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ASSESSMENT and QUALIFICATIONS ALLIANCE

General Certificate of Education

Chemistry 1421

CHEM2 Chemistry in Action

Mark Scheme

2009 examination - June series

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Dr Michael Cresswell Director Gener

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

Q	Part	Sub Part	Marking Guidance	Mark	Comments
2	(a)	(i)	**M1** The enthalpy change / heat change at constant pressure when <u>1 mol</u> of a compound / substance / product **M2** Is formed from its (constituent) <u>elements</u> **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	1 1 1	 Ignore reference to 1 atmosphere
2	(a)	(ii)	By definition **OR** Because they are elements	1	
2	(a)	(iii)	**M1** $\Delta H_r = \sum \Delta H_f$ (**products) -** $\sum \Delta H_f$ (**reactants**) **M2** = -1669 - 3(-558) (This also scores M1) **M3** **=(+) 5** (kJ mol^{-1})	1 1 1	Correct answer gains full marks. Assume the value is positive unless specifically stated as negative. Credit 1 mark if **–** 5 (kJ mol^{-1}). For other incorrect or incomplete answers, proceed as follows: • 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)	*One from* • Aluminium is expensive (to extract ***OR*** due to electrolysis) • High energy cost • The cost of heating strongly	1	This requires a clear statement about cost
2	(b)	(ii)	*One from* • increase collision frequency • OR more collisions • OR more chance of colliding	1	The answer MUST refer to more collisions. Ignore "more available to collide"
2	(c)	(i)	$Ba + \mathbf{2}H_2O \longrightarrow Ba(OH)_2 + H_2$	1	Ignore state symbols Allow multiples and correct ionic equations
2	(c)	(i)	**M1** $Ba^{2+} + SO_4^{2-} \longrightarrow BaSO_4$ (or the ions together) **M2** White precipitate / white solid	1 1	Allow crossed out Na^+ ions, but penalise if not crossed out Ignore state symbols Ignore "milky"
2	(c)	(iii)	**M1** Barium meal or (internal) X-ray or to block X-rays **M2** $BaSO_4$ / barium sulfate is insoluble (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 x 1.92 x 9.5 = **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 x 0.96 x 9.5 = **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)	**M1** Addition of (a)(ii) and (a)(iii) **M2** Multiply by 10 and convert to kJ (divide by 1000) <u>leading to an answer</u> Therefore ΔH = **(-) 2.69** ***OR*** **(-) 2.7(0)** (kJ mol^{-1})	2	Consequential on (a)(ii) and (a)(iii) Penalise wrong units Ignore the sign Ignore greater numbers of significant figures (2.69496) Subtraction in M1 is CE
3	(b)		One from: • 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** Concentrations of reactants and products remain constant **M2** Forward rate = Reverse / backward rate	1 1	For M1 NOT "equal concentrations" NOT "amount" Credit the use of [ ] for concentration Ignore dynamic, ignore closed system
4	(b)		**M1** The (forward) reaction / to the right is exothermic or releases heat OR converse for reverse reaction. **M2** The equilibrium responds by absorbing heat / lowering temperature ***OR*** Promotes the endothermic reaction by absorbing heat / lowering temperature ***OR*** Temperature increase is opposed (by shift to the left) ***OR*** Change is opposed by absorbing heat / lowering temperature.	1 1	
4	(c)	(i)	A substance that speeds up / alters the rate but is unchanged at the end / not used up.	1	Both ideas needed 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	

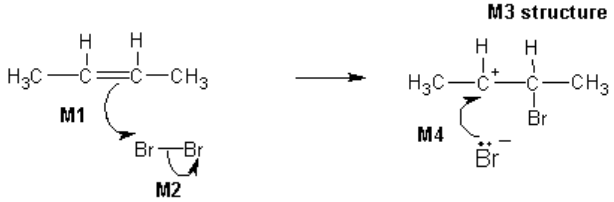
4	(d)	(i)	An activity which has no <u>net / overall</u> (annual) carbon emissions to the atmosphere ***OR*** An activity which has no <u>net / overall</u> (annual) greenhouse gas emissions to the atmosphere. ***OR*** There is no change in the <u>total amount</u> of carbon dioxide / carbon /<u>greenhouse gas present in the atmosphere</u>.	1	The idea that the carbon / CO_2 given out equals the carbon / CO_2 that was taken in Ignore carbon monoxide
4	(d)	(ii)	A method which shows (see below) OR states in words that two times the first equation + the second equation gives the correct ratio. **2** ($CH_4 + H_2O \longrightarrow CO + 3H_2$) $CH_4 + CO_2 \longrightarrow 2CO + 2H_2$ $3CH_4 + 2H_2O + CO_2 \longrightarrow$ **4**CO + **8**H_2 Ratio = 1 : 2	1	

