General Certificate of Education (A-level)
January 2012

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 when 1 mol of an (ionic) compound/lattice (under standard conditions) Is dissociated/broken/separated into its (component) ions The ions being in the gaseous state (at infinite separation)	1 1 1	Allow heat energy change Mark independently. Ignore any conditions.
1(b)	There is an attractive force between the nucleus of an O atom and an external electron.	1	Allow any statement that implies attraction between the nucleus and an electron
1(c)	$Mg^{2+}(g) + O(g) + 2e^-$ $Mg^{2+}(g) + O^-(g) + e^-$ $Mg^{2+}(g) + O^{2-}(g)$ First new level for Mg^{2+} and O above last on L Next level for Mg^{2+} and O^- below that Next level for Mg^{2+} and O^{2-} above that and also above that for Mg^{2+} and O	1 1 1 1	Ignore lack of state symbols Penalise incorrect state symbols If levels are not correct allow if steps are in correct order with arrows in the correct direction and correct ΔH values Allow +124 Allow M4 with incorrect number of electrons
1(d)	LE MgO = 602 + 150 + 736 + 1450 + 248 - 142 + 844 = +3888 kJ mol^{-1}	1 1	Note use of 124 instead of 248 CE=0 Allow 1 for -3888 Allow no units Penalise wrong units

1(e)	Forms a protective layer/barrier of MgO / MgO prevents oxygen attacking Mg	1	Allow activation energy is (very) high Allow reaction (very) slow
1(f)	$\Delta G = \Delta H - T\Delta S$ $\Delta S = (-602 - (-570)) \times 1000/ 298$ $= -107\ J\ K^{-1}\ mol^{-1}$ / $-0.107\ kJ\ K^{-1}\ mol^{-1}$	1 1 1	$\Delta S = \frac{(\Delta H - \Delta G)}{T}$ If units not correct or missing, lose mark Allow -107 to -108 +107 with correct units scores max 1/3
1(g)	1 mol of solid and 0.5 mol of gas reactants form 1 mol solid products System becomes more ordered	1 1	Decrease in number of moles (of gas/species) Allow gas converted into solid Numbers of moles/species, if given, must be correct Allow consequential provided ΔS is -ve in 1(f) If ΔS is +ve in 1(f) can only score M1

Question	Marking Guidance	Mark	Comments
2(a)	Standard pressure (100 kPa) (and a stated temperature)	1	Allow standard conditions. Do not allow standard states Allow any temperature Allow 1 bar but not 1atm Apply list principle if extra wrong conditions given Penalise reference to concentrations
2(b)	<u>Hydrogen bonds</u> between water molecules <u>Energy</u> must be supplied in order <u>to break</u> (or loosen) them	1 1	 Allow M2 if intermolecular forces mentioned Otherwise cannot score M2 CE = 0/2 if covalent or ionic bonds broken
2(c)	$T = \Delta H/\Delta S$ $= (6.03 \times 1000)/22.1$ $= 273$ K	1 1 1	 Allow 272 to 273; units K must be given Allow 0°C if units given 0.273 (with or without units) scores 1/3 only Must score M2 in order to score M3 Negative temperature can score M1 only
2(d)	The heat given out escapes	1	

2(e)	(Red end of white) light (in visible spectrum) absorbed by ice Blue light / observed light is reflected / transmitted / left	1 1	Allow complementary colour to blue absorbed Penalise emission of blue light

Question	Marking Guidance	Mark	Comments
3(a)(i)	<u>Ionic lattice / solid / giant ionic</u> Strong (electrostatic) forces/attraction between ions	1 1	CE = 0/2 if molecules / IMFs / atoms / metallic Allow strong ionic bonds for M2 only Allow lot of energy to break ionic bonds
3(a)(ii)	Molecular/molecules Weak dipole-dipole and/or van der Waals forces <u>between molecules</u>	1 1	QoL Type of force must be mentioned
3(b)	P_4O_{10} bigger molecule/has larger surface area than SO_2 van der Waals forces <u>between molecules</u> stronger	1 1	Allow M_r of P_4O_{10} greater than for SO_2 If P_4O_{10} macromolecule/ionic, CE = 0/2 Allow stronger IMF
3(c)	$Na_2O + H_2O \rightarrow 2Na^+ + 2OH^-$ 14 $P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$ 0	1 1 1 1	Allow 2NaOH Allow 12-14 Allow ions Allow -1 to +2
3(d)	$6Na_2O + P_4O_{10} \rightarrow 4Na_3PO_4$	1	Allow ionic Allow correct formula of product with atoms in any order

