AQA Qualifications

A-level

Chemistry

Paper 1 (7405/1): Inorganic and Physical Chemistry
Mark scheme

7405
Specimen paper

Version 0.5

Question	Marking guidance		Mark	AO	Comments
01.1	This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.		6	2 AO1a 2 AO2a 2 AO2b	**Indicative chemistry content** **Stage 1:** Electrons round P • P has 5 electrons in the outside shell • With 3 electrons from 3 fluorine, there are a total of 8 electrons in outside shell • so 3 bond pairs, 1 non-bond pair **Stage 2:** Electron pair repulsion theory • Electron pairs repel as far as possible • Lone pair repels more than bonding pairs **Stage 3:** Conclusions • Therefore, tetrahedral / trigonal pyramidal shape • With angle of 109(.5)° decreased to 107°
	Level 3 5–6 marks	All stages are covered and the explanation of each stage is generally correct and virtually complete. Answer is communicated coherently and shows a logical progression from stage 1 to stage 2 then stage 3.			
	Level 2 3–4 marks	All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete. Answer is mainly coherent and shows progression from stage 1 to stage 3.			
	Level 1 1–2 marks	Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete. Answer includes isolated statements but these are not presented in a logical order or show confused reasoning.			
	Level 0 0 marks	Insufficient correct chemistry to gain a mark.			

01.2	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^7$	1	AO1a	Allow correct numbers that are not superscripted
01.3	Too many electrons in d sub-shell / orbitals	1	AO3 1b	
01.4	Tetrahedral (shape) 109.5°	1 1	AO2a AO2a	 Allow 109°

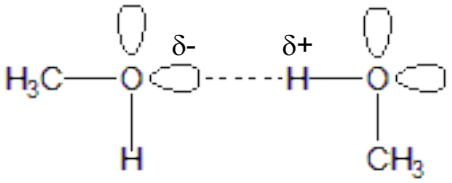
Question	Marking guidance	Mark	AO	Comments
02.1	The number of protons increases (across the period) / nuclear charge increases	1	AO1a	
	Therefore, the attraction between the nucleus and electrons increases	1	AO1a	Can only score M2 if M1 is correct
02.2	S_8 molecules are bigger than P_4 molecules	1	AO1a	Allow sulfur molecules have bigger surface area and sulfur molecules have bigger M_r
	Therefore, van der Waals / dispersion / London forces between molecules are stronger in sulfur	1	AO1a	
02.3	Sodium oxide contains O^{2-} ions	1	AO2c	
	These O^{2-} ions react with water forming OH^- ions	1	AO2c	$O^{2-} + H_2O \longrightarrow 2OH^-$ scores M1 and M2
02.4	$P_4O_{10} + 12OH^- \longrightarrow 4PO_4^{3-} + 6H_2O$	1	AO2d	

Question	Marking Guidance	Mark	AO	Comments
03.1	The ions in the ionic substance in the salt bridge move through the salt bridge To maintain charge balance / complete the circuit	1 1	AO1b AO1b	
03.2	F^-	1	AO3 1a	
03.3	$E^\ominus$ SO_4^{2-}/ SO_2 < $E^\ominus$ Br_2/Br^-	1	AO3 1a	Allow correct answer expressed in words, eg electrode potential for sulfate ions / sulfur dioxide is less than that for bromine / bromide
03.4	1.23 (V)	1	AO2d	
03.5	A fuel cell converts more of the available energy from combustion of hydrogen into kinetic energy of the car / an internal combustion engine wastes more (heat) energy	1	AO3 1b	

Question	Marking guidance	Mark	AO	Comments
04.1	Bonds broken = 2(C=O) + 3(H–H) = 2 × 743 + 3 × H–H Bonds formed = 3(C–H) +(C–O) + 3(O–H) = 3 × 412 + 360 + 3 × 463 –49 = [2 × 743 + 3 × (H–H)] – [3 × 412 + 360 + 3 × 463]	1	AO1b	Both required
	3(H–H) = –49 – 2 × 743 + [3 × 412 + 360 + 3 × 463] = 1450	1	AO1b	Both required
	H–H = 483 (kJ mol^{-1})	1	AO1b	Allow 483.3(3)
04.2	Mean bond enthalpies are not the same as the actual bond enthalpies in CO_2 (and/or methanol and/or water)	1	AO1b	
04.3	The carbon dioxide (produced on burning methanol) is used up in this reaction	1	AO3 1b	
04.4	4 mol of gas form 2 mol	1	AO2f	
	At high pressure the position of equilibrium moves to the right to lower the pressure / oppose the high pressure	1	AO3 1b	
	This increases the yield of methanol	1	AO3 1b	
04.5	Impurities (or sulfur compounds) block the active sites	1	AO1b	Allow catalyst poisoned

