or ammonium ion e.g.

HCl(aq) + NaOH(aq) → NaCl(aq) + H2O(l)

H2SO4(aq) + KOH(aq) → KHSO4(aq) + H2O(l)

**TYPES OF SALTS**

There are five main types of salts namely:

1. Normal salt.

2. Acid salts

3. Basic salts

4. Double salts.

5. Complex salts.

1. **Normal salts**: are the salts formed when all the replaceable hydrogen ion in the acid has been completely replaced by a metal ion e.g. NaCl, K2SO4, Na3PO4, NaNO3 etc. Normal salts are neutral to litmus

HCl(aq) + NaOH(aq) NaCl(aq) + H2O(l)

H2SO4(aq) + KOH(aq) K2SO4(aq) + H2O(aq)

2. **Acid salt**s: Acid salts are formed when the replaceable hydrogen ion in the acids are only partially replaced by a metal e.g. NaHSO4, Na2HPO4, NaH2PO4, NaHCO3. They can be produce from acids which contain more than one replaceable hydrogen ion. Acids with two replaceable hydrogen ions can form only one acid salt while acid with three replaceable hydrogen ions can form two different acid salts

H2SO4(aq) + NaOH(aq) NaHSO4(aq) + H2O(l)

2H3PO4(aq) + 3NaOH(aq) NaH2PO4(aq) + Na2HPO4(aq) +3H2O(l)

Acid salts turn blue litmus red. Acid salts can be converted to normal salt if the remaining replaceable hydrogen ions in the acid salt are replaced in with metallic ions.

KHSO4(aq) + KOH(aq) K2SO4(aq) + H2O(l)

3. **Basic salts**: Basic salts are formed when only part of the hydroxide ions of a base are replaced by the negative ions from an acid. It can occur when there is insufficient supply of acid for complete neutralization of the base e.g Zn(OH)Cl , Mg(OH)Cl, Mg(OH)NO3, Bi(OH)2NO3 e. t .c.

Zn(OH)2(aq) + HCl(aq) Zn(OH)Cl(aq) + H2O(l)

Because of the presence of hydroxide ion in the salt, it has basic properties. Basic salts turn red litmus blue. Basic salts react with excess acid to form a normal salt and water only.

Mg(OH)NO3(aq) + HNO3(aq) Mg(NO3)2(aq) + H2O(l)

4. **Double salts**: Double salts are salt which ionize to produce three different types of ions in solution. Usually two of these are positively charged (metallic or NH4+ ion) while the other is negatively charged e.g. (NH4)2Fe(SO4)2.6H2O, KAl(SO4)2.12H2O, KCr(SO4)2.12H2O.

(NH4)2Fe(SO4)2.6H2O: Ammonium iron (II) tetraoxosulphate (VI) hexahydrate.

KAl (SO4)2.12H2O: Aluminium Potassium tetraoxosulphate (V) dodecahydrate (Potash alum).

KCr (SO4)2.12H2O: Chromium (III) Potassium tetraoxosulphate (VI) dodecahydrate (Chrome alum).

5. **Complex salts**: Complex salts contains complex ion i.e ion consisting of a charged group of atom e.g. Na2Zn(OH)4, K4Fe(CN)6, NaAl(OH)4.

Na2Zn(OH)4: Sodium tetrahydroxozincate (ii)

K4Fe(CN)6 :Potassium hexacyanoferrate (iii)

NaAl(OH)4:Sodium tetrahydroxoaluminate (iii)

Na2Zn(OH)4 2Na+ + [Zn(OH)4]2-

K4Fe(CN)6  4K+ + [Fe(CN)6]4-.

**HYDROLYSIS OF SALT**

Some salts undergoes hydrolysis in water to give an acidic or alkaline medium (solution) e.g. Na2CO3, NaHCO3, AlCl3, Na2S, NH4Cl, CH3COONa e.t.c.

Na2CO3 + H2O NaOH + H2CO3.

AlCl3 + H2O Al (OH)3 + HCl.

Na2S + H2O NaOH + H2S

Hydrolysis of salt occurs when a salt react with water e.g salt of strong acid and weak base gives acidic solution. The change in PH of solution is due to hydrolysis.

**USES OF SALTS**

1. NH4Cl is used as an electrolyte in dry cell (Leclanche cell)

2. CaCO3 is used as medicine to neutralise acidity in the stomach

3. CaCl2 is used as antifreeze while fused CaCl2 is used as a drying agent and also in dessicator.

4. CaSO4 is used for making plaster of Paris.

5. CuSO4 is used in dyeing and calico printing.

6. MgSO4 is used as a laxative.

7. KNO3 is used for making gunpowder, matches and soil fertilizer.

8. NaCl is used for preserving food and in glazing pottery.

9. ZnCl2 is used in petroleum refining

**EVALUATION**

1. Define salt?

2. List the five main types of salts giving two examples each

3. Name four salts and state the use of each of them

**SOLUBILITY RULE**

|  |  |  |
| --- | --- | --- |
| **S/NO** | **SOLUBLE SALTS** | **INSOLUBLE SALTS** |
| 1. | All Na+, K+ and NH4+ salt |  |
| 2. | All trioxonitrate (v) |  |
| 3. | All chloride except | PbCl2, HgCl2 and AgCl are soluble in hot water. |
| 4. | Trioxocarbonate (iv) of Na+, K+ and NH4+ | All other trioxocarbonate (iv). |
| 5. | Trioxosulphate (vi) of Na+, K+, NH4+ & Cu2+ | All other trioxosulphate (IV) |
| 6. | Sulphide of Na+, K+ and NH4+ | All other sulphide. |
| 7. | All tetraoxosulphate (vi) except | PbSO4, BaSO4 and CaSO4 are slightly soluble in H2O |
| 8. | All hydrogen trioxocarbonate (iv) |  |
| **S/NO** | **SOLUBLE BASE/ALKALIS** | **INSOLUBLE BASE/ALKALIS** |
| 1. | K2O, Na2O are very soluble  MgO, CaO are slightly soluble | Other oxide are insoluble |
| 2. | NaOH, KOH, Ca(OH)2 are very soluble  Mg (OH)2 is slightly soluble. | Other hydroxides are insoluble. |

**METHOD OF PREPARATION OF SALTS**

The method of preparing a particular salt depends on its:

1. Solubility in water

2. Stability to heat.

It is necessary, therefore, for us to become familiar with the simple rules of solubility indicated above. Knowing the solubility of the salt enables us to determine which method to be used.

**SOLUBLE SALT**

Soluble salts can be prepared by the following method:

1. Neutralization of an acid by an alkali

2. Action of dilute acid on a metal.

3. Action of dilute acid on an insoluble base.

4. Action of dilute acid on trioxocarbonate (IV).

**RECOVERING SOLUBLE SALTS FROM SOLUTION**

This can be done by:

1. Heating to dryness: This is used to prepare soluble salts which are not destroyed or decomposed by heat e.g. most chlorides such as NaCl, ZnCl2, FeCl2 and FeCl3 are recovered by heating.

2. Crystallization: This is used to prepare salt which are easily decomposed or destroyed by dry heating. All trioxonitrate (V) and tetraoxosulphate (VI) are recovered by crystallization.

**INSOLUBLE SALTS**

Insoluble salts can be prepared by the following method:

1. Double decomposition or precipitation.

Pb (NO3)2(aq) + 2NaCl (aq) 2NaNO3 (aq) + PbCl2(s)

AgNO3 (aq) + NH4Cl (aq) NH4NO3 (aq) + AgCl(s)

2. Direct combination of 2 elements.

Fe(s) + S(s) FeS(s)

2Fe(s) + 3Cl2(g) 2FeCl3(s)

**ANHYDROUS AND HYDRATED SALT**

Anhydrous salts: are salts which do not contain water and cannot be crystallized out from aqueous solution.

Hydrated salts/salts with water of crystallization: are salts which combine chemically with water. The water molecule is loosely held to the salt molecule and when heated, such salt lose their water of crystallization. The water attached is known as water of crystallization e.g

Cu(NO3)2.3H2O: Copper (ii) trioxonitrate (v) trihydrate.

MgSO4.7H2O: Magnesium tetraoxosulphate (vi) heptahydrate.

FeSO4.7H2O: Iron (ii) tetraoxosulphate (vi) heptahydrate.

|  |  |
| --- | --- |
| Salts without water of crystallization | Salts with water of crystallization |
| NaCl | CuSO4.5H2O |
| KNO3 | FeSO4.7H2O |
| KMnO4 | ZnSO4.7H2O |
| (NH4)2SO4 | Na2CO3.10H2O |
| K2SO4 | Cu(NO3)2.3H2O |
| Pb(NO3)2 | MgSO4.7H2O |
| AgNO3 | Zn(NO3)2.6H2O. |

Calculation of water of crystallization

14g of hydrated H2C2O4.xH2O was heated to give an anhydrous salt weighing 9.99g.

(a). Calculate the value of x.

(b). Give the formula of the hydrated salt.

(c). Calculate the % of water of crystallization.

