



General Certificate of Education

Chemistry 1421

CHEM2 Chemistry in Action

Mark Scheme

2009 examination - June series

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Q	Part	Sub Part	Marking Guidance	Mark	Comments
1	(a)		Sulfur OR S OR S ₈	1	Sulphur
1	(b)		M1 The activation energy is the <u>minimum</u> / <u>least</u> / <u>lowest</u> M2 Energy for a reaction to occur / to go / to start OR Energy for a <u>successful</u> / <u>effective</u> collision	1 1	Mark these independently
1	(c)		Explanation: M1 <u>Twice</u> as many / <u>double</u> number of <u>particles</u> M2 <u>More</u> / <u>twice</u> / <u>double</u> (effective) <u>collisions</u> (in a given time) OR <u>Double</u> / <u>greater</u> / <u>increased</u> collision frequency	1 1	M1 NOT molecules
1	(d)	(i)	(Measured) <u>change</u> in <u>concentration</u> (of a substance) in unit <u>time</u> / given <u>time</u>	1	May be written mathematically OR the gradient of the <u>concentration</u> (against) <u>time</u>
1	(d)	(ii)	The measured change / amount (of precipitate) / cloudiness is <u>fixed</u> or <u>constant</u> or <u>unchanged</u>	1	

Q	Part	Sub Part	Marking Guidance	Mark	Comments
2	(a)	(i)	<p>M1 The enthalpy change / heat change at constant pressure when <u>1 mol</u> of a compound / substance / product</p> <p>M2 Is formed from its (constituent) <u>elements</u></p> <p>M3 With all <u>reactants and products / all substances in standard states</u> OR All <u>reactants and products / all substances in normal states under standard conditions</u> / 100 kPa / 1 bar <u>and</u> specified T / 298 K</p>	1 1 1	Ignore reference to 1 atmosphere
2	(a)	(ii)	<p>By definition OR Because they are elements</p>	1	
2	(a)	(iii)	<p>M1 $\Delta H_r = \sum \Delta H_f(\text{products}) - \sum \Delta H_f(\text{reactants})$</p> <p>M2 = -1669 - 3(-558) (This also scores M1)</p> <p>M3 = (+) 5 (kJ mol⁻¹)</p>	1 1 1	<p>Correct answer gains full marks. Assume the value is positive unless specifically stated as negative. Credit 1 mark if – 5 (kJ mol⁻¹).</p> <p>For other incorrect or incomplete answers, proceed as follows:</p> <ul style="list-style-type: none"> • check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (M1 and M2) • If no AE, check for a correct method; this requires either a correct cycle with 3BaO OR a clear statement of M1 which could be in words and scores <u>only M1</u>

2	(b)	(i)	<i>One from</i> <ul style="list-style-type: none"> Aluminium is <u>expensive</u> (to extract OR due to electrolysis) <u>High energy cost</u> The <u>cost of heating strongly</u> 	1	This requires a clear statement about <u>cost</u>
2	(b)	(ii)	<i>One from</i> <ul style="list-style-type: none"> <u>increase collision frequency</u> OR <u>more collisions</u> OR <u>more chance of colliding</u> 	1	The answer MUST refer to <u>more collisions</u> . Ignore “more available to collide”
2	(c)	(i)	$\text{Ba} + 2\text{H}_2\text{O} \longrightarrow \text{Ba(OH)}_2 + \text{H}_2$	1	Ignore state symbols Allow multiples and correct ionic equations
2	(c)	(i)	M1 $\text{Ba}^{2+} + \text{SO}_4^{2-} \longrightarrow \text{BaSO}_4$ (or the ions together)	1	Allow crossed out Na^+ ions, but penalise if not crossed out
			M2 <u>White precipitate</u> / <u>white solid</u>	1	Ignore state symbols Ignore “milky”
2	(c)	(iii)	M1 Barium meal or (internal) X-ray or to block X-rays M2 <u>BaSO₄</u> / <u>barium sulfate is insoluble</u> (and therefore not toxic)	1 1	Accept a correct reference to M1 written in the explanation in M2, unless contradictory. For M2 NOT barium ions NOT barium NOT barium meal and NOT “It”. Ignore radio-tracing.

