Chapter (2) Quantitative chemistry

Lesson (1)
Mole and chemical equation

Chemical Equation

*When oxygen gas reacts with magnesium, magnesium oxide is formed. Such Reactions are described by balanced equations known as "**chemical equations**"*

$$2Mg(s) + O_2(g) \xrightarrow{\Delta} \Delta\ 2MgO(s)$$

The chemical equation of magnesium reaction with oxygen

Chemical equation properties

1- It is composed of the chemical formulas and symbols of the reactants and products

2- Both sides of the equation (the reactants and products) are separated by an arrow describing the conditions and direction of the reaction ***(in the previous equation, the triangle on the arrow describes heat)***

3- It describes the quantity of reactants and products (the no. of molecules)

4- It describes the state of reactants and products – ***solids are denoted by (s), liquids (l), gas (g) and aqueous solutions (aq.)*** *as shown in the previous equation*

Chemical equations should be balanced, which means that the no. of molecules of reactants should equal the no. of molecules of products. This is known as ***"law of mass conservation"***

Chemical equation: *The representation of chemical reaction using chemical symbols, formulas of reactants and products, and the description conditions of reaction.*

Molecule: *is the smallest particle in a chemical element or compound that has the chemical properties of that element or compound and exists alone*

Atom: *The smallest building unit of matter which takes part in chemical reaction*

<u>How to balance a chemical equation:</u> *to balance a chemical equation, we should make sure that the right side of the equation has the same atoms of the left side of it*

<u>Example:-</u>

Balance the following equations:-

1- $Al + O_2 \rightarrow Al_2O_3$

2- $NaNO_3 \xrightarrow{\Delta} NaNO_2 + O_2$

Solution:-

*1- we find that there are 3 oxygen atoms on the right side of the equation, while there are only 2 on the left side of it. To balance the no. of oxygen atoms on both sides, we should increase the no. of oxygen atoms on both of them to 6 (**6 is the least common multiple of 2 and 3)***

$$Al + 3\ O_2 \rightarrow 2\ Al_2O_3$$

There are four aluminium atoms on the right side of the equation, while there's a single atom on the left side. To balance the no. of aluminium atoms on both sides, we increase the no. of atoms in left size to 4 aluminium atoms

$$4Al + 3\ O_2 \rightarrow 2\ Al_2O_3$$

2- The no. of oxygen atoms on the right side of the equation is 3, while that on the right side of the equation is 4, to balance the no. of oxygen atoms, we increase the no. of oxygen atoms on both sides to 6

$$NaNO_3 \xrightarrow{\Delta} NaNO_2 + O_2$$

The Mole

*We studied before that every element has its own **mass number** (the number of protons and neutrons in the nucleus of the element atom)*

*Thus, if we want to calculate the atomic mass of an element , we only calculate the mass of its **nucleus (because the mass of electrons is too small if compared to those of protons and neutrons**)*

*Atomic masses are measured by a unit called **"Atomic unit"** or **a.m.u**.*

Atomic unit (a.m.u) = 1.66 x 10^{-24} gm = 1.66 x 10^{-27} kilogram

If the mass no. of oxygen is 12, so its atomic mass equals 12 a.m.u and so on.

"Mole" (the abbreviation of molecule) is the measuring unit of the quantity of matter

<u>How to calculate the mole of elements</u>

If the atomic mass of oxygen is 16 a.m.u, so one mole of oxygen equals 16 grams
If the atomic mass of nitrogen is 14 a.m.u, so one mole of nitrogen equals 14 grams
If the atomic mass of carbon is 12 a.m.u, so one mole of carbon equals 12 grams

Calculate the mole of helium (if its atomic mass equals 2 grams)

*If we want to know the mass of a molecule of a compound, we add the masses of the atoms forming it, which is known as "**Molecular mass"***

***Molecular mass:** The sum of the masses of the atoms forming molecules of a compound*

Example:-

The molecular mass of carbon dioxide molecule (CO2) is the sum of the masses of 2 oxygen atoms and 1 carbon atom.

if the atomic mass of oxygen equals 16 a.m.u, and that of carbon atom equals 12 a.m.u

Therefore, the molecular mass of CO2 molecule = 12+16+16 = 44 a.m.u

N.B: mole of carbon dioxide gas = 44 gm

Calculate the mole of water (H_2O), if the atomic mass of oxygen equals 16 a.m.u, and that of hydrogen equals 1 a.m.u

<u>Mole and the mass of matter</u>

We calculated before that mole of carbon dioxide equals 44 gm, so when we use 44 gm of carbon , it means that we used one mole of it

