Chapter 3 - Relative Mass, Moles and Chemical Equations

I Relative Mass

(a) Average Relative Atomic Mass

1. Calculate the average relative atomic mass of oxygen from the table

Isotope	Percentage Abundance
Oxygen-16	99.757%
Oxygen-17	0.038%
Oxygen-18	0.205%

2. The masses of the two isotopes of copper, copper-63 and copper-65, occurring in nature are 62.9298 and 64.9278 respectively. If the relative atomic mass of copper is 63.546, then the abundance of copper-63 is ___ %.
3. There are two isotopes of X in nature. The abundance of

$$^{71}_{31}\mathrm{X} = 30\%$$
$$^{69}_{31}\mathrm{X} = 70\%$$

The relative atomic mass of X is ___.

(b) Relative molecular/formula mass (M_r)

$$Relative\ molecular\ mass = \frac{mass\ of\ molecule\ of\ substance}{\frac{1}{12} \times mass\ of\ an\ atom\ of\ C-12}$$

$$Relative\ formula\ mass = \frac{mass\ of\ one\ formula\ unit}{\frac{1}{12} \times mass\ of\ an\ atom\ of\ C-12}$$

1. Calculate the relative mass of the following substances.

CO_2	Na_2CO_3	$Al_2(SO_4)_3$
$Na_2CO_3 \cdot 10H_2O$	$BaSO_4$	N_2
Mg(OH)Cl	$KAl(SO_4)_2 \cdot 12H_2O$	Cu

II The Mole Concept and Avogadro's Number

(a) Relationship between number of moles and number of particles.

$$Number\ of\ moles = \frac{number\ of\ particles}{6.02 \times 10^{23}/mol}$$

1. The number of Cl_2 molecules in 2.50 mol of Cl_2 is ___ molecules.

2. The number of formula units of 0.211 mol of $MgCl_2$ is ___ formula units.
3. Calculate the number of moles of 1.5 x 10^{24} of chlorine molecules.
4. Calculate the number of moles of 8.9 x 10^{21} of helium atoms.
5. Calculate the number of chloride atoms in 2.59 moles of chlorine gas.
6. Calculate the number of chloride ions in 0.57 mol of $MgCl_2$.

(b) Relationship between number of moles of a substance and its mass.

$$no\ of\ moles = \frac{mass}{molar\ mass} mol$$

1. Calculate the number of moles of molecules in 4.5g of water.
2. Calculate the amount of atoms in 5.2g of iron.
3. What is the mass of 2 moles of methane?
4. Calculate the mass of 2.54 mol of CuS.
5. Given: The mass of 0.25 mol of benzene is 19.5g. Calculate the molar mass of benzene.
6. It is found that the mass of 2.45mol glycerine is 225.40g. Find the relative molecular mass of glycerine.
7. Calculate the number of atoms in 28g of iron.
8. Calculate the mass in grams for 1.5 x10^{24} chlorine.
9. Calculate the mass of 1.50 moles of sodium.
10. Calculate the number of moles of hydrogen atoms in 16.0g of ammonia.
11. Calculate the number of moles of 34g of magnesium sulphate.
12. Calculate the number of formula units in 36g of potassium chloride.
13. Find the mass of calcium which has the same number of atoms as 12g of magnesium.

(c) Relationship between number of moles of a gas and its volume.

$$no\ of\ moles\ of\ gas = \frac{volume\ of\ gas}{molar\ volume} mol$$

$$molar\ volume\ at\ r.t.p. = 24.0 dm^3/mol$$

$$molar\ volume\ at\ s.t.p. = 22.4 dm^3/mol$$

1. A gas jar (240 cm^3) is full of chlorine gas. What is the number of moles of chlorine, Cl_2, at room condition?
2. Find the volume occupied by 1.23 mol of nitrogen at s.t.p.
3. What is the volume of 7g of nitrogen, N_2, at room conditions?
4. What is the mass in grams of 3dm^3 of carbon dioxide, CO_2, at room conditions?
5. Calculate the mass of 6L of ammonia gas at r.t.p.
6. Find the number of hydrogen atoms in 21L of methane gas at s.t.p.
7. Which of the following contains the largest number of molecules?
    1. 4.0g H_2

