

CIE A-Level Chemistry 9701 Paper 2 Practice

Paper (AS) - ANSWERS

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

Part	Answer	Marking points	marks
1(a)	The enthalpy change when 1 mol of an ionic compound is formed from its gaseous ions under standard conditions (ΔH_{latt} is negative).	1 mark: 1 mol of ionic compound formed from its gaseous ions 1 mark: exothermic, so ΔH is negative	2
1(b)	$\Delta H_{\text{latt}} = -411 - (107 + 122 + 496 - 349) = -411 - 376 = -787 \text{ kJ/mol}$	1 mark: signs of all Born-Haber terms correct 1 mark: $107 + 122 + 496 - 349 = 376$ 1 mark: -787 kJ/mol	3
1(c)	Sum = $148 + 249 + 2189 + 657 = 3243$; $\Delta H_{\text{latt}} = -602 - 3243 = -3845 \text{ kJ/mol}$	1 mark: IE total 2189 and EA total 657 1 mark: $148 + 249 + 2189 + 657 = 3243$ 1 mark: -3845 kJ/mol	3
1(d)	The charges on Mg^{2+} and O^{2-} are twice those on Na^{+} and Cl^{-} , so the product of charges rises by a factor of 4; the ions are also smaller, so the inter-ionic distance is shorter and the electrostatic attraction is much stronger.	1 mark: ions carry 2+ and 2- charges 1 mark: charge product about 4 times larger 1 mark: smaller ions give a shorter distance	3
1(e)	$\Delta H_{\text{sol}} = -\Delta H_{\text{latt}} + \Delta H_{\text{hyd}}(\text{Na}^{+}) + \Delta H_{\text{hyd}}(\text{Cl}^{-}) = 787 - 406 - 364 = +17 \text{ kJ/mol}$ (endothermic)	1 mark: breaking the lattice costs +787 kJ/mol 1 mark: $-406 - 364$ 1 mark: +17 kJ/mol	3
1(f)	$\Delta G = 17 - 298 \times 43/1000 = +4.2 \text{ kJ/mol}$, which is positive, so solution is not favoured at standard conditions; in practice the solution is unsaturated, and the large entropy of mixing drives ΔG negative, so NaCl still dissolves.	1 mark: $\Delta G = +4.2 \text{ kJ/mol}$ 1 mark: positive at standard conditions, but entropy of	2

		mixing in dilute solution makes dG negative	
2(a)	The emf of a cell made by joining the half-cell to a standard hydrogen electrode at 298 K with ion concentrations of 1 mol/dm ³ (gas pressure 1 atm), the hydrogen electrode being taken as 0.00 V.	1 mark: standard conditions, 1 mol/dm ³ , 298 K, 1 atm 1 mark: measured against the standard hydrogen electrode taken as 0.00 V	2
2(b)	$E_{\text{cell}} = E(\text{cathode}) - E(\text{anode}) = 0.34 - (-0.76) = +1.10 \text{ V}$	1 mark: $E_{\text{cell}} = E_{\text{cathode}} - E_{\text{anode}}$ 1 mark: +1.10 V	2
2(c)	$n = 2$; $dG = -2 \times 96,500 \times 1.10 = -212,300 \text{ J/mol} = -212 \text{ kJ/mol}$	1 mark: $n = 2$ 1 mark: $-2 \times 96,500 \times 1.10$ 1 mark: -212 kJ/mol	3
2(d)	Negative electrode (oxidation): $\text{Zn} \rightarrow \text{Zn}^{2+} + 2\text{e}^-$; positive electrode (reduction): $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$; electrons flow from zinc to copper through the external circuit, and copper is the positive electrode.	1 mark: $\text{Zn} \rightarrow \text{Zn}^{2+} + 2\text{e}^-$ (oxidation) 1 mark: $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$ (reduction) 1 mark: electrons Zn $\rightarrow$ Cu and copper is positive	3
2(e)	The emf increases. By the Nernst equation $E = E^\circ - (0.059/n)\log([\text{Zn}^{2+}]/[\text{Cu}^{2+}])$, a larger $[\text{Cu}^{2+}]$ makes the log term more negative, so E rises as the copper half-cell potential increases.	1 mark: emf increases 1 mark: Nernst equation; the reduction potential of the copper half-cell rises	2
2(f)	$E = 1.10 - (0.059/2)\log(1.0/0.010) = 1.10 - 0.059 = +1.041 \text{ V}$	1 mark: substitution with $\log 100 = 2$ 1 mark: +1.041 V	2
3(a)	A species that donates a proton (H ⁺) to another species.	1 mark: a proton (H ⁺) donor	1
3(b)	$[\text{H}^+] = \sqrt{1.80 \times 10^{-5} \times 0.100} = 1.34 \times 10^{-3} \text{ mol/dm}^3$; pH = 2.87	1 mark: $K_a = [\text{H}^+]^2/[\text{HA}]$ with $[\text{H}^+] = [\text{A}^-]$ 1 mark: $[\text{H}^+] = 1.34 \times 10^{-3}$ mol/dm ³ 1 mark: pH = 2.87	3
3(c)	$[\text{H}^+] = 10^{-3.10} = 7.94 \times 10^{-4}$; $K_a = (7.94 \times 10^{-4})^2/(0.050 - 7.94 \times 10^{-4}) = 1.28 \times 10^{-5}$	1 mark: $[\text{H}^+] = 7.94 \times 10^{-4}$ mol/dm ³ 1 mark: denominator 0.050 - $[\text{H}^+]$ 1 mark: K_a about 1.28×10^{-5}	3