Q	Part	Sub Part	Marking Guidance	Mark	Comments
3	(a)	(i)	$q = mc \Delta T$	1	Ignore case except T
3	(a)	(ii)	$8.80 \times 1.92 \times 9.5 = \mathbf{161}$ (J) to 160.5(12) (J)	1	Credit 0.161 provided it is clear that it is kJ. Penalise wrong units
3	(a)	(iii)	$11.95 \times 0.96 \times 9.5 = \mathbf{109}$ (J) to 108.98(4) (J)	1	Credit 0.109 provided it is clear that it is kJ. Penalise wrong units.
3	(a)	(iv)	<p>M1 Addition of (a)(ii) and (a)(iii)</p> <p>M2 Multiply by 10 and convert to kJ (divide by 1000) <u>leading to an answer</u></p> <p>Therefore $\Delta H = \mathbf{(-) 2.69 OR (-) 2.7(0)}$ (kJ mol⁻¹)</p>	2	<p>Consequential on (a)(ii) and (a)(iii)</p> <p>Penalise wrong units</p> <p>Ignore the sign</p> <p>Ignore greater numbers of significant figures (2.69496)</p> <p>Subtraction in M1 is CE</p>
3	(b)		<p>One from:</p> <ul style="list-style-type: none"> No account has been taken of the intermolecular forces initially in the two liquids OR each liquid has its own intermolecular forces in operation before mixing. The liquids may react or reference to reaction or reference to bonds broken or formed 	1	Any statement which shows that there are other intermolecular forces to consider. Ignore heat loss and ignore poor mixing.

Q	Part	Sub Part	Marking Guidance	Mark	Comments
4	(a)		M1 <u>Concentrations</u> of reactants and products remain constant	1	For M1 NOT "equal concentrations" NOT "amount" Credit the use of [] for concentration Ignore dynamic, ignore closed system
			M2 Forward <u>rate</u> = Reverse / backward <u>rate</u>	1	
4	(b)		M1 The (forward) reaction / to the right is exothermic or releases heat OR converse for reverse reaction.	1	
			M2 The equilibrium responds by <u>absorbing heat / lowering temperature</u> OR Promotes the endothermic reaction by <u>absorbing heat / lowering temperature</u> OR <u>Temperature increase is opposed</u> (by shift to the left) OR Change is opposed by <u>absorbing heat / lowering temperature</u> .	1	
4	(c)	(i)	A substance that speeds up / alters the rate but is unchanged at the end / not used up.	1	<u>Both ideas needed</u> Ignore references to activation energy and alternative route.
4	(c)	(ii)	None OR no change OR no effect OR nothing OR Does not affect it / the position (of equilibrium) OR (The position is) the same or unchanged.	1	

4	(d)	(i)	<p>An activity which has no <u>net / overall</u> (annual) carbon emissions to the atmosphere</p> <p>OR</p> <p>An activity which has no <u>net / overall</u> (annual) greenhouse gas emissions to the atmosphere.</p> <p>OR</p> <p>There is no change in the <u>total amount</u> of carbon dioxide / carbon /greenhouse gas present in the atmosphere.</p>	1	<p>The idea that the carbon / CO₂ given out equals the carbon / CO₂ that was taken in</p> <p>Ignore carbon monoxide</p>
4	(d)	(ii)	<p>A method which shows (see below) OR states in words that two times the first equation + the second equation gives the correct ratio.</p> $ \begin{array}{rcl} 2 (\text{CH}_4 + \text{H}_2\text{O}) & \longrightarrow & \text{CO} + 3\text{H}_2 \\ \text{CH}_4 + \text{CO}_2 & \longrightarrow & 2\text{CO} + 2\text{H}_2 \\ \hline 3\text{CH}_4 + 2\text{H}_2\text{O} + \text{CO}_2 & \longrightarrow & 4\text{CO} + 8\text{H}_2 \end{array} $ <p style="text-align: center;">Ratio = 1 : 2</p>	1	