2. 6.0g H_2O
3. 1.0 mol O_2
4. 2.0g CO_2

8. Which of the following is the heaviest?
    1. 1 mole of water
    2. 1 gram of water
    3. 1 molecule of water
    4. 1 mole of oxygen atoms

III Percentage Composition

$$\%\text{ of element in compound} = \frac{\text{mass of element in one mole of compound}}{\text{molar mass of compound}} \times 100\%$$

(a) Calculate percentage composition of an element in a compound

1. A chemist extracts iron from two iron ores (haematite, Fe_2O_3; magnetite, Fe_3O_4). Which will provide the greater mass of iron if the chemist takes the same mass of each compound?
2. Calculate
    1. The percentage of calcium in calcium carbonate [Ca=40, O=16]
    2. The percentage of oxygen in calcium carbonate [Ca=40, O=16]
3. Among the oxides of iron, which one contains the highest iron composition?

   A. FeO B. Fe_2O C. Fe_3O_4 D. Fe_2O_3
4. Which of the following compounds contain the highest percentage of sodium?
   A. Carnallite ($KCl{\cdot}MgCl_2{\cdot}6H_2O$)

   B. KCl

   C. K_2CO_3

   D. Polyhalite($2CaSO_4{\cdot}K_2SO_4{\cdot}2H_2O$)
5. Ammonium sulphate, ammonium nitrate, ammonium bicarbonate and urea are common fertilizers used by farmers. They contain different percentage of nitrogen element. Based on the table given below, choose the most economical and highest nitrogen content fertilizer.

Type of fertilizer	**Ammonium sulphate**	**Ammonium nitate**	**Ammonium bicarbonate**	**Urea $CO(NH_2)_2$**
Price(RM) per ton	450	810	330	1080

6. Which of the following compounds has the highest percentage of iron?

   A. $Fe_2O_3{\cdot}H_2O$ B. $FeSO_4$ C. Fe_3O_4 D. FeO
7. The haemoglobin in a mammal's red blood cell consist of 0.33% of iron. If the molecular weight of haemoglobin is about 6800, then how many of iron does on haemoglobin molecule consist of ? (Fe=54)
8. A, B and C are three compounds containing the element and some of their data are given in Table 3.

Compound	**A**	**B**	**C**

Compound	A	B	C
Relative molecular mass	60	80	96
Composition of E by mass	40%	15%	50%

The atomic ratio of the element E in these three compounds is A:B:C = ___.

(b) Calculate mass of an element in compounds

1. Calculate the mass of copper in 32g of copper (II) sulphate(VI), $CuSO_4$. (O=16, S=32, Cu=64)

(c) Calculate mass of water of crystallization

1. Calculate the mass of water of crystallization in 12.5g of hydrated copper(II) sulphate(VI), $CuSO_4 \cdot 5H_2O$ (O=16, S=32, Cu=64, H=1)

IV Chemical Formulae

(a) Empirical formula

1. Experiment shows that a sample of an oxide of copper contains 8 g of copper combined with 1 g of oxygen. Find the empirical formula of the compound. [Cu=63.5, O=16]
2. Experiment shows that 30 g of aluminium sulphide contains 19.2 g of sulphur. Find the formula of the compound. [Al=27, S=32]
3. A 0.4764g sample of an oxide of iron was reduced by a stream of carbon monoxide. The mass of iron that remained was 0.3450g. Find the empirical formula of the oxide. [Fe=56, 0=16]

(b) Finding molecular formula

1. A compound has the empirical formula of CH_2. The relative molecular mass of compound is 56. What is the molecular formula of the compounds? [C=12, H=1]
2. Experiment shows that a sample of hydrogen peroxide contains 0.5g of hydrogen combined with 8.09 of
3. A gaseous hydrocarbon X contains 85.7% of carbon by mass. 4.2g of the gas X occupies a volume of 3.36 dm? at s.t.p.

   a. Determine the empirical formula of X.

   b. Determine the relative molecular mass of X.

   c. Determine the molecular formula of X.
4. Phosphorus forms an oxide with molecular formula P,O10. The relative molecular mass of the oxide is 204; What & the value of n? [P=31, 0=16]
5. When 1.60g of the oxide of metal M was reduced, 1.12g of metal M was formed. If the relative atomic mass of M is 56. Find the chemical formula of the oxide.
6. A sample of metallic element M, weighing 3.172 g, combines with 0.6015 L of oxygen gas at 20°C and 1.01x 10° Pa to form a metallic oxide with the formula MO. If the density of O; gas under these conditions is 1.328 g L^{-1}, what is the relative atomic mass of M?
7. Some powdered zinc was burnt in a crucible. All zinc was converted into a white solid. The following results were obtain.

