Version 1

General Certificate of Education
June 2011

Chemistry CHEM5

Energetics, Redox and Inorganic Chemistry

Final

Mark Scheme

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Question	Marking Guidance	Mark	Comments
1(a)(i)	(Enthalpy change for formation of) 1 mol (of CaF_2) from its ions	1	allow heat energy change do not allow energy or wrong formula for CaF_2 penalise 1 mol of ions CE=0 if atoms or elements or molecules mentioned ignore conditions
	ions in the gaseous state	1	ions can be mentioned in M1 to score in M2 allow fluorine ions $Ca^{2+}(g) + 2F^-(g) \rightarrow CaF_2$ scores M1 and M2
1(a)(ii)	(enthalpy change when) 1 mol of gaseous (fluoride) ions (is converted) into aqueous ions / an aqueous solution	1	allow $F^-(g) \rightarrow F^-(aq)$ (ignore + aq) do not penalise energy instead of enthalpy allow fluorine ions do not allow F^- ions surrounded by water
1(b)	water is polar / H on water is $\delta+$ / is electron deficient / is unshielded	1	penalise H^+ on water 1 mark
	(F^- ions) attract water / $\delta+$ on H / hydrogen	1	allow H on water forms H-bonds with F^- allow fluorine ions penalise co-ordinate bonds for M2 penalise attraction to O for M2

1(c)	ΔH = –(–2611) –1650 +2×–506	1	ignore cycles M1 is for numbers and signs correct in expression
	= –51 (kJ mol^{-1})	1	correct answer scores 2 ignore units even if incorrect

Question	Marking Guidance	Mark	Comments
2(a)	$KNO_3(s) \rightarrow K^+(aq) + NO_3^-(aq)$	1	do not allow equations with H_2O allow aq and the word 'water' in equation
2(b)	increase in disorder because solid $\rightarrow$ solution / increase in number of particles / 1 mol (solid) gives 2 mol (ions/particles) / particles are more mobile	1	allow random or chaos instead of disorder penalise if molecules/atoms stated instead of ions allow any reference to increase in number of particles even if number of particles wrong
2(c)	$\Delta G = \Delta H - T\Delta S$ / $T = \Delta H/\Delta S$ $T = \Delta H/\Delta S = (34.9 \times 1000)/117$ = 298 K	1 1 1	 also scores M1 correct answer scores 3, units essential 0.298 scores M1 only
2(d)(i)	positive / increases / $\Delta G > 0$	1	Allow more positive
2(d)(ii)	if ans to (d) (i) positive, dissolving is no longer spontaneous / no longer feasible / potassium nitrate does not dissolve / less soluble if ans to (d) (i) negative, dissolving is spontaneous / feasible / potassium nitrate dissolves / more soluble	1	If no mention of change to ΔG in (d)(i), Mark = 0 for (d)(ii)

Question	Marking Guidance	Mark	Comments
3(a)(i)	$\Delta H = \Sigma$ bonds broken – Σbonds formed	1	
	= 944/2 + 3/2 $\times$ 436 –3 $\times$ 388	1	
	= –38 (kJ mol^{-1})	1	ignore units even if incorrect correct answer scores 3 –76 scores 2/3 +38 scores 1/3
3(a)(ii)	mean / average bond enthalpies are from a range of compounds or mean / average bond enthalpies differ from those in a single compound / ammonia	1	
3(b)	$\Delta S = \Sigma S$ products – ΣS reactants	1	
	= 193 – (192/2 + 131 $\times$ 3/2)	1	
	= –99.5 J K^{-1} mol^{-1}	1	units essential for M3 correct answer with units scores 3 –199 J K^{-1} mol^{-1} & –99.5 score 2/3 – 199 and + 99.5 J K^{-1} mol^{-1} score 1/3

