IJA # 2710

Archival Materials of Chemistry Notes from the Frank Iny School

FRANK INY SCHOOL

Chemistry Notes for the Second Year Intermediate
1959 - 1960

INTRODUCTION

1. **What is Chemistry ?**

Chemistry is a science which deals with the constitution of matter, its properties, its methods of preparation, its reaction with other substances, and the changes which occur on it.

2. **What can a chemist do ?**

A chemist can know the reasons for the chemical changes of matter and can make from simple substances new preparations which increase the prosperity of the human race. It is the chemist who can make soap, matches, cement, photographic films, dyes, explosives, glass and drugs. Every industry needs the chemist and the progress of mankind lies in his hands.

3. **Is chemistry a well-developed science?**

Chemistry is still in its childhood. New discoveries show us that there is a very wide field for investigating the secrets of nature. There are some simple chemical reactions which nature can easily do, but are still not done in the laboratory by the chemist. Our bodies are complicated chemical factories about which we know very little.

The future will prove how little we now know about the nature of matter and how vast is the field of science which lies before us.

PRELIMINARY DEFINITIONS

4. Matter: Is anything that occupies a space and has a weight e.g. iron, wood, air.

5. Body: Is a limited part of matter e.g. knife, chair.

6. Mass: Is the quantity of matter which a body contains.

7. States of matter:-

a) Solids: Are those substances that have a definite shape and volume. Their molecules are close to each other and have a big attraction among them e.g. glass.

b) Liquids: Are those substances that have variable shape and definite volume, their molecules are somewhat close to each other and have less attraction among them than in the case of Solids.

c) Gases: Are those substances which have variable shape and volume, their molecules are far apart from each other, and have less attraction among them than in the case of liquids.

8. Properties of Matter

a) Physical Properties:-

Are those properties that concern the outside appearance of the substance and have no relation to its composition.

b) Chemical properties:-

Are those properties that concern the actual composition and behaviour of the substance.

9. Changes of matter:-

a) Physical changes

Are temporary changes that occur on the appearance of matter such as a change of state without any alteration of mass e.g. 1- Melting of Wax. 2- Heating a piece of iron until it becomes red, then white. 3- Evaporation of water.

b) Chemical changes

Are permanent changes that occur on the actual composition of the substance with the loss of original properties e.g.

1- The burning of wood. 2- The Rusting of iron etc.

10. Constitution of Matter

All substances are composed of very small particles invisible to the naked eye and the microscope which are called "molecules". These molecules are in turn composed of smaller particles called " atoms ".

11. A Molecule:

Is the smallest part of the substance that has all the properties of that substance.

12. An Atom:

Is the smallest part of the substance that can enter into a chemical reaction.

13. Types of Matter:-

a) An Element: Is that substance which has so far not been subdivided into simpler substances. The atoms of an element are all similar. e.g. Silver, mercury, oxygen and hydrogen. The molecules of an element are composed of similar atoms.

b) A Compound:-

Is that substance formed by the union of two or more elements in definite proportions by weight so that it differs in its properties from its constituents. The atoms of a compound are not similar. e.g. water is a compound formed by the union of hydrogen and oxygen in the ratio of 1:8 by weight.

c) A Mixture:-

Is that substance made by the addition of two or more substances in any proportion, so that all the constituents retain their original properties. e.g. Air is a mixture of many gases.

14. Differences between Mixtures and Compounds

Compound	Mixture
1. The properties of a compound are entirely different from those of its constituents.	1. A mixture possesses the common properties of its constituents.
2. The constituents of a compound are combined in definite proportions by weight.	2. The proportions of the constituents of a mixture are variable.
3. The constituents of a compound cannot be separated, but by difficult chemical means. e.g. electrolysis, reduction, etc..	3. The constituents of a mixture can be separated easily by mechanical or physical processes e.g. by a magnet or by distillation, etc..
4. A compound is a homogeneous substance.	4. A mixture is usually a heterogeneous substance.

Kinds of Elements

15. There are ninety six elements in nature. They are divided into two kinds according to their properties.

1. Metals
2. Non-Metals

16. Some important Metals and their Symbols

Name of Metal	Symbol	Name of Metal	Symbol
Potassium	K	Nickel	Ni
Sodium	Na	Tin	Sn
Barium	Ba	Lead	Pb
Magnesium	Mg		
Aluminium	Al	Arsenic	As
Chromium	Cr	Copper	Cu
Manganese	Mn	Mercury	Hg
Zinc	Zn	Silver	Ag
Iron	Fe	Gold	Au
Cobalt	Co	Platinium	Pt

17. Some important Non-Metals and their Symbols

Oxygen	O_2	Phosphorus	P
Chlorine	Cl_2	Nitrogen	N_2
Bromine	Br_2	Carbon	C
Iodine	I_2	Silicon	Si
Sulphur	S	Helium	He
		Hydrogen	H_2

Note: 1. All symbols begin with capital letters, the second letter is always small.

2. All gases are made up of 2 atoms except the inert gases, they are of one atom and ozone is of three atoms.

18. Comparison Between Metals & Non-Metals

Metals	Non-Metals
1. They are bright and reflect light when freshly cut.	1. They are dull, and do not reflect light when freshly cut.
2. They are all solids except mercury.	2. They are solids, liquids or gases e.g. S, Br_2, N_2
3. They are malleable & ductile.	3. They are brittle.
4. They are good conductors of heat and electricity.	4. They are bad conductors of heat & electricity.
5. They form basic oxides.	5. They form acidic oxides.
6. Generally they dissolve in mineral acids and give off hydrogen.	6. Usually they do not dissolve in mineral acids.
7. They form amalgams & alloys.	7. They do not form amalgams & alloys.
8. Their Specific gravities are generally high.	8. Their Specific gravities are usually low.

19. A Solution: Is a homogeneous mixture formed by the disappearance of the molecules of a substance called 'Solute' among the molecules of another substance called "Solvent".

For example, the behaviour of some solids such as sugar or salt when brought into contact with water is a familiar fact of experience, The solid seems to disappear into the liquid, and we say that it has "Dissolved", while the resulting homogeneous mixture is termed a "Solution". The dissolved substance is called the "Solute" and the liquid in which it is dissolved, the "Solvent". If we dissolve sugar (solute) in water (solvent) the sugar will be divided into molecules. These molecules will disappear in the spaces found among the molecules of water and the resulting mixture is Solution of sugar in water.

20. Saturation: Is that limit beyond which apparently we cannot dissolve any more of the solute in a certain quantity of the solvent at a definite temperature.

21. Solubility: Is the weight (number of grams) of solute which is sufficient to saturate 100 grams of the solvent at a certain temperature. e.g., the solubility of sodium chloride (Na Cl) in water at $0^{\circ}C$ is 35.6 grams, i.e. 35.6 grams of sodium chloride will saturate 100 gms. of water at $0\ ^{\circ}C$.

22. The general bases of Solubility:

1. The solubility of solids in liquids increases with the increase of temperature.
2. The solubility of solids in liquids does not increase with the increase of agitation and stirring.
3. The Mass of gases dissolved in liquids increases with the increase of pressure.
4. The solubility of gases in liquids decreases with the increase of temperature.
5. The boiling point (B.P.) of a liquid rises and its freezing point becomes lower when a solid substance dissolves in it. For examples, A solution of sugar and water boils at a temperature higher than $100\ ^{\circ}C$ and it freezes at a temperature lower than $0\ ^{\circ}C$.

23. Kinds of Solutions:

1. A true solution: Is that solution which is homogeneous and transparent, in which the solid particles (solute) are very small and pass through filter paper, and do not separate under gravity. e.g. solution of sugar in water.
2. A Colloidal solution: Is that solution which is semi-homegeneous and semi-transparent, in which the solid particles are comparatively large in size, do not pass easily through filter paper, and do not settle under gravity, e.g. milk, gum, blood.

3. A Suspension: Is that solution which is not homogeneous and not transparent, and which consists of gross particles of solid matter which do not pass through filter paper and which settle under gravity, e.g. solution of chalk, or clay in water.

24. CLASSIFICATION OF SOLUTIONS: Solutions are classified according to the proportion of solute and solvent which they contain as follows:-

(a) A Dilute Solution:- Is that solution which contains a small amount of solute in proportion to the solvent.

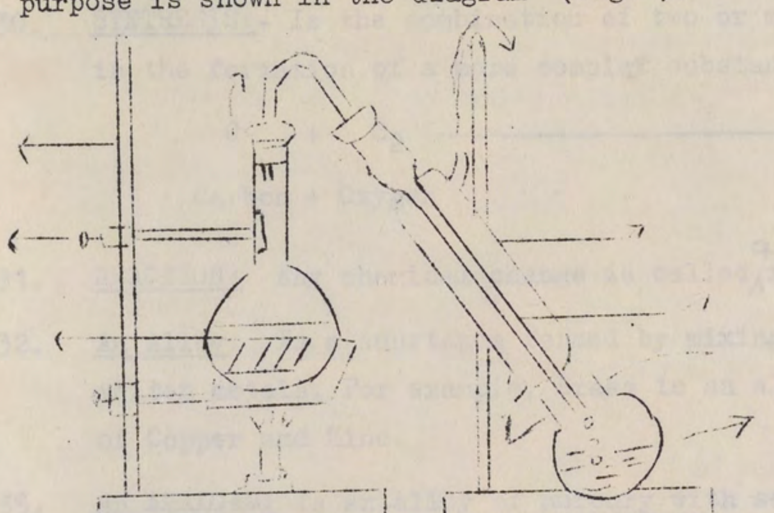
(b) A Concentrated Solution:- Is that solution which contains a large amount of solute in proportion to the solvent.

