

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 $\text{CaF}_2$ ) from its ions  ions in the gaseous state	1  1	allow heat energy change do not allow energy or wrong formula for $\text{CaF}_2$ penalise 1 mol of ions CE=0 if atoms or elements or molecules mentioned ignore conditions  ions can be mentioned in M1 to score in M2 allow fluorine ions $\text{Ca}^{2+}(\text{g}) + 2\text{F}^{-}(\text{g}) \rightarrow \text{CaF}_2$ 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 $\text{F}^{-}(\text{g}) \rightarrow \text{F}^{-}(\text{aq})$ (ignore + aq) do not penalise energy instead of enthalpy allow fluorine ions do not allow $\text{F}^{-}$ ions surrounded by water
1(b)	water is polar / H on water is $\delta+$ / is electron deficient / is unshielded  ( $\text{F}^{-}$ ions) attract water / $\delta+$ on H / hydrogen	1  1	penalise $\text{H}^{+}$ on water 1 mark  allow H on water forms H-bonds with $\text{F}^{-}$ allow fluorine ions penalise co-ordinate bonds for M2 penalise attraction to O for M2

1(c)	$\Delta H = -(-2611) - 1650 + 2 \times -506$ $= -51 \text{ (kJ mol}^{-1}\text{)}$	1	ignore cycles M1 is for numbers and signs correct in expression
		1	correct answer scores 2 ignore units even if incorrect

Question	Marking Guidance	Mark	Comments
2(a)	$\text{KNO}_3(\text{s}) \rightarrow \text{K}^+(\text{aq}) + \text{NO}_3^-(\text{aq})$	1	do not allow equations with $\text{H}_2\text{O}$ 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)	$\Delta G = \Delta H - T\Delta S$ / $T = \Delta H / \Delta S$  $T = \Delta H / \Delta S = (34.9 \times 1000) / 117$  $= 298 \text{ K}$	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 $\Delta G$ in (d)(i), Mark = 0 for (d)(ii)

Question	Marking Guidance	Mark	Comments
3(a)(i)	$\Delta H = \Sigma \text{ bonds broken} - \Sigma \text{ bonds formed}$  $= 944/2 + 3/2 \times 436 - 3 \times 388$  $= -38 \text{ (kJ mol}^{-1}\text{)}$	1  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)	$\Delta S = \Sigma S \text{ products} - \Sigma S \text{ reactants}$  $= 193 - (192/2 + 131 \times 3/2)$  $= -99.5 \text{ J K}^{-1} \text{ mol}^{-1}$	1  1  1	units essential for M3 correct answer with units scores 3 -199 J K <sup>-1</sup> mol <sup>-1</sup> & -99.5 score 2/3 - 199 and + 99.5 J K <sup>-1</sup> mol <sup>-1</sup> score 1/3

3(c)(i)	$\Delta G = \Delta H - T\Delta S = -46 + 800 \times 99.5/1000$ $= 33.6 \quad \text{or} \quad 33600$ $\text{kJ mol}^{-1} \quad \text{with J mol}^{-1}$	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 <sup>-1</sup> (scores 3/3) • -112 gives 43 to 44 kJ mol <sup>-1</sup> (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)
	$2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$	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'
	$\text{S} + \text{O}_2 \rightarrow \text{SO}_2$	1	ignore state symbols allow multiples and $\text{S}_8$
	covalent	1	penalise giant covalent



