# Answers to examination-style questions

| Answers | Marks | Examiner's tips |
|---|---|---|
| **1 a)** $\Delta G = \Delta H - T\Delta S$ | **1** | |
| **b)** Boiling is a spontaneous change at boiling point. | **1** | Accept: $\Delta H = T\Delta S$ |
| **c)** When $\Delta G = 0$, $\Delta S = \frac{\Delta H}{T}$ $= 23.4 \times \frac{1000}{240}$ $= 97.5\ \text{J K}^{-1}\ \text{mol}^{-1}$ | **2** | You were told in part **b)** that $\Delta G = 0$. |
| **d)** H bonding in both.<br>H bonding is stronger in HF,<br>because H—F is more polar than H—N,<br>since F is more electronegative than N. | **3** | Accept 'more energy is needed to overcome the intermolecular forces'. |
| **2 a)** $\frac{1}{2}N_2(g) + \frac{3}{2}H_2(g) \rightarrow NH_3(g)$ | **1** | Since you are making 1 mole of ammonia this is the only equation. You cannot have multiples here. |
| **b)** $\Delta S = \Sigma S(\text{products}) - \Sigma S(\text{reactants})$<br>$= 193 - \left(\frac{192}{2} + \frac{3}{2} \times 131\right)$<br>$= -99.5\ \text{J K}^{-1}\ \text{mol}^{-1}$ | **3** | Accept +99.5 but only award one mark. |
| **c) i)** $\Delta G = \Delta H - T\Delta S$<br>$= -46.2 - \left(\frac{700 \times -99.5}{1000}\right)$<br>$= +23.45\ \text{kJ mol}^{-1}$<br>**ii)** It would decrease. | **3** | You could use the entropy change value suggested in the question ($-125\ \text{J K}^{-1}\ \text{mol}^{-1}$) and this would give $+41.3\ \text{kJ mol}^{-1}$ as the answer. |
| **d)** to speed up the reaction | **1** | This also supplies the activation energy. |
| **3 a) i)** **W**: Pt<br>**X**: KCl, $KNO_3$<br>**Y**: Mg<br>**Z**: $MgCl_2(aq)$, $MgSO_4(aq)$, and $Mg(NO_3)_2(aq)$ | **6** | **X** and **W** are examples of metal salts, other possible Mg and K salts can be given. |
| **ii)** $Pt\vert H_2(g)\vert H^+(aq)\Vert Mg^{2+}(aq)\vert Mg$ | | In this cell diagram, one mark is for all the species being correct and the other mark is for the correct order. |

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| **b) i)** +0.84 V | **6** | Remember: $E = E_{right} - E_{left}$ |
| **ii)** +3 | | |
| **iii)** $2MnO_2 + 2H_2O + Zn$<br>$\rightarrow 2MnO(OH) + 2OH^- + Zn^{2+}$ | | |
| **iv)** oxidising agent: $MnO_2$<br>reducing agent: Zn | | |
| **v)** Zn is used up. | | |
| **c) i)** $4H^+ + SO_4^{2-} + 2e^- \rightarrow SO_2 + 2H_2O$<br>$2Br^- \rightarrow Br_2 + 2e^-$<br>$4H^+ + SO_4^{2-} + 2Br^-$<br>$\rightarrow SO_2 + 2H_2O + Br_2$ | **5** | Accept: $2H_2SO_4 + 2KBr \rightarrow K_2SO_4 + SO_2 + 2H_2O + Br_2$ if you include the spectator ions and join the sulfuric acid ions together.<br><br>Accept: $H_2SO_4 + 2KCl \rightarrow K_2SO_4 + 2HCl$ |
| **ii)** $H_2SO_4$ cannot oxidise $Cl^-$.<br><br>$H_2SO_4 + KCl \rightarrow KHSO_4 + HCl$ | | Accept: $Cl_2$ is a stronger oxidising agent than $H_2SO_4$. |
| **4 a)** The order is 1.<br><br>When the concentration of iodine is double the gradient doubles. | **2** | gradient = rate |
| **b)** Curve **X** starts at the origin and is below curve **B**.<br><br>Curve **X** finishes at the same level as curve **B**. | **2** | A lower temperature means a slower reaction, but still makes the same amount of product. |
| **c)** Curve **Y** starts at the origin and is steeper than curve **A**.<br><br>Curve **Y** finishes at the same level as curve **A**. | **2** | A catalyst speeds up the reaction but still makes the same amount of product. |