(c) An Unsaturated Solution:- Is that solution which contains a quantity of solute less than that which is sufficient to saturate it at a certain temperature and pressure. Such a solution can dissolve more of the solute under the same conditions of temperature and pressure. For example, if a pinch of sugar is dissolved in a glass of water, the solution is unsaturated because it can readily dissolve more sugar.

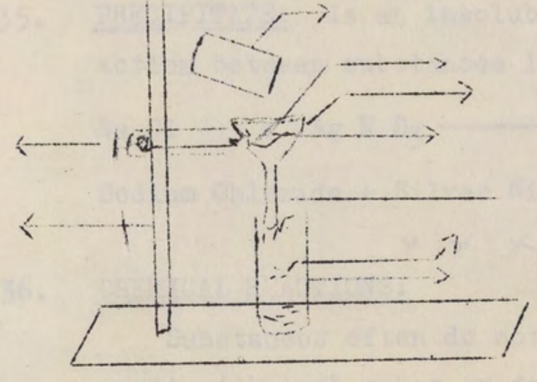
(d) A Saturated Solution:- Is that solution which contains all the solute it can normally dissolve at a given temperature and pressure. For example, if several teaspoonfuls of sugar are stirred in a glass of water, some of the sugar will dissolve while the rest will drop to the bottom of the glass. The clear solution is now said to be saturated at the given temperature and pressure.

(e) A Supersaturated Solution:- Is that solution which contains more of the solute than it can normally hold at the given temperature and pressure. For example, if we dissolve 10 grams of $K\ Cl\ O_3$ in 100 grams of water we get a saturated solution at $30^{o}C$. Upon raising the temperature of this solution to $50^{o}C$, we find that the 100 grams of water will now dissolve 20 grams of $K\ Cl\ O_3$ then producing a saturated solution. If the solution is carefully cooled back to $30^{o}C$, we observe that the excess $K\ Cl\ O_3$ does not crystallize out, but remains dissolved, thus yielding a solution of $K\ Cl\ O_3$ at $30^{o}C$ which has more solute in it than a saturated solution at that temperature should normally have. Such a solution is said to be "Supersaturated". This condition is unstable, for if the solution is shaken, the 10 gms of $K\ Cl\ O_3$ which are in excess will quickly crystallize out, leaving the original saturated solution which contains 10 gms of $K\,Cl\,O_3$ dissolved in 100 grams of water at $30^{\circ}C$.

25. DISTILLATION:- Is the process of converting a liquid into vapour by heat, and then condensing the vapour back to liquid again, thus leaving behind non-volatile impurities. The pure liquid thus gotten is called the "Distillate". A suitable apparatus for this purpose is shown in the diagram (Fig.1).



26. FILTRATION:- Is the process of running a liquid through a porous material, such as coarse paper, sand, etc...in order to remove suspended solid matter. The clear liquid which runs through the filter is called "Filtrate".



(Fig 2)

27. DECOMPOSITION:- Is the process of separating a compound into its elements or into simpler substances. For example, heating $K\,Cl\,O_3$ to yield $K\,Cl$ and oxygen.

$$2\,K\,Cl\,O_3 \xrightarrow{\theta} 2\,K\,Cl + 3\,O_2$$

Potassium Chlorate → Potassium Chloride + Oxygen

28. Electrolysis:- Is the process of decomposing a compound by means of an electric current.

29. ANALYSIS:- Is the process of finding the composition of a substance by decomposition into its elements or into simpler substances. For example, water can be analysed by electrolysis yielding hydrogen and oxygen.

$$\text{Water} \xrightarrow[\text{Sulphuric acid}]{\text{Electric current}} \text{Hydrogen + Oxygen.}$$

30. SYNTHESIS:- Is the combination of two or more substances, resulting in the formation of a more complex substance. For example,

$$\underset{\text{Carbon + Oxygen}}{C + O_2} \longrightarrow \underset{\text{Carbon dioxide}}{CO_2}$$

31. REACTION: Any chemical change is called a reaction.

32. An Alloy: Is a substance formed by mixing together two or more molten metals. For example, Brass is an alloy which is composed of Copper and Zinc.

33. An AMALGAM: Is an alloy of mercury with some other metal. For example, gold amalgam.

34. SUBLIMATION: Is the process of a solid vaporizing and then condensing back to a solid without passing through the liquid state. For example, sublimation of iodine.

35. PRECIPITATE: Is an insoluble substance resulting from a chemical action between substances in solutions. For example,

$$NaCl + AgNO_3 \longrightarrow AgCl + NaNO_3$$

Sodium Chloride + Silver Nitrate ⟶ Silver Chloridge + Sodium Nitrate.

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36. CHEMICAL REACTIONS:

Substances often do not remain as they are, but they either react with each other or decompose into simpler substances. Such changes which alter the composition of a substance and form one or more new substances, are called "Chemical Reactions". Chemistry is a science which deals with such changes as distinguished from other sciences.

The Chemist has devised a highly practical system to represent elements and compounds by means of symbols and formulas indicating how substances are built up, and how they react with each other. By this means he can indicate what is present in a test tube, and what happens when something is added to it. To make this clear, the student has to be acquainted with the following:-

(a) Symbols: A chemical symbol consists of one or two letters of the English name or the latin name of an element denoting one atom of it. For example, the symbol for Oxygen is O, and that of Silver is Ag, (from Latin, Argentum).

(b) Valency or Valence: is the "Force" or "ability" of an element to combine with other elements to form a chemical compound. This force or ability is measured by the number of hydrogen atoms which will combine with one atom of the element. So the valency of an element is defined as the number of hydrogen atoms (or any monovalent element, e.g. Chlorine) with which one atom of the element can combine, or which it can displace. Accordingly, the valency of an element which does not combine with any other element is Zero, e.g. Helium. The valency of an element which combines with one atom of hydrogen is one. Such an element is said to be "Monovalent"; e.g. Chlorine, in (HCl), or hydrochloric acid. The valency of an element which combines with two atoms of hydrogen is 2. Such an element is "Divalent"; e.g. Oxygen in (H_2O) or water. The valency of an element which combines with three atoms of hydrogen is 3, and it is "Trivalent"; e.g. nitrogen in (NH_3) or ammonia and so on. Valency could reach 8 as a maximum. Some of the elements have constant valencies in all their compounds, while others have variable valencies according to the kind of compound they are present in, and to the condition of the reactions. The following table gives the symbols of the important elements and their valencies:-

Element	Symbol	Valence	Element	Symbol	Valence
Sodium	Na	1	Tin	Sn	2,4
Potassium	K	1	Aluminium	Al	3
Silver	Ag	1	Gold	Au	3,1
Magnesium	Mg	2	Chlorine	Cl	1
Calcium	Ca	2	Iodine	I	1
Zinc	Zn	2	Oxygen	O	2,4
Barium	Ba	2	Nitrogen	N	2,3,5
Copper	Cu	2,1	Phosphorus	P	3,5
Mercury	Hg	2,1	Carbon	C	4,2
Iron	Fe	2,3	Silicon	Si	4
Lead	Pb	2,4	Sulphur	S	2,4,6

37. RADICALS AND THEIR VALENCE.

A radical is a group of elements which behave as a unit in chemical reactions, and which has an individual valence just like any other element. For example, (NH_4) is a radical called ammonium and is univalent. Again, in Sulphuric acid which has the formula H_2SO_4, the group (SO_4) is the sulphate radical which is divalent because it combines with two stoms of hydrogen to form (H_2SO_4). It is important to note that radicals do not exist in a free state as other compounds do.

Below is a list of different radicals with their symbols and valencies:

Radical	Symbol	Valency	Radical	Symbol	Valency
Nitrate	NO_3	1	Acetate	CH_3COO	1
Chlorate	ClO_3	1	Sulphate	SO_4	2
Ammonium	NH_4	1	Carbonate	CO_3	2
Hydroxide	OH	1	Silicate	SiO_3	2
Bicarbonate	HCO_3	1	Phosphate	PO_4	3

38. CHEMICAL AFFINITY: Is the tendency of a certain element to combine with another element. For example, Oxygen has a Chemical affinity towards most elements, that is, it unites with most elements forming their Oxides.

39. CHEMICAL FORMULAS: A chemical formula represents the composition of a molecule. It is made up of one or more symbols with a Subscript which denotes the number of atoms which compose the molecule. The subscript 1 is never written. For example, the formula for the hydrogen molecule is H_2, which shows that a molecule of hydrogen contains two atoms of hydrogen. The formula for water is H_2O, which shows that a molecule of water contains or consists of two atoms of hydrogen and one atom of Oxygen. Again, the formula for sulphuric acid is H_2SO_4, i.e. one molecule of sulphuric acid is composed of two atoms of hydrogen, one atom of sulphur and four atoms of oxygen.

N.B.1. The formula of a compound must not be changed at all.

