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General Certificate of Education (A-level)
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Chemistry CHEM5

(Specification 2420)

Unit 5: Energetics, Redox and Inorganic Chemistry

Final

Mark Scheme

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Question	Marking Guidance	Mark	Comments
1(a)	(Enthalpy change to) break the bond in 1 mol of chlorine (molecules)	1	Allow (enthalpy change to) convert 1 mol of chlorine molecules into atoms Do not allow energy or heat instead of enthalpy, allow heat energy
	To form (2 mol of) gaseous chlorine atoms / free radicals	1	Can score 2 marks for 'Enthalpy change for the reaction': $Cl_2(g) \rightarrow 2Cl(g)$ Equation alone gains M2 only Can only score M2 if 1 mol of chorine molecules used in M1 (otherwise it would be confused with atomisation enthalpy) Any mention of ions, CE = 0
1(b)	(For atomisation) only 1 mol of chlorine atoms, not 2 mol (as in bond enthalpy) is formed / equation showing ½ mol Chlorine giving 1 mol of atoms	1	Allow breaking of one bond gives two atoms Allow the idea that atomisation involves formation of 1 mol of atoms not 2 mol Allow the idea that atomisation of chlorine involves half the amount of molecules of chlorine as does dissociation Any mention of ions, CE = 0
1(c)(i)	$\frac{1}{2}F_2(g) + \frac{1}{2}Cl_2(g) \rightarrow ClF(g)$	1	

1(c)(ii)	ΔH = ½E(F–F) + ½ E(Cl-Cl) – E(Cl-F) E(Cl-F) = ½E(F–F) + ½E(Cl-Cl) - ΔH = 79 + 121 – (–56) = 256 (kJ mol^{-1})	1 1	Allow correct cycle -256 scores zero Ignore units even if wrong
1(c)(iii)	½Cl_2 + 3/2F_2 $\rightarrow$ ClF_3 ΔH = ½ E(Cl-Cl) + 3/2 E(F–F) - 3E(Cl-F) = 121 + 237 – 768 / (or 3 x value from (c)(ii)) = –410 (kJ mol^{-1})	1 1 1	If equation is doubled CE=0 unless correcr answer gained by /2 at end This would score M1 This also scores M1 (note = 358 – 768) If given value of 223 used ans = –311 Allow 1/3 for +410 and +311
1(c)(iv)	(Bond enthalpy of) <u>Cl-F</u> bond in ClF is different from that in ClF_3	1	Allow <u>Cl-F</u> bond (enthalpy) is different in different compounds (QoL)
1(d)	NaCl is ionic / not covalent	1	

Question	Marking Guidance	Mark	Comments
2(a)	$MgCl_2(s) \rightarrow Mg^{2+}(g) + 2Cl^{-}(g)$	1	
2(b)	The magnesium <u>ion</u> is smaller / has a smaller radius / greater charge density (than the calcium ion)	1	If not ionic or if molecules / IMF / metallic / covalent / bond pair / electronegativity mentioned, CE = 0
	Attraction between ions / to the chloride ion stronger	1	Allow ionic bonds stronger Do not allow any reference to polarisation or covalent character Mark independently
2(c)	The oxide ion has a greater charge / charge density than the chloride ion	1	If not ionic or if molecules / IMF / metallic / covalent / bond pair mentioned, CE = 0 Allow oxide ion smaller than chloride ion
	So it attracts the magnesium ion more strongly	1	Allow ionic bonds stronger Mark independently
2(d)	$\Delta H_{solution} = \Delta H_L + \Sigma\Delta H_{hyd}$ Mg^{2+} ions + $\Sigma\Delta H_{hyd}$ Cl^{-} ions	1	Allow correct cycle
	$-155 = 2493 + \Delta H_{hyd}$ Mg^{2+} ions $- 2\times364$		
	ΔH_{hyd} Mg^{2+} ions $= -155 - 2493 + 728$	1	
	$= -1920$ (kJ mol^{-1})	1	Ignore units Allow max 1 for +1920 Answer of + or -1610, CE = 0 Answer of -2284, CE = 0

2(e)	Water is polar / O on water has a delta negative charge Mg^{2+} ion / +ve ion / + charge attracts (negative) O on a water molecule	1 1	Allow O (not water) has lone pairs (can score on diagram) Allow Mg^{2+} attracts lone pair(s) M2 must be stated in words (QoL) Ignore mention of co-ordinate bonds CE = 0 if O^{2-} or water ionic or H bonding
2(f)	Magnesium oxide reacts with water / forms $Mg(OH)_2$	1	Allow MgO does not dissolve in water / sparingly soluble / insoluble