5	(b)	(ii)	<p>M1 Use of Na OR Mg</p> <p>M2 Balanced equation consequential on correct reactants</p> <p>EITHER $\text{TiCl}_4 + 4\text{Na} \longrightarrow \text{Ti} + 4\text{NaCl}$ OR $\text{TiCl}_4 + 2\text{Mg} \longrightarrow \text{Ti} + 2\text{MgCl}_2$</p>	2	Or multiples Ignore state symbols
5	(b)	(iii)	<p>One from</p> <ul style="list-style-type: none"> • TiC / carbide is produced • Product is brittle • Product is a poor engineering material 	1	
5	(c)	(i)	<p>One from</p> <p>To allow</p> <ul style="list-style-type: none"> • <u>ions to move</u> • <u>current to flow</u> • it to <u>conduct electricity</u> 	1	
5	(c)	(ii)	$2\text{O}^{2-} \longrightarrow \text{O}_2 + 4\text{e}^-$	1	<p>Or multiples including</p> $3\text{O}^{2-} \longrightarrow 1.5 \text{O}_2 + 6\text{e}^-$ Ignore state symbols Ignore charge on the electron Credit the electron being subtracted on the LHS
5	(c)	(iii)	<p>Carbon / graphite / the electrodes <u>oxidise</u></p> <p>OR</p> <p>Carbon / graphite / the electrodes <u>burn in</u> / <u>react with</u> the <u>oxygen</u> formed</p> <p>OR</p> <p>carbon dioxide / CO_2 is formed</p>	1	

5	(c)	(iv)	Recycling involves <u>lower electricity</u> OR <u>less energy</u> consumption OR The converse for electrolysis	1	Ignore references to raw materials Assume that "it" means recycling The answer MUST show some evidence of comparison e.g. lower or less
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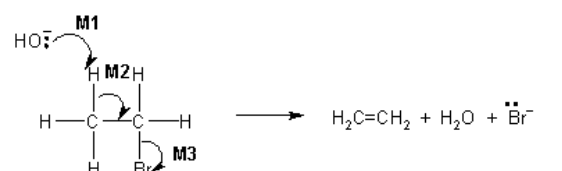
Q	Part	Sub Part	Marking Guidance	Mark	Comments
6	(a)		Hydrochloric acid contains <u>chloride ions / Cl⁻</u> OR <u>Chloride ions / Cl⁻</u> (in the acid) would react OR <u>Chloride ions / Cl⁻</u> would interfere with the test OR Would form a (white) <u>precipitate</u> OR Would form <u>insoluble</u> AgCl	1	QoL If a precipitate colour is given it must be white
6	(b)		M1 No precipitate OR Colourless solution OR No change. M2 <u>Silver fluoride / AgF</u> is soluble (in water)	1 1	Ignore “nothing” Do not penalise the spelling “flouride”
6	(c)		M1 <u>Yellow precipitate</u> OR <u>Yellow solid</u> M2 $\text{Ag}^+ + \text{I}^- \longrightarrow \text{AgI}$	1 1	Both words needed for M1 Ignore “pale” as a prefix before “yellow” Ignore state symbols Allow crossed out nitrate ions, but penalise if not crossed out

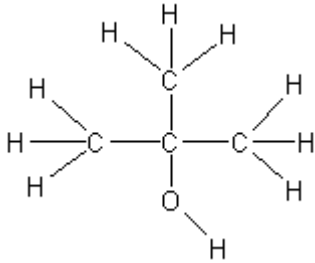
[illegible]

7	(c)	(ii)		1	<p>Award credit provided it is obvious that the candidate is drawing the <u>trans isomer</u>.</p> <p>Do not penalise poor C–C bonds</p> <p>Trigonal planar structure not essential</p>
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Q	Part	Sub Part	Marking Guidance	Mark	Comments
8	(a)		<u>Electron pair donor</u> OR Species which uses a pair of electrons to form a co-ordinate / covalent bond.	1	QoL Credit "lone pair" as alternative wording
8	(b)		<div style="text-align: center;"> </div> <p>M1 Must show an arrow from the lone pair of electrons on the carbon atom of the negatively charged cyanide ion to the central C atom.</p> <p>M2 Must show the movement of a pair of electrons from the C-Br bond to the Br atom. Mark M2 independently.</p> <p>Award full marks for an S_N1 mechanism in which M1 is the attack of the cyanide ion on the intermediate carbocation.</p>	2	<p>Penalise M1 if covalent KCN is used</p> <p>Penalise M2 for formal charge on C or incorrect partial charges</p> <p>Penalise once only for a line and two dots to show a bond.</p> <p>Max 1 mark for the wrong reactant or "sticks"</p>

