

DP Chemistry Review

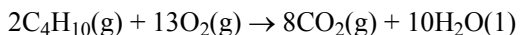
Topic 1: Quantitative chemistry

1.1 The mole concept and Avogadro's constant

Assessment statement	notes
Apply the mole concept to substances.	The mole concept applies to all kinds of particles: atoms, molecules, ions, electrons, formula units, and so on. The amount of substance is measured in moles (mol). The approximate value of Avogadro's constant (L), $6.02 \times 10^{23} \text{ mol}^{-1}$, should be known.
Determine the number of particles and the amount of substance (in moles).	Convert between the amount of substance (in moles) and the number of atoms, molecules, ions, electrons and formula units.

Problems

- What is the total number of atoms in 0.20 mol of propanone, CH_3COCH_3 ?
 A. 1.2×10^{22} C. 1.2×10^{24}
 B. 6.0×10^{23} D. 6.0×10^{24}
- Which contains the same number of ions as the value of Avogadro's constant?
 A. 0.5 mol NaCl C. 1.0 mol Na_2O
 B. 0.5 mol MgCl_2 D. 1.0 mol MgO
- Avogadro's constant has the same value as the number of
 A. molecules in 1 mol of solid iodine. C. ions in 1 mol of solid potassium bromide.
 B. atoms in 1 mol of chlorine gas. D. protons in 1 mol of helium gas.
- Which sample has the least number of atoms?
 A. 1 mol of H_2SO_4 C. 2 mol of H_2O_2
 B. 1 mol of CH_3COOH D. 2 mol of NH_3
- How many oxygen atoms are present in 0.0500 mol carbon dioxide?
 A. 3.01×10^{22} C. 6.02×10^{23}
 B. 6.02×10^{22} D. 1.20×10^{24}
- What amount of oxygen, O_2 , (in moles) contains 1.8×10^{22} molecules?
 A. 0.0030 C. 0.30
 B. 0.030 D. 3.0
- What amount (in moles) is present in 2.0 g of sodium hydroxide, NaOH?
 A. 0.050 C. 20
 B. 0.10 D. 80
- How many hydrogen atoms are contained in one mole of ethanol, $\text{C}_2\text{H}_5\text{OH}$?
 A. 5 C. 1.0×10^{23}
 B. 6 D. 3.6×10^{24}
- Which of the following contains the greatest number of molecules?
 A. 1 g of CH_3Cl C. 1 g of CHCl_3
 B. 1 g of CH_2Cl_2 D. 1 g of CCl_4
- Consider the following equation.



How many moles of $\text{CO}_2(\text{g})$ are produced by the complete combustion of 58 g of butane, $\text{C}_4\text{H}_{10}(\text{g})$?

1.2 Formulas

Assessment statement	Notes
Define the terms <i>relative atomic mass</i> (A_r) and <i>relative molecular mass</i> (M_r).	
Calculate the mass of one mole of a species from its formula.	The term molar mass (in g mol^{-1}) will be used.
Solve problems involving the relationship between the amount of substance in moles, mass and molar mass.	
Distinguish between the terms <i>empirical formula</i> and <i>molecular formula</i> .	
Determine the empirical formula from the percentage composition or from other experimental data.	
Determine the molecular formula when given both the empirical formula and experimental data.	

Problems

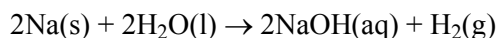
- How many hydrogen atoms are in one mole of ethanol, $\text{C}_2\text{H}_5\text{OH}$?
 - 1.00×10^{23}
 - 3.61×10^{24}
 - 5.00
 - 6.00
- Which expression gives the amount (in mol) of a substance, if the mass is given in grams?
 - $\frac{\text{mass}}{\text{molar mass}}$
 - $\frac{\text{molar mass}}{\text{mass}}$
 - $\frac{1}{\text{molar mass}}$
 - $\text{mass} \times \text{molar mass}$
- What is the empirical formula of a compound containing 50% by mass of element X ($A_r = 20$) and 50% by mass of element Y ($A_r = 25$)?
 - XY
 - X_3Y_2
 - X_4Y_5
 - X_5Y_4
- What is the total number of ions present in the formula, $\text{Al}_2(\text{SO}_4)_3$?
 - 2
 - 3
 - 5
 - 6
- Which of the following quantities has units?
 - Relative atomic mass
 - Relative molecular mass
 - Molar mass
 - Mass number
- The relative molecular mass (M_r) of a compound is 60. Which formulas are possible for this compound?
 - $\text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2$
 - $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
 - $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$
 - I and II only
 - I and III only
 - II and III only
 - I, II and III
- Which of the following compounds has/have the empirical formula CH_2O ?
 - CH_3COOH
 - $\text{C}_6\text{H}_{12}\text{O}_6$
 - $\text{C}_{12}\text{H}_{22}\text{O}_{11}$
 - II only
 - III only
 - I and II only
 - II and III only

8. The percentage by mass of the elements in a compound is

$$\text{C} = 72\%, \quad \text{H} = 12\%, \quad \text{O} = 16\%.$$

What is the mole ratio of C:H in the empirical formula of this compound?