3(c)(i)	$\Delta G = \Delta H - T\Delta S = -46 + 800 \times 99.5/1000$ = 33.6 or 33600 kJ mol^{-1} with J mol^{-1}	1 1 1	mark is for putting in numbers with 1000 if factor of 1000 used incorrectly CE = 0 allow 33 to 34 (or 33000 to 34000) correct units for answer essential if answer to part (b) is wrong or if -112 used, mark consequentially e.g. • –199 gives 113 to 114 kJ mol^{-1} (scores 3/3) • –112 gives 43 to 44 kJ mol^{-1} (scores 3/3)
3(c)(ii)	If answer to (c) (i) is positive: not feasible / not spontaneous If answer to (c) (i) is negative: feasible / spontaneous	1	if no answer to (c) (i) award zero marks

Question	Marking Guidance	Mark	Comments
4(a)(i)	white flame / white light	1	Mark flame independent of other observations
	solid / powder / smoke / ash / <u>white fumes</u>	1	penalise precipitate penalise wrong colour if more than one observation for M2 apply list principle. (If an observation is incorrect, the incorrect observation negates a correct one)
	$2Mg + O_2 \rightarrow 2MgO$	1	ignore state symbols allow multiples
	ionic	1	do not allow reference to covalent character
4(a)(ii)	blue flame	1	do not allow any other colour Mark flame independent of other observations
	fumes or misty or pungent/choking/smelly gas	1	do not allow incorrect smell (e.g. bad eggs) apply list principle as in (a) (i) do not allow just 'gas' or 'colourless gas'
	$S + O_2 \rightarrow SO_2$	1	ignore state symbols allow multiples and S_8
	covalent	1	penalise giant covalent

4(b)	ionic	1	If covalent, can only score M3
	O^{2-} / oxide ion reacts with water / accepts a proton	1	M2 requires reference to O^{2-} / oxide ion
	forming OH^- ions/ NaOH / sodium hydroxide (can show in equation from Na_2O even if incorrect)	1	allow $O^{2-} + H_2O \rightarrow 2OH^-$ or $O^{2-} + H^+ \rightarrow OH^-$ to score M2 & M3 also allow equations with spectator Na^+ ions on both sides.
4(c)	(heat until) molten	1	or dissolve in <u>molten</u> cryolite do not allow solution in water
	conducts electricity / can be electrolysed / electrolyse and identify Al / O_2 at an electrode	1	M2 can only be gained if M1 scored
4(d)	insoluble (in water)	1	allow oxide impermeable to air / water or oxide is unreactive / inert
4(e)(i)	$Al_2O_3 + 6H^+ \rightarrow 2Al^{3+} + 3H_2O$	1	allow $O^{2-} + 2H^+ \rightarrow H_2O$ and formation of aquated Al^{3+} species allow spectator Cl^- ions penalise HCl (not ionic!)
4(e)(ii)	$Al_2O_3 + 2OH^- + 3H_2O \rightarrow 2Al(OH)_4^-$ or $Al_2O_3 + 6OH^- + 3H_2O \rightarrow 2Al(OH)_6^{3-}$	1	allow formation of $Al(H_2O)_2(OH)_4^-$ allow Na^+ spectator ions penalise NaOH (not ionic!)

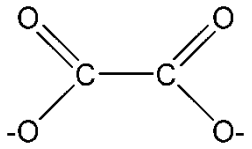
Question	Marking Guidance	Mark	Comments
5(a)	loses electrons / donates electrons	1	penalise donates electron pair
5(b)	Zn	1	
	(most) negative E^o / lowest E^o / least positive	1	can only score M2 if M1 correct do not allow e.m.f instead of E^o
5(c)	$\underline{E^o\ F_2}$ ($/F^-$) > $\underline{E^o\ O_2}$ ($/H_2O$)	1	or e.m.f is positive or e.m.f = 1.64 V
	Fluorine reacts to form oxygen (can score from equation in M3 even if equation unbalanced provided no contradiction) or fluorine oxidises water or fluorine is a more powerful oxidising agent than oxygen	1	
	$2F_2 + 2H_2O \rightarrow 4F^- + 4H^+ + O_2$	1	allow 4HF in equation balanced equation scores M2 and M3