2. A number written before the formula indicates the number of molecules of that element or compound, and if multiplied by the number of atoms, it gives the total atoms of each element. For example,
2 H_2SO_4 means 2 molecules of sulphuric acid; i.e. four atoms of hydrogen, two atoms of sulphur and eight atoms of oxygen.

40. WRITING FORMULAS: A knowledge of the valencies of the different elements & radicals is an essential requirement for writing the formulas of the different compounds correctly. If we know that two elements or radicals combine to form a compound we proceed to build up its formula according to the following steps:-

1. Represent by symbols, first the metallic part, and then the non-metallic part, of the compound as follows:-

$Na\ Cl$, $Na\ SO_4$, $Ca\ CO_3$. $Ca\ PO_4$.

2. Write a subscript number for each element or radical equal to the valence of the other element or radical in the compound, enclosing radicals in parentheses as follows:

$Na_1\ Cl_1$, $Na_2\ (SO_4)1$, $Ca_2\ (CO_3)_2$, $Ca_3\ (PO_4)_2$

3. The subscript 1 is omitted, as are also the parentheses of radicals whose subscript is 1. Subscripts are omitted also when the two parts of the compound have similar subscript numbers; i.e., when they are of the same valency. The completed formulas of the above compounds are therefore:

$NaCl$, Na_2SO_4, $CaCO_3$. $Ca_3(PO_4)_2$

41. CHEMICAL EQUATIONS: A chemical equation consists of symbols and formulas representing a complete chemical reaction. For example, the following equation represents the reaction between Zinc and hydrochloric acid:

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$

A chemical equation tells in shorthand language what the substances which react are, and what products are formed. The two sides of an equation are separated by an arrow. When reading a chemical equation, the words "Yields" of "Forms" are substituted for the arrow.

42. WRITING EQUATIONS: If we are given two or more substances which will react with each other and yield certain products under given conditions, we may represent this chemical action by an equation as follows:

1- On the left of the arrow express by means of a symbol or a formula each substance involved in the chemical reaction.

2- On the right of the arrow express in a similar way each product formed.

3- Balance the equation by writing Coefficients **before** the symbols or formulas, if necessary, so as to give the same number of atoms of each element on both sides of the arrow.

4- When a gas is evolved it is indicated by an arrow pointing upward ($\uparrow$) . When a precipitate is formed it is indicated by an arrow pointing downward ($\downarrow$).

5- When heat is applied in a chemical reaction, it is expressed by the sign ($\ominus$) or ($\triangle$) and is written above the arrow. If an electric current is applied, it is expressed by the sign ($\sim\sim$) and is put above the arrow. If any other catalyst is applied an indication of it should appear with the arrow also.

N.B. 1- Subscripts in the formulas should never be changed because that would mean an alteration in the composition of the substance.

2- Most gaseous elements such as hydrogen, oxygen, nitrogen and Chlorine, exist in the free (uncombined) state as diatomic molecules. Viz : H_2, O_2, N_2, Cl_2.

43. TYPES OF CHEMICAL REACTIONS:- In general, there are four types of chemical reactions:-

1- Direct Combination or "Synthesis" which is a chemical union of two or more elements or compounds forming a more complex substance. For example,

(a) $H_2 + Cl_2 \xrightarrow{\text{sun light}} 2\ H\ Cl$

hydrogen Chlorine hydrochloric acid

(b) $C + O_2 \xrightarrow{\ominus} CO_2$

Carbon Oxygen Carbon dioxide

(c) $Ca\ O + H_2O \longrightarrow Ca\ (OH)_2$

Calcium oxide Water Calcium hydroxide

2- Decomposition or "Analysis", is a reaction in which a compound is broken up into simpler compounds. For example,

(a) $2\ H_2O \xrightarrow[H_2\ SO_4]{\sim\sim\sim} 2\ H_2\uparrow + O_2\uparrow$

Water Catalyst hydrogen oxygen

(b) $2K\ Cl\ O_3 \xrightarrow{\ominus} 2K\ Cl + 3O_2$

potassium Chlorate pot.Chloride oxygen

(c) $Ca\ CO_3 \xrightarrow{\ominus} Ca\ O + CO_2\uparrow$

Calcium Carbonate Calcium oxide Carbon dioxide

3- Simple Replacement or "Substitution", is the reaction in which a free element replaces another element in a compound For example,

(a) $Zn + H_2\ SO_4 \longrightarrow Zn\ SO_4 + H_2\uparrow$

Zinc Sulphuric acid Zinc sulphate hydrogen

(b) $Na + 2\ H_2\ O \longrightarrow 2\ Na\ OH + H_2\uparrow$

sodium Water Sod.hydroxide hydrogen

4- Double Replacement or "Metathesis" , is the reaction in which two compounds exchange metallic and non-metallic components to form two new compounds. For example,

$Ag\ NO_3 + Na\ Cl \longrightarrow Na\ No_3 + Ag\ Cl\downarrow$

silver nitrate sod.chloride sod.nitrate silver Chloride

A I R

WHAT IS AIR ?

Is it a mixture or a compound ?
What are the gases which constitute it ?
What is the importance of each constituent for living bodies ?

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44. **THE CONSTITUENTS OF AIR.**

Air is a mixture of different gases and not a compound. It is a mixture of the following gases:-

1.	Oxygen	21 %
2.	Nitrogen	78 %
3.	Carbon Dioxide	0.04% approximately
4.	Water vapour	variable proportions
5.	Rare gases (Argon, Neon., Krepton & Helium)	1 % approximately
6.	Dust.	

45. **AIR IS A MIXTURE.**

Experiments proved that air is a mixture and not a compound because:-

1. Every gas which is a part of air retains its physical and chemical properties.
2. The proportions of the constituents of air are variable.
3. Its constituents can be separated easily as when liquid air is evaporated, nitrogen is liberated first leaving Oxygen.

46. **ALL THE CONSTITUENTS OF AIR ARE NECESSARY FOR LIFE.**

1. Oxygen: It is necessary for respiration in both plants and animals.
2. Nitrogen: It dilutes oxygen and if only oxygen was found in the air, the lungs would have been burnt. Nitrogen is also taken by certain bacteria which live in the roots of some plants and is changed into proteins, (e.g. beans roots).
3. Carbon dioxide: It is taken through the leaves of plants and changed into starch or sugar in the presence of sunlight and chlorophyll.
4. Water vapour: It prevents much evaporation from the bodies of plants and animals.
5. Rare gases: They are inactive gases and are of no importance for life.

47. AIR IS NECESSARY FOR BURNING AND RUSTING.

When some subtances are heated in the air their weights increase. For example, if we leave a piece of iron for a few days in a damp place it will rust and increase in weight. In such cases a certain part of air disappears during rusting or burning and rusting is accompanied by an increase in weight.

Lavoisier, a French scientist heated some mercury for a few days in a retort the neck of which extends into an air jacket converted in a trough containing mercury. He found that mercury rose to about one-fifth of the jacket and that the mercury in the retort became covered by a red powder which differed from mercury in evéry detail. He then took a burning piece of wood and introduced it into the jacket and found that it was extinguished. Therefore he said that only one fifth of the air is necessary for burning. This one fifth of air was later called Oxygen. It is the part which has disappeared from the air jacket and combined with the mercury in the retort to form the red powder.

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OXYGEN

48. **OCCURENCE:** Oxygen is the most abundant element in nature. It occurs both in the free state and combined with other elements.

1. In the free state; it is found in air in the ratio of 21 % by volume. It is also found dissolved in water in a proportion little more than that present in air.

2. In the combined state; it constitutes about one half of the earth crust, eight ninths the weight of water, and about 70 % of the living bodies.

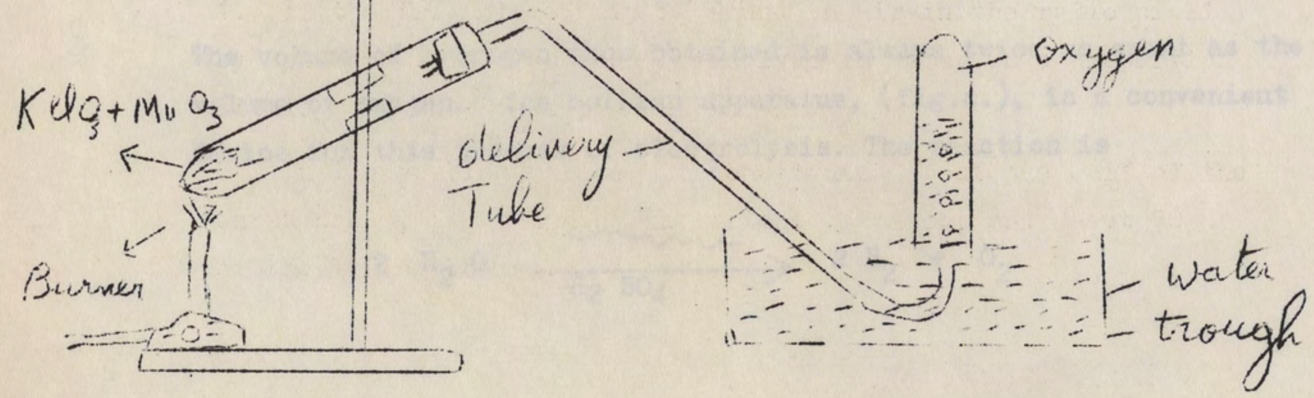
49. **METHODS OF PREPARATION**

1. Laboratory methods:-

(a) From potassium chlorate. Oxygen is readily prepared in the lab., by gently heating a mixture of potassium chlorate ($K\,Cl\,O_3$) and manganese dioxide ($Mn\,O_2$). The evolved gas is collected by an upward displacement of water as shown in (Fig.3). The equation for the reaction is:

$$2\,K\,Cl\,O_3 \xrightarrow[\theta]{Mn\ O_2} 2\,K\,Cl + 3O_2\uparrow$$

potassium chlorate → potassium chloride, oxygen



$$2KClO_3 \xrightarrow{\theta} 2KCl + 3O_2\uparrow$$

Fig. 3

The manganese dioxide does not enter into the reaction. Its function is simply to help the evolution of oxygen at a faster rate and at a lower temperature without undergoing any change itself.
Such a substance is called "catalytic agent" or "catalyst".