8	(c)	<p>Ethylamine / $\text{CH}_3\text{CH}_2\text{NH}_2$ is a nucleophile OR Ethylamine could react further OR Ethylamine could make secondary / tertiary amines OR To make reaction with ammonia more likely OR To minimise further substitution OR The idea of releasing free amine from the salt OR The idea of removing a proton from the intermediate alkylammonium ion OR The idea that ammonia acts <u>both</u> initially as a nucleophile and then as a base</p>	1	Do not credit a simple reference to the equation or the mechanism requiring two moles of ammonia.
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8	(d)	<p>Elimination</p>  <p>M1 Must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to the correct H atom</p> <p>M2 Must show an arrow from the correct C-H bond to the C-C bond and should only be awarded if an attempt has been made at M1</p> <p>M3 Is independent.</p> <p>Award full marks for an E1 mechanism in which M2 is on the correct carbocation.</p>	<p>1</p> <p>Credit “base elimination” but NOT “nucleophilic elimination” No other prefix.</p> <p><u>Mechanism</u> Penalise M1 if covalent KOH</p> <p>Penalise M3 for formal charge on C or incorrect partial charges</p> <p>Penalise once only for a line and two dots to show a bond.</p> <p>Max 2 marks <u>for the mechanism</u> for wrong reactant or “sticks”</p> <p>3</p>
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Q	Part	Sub Part	Marking Guidance	Mark	Comments
9	(a)		Secondary OR 2° (alcohol);	1	
9	(b)		<p>Spectrum is for butanone (or formula) or butan-2-one</p> <p>If butanone is correctly identified, award <u>any two</u> from</p> <ul style="list-style-type: none"> (Strong) absorption / peak at approximately 1700 (cm^{-1}) / 1710 (cm^{-1}) / in the range 1680 – 1750 (cm^{-1}) This needs to be stated. (Characteristic) absorption / peak for C=O (may be shown on the spectrum in the correct place). No absorption / peak in range 3230 to 3550 cm^{-1}. No absorption / peak for an OH group. 	1 2	<p><u>The explanation marks depend on correctly identifying butanone.</u></p> <p>Look at the spectrum to see if anything is written on it that might gain credit.</p> <p>Allow the words “dip” OR “spike” OR “low transmittance” as alternatives for absorption.</p>
9	(c)		<p><u>Displayed structure</u> for 2-methylpropan-2-ol</p> 	1	Must have <u>all bonds</u> drawn out but ignore the bond angles

Q	Part	Sub Part	Marking Guidance	Mark	Comments
10	(a)		<p>M1 $\text{MnO}_2 + 4\text{H}^+ + 2\text{e}^- \longrightarrow \text{Mn}^{2+} + 2\text{H}_2\text{O}$</p> <p>M2 An oxidising agent is an <u>electron acceptor</u> OR <u>receives / accepts / gains electrons</u></p> <p>M3 MnO_2 is the oxidising agent</p>	1 1 1	OR multiples Ignore state symbols M2 NOT an “electron pair acceptor” Ignore “takes electrons” or “takes away electrons”
10	(b)		<p>M1 Formation of SO_2 and Br_2 (could be in an equation)</p> <p>M2 Balanced equation Several possible equations $2\text{KBr} + 3\text{H}_2\text{SO}_4 \rightarrow 2\text{KHSO}_4 + \text{Br}_2 + \text{SO}_2 + 2\text{H}_2\text{O}$ OR $2\text{KBr} + 2\text{H}_2\text{SO}_4 \rightarrow \text{K}_2\text{SO}_4 + \text{Br}_2 + \text{SO}_2 + 2\text{H}_2\text{O}$</p> <p>M3 $2\text{KBr} + \text{Cl}_2 \rightarrow 2\text{KCl} + \text{Br}_2$</p> <p>M4 % atom economy of bromine $= \frac{\text{Br}_2}{2\text{KBr} + \text{Cl}_2} \times 100 = \frac{(2 \times 79.9)}{238 + 71} \times 100 = \frac{159.8}{309} \times 100$ = 51.7% OR 52%</p> <p>M5 One from: <ul style="list-style-type: none"> • High atom economy • Less waste products • Cl_2 is available on a large-scale • No SO_2 produced • Does not use concentrated H_2SO_4 • (Aqueous) KBr or bromide (ion) in seawater. • Process 3 is simple(st) or easiest to carry out </p>	1 1 1 1 1	<p>M2 Could be ionic equation with or without K^+ $2\text{Br}^- + 6\text{H}^+ + 3\text{SO}_4^{2-} \rightarrow \text{Br}_2 + 2\text{HSO}_4^- + \text{SO}_2 + 2\text{H}_2\text{O}$ $(3\text{H}_2\text{SO}_4)$</p> <p>$2\text{Br}^- + 4\text{H}^+ + \text{SO}_4^{2-} \rightarrow \text{Br}_2 + \text{SO}_2 + 2\text{H}_2\text{O}$ $(2\text{HBr} + \text{H}_2\text{SO}_4)$</p> <p>Accept HBr and H_2SO_4 in these equations as shown or mixed variants that balance. Ignore equations for KBr reacting to produce HBr M3 Could be ionic equation with or without K^+ $2\text{Br}^- + \text{Cl}_2 \rightarrow 2\text{Cl}^- + \text{Br}_2$</p> <p>M4 Ignore greater number of significant figures</p> <p>M5 Ignore reference to cost Ignore reference to yield</p>