Solution

(a). Mass of hydrated salt = Molar mass of hydrated salt

Mass of water molecule Molar mass of water molecule

14 = (90+18x)

(14-9.99) 18x

14 = (90 +18x)

4.01 18x

14(18x) = 4.01 (90 + 18x)

252x = 360.9 + 72.18x

252x – 72.18x = 360.9

179.82x = 360.9

x = 360.9/179.82

x = 2.007

x = 2 to the nearest whole number.

(b) Formula of hydrated salt = H2C204.2H20.

(c) To calculate the % of water of crystallization:

% of water of crystallization = Mass of water x 100%

Total mass

= 36 x 100

(90 + 36)

= 36 x 100

126

= 3600

126

= 28.57%

**EFFLORESCENCE, DELIQUESCENCE AND HYGROSCOPIC**

When certain compound is exposed to the air, they either lose their water of crystallization or they absorb moisture from their surroundings. The term efflorescent, deliquescent and hygroscopic are used to describe such compound.

**EFFLORESCENTS**: are substances which on exposure to air, lose some or all of their water of crystallization. The phenomenon or process is efflorescence. There is loss of weight or mass of the substances.

e.g Na2CO3.10H2O Na2CO3.H2O + 9H2O

Other examples are Na2SO4.10H2O, MgSO4.7H2O and CuSO4.5H2O e.t.c

**DELIQUESCENTS**: are substances that absorb so much water from air and form a solution e.g. NaOH, CaCl2, FeCl3, MgCl2, KOH and P4O10. There is a gain in weight.

**HYGROSCOPIC**: are substances which absorb moisture on exposure to the atmosphere without forming a solution. If they are solids, no solution will be formed but if a liquid absorb water, it gets diluted. There is little or no difference in mass e.g Conc. H2SO4, NaNO3, CuO, CaO and anhydrous Na2CO3.

**DRYING AGENTS**

These are substances which have high affinity for water or moisture. They are either deliquescent or hygroscopic. They remove water molecules to effect physical change. Drying agents are different from dehydrating agents which removes elements of water i.e hydrogen and oxygen atoms or intra-molecular water.

Drying agents which react with gases are not used to dry the gas e.g conc. H2SO4 is not used to dry NH3 and H2S gas.

NH3(g) + H2SO4(aq) (NH4)2SO4(aq)

H2S(g) + H2SO4(aq) 2H2O(l) + SO2(g) + S(s)

|  |  |
| --- | --- |
| Drying agent | Gases |
| Conc. H2SO4 | All gases except NH3 & H2S |
| Fused CaCl2 | All gases except NH3 |
| CaO or quicklime | For ammonia |
| P2O5 | All gases except ammonia |
| Silica gel | All gases |

Salts are usually dried in dessicator.

**EVALUATION**

1. Using balanced equations, state two methods of preparing: (a) Soluble salt (b) insoluble salt

2. How can soluble salts be recovered from their solution?

**GENERAL EVALUATION/REVISION**

1. Calculate the percentage of water in sodium trioxocarbonate (iv) heptahydrate

2. What is the number of molecules in 6.4g of sulphur (iv) oxide (NA=6.0X1023/mol)

3. Write an equation to show the acid formed when phosphorus (v) oxide is dissolved in cold water and name the acid formed

4. Differentiate between a base and an alkali

5. Define: Efflorescence, Deliquescence and Hygroscopy

**WEEKEND ASSIGNMENT**

1. The two types of bonds that exist in H3O+ are a. covalent and ionic b. co-ordinate covalent and covalent c. metallic and ionic d. polar covalent and metallic

2. How many moles of hydrogen ions are there in 50cm3 of 0.20moldm-3 H2SO4?

a. 0.01 b 0.02 c 0.10 d 0.20

3. Which of these is not recovered through dry heating (evaporation)?

a. NaClO3 b. NH4NO3 c. CuHSO4 d. NaHCO3.

4. Which pH value indicates a basic solution? a. -1 b.3 c.9 d.7

5. All common gases are dried using P2O5 except a. NO2 b. NH3 c. SO2 d. H2S

**THEORY**

1. Give the reason for each of the following:

a. Sodium salts cannot be prepared by double decomposition

b. Na2CO3(aq) which is a salt solution, turns red litmus blue.

2. 1.34g of hydrated Na2SO4 was heated to give an anhydrous salt weighing

0.71g.

a. Calculate the number of molecules of water of crystallization

b. Give the formula of the hydrated salt [Na=23, S=32, O=16, H=1].

**WEEK FOUR**

**TOPIC: CARBON AND ITS PROPERTIES**

**CONTENT**

* Occurrence and Allotropes
* Properties

**OCCURRENCE**

1. It occurs naturally as diamond and graphite.

2. It occurs in an impure form as coal.

3. It occurs in the combined state as petroleum, wood and natural gases.

4. It occurs in minerals such as limestone (CaCO3) and dolomite (MgCO3)

5. It occur in the atmosphere (air) as CO2

6. It is an essential constituent of all forms of plant and animal life.

**ALLOTROPES OF CARBON**

Allotropy is the phenomenon whereby an element exists in two or more different forms in the same physical state. The different forms of the elements are known as allotropes. They have the same chemical properties but different physical properties.

Carbon exists in several allotropic forms:

(1). Crystalline Allotropes e.g Diamond and graphite

(2). Non-crystalline Allotropes/Amorphous carbon e.g coal, charcoal, coke, lampblack and carbon black (soot)

**Crystalline Allotropes of carbon**

Diamond: Diamond is the purest form of carbon. The diamond crystal is octahedral in shape. It is actually a giant molecule in which the carbon atoms are closely packed and held together by strong covalent bonds.

Basic Tetrahedral Shape in Diamond Crystals

**PROPERTIES OF DIAMOND**

(1) Diamond is extremely hard and strong with high melting point because of strong covalent bond. Diamond is the hardest substance known in the world.

(2) It has a high density because of its compactness of crystal.

(3) It is a very resistant to chemical action and temperature because all four valence electrons are saturated bonded.

(4) It is a non-conductor of electricity because there are no free valence electrons in the crystal lattice.

(5) Transparent and highly refractive, hence it is used as a jewel and sparkling substance.

**USES**

(1) They are used industrially in drills for in mining since they are dense and hard.

(2) They are used to sharpen very hard tools.

(3) They are used for cutting glass and metals.

(4) They are also used as pivot supports in precision instruments and as dies for drawing wires

(5) It is valuable in making jewellery (i.e. its high refractive index and dispersion power give it a sparkling brilliance when it is cut and polished).

Artificial diamond: They are made by subjecting graphite to a very high temperature and pressure for several hours in the presence of nickel or rhodium catalyst.

**GRAPHITE**: The graphite crystal is hexagonal in shape. The carbon atoms in graphite form flat layers. These layers are arranged in parallel, one above the other to form a crystal lattice.

**PROPERTIES OF GRAPHITE**

(1) Graphite is soft and slippery because of weak forces holding its layers. Each layer can slide over one another. Hence, graphite acts as a lubricant.

(2) It is less dense and prone to chemical attack due to its open structures in layers.

(3) It is a good conductor of electricity because of the presence of free delocalized electrons (mobile electron) in the crystal lattice.

(4) It is inert and used to absorb radiations in nuclear station in atomic pile.

**USES**

(1) It is usually used on bicycle chains and for the bearings of some motor cars.

(2) It is used as a non greasy lubricant (i.e combining it with oil makes a high temperature lubricant).

(3) It is used as electrodes in electroplating and in dry cells (since it is a good conductor of electricity and relatively inert).

(4) Graphite can be used to make a non-conductor conductive by coating with it.

(5) It is used to line crucibles for making high-grade steel and other alloys (since it can withstand high temperature).

(6) It is used in making lead pencils i.e. combining it with clay makes lead in pencils.

(7) It is used as a black pigment in paints.

(8) It is used as a neutron moderator in atomic piles.

**INDUSTRIAL PREPARATION OF GRAPHITE**

Graphite is produced industrially by heating coke in an electric furnace to a very high temperature for about 20 to 30 hours. This process is called the Acheson process. Acheson process is a process of producing graphite from coke at high temperature. Air is excluded by covering the coke with sand. The graphite produced is very pure and free from grit.

**DIFFERENCES IN PROPERTIES BETWEEN GRAPHITE AND DIAMOND**

|  |  |
| --- | --- |
| Graphite | Diamond |
| 1. It has a density of 2.3gcm-3 | 1. It has a density of 3.5gcm-3 |
| 2. It is a black, opaque solid | 2. It is a colourless, transparent solid |
| 3. It is very soft, marks paper | 3. It is the hardest known substance. |
| 4. It is a good conductor of electricity | 4. It is a non-conductor of electricity |
| 5. Attacked by potassium trioxochlorate (v) and trioxonitrate (v) acid together. | 5. Not attacked by these reagents. |

Note: Diamond is transparent to x-rays while glass is almost opaque.