3(d)	$[H^+] = K_a \times [\text{acid}]/[\text{salt}] = 1.80 \times 10^{-5} \times 0.200/0.100 = 3.60 \times 10^{-5} \text{ mol/dm}^3$; pH = 4.44	1 mark: buffer equation $[H^+] = K_a \times [HA]/[A^-]$ 1 mark: $[H^+] = 3.60 \times 10^{-5} \text{ mol/dm}^3$ 1 mark: pH = 4.44	3
3(e)	The added H^+ is removed by combining with ethanoate ions to form the weak acid HA, so the ratio $[HA]/[A^-]$ changes only slightly and the pH hardly moves.	1 mark: H^+ reacts with A^- to form HA 1 mark: the ratio $[HA]/[A^-]$ is almost unchanged	2
3(f)	At the equivalence point the total volume is 50.0 cm ³ so $[CH_3COO^-] = 0.0500 \text{ mol/dm}^3$; $K_b = K_w/K_a = 5.56 \times 10^{-10}$; $[OH^-] = \sqrt{5.56 \times 10^{-10} \times 0.0500} = 5.27 \times 10^{-6} \text{ mol/dm}^3$; pOH = 5.28 and pH = 8.72	1 mark: $[CH_3COO^-] = 0.0500 \text{ mol/dm}^3$ 1 mark: $K_b = K_w/K_a = 5.56 \times 10^{-10}$ 1 mark: $[OH^-] = 5.27 \times 10^{-6} \text{ mol/dm}^3$ 1 mark: pH = 8.72	4
4(a)	Doubling $[A]$ doubles the rate, so first order in A; doubling $[B]$ increases the rate fourfold, so second order in B; rate = $k[A][B]^2$	1 mark: experiments 1 and 2 give first order in A 1 mark: experiments 1 and 3 give a fourfold rate increase 1 mark: second order in B 1 mark: rate = $k[A][B]^2$	4
4(b)	$k = 2.40 \times 10^{-3} / (0.100 \times 0.100^2) = 2.4 \text{ dm}^6 \text{ mol}^{-2} \text{ s}^{-1}$	1 mark: correct substitution giving 2.4 1 mark: units $\text{dm}^6 \text{ mol}^{-2} \text{ s}^{-1}$	2
4(c)	rate = $2.4 \times 0.150 \times (0.0500)^2 = 9.0 \times 10^{-4} \text{ mol dm}^{-3} \text{ s}^{-1}$	1 mark: correct substitution 1 mark: $9.0 \times 10^{-4} \text{ mol dm}^{-3} \text{ s}^{-1}$	2
4(d)	The rate-determining step involves one A and two B particles, since two B particles must collide; the orders equal the number of each species in the rate-determining step, one for A and two for B.	1 mark: one A and two B in the rate-determining step 1 mark: orders equal particle numbers in that step	2
4(e)	$E_a = R \ln(k_2/k_1) / (1/T_1 - 1/T_2) = 8.314 \times \ln 4 / (1/300 - 1/320) = 55.3 \text{ kJ/mol}$	1 mark: two-point Arrhenius equation 1 mark: $\ln 4 = 1.386$ and $1/300 - 1/320 = 2.08 \times 10^{-4}$ 1 mark: 55.3 kJ/mol	3