Question	Marking Guidance	Mark	Comments
3(a)	$\Delta G = \Delta H - T\Delta S$	1	Or expression $\Delta H - T\Delta S$ must be evaluated
	If ΔG / expression <=0 reaction is feasible	1	Or any explanation that this expression <=0 Do not allow just $\Delta G = 0$
3(b)	The molecules become more disordered / random when water changes from a liquid to a gas / evaporates	1	For M1 must refer to change in state AND increase in disorder
	Therefore the entropy change is positive / Entropy increases	1	Only score M2 if M1 awarded
	$T\Delta S > \Delta H$	1	Allow M3 for *T* is large / high (provided M2 is scored)
	$\Delta G < 0$	1	Mark M3, M4 independently
3(c)(i)	Condition is $T = \Delta H / \Delta S$	1	
	$\Delta S = 189 - 205/2 - 131 = -44.5$;	1	
	$\Delta H = -242$ therefore $T = (-242 \times 1000)/-44.5)$	1	
	= 5438 K (allow 5400 – 5500 K)	1	Units essential (so 5438 alone scores 3 out of 4) 2719 K allow score of 2 5.4 (K) scores 2 for M1 and M2 only 1646 (K) scores 1 for M1 only
3(c)(ii)	It would decompose into <u>hydrogen and oxygen</u> / its elements	1	Can score this mark if mentioned in M2
	Because ΔG for this reaction would be <= 0	1	Allow the reverse reaction / decomposition is feasible Only score M2 if M1 awarded

3(d)	$\Delta H = T\Delta S$	1	Allow correct substituted values instead of symbols
	ΔS = 70-189 = -119 J K^{-1} mol^{-1}	1	
	ΔH = (-119 × 373)/1000 = -44.4 kJ (mol^{-1}) (allow -44 to -45)	1	Allow -44000 to -45000 J (mol^{-1}) Answer must have correct units of kJ or J

Question	Marking Guidance	Mark	Comments
4(a)	Na_2O is an ionic lattice / giant ionic / ionic crystal With strong forces of attraction between ions	1 1	CE= 0 if molecules, atoms, metallic mentioned Mention of electronegativity max 1 out of 2 Allow strong ionic bonds/lots of energy to separate ions
4(b)	SO_3 is a larger molecule than SO_2 So van der Waals' forces between molecules are stronger	1 1	Allow greater M_r / surface area Any mention of ions, CE= 0
4(c)	Ionic Contains O^{2-} ions / oxide ions These / O^{2-} ions (accept protons to) form OH^- / hydroxide / water (must score M2 to gain M3)	1 1 1	Do not allow ionic with covalent character Equations of the form $O^{2-} + H^+ \rightarrow OH^-$ / $O^{2-} + 2H^+ \rightarrow H_2O$ / $O^{2-} + H_2O \rightarrow 2OH^-$ score M2 and M3
4(d)(i)	$SO_2 + H_2O \rightarrow H^+ + HSO_3^-$	1	Allow $2H^+ + SO_3^{2-}$ but no ions, no mark Only score (d)(ii) if (d)(i) correct
4(d)(ii)	Reaction is an equilibrium / reversible reaction displaced mainly to the left / partially ionised / dissociated	1	Allow reaction does not go to completion
4(e)	SiO_2 reacts with bases / NaOH / CaO / $CaCO_3$	1	Ignore incorrect formulae for silicate

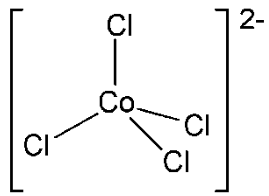
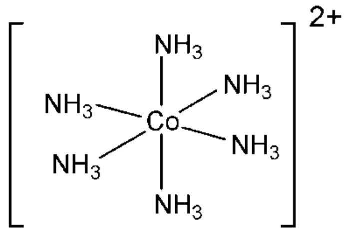
Question	Marking Guidance	Mark	Comments
5(a)	Yellow (solution)	1	
	Orange solution	1	
	$2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$	1	Allow equation with H_2SO_4
5(b)	Yellow / purple (solution)	1	Allow orange / brown (solution)
	Brown precipitate / solid	1	
	$[Fe(H_2O)_6]^{3+} + 3OH^- \rightarrow Fe(H_2O)_3(OH)_3 + 3H_2O$	1	
5(c)	Blue (solution)	1	Allow pale blue
	Dark / deep blue solution	1	Ignore any reference to blue ppt
	$[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 4H_2O$	1	Can be in two equations
5(d)	Colourless (solution)	1	
	White precipitate / solid	1	Do not allow grey
	Bubbles / effervescence / gas evolved / given off	1	Do not allow just CO_2
	$2[Al(H_2O)_6]^{3+} + 3CO_3^{2-} \rightarrow 2Al(H_2O)_3(OH)_3 + 3CO_2 + 3H_2O$	1	

Question	Marking Guidance	Mark	Comments
6(a)	Variable / many oxidation states	1	
6(b)	$V_2O_5 + SO_2 \rightarrow V_2O_4 + SO_3$ $V_2O_4 + ½O_2 \rightarrow V_2O_5$	1 1	Equations can be in either order Allow multiples
6(c)(i)	In a different phase / state <u>from reactants</u>	1	
6(c)(ii)	Impurities poison / deactivate the catalyst / block the active sites	1	Allow (adsorbs onto catalyst AND reduces surface area)
6(d)(i)	The catalyst is a reaction product	1	
6(d)(ii)	Mn^{2+}/ Mn^{3+} ion(s)	1	
6(d)(iii)	$4Mn^{2+} + MnO_4^- + 8H^+ \rightarrow 5Mn^{3+} + 4H_2O$ $2Mn^{3+} + C_2O_4^{2-} \rightarrow 2Mn^{2+} + 2CO_2$	1 1	Equations can be in either order