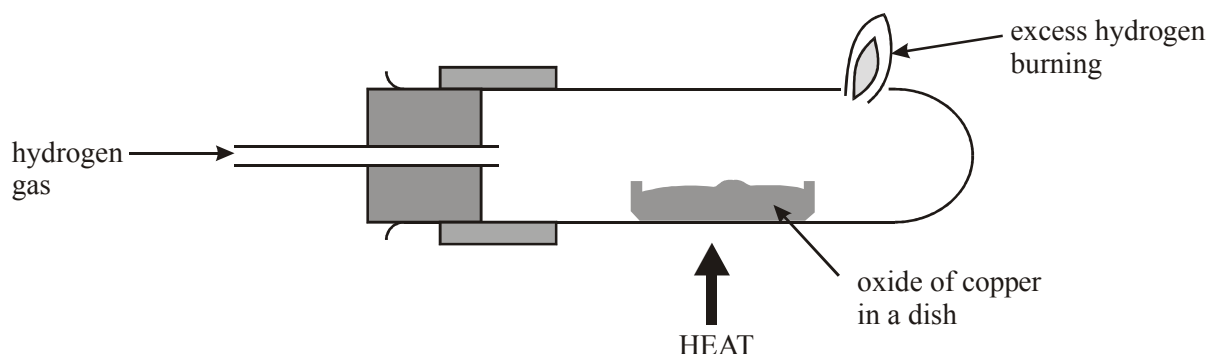
- A. 1 : 1
B. 1 : 2
C. 1 : 6
D. 6 : 1
9. A hydrocarbon contains 90% by mass of carbon. What is its empirical formula?
A. CH_2
B. C_3H_4
C. C_7H_{10}
D. C_9H_{10}
10. (i) Crocetin consists of the elements carbon, hydrogen and oxygen. Determine the empirical formula of crocetin, if 1.00 g of crocetin forms 2.68 g of carbon dioxide and 0.657 g of water when it undergoes complete combustion.
(ii) Determine the molecular formula of crocetin given that 0.300 mole of crocetin has a mass of 98.5 g
11. An organic compound A contains 62.0% by mass of carbon, 24.1% by mass of nitrogen, the remainder being hydrogen.
(i) Determine the percentage by mass of hydrogen and the empirical formula of A.
(ii) Define the term *relative molecular mass*.
(iii) The relative molecular mass of A is 116. Determine the molecular formula of A.
12. An organic compound A contains 62.0% by mass of carbon, 24.1% by mass of nitrogen, the remainder being hydrogen.
(i) Determine the percentage by mass of hydrogen and the empirical formula of A.
(ii) Define the term relative molecular mass.
(iii) The relative molecular mass of A is 116. Determine the molecular formula of A.
13. An organic compound, A, containing only the elements carbon, hydrogen and oxygen was analysed.
(a) A was found to contain 54.5% C and 9.1% H by mass, the remainder being oxygen. Determine the empirical formula of the compound.
(b) A 0.230 g sample of A, when vaporized, had a volume of 0.0785 dm^3 at 95°C and 102 kPa. Determine the relative molecular mass of A.
(c) Determine the molecular formula of A using your answers from parts (a) and (b).
14. Sodium reacts with water as follows.



1.15 g of sodium is allowed to react completely with water. The resulting solution is diluted to 250 cm^3 . Calculate the concentration, in mol dm^{-3} , of the resulting sodium hydroxide solution.

15. The relative molecular mass of aluminium chloride is 267 and its composition by mass is 20.3% Al and 79.7% chlorine. Determine the empirical and molecular formulas of aluminium chloride.

16. An oxide of copper was reduced in a stream of hydrogen as shown below.



After heating, the stream of hydrogen gas was maintained until the apparatus had cooled. The following results were obtained.

