

CIE A-Level Chemistry 9701 Paper 2 Practice

Paper (AS)

Total: 100 marks · 2 hours · 7 questions · 41 parts

Q 1 · Lattice energy and Born-Haber cycles [16]

- (a) Define the lattice energy of an ionic compound. [2]
- (b) Calculate the lattice energy of sodium chloride from: $\Delta H_f[\text{NaCl(s)}] = -411 \text{ kJ/mol}$, $\Delta H_{\text{atom}}[\text{Na}] = +107$, $\frac{1}{2} \Delta H_{\text{diss}}[\text{Cl}_2] = +122$, $\text{IE}_1[\text{Na}] = +496$, $\text{EA}[\text{Cl}] = -349$. [3]
- (c) Data for magnesium oxide: $\Delta H_f[\text{MgO}] = -602$, $\Delta H_{\text{atom}}[\text{Mg}] = +148$, $\frac{1}{2} \Delta H_{\text{diss}}[\text{O}_2] = +249$, $\text{IE}_1 + \text{IE}_2[\text{Mg}] = 738 + 1451$, $\text{EA}_1 + \text{EA}_2[\text{O}] = -141 + 798$. Calculate the lattice energy of MgO. [3]
- (d) Explain why the lattice energy of MgO is far more negative than that of NaCl. [3]
- (e) The hydration enthalpies of $\text{Na}^+(\text{g})$ and $\text{Cl}^-(\text{g})$ are -406 and -364 kJ/mol . Calculate the standard enthalpy of solution of NaCl(s). [3]
- (f) The standard entropy change on dissolving NaCl is $+43 \text{ J K}^{-1} \text{ mol}^{-1}$. Calculate ΔG at 298 K in kJ/mol and explain why NaCl still dissolves readily in water. [2]

Q 2 · Electrochemistry and cells [14]

- (a) Define the standard electrode potential of a half-cell. [2]
- (b) E for Zn^{2+}/Zn is -0.76 V and E for Cu^{2+}/Cu is $+0.34 \text{ V}$. Calculate the standard emf of the cell $\text{Zn} \mid \text{Zn}^{2+} \parallel \text{Cu}^{2+} \mid \text{Cu}$. [2]
- (c) Use $\Delta G = -nFE$ to calculate the standard free energy change of this cell ($F = 96,500 \text{ C/mol}$), in kJ/mol . [3]
- (d) Write the two half-equations and state the direction of electron flow and which electrode is the positive electrode. [3]
- (e) If the concentration of Cu^{2+} is raised from 1.0 to 2.0 mol/dm^3 with everything else unchanged, how does the emf change? Explain. [2]
- (f) If $[\text{Zn}^{2+}] = 1.0 \text{ mol/dm}^3$ and $[\text{Cu}^{2+}] = 0.010 \text{ mol/dm}^3$ at 298 K , calculate the emf of the cell. [2]

Q 3 · Acid-base equilibria and buffers [16]

- (a) Define an acid according to the Bronsted-Lowry theory. [1]
- (b) Calculate the pH of 0.100 mol/dm³ ethanoic acid ($K_a = 1.80 \times 10^{-5}$). [3]
- (c) A weak acid solution of concentration 0.050 mol/dm³ has pH 3.10. Calculate its K_a . [3]
- (d) A solution contains 0.200 mol/dm³ ethanoic acid and 0.100 mol/dm³ sodium ethanoate. Calculate its pH ($K_a = 1.80 \times 10^{-5}$). [3]
- (e) Adding a small amount of HCl to this buffer changes the pH only slightly. Explain why. [2]
- (f) 25.0 cm³ of 0.100 mol/dm³ ethanoic acid is titrated with 0.100 mol/dm³ NaOH. Calculate the pH at the equivalence point ($K_w = 1.00 \times 10^{-14}$, $K_a = 1.80 \times 10^{-5}$). [4]

Q 4 · Reaction kinetics [14]