**EVALUATION**

1. (a) What is allotropy? (b) Mention two allotropes of carbon

2. Compare the properties of these allotropes of carbon.

**AMORPHOUS CARBON**

Carbon also occurs in a number of other forms which has no definite crystalline structure. These non-crystalline structures which are not considered to be true allotropes include:

CHARCOAL: This is made by burning wood, bones, sugar etc in a limited amount of air. Charcoal is used to remove colour from substances. Wood charcoal is used in absorbing poisonous gases while animal charcoal is used in absorbing colours.

CARBON BLACK AND LAMP BLACK: Lamp black is obtained by burning the wick of an oil lamp excessively so that it leaves a deposit of soot on the lamp-glass and cover; while carbon black is obtained from burning coal gas, natural gas or petroleum. Carbon black and lamp black are used as an additive to rubber tyres. They are also used in making printer’s ink, carbon paper, black shoe polish, type writing ribbons e.t.c

**PHYSICAL PROPERTIES OF CARBON**

(1) All the different allotropes of carbon are black or greyish-black solids except diamond and they are odourless and tasteless.

(2) They have a high melting point of about 35000C.

(3) They are insoluble in all common solvents like water, alkalis, acids, petrol and carbon (iv) sulphide (CS2). This is the reason carbon deposits inside motor engines have to be removed mechanically. This is known as decarbonisation of motor engines.

**CHEMICAL PROPERTIES OF CARBON**

(1) Combustion:

(a) All forms of carbon burn in excess oxygen to produce carbon (iv) oxide gas.

C(s) + O2(g) CO2(g) ( Complete combustion)

(b) All forms of carbon also burn in a limited supply of air to produce carbon (ii) oxide.

C(s) + O2(g) CO(g)  ( Incomplete combustion)

(2) Combination reaction: Carbon combines directly with certain elements such as Sulphur, Hydrogen, Calcium and Aluminium at very high temperatures.

C(s) + 2S(s) CS2(l)

Carbon (iv) sulphide

C(s) + 2H2(g) CH4(g)

Methane

2C(s) + Ca(s) CaC2(s)

Calcium carbide

3C(s) + 4Al(s) Al4C3(s)

Aluminium carbide.

(3) As a reducing agent: Carbon is a strong reducing agent. It reduces the oxides of the less active metals to the metals, while carbon is itself oxidized to either carbon (iv) oxide or carbon (ii) oxide, depending on the reaction conditions.

Fe2O3(s) + 3C(s) 2Fe(s) + 3CO(g)

2CuO(s) + C(s) 2Cu(s) + CO2(g)

H2O(g) + C(s) CO(g) + H2(g)

CO2(g) + C(s) 2CO(g)

K Na Ca Mg Al Zn Fe Sn Pb H

Cu Hg Ag Au

The oxide is not reduced The oxide is reduced to the metal when

when heated heated

ZnO(s)  + C(s) Zn(s) + CO(g)

PbO(s) + C(s) Pb(s) + CO(g)

(4) Reaction with strong oxidizing agents: When carbon is heated with conc. HNO3 or conc. H2SO4, it is oxidized to Carbon (iv) oxide.

C(s) + 4HNO3(aq) 2H2O(l) + 4NO2(g) + CO2(g)

C(s) + 2H2SO4(aq) 2H2O(l) + 2SO2(g) + CO2(g)

**EVALUATION**

1. List the amorphous allotropes of carbon and state the use of each

2. Write balanced equations to show the chemical properties of carbon

**WEEKEND ASSIGNMENT**

1. The existence of an element in two or more form in the same physical state is known as a. allotropy b. isotopy c. isomerism d. hybridization.

2. The equation Fe2O3(s) + 3C(s) 2Fe(s) + 3CO(g)

a. is oxidation reaction of carbon b. reduction reaction of carbon. c. carbonization of Fe2O3 d. destructive distillation of Fe2O3.

3. Which of the following correctly describes the structure of graphite? a. ionic lattice b. network structure c. molecular solid d. layer lattice.

4. Carbon is often deposited in the exhaust pipe of cars because of a. dehydrogenation of petrol b. incomplete combustion of petrol c. presence of additives in petrol  d. presence of carbon in petrol.

5. Graphite and diamond are allotropes of Carbon but only graphite conducts electricity because graphite a. is tetrahedral while diamond is octahedral in shape b. contains mobile ions but diamond does not c. is soft but diamond is hard d. contains free electrons but diamond does not.

**THEORY**

1. Mention the respective properties of the following allotropes of carbon that account for their uses as indicated (a) Diamond used for drilling rock (b) Diamond used as a jewel (c) Graphite used for slowing down neutrons in nuclear reactors. (d) Graphite used as electrode

2. (a) State one evidence that shows that both graphite and diamond are

allotropes. (b) Give reasons why graphite is soft and diamond, its allotrope is hard.

**WEEK FIVE**

**TOPIC**: **OXIDE OF CARBON**.

**CONTENT**

* Carbon (iv) oxide
* Carbon (ii) oxide

**CARBON (iv) OXIDE**

The percentage composition of carbon (iv) oxide in the atmospheric air is about 0.03% by volume while in dissolved air is about 0.50% by volume.

**Laboratory preparation**

1. Carbon (iv) oxide is prepared in the laboratory by the action of dilute acids on a trioxocarbonate (iv) or a hydrogen trioxocarbonate (iv). Usually CaCO3, in form of marble chips, shells or ‘potash’; is used with hydrochloric acid or trioxonitrate (v) acid. Reaction between CaCO3 and HCl can be carried out in a Kipp’s apparatus.

CaCO3(s) + 2HCl(aq) CaCl2(aq) + H2O(l) + CO2(g)

NaHCO3(aq) + HNO3(aq) NaNO3(aq) + H2O(l) + CO2(g)

2. It is also prepared by heating metallic trioxocarbonates (iv) [except those of Na and K], or the hydrogen trioxocarbonate (iv) of Na or K.

CuCO3(s) CuO(s) + CO2(g)

Note: If the gas is required dry, it is pass through potassium hydrogen trioxocarbonate (iv) solution first to remove any acid fumes, and then through a U-tube containing fused Calcium chloride to remove the water vapour. The dry gas is then collected by downward delivery as it is heavier than air.

**Method of collection of gases**

The method of collection of gases depends on its:

1. Density.

2. Solubility.

There are two method of collecting gases:

(a) Downward delivery/upward displacement of air: This method is used for collecting gases that are denser than air e.g. CO2, SO2, H2S, NO2, Cl2 and HCl e.t.c.

(b) Upward delivery/downward displacement of air: This method is used for collecting gases that are less denser than air e.g NH3, H2, N2, methane and ethane.

**INDUSTRIAL PREPARATION**

CO2 is obtained industrially as a by product in fermentation processes and when limestone is heated to make quicklime.

**PHYSICAL PROPERTIES**

(1) CO2 is a colourless, odourless gas with a sharp refreshing taste.

(2) It is about 1.5 times denser than air.

(3) It is soluble in water. At room temperature and standard pressure, water dissolves its own volume of the gas.

(4) It turns damp blue litmus paper pink because CO2 dissolves in water to yield trioxocarbonate (iv) acid.

(5) On cooling, it readily liquefies and solidifies (-780C) to form a white solid known as dry ice.

**CHEMICAL PROPERTIES**

1. Reaction with water: Carbon (iv) oxide is not very active chemically. It dissolves in water to form trioxocarbonate (iv) acid (Soda water). This is a weak, dibasic acid which ionizes slightly.

(a) CO2(g) + H2O(l) H2CO3(aq)

(b) H2CO3(aq) + H2O(l) H3O+(aq) + HCO3-(aq)

(c) HCO3- (aq) + H2O(l) H3O+(aq) + CO32-(aq)

On heating, trioxocarbonate (iv) acid decomposes to form H2O(l) and CO2(g).

2. Reaction with alkalis: It reacts directly with alkalis to yield trioxocarbonate (iv)

CO2(g) + 2NaOH(aq) Na2CO3(aq) + H2O(l)

Limited

Excess CO2 reacts with alkalis to produce Hydrogen trioxocarbonate (iv) salt.

CO2(g) + NaOH(aq) NaHCO3(aq)

Excess.

3. Reaction with burning Na, K or Mg: CO2 is reduced to carbon by burning Na, K or Mg.

CO2(g) + 2Mg(s) C(s) + 2MgO(s)

Note: CO2 does not support combustion.

4. Reaction with red hot carbon: CO2 is reduced to CO, If the gas is passed over red hot carbon.

CO2(g) + C(s) 2CO(g)

The reaction is of great importance in the blast furnace and in the manufacture of gaseous fuels.

**Test for CO2:** Bubble the unknown gas through a solution of lime water (Calcium hydroxide)if the lime water turn milky due to the formation of insoluble calcium trioxocarbonate (iv), then the unknown gas is CO2

Ca(OH)2(aq) + CO2(g) CaCO3(s) + H2O(l).

If the gas is bubbled in excess, the milkiness disappears and turns to a clear solution due to the formation of soluble calcium hydrogen trioxocarbonate (iv).

