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Question	**Expected answers**	**Marks**	**Additional guidance**
1 (a) (i)	Electron affinity -696 (1 mark); Atomisation of Cl_2 +244 (1 mark); From top to bottom 2^{nd} IE +1150, 1^{st} IE +590, atomisation of Ca +178 formation -796 (1 mark)	3	**Allow** 244, 1150, 590 and 176 i.e. without plus sign
(ii)	-796 - 178 - 590 - 1150 - 244 + 696 (1); **But** -2262 (with no working) (2)	2	**Allow** ecf from the wrong figures on the Born-Haber cycle 1 error **max one mark** 2 errors **0 mark**
(iii)	Magnesium fluoride more exothermic than calcium chloride / ora because Ionic radius of Mg^{2+} is less than that of Ca^{2+} / charge density of magnesium ion is greater than that of calcium ion / ora (1); Ionic radius of F^- is less than that of Cl^- / charge density of fluoride ion is greater than that of chloride ion / ora (1); Stronger (electrostatic) attraction between cation and anion in MgF_2 than in $CaCl_2$ / stronger ionic bonds in MgF_2 (1)	3	Answer must refer to the correct particle. **Not** Mg or magnesium has a smaller radius or fluorine has a smaller radius **Allow** magnesium or fluorine has a smaller ionic radius
(b)	**Any two from** For second ionisation energy the electron lost is closer to the nucleus / AW (1); For second ionisation energy the electron is lost from a particle that is already positive (1); For second ionisation energy there is one more proton than electron (1) So outer electron more firmly attracted to the nucleus (1)	2	**Allow** ora
		Total = 10	

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Question	Expected answers	Marks	Additional guidance
2 (a)	$1s^22s^22p^63s^23p^63d^5$ (1); Has an incomplete set of 3d electrons (1)	2	**Allow** 3d orbitals are not completely occupied / incomplete 3d sub-shell **Allow** has half-filled d orbitals
(b) (i)	**Any two from** Variable oxidation state / variable valency (1); Act as catalysts (1); Form complexes / form complex ions (1); Form coloured compounds (1)	2	**Not** high melting point / good thermal and electrical conductors / high density etc
(c)	Iron (II) ions give a green ppt (1); Iron (III) ions give an orange-rust ppt (1)	2	Precipitate must be used once **Allow** solid instead of ppt
(d)	$4Fe^{2+} + O_2 + 4H^+ \rightarrow 4Fe^{3+} + 2H_2O$ Correct reactants and products (1); Correct balancing (1)	2	
(e) (i)	Copper may react with potassium manganate(VII) / iron(III) ions formed in titration may be reduced back to iron(II) ions by the copper (1)	1	
(ii)	MnO_4^- gains electrons and is reduced / Mn oxidation state changes from +7 to +2 so it is reduced (1); Fe^{2+} loses electrons and is oxidised / Fe oxidation state changes from +2 to +3 so it is oxidised (1)	2	
(iii)	Moles of MnO_4^- = 4.50×10^{-4} (1); Moles of Fe^{2+} = 5 × moles MnO_4^- / 2.25×10^{-3} (1); Mass of Fe = moles of Fe^{2+} × 55.8 / 0.1256 (1); Percentage = 18.6 % (1)	4	**Allow** answers that use 56 for A_r of Fe this gives 18.7 **Allow** ecf
		Total = 15	

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Question	Expected answers	Marks	Additional guidance
3 (a)	(Pale blue solution) to a (light) blue ppt (1); with excess dark blue solution (1)	2	
(b)	Octahedral shape with clear indication of 3D either by construction lines or wedges etc (1); 90° (1)	2	**Ignore** mistakes with the ligands question focuses on octahedral and the bond angle
(c)	Water molecule 2 lone pairs (and 2 bond pairs) (1); Water ligand 1 lone pair and 3 bond pairs / lone pair is now a bond pair / water has one less lone pair when it is a ligand (1); Lone pairs repel more than bond pairs (1)	3	**Not** atoms repel
		Total = 7	

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Question	Expected Answers	Marks
1 (a)	Vanadium used in alloys for strength Vanadium(V) oxide used as a catalyst (Don't accept just the word catalyst)	1
(b)	Diagram to show: V/V^{2+} system Hydrogen electrode (Pt, H_2 and H^+ must be labelled) Salt bridge + voltmeter + complete circuit Temp 298K, concentration 1 mol.dm^{-3}, pressure 1 atm All 3 = 2 marks; any 2 = 1 mark	1 1 1 2
(c) (i)		