Question	Marking Guidance	Mark	Comments
4(a)	HCl 1.0 mol dm^{-3}	1	Allow H_2SO_4 0.5 mol dm^{-3} Allow HNO_3 1.0 mol dm^{-3} Allow name or formula Concentration can be given after "conditions"
	(Hydrogen at) 100kPa / 1 bar	1	
	298 K	1	
4(b)	Pt / Platinum	1	Mark on if no answer for M1 If wrong answer for M1, only mark on if electrode is Au, Ag, Pb or Ti
	Inert / unreactive / does not create a potential difference	1	
	Conducts electricity / allows electron flow / conducts / conductor	1	
4(c)	KCl	1	Allow NaCl, KNO_3, Na_2SO_4 etc NOT NH_4Cl
	Does not react with either electrode / solution in electrode	1	Allow unreactive / inert
	Ions can move	1	Allow conducts electricity / electrical connection / carries charge Do not allow just connects / completes the circuit Do not allow conducts / carries electrons Mark these independently

4(d)	$Pt\|H_2\|H^+\|\|Fe^{3+},Fe^{2+}\|Pt$	1	Ignore state symbols Order must be correct | must be correct but allow | instead of , separating Fe^{3+} from Fe^{2+} Allow , instead of | separating H_2 and H^+
4(e)(i)	$2Fe^{3+} + H_2 \rightarrow 2Fe^{2+} + 2H^+$	1	Allow multiples
4(e)(ii)	The <u>Fe^{3+}</u> ions would be used up / reaction completed	1	Answer must relate to reactants in 4(e)(i) equation if given Allow reactant / reactants used up Do not allow concentration of Fe^{3+} decreases Allow concentration of Fe^{3+} falls to zero

Question	Marking Guidance	Mark	Comments
5(a)	H_2O_2	1	Ignore state symbols
5(b)	$E^\ominus$ Cl_2/Cl^- > $E^\ominus$ O_2/H_2O	1	Allow potential for chlorine/Cl_2 greater than for oxygen/O_2 Allow 1.36 > 1.23 / E cell = 0.13
	$Cl_2 + H_2O \rightarrow 2Cl^- + 1/2O_2 + 2H^+$	1	Allow multiples Allow + HCl
5(c)	Activation energy is high / light/UV provides the activation energy / light breaks chlorine molecule / Cl–Cl bond	1	If light used to break Cl–Cl bond award 1 mark and ignore product e.g. Cl^-
5(d)	<u>O</u> <u>(-1)</u> (in H_2O_2)	1	Must give oxidation state of O in H_2O_2= -1
	Changes to <u>O(-2)</u> (in water)	1	Must give oxidation state of O in water = -2 CE = 0/2 if refers to oxidation state of H changing
5(e)	$E^\ominus$ H_2O_2/H_2O > $E^\ominus$ O_2/H_2O_2	1	Allow stated in words Allow 1.77 > 0.68 / *E* cell = 1.09
	$2H_2O_2 \rightarrow O_2 + 2H_2O$	1	Allow multiples H^+ and e^- must be cancelled

Question	Marking Guidance	Mark	Comments
6(a)	$2MnO_4^- + 16H^+ + 5C_2O_4^{2-} \rightarrow 2Mn^{2+} + 8H_2O + 10CO_2$	1 1	For all species correct / moles and species correct but charge incorrect For balanced equation including all charges (also scores first mark)
6(b)	<u>Manganate(VII) ions</u> are <u>coloured</u> (purple) All other reactants and products are **not** coloured (or too faintly coloured to detect)	1 1	 Allow (all) other species are colourless Allow Mn^{2+} are colourless / becomes colourless / pale pink
6(c)	The catalyst for the reaction is a reaction product Reaction starts off slowly / gradient shallow Then gets faster/rate increases / gradient increases	1 1 1	 Allow concentration of MnO_4^- decreases faster / falls rapidly
6(d)	Mn^{2+} ions	1	Allow Mn^{3+} ions
6(e)	$MnO_4^- + 8H^+ + 4Mn^{2+} \rightarrow 5Mn^{3+} + 4H_2O$ $2Mn^{3+} + C_2O_4^{2-} \rightarrow 2Mn^{2+} + 2CO_2$	1 1	Allow multiples