04.6	Stage 1: moles of components in the equilibrium mixture $CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$ Initial moles: 1.0 / 3.0 / 0 / 0 Eqm moles: (1–0.86) = 0.14 / (3-3×0.86) = 0.42 / 0.86 / 0.86	1	AO2f	Extended response question
	Stage 2: Partial pressure calculations Total moles of gas = 2.28	1	AO2f	
	Partial pressures = mol fraction × p_{total} p_{CO2} = mol fraction × p_{total} = 0.14 × 500/2.28 = 30.7 kPa p_{H2} = mol fraction × p_{total} = 0.42 × 500/2.28 = 92.1 kPa	1	AO2f	M3 is for partial pressures of both reactants Alternative M3 = pp_{CO2} = 0.0614 × 500 pp_{H2} = 0.1842 × 500
	p_{CH3OH} = mol fraction × p_{total} = 0.86 × 500/2.28 = 188.6 kPa p_{H2O} = mol fraction × p_{total} = 0.86 × 500/2.28 = 188.6 kPa	1	AO2f	M4 is for partial pressures of both products Alternative M4 = pp_{CH3OH} = 0.3772 × 500 pp_{H2O} = 0.3772 × 500
	Stage 3: Equilibrium constant calculation $K_p = p_{CH3OH} \times p_{H2O} / p_{CO2} \times (p_{H2})^3$	1	AO2f	
	Hence K_p = 188.6 × 188.6 / 30.7 × $(92.1)^3$ = 1.483 × 10^{-3} = 1.5 × 10^{-3}	1	AO1b	Answer must be to 2 significant figures
	Units = $\underline{kPa^{-2}}$	1	AO2f	

Question	Marking guidance	Mark	AO	Comments
05.1	$\Delta S = 238 + 189 - 214 - 3 \times 131 = -180$ J K^{-1} mol^{-1}	1	AO1b	
	$\Delta G = \Delta H - T\Delta S$	1	AO1a	
	$= -49 - \frac{523 \times (-180)}{1000}$	1	AO1b	
	$= +45.1$ kJ mol^{-1}	1	AO1b	Units essential
05.2	When $\Delta G = 0$, $\Delta H = T\Delta S$ therefore $T = \Delta H/\Delta S$	1	AO1b	
	$= -49 \times 1000/-180 = 272$ (K)	1	AO1b	Mark consequentially to ΔS in 5.1

05.3	Diagram marks  			
	Diagram of a molecule showing O–H bond and two lone pairs on each oxygen	1	AO2a	
	Labels on diagram showing δ+ and δ- charges	1	AO2a	Allow explanation of position of δ+ and δ- charges on H and O
	Diagram showing δ+ hydrogen on one molecule attracted to lone pair on a second molecule	1	AO2a	
	Explanation mark Hydrogen bonding (the name mentioned) is a strong enough force (to hold methanol molecules together in a liquid)	1	AO2a	

Question	Marking guidance	Mark	AO	Comments
06.1	Burette Because it can deliver variable volumes	1 1	AO3 1b AO2g	
06.2	The change in pH is gradual / not rapid at the end point An indicator would change colour over a range of volumes of sodium hydroxide	1 1	AO3 1a AO3 1a	 Allow indicator would not change colour rapidly / with a few drops of NaOH
06.3	$[H^+] = 10^{-pH} = 1.58 \times 10^{-12}$ $K_w = [H^+]\,[OH^-]$ therefore $[OH^-] = K_w / [H^+]$ Therefore, $[OH^-] = 1 \times 10^{-14}/1.58 \times 10^{-12} = 6.33 \times 10^{-3}$ (mol dm^{-3})	1 1 1	AO2h AO2h AO2h	 Allow 6.31–6.33 × 10^{-3} (mol dm^{-3})
06.4	At this point, $[NH_3] = [H^+]$ Therefore $K_a = \frac{[H^+]^2}{[NH_4^+]}$ $[H^+] = 10^{-4.6} = 2.51 \times 10^{-5}$ $K_a = (2.51 \times 10^{-5})^2/2 = 3.15 \times 10^{-10}$ (mol dm^{-3})	 1 1 1	 AO2f AO2f AO2f	 Allow 3.15–3.16 × 10^{-10} (mol dm^{-3})
06.5	When $[NH_3] = [NH_4^+]$, $K_a = [H^+]$ therefore $-\log K_a = -\log [H^+]$ Therefore pH = $-\log_{10}(3.15 \times 10^{-10}) = 9.50$	1 1	AO2h AO2h	Answer using alternative value M2 pH = $-\log_{10}(4.75 \times 10^{-9}) = 8.32$ Allow consequential marking based on answer from 6.4

Question	Marking guidance	Mark	AO	Comments
07.1	**Y**	1	AO3 1a	
07.2	**X**	1	AO3 1a	
07.3	Jump in trend of ionisation energies after removal of fifth electron Fits with an element with 5 outer electrons ($4s^2 3d^3$) like V	 1	 AO2b	
07.4	Explanation: Two different colours of solution are observed Because each colour is due to vanadium in a different oxidation state	1 1	AO2g AO2g	