4(f)	At a higher temperature the molecules have greater average kinetic energy, so a much larger fraction has energy at or above E_a ; successful collisions are therefore more frequent and k increases.	1 mark: larger fraction of molecules with energy at or above E_a	1
5(a)	A d-block element that forms at least one ion in which the d subshell is incompletely filled.	1 mark: a d-block element 1 mark: forms an ion with an incomplete d subshell	2
5(b)	Ligands split the five d orbitals into groups of different energy. Electrons absorb visible light and are promoted between the split d orbitals, a d-d transition; the light not absorbed is transmitted or reflected and gives the observed colour.	1 mark: ligand field splits the d orbitals 1 mark: d-d transition absorbs visible light, the remainder gives the colour	2
5(c)	$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightleftharpoons [\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 4\text{H}_2\text{O}$; the colour changes from pale blue to deep blue.	1 mark: correct equation with coordination number 4 1 mark: pale blue to deep blue	2
5(d)	$n(\text{MnO}_4^-) = 0.0200 \times 0.02450 = 4.90 \times 10^{-4} \text{ mol}$; $n(\text{Fe}^{2+}) = 5 \times 4.90 \times 10^{-4} = 2.45 \times 10^{-3} \text{ mol}$; $[\text{Fe}^{2+}] = 2.45 \times 10^{-3} / 0.0250 = 0.0980 \text{ mol/dm}^3$	1 mark: $n(\text{MnO}_4^-) = 4.90 \times 10^{-4} \text{ mol}$ 1 mark: $n(\text{Fe}^{2+}) = 2.45 \times 10^{-3} \text{ mol}$ (factor 5) 1 mark: $[\text{Fe}^{2+}] = 0.0980 \text{ mol/dm}^3$	3
5(e)	$n(\text{Fe}^{2+}) = 2.45 \times 10^{-3} \times 10 = 0.0245 \text{ mol}$; $m = 0.0245 \times 55.8 = 1.37 \text{ g}$	1 mark: $n = 0.0245 \text{ mol}$ 1 mark: 1.37 g	2
5(f)	The MnO_4^- ion is purple and is reduced to almost colourless Mn^{2+} ; at the end point one excess drop leaves a permanent pale pink colour, so the reagent acts as its own indicator.	1 mark: purple MnO_4^- reduced to colourless Mn^{2+} , permanent pale pink at the end point	1
6(a)	Ethanal: acidified $\text{K}_2\text{Cr}_2\text{O}_7$ with heating, distilling off the aldehyde at once to prevent further oxidation; ethanoic acid: excess acidified $\text{K}_2\text{Cr}_2\text{O}_7$ heated under reflux.	1 mark: acidified dichromate, $\text{K}_2\text{Cr}_2\text{O}_7/\text{H}^+$ 1 mark: distillation used to remove ethanal at once 1 mark: excess oxidising agent under reflux for the acid	3
6(b)	$\text{CH}_3\text{COOH} + \text{C}_2\text{H}_5\text{OH} \rightleftharpoons \text{CH}_3\text{COOC}_2\text{H}_5 + \text{H}_2\text{O}$; concentrated sulfuric acid catalyst with heating.	1 mark: correct reversible equation 1 mark: concentrated H_2SO_4 catalyst and heat	2

