ELEMENTS, COMPOUNDS AND MIXTURES

Matter is broadly classified into three, namely: elements, compounds and mixtures.

ELEMENTS

An element is the simplest type of any substance, with unique physical and chemical properties as well as a constant atomic number. The atomic number of one element is different from the atomic number of another element. The atomic number is the number of protons contained in the nucleus of an atom of the element. More than one hundred elements are known. Some examples of the common elements include: hydrogen, carbon, oxygen, sodium, calcium, potassium, etc.

COMPOUNDS

A compound is a substance made up of two or more elements that are chemically combined. This combination is usually in fixed mass ratio. Examples of chemical compounds include: water (H2O), formed by chemical combination of one molecule of hydrogen (which contains two atoms of hydrogen) and one atom of oxygen; sodium chloride (NaCl), formed by chemical combination of one atom of sodium and one atom of chlorine etc.

MIXTURES

A mixture is a substance containing two or more elements/compounds that are not chemically combined. Consequently, mixtures are formed by physical mixing of their components. Some common examples include: sodium chloride solution (obtained by dissolving sodium chloride in water; air (mixture of oxygen, nitrogen, noble gases, carbon (iv) oxide, dust and moisture etc) etc.

Comparison of the characteristics of compounds and mixtures

Mixtures/ Compounds

1. Have variables composition by mass

Have fixed composition by mass

2. Retain most of the properties of their constituents

   Properties vary from those of most of their constituents.

3. Constituents can easily be separated by physical means

   Constituent can only be separated by chemical means

4. Great heat (energy) changes are not usually involved in their formation

   Great heat changes are usually involved in their formation

5. May be homogenous or heterogeneous

   Are always homogenous

ATOMS, MOLECULES AND STRUCTURE

Matter is anything that occupies space and has mass. It is made up of atoms, molecules and ions.

ATOM

An atom is known as the smallest part of an element which can take part in a chemical reaction. It comprises of tiny particles called electrons, protons and neutrons. These three particles are present in all atoms except for hydrogen with only one proton and one electron.

MOLECULE

This is known as the smallest particles of a substance, either an element or a compound which is capable of independent existence.

This occurs when two or more atoms join together chemically. Atomicity is known as the number of atoms in a molecules of a given element. Example, the atomicity of O_2 and H_2 is two and is known as diatomic. Others such as phosphorus and sulphur exist as polyatomic molecules.

The molecules of helium and neon are monoatomic because they exist independently as a single atom.

DALTON'S ATOMIC THEORY

The atom is the basic particle which all matter is made. Whether matter is continuous or discontinuous i.e composed of particles, had for many years remained the object of speculative debate until. Democritus proposed that all matter is made up of discret particles which is called atoms. This preposition remained in the realm of philosophy until John Dalton (1803) stated the first theory of the atom from experimental data. The main points of the

Dalton's atomic theory is;

1) All matter is composed of tiny particles called atom .

2) The atoms of an element are exactly, alike, particularly in their masses, atoms of different elements have different masses.

3) Chemical reaction occurs by the combination of whole, but not fractional atoms, ie atoms are indivisible.

4) When atoms combine with other atoms, they do so in small whole number ratios.

Towards the end of the nineteenth century, the concept of the indivisibility of atoms began to show sign of weakness.

MODIFICATION OF THE DACTION'S ATOMIC THEORY

1) Radioactive substances/atoms undergo spontaneous disintegration or artificial disintegration to produce even smaller particles.

E.g:

$_{92}U^{238} \rightarrow {}_{90}Th^{234} + {}^{4}_{2}He$

Uranium Thorium Helium

2) The discovery of isotopes.

3) Many molecules most especially the organic compounds are now known to be compounds which consist of very large number of atoms joined together especially in the formation of polymers.

$K_2Cr_2O_7$ . . Ans.

- oxidation number of K = +1
- Let the oxidation number of Cr = x
- oxidation number of oxygen = −2

$\therefore K_2Cr_2O_7 = 0$

$(+1\times2) + 2x + (-2\times7) = 0$

$2 + 2x - 14 = 0$

$2x - 12 = 0$

$\cancel{x = \frac{12}{2}}$ $2x = +12$

$x = \frac{+12}{2} = \underline{+6}$

The compound is heptaoxodichromate (VI).

4. Calculate the oxidation state of sulphur in SO_4^{2-}

$SO_3^{2-} = -2$

$S + (-2\times3) = -2$

$S - 6 = -2$

$S = +6 - 2$

$S = \underline{+4}$

The compound is tetraoxosulphate (VI) ion.