A catalytic agent or (catalyst) is a subtance which changes the speed of a chemical reaction without itself undergoing any change either in weight or in composition.

(b)- From red mercuric oxide (Historical method). By heating red mercuric oxide vigorously in a test tube closed by a rubber-stopper through which passes a delivery tube, which extends to a trough containing water, the red mercuric oxide will decompose into metallic mercury which remains in the test tube and oxygen which passes through the delivery tube and is collected by an upward displacement of water. The equation for the reaction is:

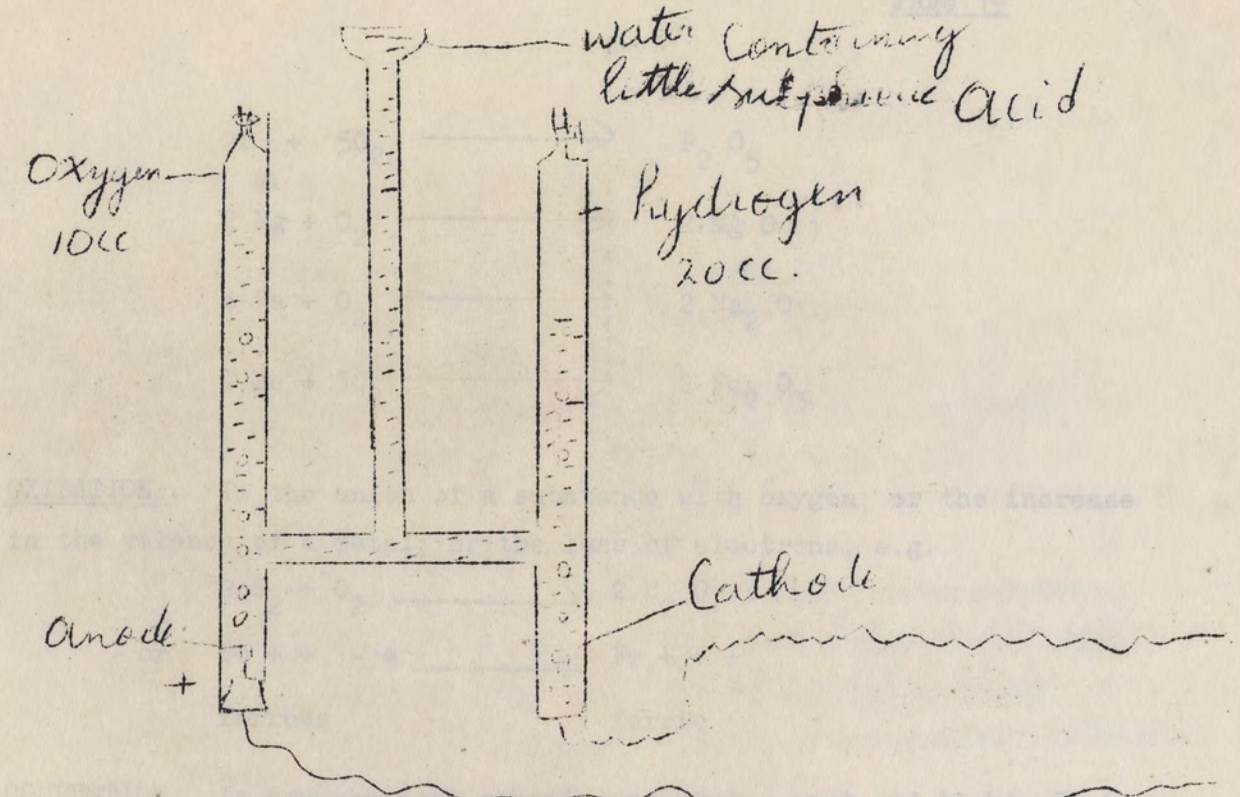
$$2\ HgO \xrightarrow{\Theta} 2\ Hg + O_2 \uparrow$$

2- Commercial methods:-

(a) Electrolysis of Water:- The apparatus is filled with acidified water (a little H_2SO_4 is added to water to make it electrically conductive) and a current is passed through the solution by connecting the two platinum foils at the bottom of the two side tubes, with the poles of an electric battery (D.C.) The platinum foils are called "Electrodes". The water is decomposed into oxygen and hydrogen. The oxygen collects over the positive electrode "anode", while the hydrogen collects over the negative electrode (cathode).

The volume of hydrogen thus obtained is always twice as great as the volume of oxygen. The Hoffman apparatus, (fig.4.), is a convenient device for this process of electrolysis. The reaction is

$$2\ H_2O \xrightarrow[H_2SO_4]{\sim\sim\sim} 2\ H_2 + O_2$$



Hoffman Apparatus. Fig.4

(b) Distillation of liquid air:- Air may be liquified by subjecting it to a high pressure and a low temperature. When liquid air is allowed to boil, the nitrogen, having a lower boiling point escapes as a gas leaving nearly pure liquid oxygen, which is directed into iron cylinders for transportation.

50. PROPERTIES OF OXYGEN:-

a- physical properties:-

1. It is a gas under ordinary conditions
2. It is colourless, odourless and tasteless gas.
3. It is slightly heavier than air.
4. It is sparingly soluble in water.
5. It can be liquified and solidified by subjecting it to an extremely low temperature and a high pressure.

b- Chemical properties:-

1. Oxygen does not burn, but it supports combustion.
2. Chemically it is very active. It combines with nearly all elements to form oxides:-

$$S + O_2 \longrightarrow SO_2$$

$$C + O_2 \longrightarrow CO_2$$

$$2P + 5O_2 \longrightarrow P_2O_5$$

$$2\ Mg + O_2 \longrightarrow 2\ MgO$$

$$4\ Na + O_2 \longrightarrow 2\ Na_2O$$

$$4\ Fe + 3O_2 \longrightarrow 2\ Fe_2O_3$$

51. OXIDATION:- Is the union of a substance with oxygen; or the increase in the valency of a metal; or the loss of electrons. e.g.

$$2\ H_2 + O_2 \longrightarrow 2\ H_2O$$

or $Fe^{++} - e \longrightarrow Fe^{+++}$

ferrous → ferric

52. COMBUSTION: Is any chemical reaction producing heat and light. It is usually a rapid oxidation, although oxygen is not the only gas that supports combustion. For example, sodium burns vigorously in Chlorine, producing sodium chloride.

53. KINDLING TEMPERATURE:- Is the lowest temperature at which the substance begins to burn. For example, yellow phosphorous has an extremely low kindling temperature (36^0C) and must therefore be kept under water. On the other hand, coal has a relatively high kindling temperature. In making fire in a stove we have to start first by igniting paper which has a fairly low kindling temperature. The heat generated is sufficient to raise the wood to its kindling temperature, which in turn, heats the coal until the kindling temperature of coal is reached.

54. SPONTANEOUS COMBUSTION: - It is self-burning caused by slow oxidation of an oxidizable substance embeded in another substance which is a bad conductor of heat. e.g. If a piece of cotton cloth is moistened with oil and left, the oil will gradually be oxidized and the heat generated will not be dissipated because the cotton cloth is a bad conductor of heat, so heat will accumulate until the kindling point of cotton is reached and fire takes place.

55. USES OF OXYGEN : -

(a) - uses of oxygen in the air:-

1. Respiration of both animal and plants.
2. For burning.
3. Aeration of drinking water for killing bacteria.
4. It assists certain bacteria to decay waste matter.

(b) - Uses of pure oxygen:-

1. to produce high temperature by means of oxy-hydrogen and oxy-acetylene torches, for cutting and welding steel. Recently, mixtures of liquid oxygen and gasoline have been used to shoot experimental rockets into the upper atmosphere.
2. For artificial respiration as in case of pneumonia, drowning and (CO) poisoning.
3. For aviators and mountain climbers at high altitudes.

O X I D E S

57. DEFINITION: An oxide is a compound consisting of oxygen and one other element.

Many compounds containing oxygen are not oxides since they consist of three or more elements e.g. $Ca\ CO_3$.

58. CLASSIFICATION OF OXIDES:-

1- Acidic oxides: are usually non-metallic oxides. If soluble in water they combine with it forming an acid. Their solutions in water change blue litmus paper to red. They combine with bases to form salts and water.

$$SO_3 + H_2O \longrightarrow H_2\ SO_4$$

$$CO_2 + Ca(OH)_2 \longrightarrow Ca\ CO_3 + H_2\ O$$

carbon dioxide	calcium hydroxide	calcium carbonate	
acidic oxide	base	salt	water

Examples:- Sulphur Dioxide ($S\ O_2$), Sulphur Trioxide ($S\ O_3$), Carbon Dioxide ($C\ O_2$), phosphorus pentoxide ($P_2\ O_5$), Sileca or Silicon dioxide ($Si\ O_2O$, Chromium Trioxide ($Cr_2\ O_3$).