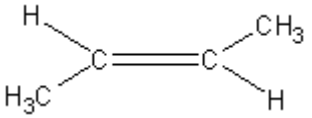
Q	Part	Sub Part	Marking Guidance	Mark	Comments
5	(a)	(i)	**2**C + O_2 → **2**CO ***OR*** C + CO_2 → **2**CO	1	Or multiples. Ignore state symbols.
5	(a)	(ii)	Fe_2O_3 + **3**CO → **2**Fe + **3**CO_2	1	Or multiples Penalise FE and Fe_2 Ignore state symbols
5	(a)	(iii)	**Economic**: • Scrap iron/steel has higher iron content. • Recycling involves lower energy consumption • Blast furnace not required **Environmental**: • Reduces greenhouse gas / CO_2 / SO_2 emission. • Reduces acid rain • Reduces mining • Reduces landfill • Removes an eyesore	1 1	Ignore cost Assume that "it" means recycling for both reasons
5	(b)	(i)	**M1** Use of Cl_2 and C **M2** Balanced equation consequential on correct reactants **EITHER** TiO_2 + **2**Cl_2 + **2**C ⟶ $TiCl_4$ + **2**CO **OR** TiO_2 + **2**Cl_2 + C ⟶ $TiCl_4$ + CO_2	2	Or multiples Ignore state symbols

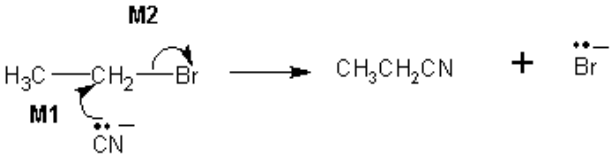
5	(b)	(ii)	**M1** Use of Na OR Mg **M2** Balanced equation consequential on correct reactants **EITHER** $TiCl_4$ + **4**Na ⟶ Ti + **4**NaCl **OR** $TiCl_4$ + **2**Mg ⟶ Ti + **2**$MgCl_2$	2	Or multiples Ignore state symbols
5	(b)	(iii)	One from • TiC / carbide is produced • Product is brittle • Product is a poor engineering material	1	
5	(c)	(i)	One from To allow • ions to move • current to flow • it to conduct electricity	1	
5	(c)	(ii)	**2**O^{2-} ⟶ O_2 + **4**e^-	1	Or multiples including **3**O^{2-} ⟶ **1.5** O_2 + **6**e^- Ignore state symbols Ignore charge on the electron Credit the electron being subtracted on the LHS
5	(c)	(iii)	Carbon / graphite / the electrodes oxidise ***OR*** Carbon / graphite / the electrodes burn in / react with the oxygen formed ***OR*** carbon dioxide / CO_2 is formed	1	

5	(c)	(iv)	Recycling involves lower electricity OR less energy 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

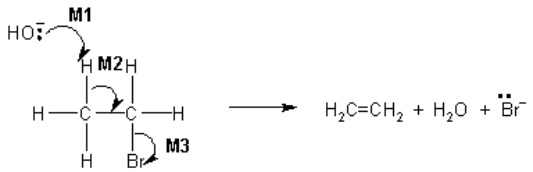
Q	Part	Sub Part	Marking Guidance	Mark	Comments
6	(a)		Hydrochloric acid contains <u>chloride ions / Cl^-</u> ***OR*** <u>Chloride ions / Cl^-</u> (in the acid) would react ***OR*** <u>Chloride ions / Cl^-</u> would interfere with the test ***OR*** Would form a (white) <u>precipitate</u> ***OR*** Would 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** $Ag^+ + I^- \longrightarrow AgI$	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