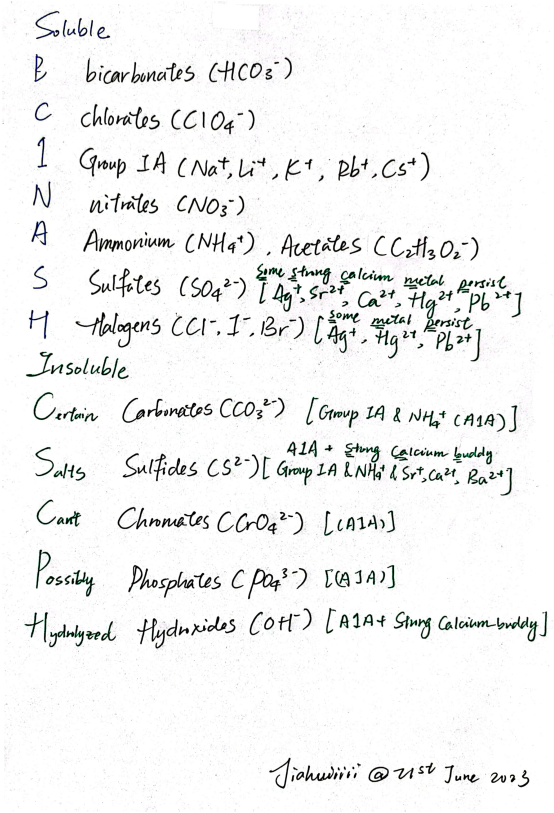
Mass of apparatus + zinc	**153.27g**
Mass of apparatus	150.00g
Mass of zinc	
Mass of apparatus + product	154.07g
Mass of product	
Mass of oxygen in product	

(a) Complete the table.
(b) Calculate the empirical formula of the compound formed. [Zn=65, 0=16]

8. 2.32 g of hydrogen is used in the reduction of oxide of metal R to gain 1.68 g of metal R. It is known that metal R has a relative atomic mass of 56, find the molecular formula of the oxide. Given that 2 mol of Hz will react with 1 mol of O_2.[H=1, 0=16]
9. The mass percentage of magnesium and nitrogen in magnesium nitride is 72% and 28%, the chemical formula of magnesium nitride could be ___.
10. Smoking is hazardous as cigarette forms various toxic and carcinogenic substances during combustion. Which of the following compound has a mass ratio of 3:4?
    A. NO B. SO_2 C. CO D. CO_2
11. The relative mass ratio of X and Y is 7:8, and their mass ratio (X to Y) in a compound is 7:4. What is the chemical formula of the compound?
12. If both dinitrogen trioxide, N_2O_3 and nitrogen dioxide, NO_2 contain the same mass in nitrogen, what is the mess ratio of N_2O_3 to NO_2?

V Balancing Chemical Equations

Solubility



1. Balance the following chemical equations.

   (a) $C_2H_{6(g)} + O_{2(g)} \rightarrow H_2O_{(g)} + CO_{2(g)}$

   (b) $O_{2(g)} + C_6H_{12}O_{6(s)} \rightarrow H_2O_{(l)} + CO_{2(g)}$

   (c) $KOH_{(aq)} + H_3PO_{4(aq)} \rightarrow K_3PO_{4(aq)} + H_2O_{(l)}$

   (d) $Mg_{(s)} + N_{2(g)} \rightarrow Mg_3N_{2(s)}$

   (e) $KNO_{3(s)} \rightarrow KNO_{2(s)} + O_{2(g)}$

   (f) $Fe_{(s)} + H_2SO_{4(aq)} \rightarrow FeSO_{4(aq)} + H_{2(g)}$

   (g) $MgCO_{3(s)} \rightarrow MgO_{(s)} + CO_{2(g)}$

   (h) $Al_{(s)} + O_{2(g)} \rightarrow Al_2O_{3(s)}$

   (i) $C_2H_{2(g)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(g)}$

   (j) $BaCl_{2(aq)} + Na_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + NaCl_{(aq)}$