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| **d) i)** $S_2O_8^{2-} + 2Fe^{2+} \rightarrow 2SO_4^{2-} + 2Fe^{3+}$<br>$2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$ | **4** | These equations would allow the electrons to cancel out if the overall equation was written. You do not need to have the 2s in the second equation. |
| **ii)** alternative route | | |
| not used up | | Accept: 'regenerated' instead of 'not used up'. Another alternative would be that 'it speeds up the reaction'. |
| **e) i)** a different phase from the reactants | **4** | |
| **ii)** Reactants adsorb weakly onto the surface of silver | | |
| **iii)** The reaction may be too fast, leading to an explosion | | |
| **5 a)** $\Delta H^\ominus_{sol} = \Delta H^\ominus_{lattice} + \sum \Delta H^\ominus_{hyd}$<br>so $\Delta H^\ominus_{lattice} = \Delta H^\ominus_{sol} - \sum \Delta H^\ominus_{hyd}$<br>$\Delta H^\ominus_{lattice}(MgCl_2) = -155 + 1920 + 728$<br>$= +2493 \text{ kJ mol}^{-1}$<br>$\Delta H^\ominus_{lattice}(NaCl) = +3.9 + 406 + 364$<br>$= +773.9 \text{ kJ mol}^{-1}$ | **3** | |
| **b)** Attraction between ions is weaker. The charge on $Na^+$ is only half that on $Mg^{2+}$. | **2** | |
| **c)** $Al^{3+}$ ions have higher charge/size ratio so can attract water molecules more strongly. | **2** | There are stronger ion–dipole forces between the aluminium ion and the water molecules. |
| **d)** $K_a = \dfrac{[H^+][A^-]}{[HA]}$<br>$= \dfrac{[H^+]^2}{[HA]}$<br>$= \sqrt{1.26 \times 10^{-5} \times 2.0}$<br>$= 5.01 \times 10^{-3}$ | **4** | $[H^+]=[A^-]$<br>or $[H^+] = \sqrt{K_a[HA]}$ |
| pH = 2.30 | | The correct answer of 2.30 would gain the four marks.<br>pH value must be given to two decimal places. |

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| **e)** $SiCl_4 + 4H_2O \rightarrow Si(OH)_4 + 4HCl$<br>pH = 0 | **2** | Since the products are so acidic, the pH range allowed is −1 to 1. |
| **6 a)** $Mg^{2+}(g) + 2e^- + 2Cl(g)$<br>$Mg^{2+}(g) + 2e^- + Cl_2(g)$<br>$Mg^+(g) + e^- + Cl_2(g)$<br>$Mg(g) + Cl_2(g)$ | **4** | |
| **b)** 2nd IE + 642 + 150 + 736 + (2 × 121) = (2 × 364) + 2493<br>IE = +1451 kJ $mol^{-1}$ | **3** | One mark is for the factors of 2×. |
| **c)** $\Delta H = -\Delta H^\ominus_{\text{lattice formation}} + \Sigma\Delta H^\ominus_{\text{hydration}}$<br>= 2493 – 1920 – (2 × 364)<br>= −155 kJ $mol^{-1}$ | **3** | Accept: a cycle with state symbols or labels instead.<br>If you get the sign of the answer wrong, you can score a maximum of one mark. |
| **d) i)** increase in disorder on dissolving | **2** | Accept: $\Delta S$ positive, $\Delta G$ negative, $T\Delta S > \Delta H$ |
| **ii)** moles of $NH_4Cl = \frac{2}{53.5} = 0.0374$<br>heat absorbed = 15 × 0.0374 = 0.561<br>$Q = mc\Delta T$<br>$\Delta T = \frac{Q}{mc}$<br>= (0.561 × 1000)/(50 × 4.2) = 2.6 °C<br>Final temperature = 20 – 2.6 = 17.4 °C | **5** | Answers in a range of 2.5 to 2.7 are allowed, since you may have rounded your calculations on the top and bottom line. You must put temperature change to at least 1 dp. |
| **7 a)** the ability of an atom or element to attract electrons or electron density<br>from a covalent bond | **2** | Do not put 'electron', i.e. singular, in the first line. |
| **b)** It increases.<br>more protons<br>similar or same shielding | **3** | If the trend is wrong you get no marks.<br>Accept: greater nuclear charge and electrons are in the same shell or they have a similar radius or a smaller radius. |