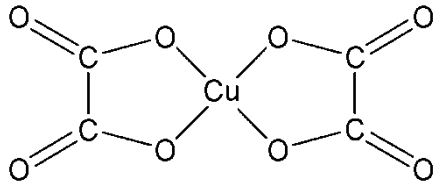
5(d)(i)	order correct Zn Zn^{2+} Ag_2O Ag or reverse of this order all phase boundaries correct e.g. $Zn\|Zn^{2+}\|\|Ag_2O\|Ag$ or $Ag\|Ag_2O\|\|Zn^{2+}\|Zn$ scores 2	1 1	ignore ss , H^+ and H_2O, no. of moles allow $Zn\|Zn^{2+}\|\|Ag_2O$,Ag or $Zn\|Zn^{2+}\|\|Ag_2O\|H^+\|Ag$ for M1 & M2 M2 cannot be gained unless M1 scored allow H^+ either side of Ag_2O with comma or | for M2 penalise • wrong phase boundary (allow dashed lines for salt bridge) • Pt • use of + (from half equation) • water/H^+ outside Ag in Ag electrode
5(d)(ii)	1.1 (V)	1	Allow no units, penalise wrong units allow correct answer even if no answer to (d)(i) or answer to (d)(i) incorrect allow –1.1 if silver electrode on Left in (d)(i) even if the species are in the wrong order.
5(d)(iii)	Reaction(s) not reversible or H_2O electrolyses	1	do not allow hard to reverse mention of primary cell is not enough to show that reaction(s) are irreversible
5(e)(i)	–0.46 (V)	1	Allow no units, penalise wrong units

5(e)(ii)	$2PbSO_4 + 2H_2O \rightarrow Pb + PbO_2 + 2HSO_4^- + 2H^+$ lead species correct on correct sides of equation equation balanced and includes H_2O, HSO_4^- and H^+ (or H_2SO_4)	 1 1	 allow ions / species must be fully cancelled out or combined allow 1/2 for balanced reverse equation
5(f)(i)	reagents / PbO_2 / H_2SO_4 /acid / ions used up (or concentration decreases)	1	
5(f)(ii)	fuel cell	1	Ignore any other words
5(f)(iii)	reagents / fuel supplied continuously concentrations (of reagents) remain constant	1 1	

Question	Marking Guidance	Mark	Comments
6(a)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$	1	allow [He] $2s^2$. or [Ne] $3s^2$.or [Ar]$3d^{10}$
	d sub-shell / shell / orbitals / sub-level full (or not partially full)	1	can only score M2 if d^{10} in M1 correct allow 'full d orbital' if d^{10} in M1 do not allow d block
6(b)	atom or ion or transition metal bonded to / surrounded by one or more ligands	1	Allow Lewis base instead of ligand
	by co–ordinate / dative (covalent) bonds / donation of an electron pair	1	can only score M2 if M1 correct
6(c)	H_2 / hydrogen	1	do not allow H
	no lone / spare / non-bonded pair of electrons	1	only score M2 if M1 correct or give 'H' in M1
6(d)(i)	+2 or 2+ or Pd^{2+} or II or +II or II+ or two or two plus	1	
6(d)(ii)	tetrahedral	1	these shapes can be in any order
	square planar	1	allow phonetic spelling e.g. tetrahydral

Question	Marking Guidance	Mark	Comments
7(a)(i)	absorbs (certain frequencies of) (white) light / photons	1	not absorbs white / u.v. light
	<u>d</u> electrons excited / promoted	1	or <u>d</u> electrons move between levels / orbitals d electrons can be implied elsewhere in answer
	the colour observed is the light not absorbed / light reflected / light transmitted	1	allow blue light transmitted penalise emission of light in M3
7(a)(ii)	ΔE is the energy gained by the (excited) electrons (of Cu^{2+})	1	allow: • energy difference between orbitals / sub-shells • energy of photon / light absorbed • change in energy of the electrons • energy lost by excited electrons • energy of photon / light emitted
	h (Planck's) constant	1	
	ν frequency of light (absorbed by $Cu^{2+}(aq)$)	1	do not allow wavelength If energy lost / photon lost / light emitted in M1 do not penalised light emitted