Mass of empty dish = 13.80 g

Mass of dish and contents before heating = 21.75 g

Mass of dish and contents after heating and leaving to cool = 20.15 g

- Explain why the stream of hydrogen gas was maintained until the apparatus cooled.
 - Calculate the empirical formula of the oxide of copper using the data above, assuming complete reduction of the oxide.
 - Write an equation for the reaction that occurred.
 - State **two** changes that would be observed inside the tube as it was heated.
17. 0.502 g of an alkali metal sulfate is dissolved in water and excess barium chloride solution, $\text{BaCl}_2(\text{aq})$ is added to precipitate all the sulfate ions as barium sulfate, $\text{BaSO}_4(\text{s})$. The precipitate is filtered and dried and weighs 0.672 g.
- Calculate the amount (in mol) of barium sulfate formed.
 - Determine the amount (in mol) of the alkali metal sulfate present.
 - Determine the molar mass of the alkali metal sulfate and state its units.
 - Deduce the identity of the alkali metal, showing your workings.
 - Write an equation for the precipitation reaction, including state symbols.
18. A 3.245-g sample of a titanium chloride was reduced with sodium to metallic titanium. After the resultant sodium chloride was washed out, the residual metal was dried, and weighed 0.819 g. What is the empirical formula of this titanium chloride?
19. What is the nitrogen content (fertilizer rating) of NH_4NO_3 ? Of $(\text{NH}_4)_2\text{SO}_4$? of NH_3 ?
20. A household cement gave the following analytical data: A 28.5-g sample, on dilution with acetone, yielded a residue of 4.6 g of aluminum powder. The filtrate, on evaporation of the acetone and solvent, yielded 3.2 g of plasticized nitrocellulose, which contained 0.8 g of benzene-soluble plasticizer. a) Make a drawing of the process, b) Determine the composition of this cement
21. One of the earliest methods for determining the molar mass of proteins was based on chemical analysis. A hemoglobin preparation was found to contain 0.335% iron. (a) If the hemoglobin molecule contains 1 atom of iron, what is its molar mass? (b) If it contains 4 atoms of iron, what is its molar mass?

1.3 Chemical equations

Assessment statement	Notes
Deduce chemical equations when all reactants and products are given.	You should be aware of the difference between coefficients and subscripts.
Identify the mole ratio of any two species in a chemical equation.	
Apply the state symbols (s), (l), (g) and (aq).	

Problems

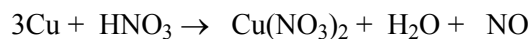
1. Air bags in cars inflate when sodium azide decomposes to form sodium and nitrogen:



Calculate the amount, in moles, of nitrogen gas produced by the decomposition of 2.52 mol of $\text{NaN}_3(\text{s})$.

- | | |
|---------|---------|
| A. 1.68 | C. 3.78 |
| B. 2.52 | D. 7.56 |

2. Copper can react with nitric acid as follows.



What is the coefficient for HNO_3 when the equation is balanced?

- | | |
|------|-------|
| A. 4 | C. 8 |
| B. 6 | D. 10 |

3. $_ \text{C}_2\text{H}_2(\text{g}) + _ \text{O}_2(\text{g}) \rightarrow _ \text{CO}_2(\text{g}) + _ \text{H}_2\text{O}(\text{g})$

When the equation above is balanced, what is the coefficient for oxygen?

- | | |
|------|------|
| A. 2 | C. 4 |
| B. 3 | D. 5 |

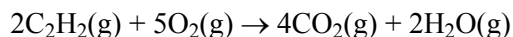
4. (i) Calcium carbonate is added to separate solutions of hydrochloric acid and ethanoic acid of the same concentration. State **one** similarity and **one** difference in the observations you could make.
- (ii) Write an equation for the reaction between hydrochloric acid and calcium carbonate.
- (iii) Determine the volume of 1.50 mol dm^{-3} hydrochloric acid that would react with exactly 1.25 g of calcium carbonate.
- (iv) Calculate the volume of carbon dioxide, measured at 273 K and $1.01 \times 10^5 \text{ Pa}$, which would be produced when 1.25 g of calcium carbonate reacts completely with the hydrochloric acid.