How to know the no. of moles in matter

$$\frac{\textit{The mass of matter (in grams)}}{\textit{The mass of one mole (gm/mole)}}$$

The no. of carbon dioxide moles in 440 grams of it equals 440 (the mass of matter) ***divided by*** *44 (the mass of one mole) = 10 moles*

Every substance has different molar mass ***due to the difference of the molecular structure and atomic masses of elements***

Note: *The mole of diatomic (nonmetal) elements are calculated in a different way (if they are pure elements)*
The mole of oxygen gas (in the form of molecules) O_2 *= 16+16= 32 gm*
The mole of oxygen gas (in the form of atoms) = 16 gm

There are some elements whose molar masses change by the change of their physical state (solid, liquid, gas) for example:-

1- ***Phosphorus****: Phosphorus molecule in gaseous state consists of 4 Phosphorus atoms (*P_4*) while its molecule in solid state consists of only 1 atom*

2- ***Sulphur:*** *Sulphur molecule in gaseous state is octatomic (consists of 8 atoms), while its molecule in solid state consists of only 1 atom*
So, we can say that in some elements, the mole in solid state is different from that in gas state

The importance of mole

It helps us calculate the amounts of substances required for chemical reaction

$$2Mg(s) + O2(g) \text{ --------> } \Delta \ 2MgO(s)$$

From the previous reaction, we deduce that the ratio between magnesium and oxygen equals 2:1, so the reaction needs 2 magnesium moles and 1 oxygen mole (the no. of moles of magnesium should be double that of oxygen)

Limiting reactant

We said that chemical reactions require certain amounts of reactants to get the required amount of products But if the amount of a certain reactant is smaller than the required amount, it's completely consumed. Such small amounts of reactants are known as **"Limiting reactant"**

Limiting reactant: *The substance that is totally consumed when chemical reaction is complete due to its lack*

Mole and Avogadro's number

Scientist ***Amedeo Avogadro*** *discovered that the no. of matter units (atoms,molecules,ions…etc) in all moles of all elements is constant. Later, that no. was calculated to be* ***$\underline{6.02 \times 10^{23}}$*** *and called "Avogadro's number"*

Avogadro's number: *A constant number representing the no. of atoms, molecules or ions in one mole, it equals* 6.02×10^{23} *matter unit/mole*

A mole of water (44 gram of it) has 6.02×10^{23} *molecules and so on*

<u>Ionic reactions</u>

Some physical processes, as the dissociation of some molecules into ions when they dissolve in water, are described by ***"ionic reactions"***

When dissolving sodium chloride in water, we describe it by the following ionic reaction:-

$$\textbf{Nacl}(s) \text{ ------------}\rightarrow \textbf{Na}^{+} (aq) + \textbf{Cl}^{-} (aq)$$

The previous reaction states that a solid mole of NaCl produces a mole of positive sodium ions (6.02×10^{23} *ions) and a mole of negative chlorine ions (*6.02×10^{23} *ions) when it dissolves in water*

*When sulphuric acid reacts with sodium hydroxide forming sodium sulphate and water (****Neutralization reaction)*** *, we describe the reaction as the following:-*

$$2NaOH(aq) + H2SO4(aq) \text{------}\rightarrow Na2SO4(aq) + 2H2O\ (l)$$

In neutralization reactions, we don't need to write the signs of ions in their ionic reactions.

When adding potassium chromate ($K_2C_2O_7$) to silver nitrate solution ($AgNO_3$), insoluble silver chromate($Ag_2Cr_2O_7$) is formed as a red ppt.

$$K_2Cr_2O_{7(aq)} + 2AgNO_{3(aq)} \dashrightarrow 2KNO_{3(aq)} + Ag_2Cr_2O_7$$

<u>Example (1)</u>

Calculate the no. of carbon molecules in 48 grams of carbon (C=12)

Solution:-

The mole of carbon = 12+12 = 24g (diatomic element)
Therefore, the no. of moles = 48 /24 = 2 moles
The no. of molecules = 2 x 6.02×10^{23} = 12.04×10^{23} atoms

<u>Example(2)</u>

Calculate the no. of carbon atoms in 50 grams of calcium carbonate $CaCO_3$ (Ca = 40, C=12, O=16)

Solution:-

One mole of $CaCO_3$ = *40 + 12 + (16x3) = 100 gm*

Therefore, 100 gm (one mole) of $CaCO_3$ contains one mole of carbon

50 gm of $CaCO_3$ *= 0.5 mole of $CaCO_3$ = 0.5 mole of carbon*

The no. of carbon atoms = 0.5 x 6.02×10^{23} = 3.01×10^{23} atoms.