7(a)(iii)	$[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$	1	note that $[CuCl_4^-]^{2-}$ is incorrect penalise charges shown separately on the ligand and overall penalise HCl
	tetrahedral	1	
	Cl^- / Cl / chlorine too big (to fit more than 4 round Cu)	1	allow water smaller than Cl^- explanation that change in shape is due to change in co-ordination number
7(b)		1	allow: • ion drawn with any bond angles • ion in square brackets with overall / 2- charge shown outside the brackets • ion with delocalised O=C—O bonds in carboxylate group(s)
	lone pair(s) on O^- / O	1	allow position of lone pair(s) shown on O in the diagram even if the diagram is incorrect.
7(c)(i)	$[Cu(H_2O)_6]^{2+} + 2C_2O_4^{2-} \rightarrow [Cu(C_2O_4)_2(H_2O)_2]^{2-} + 4H_2O$		
	product correct	1	
	equation balanced	1	
	6	1	note can only score M3 and M4 if M1 awarded or if complex in equation has 2 waters and 2 ethanedioates
	octahedral	1	If this condition is satisfied the complex can have the wrong charge(s) to allow access to M3 and M4 but not M1

7(c)(ii)	 90°	1 1	ignore charges diagram must show both ethanedioates with correct bonding ignore water allow 180° mark bond angle independently but penalise if angle incorrectly labelled / indicated on diagram

Question	Marking Guidance	Mark	Comments
8(a)	$2Fe^{2+} + S_2O_8^{2-} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$	1	
	$2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$	1	
	two negative ions repel / lead to reaction that is slow / lead to reaction that has high E_a	1	
	iron able to act because changes its oxidation state	1	allow iron has variable oxidation state
	With iron ions have alternative route / route with lower activation energy	1	
8(b)(i)	$[Fe(H_2O)_6]^{3+} \rightarrow [Fe(H_2O)_5OH]^{2+} + H^+$	1	can have H_2O on LHS and H_3O^+ on R do not penalise further hydrolysis equations allow high charge density
	Fe^{3+} ion has higher charge (to size ratio) (than Fe^{2+})	1	
	increases polarisation of co-ordinated water / attracts O releasing an H^+ ion / weakens O—H bond	1	

8(b)(ii)	$Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+}$	1	or 6 mol Fe(II) react with 1 mol dichromate If factor of 6 not used max =3 for M2, M4 and M5 e.g. 1:1 gives ans= 8.93 to 8.98% (scores 3)
	moles dichromate = $23.6 \times 0.218/1000 = 5.14 \times 10^{-4}$	1	
	moles iron = $5.14 \times 10^{-4} \times 6 = 0.00309$	1	M3 also scores M1
	mass iron = $0.00309 \times 55.8 = 0.172$	1	Mark is for moles of iron $\times$ 55.8 conseq Allow use of 56 for iron
	% by mass of iron = $0.172 \times 100/0.321 = 53.7\%$	1	Answer must be to at least 3 sig figures allow 53.6 to 53.9 Mark is for mass of iron $\times$ 100/0.321 conseq

8(c)	brown precipitate / solid	1	Allow red-brown / orange solid Not red or yellow solid
	bubbles (of gas) / effervescence/ fizz	1	Allow gas evolved / given off Do not allow just gas or CO_2 or CO_2 gas
	$2[Fe(H_2O)_6]^{3+} + 3CO_3^{2-} \rightarrow 2Fe(H_2O)_3(OH)_3 + 3CO_2 + 3H_2O$	1	Allow $2[Fe(H_2O)_6]^{3+} + 3CO_3^{2-} \rightarrow 2Fe(OH)_3 + 3CO_2 + 9H_2O$ Use of Na_2CO_3 e.g. …+ $3Na_2CO_3 \rightarrow$ .. + .. + .. + $6Na^+$

UMS conversion calculator www.aqa.org.uk/umsconversion