CaCO3(s) + H2O(l) + CO2(g) Ca(HCO3)(aq)

Finally, if the clear solution is heated, the milkiness reappears due to the decomposition of soluble Ca(HCO3)2 to form insoluble CaCO3

Ca(HCO3)2(aq) CaCO3(s) + H2O(l) + CO2(g)

**Uses of carbon (iv) oxide**

1. It is used as fire extinguishers since it does not support combustion.

2. It gives carbonated (aerated) drinks their refreshing taste. Beer, cider and champagne contains CO2

3. It is used in the manufacture of Na2CO3 (washing soda) by the Solvay process.

4. It is used as a leavening agent in the baking of bread. Yeast and baking powder produces CO2 which make the dough of bread to rise.

5. It is used in the manufacture of fertilizer (such as urea and (NH4)2SO4.

6. Solid CO2 (i.e dry ice) is used as a refrigerant for perishable goods e.g ice cream. (It sublimes on warming and provides a lower temperature).

7. Gaseous CO2 is used to preserve fruits.

8. CO2 is also used as a coolant in nuclear reactors.

**EVALUATION**

1. Describe the laboratory preparation of dry carbon (iv) oxide.

2. Write balanced equation to show the following reactions of CO2:

(a) Reaction with sodium hydroxide

(b) Reaction with burning magnesium

**CARBON (II) OXIDE**

**LABORATORY PREPARATION**

1. Carbon (ii) oxide can be prepared by passing Carbon (iv) oxide through red-hot carbon while the Carbon (iv) oxide is itself reduced to Carbon (ii) oxide. The gaseous mixture is passed through concentrated NaOH to remove the excess Carbon (iv) oxide.

CO2(g) + C(s) 2CO(g)

The pure Carbon (ii) oxide is collected over water.

2. Carbon (ii) oxide can also be prepared by the dehydration of methanoic (formic) acid or ethanedioic (oxalic) acid, using concentrated tetraoxosulphate (vi) acid.

HCOOH(l) Conc. H2SO4 CO(g)  + H2O

Methanoic acid

Note: The gaseous mixture is passed through concentrated NaOH to remove the CO2.

Caution: The preparation of CO must be done in a fume cupboard as the gas is poisonous.

The major air pollutants that can result from smoky vehicles are Carbon (ii) oxide and Carbon particles.

When CO is breath in for any length of time, even 1% of it in the air may cause death, which makes it clear how dangerous it can be to run a car engine in a closed garage or a generator in a closed room. Very often the victim collapse without warning so insidious is its effect.

**PHYSICAL PROPERTIES OF CO**

(1) CO is a poisonous, colourless, tasteless and odourless gas.

(2) It is insoluble in water, but dissolves in a solution of ammoniacal copper (i) chloride.

(3) It is neither lighter nor heavier than air.

(4) It is neutral to litmus.

**CHEMICAL PROPERTIES OF CO**

(1) As a reducing agent: CO is a strong reducing agent. It reduces some metallic oxides to the metals and it is oxidized to CO2.

PbO(s) + CO(g) Pb(s) + CO2(g)

Fe2O3(s) + 3CO(g) 2Fe(s) + 3CO2(g)

CuO(s) + CO(g) Cu(s) + CO2(g)

2. Combination reaction

(a). With oxygen: CO burns in air with a faint pale blue flame to form CO2 .

2CO(g) + O2(g) 2CO2(g)

(b). With haemoglobin: CO combine irreversibly with haemoglobin in the red blood cells to form carboxy-haemoglobin thereby preventing the red corpuscle from acting as oxygen carrier.

3. CO mixed with NaOH at 1500C under 50atm pressure to form Sodium formate.

CO(g) + NaOH(aq) HCOONa(aq)

This product decomposes into Sodium oxalate and H2 at 4000C

COONa

2HCOONa(aq) + H2(g) 4000C COONa

4. CO combined with certain metals (e.g Ni, Fe, Cobalt) when hot to form a volatile carbonyl.

Ni(s) + 4CO(g) Ni(CO)4(aq)

5. CO is absorbed readily by a solution of Copper (i) Chloride (CuCl) in aqueous NH3 or conc. HCl forming a compound, CuCl.CO.2H2O. This reaction is used to separate CO from a mixture of gases.

CO(g) + CuCl(s) + 2NH4OH(aq) CuCl.CO.2H2O(aq) + 2NH3(g)

6. CO combined with Chlorine gas when expose to ultra-violet light or passed over a catalyst of activated charcoal at 1500C to form carbonyl chloride.

CO(g) + Cl2(g) COCl2(g)

This product, COCl2, is also known as Phosgene and was employed as a poisonous gas in the First World War. It is now use in the manufacture of dyestuff.

**Test for Carbon (ii) oxide**

When a lighted splint is inserted into a test tube containing CO(g) and some lime water added to it and shaken, the CO(g) burn with a pale-blue flame and turn lime water milky after burning but not before burning.

**Uses of Carbon (ii) oxide**

(1) CO is used in the extraction of metals from their ores.

(2) It is also an important constituent of gaseous fuels like producer gas and water gas.

(3) CO gas is used in the manufacture of methyl alcohol, synthetic petrol, carbonyl chloride, oxalate and formate.

**EVALUATION**

1. Describe the laboratory preparation of Carbon (ii) oxide.

2. Explain why Carbon (ii) oxide cannot be collected by any method of delivery

3. Write two equations to show the chemical properties of Carbon (ii) oxide

**GENERAL EVALUATION/REVISION**

1. What is the pH of a solution whose H+ concentration is 3.0 x 10-5moldm-3?

2. Mention the separation technique that be used to recover a soluble salt that (a) decompose on heating (b) does not decompose on heating

3. How many molecules are there in 14g of Nitrogen gas at s.t.p? [N=14, NA=6.0 x 102]

4. What is the number of oxygen atoms in 32g of the gas?

5. State Avogadro’s law

**WEEKEND ASSIGNMENT**

1. Kipp’s apparatus is important in the laboratory because it (a) allows intermittent supply of gases. (b) is used for preparing poisonous gases. (c) is used to prepare light gas. (d) is used to prepare sensitive gas

2. Gas prepared by the reaction between methanoic acid and concentrated tetraoxosulphate (vi) acid is (a) SO2 (b) CO (c) CO2 (d) H2S.

3. Gas which dissolves in ammoniacal copper (i) chloride but insoluble in water is

(a) NH3 (b) CO (c) N2O (d) CO2.

4. Where else is CO2 found in free state apart from the atmosphere?

(a) In carbonated drinks. (b) Dissolved form in water. (c) In corals. (d) In limestone region

5. It is dangerous to stay in a badly ventilated room which has a charcoal fire because of the presence of (a) carbon (ii) oxide (b) carbon (iv) oxide (c) hydrogen sulphide (d) producer gas.

**THEORY**

1(a) Why is the laboratory preparation of carbon (ii) oxide done in a fume chamber?

(b) State the property of CO2 that makes it to be used in (i) carbonated drinks (ii) fire extinguishers

2(a) Why it is not advisable to stay in a closed garage for a long time when racing a car engine.

(b). State what is observed when (i) excess CO2 is bubbled through lime water. (ii) the solution in b(i) above is heated.

**WEEK SIX**

**TOPIC**: **COAL AND FUEL GASES**

**CONTENT**

* Coal.
* Fuel gases/Gasification of coke.

**COAL**

Coal is an impure form of carbon. Coal is a complex mixture of compounds composed mainly of carbon, hydrogen and oxygen with small amounts of nitrogen, sulphur and phosphorus as impurities.

**Carbonization of coal.**

Coal was formed by the gradual decomposition of plant vegetation under pressure and in the absence of air. Carbon (iv) oxide, methane, and steam were liberated, leaving behind a material that contained a very high percentage of carbon.

During this process of carbonization, the vegetable material was converted in stages into peat. They gradually passed through several stages: Peat lignite bituminous anthracite.

**Types of Coal**

There are 4 different types of coal namely:

(1) Peat-like coal: It contains about 60% of carbon by mass.

(2) Lignite coal (brown coal): It contains about 67% of carbon by mass.

(3) Anthracite coal (or hard coal): It is tough and hard. It contains about 94% of carbon by mass. Impurities present may include nitrogen, sulphur and phosphorus. Anthracite is the last stage of coal.

(4) Bituminous (soft) coal: These are use every day at home. It contains about 88% by mass of carbon.

**Destructive Distillation of Coal**

The process by which a wide variety of substances can be obtained from coal is known as the destructive distillation of coal.

During the process, coal is heated to a very high temperature in the absence of air so that all the volatile components distil over.

Coal Coke + Ammoniacal liquor + Coal tar + Coal gas.

Coal decomposes to yield a number of products such as:

Solid product e.g coke: It is the non-volatile residue left behind after destructive distillation.

**Uses of coke**

(i) Coke is mainly used as a fuel.

(ii) It is a very important industrial reducing agent and is used in the extraction of metals, especially iron, from their ores.

(iii) It is also used in the production of gaseous fuels, like water gas and producer gas.

