

IB Chemistry SL Paper 2 Mock Paper (10 questions, 50 marks, 75 minutes)

IBDP (Year 12-13) Chemistry | 時限：75 分鐘 | 總分：50 分 | 共 10 題

Section A (Questions 1 to 5, 25 marks)

Answer ALL questions. A calculator is allowed. Unless told otherwise, give numerical answers to 3 significant figures and show your working, stating units in every final answer.

1. Calcium carbonate ($M_r = 100.0$) decomposes on heating: $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$. 25.0 g of calcium carbonate is completely decomposed. (a) Calculate the amount, in mol, of calcium carbonate. (b) Calculate the volume of carbon dioxide formed at room temperature and pressure (molar volume $24.0 \text{ dm}^3 \text{ mol}^{-1}$). (c) Calculate the mass of calcium oxide formed ($M_r = 56.08$).

答案：(a) $n = 25.0 / 100.0 = 0.250 \text{ mol}$. (b) $n(\text{CO}_2) = 0.250 \text{ mol}$, so $V = 0.250 \times 24.0 = 6.00 \text{ dm}^3$. (c) $m = 0.250 \times 56.08 = 14.0 \text{ g}$ (3 s.f.).

2. 25.0 cm^3 of $0.100 \text{ mol dm}^{-3}$ sodium hydroxide is titrated with $0.125 \text{ mol dm}^{-3}$ hydrochloric acid ($\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$). (a) Calculate the amount, in mol, of sodium hydroxide. (b) Calculate the volume of acid required, in cm^3 . (c) Calculate the mass of hydrogen chloride used ($M_r = 36.46$).

答案：(a) $n(\text{NaOH}) = 0.100 \times 25.0 / 1000 = 2.50 \times 10^{-3} \text{ mol}$. (b) The ratio is 1:1, so $V = 2.50 \times 10^{-3} / 0.125 \times 1000 = 20.0 \text{ cm}^3$. (c) $m = 2.50 \times 10^{-3} \times 36.46 = 0.0912 \text{ g}$.

3. A 0.0250 mol sample of a gas occupies a certain volume at 298 K and 100 kPa and has a mass of 1.10 g . ($R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$) (a) Use $pV = nRT$ to calculate the volume of the sample in cm^3 . (b) Calculate the molar mass and decide whether the gas is carbon dioxide ($M_r = 44.0$) or oxygen ($M_r = 32.0$).

答案：(a) $V = nRT / p = 0.0250 \times 8.314 \times 298 / 100000 = 6.19 \times 10^{-4} \text{ m}^3$, which is 619 cm^3 . (b) $M = 1.10 / 0.0250 = 44.0 \text{ g mol}^{-1}$, so the gas is carbon dioxide.

4. 0.0200 mol of a metal is dissolved in 50.0 g of water and the temperature rises from 21.0 to 27.5 degrees C. (Specific heat capacity of water = $4.18 \text{ J g}^{-1} \text{ K}^{-1}$; ignore the heat capacity of the container.) (a) Calculate the heat energy absorbed by the water in J and in kJ. (b) Calculate the enthalpy change of reaction in kJ mol^{-1} and state whether the sign shows an exothermic or endothermic change.

答案：(a) $q = mc\Delta T = 50.0 \times 4.18 \times 6.5 = 1358.5 \text{ J} = 1.36 \text{ kJ}$. (b) $\Delta H = -q / n = -1.36 / 0.0200 = -67.9 \text{ kJ mol}^{-1}$; the negative sign means the reaction is exothermic, which agrees with the temperature rise.

5. Hydrogen reacts with iodine vapour in a 2.00 dm^3 container: $\text{H}_2(\text{g}) + \text{I}_2(\text{g})$ is in equilibrium with $2\text{HI}(\text{g})$. The initial concentration of both H_2 and I_2 is $0.250 \text{ mol dm}^{-3}$; at equilibrium the concentration of HI is $0.350 \text{ mol dm}^{-3}$. (a) Calculate the equilibrium concentration of H_2 . (b) Calculate K_c to 3 significant figures. (c) The container is compressed to 1.00 dm^3 . State and explain how the equilibrium concentration of HI changes.

答案 : (a) Forming $0.350 \text{ mol dm}^{-3}$ of HI uses $0.175 \text{ mol dm}^{-3}$ of H_2 , so at equilibrium $[\text{H}_2] = [\text{I}_2] = 0.250 - 0.175 = 0.0750 \text{ mol dm}^{-3}$. (b) $K_c = [\text{HI}]^2 / ([\text{H}_2][\text{I}_2]) = 0.350^2 / 0.0750^2 = 21.8$. (c) There are equal numbers of gas moles on both sides (2 and 2), so changing the pressure does not shift the position of equilibrium. The amounts in mol stay the same, so halving the volume doubles each concentration and $[\text{HI}]$ becomes about $0.700 \text{ mol dm}^{-3}$.

Section B (Questions 6 to 10, 25 marks)

Answer ALL questions. A calculator is allowed. Unless told otherwise, give numerical answers to 3 significant figures and show your working, stating units in every final answer.

6. (a) Calculate the pH of $0.0100 \text{ mol dm}^{-3}$ hydrochloric acid. (b) A weak acid HA has concentration $0.0100 \text{ mol dm}^{-3}$ and pH 3.20. Calculate K_a to 2 significant figures. (c) Calculate the pH of $0.0500 \text{ mol dm}^{-3}$ sodium hydroxide at 25 degrees C.