The mole and the volume of gas

It's known that the volume of gas is the volume of its container, but scientists discovered that ***<u>moles of all gases occupy certain volume of 22.4 litres if they are put in certain conditions called "Standard temperature and pressure (STP)"</u>***

STP: *The presence of matter in temperature of 0 degree Celsius (273 Kelvin) and pressure of 760 mm.Hg (1 atomic pressure)*

This means that a mole of methane gas (CH_4) occupies volume of 22.4 litres (if it's in (STP), and the same to a mole of Hydrogen gas (H_2) and any gas

Volume of gas (in litres) = 22.4 x no. of moles

Example (1)

Calculate the volume of 64 gm of oxygen gas in STP conditions (O=16)

Solution:-

If one mole of oxygen =16+16= 32 gm (diatomic element)

The no. of moles = 64 /32= 2 moles

The volume of oxygen gas = 22.4 x the no. of moles = 22.4 x2 =44.8L

Example:-

Calculate the volume of oxygen required for 90 g of water when reacting with hydrogen in STP (O= 16, H=1)

Solution:-

$$2H_{2(g)} + O_{2(g)} \text{------}\rightarrow 2H_2O$$

$$2\text{ mol} \quad 1\text{ mol} \quad 2\text{ mol}$$

One mole of water = 16 + 1x2 = 18 grams

If one mole of oxygen produces 2 moles of water(36 grams of water)

Therefore, The no. of moles in oxygen = 90/36 = 2.5 mol

The volume of oxygen = 22.4 x2.5 = 50 L

Some laws on gases and moles

Gay-Lussac's law: *The volumes of reactant and product gases have certain volumes expressed in whole numbers*

In other words, The volumes of reactant gases and the products are inversely proportional, which means that:-

1- If one volume of hydrogen reacts with one volume of chlorine, one volume of hydrogen chloride gas is formed

$$H_2(g) + Cl_2(g) \text{------}\rightarrow 2HCl\ (g)$$

2- If one volume of nitrogen reacts with 3 volumes of hydrogen, 2 volumes of ammonia gas are formed

$$N_2(g) + 3H_2(g) \text{-----}\rightarrow 2NH_3\ (g)$$

Avogadro's law: *Equal volumes of gases in the same conditions of pressure and temperature have the same no. of molecules*

Avogadro stated that any gas of volume 22.4L in the standard conditions of pressure and temperature (STP) has $6.02x10^{23}$ molecules

At the end of this lesson, we conclude that mole has three definitions:-

1- The mass of molecules, ions and atoms in grams
2- A constant no. of molecules, atoms, ions or formula units whose value equals $6.02x10^{23}$
3- The mass of 22.4L in standard conditions of pressure and temperature

Mole: *The quantity of matter which contains Avogadro no. of ions, molecules or ions*

Lesson (2)

The calculation of chemical reactions

Weight percent

The weight percent of a substance $= \frac{100\text{x the mass (or the mole) the substance}}{\text{the mass of (or the mole) the compound}}$

Example

Calculate the weight percent of oxygen in carbon dioxide gas (C=12,O=16)

Solution

The mole of carbon dioxide $CO_2 = 12+16+16=44$ *gm*

The mass of oxygen atoms forming CO_2 *mole* $= 16 + 16 = 32$ *gm*

The weight percent of oxygen $= (32 / 44)\text{x } 100 = 72.7\%$

Example (2)

Calculate the mass of iron in 1000 kg of hematite (Fe_2O_3) *(if the weight percent of Fe equals 58%)*

Solution:-

The mass of iron $= 58\% \text{ x } 1000 = 580$ *kg*

Example (3)

Calculate the weight percent of iron in ferric oxide (Fe_2O_3) *(Fe=56, O=16)*

Solution:-

Mole of ferric oxide $= 56+56+16+16+16 = 160$ *gm*

The mass of iron atoms forming one mole of ferric oxide $= 56 + 56 = 112$ *gm*

Weight percent of iron $= (112/160) \text{ x } 100 = 70\%$

Example (4)

Calculate the no. of carbon moles in an organic compound containing only hydrogen and carbon atoms. The weight percent of carbon = 85.71% and the molar mass of the compound = 28 gm (C=12)

Solution:-

The mass of carbon in this compound = 85.71% x 28 = 24 gm
The molar mass of carbon = 12 gm
The no. of carbon moles = 24 / 12 = 2 moles