2- Basic oxides. They are all oxides of metals. If they dissolve in water they form an ALKALI or soluble hydroxide. Their solutions in water change red litmus paper to blue. They combine with acids to form salts and water.

$$Ca\ O + H_2O \longrightarrow Ca\ (OH)_2$$

$$Ca\ O + 2\ H\ Cl \longrightarrow Ca\ Cl_2 + H_2\ O$$

calcium oxide	hydrochloric acid	calcium chloride	
Basic oxide	acid	salt	water

Examples:- Sodium oxide (Na_2O), calcium oxide ($Ca\ O$), Copper oxide ($Cu\ O$).

3- Neutral oxides:- Are those oxides which when dissolved in water do not affect litmus. They will combine neither with acids nor with bases, so no salts are formed.

Examples are:- Water ($H_2\ O$), Carbon monoxide ($C\ O$), Nitrous oxide (N_2O) and ($N\ O$).

4- <u>Amphoteric oxides:-</u> Are those oxides which possess the properties of both acidic and basic Oxides. They combine with both acids and bases to form salts.

$$Al_2O_3 + 6HCl \longrightarrow 2AlCl_3 + 3H_2O$$

Aluminium oxide amphoteric axide	hydrochloric acid	Aluminium chloride salt	water

$$Al_2O_3 + 2NaOH \longrightarrow 2NaAlO_2 + H_2O$$

Aluminium oxide	Sod.hydroxide base	Sod. Aluminate salt	water

Examples:- Zinc oxide ($Zn O$), Aluminium oxide (Al_2O_3), Lead Monoxide ($Pb O$), Stannous oxide ($Sn O$).

5- <u>Peroxides:-</u> These are usually the oxides of metals containing a greater percentage of oxygen than their basic oxides. They give off oxygen on heating.

$$2BaO_2 \xrightarrow{\theta} 2BaO + O_2 \uparrow$$

Barium peroxide	Barium oxide	oxygen

Examples:- Barium peroxide ($Ba O_2$), Sodium peroxide ($Na_2 O_2$), Zinc peroxide ($Zn O_2$) & hydrogen peroxide ($H_2 O_2$).

A C I D S

59. <u>DEFINITION:</u> - An acid is a hydrogen compound whose hydrogen may be replaced by a metal and whose water solution changes the colour of litmus from blue to red.
Many compounds such as sugar and alcohol, contain hydrogen, but are not acids, because their hydrogen atoms cannot be replaced by a metal. The hydrogen of the acid is always accompanied by a non-metallic element such as Cl,S or by a radical such as ($N O_3$), (SO_4) and ($P O_4$).

60. PREPARATION OF ACIDS:- There are two common methods for the preparation of acids:

1- By the action of acidic oxides (acid anhydride) with water e.g.

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

2- By the action of sulphuric acid with a salt of the required acid e.g.

$$H_2SO_4 + 2\,NaCl \longrightarrow 2\,HCl + Na_2SO_4$$

61. PROPERTIES OF ACIDS:-

1- Acids taste sour.

2- They change litmus colour from blue to red.

3- All acids contain hydrogen which is replaceable by active metals e.g.

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$

4- They react with marble ($CaCO_3$) causing effervescence and evolution of CO_2.

$$2HCl + CaCO_3 \longrightarrow CaCl_2 + CO_2 + H_2O$$

5- Acids react with bases forming salt and water.

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

62. NAMING OF ACIDS:-

a- In case the acids do not contain oxygen i.e. when they are only composed of hydrogen and a non-metal, they are named by using the full name of the non-metal with the prefix hydro - and ending with - ic. Examples hydrochloric acid (HCl), hydrosulphuric acid H_2S.

b- In case they contain enough oxygen, they are named by using the name of non-metal ending with - ic. Examples, sulphuric acid (H_2SO_4) , carbonic acid (H_2CO_3) and nitric acid (HNO_3).

c- When the acids contain one less atom of oxygen, they are named by using the name of the non-metal ending with - ous. Examples, sulphurous acid (H_2SO_3) and nitrous acid (HNO_2)

BASES

63. DEFINITION:- A base is a compound of a metallic element or a radical with one or more hydroxyl (O H) groups. The water solution of a base change the colour of litmus from red to blue.

64. PREPARATION OF BASES:-

1- By the action of basic oxides with water:-

$$Ca\,O + H_2O \longrightarrow Ca(OH)_2$$

$$Mg\,O + H_2O \longrightarrow Mg(OH)_2$$

2- By the action between a base and a salt.

$$Na_2CO_3 + Ca(OH)_2 \longrightarrow 2Na\,OH + Ca\,CO_3 \downarrow$$

$$Fe\,Cl_3 + Na\,OH \longrightarrow 3Na\,Cl + Fe(OH)_3 \downarrow$$

3- By the action of an active metal and water:

$$2\,Na + H_2O \longrightarrow 2\,Na\,OH + H_2 \uparrow$$

65. PROPERTIES OF BASES:-

1- In general bases have a bitter taste.
2- Bases turn red litmus into blue.
3- Bases contain hydroxyl (O H) group.
4- Bases do not react with marble.
5- Bases neutralize acids forming salt and water.

66. NAMING OF BASES:- Bases are named by placing the name of the metal before the word " hydroxide ".
Examples: Sodium hydroxide ($Na\,OH$), Calcium hydroxide ($Ca(OH_2)$).
Strong soluble bases such as ($Na\,OH$) and ($K\,O\,H$) are often called alkalies.

(SALTS)

67. DEFINITION:- A "salt" is a compound consisting of a metal or a metallic radical combined with a non-metal or an acid radical. In other words, a salt is an acid the hydrogen of which is replaced by a metal or a radical. The term salt, as commonly used, refers to sodium chloride, but in chemistry salt is the general name of a class of compounds which resemble Sod. Chloride.

68. PREPARATION OF SALTS:- Salts are prepared by a variety of methods.

1- Neutralization:- Neutralization is the reaction between an acid and a base, forming salt and water. For example:

$$NaOH + HCl \longrightarrow NaCl + H_2O$$

In making Na Cl by this method a small quantity of Na OH solution is placed in a dish with a piece of blue litmus paper. Hydrochloric acid is then added drop by drop until the litmus paper just turns red. If this neutral solution is now evaporated to dryness, a white deposit of (Na Cl) remains, and may be identified by its salty taste.

2- Action of an Acid on a Metal:-

$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$$

3- Action of an Acid on metallic oxide:

$$CaO + 2HCl \longrightarrow CaCl_2 + H_2O$$

4- Action of an Acid on the Salt of a More Volatile Acid

$$H_2SO_4 + 2NaCl \longrightarrow Na_2SO_4 + 2HCl$$

5- Double Replacement Resulting in the Formation of an Insoluble product:

$$BaCl_2 + Na_2SO_4 \longrightarrow 2NaCl + BaSO_4$$

6- Direct Union of the Elements

$$Zn + S \longrightarrow ZnS$$

7- Union of a metallic oxide and a Non-Metallic Oxide

$$CaO + SiO_2 \longrightarrow CaSiO_3$$

69. PROPERTIES OF SALTS: Salts vary widely in characteristics. As a general rule, salts are white, crystalline solids with a salty taste. They are usually soluble in water, and Neutral to litmus paper. Among the many exceptions to the above, are copper sulphate, which is blue; calcium carbonate (marble) which is insoluble in water and sodium carbonate which in solution reacts basic to litmus, owing to hydrolysis.

70. TYPES OF SALTS:

1- An "acidic salt" is one in which only part of the hydrogen of the acid has been replaced by a metal. Thus Sodium acid carbonate, or sodium bicarbonate ($Na\ HCO_3$), and sodium acid phosphate ($Na\ H_2\ PO_4$) are acid salts.

2- A "basic salt" is one which contains one or more hydroxyl (OH) radicals. Thus bismuth subnitrate $Bi\ (OH)_2\ NO_3$ is a basic salt used in medicine.

3- A "Normal salt" is one which contains only a metal or a metallic radical, combined with a non-metal or an acidic radical. It contains neither hydrogen replaceable by a metal nor a hydroxyl radical. Thus $Ca\ CO_3$ & NaCl are normal salts.

4- A double salt is one which contains two metals combined with one acidic radical. Thus common alum is a double sulphate of potassium and aluminum, having the formula $K_2\ SO_4 .\ Al_2\ (SO_4)_3 .\ 24\ H_2\ O$ or $K\ Al\ (SO_4)_2 .\ 12\ H_2\ O$.