Question	Marking Guidance	Mark	Comments
7(a)	Variable oxidation state	1	
	eg Fe(II) and Fe (III)	1	Any correctly identified pair Allow two formulae showing complexes with different oxidation states even if oxidation state not given
	(Characteristic) colour (of complexes)	1	
	eg Cu^{2+}<u>(aq)</u> / $[Cu(H_2O)_6]^{2+}$ is blue	1	Any correct ion with colour scores M3 and M4 Must show (aq) or ligands OR identified coloured compound (e.g. $CoCO_3$)
7(b)	Tetrahedral	1	
	$[CuCl_4]^{2-}$ / $[CoCl_4]^{2-}$	1	Any correct complex (Note charges must be correct)
	Square planar	1	
	$(NH_3)_2PtCl_2$	1	Any correct complex
	Linear	1	Do not allow linear planar
	$[Ag(NH_3)_2]^+$	1	$[AgCl_2]^-$ etc
7(c)(i)	$[Ca(H_2O)_6]^{2+}$ + $EDTA^{4-}$ $\rightarrow$ $[CaEDTA]^{2-}$ + $6H_2O$	1	If equation does not show increase in number of moles of particles CE = 0/3 for 7(c)(ii) If no equation, mark on

7(c)(ii)	2 mol of reactants form 7 mol of products Therefore disorder increases Entropy increases / +ve entropy change / free-energy change is negative	1 1 1	Allow more moles/species of products Allow consequential to 7(c)(i)
7(c)(iii)	Moles EDTA = 6.25 x 0.0532 / 1000 = (3.325 x 10^{-4}) Moles of Ca^{2+} in 1 dm^3 = 3.325 x 10^{-4} x 1000 / 150 = (2.217 x 10^{-3}) Mass of $Ca(OH)_2$ = 2.217 x 10^{-3} x 74.1 = 0.164 g	1 1 1	Mark is for M1 x 1000 / 150 **OR** M1 x 74.1 If ratio of Ca^{2+} : EDTA is wrong or 1000 / 150 is wrong, CE and can score M1 only This applies to the alternative M1 x 74.1 x 1000 / 150 Answer expressed to 3 sig figs or better Must give unit to score mark Allow 0.164 to 0.165

Question	Marking Guidance	Mark	Comments
8(a)	Electron pair donor	1	Allow lone pair donor
8(b)	$[Cu(H_2O)_6]^{2+} + 2NH_3 \rightarrow Cu(H_2O)_4(OH)_2 + 2NH_4^+$	1	
	(Blue solution) gives a (pale) blue precipitate/solid	1	M2 only awarded if M1 shows Bronsted-Lowry reaction
8(c)	$[Cu(H_2O)_6]^{2+} + 4NH_3 \rightarrow [Cu(H_2O)_2(NH_3)_4]^{2+} + 4H_2O$	1	Allow formation in two equations via hydroxide
	(Blue solution) gives a dark/deep blue solution	1	If 8(b) and 8(c) are the wrong way around allow one mark only for each correct equation with a correct observation (max 2/4) M2 only awarded if M1 shows Lewis base reaction
8(d)	(Start with) green (solution)	1	
	Green precipitate of $Fe(H_2O)_4(OH)_2$ / $Fe(OH)_2$ / iron(II) hydroxide	1	Do not allow observation if compound incorrect or not given
	Slowly changes to brown solid	1	Allow red-brown ppt Allow turns brown or if precipitate implied Can only score M3 if M2 scored
	(Iron(II) hydroxide) oxidised by air (to iron(III) hydroxide)	1	Allow $Fe(OH)_2$ oxidised to $Fe(OH)_3$ by air / O_2 Ignore equations even if incorrect

8(e)(i)	$2[Al(H_2O)_6]^{3+}$ + $3H_2NCH_2CH_2NH_2$ $\rightarrow$ $2Al(H_2O)_3(OH)_3$ + $3[H_3NCH_2CH_2NH_3]^{2+}$ White precipitate	1 1 1	For correct Al species For correct balanced equation Allow equation with formation of $3[H_2NCH_2CH_2NH_3]^+$ from 1 mol $[Al(H_2O)_6]^{3+}$
8(e)(ii)	$[Co(H_2O)_6]^{2+}$ + $3H_2NCH_2CH_2NH_2$ $\rightarrow$ $[Co(H_2NCH_2CH_2NH_2)_3]^{2+}$ + $6H_2O$ Complex with 3 en showing 6 correct bonds from N to Co Co-ordinate bonds (arrows) shown from N to Co $4[Co(H_2NCH_2CH_2NH_2)_3]^{2+}$ + O_2 + $2H_2O$ $\rightarrow$ $4[Co(H_2NCH_2CH_2NH_2)_3]^{3+}$ + $4OH^-$	1 1 1 1 1	Ignore charge Accept N – N for ligand Ignore incorrect H If C shown, must be 2 per ligand Can only score M3 if M2 correct For Co(III) species For balanced equation (others are possible) Allow + O_2 + $4H^+$ $\rightarrow$ $2H_2O$ If en used can score M4 and M5 only If Cu not Co, can only score M2 and M3 Allow $N_2C_2H_8$ in equations