Calculating chemical formula

Chemical formulas have two main kinds:-

1- Empirical formula
2- Molecular formula

Empirical formula: *The formula that describe the simplest ratio between the atoms of the elements forming the compound molecules*

Example:-

*The formula of Propylene is C_3H_6, if we divided both numbers by 3, the empirical formula will be CH_2 (**empirical formula describes only the ratio between the components of molecules)***

How to calculate chemical formula

We can calculate them using the weight percents of the elements forming the compounds

Example:-

Calculate the empirical formula of a compound containing 25.9% nitrogen and 74.1% oxygen (O=16, N=14)

Solution:-

The no. of nitrogen moles = weight percent /molar mass = 25.9/14 = 1.85 mol.
The no. of oxygen moles =weight percent / molar mass = 74.1 / 16 = 4.63 mol.

$$\text{Nitrogen} : \text{Oxygen}$$
$$\frac{1.85}{1.85} : \frac{4.63}{1.85}$$
$$1 : 2.5$$

So, the ratio between Nitrogen and oxygen = 1 : 2.5 ***(we multiply both sides by 2 because decimals such as "2.5" cannot be used in chemical formulas)*** *= 2 : 5*

The chemical formula = N_2O_5

<u>How to know the no. of atoms in a compound (Molecular formula)</u>

The no. chemical formula units = *The molar mass of compound / the molar mass of chemical formula units*

Molecular formula: *The symbolic formula of the molecule of a compound which describes the kind and the actual no. of the atoms forming that molecule*

Example:-

Acetic acid of weight 60 gm contains 40% carbon, 6.67% hydrogen and oxygen 53.33%
(C=12, O=16, H=1). Calculate its molecular formula

Solution:-

Oxygen :	Hydrogen :	Carbon
$\frac{53.33}{16}$	$\frac{6.67}{1}$	$\frac{40}{12}$
3.33	6.67	3.33
1	2	1

The empirical formula: CH_2O

The molar mass of Acetic acid = 12 + 1+1+16 = 30 gm

The no. of units = 60/30 = 2 units

The molecular formula = $CH_2O \times 2 = C_2H_4O_2$

Actual and theoretical yields

*When a chemical reaction occurs to get certain amount of chemical substances, the chemical equation of the reaction determines **theoretically** the amount of the products. **But practically, the amount of the products will be less than the theoretical amount because:-***

1- The products may be volatile and parts of them spread in the air
2- Parts of the products may stick to the glass containers walls
3- The reactants may be impure
4- side reactions may occur

Practical yield: *The amount of substances we get practically from the reaction*

Theoretic yield: *The amount of substances we expect to get form the reaction*

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*The percentage yield **(the percentage of practical yield)***

$$100 \times \frac{\text{Practical yield}}{\text{Theoretical yield}}$$

Example:-

39.4 gm of solid barium sulphate $BaSO_4$ precipitated when 40 gm of barium chloride solution $BaCl_2$ reacted with potassium sulphate. Calculate the percentage yield of barium sulphate

Solution

$$2BaCl_2 + 2KSO_4 \rightarrow 2BaSO_4 + 2KCl$$

Mole of $BaCl_2$ = 137 + 35.5 + 35.5 = 208 gm

Mole of $BaSO_4$ = 137 + 32 + 16+16+16+16 = 233 gm

The no. of $BaCl_2$ moles = mass of substance / molar mass = 40/208 = 0.19 mol

2 moles of $BaCl_2$ → 2 moles of $BaSO_4$
0.19 mole of $BaCl_2$ → 0.19 mol of $BaSO_4$

The mass of $BaSO_4$ = 0.19 x molar mass = 0.19 x 233 = 44.8 gm

The practical yield = 39.4 gm

The theoretical yield = 44.8 gm

The percentage yield = the practical yield / the theoretical yield x 100
= 39.4/44.8 x 100 = 87.95%

Definitions of lesson (1)

1- Chemical equation: *The representation of chemical reaction using chemical symbols,. formulas of reactants and products, and the conditions of it*

2- Avogadro's number: *The no. of ions, molecules and atoms in one mole of matter ($6.02x10_{23}$ matter unit/mole)*

3- Mole: *The mass of atoms, molecules, or formula units of matter in grams which contain Avogadro's number of them*

4- Avogadro's law: *Equal volumes of gases in the same conditions of pressure and temperature have the same no. of molecules*

5- Gay-Lussac's law: *The volumes of reactant and product gases have certain volumes expressed in whole number*

6- Empirical formula: *The formula that describe the simplest ratio between the atoms of the elements forming the compound molecules*

7- Molecular formula: *The symbolic formula of the molecule of a compound which describes the kind and the actual no. of the atoms forming that molecule*