   (k) $Ca_{(s)} + H_2O_{(l)} \rightarrow Ca(OH)_{2(s)} + H_{2(g)}$

   (l) $NaHCO_{3(s)} \rightarrow Na_2CO_{3(s)} + H_2O_{(g)} + CO_{2(g)}$

   (m) $C_7H_5N_3O_{6(s)} \rightarrow N_{2(g)} + H_2O_{(g)} + CO_{(g)} + C_{(s)}$

2. Write balanced equation for each of the following reactions.

   (a) Sulphur trioxide gas and water combine to make sulphuric acid.

   (b) Lead (II) nitrate solution and sodium iodide solution react to make lead (II) iodide solid and sodium nitrate solution.

   (c) Calcium chloride solution and dilute sulphuric acid react to make calcium sulphate solid and hydrochloric acid.

   (d) Calcium carbonate solid will decompose when you heat it to give calcium oxide solid and carbon dioxide.

   (e) Sodium hydroxide solution neutralizes carbonic acid.

(f) Zinc oxygen react to form zinc oxide and sulphur

(g) Lithium oxide solid and water react to make lithium hydroxide solution.

(h) Aluminum hydroxide solid and sulphuric acid neutralize to make water and aluminum sulphate solution.

(i) Sulphur burns in oxygen to make sulphur dioxide gas.

(j) Barium hydroxide solution and sulphuric acid react to make water and barium sulphate solid.

(k) Aluminum sulphate solution and sodium hydroxide solution react to become aluminum hydroxide solid and sodium sulphate solution.

(l) Copper metal and silver nitrate solution react to form silver metal and copper (II) nitrate solution.

(m) Sodium metal and chlorine gas react to make sodium chloride solid.

(o) Propane (C_3H_8) gas burns in excess oxygen to form carbon dioxide and water.

(p) Zinc and copper (II) sulphate solution react to yield zinc sulphate solution and copper metal.

(q) Dilute sulphuric acid reacts with zinc to form zinc sulphate solution and hydrogen.

(r) Chlorine gas and sodium iodide solution react to yield sodium chloride solution and iodine solid.

VI Types of Chemical Reactions

A. Combination reaction **B. Decomposition reaction** **C. Displacement reaction**
D. Double displacement reaction **E. Combustion reaction** **F. Acid-base reaction**

1. $C_4H_8 + 6O_2 \rightarrow 4CO_2 + 4H_2O$
2. $HCl + NaOH \rightarrow H_2O + NaCl$
3. $2KNO_{3(s)} \rightarrow 2KNO_{2(s)} + O_{2(g)}$
4. $AgNO_3 + NaCl \rightarrow NaNO_3 + AgCl$
5. $2Mg + O_2 \rightarrow 2MgO$
6. $2Ag + S \rightarrow Ag_2S$
7. $MgCO_{3(s)} \rightarrow MgO_{(s)} + CO_{2(g)}$
8. $Cl_2 + 2KBr \rightarrow 2KCl + Br_2$
9. $N_2 + 3H_2 \rightarrow 2NH_3$
10. $2H_2O \rightarrow 2H_2 + O_2$
11. $2NaI + Cl_2 \rightarrow 2NaCl + I_2$
12. $Na_2SO_4 + BaBr_2 \rightarrow 2NaBr + BaSO_4$
13. $2C_2H_6 + 7O_2 \rightarrow 6H_2O + 4CO_2$
14. $H_2SO_4 + KNO_3 \rightarrow KHSO_4 + HNO_3$
15. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
16. $Fe + 2AgNO_3 \rightarrow Fe(NO_3)_2 + 2Ag$
17. $2Pb + O_2 \rightarrow 2PbO$
18. $NH_3{\cdot}H_2O + HBr \rightarrow H_2O + NH_4Br$
19. $MgSO_4 + 2KOH \rightarrow Mg(OH)_2 + K_2SO_4$
20. $2NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$

VII Reaction Stoichiometry

2 Calculations based on chemical equations

1. Copper reacts with nitric acid according to the following equation [Cu=63.5]

$$3\,Cu_{(s)} + 8\,HNO_{3\,(aq)} \longrightarrow 3\,Cu(NO_3)_{2\,(aq)} + 2\,NO_{(g)} + 4\,H_2O_{(l)}$$

   If 7.62g of copper reacts, calculate the following:

   (a) The number of moles of copper reacted.