(iv) It is used for the manufacture of graphite, calcium carbide, silicon carbide and carbon (iv) sulphide.

2. Liquid product: It include: Ammoniacal liquor and coal tar.

(a) Ammoniacal liquor: is a solution of NH3 in water.

(b) Coal tar: This is the thick, viscous substance from which more than a hundred other products are derived. Products obtained by fractional distillation of coal tar include toluene, phenol, benzene, naphthalene and anthracene which are used in the synthesis of important commercial product like dyes, paints, insecticides, drugs, plastics and explosives.

3. Gaseous product e.g coal gas: It consists mainly of about 50% hydrogen, 30% methane, 10% carbon (ii) oxide with small amounts of gaseous impurities such as SO2, CO2, ethane, N2, hydrogen sulphide, carbon (iv) sulphide and hydrogen cyanide.

|  |  |
| --- | --- |
| Distillates of Coal | Uses |
| 1.Ammoniacal liquor | To produce (NH4)2SO4 for fertilizer. |
| 2.Coal tar | To produce useful chemicals such as disinfectants and perfumes |
| 3.Coal gas | Used as industrial fuel. |

**Uses of coal**

1. Coal is used mainly as fuel to generate power for steam engines, factories and electrical plants.

2. It is also used for making various chemicals.

**EVALUATION**

1. List the types of coal.

2. List the products of the destructive distillation of coal and state the use of each product

**FUEL GASES/GASIFICATION OF COKE**

There are 3 types of fuel gases.

Producer gas: Producer gas is a mixture of nitrogen and carbon (ii) oxide. It is prepared by passing a stream of air through red hot coke.

2C(s) + O2(g) + N2(g) 2CO(g) + N2(g) + Heat

Producer gas

Water gas: Water gas is a mixture of hydrogen and carbon (ii) oxide gas. It is prepared by passing steam over white hot coke.

H2O(g) + C(s) CO(g) + H2(g)

Steam white hot coke Water gas

Water gas is then mixed with excess steam, and the mixture passed over iron (iii) oxide catalyst at 4500C.The carbon (ii) oxide decomposes the steam and the product are hydrogen and carbon (iv) oxide.

CO(g) + H2(g) + H2O(g) CO2(g) + 2H2(g)

Caustic soda or water is used to absorbed carbon (iv) oxide from the mixture. Ammoniacal copper (i) chloride can be used to remove unreacted carbon (ii) oxide. The final product is hydrogen.

**Differences between Producer Gas and Water Gas**

(1) Producer gas has a low calorific value while water gas has a high calorific value (i.e producer gas has a lower heating ability than water gas.

(2) Water gas consists of equal volumes of hydrogen and carbon (ii) oxide both of which are combustible whereas producer gas consists of 33% combustible CO and 67% non-combustible N2.

Note: Industrially, producer gas and water gas can be made in the same plant, by passing air and steam through heated coke at a temperature above 10000C.

Producer gas is inexpensive and is widely used in heating furnaces and firing of retorts (in the manufacture of Zn and coal gas) and limekilns. It is also a source of nitrogen for the manufacture of NH3 (Haber process).

Water gas is an important industrial fuel and is used in the manufacture of hydrogen and other organic compounds e.g. methanol and butanol.

3. Synthetic gas: It is a mixture of hydrogen and carbon (ii) oxide gas. It is prepared by mixing steam with methane (obtained as natural gas) and passing them over Nickel catalyst at about 8000C.

CH4(g) + H2O(g) CO(g) + 3H2(g)

Synthetic gas is not a major source of air pollution because sulphur is removed in the gasification process/it does not contain sulphur or sulphur compounds.

**EVALUATION**

1. List the three types of fuel gases.

2. What can be used to absorb carbon (iv) oxide from a water gas mixture?

3. What can be used to remove unreacted carbon (ii) oxide from a water gas mixture?

**WEEKEND ASSIGNMENT**

1. One of these is a reaction of charcoal (a) C(s) + O2(g) CO2(g)

(b) CO2(g) + C(s) CO(g) (c) 2CO(g) + O2(g) 2CO2(g)

(d) CO2(g) + 2CO(g) 2CO(g)

2. The liquid product of the destructive distillation of coal is

(a) ammoniacal liquor (b) coal fume (c) dyestuff (d) coal plasma.

3. Producer gas is a gas with a low heating power because it contains more

(a) CO2 than O2 (b) nitrogen than carbon (ii) oxide (c) CO2 than nitrogen (d) nitrogen than CO2.

4. Which of the following compounds would form a solution on exposure to air?

(a) CuSO4.5H2O (b) FeCl3 (c) NaNO3 (d) Na2SO4.10H2O.

5. Which of the following compounds is **insoluble** in water? (a) CaCl2 (b) NaCl (c) Na2SO4 (d) PbSO4.

**THEORY**

1. Name four products of the destructive distillation of coal and state one use of each.

2. List two differences between producer gas and water gas.

**WEEK SEVEN**

**TOPIC**: **TRIOXOCARBONATE (iv) ACID**

H2CO3 is formed when CO2(g) is dissolved in water. H2CO3 is a weak dibasic acid. It forms two series of salts:

1. Normal trioxocarbonate (iv)

2. Acidic hydrogen trioxocarbonate (iv)

**Normal trioxocarbonate (iv)**

Normal trioxocarbonate (iv) may be regarded as salts derived from H2CO3 by the complete replacement of the hydrogen by a metal or cationic radical.

**Preparation of soluble trioxocarbonates (iv)**

The CO32- of Na+, K+, and NH4+ are soluble in water. They are prepared in the laboratory by:

Bubbling CO2 through a solution of corresponding alkali.

2KOH(aq) + CO2(g) K2CO3(aq) + H2O(l)

Decomposition of corresponding hydrogen trioxocarbonates (iv).

2KHCO3(s) K2CO3(aq) + H2O(l) + CO2(g)

**Preparation of insoluble trioxocarbonates (iv)**

The insoluble metallic trioxocarbonates (iv) can be prepared by adding a solution of Na2CO3 or NaHCO3 to a solution of the corresponding metallic salt.

CaCl2(aq) + Na2CO3(aq) CaCO3(s) + 2NaCl(aq)

CaCl2(aq) + 2NaHCO3(aq) CaCO3(s)  + 2NaCl(aq) + H2O(l) + CO2(g) 2AgNO3(aq) + Na2CO3(aq) Ag2CO3(s) + 2NaNO3(aq)

2AgNO3(aq) + 2NaHCO3(aq) Ag2CO3(s) + 2NaNO3(aq) + H2O(l) + CO2(g)

Note: When preparing the CO32- of the less electropositive metals like Cu, use NaHCO3

**Properties of CO32- Salts**

Solubility: The trioxocarbonate (iv) of alkali metal and NH4+ are soluble while the other trioxocarbonate (iv) are insoluble in water.

Na2CO3(s) + 2H2O(l) 2NaOH(aq) + H2CO3(aq)

2. Action of heat: The trioxocarbonate (iv) of Na, K and Barium cannot be decomposed by heat while all other CO32- decompose on heating to liberate CO2.

ZnCO3(s) ZnO(s) + CO2(g)

2Ag2CO3(s) 4Ag(s) + 2CO2(g) + O2(g)

(NH4)2CO3(s) 2NH3(g) + CO2(g) + H2O(l)

1. Reaction with dilute acids: All trioxocarbonates (iv) react with dilute acids to form CO2, H2O and a salt.

Na2CO3(aq) + H2SO4(aq) Na2SO4(aq) + H2O(l) + CO2(g)

ZnCO3(s) + 2HCl(aq) ZnCl2(aq) + H2O(l) + CO2(g)

|  |  |  |
| --- | --- | --- |
| Metal | Solubility/effect of heat | Reaction with acids |
| K, Na | Soluble in water. Does not decompose on heating | These trioxocarbonate (iv) react with dilute acids to give a salt, water and carbon (iv) oxide. |
| Ca, Mg, Al, Zn  Fe, Sn  Pb, Cu | Insoluble in water. Decompose to yield the oxide and carbon (iv) oxide. Al2(CO3)3 does not exist. |
| Hg, Ag  Au | Insoluble in water. Decomposed to the metal, CO2 and oxygen |

**Test for any CO32-**

The unknown substance is placed in a test-tube and dilute trioxonitrate (v) acid is added into the test tube. If a CO32- is present, there will be effervescence and the gas which evolved will turn calcium hydroxide solution (lime water) milky.

CO32-(s) + 2H+(aq) H2O(l) + CO2(g)

**EVALUATION**

1. Describe the laboratory preparation of soluble trioxocarbonate (iv) salts

2. Giving suitable equation, state two properties of trioxocarbonate (iv) salts.

**HYDROGEN TRIOXOCARBONATE (iv).**

HCO3- may also be regarded as salts derived from H2CO3 by the partial replacement of the hydrogen by a metal or cationic radical.

**Preparation of HCO3-**

HCO3- can be prepared by passing CO2 through a cold solution of the corresponding OH- or CO32-.