Balancing redox equations.

Balancing chemical equations for many re
reactions can be obtained by considering two
equations involved in the reactions.

The oxidation half-equations shows the pro
of electrons in the reactions while the reduction
half-equations shows the transfer of these e
to the substance being reduced.

Steps in balancing redox reaction

- Ion-electron method.

Example: Write a balanced ionic equation for
redox reaction between acidified potassium te
oxomanganate (VII) and Iron (II) tetraoxosulphate (

Soln

STEP I:

$$KMnO_4 \longrightarrow K^+ + MnO_4^-$$

$$FeSO_4 \longrightarrow Fe^{2+} + SO_4^{2-}$$

- MnO_4^- is the oxidizing agent hence MnO_4^- is r
to Mn^{2+} i.e. $MnO_{4(aq)}^- \longrightarrow Mn^{2+}_{(aq)}$ ---- (1)
- ~~FeSO4~~ Fe^{2+} is the reducing agent, hence it is
oxidized to Fe^{3+}

$$Fe^{2+}_{(aq)} \longrightarrow Fe^{3+}_{(aq)} \text{ ---- } (2)$$

STEP II:

i. Reduction half-equation

a. Balance the number of atoms first
adding the correct number of H^+ and H_2O
the appropriate side (In neutral or acid solution,
H_2O and H^+ may be added for balancing Oxygen
hydrogen. In alcaline solution, OH^- may be used)

$$MnO_{4(aq)}^- + 8H^+_{(aq)} \longrightarrow Mn^{2+}_{(aq)} + 4H_2O_{(l)} \text{ ---- } (3)$$

b. to balance the number of charges o

" . LHS = (-1) + (+8) = +7.

but the ...

The difference in number of charges is 5e; we add $5e^-$ on the LHS to give:

$$MnO_{4\,(aq)}^- + 8H^+_{(aq)} + 5e^- \rightarrow Mn^{2+}_{(aq)} + 4H_2O_{(l)} \quad \text{--- (4) Balanced}$$

ii. Oxidation half-equation.

a. $Fe^{2+} \rightarrow Fe^{3+}$ — — — (5) unbalanced.

To balance the number of charges, LHS = +2 and RHS = +3.

Therefore, we add one (1) electron (e^-) to the RHS to give

$$Fe^{2+}_{(aq)} \rightarrow Fe^{3+}_{(aq)} + e^- \quad \text{--- (6) balanced.}$$

STEP III

Write out the ~~reduction and oxidation~~ two half-equations

Reduction: $MnO_{4\,(aq)}^- + 8H^+_{(aq)} + 5e^- \rightarrow Mn^{2+}_{(aq)} + 4H_2O_{(l)}$

Oxidation: $Fe^{2+} \rightarrow Fe^{3+} + e^-$

However, the number of electrons on the two half equations are not the same. Hence, multiply the oxidation half-equation by 5 to give

$$5Fe^{2+}_{(aq)} \rightarrow 5Fe^{3+}_{(aq)} + 5e^- \quad \text{--- (7)}$$

Now, combining the two half equations i.e equation (4) and (7) to eliminate the electron ~~we~~ will give the overall ionic equation as follows:

$$MnO_{4\,(aq)}^- + 8H^+_{(aq)} + \cancel{5e^-} + 5Fe^{2+}_{(aq)} \rightarrow Mn^{2+}_{(aq)} + 5Fe^{3+}_{(aq)} + \cancel{5e^-} + 4H_2O_{(l)}$$

$$\Rightarrow MnO_{4\,(aq)}^- + 8H^+_{(aq)} + 5Fe^{2+}_{(aq)} \rightarrow Mn^{2+}_{(aq)} + 5Fe^{3+}_{(aq)} + 4H_2O_{(l)}$$

The mole (mol) is the base S.I unit for ex[illegible] quantities of substances. One mole of particle[illegible] ions or molecules) is equal to avogadro's numb[illegible] ($N_A = 6.022 \times 10^{23}$) of the particles.

A mole of oxygen atom contain $6.022 \times 10^{2[illegible]}$ atom of oxygen. It has a mass of 16g.