   (b) The number of moles of nitric acid required.

   (c) The number of moles of NO produced.

2. Nitrogen dioxide reacts with water according to the following equation:

$$3\,NO_{2\,(g)} + H_2O_{(l)} \longrightarrow 2\,HNO_{3\,(aq)} + NO_{(g)}$$

   If 0.50mol of nitrogen dioxide reacted, calculate the following:

   (a) The number of moles of nitric acid produced.

(b) The mass of nitrogen monoxide produced.

3. Calculate the mass of water produced from the complete combustion of 0.25 mol of propane, C_3H_8.
4. Magnesium reacts with hydrochloric acid. Calculate the volume of hydrogen gas, measured at room conditions, produced from the reaction of 14.6 g of HCl.
5. Aspirin ($C_9H_8O_4$) is produced from salicylic acid ($C_7H_6O_3$) and ethanoic acid ($C_2H_4O_2$) by the following reaction:

$$\mathrm{C_7H_6O_{3\,(s)} + C_2H_4O_{2\,(l)} \longrightarrow C_9H_8O_{4\,(s)} + H_2O_{(l)}}$$

What mass of salicylic acid is needed to prepare a tablet containing 300mg of aspirin? (C=12, H=1, O=16)

6. Hydrogen gas is prepared by reacting methane gas with steam using platinum as catalyst. The reaction is represented by the equation:

$$\mathrm{CH_{4\,(g)} + H_2O_{(g)} \longrightarrow CO_{(g)} + 3\,H_{2\,(g)}}$$

If 60 dm³ of hydrogen gas is produced at room temperature and pressure, calculate the following:

(a) The mass of methane reacted in the reaction.

(b) The number of carbon monoxide molecules reaction.

7. Antacid tablet contains magnesium hydroxide which is used to neutralize the acid in our stomach to relieve indigestion and heartburn. Each tablet has 250 mg of magnesium hydroxide. A doctor prescribes 2 tablets each time and 3 times per day for a patient with hyperacidity. How many grams of hydrochloric acid can be neutralized per day according to the prescription? [A_r of H=1, O=16, Mg=24, Cl=35.5]
8. Iron metal reacts with excess hydrochloric acid to produce iron(II) chloride and hydrogen gas.

(a) Write a balanced chemical equation for the reaction.

(b) If 2.8 g of iron metal is used in the reaction, calculate the following:

(i) The maximum mass of iron(II) chloride formed.

(ii) The volume of hydrogen gas produced at room condition.

9. The equation for the fermentation of glucose is as follows:

$$\mathrm{C_6H_{12}O_{6\,(aq)} \longrightarrow 2\,CH_3CH_2OH_{(aq)} + 2\,CO_{2\,(g)}}$$

If 5.25g of carbon dioxide were produced, calculate:

(a) the mass of ethanol, CH_3CH_2OH, produced.

(b) the mass of glucose consumed.

3 Reactions involving gases

1. Sulphur dioxide reacts with oxygen according to the equation, $2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)}$. 40cm³ of SO_2 reacts with O_2 to produce SO_3. What volume of O_2 is required, and what volume of SO_3 is produced?

4 Limiting reactant

1. The equation shows the formation of ClF_3. $Cl_{2(g)} + 3F_{2(g)} \rightarrow 2ClF_{3(g)}$. If 0.75 mol of Cl_2 is mixed with 3 mol of F_2 and reacts, determine the limiting reactant of this reaction.
2. 8 g of iron powder and 4 g of sulphur powder are mixed together and heated until the reaction is completed. How many grams of iron (II) sulphide is produced? [Fe=56, S=32]

3. Ethane, C_2H_6, burns in oxygen according to the equation, $2C_2H_{6(g)} + 7O_{2(g)} \rightarrow 4CO_{2(g)} + 6H2_{O(l)}$. 20cm³ of ethane was reacted with 100cm^3 of oxygen gas (an excess). Calculate

   (a) the volume of CO_2 produced

   (b) the volume of oxygen remained at the end of the reaction.