71. NAMING SALTS: The name of a salt consists of two parts, the name of the metal and the name derived from the acid. For example :

Acids of Chlorine	Formulas	Sodium Salts of the acids	Formulas
Hydrochloric acid	H Cl	Sod. Chloride	Na Cl
Chlorous acid	$H\ Cl\ O_2$	Sod. Chlorite	$Na\ Cl\ O_2$
Chloric acid	$H\ Cl\ O_3$	Sod. Chlorate	$Na\ Cl\ O_3$

(H Y D R O G E N)

72. OCCURENCE. Hydrogen is not as abundant as oxygen. It occurs both free and in the combined state in nature. In the combined state it occurs nearly everywhere, but in the free state, it occurs in natural gas and in volcanic gases. Traces of hydrogen are found in the lower strata of the earth's atmosphere and gradually its quantity increases at high altitudes. Hydrogen is known to occur abundantly in the sun's atmosphere.

In the combined state hydrogen constitutes about 1% of the earth crust and one ninth of the weight of water. It occurs in all acids, in animal and vegetable matter, such as butter, starch, sugar, in hydrocarbons such as kerosene, gasoline, etc.;

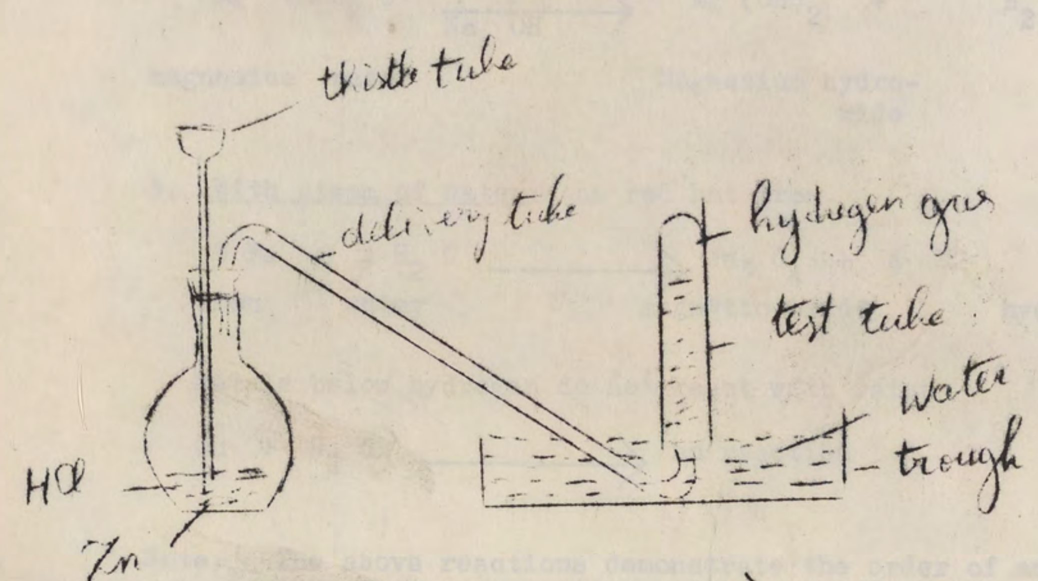
73. METHODS OF PREPARATION:-

1- LABORATORY METHODS.

a) by the action of certain metals on non oxidizing acids.

Metals such as zinc and iron react with certain dilute acids, notably hydrochloric acid and sulphuric acid.

Zinc is put in a flask closed by a rubber stopper, through which a thistle tube extends to the bottom of the flask, and a delivery tube also extends to a trough containing water, over which a large test tube filled with water is inverted. The dilute acid is poured through the thistle tube until it covers its lower end. Zinc replaces the hydrogen of the acid.



$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$

Fig.5

and liberates this hydrogen as a gas, which passes through the delivery tube and is collected by an upward displacement of water, at the same time forming a new salt compound called zinc chloride.

$$Zn + 2\,HCl \longrightarrow ZnCl_2 + H_2$$

$$Fe + \underset{\text{dil.}}{H_2SO_4} \longrightarrow FeSO_4 + H_2$$

$$Ag + HCl \longrightarrow \text{no reaction}$$

b- By the action of certain metals on water:-

Various active metals (above hydrogen) react with water under certain conditions liberating hydrogen and forming either a hydroxide or an oxide of the metal as follows:-

1. With cold water: as potassium, sodium & calcium

$$\underset{\text{sodium}}{2\,Na} + \underset{\text{water}}{H_2O} \longrightarrow \underset{\text{sodium hydroxide}}{2\,NaOH} + H_2 \quad \text{vigorously}$$

$$\underset{\text{calcium}}{Ca} + \underset{\text{water}}{2\,H_2O} \longrightarrow \underset{\text{calcium hydroxide}}{Ca(OH)_2} + H_2 \quad \text{slowly}$$

2. With hot water: as Magnesium, using Na OH as a catalyst.

$$\underset{\text{magnesium}}{Mg} + \underset{\text{water}}{2H_2O} \xrightarrow[NaOH]{} \underset{\text{Magnesium hydroxide}}{Mg(OH)_2} + H_2 \quad \text{slowly}$$

3. With steam of water: as red hot iron

$$\underset{\text{iron}}{3\,Fe} + \underset{\text{water}}{4\,H_2O} \longrightarrow \underset{\text{magnetic oxide}}{Fe_3O_4} + \underset{\text{hydrogen}}{4\,H_2} \quad \text{Rapid}$$

Metals below hydrogen do not react with water

$$Cu + H_2O \longrightarrow \text{no reaction}$$

Note: The above reactions demonstrate the order of activity of metals.

(REPLACEMENT SERIES)

1	Potassium	K)	Highest
2	Sodium	Na)	activity
3	Calcium	Ca)	decreasing
4	Magnesium	Mg)	to
5	Aluminum	Al)	
6	Zinc	Zn)	
7	Iron	Fe)	
8	Nickle	Ni)	
9	Tin	Sn)	
10	Lead	Pb)	
11	HYDROGEN	H)	lowest
12	Copper	Cu)	activity
13	Mercury	Mg)	
14	Silver	Ag)	
15	Platinum	Pt)	
16	Gold	Au)	

Note: metals above hydrogen in the replacement series replace it from dilute acids, while metals below hydrogen do not replace it from acids.

II. COMMERCIAL METHODS:-

a- By electrolysis of water:- When an electric current is passed through acidified water, hydrogen is liberated at the cathode.

b- By the action of Hot Coke on steam:-
When steam is passed over white - hot coke (carbon), a mixture of hydrogen and carbon monoxide gas is formed which is called " water gas ".

$$H_2O + C \longrightarrow CO + H_2$$

When the mixture of both gases is cooled to a very low temperature, the CO gas changes to a solid, leaving pure hydrogen. In other cases, when the mixture of both hydrogen and carbon monoxide gases is mixed with more steam and passed over a catalyst, (divided Fe), CO will be changed into CO_2

$$CO + H_2O + H_2 \longrightarrow CO_2 + 2H_2$$

Then $CO_2 + H_2$ are treated with water at a pressure of 3o atmos-

74. **PROPERTIES OF HYDROGEN:**

a- Physical Properties:

1. It is a gas under ordinary conditions.
2. It is colourless, odourless & tasteless gas.
3. It is the lightest gas known, being 14.5 times lighter than air.
4. It is very slightly soluble in water.
5. It is absorbed in large volumes by the metals palladium and platinum accompanied by the liberation of much heat.

b- Chemical Properties:

1. Hydrogen does not support combustion; it burns with a pale flame. When it is mixed with air or oxygen it explodes at kindling temperature.

$$2\,H_2 + O_2 \longrightarrow 2\,H_2O$$

2. It is not active at ordinary temperature.
3. It combines directly with other elements at high temperatures & sometimes it combines on mere exposure to light.

$$\underset{\text{Hydrogen}}{H_2} + \underset{\text{Chlorine}}{Cl_2} \longrightarrow \underset{\text{hydrogen chloride}}{2\,HCl}$$

$$\underset{\text{Hydrogen}}{3\,H_2} + \underset{\text{nitrogen}}{N_2} \xrightarrow[\text{Fe + }\theta]{\text{200 atm.}} \underset{\text{ammonia}}{2\,NH_3}$$

$$\underset{\text{Hydrogen}}{H_2} + \underset{\text{sulphur}}{S} \longrightarrow \underset{\text{hydrogen sulphide}}{H_2S}$$

$$\underset{\text{Hydrogen}}{H_2} + \underset{\text{Calcium}}{Ca} \longrightarrow \underset{\text{Calcium hydride}}{CaH_2}$$

4. It is a powerful reducing agent. It removes oxygen from so many of its compounds.

75. **REDUCTION:-** Is the process of removing oxygen from a compound. A substance which can effect such a removal of oxygen is called a " Reducing agent ".

To prove that hydrogen is a reducing agent, we pass the dry gas (H_2) over heated copper oxide as in the figure below.