07.5				Extended response Maximum of 5 marks for answers which do not show a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.
	Stage 1: mole calculations in either order Moles of vanadium = 50.0 × 0.800/1000 = 4.00 x 10^{-2}	1	AO2d	
	Moles of SO_2 = pV/RT = (98 000 × 506 × 10^{-6})/(8.31 × 293) = 2.04 × 10^{-2}	1	AO2d	
	Stage 2: moles of electrons added to NH_4VO_3 When SO_2 (sulfur(IV) oxide) acts as a reducing agent, it is oxidised to sulfate(VI) ions so this is a two electron change	1	AO2d	
	Moles of electrons released when SO_2 is oxidised = 2.04 × 10^{-2} × 2 = 4.08 × 10^{-2}	1	AO2d	
	Stage 3 : conclusion But in NH_4VO_3 vanadium is in oxidation state 5	1	AO2b	
	4.00 × 10^{-2} mol vanadium has gained 4.08 × 10^{-2} mol of electrons therefore 1 mol vanadium has gained 4.08 × 10^{-2}/ 4.00 × 10–2 = 1 mol of electrons to the nearest integer, so new oxidation state is 5–1=4.	1	AO2d	

Question	Marking guidance	Mark	AO	Comments
08.1	An electron pair on the ligand	1	AO1a	
	Is donated from the ligand to the central metal ion	1	AO1a	
08.2	Blue precipitate	1	AO1b	
	Dissolves to give a dark blue solution	1	AO1b	
	$[Cu(H_2O)_6]^{2+} + 2NH_3 \longrightarrow Cu(H_2O)_4(OH)_2 + 2NH_4^+$	1	AO2d	
	$Cu(H_2O)_4(OH)_2 + 4NH_3 \longrightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 2OH^- + 2H_2O$	1	AO2d	
08.3	$[Cu(NH_3)_4(H_2O)_2]^{2+} + 2H_2NCH_2CH_2NH_2 \longrightarrow [Cu(H_2NCH_2CH_2NH_2)_2(H_2O)_2]^{2+} + 4NH_3$	1	AO2b	
08.4	Cu–N bonds formed have similar enthalpy / energy to Cu–N bonds broken	1	AO3 1b	
	And the same number of bonds broken and made	1	AO3 1b	
08.5	3 particles form 5 particles / disorder increases because more particles are formed / entropy change is positive	1	AO2e	
	Therefore, the free-energy change is negative	1	AO2e	M2 can only be awarded if M1 is correct

Question	Marking guidance	Mark	AO	Comments
09.1	Start a clock when KCl is added to water	1	AO3 2b	
	Record the temperature every subsequent minute for about 5 minutes	1	AO3 2b	Allow record the temperature at regular time intervals until some time after all the solid has dissolved for M2
	Plot a graph of temperature vs time	1	AO3 2a	
	Extrapolate back to time of mixing = 0 and determine the temperature	1	AO3 2a	
09.2	Heat taken in = $m \times c \times \Delta T = 50 \times 4.18 \times 5.4 = 1128.6$ J	1	AO2h	Max 2 if 14.6 °C used as ΔT
	Moles of KCl = 5.00/74.6 = 0.0670	1	AO2h	
	Enthalpy change per mole = +1128.6/0.0670 = 16 839 J mol^{-1}	1	AO2h	
	= +16.8 (kJ mol^{-1})	1	AO1b	Answer must be given to this precision
09.3	$\Delta H_{solution} = \Delta H_{lattice} + \Delta$H(hydration of calcium ions) + 2 × ΔH(hydration of chloride ions)			
	$\Delta H_{lattice} = \Delta H_{solution} - \Delta$H(hydration of calcium ions) –2 ×ΔH(hydration of chloride ions)	1	AO2f	
	$\Delta H_{lattice}$ = –82.9 – (–1650 + 2 × –364) = +2295 (kJ mol^{-1})	1	AO2f	
09.4	Magnesium ion is smaller than the calcium ion	1	AO2a	
	Therefore, it attracts the chloride ion more strongly / stronger ionic bonding	1	AO2a	

Question	Marking guidance	Mark	AO	Comments
10.1	**Q** is calcium or magnesium	1	AO3 1b	Mark this question independently
	bromide	1	AO3 1b	
	R is aluminium	1	AO3 1b	
	chloride	1	AO3 1b	
	S is iron(III)	1	AO3 1b	
	sulfate	1	AO3 1b	
10.2	$Ba^{2+} + SO_4^{2-} \longrightarrow BaSO_4$	1	AO1a	
	$[Fe(H_2O)_6]^{3+} + 3OH^- \longrightarrow Fe(H_2O)_3(OH)_3 + 3H_2O$	1	AO1a	
	$2[Fe(H_2O)_6]^{3+} + 3CO_3^{2-} \longrightarrow 2Fe(H_2O)_3(OH)_3 + 3H_2O + 3CO_2$	1	AO1a	
	$[Fe(H_2O)_6]^{3+} + 4Cl^- \longrightarrow [FeCl_4]^- + 6H_2O$	1	AO1a	