8- Practical yield: *The amount of substances we get practically from the reaction*

9- Theoretical yield: *The amount of substances we expect to get form the reaction*

Rationalize (Give reasons for)

1- The volume of 26 gm Acetylene gas (C_2H_2) is equal to the volume of 2g of hydrogen gas in (STP) conditions

Because the mole of Acetylene molecule equals 26 gm, and the mole of hydrogen molecule equals 2g. By applying Avogadro's law, we'll find that the volumes of both gases are equal in (STP) conditions (because they contain the same no. of moles)

2- The molar mass of phosphorus differs according to its physical state
Because in gaseous state, phosphorus molecule consists of 4 atoms, while in solid state, It consists of 1 atom. So, the molar mass of gaseous phosphorus is different from that of solid phosphorus

3- Litre of oxygen gas has the same no. of molecules in a litre of chlorine gas in STP conditions
Because according to Avogadro's law, equal volumes of gases in STP conditions have the same no. of molecules

4- the no. of molecules in 9 gm of water H_2O is equal to that in 39 gm of Aromatic Benzene (C_2H_2)
Because the mass of one mole of water = 9 gm, whereas the mass of one mole of Aromatic Benzene = 39 gm, so they have the same no. of molecules (Avogadro's number) because they have the same no. of moles

5- Chemical equations should be balanced
In order to get the required amounts of products

6- Gas should be in STP conditions in order to calculate its volume using its molar mass
Because in STP conditions, one mole of any gas occupies volume of 22.4 litres

7- The molar mass of sulphur in solid state is different from that in gas state
Because a molecule of gaseous sulphur contains 8 atoms of sulphur, while that of solid sulphur contains only 1 atom. So, They have different molar masses

8- The actual (practical) yield is always less than the theoretical yield
Because the reactants may be impure, side reactions may occur, the products may be volatile and spread in the air, or they can stick to the glass containers walls

Chemical reactions

1- The reaction of sodium chloride with silver nitrates forming a white ppt. of silver chloride and sodium nitrates

$$NaCl_{(aq)} + AgNO_3 \rightarrow NaNO_{3\,(aq)} + AgCl$$

2- The reaction of Nitric acid with potassium hydroxide solution forming potassium nitrate solution and water

$$HNO_3\,_{(aq)} + KOH_{(aq)} \rightarrow KNO_{2(aq)} + H_2O\,_{(l)}$$

3- The reaction of potassium chromate with silver nitrate solution forming insoluble silver chromate (red ppt.) and potassium nitrite

K2Cr2O7(aq) + 2AgNO3(aq) ---------→ 2KNO3(aq) + Ag2Cr2O7

4- The reaction of sulphuric acid with sodium hydroxide forming sodium sulphate and water (Neutralization reaction) ,

2NaOH(aq) + H2SO4(aq)------→ Na2SO4(aq) + 2H2O (l)

Exercises on lesson (1)

<u>1- Choose the correct answer</u>

1- When 50 gm of $CaCO_3$ decomposes thermally, ……..gm of CaO is formed (Ca = 40, C=12, O=16)

A- 28 B- 16 C- 76 D- 35

2- The volume of hydrogen required to form 11.2 L of water is……….

A- 22.4 L B- 11.2 L C- 68.2 L D- 44.8 L

3- One atomic unit equals …………. Gm

A- $1.66\text{x}10^{-24}$ B- $2.73\text{x}10^{-23}$ C- $1.75\text{x}10^{-15}$ D- $3.65\text{x}10^{-13}$

4- The unit used in IS for measuring the quantity of matter is…..

A- Mole B- Joule C- Calenda D- Kelvin

5- The mass of 44.8L of ammonia gas (NH_3) in STP conditions is ………gm. (N=14, H=1)

A- 0.5 B-2 C- 17 D- 34

6- If an amount of sodium has $3.01x10^{23}$ atoms, so its mass is ……..gm

A- 11.5 B- 0.5 C- 23 D-46

7- The chemical equation should be balanced according to ....