1. 2OH-(aq) + CO2(g) CO32-(aq) + H2O(l)

2. CO32-(aq) + CO2 (g) + H2O (l) 2HCO3-(aq)

**Properties of HCO3-**

1. Solubility: All hydrogen trioxocarbonate (IV) are soluble in water.

2. Action of heat: They can all be decomposed by heat.

2NaHCO3(s) Na2CO3(s) + H2O(l) + CO2(g)

3. Reaction with dilute acids: All HCO3- reacts with dilute acid to produce CO2, H2O and a salt. 2NaHCO3 (aq) + H2SO4 (aq) Na2SO4(aq) + 2H2O(l) + 2CO2(g)

NOTE: This reaction is used to test for HCO3-

**EVALUATION**

1. Describe the laboratory preparation of HCO3-

2**.** Listthe properties of HCO3-

**GENERAL EVALUATION/REVISION**

1. State Boyle’s law and Charles’ law

2. A certain mass of gas occupies 300cm3 at 35oC. At what temperature will it have its volume reduced by half, assuming its pressure remains constant

3. An enclosed vessel contains 2.8g of nitrogen and 14.2g of chlorine at atmospheric pressure and 0oC. What will be the partial pressure of nitrogen, if the temperature is raised to 180oC?

4. A certain mass of hydrogen gas collected over water at 10oC and 760mmHg pressure has a volume of 37cm3. Calculate the volume when it is dry at s.t.p (saturated vapour pressure of water at 10oC = 9.2mmHg)

5. State Graham’s law of diffusion

**WEEKEND ASSIGNMENT**

1. All are decomposed by heat except (a) BaCO3 (b) CuCO3 (c) ZnCO3 (d) Ag2CO3

2. The liquid from a bee sting is found to be acidic. Which of the following solutions will neutralize the bee sting? (a) Solution of pH 9 (b) Solution of pH 7 (c) Solution of pH 5

(d) Solution of pH 1

3. What is the IUPAC name of K4Fe(CN)6? (a) Potassium hexacyanoferrate (ii) (b) Potassium hexacyanoferrate (iv) (c) Potassium hexacyanoferrate (vi)

(d) Potassium hexacyanoferrate (vii)

4. Which of the following trioxocarbonates (iv) are not decomposed by heat? (a) Calcium and sodium trioxocarbonate (iv) (b) Potassium and zinc trioxocarbonate (iv) (c) Magnesium and potassium trioxocarbonate (iv) (d) Sodium and potassium trioxocarbonate (iv)

5. An aqueous solution of CaCl2 is (a) acidic solution. (b) alkaline solution (c) a buffer solution (d) a neutral solution

**THEORY**

1. State the function of each of the following substances in the laboratory preparation of dry carbon (iv) oxide: (a) potassium hydrogen trioxocarbonate (iv) solution; (b) fused calcium chloride.

2(a) Draw a labelled diagram for the laboratory preparation of dry carbon (iv) oxide. (b) Write a balanced equation for the decomposition of potassium hydrogen trioxocarbonate (iv).

**WEEK EIGHT AND NINE**

**INTRODUCTION TO HYDROCARBONS**

**CONTENTS**

Sources of hydrocarbon

Classification (of aliphatic hydrocarbon)

Petroleum and natural gases

(i) Refining of Petroleum by fractional distillation

(ii) Uses of different fractions

(iii) Cracking of petroleum (thermal and catalytic)

(iv) Antiknock and Octane rating

**PETROLEUM CHEMISTRY**

**HYDROCARBON AND CRUDE OIL:**

Hydrocarbon are very simple organic compound composed mainly of hydrogen and carbon only.

The sources of hydrocarbons are coal, natural gases and petroleum.

Hydrocarbon can be divided into two main classes:

Aliphatic hydrocarbon

Aromatic hydrocarbon

**ALIPHATIC HYDROCARBON**: They are further divided into three groups: Alkanes, Alkenes and Alkynes. The Aliphatic may be Acyclic or Cyclic. The acyclic hydrocarbons are the straight or branched chain hydrocarbon while the cyclic hydrocarbons consist of closed ring chain such as cycloalkane e.g. cyclopropane.

**AROMATIC HYDROCARBON**

Contain ring structure having non localized orbital e.g C6H6. Aromatic hydrocarbons are all cyclic hydrocarbons. The basic cyclic structure is the benzene ring.

**PETROLEUM (CRUDE OIL)**

Petroleum is the chief source of aliphatic hydrocarbon. It is a dark viscous liquid which is usually trapped or found under the ground or sea beds in certain part of the world e.g. Nigeria, Saudi Arabia, Iran, USA, Iraq and Russia. Petroleum is a mixture of Alkanes, alkenes, cyclo alkanes and aromatic hydrocarbons together with about 1 – 6% impurities consisting mainly of compounds of sulphur and minute quantity of H2 and O2 compounds. Natural gas consists mainly of methane.

**Origin of Crude oil and Natural gas**

Natural gas and petroleum are formed by the decomposition of vast quantities of organic material, undoubtedly of marine origin, buried in sediment. When these tiny aquatic organisms died, their remains gradually settled on the sea beds. Over the years, the remains became covered by mud, silt and other sediments. As the sediment piled up, their mass exerted a great pressure on the lower layers, changing them to hard sedimentary rocks. During this process, bacterial activity, heat and pressure probably changed the plants and animal remains into crude oil and natural gas. The oil and gas so formed slowly moved to other areas through the tiny holes or pores in the porous rocks around them. Since oil and gas are not dense, they tend to seep upwards until they meet a non- porous layer or rocks and are trapped under it, thus forming an oil trap.

**REFINING OF PETROLEUM**

The process of petroleum refining is basically that of converting crude oil into a range of products required to meet an economic market demand. How is this achieved? Crude oil consists of a very complex mixture of hydrocarbons, which individually, they exist as gas, liquid or solid at normal temperatures and pressures. The crude oil can be separated into fractions by comparatively simple distillation and for every given variety of crude oil; their relative proportions and properties are fixed. Modern competitive marketing conditions, however, demand that these fractions from crude oil are of such a quality that simple distillation is not enough.

Fractional distillation, necessitating more advanced refinery techniques is now adopted.

Crude oil (petroleum) is composed mainly of a complex mixture of hydrocarbons. By using fractional distillation, crude oil can be separated into fractions or groups of similar compounds. Each fraction contains several compounds all of which fall within a certain range of boiling points. These fractions can be differentiated from one another by their different volatility, odour texture and their relative rate of ignition and burning. The fractional distillation is carried out in a fractionating column of towers. The crude oil is passed into a fractionating column with a temperature ranging between 4000C at the bottom of the column of the steel pipe and 400C at the top part of the column.

The fractionating column is divided into several compartments by perforated plates called trays, each of which is maintained within a specified range of temperature. The crude oil is first heated to about 400oC so that all the components are vaporised. The vapour enters the bottom of the fractionating column. They rise up the column and cool. Those with high boiling points will soon condense to liquids and will not move far up the column, whereas those with low boiling points will have to cool considerably before they condense and so will move towards the top of the column. This means that substances with higher boiling points separated out in the trays on the lower part of the column, while those with lower boiling points separate out in the trays on the upper part of the column. The fractions are collected in horizontal trays at different heights on the column, redistilled to improve purity and then further treated to obtain different liquid fuels and petrol chemicals.

The petroleum fractions are gases, petrol, kerosene, diesel oil, lubricating oil and bitumen.

**USES OF PETROLEUM FRACTION**

1. Natural gas: The gas fractions consist mainly of hydrocarbon containing 1 – 4 carbon atoms per molecule and distilling around 40oC. These are methane, ethane, ethane, propane and butane. Methane and ethane are usually burnt as fuel. The propane and butane are liquefied and distributed in high pressure gas cylinder or tank to the public for lighting and heating purposes in homes. They are also used for synthesising a large number of compound e.g. methanol, butadiene etc, They are also used for the manufacture of products like hydrogen, carbon(iv)sulphide, tetrachloromethane and ethyne.

2. Petrol or Motor gasoline: Petrol is the most important product derived from petroleum because of the rapid increase of the use of motor vehicles. Petrol is a complex mixture of volatile hydrocarbons containing C6 – C10 carbon atoms per molecule.(such as hexane, heptane and octane) distilling off between 500C – 2000C. Petrol is used as a fuel for aeroplanes and vehicles. It is also a good solvent for paints, grease and stains etc. It is a volatile liquid. Since straight chains hydrocarbons making up the petrol fraction of petroleum usually cause engine knock and engine wear, they have to be reformed to branched chain hydrocarbons which are not prone to knocking.

3. Kerosene or paraffin oil: This is a mixture of hydrocarbons containing C10 – C16 carbon atoms per molecule and boiling between 1700C – 2500C. It is a fairly volatile liquid and is used as a fuel for lightning and heating. It is also used as a major fuel in jet engines, aeroplanes and tractors and gas turbines. It is a good solvent for grease and paints.