Question	Marking Guidance	Mark	Comments
7(a)	Diagram of an Fe^{3+}/Fe^{2+} electrode that includes the following parts labelled:		
	Solution containing Fe^{2+} and Fe^{3+} ions	1	
	Platinum electrode connected to one terminal of a voltmeter	1	Must be in the solution of iron ions (one type will suffice)
	Salt bridge	1	Do not allow incorrect material for salt bridge and salt bridge must be in the solution (ie it must be shown crossing a meniscus)
	298 K and 100 kPa / 1 bar	1	
	<u>all solutions</u> unit / 1 mol dm^{-3} concentration	1	Allow zero current / high resistanve voltmeter as alternative to M4 or M5 Ignore hydrogen electrode even if incorrect
7(b)	$Cu^{2+} + Fe \rightarrow Cu + Fe^{2+}$	1	Ignore state symbols
	$Fe\|Fe^{2+}\|\|Cu^{2+}\|Cu$ correct order	1	Allow $Cu\|Cu^{2+}\|\|Fe^{2+}\|Fe$
	Phase boundaries and salt bridge correct, no Pt	1	Allow single/double dashed line for salt bridge Penalise phase boundary at either electrode end Can only score M3 if M2 correct
	Copper electrode	1	Allow any reference to copper

7(c)	$E^⊖$ Au^+(/Au) > $E^⊖$ O_2(/H_2O)	1	Allow *E* cell/e.m.f. = 0.45 V Allow 1.68 > 1.23
	So Au^+ ions will oxidise water / water reduces Au^+	1	QoL
	$2Au^+ + H_2O \rightarrow 2Au + 1/2O_2 + 2H^+$	1	Allow multiples

7(d)	$E^⊖$ Ag^+(/Ag) > $E^⊖$ Fe^{2+}(/Fe)	1	Allow *E* cell/e.m.f. = 1.24 Allow 0.80 > -0.44
	And $E^⊖$ Ag^+(/Ag) > $E^⊖$ Fe^{3+}(/Fe^{2+})	1	Allow *E* cell/e.m.f. = 0.03 Allow 0.80 > 0.77
	So silver ions will oxidise iron (to iron(II) ions) and then oxidise Fe(II) ions (further to Fe(III) ions producing silver metal)	1	Allow Ag^+ ions will oxidise iron to iron(III)

Question	Marking Guidance	Mark	Comments
8(a)	A ligand is an electron pair / lone pair donor	1	Allow uses lone / electron pair to form a co-ordinate bond
	A bidentate ligand donates two electron pairs (to a transition metal ion) from different atoms / two atoms (on the same molecule / ion)	1	QoL
8(b)	$CoCl_4^{2-}$ diagram 	1	Four chlorines attached to Co with net 2- charge correct Charge can be placed anywhere, eg on separate formula Penalise excess charges
	Tetrahedral shape	1	
	109^o 28'	1	Allow 109^o to 109.5^o
	$[Co(NH_3)_6]^{2+}$ diagram 	1	Six ammonia / NH_3 molecules attached to Co with 2+ charge correct
	Octahedral shape	1	
	90^o	1	Allow 180^o if shown clearly on diagram CE= 0 if wrong complex but mark on if only charge is incorrect
8(c)	In different complexes the d orbitals / d electrons (of the cobalt) will have different energies / d orbital splitting will be different	1	
	Light / energy is absorbed causing an electron to be excited	1	
	Different frequency / wavelength / colour of light will be absorbed / transmitted / reflected	1	

8(d)	1 mol of H_2O_2 oxidises 2 mol of Co^{2+}	1	Or $H_2O_2 + 2Co^{2+} \rightarrow 2OH^- + 2Co^{3+}$
	M_r $CoSO_4.7H_2O$ = 281	1	If M_r wrong, max 3 for M1, M4, M5
	Moles Co^{2+} = 9.87/281 = 0.03512	1	
	Moles H_2O_2 = 0.03512/2 = 0.01756	1	M4 is method mark for (M3)/2 (also scores M1)
	Volume H_2O_2 = (moles × 1000)/concentration = 0.01756 × 1000)/5.00		
	= 3.51 cm^3 / (3.51 x 10^{-3} dm^3)	1	Units essential for answer M5 is method mark for (M4) x 1000/5 Allow 3.4 to 3.6 cm^3 If no 2:1 ratio or ratio incorrect Max 3 for M2, M3 & M5 Note : Answer of 7 cm^3 scores 3 for M2, M3, M5 (and any other wrong ratio max 3) Answer of 16.8 cm^3 scores 3 for M1, M4, M5 (and any other wrong M_r max 3) Answer of 33.5 cm^3 scores 1 for M5 only (so wrong M_r AND wrong ratio max 1)