10	(c)		<p>M1 HBr -1</p> <p>M2 HBrO (+)1</p> <p>M3 Equilibrium will shift <u>to the right</u> OR <u>L to R</u> OR Favours forward reaction OR Produces more HBrO</p> <p>M4 <u>Consequential on correct M3</u> OR to <u>oppose the loss</u> of HBrO OR <u>replaces</u> (or implied) the HBrO (that has been used up)</p>	<p>1</p> <p>1</p> <p>1</p> <p>1</p>	
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Q	Part	Sub Part	Marking Guidance	Mark	Comments
11	(a)		<p>M1 (Free-) radical substitution</p> <p>M2 $\text{Cl}_2 \longrightarrow 2\text{Cl}\cdot$</p> <p>M3 $\text{Cl}\cdot + \text{CH}_4 \longrightarrow \cdot\text{CH}_3 + \text{HCl}$</p> <p>M4 $\text{Cl}_2 + \cdot\text{CH}_3 \longrightarrow \text{CH}_3\text{Cl} + \text{Cl}\cdot$</p> <p>M5 $\text{CH}_4 + 3\text{Cl}_2 \longrightarrow \text{CHCl}_3 + 3\text{HCl}$</p>	<p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p>	<p>Both words needed</p> <p>Penalise the absence of a radical dot once only</p> <p>Ignore termination steps except, if and only if both M3 and M4 do not score, then accept for one mark</p> <p>$\text{Cl}\cdot + \cdot\text{CH}_3 \longrightarrow \text{CH}_3\text{Cl}$</p>
11	(b)		<p>M1 UV (light)/ sunlight / light / UV radiation</p> <p>M2 <u>C–Cl</u> or <u>carbon-chlorine bond</u> breakage OR homolysis of <u>C–Cl</u> OR equation to show a chlorine-containing organic compound forming two radicals</p> <p>M3 $\text{Cl}\cdot + \text{O}_3 \longrightarrow \text{ClO}\cdot + \text{O}_2$</p> <p>M4 $\text{ClO}\cdot + \text{O}_3 \longrightarrow \text{Cl}\cdot + 2\text{O}_2$</p> <p>M5 Any one from</p> <ul style="list-style-type: none"> Combination $2\text{O}_3 \rightarrow 3\text{O}_2$ <u>Stated</u> that $\text{Cl}\cdot$ / chlorine atom is regenerated / not used up <u>Stated</u> that the $\text{Cl}\cdot$ / chlorine atom is unaffected by the process. <p>M6 <u>Stated</u> that the role of the $\text{Cl}\cdot$ / chlorine atom is to find an alternative route OR lower E_a / activation energy</p>	<p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p> <p>1</p>	<p>For M1 and M2, ignore use of Cl_2, but credit UV and C–Cl bond breakage if seen</p> <p>Ignore other equations</p> <p>Penalise the absence of a radical dot once only</p> <p>Accept radical dot anywhere on either radical.</p> <p>For M5 accept $\text{Cl}\cdot$ on <u>both sides</u> of the equation</p>

11	(c)		<p>M1 Halothane contains C–Cl / Cl OR Desflurane does not contain C–Cl bonds / Cl OR Desflurane contains C–F / F as the <u>only</u> halogen</p> <p>M2 Desflurane / molecules that have fluorine as the <u>only</u> halogen, cause no damage / do not deplete / do not react with the ozone (layer) OR Halothane / chlorine-containing molecules, damage / deplete / react with the ozone (layer)</p>	<p>1</p> <p>1</p>	<p>Mark independently. For M1, credit the idea that desflurane contains C–F bonds that are difficult to break OR that halothane contains C–Cl bonds which are easy to break.</p>
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