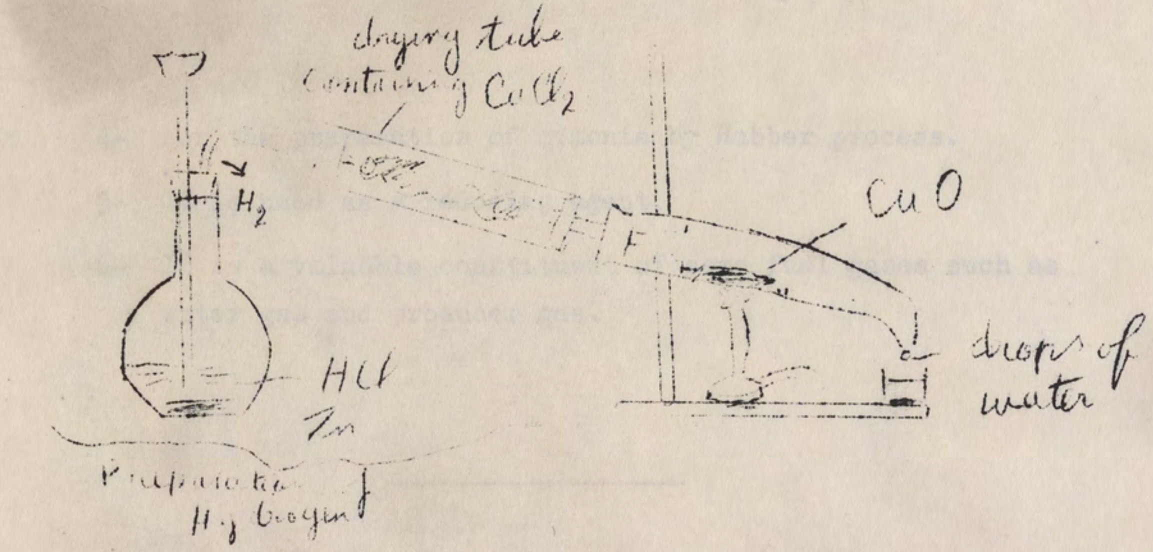


Fig.6

The hydrogen combines with the oxygen present in the oxide, forming water, the residue left behind in the tube is metallic copper. Whenever reduction takes place, it is always accompanied by oxidation, as can be observed by examining the equation for this reaction:-

$$CuO + H_2 \longrightarrow Cu + H_2O$$

CuO	H_2	Cu	H_2O
copper oxide substance reduced also oxidizing agent	hydrogen reducing agent, also substance oxidized	copper	water

76. TEST FOR HYDROGEN: Hydrogen may be identified by one chemical test:- When hydrogen burns, the only product formed is water.

77. USES OF HYDROGEN:- Hydrogen is used:

1- To obtain a very high temperature, for welding metals.
2- For filling balloons and airships, but owing to its great combustibility it is often substituted by helium (He).
3- For hydrogination:- Many liquid oils and fats, such as cotton seed oil & coconut oil have disagreable odours & tastes & can not in their simple state be used for cooking. They are converted into palatable solid fats fit for cooking, by passing hydrogen in the presence of powdered nickel as a catalyst. The product is called VEGETALINE.

4- For the preparation of ammonia by Habber process.

5- It is used as a reducing agent.

6- It is a valuable constituent of some fuel gases such as water gas and producer gas.

WATER

78. OCCURRENCE. Water is present in nature, and it occupies about $\frac{3}{4}$ of the earth's surface. It is also present in many salts and animal and vegetable bodies. For example, lean meat is about 60% water, while tomatoes are about 95% water. The human body contains about 70% water.

79. FORMATION. Being abundant in nature, water is not usually prepared from other materials. However, it is a product of many chemical reactions some of which are:

1. Direct union of oxygen and hydrogen by an electric spark.

$$2\ H_2 + O \longrightarrow 2\ H_2O.$$

2. Oxidation of a compound of hydrogen.

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2\ H_2O$$

3. Reduction of an oxide by hydrogen.

$$CuO + H_2 \longrightarrow Cu + H_2O$$

4. Neutralization of acids and bases.

$$NaOH + HCl \longrightarrow Na\ Cl + H_2O$$

80. PROPERTIES.

a- Physical Properties:

1. Water is liquid at ordinary temperature. It is tasteless and odourless. It has no colour when in thin layers, but it acquires a bluish tinge when it is observed through great thickness.
2. Water freezes at $0^\circ C$ ($32^\circ F$), and boils at $100^\circ C$ ($212^\circ F$).
3. Its greatest density, namely 1, (i.e. 1cc weighs 1 gm), is reached at 4 degrees centigrade.
4. It dissolves almost all substances to some extent, and may therefore be considered as a universal solvent. The pleasant taste of drinking water is due to dissolved air and minerals.
5. Water when pure, does not conduct electricity.

b- Chemical Properties:

1. Water is extremely stable.
2. It reacts with various active metals such as Na, Ca, Fe, with formation of hydrogen.
3. It is decomposed by an electric current into hydrogen and oxygen.
4. It combines with certain metallic oxides forming bases:

$$Ca\ O + H_2O \longrightarrow Ca\ (OH)_2$$

Calcium oxide + water — Calcium hydroxide

5. It combines with certain non-metallic oxides forming acids.

$$C\,O_2 + H_2O \longrightarrow H_2C\,O_3$$

Carbon dioxide + water Carbonic acid

6. Water reacts with certain salts, forming both an acid and a base. This process is called "hydrolysis".

$$Al_2(SO_4)_3 + 6\,H_2O \longrightarrow 2\,Al(OH)_3 + 3\,H_2SO_4$$

Aluminium sulphate + water Aluminium hydroxide + Sulphuric acid

7. Water combines with some compounds when they crystallize from solution, forming hydrates, and this water is called water of crystallization. For example:

$$Cu\,SO_4 + 5\,H_2O \longrightarrow Cu\,SO_4.5H_2O$$

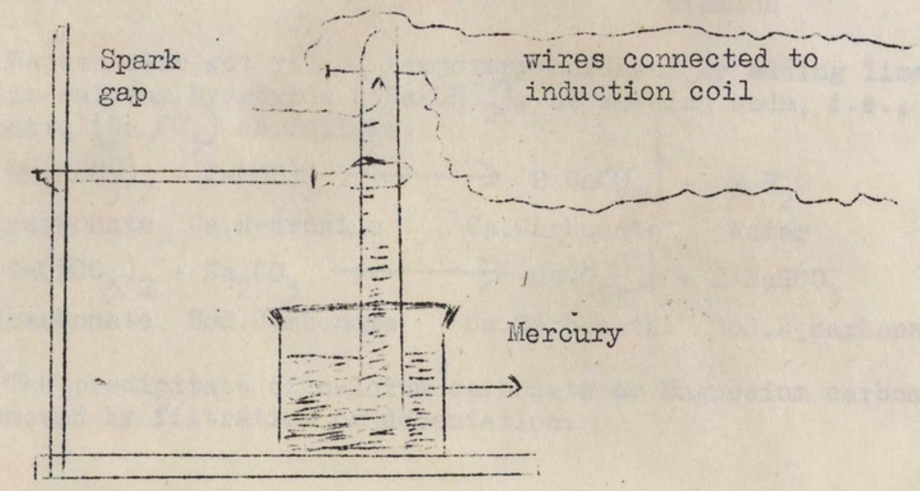
unhydrous copper sulphate plus water Hydrated crystallized copper sulphate

8. Water acts as a catalyst. Many chemical reactions cannot take place unless there is some moisture present, as for example, rusting of iron.

81. WATER IS A COMPOUND. Water is a compound of oxygen and hydrogen, in the ratio of 8:1 by weight and 1:2 by volume. One of the first steps in the study of a chemical compound is to learn its composition, that is what elements it contains, and the exact amount of each. There are two methods of obtaining this information.

1. Analysis. On passing an electric current in an acid water in a voltametre (Höffman apparatus), we get hydrogen at the Cathode and oxygen at the anode. See pages 18 and 19.

2. Synthesis. On passing a spark through a mixture of definite quantities of oxygen and hydrogen in an eudiometer, an explosion ôccurs and drops of water form on the inner surface of the tube.



Eudiometer

82. WATER CYCLE IN NATURE. Water has the following cycle in nature:

1. Water evaporates from oceans and seas.
2. After evaporation it condenses and forms clouds.
3. Clouds change into rain.
4. Rain falls on the earth's surface dissolving some salts found on its crust. Rain water then passes down through the soil until it meets a solid layer where it collects. When sufficiently large quantities of water are collected in this way, water is again forced up to the earth's surface forming springs.
5. Waters from Springs and Brooks flow and meet together to form a river. This river flows into the sea and thus the cycle is repeated.

83. HARDNESS OF WATE R. Hard water is that water which does not lather with soap, because of the presence of SOLUBLE calcium or magnesium salt in it which form an insoluble precipitate with soap.

$$Ca\,Cl_2 + 2\,NaC_{17}H_{35}CO_2 \longrightarrow Ca(H_{17}H_{35}CO_2)_2 + 2\,NaCl$$

Sod.Stearate soluble soap → Calcium Stearate insoluble soap

Hardness is of two kinds:

a- Temporary Hardness: Is the hardness caused by the presence of the bicarbonate of either Calcium or Magnesium ($Ca(HCO_3)_2$, or $Mg(HCO_3)_2$). These are unstable salts, i.e. they easily decompose on heating forming the insoluble carbonates. Therefore this hardness can be got rid of by boiling the hard water, as is represented by the following equations:

$$Ca(HCO_3)_2 \xrightarrow{\theta} CaCO_3\downarrow + CO_2\uparrow + H_2O$$

Ca.bicarbonate → Calcium Carbonate + Carbon dioxide + Water

$$Mg(HCO_3)_2 \xrightarrow{\theta} MgCO_3\downarrow + CO_2\uparrow + H_2O$$

Mg. bicarbonate → Mg.carbonate + Carbon dioxide + Water

We can also get rid of temporary hardness by adding lime water that is calcium hydroxide ($Ca(OH)_2$), or washing soda, i.e., sodium carbonate (Na_2CO_3) as follows:

$$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2\,CaCO_3\downarrow + 2\,H_2O$$

Ca.Bicarbonate + Ca.Hydroxide → Ca.Carbonate + Water

$$Ca(HCO_3)_2 + Na_2CO_3 \longrightarrow CaCO_3\downarrow + 2\,NaHCO_3$$

Ca.Bicarbonate + Sod.Carbonate → Ca.Carbonate + Sod.Bicarbonate

The precipitate of calcium carbonate or Magnesium carbonate can be removed by filtration or decantation.

b- <u>Permanent Hardness:</u> Is that hardness due to the presence of soluble salts of Mg and Ca in water. These salts do not decompose on heating. They are: Calcium sulphate ($CaSO_4$), Calcium chloride ($CaCl_2$), Magnesium sulphate ($MgSO_4$) and Magnesium Chloride ($MgCl_2$). In other words, they are Sulphate and Chloride salts of Magnesium and Calcium.