	V^{2+}	VO_2^+	VO^{2+}	V^{3+}
Oxidation Number	+2	+5	+4	+3
Colour	lilac	yellow	blue	Green

Marks: 4

Question	Expected Answers	Marks
(ii)	Correct calculation of cell potential as –0.44 V Because it is –ve, reaction not feasible Alternative: V better reducing agent than Zn Because the E° for V/V^{2+} is more -ve	1 1
		Total: 12

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Question	Expected Answers	Marks
2 (a) (i)	Central ion surrounded by molecules/ions/ligands	1
(ii)	Molecule/ion with a lone pair of electrons Able to form a dative covalent or co-ordinate bond / which can be donated	1 1
(b)	Two lone pairs/ able to form two dative covalent / co-ordinate bonds	1
(c)	Stereoisomerism – same atoms with same order of bonds but a different spatial arrangement / same structure but different arrangement of atoms Both isomers drawn for cis / trans Both isomers drawn for optical (must be mirror images) (all diagrams to show 3-D arrangement) Enantiomers/non superimposable mirror images **Rotate** plane polarised light in opposite direction by same number of degrees (any two for 1 mark)	1 2 2 1 1
		Total: 11

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Question	**Expected Answers**	**Marks**
3 (a) (i)	Two orbital boxes higher and 3 orbital boxes lower Correct arrangement of electrons (see additional sheet)	1 1
(ii)	One lower energy and one higher energy d-orbital shown (see additional sheet)	2
(b)	Electrons promoted from low to high energy d-orbitals Energy involved lies in visible region of spectrum / needs visible light Some of the visible light is transmitted / absorbed Idea that colour depends upon the actual wavelengths transmitted / energy gap Need at least one unpaired d-orbital or Cu^{+} $1s^22s^22p^63s^23p^63d^{10}$ Only Cu^{2+} has an unpaired electron or Cu^{2+} $1s^22s^22p^63s^23p^63d^9$ QWC: communicates by using at least 3 terms from the following list d-orbitals, visible, spectrum, transmitted, wavelength, energy gap, unpaired electron, high or low energy, absorbed, d-sub shell	1 1 1 1 1 1 1
(c)	Compound absorbs green/yellow Blue and red transmitted (to give purple) (allow all colours absorbed except violet/blue and red for 1 mark)	1 1
		Total: 13

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Question	**Expected Answers**	**Marks**
4 (a) (i)	$Cr_2O_7^{2-} + 14H^+ + 6I^- \rightleftharpoons 2Cr^{3+} + 3I_2 + 7H_2O$ All species correct (ignore electrons for this mark) Equation balanced (penalise if electrons not cancelled out)	1 1
(ii)	Brown colour disappears $S_2O_3^{2-}$ reacts with I_2 (to form colourless I^-) Green colour remains due to Cr^{3+} (must say what gives green colour)	1 1 1
(b) (i)	Oxidation Number of Cr on both sides = +6 Oxidation Number does not change therefore not redox	1 1
(ii)	Orange to yellow (both needed for 1 mark)	1
(iii)	Any suitable **named** acid or correct formula eg H_2SO_4	1
		Total: 9

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Question	Expected Answers	Marks
2 (a) (i)	O_3: 1 and C_2H_4 ✓	[1]
(ii)	2 ✓	[1]
(iii)	rate = $k[O_3][C_2H_4]$ ✓	[1]
(b) (i)	measure gradient/tangent ✓ at t = 0/start of reaction ✓	[2]
(ii)	$k = \frac{\text{rate}}{[O_3][C_2H_4]}$ ✓ $k = \frac{1.0 \times 10^{-12}}{0.5 \times 10^{-7} \times 1.0 \times 10^{-8}} = 2 \times 10^3$ ✓ $dm^3\ mol^{-1}\ s^{-1}$ ✓	[3]
(iii)	2 mol CH_2O forms for every 0.5 mol O_2 / stoichiometry of CH_2O : O_2 is not 1:1 ✓	[1]
(iv)	rate increases ✓ k increases ✓	[2]
(c) (i)	each atom has two unpaired electrons ✓	[1]
(ii)	2 oxygen atoms bonded by double bond ✓ third oxygen bonded by a covalent bond and outer shells correct ✓ For 2nd mark, all O atoms must have an octet. A triangular molecule would have 3 single covalent bonds for 1st mark but the origin of each electron must be clear for 2nd mark	[2]
(iii)	amount of O_3 in 150 kg = $150 \times 10^3/48 = 3.13 \times 10^3$ mol ✓ amount of Cl radicals in 1 g = 1 /35.5 = 2.82×10^{-2} mol ✓ 1 mol Cl destroys $3.13 \times 10^3/2.82 \times 10^{-2} = 1.11 \times 10^5$ mol O_3 1 Cl radical destroys 1.11×10^5 O_3 molecules ✓ (calculator: 110937)	[3]
		Total: 17