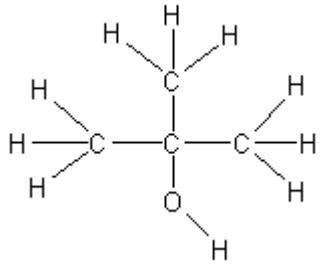
Q	Part	Sub Part	Marking Guidance	Mark	Comments
7	(a)		Contains a C=C ***OR*** a double bond	1	
7	(b)		**Electrophilic addition** Mechanism:  **M1** Must show an arrow from the double bond towards one of the Br atoms on a Br-Br molecule. **M2** Must show the breaking of the Br-Br bond. **M3** Is for the structure of the secondary carbocation with Br substituent. **M4** Must show an arrow from the lone pair of electrons on a negatively charged bromide ion towards the positively charged carbon atom.	1 4	Both words needed Ignore partial negative charge on the double bond. M2 Penalise partial charges on bromine if wrong way and penalise formal charges Penalise once only in any part of the mechanism for a line and two dots to show a bond. Deduct 1 mark for sticks. Deduct 1 mark for wrong reactant, but mark consequentially. If HBr, mark the mechanism consequentially and deduct one mark If but-1-ene, mark the mechanism consequentially and deduct one mark. If both HBr and but-1-ene, mark the mechanism consequentially and deduct ONLY one mark.
7	(c)	(i)	**M1** Compounds with the <u>same structural formula</u> **M2** With <u>atoms/bonds/groups</u> arranged <u>differently in space</u> ***OR*** <u>atoms/bonds/groups</u> have <u>different spatial arrangements/ different orientation</u>.	1 1	Penalise M1 if "same structure" Ignore references to "same molecular formula" or "same empirical formula" Mark independently.

7	(c)	(ii)		1	Award credit provided it is obvious that the candidate is drawing the <u>trans isomer</u>. Do not penalise poor C–C bonds Trigonal planar structure not essential

Q	Part	Sub Part	Marking Guidance	Mark	Comments
8	(a)		Electron pair donor ***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)		 **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. **M2** Must show the movement of a pair of electrons from the C-Br bond to the Br atom. Mark M2 independently. Award full marks for an S_N1 mechanism in which M1 is the attack of the cyanide ion on the intermediate carbocation.	2	Penalise M1 if covalent KCN is used Penalise M2 for formal charge on C or incorrect partial charges Penalise once only for a line and two dots to show a bond. Max 1 mark for the wrong reactant or "sticks"

8	(c)		Ethylamine / $CH_3CH_2NH_2$ 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	1	Do not credit a simple reference to the equation or the mechanism requiring two moles of ammonia.

8	(d)		**Elimination**  **M1** Must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to the correct H atom **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 **M3** Is independent. Award full marks for an E1 mechanism in which M2 is on the correct carbocation.	1 3	Credit "base elimination" but NOT "nucleophilic elimination" No other prefix. <u>Mechanism</u> Penalise M1 if covalent KOH Penalise M3 for formal charge on C or incorrect partial charges Penalise once only for a line and two dots to show a bond. Max 2 marks **<u>for the mechanism</u>** for wrong reactant or "sticks"

Q	Part	Sub Part	Marking Guidance	Mark	Comments
9	(a)		Secondary ***OR*** 2^{o} (alcohol);	1	
9	(b)		Spectrum is for **butanone (or formula) or butan-2-one** If butanone is correctly identified, award <u>any two</u> from • (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	<u>The explanation marks depend on correctly identifying butanone.</u> Look at the spectrum to see if anything is written on it that might gain credit. Allow the words “dip” OR “spike” OR “low transmittance” as alternatives for absorption.
9	(c)		<u>Displayed structure</u> for 2-methylpropan-2-ol 	1	Must have <u>all bonds</u> drawn out but ignore the bond angles