A- Avogadro's law B- Gay-Lussac's law C- law of mass conservation D- Law of energy conservation

8- 0.5 mole of carbon dioxide gas (CO_2) weighs….. gm (C=12, O=16)

A- 22 B- 44 C-66 D-88

9- When 64 gm of oxygen reacts with hydrogen, ….. litres of water vapour (H_2O) are formed

A- 11.2 B- 22.4 C- 44.8 D- 89.6

10- The no. of moles in 36g of water equals…………. (H=1,O=16)

A- 1 B-2 C- 3 D- 4

11- The no. of molecules in 128g of sulphur dioxide (SO_2) equals…… (S=32, O=16)

A- 2 B- $6.02x10^{23}$ C- $3.01x10^{23}$ D- $12.04x10^{23}$

12- The no. of sodium ions resulted from the dissolution of 40g of sodium hydroxide (NaOH) equals…..(Na=23,O=16,H=1)

A- 2 B- $6.02x10^{23}$ C- $3.01x10^{23}$ D- $12.04x10^{23}$

13- The volume of 4g of hydrogen in STP conditions equals …

A- 11.2 B- 22.4 C- 44.8 D- 89.6

14- The volumes of reactant gases are inversely proportional to those of products according to……….

A- Avogadro's law B- Gay-Lussac's law C- law of mass conservation D- Law of energy conservation

2- Solve the following problems

1- Find the no. of sodium ions resulted from the dissolution of 117g of sodium chloride (NaCl) in water (Na=23,Cl=35.5)

2- 26.5g of sodium carbonate (Na_2CO_3) reacted with an abundant amount of hydrochloric acid in STP conditions (Na=23,C=12, O=16) find:-

- *a- The no. of water molecules*
- *b- The volume of carbon dioxide gas*

3- Calculate the no. of moles in 144gm. of carbon (C=12)

4- Calculate the mass of 2.4 moles of calcium carbonate ($CaCO_3$)
(Ca=40, C=12, O=16)

5- Calculate the volume of 56g of nitrogen gas in STP conditions (N=14)

6- 23g of sodium (Na) reacted with water(H_2O) forming sodium hydroxide (NaOH) and hydrogen gas (Na=23, O=16, H=1), Find:-

- *a- The no. of sodium ions resulted from the reaction*
- *b- The volume of evolving hydrogen gas*

7- Calculate the molar mass of gaseous phosphorus in STP conditions, and the no. of atoms in one mole of it.

3- Balance the following equations

1- $N_{2(g)} + H_{2(g)} \xrightarrow{\Delta} NH_{3(g)}$

2- $Cu(NO_3)_{2(s)} \xrightarrow{\Delta} CuO_{(s)} + NO_{2(g)} + O_{2(g)}$

3- $3\ Al_{(s)} + O_{2(g)} \xrightarrow{\Delta} Al_2O_{3(s)}$

The Answers

1- Choose

1- 28gm

→ The molar mass of calcium carbonate = 40 + 12 + 16+16+16 = 100 gm
The molar mass of calcium oxide (CaO) = 40+16 = 56
The no. of moles = the mass of the sample/ the molar mass = 50/100 = 0.5 mol
1 mole of calcium carbonate → 1 mole of calcium oxide CaO
0.5 mole of calcium carbonate → 0.5 mole of calcium oxide CaO
The mass of calcium oxide = 0.5 x molar mass = 0.5 x 56 = 28g

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2- 11.2 L

$$2H_2 + O_2 \rightarrow 2H_2O$$

2 moles of hydrogen → 2 moles of water
The volume of hydrogen gas = the volume of water
The volume of water = 11.2 L
The volume of hydrogen gas = 11.2 L

3- 1.66×10^{-24}

4- Mole

5- 34g

→ The molar mass of ammonia gas = 14+1+1+1= 17gm
The no. of moles = the volume of gas in STP / 22.4 = 44.8/22.4 = 2 moles
The mass of 44.8 L of ammonia gas = no. moles x molar mass = 2 x 17 = 34g

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6- 11.5gm

→ the molar mass of sodium = 23 gm
The no. of moles = no. of atoms / Avogadro's number = 0.5 mol.
The mass of sodium = 0.5 x 23 = 11.5 gm

7- law of mass conservation

8- 22 g

→ The molar mass of carbon dioxide gas = 16 + 16+12 = 44g
The mass of carbon dioxide = 0.5 x 44 = 22g

9- 89.6 L

$$2H_2 + O_2 \rightarrow 2H_2O$$

Molar mass of oxygen O_2 = 16+16 = 32 gm
The no. of moles = 64 / 32 = 2 moles
1 mole of oxygen → 2 moles of water
2 moles of oxygen → 4 moles of water
The volume of water vapour in STP = 22.4 x the no. of moles = 22.4 x 4 = 89.6L

10- 2 moles

11- $12.04x10^{23}$ molecules

→ The molar mass of sulphur oxide = 32 +16+16 = 64 g
The no. of moles = 128/64 = 2 moles
The no. of molecules = no. of moles x Avogadro's no. = $12.04x10^{23}$ molecules