In calculating moles, the ratio of ma[illegible] of substance in gram (g) to the molar mass in g/mol or g/dm³ can be applied.

$$\text{No of moles} = \frac{\text{mass of substance (g)}}{\text{molar mass (g/mol or g/dm}^3\text{)}}$$

The mass of 1 mole of a substance is called [illegible] molar mass (m). The ~~mass~~ molar mass (m) of a compound is the sum of the molar masses of elements that make up the compound, each multiplied by the number of moles of that element in a mole of the compound.

The mole ratios of reactant and products [illegible] a chemical equation are called stoichiometr[illegible]

The law of conservation of mass states that the sum of the masses of the reactants of a chemical reaction is equal to the sum of the masses of the products.

Examples

1. Calculate the molar mass of Na_2SO_4.
(Given: Na = 23.0, S = 32.0, O = 16.0)

solution.

1 mole of Na_2SO_4 (Sodium tetraoxosulphate VI) contains

2 mole atom of Na $= (2 \times 23.0)g = 46.0g$

1 mole atom of S $= (1 \times 32.0)g = 32.0g$

4 mole atoms of O $= (4 \times 16.0)g = 64.0g$

∴ molar mass of Na_2SO_4 $= 142.0 g/mol$.

of carbon (IV) oxide (CO_2)?

Answer

Equation: $C_{(s)} + O_{2(g)} \longrightarrow CO_{2(g)}$

From the equation, ~~1 mole molecule of CO_2 contains 2 mole~~

1 mole molecule of CO_2 contain 2 mole atoms of Oxy

∴ 0.1 mole molecule of CO_2 contains $\frac{2}{1} \times 0.1$ mole $= 0.2$ mole.

3. How many moles of Na_2CO_3 are there in 14.0g of the compound? (Na = 23.0, O = 16.0, C = 12.0)

Ans.

1 mole molecule of Na_2CO_3 contains:

2 mole atoms of Na $= (2 \times 23.0)g = 46.0g$

3 mole atoms of O $= (3 \times 16.0)g = 48.0g$

1 mole atom of C $= (1 \times 12.0)g = 12.0g$

Molar mass of Na_2CO_3 $= 106g/mol$.

But 106g ~~of~~ is the mass of 1 mole Na_2CO_3

∴ 14g of Na_2CO_3 contains $\frac{1 mole \times 14g}{106g} = 0.1$ mole.

4. How many moles are represented by a. 6.35g of CO_2, b. 9.11g of SiO_2, c. 15.02g of $Ca(NO_3)_2$?

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Ans.

a. molar mass of $CO_2 = (12 \times 1) + (16 \times 2)$
$= 12 + 32$
$= 44g/mol$.

But 44g of CO_2 contains 1 mole of CO_2.

∴ 6.35g of CO_2 contains $6.35g \times \left(\frac{1 mole}{44g}\right) = 0.14$ mo $= 0.1$ mole

5. How many atoms are present in 1.16g of Na

Soln

1 mole of Na ~~atom~~ $= 23.0g$

$\therefore$ 1.16g of Na atom will contain $\frac{1.16g}{23.0g} \times 6.022\times10^{23}$
$= 3.0\times10^{22}$

Assignment

6. From the equation: $2KClO_{3(s)} \longrightarrow 2KCl_{(s)} + 3O_{2(g)}$
How many moles of O_2 will be formed from 1.65 moles $KClO_3$.

Ans.

From the equation: 2 mole of $KClO_3$ produced 3 moles of O_2
$\therefore$ 1.65 moles of $KClO_3$ produced $\frac{1.65 \text{ moles}}{2 \text{ moles}} \times 3$ moles O_2
$= 2.48$ moles O_2
$\simeq 2.5$ moles O_2

PERCENTAGE COMPOSITION OF COMPOUND.

To calculate this:
- Write the formula of the compound
- Calculate its molar mass
- Divide the total mass of the atom in question by the molar mass of the compound and multiply by 100

Example:
Calculate the percentage composition of sodium tetraoxosulphate (VI) [Na = 23, S = 32, O = 16g]

Ans.

The molar mass of Na_2SO_4: $(23\times2) + (32\times1) + (16\times4)$
$= 46 + 32 + 64$
$= 142$ g/mol.

$\therefore$ % Composition of sulphur $= \frac{\text{Mass of Sulphur}}{\text{Molar Mass of } Na_2SO_4} \times 100$
$= \frac{32g}{142g} \times 100 = 22.50\%$.

% Composition by mass Oxygen $= \frac{64g}{142g} \times 100 = 45.10\%$

% composition by mass of Sodium $= \frac{46}{142} \times 100 = 32.40\%$

This formula shows the simplest ratio of the num of atoms present in a compound.