Permanent hardness is removed by adding washing soda (Na_2CO_3) as follows:

$$\underset{\text{Calcium sulphate}}{CaSO_4} + \underset{\text{Sod. Carbonate}}{Na_2CO_3} \longrightarrow \underset{\text{Sod. Sulphate}}{Na_2SO_4} + \underset{\text{Cal. Carbonate}}{CaCO_3}$$

$$\underset{\text{Magnesium chlordie}}{MgCl_2} + \underset{\text{Sodium Carbonate}}{Na_2CO_3} \longrightarrow \underset{\text{Sodium Chloride}}{2\ NaCl} + \underset{\text{Magnesium Carbonate}}{Mg\ CO_3}$$

Sodium Chlordie and Sodium sulphate remain soluble and have no action on soap lather.

----

k.

THE HALOGENS

84. MOMENCIATURE

The halogens refer to the four elements fluorine, chlorine, bromine, and iodine. These four elements can combine with metals to form salts such as common salt (NaCl) and hence the word halogen (meaning salt-former) is given to this group of elements. These four elements are grouped as one family because they resemble each other in properties and in their chemical compounds. We shall choose the chief member of this family, namely, Chlorine for our study as representative for the others.

CHLORINE

85. OCCURRENCE: This element is not present in nature in the free state due to its great chemical activity. Therefore it exists in nature in the combined form. The common compound of it is sodium chloride (NaCl) which is common salt. Other Chlorides exist in nature such as those of K, Mg and other elements.

86. PREPARATION:

Laboratory Methods

By oxidation of hydrochloric acid with an oxidizing agent such as manganes dioxide:

$$4HCl + MnO_2 \longrightarrow MnCl_2 + 2H_2O + Cl_2$$

The apparatus commonly used for this preparation is illustrated in the following diagram.

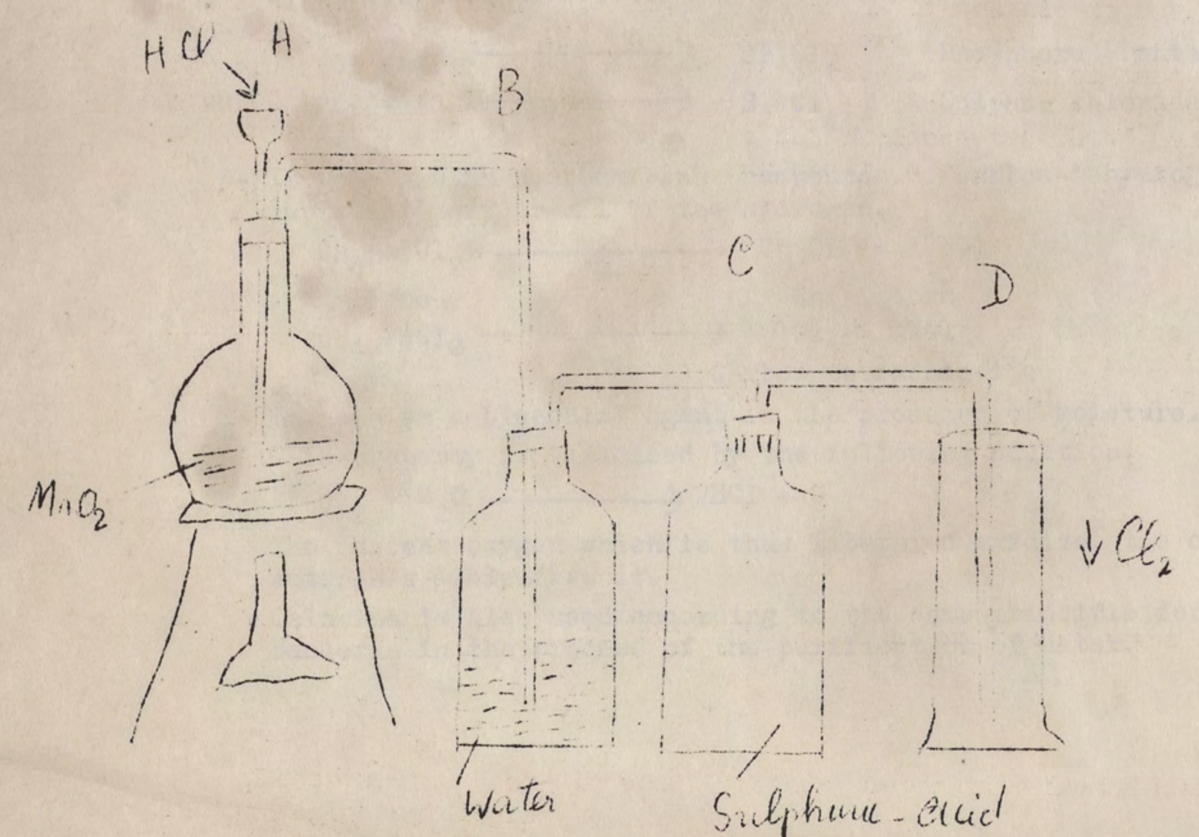


Fig. 7

Flask A contains MnO_2 to which is added concentrated HCl through a thistle tube.

The Chlorine gas which is librated in flask A is passed through the connecting tube to bottle B. This bottle contains water to absorb any gaseous (HCl) which might escape mixed with the librated chlorine. Chlorine gas then passes through a 2nd connecting tube to bottle C which contains concentrated H_2SO_4(to absorb moisture). The dry chlorine gas is lastly collected by the downward displacement of air. Chlorine gas, unlike oxygen and hydrogen, cannot be collected over water because it is soluble in it.

87. PROPERTIES:

(a) Physical properties:-

1- It is a greenish yellow gas.
2- It has a strong irritating odour and when inhaled it attacks the delicate membranes of the nose, thorat & lungs.
3- It is extremely poisonous.
4- It is about 2½ times as heavy as air.
5- It is somewhat soluble in water.
6- It is liquified easily by pressure alone at room temperature.

(b) Chemical properties:-

1- It is extremely active.
2- It combines directly with many elements forming chlorides:

a) It combines with hydrogen:

$$Cl_2 + H_2 \xrightarrow{\text{sun light}} 2HCl$$

b) It combines with metals such as heated Sodium:

$$Cl_2 + 2Na \xrightarrow{\Theta} 2Na\ Cl$$

c) It combines with phosphorous or sulphur

$$5Cl_2 + 2P \longrightarrow 2P\ Cl5 \quad \text{Phosphorus Penta chloride}$$

$$2Cl_2 + 2S \longrightarrow S_2\ Cl_4 \quad \text{Sulphur chloride}$$

3- It reacts with hydrocarbons (compounds of carbon & hydrogen), replacing part or all of the hydrogen

$$\underset{\text{Methane}}{Ch_4} + 3Cl_2 \longrightarrow \underset{\text{Chloroform}}{Ch\ Cl_3} + 3H\ Cl$$

$$Ch_4 + 4Cl_2 \longrightarrow \underset{\text{Carbon tetrachloride}}{C\ Cl_4} + 4HCl$$

4- It acts as a bleaching agent in the presence of moisture.
This property is explained by the following equation:

$$Cl_2 + H_2O \longrightarrow 2HCl + O$$

The nascent oxygen which is thus liberated oxidizes the colouring materials & bleaches it.

Chlorine is also used according to the same principle for killing Bacteria in the process of the purification of water.

5- Action of Chlorine on alkalies
a) with diluted & cold alkali it forms hypochlorite & chloride & water: -

$$Cl_2 + 2NaOH \xrightarrow[dil]{Cold} NaCl + Na\ OCl + H_2O$$

b) with concentrated & hot alkali it forms cholorate & chloride & water:-

$$3Cl_2 + 6NaOH \xrightarrow[conc]{hot} 5NaCl + NaClO_3 + 3H_2O$$

88. USES:

1- It was used in the 1st world war as a poisonous gas.

2- It is ued in the purification of water.

3- It is used in the bleaching of coloured materials.

4- It is used for the preparation of bleaching powder, carbon tetra-chloride, chloroform and other compounds.

89. TEST:

It is tested by exposing to it a filter paper moistured with a solution of potassium iodide and starch. In such a case a blue colouration indicates the presence of chlorine

$$Cl_2 + 2KI \longrightarrow 2KCl + I_2$$

$$I_2 + starch \longrightarrow blue\ colour.$$