4. Gas Oil or Diesel oil: This is a mixture of hydrocarbons containing C14 – C18 carbon atoms per molecule and boiling between 3000C – 3600C.It is used in internal combustion of diesel engines of trains, lorries and tractors etc, They are also used as raw materials in the cracking process.

5. Lubricating oil, Grease and wax: It is a mixture of long chain hydrocarbons with more than 20 carbons atoms per molecule which distil over in the temperature range of 3500C – 5000C.They are viscous liquids used as a lubricant for moving parts of engines and machines and also for making Vaseline or petroleum jelly. Paraffin wax is used for making candles, water proof materials, polish, grease ointment and cream

6. Bitumen or Asphalt: It is a complex mixture of non soluble solids made of polycyclic hydrocarbons. It is used as a biding agent for roofing materials and in road surfacing as a protective coating.

Name of fraction Boiling Point Carbon atoms Uses

Range in 0C in molecules

1. Petroleum gas below 40 1 – 4 Fuel and manufacture of other

2. Petrol 40 – 200 4 – 12 Fuel in aeroplanes and motor vehicles

3. Kerosene 200 – 250 12-18 Fuel for lighting, heating and jet

engine

4. Gas oil and 250-350 12-25 Fuel for heating and diesel

engines.

Diesel oil Raw materials for cracking

process

5. Lubricating Oil 350– 500 more than 20 Lubricating moving parts of

machines, Making candles, creams & hair care products

6. Bitumen Above 500 more than 35 Surfacing roads

**CRACKING AND REFORMING**

CRACKING: Cracking is the process use in breaking down large hydrocarbon molecules into two or more smaller hydrocarbon molecules. This is the method used in increasing the quantity of petrol. The fraction from which petrol is produced (C6 – C12) is small compare with other fractions with greater number of carbon atoms. The petroleum refineries find it difficult to cope with large demands of petrol from users, while on the other they are left with large surplus of the less volatile fractions like kerosene and diesel oil. They are therefore been forced to think of method of converting these less volatile fractions into petrol. This method is known as CRACKING.

There are two types of cracking in use in the petroleum industry:

1. THERMAL CRACKING: This involves vaporizing the oil fractions of long carbon chain (C12 – C18) and heating them for a short time to temperature around 6000C under very high pressure of about 300atoms.

2. CATALYTIC CRACKING: The long chain hydrocarbons are heated in the presence of a silica alumina or zeolite catalyst .The catalyst speeds up the process which requires less energy. The pressure needed is lower and high grades of petrol are produced by increasing the octane number of petrol. The temperature is still about 5000C. This catalytic cracking is more widely used. Catalytic cracking is better because:

(i) The process is more controllable; i.e. the conditions can be adjusted such that desirable products of certain chain lengths are obtained. This process thus yields a source of alkenes which serve as raw materials for great variety of organic chemicals.

(ii) The process does not only yield more petrol but also gives petrol a high quality. In fact, this petrol is a higher grade petrol than the one obtained directly from the petrol fractions during the distillation of crude oil.

C16H34 C8H18  + C8H16.

CH3(CH2)8CH3 CH3C (CH3)2CH2CH(CH 3)CH3  + C2H4

The overall benefits of the cracking process are:

(i)It increases the yield of petroleum

(ii)It provides a petrol mixture rich in branched chain hydrocarbons with an attendant increase in octane number.

(iii)It yields as by product, large quantity of ethane, propene, butane etc used for making plastics, synthetic rubber, detergent and many important chemicals like ethanol and phenol.

**REFORMING**: This is the process used in converting long chain hydrocarbons to shorter and branched chain molecules to improve its anti knock properties. The process usually takes place in the presence of catalysts such as oxides of silicon and aluminium at about 6000C and pressure between 8 and 15 atm in order to increase its octane number and to produce high grade petrol.

Cracking is a breaking down process while reforming is an isomerisation process (i.e. changing a compound into its isomers)

**OCTANE NUMBER**

The octane number of octane rating of petrol is a mixture of the proportion of branched chain hydrocarbons to the straight chain hydrocarbons in a given blend of gasoline (petrol).

Gasoline is composed of C7 – C9 hydrocarbons i.e. heptane, octane and nonane. These hydrocarbons are present in their straight chain or branched chain isomers. It has been shown that straight chain hydrocarbons (e.g. n – heptane) burn too rapidly in the car engine thus, causing irregular motion of the pistons which result in rattling noise.

The rattling noise is known as ‘KNOCKING’.

Petrol containing a higher percentage of straight chain hydrocarbons causes more knocking that petrol containing a higher percentage of branched-chain hydrocarbons

A straight chain alkanes like heptanes is assigned an octane number of O while a highly branched chain alkane like 2,2,4 trimethylpentane is assigned an octane number of 100 which burns very smoothly in engines. Therefore the quality of any petrol is rated according to its octane number, i.e. the percentage of heptanes to 2,2,4 – trimethylpentane in a mixture.

CH3 – CH 2– CH 2– CH 2– CH 2– CH2 – CH3

Heptane octane number = 0

CH3 CH3 2,2,4 – trimethylpentane (iso – octane)

CH3  C CH2  C CH3 octane number = 100

CH3 H

Octane number is a measure of the performance of the fuel in engines and the rating is given as the percentage of iso – octane (2,2,4 – trimethyl pentane) to straight chain hydrocarbon present. For e.g a gasoline with an octane rating of 94 is understood to contain 94% iso octane and 6% straight chain heptane. Similarly, a fuel with an octane number of 50 has a performance equivalent to 50 – 50 mixture of heptane and 2,2,4 – trimethylpentane.

When low grade petrol is used in some auto mobile engines, there is a tendency for the engine to knock. The difference in the grade of petrol is therefore, a difference in their octane numbers.

The motor car engines are known as petrol engines.

**GRADE OF PETROL**

Petrol can be graded as:

(a) Super or extra (b) Regular or Ordinary

Petrol which is graded as super or extra has an octane number closer to 100 than petrol that is graded as regular or ordinary.

Octane number of some hydrocarbons.

Straight chain Hydrocarbon Relative molecular mass Octane number

Propane 44 100

Butane 58 92

Pentane 72 61

Hexane 86 25

Heptanes 100 0

Octane 144 -27

Nonane 128 -45

The octane number of straight – chain hydrocarbons is related to their molecular mass, i.e. the lower the molecular mass of the hydrocarbon, the higher the octane number. Some fuels which are superior to 2,2,4 – trimethylpentane have an octane number greater than 100.

**SYNTHETIC PETROL**

Synthetic Petrol is made from materials such as coal, coke and hydrogen which do not occur in

crude petroleum. Synthetic petroleum can be gotten from two sources:

1. From Coal: When powdered coal is heated with hydrogen in the presence of Fe or Sn as catalyst at 5000C and 20 atmospheric pressure, it is converted into an oily mixture of hydrocarbons. The mixture is separated by distillation into a petrol fraction boiling at 2000C and heavy oil residue which can be further treated with fresh coal to obtain more petrol.

2. From Coke: When steam is passed over heated coke at 1000C, a mixture containing equal volumes of CO and hydrogen known as water gas is obtained.

C + H2O CO + H2

Water gas

The water gas can be hydrogenated to a mixture of hydrocarbons by adding hydrogen and passing it over finely divided nickel as catalysts at 2000C. About half of the product is petrol, the less volatile fraction being used as fuel for diesel engines.

**PETROCHEMICALS**

Petrochemicals are substances that are manufactured from the by – products of petroleum. These include plastics, synthetic rubber and fibres. Petroleum and natural gas are now used in increasing amounts to produce many inorganic compounds. Examples include ethanol, ethane, propane 1, 2, 3 – triol, benzene and toluene. These small molecules organic compounds are in turn used to make large – molecule organic compounds like plastic, synthetic rubber, insecticides, detergents and synthetic fibres like nylon and Dacron.

**PROBLEMS OF PETROLEUM CHEMISTRY**

1. The petrol produced is too small to meet the demand of the world

2. The quality of the petrol produced is too low and may result in knocking of the petrol engine

**SOLUTION TO THE PROBLEMS**

These problems can be solved by increasing the amount of petrol produced through

(a) Breaking down of larger hydrocarbon molecule into smaller hydrocarbon molecule (Pyrolysis)

C10H22 H2 + C C5H12 + CH3 – CH = CH – CH3

But – 2 – ene (iso butene)

(b) By addition of lead – tetraethyl (known as ‘anti – knock’ compounds) to prevent knocking and thereby increases the octane number.

Note; Cracking, catalytic reforming and uses of additives (tetraethyl lead) are used to improve the yield and quality of petrol.

**EVALUATION**

1. What are petrochemicals?

2. What is octane number?

3. List two types of cracking

**GENERAL EVALUATION/REVISION**

Calculate the empirical formula of an organic compound containing 81.8% Carbon and 18.2% Hydrogen.