1.4 Mass and gaseous volume relationships in chemical reactions

Assessment statement	notes
Calculate theoretical yields from chemical equations.	Given a chemical equation and the mass or amount (in moles) of one species, calculate the mass or amount of another species.
Determine the limiting reactant and the reactant in excess when quantities of reacting substances are given.	
Solve problems involving theoretical, experimental and percentage yield.	
Apply Avogadro's law to calculate reacting volumes of gases.	
Apply the concept of molar volume at standard temperature and pressure in calculations.	The molar volume of an ideal gas under standard conditions is $2.24 \times 10^{-2} \text{ m}^3 \text{ mol}^{-1}$ ($22.4 \text{ dm}^3 \text{ mol}^{-1}$).
Solve problems involving the relationship between temperature, pressure and volume for a fixed mass of an ideal gas.	
Solve problems using the ideal gas equation, $PV = nRT$	
Analyse graphs relating to the ideal gas equation.	

Problems

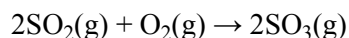
1. Ethyne, C_2H_2 , reacts with oxygen according to the equation below. What volume of oxygen (in dm^3) reacts with 0.40 dm^3 of C_2H_2 ?



- A. 0.40
B. 0.80
C. 1.0
D. 2.0
2. The temperature in Kelvin of 1.0 dm^3 of an ideal gas is doubled and its pressure is tripled. What is the final volume of the gas in dm^3 ?
- A. $\frac{1}{3}$
B. $\frac{2}{3}$
C. $\frac{3}{2}$
D. $\frac{1}{6}$
3. A cylinder of gas is at a pressure of 40 kPa. The volume and temperature (in K) are both doubled. What is the pressure of the gas after these changes?
- A. 10 kPa
B. 20 kPa
C. 40 kPa
D. 80 kPa
4. A fixed mass of an ideal gas has a volume of 800 cm^3 under certain conditions. The pressure (in kPa) and temperature (in K) are both doubled. What is the volume of the gas after these changes with other conditions remaining the same?
- A. 200 cm^3
B. 800 cm^3
C. 1600 cm^3
D. 3200 cm^3
5. For which set of conditions does a fixed mass of an ideal gas have the greatest volume?

	Temperature	Pressure
A.	low	low
B.	low	high
C.	high	high
D.	high	low

6. 3.0 dm^3 of sulfur dioxide is reacted with 2.0 dm^3 of oxygen according to the equation below.

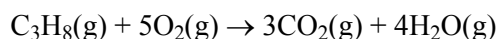


What volume of sulfur trioxide (in dm^3) is formed? (Assume the reaction goes to completion and all gases are measured at the same temperature and pressure.)

- A. 5.0
B. 4.0
C. 3.0
D. 2.0
7. Which change in conditions would increase the volume of a fixed mass of gas?

	Pressure /kPa	Temperature /K
A.	Doubled	Doubled
B.	Halved	Halved
C.	Doubled	Halved
D.	Halved	Doubled

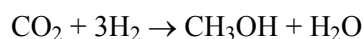
8. What will happen to the volume of a fixed mass of gas when its pressure and temperature (in Kelvin) are both doubled?
- A. It will not change.
B. It will increase.
C. It will decrease.
D. The change cannot be predicted.
9. Propane and oxygen react according to the following equation.



Calculate the volume of carbon dioxide and water vapour produced and the volume of oxygen remaining, when 20.0 dm^3 of propane reacts with 120.0 dm^3 of oxygen. All gas volumes are measured at the same temperature and pressure.

10. A toxic gas, A, consists of 53.8% nitrogen and 46.2% carbon by mass. At 273 K and $1.01 \times 10^5 \text{ Pa}$, 1.048 g of A occupies 462 cm^3 . Determine the empirical formula of A. Calculate the molar mass of the compound and determine its molecular structure.
11. State and explain what would happen to the pressure of a given mass of gas when its absolute temperature and volume are both doubled.
12. 100 cm^3 of ethene, C_2H_4 , is burned in 400 cm^3 of oxygen, producing carbon dioxide and some liquid water. Some oxygen remains unreacted.
- (a) Write the equation for the complete combustion of ethene.
(b) Calculate the volume of carbon dioxide produced and the volume of oxygen remaining.

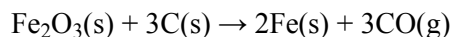
Limiting reagent



What is the maximum amount of methanol that can be formed from 2 mol of carbon dioxide and 3 mol of hydrogen?

- A. 1 mol
B. 2 mol
C. 3 mol
D. 5 mol

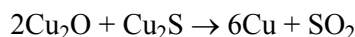
2. 6.0 moles of $\text{Fe}_2\text{O}_3(\text{s})$ reacts with 9.0 moles of carbon in a blast furnace according to the equation below.



What is the limiting reagent and hence the theoretical yield of iron?