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| **c) i)** MgO is ionic<br>$P_4O_{10}$ is covalent | **3** | If you mention molecules you score 0. |
| **ii)** The electronegativity difference is small. | | Accept: the electronegativities are similar, but you cannot say they are the same. |
| **d)** $Na_2O + H_2O \rightarrow 2Na^+ + 2OH^-$ | **2** | |
| $SO_2 + H_2O \rightarrow H_2SO_3$ | | |
| **e)** $MgO + 2HCl \rightarrow MgCl_2 + H_2O$ | **1** | Accept: the ionic equation $MgO + 2H^+ \rightarrow Mg^{2+} + H_2O$ |
| **f)** $P_4O_{10} + 12NaOH \rightarrow 4Na_3PO_4 + 6H_2O$ | **1** | Accept: the ionic equation $P_4O_{10} + 12OH^- \rightarrow 4PO_4^{3-} + 6H_2O$ |
| **8 a) i)** $SO_2 + V_2O_5 \rightarrow SO_3 + V_2O_4$ | **3** | |
| $V_2O_4 + \frac{1}{2}O_2 \rightarrow V_2O_5$ | | |
| V(IV) or +4 and V(V) or +5 | | Must have both oxidation states. |
| **ii)** $MnO_4^- + 8H^+ + 4Mn^{2+} \rightarrow 5Mn^{3+} + 4H_2O$ | **3** | |
| $2Mn^{3+} + C_2O_4^{2-} \rightarrow 2Mn^{2+} + 2CO_2$ | | |
| Mn(III) or +3 and Mn(II) or +2 | | Must have both oxidation states. |
| **b)** $[Co(NH_3)_6]^{2+}$ (formed) | **3** | |
| complex easier to oxidise | | |
| $H_2O_2$ | | Accept: air or oxygen |
| **c)** moles of dichromate = $\left(\frac{29.2}{1000}\right) \times 0.04$<br>= 0.001 168 | **6** | You may have rounded to 0.001 17, which is OK since there are three significant figures. |

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| moles of $\mathbf{Q}^{2+} = \left(\frac{25}{1000}\right) \times 0.140 = 0.003\,50$ | | |
| Each mole of dichromate needs 6 electrons or half equation with $6e^-$. | | |
| moles of electrons = $6 \times 0.001\,168$ = $0.007\,008$ | | moles $\mathbf{Q}^{2+}$:moles dichromate = 3 : 1 |
| moles of electrons per mole of **Q** $= \frac{0.007\,008}{0.0035} = 2.002 = 2$ | | |
| **Q** has an oxidation state of 4. | | Accept: $\mathbf{Q}^{4+}$ |
| **9 a)** $CH_3CH_2Cl$<br>two peaks integration ratio 3 : 2<br>split into triplet and quartet | **6** | If two peaks not stated then no marks for $CH_3CH_2Cl$. |
| $CH_3CHCl_2$<br>two peaks integration ratio 3 : 1<br>split into doublet and quartet | | If two peaks not stated then no marks for $CH_3CHCl_2$. |
| **b) i)** $Cl_2 + 2Br^- \rightarrow 2Cl^- + Br_2$ | **9** | Accept: $Cl_2 + 2I^- \rightarrow 2Cl^- + I_2$ since only one correct equation is required. |
| KBr orange-brown solution | | You must state that it is a solution. Just the colour is insufficient. |
| KI brown solution or black solid | | Any mention of purple loses the mark since iodine is only purple as a vapour. |
| **ii)** $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$ | | |
| $BaCl_2$: white precipitate | | Accept equation, i.e. $BaCl_2 + H_2SO_4 \rightarrow BaSO_4 + 2HCl$ |
| $MgCl_2$: no precipitate or no change | | Do not accept: 'nothing' or 'no observation'. |
| **iii)** $CoCl_2$ solution goes blue. | | |
| $CuCl_2$ solution goes green. | | Accept: yellow or yellow green |
| $[Co(H_2O)_6]^{2+} + 4Cl^- \rightarrow CoCl_4^{2-} + 6H_2O$ | | Accept: $[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow CuCl_4^{2-} + 6H_2O$ |