4. If 10 cm³ of nitrogen was mixed with 20 cm³ of hydrogen and reacts according to the equation below:

$$\mathrm{N_{2\,(g)} + 3\,H_{2\,(g)} \longrightarrow 2\,NH_{3\,(g)}}$$

   (a) Determine the limiting reactant.

   (b) What is the volume of ammonia produced?

   (c) What would be the volume of the excess reactant left over?

10 Percentage yield of a reaction

$$Percentage\ yield = \frac{actual\ yield}{theoretical\ yield} \times 100\%$$

1. 128 g of SO_2 was completely reacted with O_2 to produce SO_3. The equation for the reaction is:

   $2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)}$

   140g SO_3 was produced in the reaction. Calculate the percentage yield of SO_3.

11 Percentage purity

$$Percentage\ purity = \frac{\text{Mass of pure substance present}}{\text{Mass of sample}} \times 100\%$$

1. An impure sample of calcium carbonate, CaCO3, contains calcium sulphate, CaSO4, as an impurity. When excess hydrochloric acid was added to 6g of the sample, 1200 cm³ of gas were produced (measured at R.T.P.). Calculate the percentage purity of calcium carbonate sample.
2. 35g of $CH_3COOC_2H_5$ (M_r=88) are obtained from 23g of CH_3CH_2OH (M_r = 46) by esterification with ethanoic acid, CH_3COOH. Calculate the percentage yield of the reaction.

$$\mathrm{CH_3CH_2OH + CH_3COOH \rightleftharpoons CH_3COOC_2H_5 + H_2O}$$

3. 2.2g of zinc chloride was obtained when 2g of brass is dissolved in excess dilute hydrochloric acid. What is the mass percentage of zinc in the alloy?
4. Chalk is almost pure calcium carbonate. We can calculate its purity by measuring the volume of carbon dioxide given off. 10 g of chalk was reacted with an excess of dilute hydrochloric acid. 2.128 liters of carbon dioxide gas was collected at standard temperature and pressure (STP).

VIII Three(Two) Important Laws of Chemistry

1 The Law of Conservation of Mass

1. When the grey magnesium is ignited, it burns brightly combining with oxygen from the a white powder, magnesium oxide. to form a white powder, magnesium oxide. If the mass of magnesium is 0.024g and the mass of oxygen is 0.016g, what is the mass of the magnesium oxide produced?
2. When methane is burned in air, it reacts with oxygen to form carbon dioxide and water. When 10.0g of methane is burned, exactly 40.0g of oxygen is consumed and 27.5g of carbon dioxide is produced. What mass of water is produced?

2 The Law of Constant Composition

1. By experiment, 1 g hydrogen combined with 8 g oxygen to form 9 g water. Calculate the mass of oxygen that combined with 3.00 g of hydrogen.

$$\begin{array}{rccc} & \text{hydrogen} + \text{oxygen} & \longrightarrow & \text{water} \\ mass\ ratio: & 1 & : & 8 \end{array}$$

   For example, pure water obtained from different sources such as a river, a well, a spring, the sea, etc., always contains hydrogen and oxygen together in the ratio of 1:8 by mass.

   Similarly, carbon dioxide (CO2) can be obtained by different methods such as, burning of carbon, or by heating of limestone, or applying dilute HCI to marble pieces, Each sample of CO2 contains carbon and oxygen in a 3:8 ratio.

2. $$\begin{array}{rccc} & \text{carbon} + \text{oxygen} & \longrightarrow & \text{carbon monoxide} \\ mass\ ratio: & 3 & : & 4 \end{array}$$

   Calculate the mass of carbon in 10g of carbon monoxide.

3. A 10g sample of the compound copper (II) oxide contains 2.0 would a 30g sample of the same compound contain? oxygen. What mass of oxygen would a 30g sample of the same compound obtain?

`by jiahuiiiii @ 21st June 2023 2100`