State the law of constant composition

Write a balanced equation for the following:

(a) Reaction between hydrochloric acid and sodium hydroxide

(b) Reaction oxygen and red hot coke (c) thermal decomposition of potassium hydrogen trioxocarbonate (iv)

4. Using electron dot representation show how each of the following compound, molecule/ion is formed (a) NaCl (b) NH3 (c) H3O+

5. State 3 postulates of kinetic theory of gases.

**WEEKEND ASSIGNMENT**

1. Oil deposits in Nigeria are (a) on land and offshore (b) only offshore (c) mainly imported (d) downstream

2. Fractional distillation involves the following processes (a) Boiling (b) Boiling and condensation (c) Boiling, evaporation and condensation. (d) Condensation and collection.

3. Which is the odd one out of the following (a) petroleum ether, petroleum gases, kerosene

(b) Gas oil and diesel lubricating oil (c) Petroleum ether and bitumen (d) Haematite and asphalt.

4. Which of the petrol samples are likely to cause knocking? (a) octane (b) 2,2,3,3-tetramethyl butane (c) 2,2,3-trimethyl pentane (d) 2,2,3-trimethyl pentane.

5. Nigeria earns money from (a) petroleum gas and liquids only (b) petroleum liquids and solids only (c) petroleum liquids like petrol and kerosene oil (d) petroleum gases, liquids and solids.

**THEORY**

1. (a) Distinguish between cracking and reforming. Of what importance are the two processes in the petroleum industry. (b) State the problem associated with oil producing areas.

2. Consider the following reactions schemes.

a. Petroleum Petroleum Fractions

b. C16H34 C8H18 + X

(i) State the type of process involved in each of the stages labelled I and II

(ii) Identify X

**WEEK TEN**

**APPPLIED CHEMISTRY**

**CONTENT**

Raw materials used in chemical industries and their sources.

Division of chemical industries: heavy chemical, fine chemicals, fertilizers, plastics, metallurgy, pharmaceutical, glass, ceramics, paints, cements, soap and detergent.

CHEMICAL INDUSTRY:

Chemical industry is define as one that uses chemistry to make chemicals from other chemical substances (raw materials)

The important raw materials used in chemical industry include (i) air (ii) CaCO3 (iii) Sea water and rock salt (iv) Sulphur (v) Metallic mineral ore (vi) Coal (vii) Natural gas and petroleum.

SOURCES OF RAW MATERIALS IN CHEMICAL INDUSTRY

AIR: Air is the chief source of O2 and N2. N2 is important because it is used in the manufacture of NH3. NH3 itself is used in the manufacture of trioxonitrate (v) acid which is used in the making of explosives, plastics and other materials. NH3 is also used in the manufacture of NH4+ salts like HN4O3, (NH4)2SO4 which are used in manufacturing fertilizers.

CALCIUM TRIOXOCARBONATE (iv) (CaC03): CaCO3 in the form of lime stone, chalk and marble is the source of lime or calcium oxide which is used for making concrete and cement. It can also be the source of raw materials for the production of baking powder and also for CO2 which can be used to produce sodium trioxocarbonate (iv) by the Solvay process.

SEA WATER AND ROCK SALT: Salt or NaCl occurs as rock salt in underground deposit and in sea water. The sodium chloride salt is the major starting material for many chemical industries. Sea water is also the source of NaBr from which bromine is manufactured on large scale. Electrolysis of NaCl produces chlorine. The other main product is NaOH which is used in the manufacture of soap and textile and in petroleum refining, as well as other chemicals such as Na2CO3 which is also a source of material for the glass industry and in the manufacture of detergents. It is also used in the softening of water in the public water works department. The chlorine produced can be made to react with hydrocarbon obtained from fossil fuel. The chlorohydrocarbon are versatile raw materials. They are used in the making of synthetic rubber, paints removers, refrigerant and several types of insecticides and industry cleaning.

SULPHUR: is an element which is obtained naturally from the ground by Frasch process or iron pyrites (FeS2), copper pyrite (CuFeS2), gypsum (CaSO4.2H2O) and anhydride which are the raw materials in chemical industries where SO2,H2SO3, H2SO4 are produced. From the acids, compounds like (NH4)2SO4 (fertilizer), paints, dyes, explosives, synthetic fibres and accumulator are manufactured.

NATURAL GAS and PETROLEUM: Petroleum is a major and very important raw material for petrochemicals like CH4, ethane, propane, butane, ethyne, butadiene, isoprene, benzene and phenol. From these petrochemicals, other products and chemicals like fertilizers, agricultural motor fibre and plastics are made. These chemicals have their own different industries e.g. agricultural industries. Petroleum products like petrol, diesel, and kerosene were marketed by foreign oil companies like Shell, Mobil, Gulf and Texaco.

DIVISION OF THE CHEMICAL INDUSTRIES

Chemical industries can be classified on the basis of their products. We have chemical industries which produce:

(a) Basic chemicals such as acids, alkalis, salt and organic chemicals.

(b) Chemical products that are used in the manufacture of artificial fibres and plastics.

(c) Chemical products used as starting materials in other industries that manufacture substances such as paints, fertilizers and explosives.

(d) Chemical products such as cosmetics, drugs and soap for personal use.

HEAVY AND FINE CHEMICALS

Heavy Chemicals: They are classified as heavy chemicals because they are required in large quantities in different types of chemical industries all over the world. Heavy chemicals includes tetraoxosulphate (vi) acid (the most important) hydrochloric acid, trioxonitrate (v) acid calcium trioxocarbonate (iv) acid, caustic soda (sodium hydroxide), Slaked lime, Ca(OH)2 and their special derivative, such as Caustic potash, Sodium trioxocarbonate(iv) acid, bleaching powder (CaOCl2).

Metals such as iron, copper, tin, aluminium and zinc are also heavy chemicals, as well as organic materials such as coke, coal tar, benzene, and methyl benzene. NH3 is also a heavy chemical. It is manufactured in large quantities and is used to make fertilizers as well as explosives.

FINE CHEMICALS: They are manufactured only in small quantities for paints and fuels, drugs, analytical chemicals, bulk of laboratory reagents acids photographic materials. Their purity is generally of a higher degree than that of heavy chemicals, and so they are correspondingly more expensive.

TYPES OF INDUSTRY

Due to different types of naturally occurring raw materials, many chemical industries are established some of these industries are:

Fertilizer Industry

Paint Industry

Cement Industry

Plastic Industry

Pharmaceutical Industry

FERTILIZER INDUSTRY: Fertilizer industry is an important industry. Fertilizers such as NH4NO3, (NH4)2SO4 and Urea, as well as pesticides, insecticides, germicides, herbicides and fungicides are all products of petrochemical industry which helps in agricultural production.

PAINT INDUSTRY: Paint is a fluid mixture which contain suspended colouring materials. The main use of paints is for decoration and protection against weathering and corrosion.

CEMENT INDUSTRY: Cement is produced by heating a mixture of powdered lime (CaO) and clay. When mixed with water, it can be used to fastened stones and bricks together. The mixture called mortar hardens like stone.

PLASTIC INDUSTRY: The plastic industry is divided into four categories; bags, house hold and kitchen wares, industrial plastics supplies and miscellaneous items.

The industrial plastics supplies cover items such as casing for radios, Cassette recorders and TV sets, as well as PVC pipes and fittings for the building industry. The starting raw materials for modern plastic industry are obtained by fractional distillation of crude oil of petroleum. The major raw material in the plastic industry is ethene.

PHARMACEUTICAL INDUSTRY: Many plants extracts are known to have some medical properties. Most medicinal are organic compounds, but many inorganic substances are still used in pharmacy, for example; Potassium bromine, used as sedative, bismuth carbonate, used to cure stomach disorders, mercury nitrate, used as an antiseptic for skin diseases; and mercury (1) chloride, used as a strong purgative. Drug can be used to cure disease. Drug such as quinine for the treatment of malaria and insulin for the treatment of diabetes are examples. Many of our synthetic drugs, syringes, surgical and important materials in the hospitals are manufactured from petrochemical products. Disinfectants, Cosmetics, detergents and soap are also products of petrochemicals

**EVALUATION**

1. What is a chemical industry?

2. List two types of chemical

3. List the types of chemical industry

**WEEKEND ASSIGNMENT**

1. Examples of heavy chemicals include the following except (a) NaOH (b) Perfumes

(c) H2SO4 (d) NH3

2. Fine chemicals has the following characteristics except (a) They are chemically pure

(b) They are produced by batch process (c) They are produced in large quantity because of high applicability (d) They are produced in small quantity because of limited applicability

3. Plastics are polymer whose production technique involves the following except (a) High pressure (b) low temperature (c) High temperature (d) Setting

4. Metallurgy is a scientific process which involves the following except (a) manufacture of alloys (b) manufacture of both natural and artificial catalysts (c) refining of metals (d) grading of metal

5. The major difference between cement and mortar is that (a) mortar hardens by giving off water (b) Cement hardens by giving off water (c) mortar is always white (d) Cement is always coloured because of super heating

**THEORY**

1. (a) Give one example of (i) Heavy chemicals, (ii) Fine chemicals (b) Name the major raw materials used in the manufacture of the following: (i) Polythene, (ii) Cement (iii) Soap

2. (a) What is a chemical industry? (b) Mention three types of chemical industries