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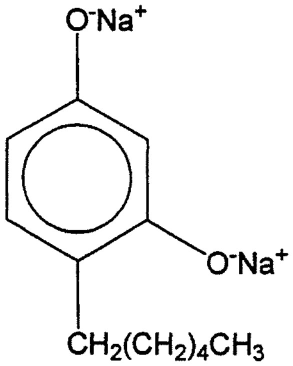
Question	**Expected Answers**	**Marks**
3 (a) (i)	proton donor ✓	[1]
(ii)	partially dissociates ✓	[1]
(b)	$C_6H_5OH(aq)$ + $OH^-(aq)$ ⇌ $C_6H_5O^-(aq)$ + $H_2O(l)$ acid 1 base 2 ✓ base 1 acid 2 ✓ *1 mark for each acid-base pair*	[2]
(c) (i)	$K_a = \dfrac{[C_6H_5O^-][H^+]}{[C_6H_5OH]}$ ✓	[1]
(ii)	concentration = 38/94 ✓ = 0.40 mol dm^{-3} ✓ *(first mark for M_r of phenol - incorrect answer here will give ecf for remainder of question)* $1.3 \times 10^{-10} \approx \dfrac{[H^+(aq)]^2}{0.40}$ ✓ *('=' sign is acceptable)* $[H^+] = \sqrt{(1.3 \times 10^{-10}) \times (0.40)} = 7.2 \times 10^{-6}$ mol dm^{-3} ✓ pH = $-\log[H^+]$ = $-\log 7.2 \times 10^{-6}$ = 5.14 ✓ ***3 marks:*** $[H^+]$✓; pH expression✓; calc of pH from $[H^+]$ ✓ ***Common errors:*** Without square root, answer = 10.28 ✓✓✗ Use of 38 as molar concentration does not score 1st 2 marks. This gives an answer of 4.15 for 3 marks ✓✓✓	[5]
(d)	 / NaOH /Na✓ weak acid/base pair mixture formed ✓ *On structure, 1 mark for O Na on either or both phenol groups.*	[2]
		Total: 12

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Question	Expected Answers	Marks
4 (a)	graphs are of pH against volume acid/alkali added with scale and units ✓ sharp rise between two slight rises ✓ equivalent point > 7 ✓ sharp rise after addition of 25 cm^3 of alkali ✓ start pH = 2.9 ✓ finish pH = 12 → 13 ✓	[6]
(b)	phenolphthalein changes colour in the pH range corresponding to the sharp rise in the titration curve ✓ methyl orange changes colour **before** the sharp rise ✓	[2]
(c)	sharp rise in pH after addition of 12.5 cm^3 NaOH ✓ pH start is higher than 2.9 ✓	[2]
(d)	moles HCl in 23.2 cm^3 = 0.200 x 23.2/1000 = 4.64 x 10^{-3} ✓ moles B in 25 cm^3 = moles HCl = 4.64 x 10^{-3} ✓ moles B in 250 cm^3 = 4.64 x 10^{-3} x 10 = 4.64 x 10^{-2} ✓ 4.64 x 10^{-2} mol B has a mass of 4.32 g molar mass of B = 4.32/4.64 x 10^{-2} = 93 g mol^{-1} ✓ 93 - 16 = 77 ✓ Therefore B is phenylamine / $C_6H_5NH_2$ ✓ *There may be other valid structures that are amines. These can be credited provided that everything adds up to 93.* *Answer could be a primary, secondary or tertiary amines.*	[6]
		Total: 16