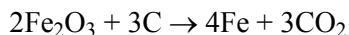
	Limiting reagent	Theoretical yield of iron
A.	Fe_2O_3	6.0 mol
B.	Fe_2O_3	12.0 mol
C.	carbon	9.0 mol
D.	carbon	6.0 mol

3. (a) Write an equation for the formation of zinc iodide from zinc and iodine.
- (b) 100.0 g of zinc is allowed to react with 100.0 g of iodine producing zinc iodide. Calculate the amount (in moles) of zinc and iodine, and hence determine which reactant is in excess.
- (c) Calculate the mass of zinc iodide that will be produced.
4. Copper metal may be produced by the reaction of copper(I) oxide and copper(I) sulfide according to the below equation.



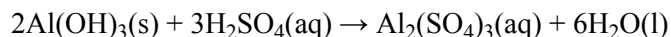
A mixture of 10.0 kg of copper(I) oxide and 5.00 kg of copper(I) sulfide was heated until no further reaction occurred.

- (a) Determine the limiting reagent in this reaction, showing your working.
5. The reaction below represents the reduction of iron ore to produce iron.



A mixture of 30 kg of Fe_2O_3 and 5.0 kg of C was heated until no further reaction occurred. Calculate the maximum mass of iron that can be obtained from these masses of reactants.

6. 0.600 mol of aluminium hydroxide is mixed with 0.600 mol of sulfuric acid, and the following reaction occurs:



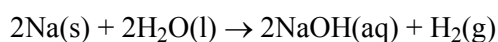
- (a) Determine the limiting reactant.
- (b) Calculate the mass of $\text{Al}_2(\text{SO}_4)_3$ produced.
- (c) Determine the amount (in mol) of excess reactant that remains.

1.5 Solutions

Assessment statement	Teacher's notes
Distinguish between the terms <i>solute</i> , <i>solvent</i> , <i>solution</i> and <i>concentration</i> (g dm^{-3} and mol dm^{-3}).	Concentration in mol dm^{-3} is often represented by square brackets around the substance under consideration, for example, $[\text{HCl}]$.
Solve problems involving concentration, amount of solute and volume of solution.	

Problems

- 0.502 g of an alkali metal sulfate is dissolved in water and excess barium chloride solution, $\text{BaCl}_2(\text{aq})$ is added to precipitate all the sulfate ions as barium sulfate, $\text{BaSO}_4(\text{s})$. The precipitate is filtered and dried and weighs 0.672 g.
 - Calculate the amount (in mol) of barium sulfate formed.
 - Determine the amount (in mol) of the alkali metal sulfate present.
 - Determine the molar mass of the alkali metal sulfate and state its units.
 - Deduce the identity of the alkali metal, showing your workings.
 - Write an equation for the precipitation reaction, including state symbols.
- Calcium carbonate is added to separate solutions of hydrochloric acid and ethanoic acid of the same concentration. State **one** similarity and **one** difference in the observations you could make.
 - Write an equation for the reaction between hydrochloric acid and calcium carbonate.
 - Determine the volume of 1.50 mol dm^{-3} hydrochloric acid that would react with exactly 1.25 g of calcium carbonate.
 - Calculate the volume of carbon dioxide, measured at 273 K and $1.01 \times 10^5 \text{ Pa}$, which would be produced when 1.25 g of calcium carbonate reacts completely with the hydrochloric acid.
- 100 cm^3 of ethene, C_2H_4 , is burned in 400 cm^3 of oxygen, producing carbon dioxide and some liquid water. Some oxygen remains unreacted.
 - Write the equation for the complete combustion of ethene.
 - Calculate the volume of carbon dioxide produced and the volume of oxygen remaining.
- Sodium reacts with water as follows.



1.15 g of sodium is allowed to react completely with water. The resulting solution is diluted to 250 cm^3 . Calculate the concentration, in mol dm^{-3} , of the resulting sodium hydroxide solution.

5. A solution containing ammonia requires 25.0 cm^3 of $0.100 \text{ mol dm}^{-3}$ hydrochloric acid to reach the equivalence point of a titration.
- (i) Write an equation for the reaction of ammonia with hydrochloric acid
 - (ii) Calculate the amount (in mol) of hydrochloric acid and ammonia that react.
 - (iii) Calculate the mass of ammonia in the solution.

SMITH N, Solving general chemistry problems Page 199 Ex.: 1 – 9 in exercise 3 only find the molarities.; page: 200 Ex.: 13 – 14, 17 – 18.