4(b)	ionic  $\text{O}^{2-}$ / oxide ion reacts with water / accepts a proton  forming $\text{OH}^-$ ions/ NaOH / sodium hydroxide (can show in equation from $\text{Na}_2\text{O}$ even if incorrect)	1  1  1	If covalent, can only score M3  M2 requires reference to $\text{O}^{2-}$ / oxide ion  allow $\text{O}^{2-} + \text{H}_2\text{O} \rightarrow 2\text{OH}^-$ or $\text{O}^{2-} + \text{H}^+ \rightarrow \text{OH}^-$ to score M2 & M3 also allow equations with spectator $\text{Na}^+$ ions on both sides.
4(c)	(heat until) molten  conducts electricity / can be electrolysed / electrolyse and identify Al / $\text{O}_2$ at an electrode	1  1	or dissolve in <u>molten</u> cryolite do not allow solution in water  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)	$\text{Al}_2\text{O}_3 + 6\text{H}^+ \rightarrow 2\text{Al}^{3+} + 3\text{H}_2\text{O}$	1	allow $\text{O}^{2-} + 2\text{H}^+ \rightarrow \text{H}_2\text{O}$ and formation of aquated $\text{Al}^{3+}$ species allow spectator $\text{Cl}^-$ ions penalise HCl (not ionic!)
4(e)(ii)	$\text{Al}_2\text{O}_3 + 2\text{OH}^- + 3\text{H}_2\text{O} \rightarrow 2\text{Al}(\text{OH})_4^-$ or $\text{Al}_2\text{O}_3 + 6\text{OH}^- + 3\text{H}_2\text{O} \rightarrow 2\text{Al}(\text{OH})_6^{3-}$	1	allow formation of $\text{Al}(\text{H}_2\text{O})_2(\text{OH})_4^-$ allow $\text{Na}^+$ spectator ions penalise NaOH (not ionic!)

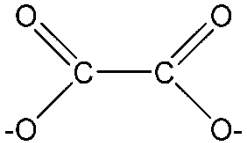
Question	Marking Guidance	Mark	Comments
5(a)	loses electrons / donates electrons	1	penalise donates electron pair
5(b)	Zn	1	can only score M2 if M1 correct do not allow e.m.f instead of $E^\circ$
	(most) negative $E^\circ$ / lowest $E^\circ$ / least positive	1	
5(c)	$E^\circ \text{F}_2 / \text{F}^- > E^\circ \text{O}_2 / \text{H}_2\text{O}$	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	
	$2\text{F}_2 + 2\text{H}_2\text{O} \rightarrow 4\text{F}^- + 4\text{H}^+ + \text{O}_2$	1	

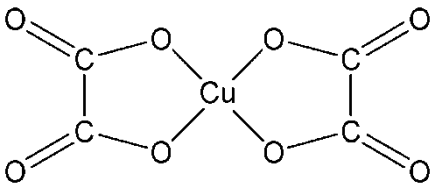


5(e)(ii)	$2\text{PbSO}_4 + 2\text{H}_2\text{O} \rightarrow \text{Pb} + \text{PbO}_2 + 2\text{HSO}_4^- + 2\text{H}^+$ lead species correct on correct sides of equation	1	allow ions / species must be fully cancelled out or combined allow 1/2 for balanced reverse equation
	equation balanced and includes $\text{H}_2\text{O}$ , $\text{HSO}_4^-$ and $\text{H}^+$ (or $\text{H}_2\text{SO}_4$ )	1	
5(f)(i)	reagents / $\text{PbO}_2$ / $\text{H}_2\text{SO}_4$ / 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	1	
	concentrations (of reagents) remain constant	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)	$\Delta E$ is the energy gained by the (excited) electrons (of $\text{Cu}^{2+}$ )	1	allow: <ul style="list-style-type: none"> <li>• energy difference between orbitals / sub-shells</li> <li>• energy of photon / light absorbed</li> <li>• change in energy of the electrons</li> <li>• energy lost by excited electrons</li> <li>• energy of photon / light emitted</li> </ul>
	$h$ (Planck's) constant	1	
	$\nu$ frequency of light (absorbed by $\text{Cu}^{2+}(\text{aq})$ )	1	do not allow wavelength If energy lost / photon lost / light emitted in M1 do not penalised light emitted