- (a) Initial rate data for $A + B \rightarrow$ products: experiment 1 $[A] = 0.100$, $[B] = 0.100$, rate 2.40×10^{-3} mol dm⁻³ s⁻¹; experiment 2 $[A] = 0.200$, $[B] = 0.100$, rate 4.80×10^{-3} ; experiment 3 $[A] = 0.100$, $[B] = 0.200$, rate 9.60×10^{-3} . Deduce the order with respect to A and to B and write the rate equation. [4]
- (b) Use experiment 1 to calculate the rate constant k , with units. [2]
- (c) Calculate the initial rate when $[A] = 0.150$ and $[B] = 0.0500$ mol/dm³. [2]
- (d) Deduce which species take part in the rate-determining step and justify your answer. [2]
- (e) k is 2.40×10^{-3} dm⁶ mol⁻² s⁻¹ at 300 K and 9.60×10^{-3} at 320 K. Calculate the activation energy ($R = 8.314$ J K⁻¹ mol⁻¹). [3]
- (f) Use collision theory to explain why the rate constant increases with temperature. [1]

Q 5 · Transition elements and redox titrations [12]

- (a) Define a transition element. [2]
- (b) Explain why most transition metal complexes are coloured. [2]
- (c) Write the ionic equation for the reaction of $[\text{Cu}(\text{H}_2\text{O})_6]^{2+}$ with excess NH_3 and describe the colour change. [2]
- (d) 25.0 cm³ of a solution containing Fe^{2+} needs 24.50 cm³ of 0.0200 mol/dm³ KMnO_4 in acid. Given $\text{MnO}_4^- + 5\text{Fe}^{2+} + 8\text{H}^+ \rightarrow \text{Mn}^{2+} + 5\text{Fe}^{3+} + 4\text{H}_2\text{O}$, calculate the concentration of Fe^{2+} . [3]
- (e) The Fe^{2+} solution has a total volume of 250 cm³. Calculate the mass of iron it contains (A_r : Fe = 55.8). [2]

(f) Why is no added indicator needed in this titration? [1]

Q 6 · Organic synthesis and structure determination [16]

(a) Starting from ethanol, state the reagents and conditions needed to make ethanal and to make ethanoic acid. [3]

(b) Write the equation for the reaction of ethanol with ethanoic acid to form ethyl ethanoate and state the catalyst and conditions. [2]

(c) 23.0 g of ethanol reacts with excess ethanoic acid to give 30.8 g of ethyl ethanoate. Calculate the percentage yield (Mr: ethanol 46.0, ester 88.0). [3]

(d) Why is the yield below 100%? Suggest one way of improving it. [2]

(e) Compare the products of the acid hydrolysis and the alkaline hydrolysis of ethyl ethanoate. [2]

(f) Compound X contains only C, H and O, has Mr = 74.0, and contains 48.6% carbon and 8.1% hydrogen. Its IR spectrum has absorptions at 1710 cm⁻¹ and a broad band from 2500 to 3300 cm⁻¹; its ¹H NMR spectrum shows a triplet, a quartet and one exchangeable singlet. Deduce the structure of X and justify your answer. [4]

Q 7 · Chemistry of nitrogen and sulfur [12]

(a) Write the equation for the catalytic oxidation of ammonia to nitrogen monoxide and state the industrial conditions. [2]

(b) 100 kg of ammonia is completely oxidised to NO. Calculate the mass of NO obtained (Mr: NH₃ 17.0, NO 30.0). [3]

(c) The NO is oxidised to NO₂, which is absorbed in water: $3\text{NO}_2 + \text{H}_2\text{O} \rightarrow 2\text{HNO}_3 + \text{NO}$. Calculate the maximum mass of nitric acid obtainable from that NO (Mr: HNO₃ 63.0). [3]

(d) Explain why the NO leaving the absorption tower is returned to the oxidation tower. [2]

(e) Flue gas contains 640 kg of SO₂, removed with CaO: $\text{CaO} + \text{SO}_2 \rightarrow \text{CaSO}_3$. Calculate the minimum mass of CaO required (Mr: SO₂ 64.1, CaO 56.1). [2]