Q	Part	Sub Part	Marking Guidance	Mark	Comments
10	(a)		**M1** $MnO_2 + \mathbf{4}H^+ + \mathbf{2}e^- \longrightarrow Mn^{2+} + \mathbf{2}H_2O$	1	OR multiples
			M2 An oxidising agent is an <u>electron acceptor</u> OR <u>receives / accepts / gains electrons</u>	1	Ignore state symbols M2 NOT an "electron pair acceptor"
			M3 MnO_2 is the oxidising agent	1	Ignore "takes electrons" or "takes away electrons"
10	(b)		**M1** Formation of SO_2 and Br_2 (could be in an equation)	1	M2 Could be ionic equation with or without K^+ $\mathbf{2}Br^- + \mathbf{6}H^+ + \mathbf{3}SO_4^{2-} \rightarrow Br_2 + \mathbf{2}HSO_4^- + SO_2 + \mathbf{2}H_2O$
			M2 Balanced equation **Several possible equations** $\mathbf{2}KBr + \mathbf{3}H_2SO_4 \rightarrow \mathbf{2}KHSO_4 + Br_2 + SO_2 + \mathbf{2}H_2O$ **OR** $\mathbf{2}KBr + \mathbf{2}H_2SO_4 \rightarrow K_2SO_4 + Br_2 + SO_2 + \mathbf{2}H_2O$	1	($\mathbf{3}H_2SO_4$) $\mathbf{2}Br^- + \mathbf{4}H^+ + SO_4^{2-} \rightarrow Br_2 + SO_2 + \mathbf{2}H_2O$ ($\mathbf{2}HBr + H_2SO_4$) 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 $\mathbf{2}KBr + Cl_2 \rightarrow \mathbf{2}KCl + Br_2$	1	M3 Could be ionic equation with or without K^+ $\mathbf{2}Br^- + Cl_2 \rightarrow \mathbf{2}Cl^- + Br_2$
			M4 % atom economy of bromine $= \frac{Br_2}{2KBr + Cl_2} \times 100 = \frac{(2 \times 79.9)}{238 + 71} \times 100 = \frac{159.8}{309} \times 100$ $= \mathbf{51.7}\%$ OR $\mathbf{52}\%$	1	M4 Ignore greater number of significant figures
			M5 One from: • 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	1	M5 Ignore reference to cost Ignore reference to yield

10	(c)		**M1**	HBr **-1**	1	
			M2	HBrO (**+)1**	1	
			M3	Equilibrium will shift <u>to the right</u> ***OR*** <u>L to R</u> ***OR*** Favours forward reaction ***OR*** Produces more HBrO	1	
			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)	1	

Q	Part	Sub Part	Marking Guidance	Mark	Comments
11	(a)		**M1** (Free-) **radical substitution**	1	Both words needed
			M2 $Cl_2 \longrightarrow$ **2**Cl•	1	Penalise the absence of a radical dot once only
			M3 Cl• + $CH_4 \longrightarrow$ •CH_3 + HCl	1	
			M4 Cl_2 + •$CH_3 \longrightarrow$ CH_3Cl + Cl•	1	**Ignore termination steps except, if and only if <u>both</u>** M3 and M4 do not score, then accept for one mark
			M5 CH_4 + **3**$Cl_2 \longrightarrow$ $CHCl_3$ + **3**HCl	1	Cl• + •$CH_3 \longrightarrow CH_3Cl$
11	(b)		**M1** UV (light)/ sunlight / light / UV radiation	1	For M1 and M2, ignore use of Cl_2, but credit UV and C–Cl bond breakage if seen
			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	1	
			M3 Cl• + $O_3 \longrightarrow$ ClO• + O_2	1	Ignore other equations
			M4 ClO• + $O_3 \longrightarrow$ Cl• + $2O_2$	1	Penalise the absence of a radical dot once only
			M5 Any **<u>one</u>** from • Combination $2O_3 \rightarrow 3O_2$ • <u>Stated</u> that Cl• / chlorine atom is regenerated / not used up • <u>Stated</u> that the Cl• / chlorine atom is unaffected by the process.	1	Accept radical dot anywhere on either radical. For M5 accept Cl• on <u>both sides</u> of the equation
			M6 <u>Stated</u> that the role of the Cl• / chlorine atom is to find an alternative route ***OR*** lower E_a / activation energy	1	

11	(c)		**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	1	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.
			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)	1	