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12- $6.02x10^{23}$ ions

One mole of sodium hydroxide = 23 + 16+1 = 40g
One mole of NaOH → one mole of sodium ions
The no. of ions = $6.02x10^{23}$ ions

13- 44.8 L

→ The molar mass of hydrogen gas = 2g
The no. of moles = 4/2 = 2 moles
The volume of gas in STP = 2 x 22.4 = 44.8 L

14- Gay-Lussac's law

Solve the following problems

1- The molar mass of sodium chloride = 23+35.5 = 58.5
The no. of moles in 117 gm of NaCl = 117/58.5 = 2 moles
One mole of NaCl → One mole of sodium positive ions
Two moles of NaCl → Two moles of sodium positive ions
The no. of sodium ions = 2 x $6.02x10^{23}$ = ***$12.04x10^{23}$ ions***

2- Na_2CO_3 +2 HCl → NaCl +H_2O+ CO_2

a- The no. of water molecules

The molar mass of sodium carbonate = 23+23+16+16+16+12 = 106g
The no. of moles in 26.5 g = 26.5 / 106 = 0.25 mole
One mole of Na_2CO_3 → one mole of water
0.25 mole of Na_2CO_3 → 0.25 mole of water
The no. of water molecules = 0.25 x $6.02x10^{23}$ = ***$1.505x10^{23}$ molecules***

b- The volume of CO_2 gas in STP conditions

One mole of Na_2CO_3 → one mole of carbon dioxide
0.25 mole of Na_2CO_3 → 0.25 mole of carbon dioxide
The volume of the gas = 0.25 x 22.4 = ***<u>5.6 Litres</u>***

3- The molar mass of carbon element = 12+12 = 24
(N.B: the molar masses of diatomic nonmetal elements are calculated this way)
The no. of moles in 144 gm of carbon = 144/24 = 6 moles

4- The molar mass of $CaCO_3$ = 40+12+16+16+16= 100g
The mass of 2.4 moles = 100 x 2.4 = 240 g

5- The molar mass of nitrogen gas = 14+14=28 gm
The no. of moles in 56 g = 56/28 = 2 moles
The volume of nitrogen gas in STP conditions = 22.4 x 2 = 44.8 L

6- $2Na + 2H_2O \rightarrow 2NaOH + 2\ H_2O$

a- the no. of sodium ions
The molar mass of sodium = 23 g
One mole of sodium → one mole of sodium hydroxide solution → one mole of sodium ions
The no. of ions = $6.02x10^{23}$ ions

b- The volume of hydrogen gas in STP conditions
One mole of sodium → one mole of hydrogen gas
The volume of hydrogen gas in STP conditions = 22.4L

7- Gaseous phosphorus molecule consists of 4 atoms
The molar mass of gaseous phosphorus = 4 x 31 = 124 gm
The no. of atoms in one mole = Avogadro's no. x the no. of atoms per molecule
= $6.02x10^{23}$ x 4 = $24.08x10^{23}$ atoms

Balance the following equations

1- $N_{2(g)} + H_{2(g)} \rightarrow \Delta\ NH_{3(g)}$

The no. of hydrogen atoms on the right side of the equation is 3, while that on the left side of it is 2. To balance the no. of hydrogen atoms on both sides, we increase it on both of them to 6

$$N_{2(g)} + 3\ H_{2(g)} \rightarrow \Delta\ 2NH_{3(g)}$$

2- $Cu(NO_3)_{2(s)}\ \Delta \rightarrow CuO_{(s)} + NO_{2(g)} + O_{2(g)}$

There are 2 nitrogen atoms on the left side of the equation, while there is only 1 nitrogen atom on the right side of it. To balance the no. of nitrogen atoms, we increase the no. of nitrogen atoms on the right side to 2

$$Cu(NO_3)_{2(s)}\ \Delta \rightarrow CuO_{(s)} + 2NO_{2(g)} + O_{2(g)}$$

3- $Al + 3\ O_2 \rightarrow Al_2$

*we find that there are 3 oxygen atoms on the right side of the equation, while there are only 2 on the left side of it. To balance the no. of oxygen atoms on both sides, we should increase the no. of oxygen atoms on both of them to 6 (**6 is the least common multiple of 2 and 3)***

$$Al + 3\ O_2 \rightarrow 2\ Al_2O_3$$

There are four aluminium atoms on the right side of the equation, while there's a single atom on the left size. To balance the no. of aluminium atoms on both sides, we increase the no. of atoms in left size to 4 aluminium atoms

$$4Al + 3\ O_2 \rightarrow 2\ Al_2O_3$$

Exercises on lesson (2)

1- Choose

1- The empirical formula of $C_4H_8O_2$ is…………..