6(c)	$n(\text{ethanol}) = 23.0/46.0 = 0.500 \text{ mol}$; theoretical mass = $0.500 \times 88.0 = 44.0 \text{ g}$; yield = $30.8/44.0 \times 100 = 70.0\%$	1 mark: $n = 0.500 \text{ mol}$ 1 mark: theoretical mass 44.0 g 1 mark: 70.0%	3
6(d)	Esterification is reversible, so reactants remain at equilibrium. Water formed can be removed continuously with a Dean-Stark trap, or the ester distilled off, or excess ethanol used, to shift the equilibrium to the right.	1 mark: the reaction is reversible and reaches equilibrium 1 mark: remove water or ester, or use excess reactant	2
6(e)	Acid hydrolysis gives ethanoic acid and ethanol and is reversible; alkaline hydrolysis with NaOH(aq) gives sodium ethanoate and ethanol and is not reversible, being saponification.	1 mark: acid hydrolysis gives ethanoic acid plus ethanol 1 mark: alkaline hydrolysis gives the ethanoate salt plus ethanol and is not reversible	2
6(f)	$\text{C} : \text{H} : \text{O} = 48.6/12.0 : 8.1/1.0 : 43.3/16.0 = 4.05 : 8.1 : 2.71$, giving $\text{C}_3\text{H}_6\text{O}_2$, and Mr 74.0 confirms this molecular formula; 1710 cm^{-1} is $\text{C}=\text{O}$ and the broad $2500\text{--}3300 \text{ cm}^{-1}$ band is O-H, so a carboxylic acid is present; the triplet and quartet show a CH_3CH_2 group with adjacent coupling; therefore X is propanoic acid, $\text{CH}_3\text{CH}_2\text{COOH}$.	1 mark: empirical formula $\text{C}_3\text{H}_6\text{O}_2$ consistent with Mr 74.0 1 mark: 1710 cm^{-1} is $\text{C}=\text{O}$ and $2500\text{--}3300 \text{ cm}^{-1}$ is the acid O-H 1 mark: triplet plus quartet indicates CH_3CH_2 with adjacent coupling 1 mark: propanoic acid, $\text{CH}_3\text{CH}_2\text{COOH}$	4
7(a)	$4\text{NH}_3 + 5\text{O}_2 \rightarrow 4\text{NO} + 6\text{H}_2\text{O}$, with a platinum-rhodium catalyst at about 900°C .	1 mark: correctly balanced equation 1 mark: Pt-Rh catalyst at about 900°C	2
7(b)	$n(\text{NH}_3) = 100,000/17.0 = 5,882 \text{ mol}$; $n(\text{NO})$ is the same; $m = 5,882 \times 30.0 = 176,471 \text{ g}$, about 176 kg	1 mark: $n(\text{NH}_3) = 5,882 \text{ mol}$ 1 mark: $n(\text{NO}) = n(\text{NH}_3)$, 1:1 1 mark: about 176 kg	3
7(c)	$n(\text{NO}_2) = 5,882 \text{ mol}$; $n(\text{HNO}_3) = 2/3 \times 5,882 = 3,921 \text{ mol}$; $m = 3,921 \times 63.0 = 247,023 \text{ g}$, about 247 kg	1 mark: $n(\text{HNO}_3) = 2/3$ $n(\text{NO}_2) = 3,921 \text{ mol}$ 1 mark: multiplied by 63.0 1 mark: about 247 kg	3

7(d)	The absorption step converts only two thirds of the NO ₂ into HNO ₃ , releasing the rest as NO; recycling and re-oxidising that NO raises the utilisation of ammonia and the yield of nitric acid.	1 mark: the absorption reaction releases NO 1 mark: recycling improves utilisation and yield	2
7(e)	$n(\text{SO}_2) = 640,000/64.1 = 9,984 \text{ mol}$; $m(\text{CaO}) = 9,984 \times 56.1 = 560,102 \text{ g}$, about 560 kg	1 mark: $n(\text{SO}_2) = 9,984 \text{ mol}$ 1 mark: about 560 kg of CaO	2