答案 : (a) $[\text{H}^+] = 0.0100 \text{ mol dm}^{-3}$, so pH = 2.00. (b) $[\text{H}^+] = 10^{-3.20} = 6.31 \times 10^{-4} \text{ mol dm}^{-3}$, so $K_a = (6.31 \times 10^{-4})^2 / 0.0100 = 4.0 \times 10^{-5}$. (c) $[\text{OH}^-] = 0.0500 \text{ mol dm}^{-3}$, so pOH = 1.30 and pH = $14.00 - 1.30 = 12.70$.

7. A current of 2.00 A is passed through copper(II) sulfate solution for 30.0 minutes. (Faraday constant $96\,500 \text{ C mol}^{-1}$; cathode: $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$) (a) Calculate the charge passed in C and the amount of electrons in mol. (b) Calculate the mass of copper deposited at the cathode ($M_r = 63.55$). (c) Calculate the volume of oxygen formed at the anode at room temperature and pressure (molar volume $24.0 \text{ dm}^3 \text{ mol}^{-1}$).

答案 : (a) $Q = It = 2.00 \times 1800 = 3600 \text{ C}$, so $n(\text{e}^-) = 3600 / 96500 = 0.0373 \text{ mol}$. (b) $n(\text{Cu}) = 0.0373 / 2 = 0.0187 \text{ mol}$, so $m = 0.0187 \times 63.55 = 1.19 \text{ g}$. (c) At the anode $2\text{H}_2\text{O}$ gives $\text{O}_2 + 4\text{H}^+ + 4\text{e}^-$, so $n(\text{O}_2) = 0.0373 / 4 = 9.33 \times 10^{-3} \text{ mol}$ and $V = 9.33 \times 10^{-3} \times 24.0 = 0.224 \text{ dm}^3$, that is 224 cm^3 .

8. (a) Explain why the melting point of magnesium oxide ($2\,852$ degrees C) is much higher than that of sodium chloride (801 degrees C). Refer to structure and bonding. (b) Explain why ammonia is very soluble in water whereas methane is almost insoluble. Refer to intermolecular forces. (c) Write the equation for the reaction of magnesium with cold water and state how its vigour compares with that of sodium.

答案 : (a) Magnesium oxide is a giant ionic lattice in which both Mg^{2+} and O^{2-} carry two charges and are small, so the electrostatic attraction (ionic bonding) is very strong. In sodium chloride each ion carries only one charge and the ions are larger, so the attraction is weaker and the melting point is lower. (b) Ammonia molecules form hydrogen bonds with water molecules and can react with water to give NH_4^+ and OH^- . Methane is non-polar and interacts with water only through weak van der Waals forces, so it is almost insoluble. (c) $\text{Mg}(\text{s}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow \text{Mg}(\text{OH})_2(\text{aq}) + \text{H}_2(\text{g})$. Magnesium reacts only very slowly with cold water, whereas sodium reacts violently and floats on the surface, because sodium is more metallic and has a lower first ionisation energy.

9. An organic compound contains 40.0% carbon, 6.7% hydrogen and 53.3% oxygen by mass and has a molar mass of 180 g mol^{-1} . (a) Determine its empirical formula. (b) Determine its molecular formula. (c) The compound gives a brick-red precipitate with Benedict solution. Suggest one possible structure by name and explain your reasoning.

答案：(a) Mole ratio: C $40.0/12.01 = 3.33$, H $6.7/1.008 = 6.65$ and O $53.3/16.00 = 3.33$, which simplifies to 1:2:1, so the empirical formula is CH_2O (formula mass 30.03). (b) $n = 180/30.03 = 6$, so the molecular formula is $\text{C}_6\text{H}_{12}\text{O}_6$. (c) Glucose (or fructose). It reduces Benedict solution, which shows an aldehyde group or an alpha-hydroxy ketone group, so it is a reducing sugar.

10. At a certain temperature the rate of decomposition of compound A was measured: when $[\text{A}] = 0.10 \text{ mol dm}^{-3}$ the rate is $2.0 \times 10^{-3} \text{ mol dm}^{-3} \text{ s}^{-1}$, and when $[\text{A}] = 0.20 \text{ mol dm}^{-3}$ the rate is $4.0 \times 10^{-3} \text{ mol dm}^{-3} \text{ s}^{-1}$. (a) Deduce the order with respect to A and explain. (b) Calculate the rate constant k, including its unit. (c) Calculate the initial rate when $[\text{A}] = 0.50 \text{ mol dm}^{-3}$ and hence the half-life under these conditions.

答案：(a) Doubling $[\text{A}]$ doubles the rate, so the reaction is first order with respect to A and $\text{rate} = k[\text{A}]$. (b) $k = 2.0 \times 10^{-3} / 0.10 = 2.0 \times 10^{-2} \text{ s}^{-1}$. (c) $\text{rate} = 2.0 \times 10^{-2} \times 0.50 = 1.0 \times 10^{-2} \text{ mol dm}^{-3} \text{ s}^{-1}$; for a first order reaction $t(\text{half}) = \ln 2 / k = 0.693 / 0.020 = 34.7 \text{ s}$, independent of the starting concentration.