A- C_2H_4O *B-* C_4H_2O *C-* CH_4O_2 *D-* $C_2H_8O_2$

2- The no. of empirical formulas in $C_2H_2O_4$ is …..

A-1 *B-2* *C- 3* *D-4*

3- If the empirical formula of a compound is CH_2 and its molar mass if 56g, its molecular formula is…..

A- C_2H_4 B- C_4H_8 C- C_3H_6 D- C_5H_{10}

4- If the molecular formula of Vitamin C is $C_6H_8O_6$, its empirical formula is….

A- $C_3H_4O_3$ B- $C_3H_4O_6$ C- $C_3H_8O_3$ D- C_3H_6O

5- The empirical formula CH_2O describes……

A- CH_3 COOH B- $C_6H_{12}O_6$ ***C-*** *HCHO D- All the previous answers*

6- The hydrocarbon compound formed from the reaction of 0.1 mol. of carbon atoms with 0.4 mol. of hydrogen atoms is……

A- CH_4 B- C_2H_4 C- C_4H_8 D- C_3H_8

<u>Write the scientific term</u>

1- A method to describe chemical formula, the quantities of reactants and products, and the conditions for chemical reaction

2- The mass of atoms or molecules in grams

3- A constant no. of the ions, molecules or atoms in one mole of matter

4- A formula describes the actual no. of atoms in molecules

5- The amount of matter we get practically from the reaction

6- The sum of the atoms masses forming the molecule

7- The volumes of the reactant and products gases have certain ratios

8- The equals volume of gases in the same conditions of temperature and pressure have the same no. of molecules

9- A formula which describe the simplest ratios between the atoms forming molecules

10- The amount of reactants we expect to get from the reaction

Solve the following problems

1- Find the molecular formula of a compound containing 85.7% carbon and 14.3% hydrogen whose molar mass is 42g

2- 130g of silver chloride (AgCl) precipitated when a mole of sodium chloride (NaCl) reacted with silver nitrates ($AgNO_3$), calculate the percentage yield (percentage of actual yield) (Ag=108, N=14, Cl= 35.5, Na= 23,O=16)

3- Calculate the weight percent of iron in $FeCO_3$ (Fe=56, C=12, O=16)

4- Calculate the weight percent of the elements forming Glucose sugar $C_6H_{12}O_6$ (C=12, H=1, O=16)

The Answers

1- Choose the correct answer

1- C_2H_4O

2- 2

3- C_4H_8

The molar mass of CH_2 the empirical formula = 12+1+1 = 14g
The no. of units = molar mass of the compound / the molar mass of the empirical formula = 56/14 = 4 units
The molecular formula = 4 x CH_2 = C_4H_8

4- $C_3H_4O_3$

5- All the previous answers

6- CH_4

Write the scientific term

1- Chemical reaction
2- Mole
3- Avogadro's number
4- Molecular formula
5- Practical yield
6- Molecular mass
7- Gay-Lussac's law
8- Avogadro's law
9- Empirical formula
10- Theoretical formula

Solve the following problems

1-

Hydrogen	:	Carbon
$\frac{14.3}{1}$		$\frac{85.7}{12}$
14.3		7.1416
2		1

The empirical formula: CH_2

The molar mass of the compound = 12 + 1+1+ = 14 gm

The no. of units = 42/14 = 3 units

The molecular formula = $CH_2 \times 3 = C_3H_6$

2- $NaCl_{(aq)} + AgNO_{3\,(aq)} \rightarrow NaNO_3 + AgCl_{(s)}$

Mole of sodium chloride = 23+35.5 = 58.5
Mole of silver chloride = 108+58.5 = 143.5
The practical yield = 140g
The theoretical yield = 143.5g

The percentage yield = 140/143.5 x 100 = 97.56%

3- The molar mass of $FeCO_3$ = 56+12+16+16+16 = 116g
The mass of iron forming one mole of $FeCO_3$ = 56g
The weight percent = 56/116 x 100 = 48.26%

4- The molar mass of glucose = 12x6 + 12x1 +16x6 = 72+12+96 = 180g
The mass of carbon = 12x6 = 72g
The mass of hydrogen = 12x1 = 12g
The mass of oxygen = 16x6= 96g
The weight percent of carbon = 72/180 x 100 = 40%
The weight percent of hydrogen = 12/180 x 100 = 6.7%
The weight percent of oxygen = 96/180 x 100 = 53.3%