MOLECULAR FORMULA:

This shows the actual number of atoms of the different elements present in one molecule of a compound.

Example 1.

The analysis of a certain organic compound shows that it contains 39.3% Carbon, 6.9% Hydrogen and 53.2% Oxygen.

a. Calculate the empirical formula

b. If the relative molecular mass is 60. What is the molecular formula of the compound

[C = 12, H = 1, O = 16]

Soln

Element Present	C	H	O
% composition by mass:	39.9	6.9	53.2
Number of mole Present:	$\frac{12}{3.33}$	$\frac{1}{6.9}$	$\frac{16}{3.33}$
Divide by the smallest number:	$\frac{3.33}{3.33}$	$\frac{6.9}{3.33}$	$\frac{3.33}{3.33}$
Ratio	1 :	2 :	1

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But molecular formula $= (CH_2O)n$

$(CH_2O)_n = 60$

$30n = 60$

$n = 60/30 = 2$

Hence, molecular formular $= (CH_2O)_2 = C_2H_4O_2$

LIMITING [illegible]

The limiting reactant in a reaction mixture is reactant in shortest supply that limits how m[uch] product can be made.

Sometimes the quantity of product is less than which should have been made given the quantiti[es] of reactants available. The ratio of the actual to the theoritical yield is usually expressed as percentage called the percent yield.

NB: In all reactions, there will be one react[ant] that will "limit" the yield of the product. However, the limiting reactant is not always th[e] one present in the smallest quantity or amou[nt].

∴ Using mole ratio: $aA \longrightarrow bB$.

Grams A	1 mol A	b mol B	Molar Mass	= Mass B
	Molar Mass A	a mol A	1 mol B	

Examples 1.

Consider the reaction: $2Al + 3S \longrightarrow Al_2S_3$

- What mass of Aluminium Sulphide can be produ[ced] from 9.00g of Al reacting with 8.00g of Sulph[ur]
- What is the limiting reactant [Al=26, S=32]

Soln

9g ~~Al~~	1 ~~mol Al~~	1 ~~mol Al₂S₃~~	150g Al_2S_3	= 25g Al_2S_3
	26g ~~Al~~	2 ~~mol Al~~	1 ~~mol Al₂S₃~~	

8g ~~S~~	1 ~~mol S~~	1 ~~mol Al₂S₃~~	150g ~~Al₂S₃~~	= 12.5g Al_2S_3
	32g ~~S~~	3 ~~mol S~~	1 ~~mol Al₂S₃~~	

There will be 12.5g of Al_2S_3 produced and Sulf[ur] is the limiting reactant.

Assignment.

What mass of aluminium sulphate can be produced from th[e] reaction of 20.0g of sulphuric acid with 25.0g alumi[nium] hydroxide. What is the limiting reactant.

Example ... [illegible]

Calcium carbonate decomposes into CaO and CO_2 [illegible] hand experiment [illegible] chemical [illegible] of CO_2 [illegible] reaction, [illegible] what happens [illegible] $CaCO_3$ [illegible]

When a chemical reaction takes place between [illegible] new substances are formed. [illegible] $CaCO_3$ [illegible] CaO + CO_2 [illegible] The reactant [illegible] are appearing. The reactant [illegible] (left hand side) are called reactants [illegible] and [illegible] is on the [illegible] hand side is called [illegible]

In chemical reactions, [illegible] are labelled [illegible] coefficient [illegible] in front [illegible] represent the moles of each compound or element.

Generally, [illegible] equation is [illegible] chemical formula of reactant appears first, followed by a reaction arrow and the chemical formula of the products. The proportions of the reactant and products are expressed by coefficients preceding their formulas and symbols in parenthesis are used to indicate their physical states; (g) for gas, (l) for liquid and (s) for solids. Also, the subscript (aq) denotes aqueous. Examples are:

1. $NaOH_{(aq)} + HCl_{(aq)} \longrightarrow NaCl_{(aq)} + H_2O_{(l)}$
2. $H_{2(g)} + Cl_{2(g)} \longrightarrow 2HCl_{(g)}$ + [illegible]

Balancing chemical equations.

When a chemical equation is written it must balanced. This follows the:

1. Law of conservation of mass
2. Law of conservation of electrical charges must be considered.
3. Writing number of mole(s) or coefficient before the chemical compound, if it's more than one (1).
4. Stating the physical state of the reactant(s) and