7(a)(iii)	$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{Cl}^- \rightarrow [\text{CuCl}_4]^{2-} + 6\text{H}_2\text{O}$ <p>tetrahedral</p> <p><math>\text{Cl}^-</math> / Cl / chlorine too big (to fit more than 4 round Cu)</p>	<p>1</p> <p>1</p> <p>1</p>	<p>note that <math>[\text{CuCl}_4]^{2-}</math> is incorrect</p> <p>penalise charges shown separately on the ligand and overall</p> <p>penalise HCl</p> <p>allow</p> <p>water smaller than <math>\text{Cl}^-</math></p> <p>explanation that change in shape is due to change in <u>co-ordination number</u></p>
7(b)	 <p><u>lone pair(s)</u> on <math>\text{O}^-</math> / O</p>	<p>1</p> <p>1</p>	<p>allow:</p> <ul style="list-style-type: none"> <li>ion drawn with any bond angles</li> <li>ion in square brackets with overall / 2- charge shown outside the brackets</li> <li>ion with delocalised <math>\text{O}=\text{C}-\text{O}</math> bonds in carboxylate group(s)</li> </ul> <p>allow position of lone pair(s) shown on O in the diagram even if the diagram is incorrect.</p>
7(c)(i)	$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 2\text{C}_2\text{O}_4^{2-} \rightarrow [\text{Cu}(\text{C}_2\text{O}_4)_2(\text{H}_2\text{O})_2]^{2-} + 4\text{H}_2\text{O}$ <p>product correct</p> <p>equation balanced</p> <p>6</p> <p>octahedral</p>	<p>1</p> <p>1</p> <p>1</p> <p>1</p>	<p>note can only score M3 and M4 if M1 awarded or if complex in equation has 2 waters and 2 ethanedioates</p> <p>If this condition is satisfied the complex can have the wrong charge(s) to allow access to M3 and M4 but not M1</p>

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



Question	Marking Guidance	Mark	Comments
8(a)	$2\text{Fe}^{2+} + \text{S}_2\text{O}_8^{2-} \rightarrow 2\text{Fe}^{3+} + 2\text{SO}_4^{2-}$	1	allow iron has variable oxidation state
	$2\text{Fe}^{3+} + 2\text{I}^- \rightarrow 2\text{Fe}^{2+} + \text{I}_2$	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	
	With iron ions have alternative route / route with lower activation energy	1	
8(b)(i)	$[\text{Fe}(\text{H}_2\text{O})_6]^{3+} \rightarrow [\text{Fe}(\text{H}_2\text{O})_5\text{OH}]^{2+} + \text{H}^+$	1	can have $\text{H}_2\text{O}$ on LHS and $\text{H}_3\text{O}^+$ on R do not penalise further hydrolysis equations allow high charge density
	$\text{Fe}^{3+}$ ion has higher charge (to size ratio) (than $\text{Fe}^{2+}$ )	1	
	increases polarisation of co-ordinated water / attracts O releasing an $\text{H}^+$ ion / weakens O—H bond	1	

8(b)(ii)	$\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6\text{Fe}^{2+} \rightarrow 2\text{Cr}^{3+} + 7\text{H}_2\text{O} + 6\text{Fe}^{3+}$ <p>moles dichromate = <math>23.6 \times 0.218/1000 = 5.14 \times 10^{-4}</math></p> <p>moles iron = <math>5.14 \times 10^{-4} \times 6 = 0.00309</math></p> <p>mass iron = <math>0.00309 \times 55.8 = 0.172</math></p> <p>% by mass of iron = <math>0.172 \times 100/0.321 = 53.7\%</math></p>	<p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p>	<p>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)</p> <p>M3 also scores M1</p> <p>Mark is for moles of iron <math>\times 55.8</math> conseq Allow use of 56 for iron</p> <p>Answer must be to at least 3 sig figures allow 53.6 to 53.9 Mark is for mass of iron <math>\times 100/0.321</math> conseq</p>
8(c)	<p>brown precipitate / solid</p> <p>bubbles (of gas) / effervescence/ fizz</p> $2[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 3\text{CO}_3^{2-} \rightarrow 2\text{Fe}(\text{H}_2\text{O})_3(\text{OH})_3 + 3\text{CO}_2 + 3\text{H}_2\text{O}$	<p>1</p> <p>1</p> <p>1</p>	<p>Allow red-brown / orange solid Not red or yellow solid</p> <p>Allow gas evolved / given off Do not allow just gas or <math>\text{CO}_2</math> or <math>\text{CO}_2</math> gas</p> <p>Allow  <math display="block">2[\text{Fe}(\text{H}_2\text{O})_6]^{3+} + 3\text{CO}_3^{2-} \rightarrow 2\text{Fe}(\text{OH})_3 + 3\text{CO}_2 + 9\text{H}_2\text{O}</math>                     Use of <math>\text{Na}_2\text{CO}_3</math>                      e.g. <math>\dots + 3\text{Na}_2\text{CO}_3 \rightarrow \dots + \dots + \dots + 6\text{Na}^+</math> </p>