GCE

Chemistry A

H032/02: Depth in chemistry

Advanced Subsidiary GCE

Mark Scheme for Autumn 2021

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

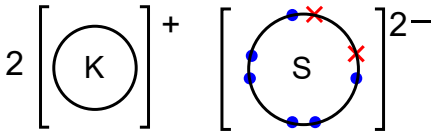
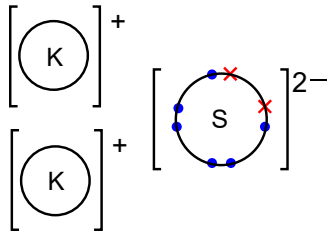
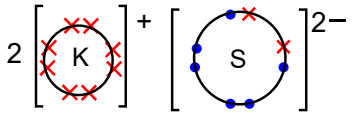
Mark schemes should be read in conjunction with the published question papers and the report on the examination.

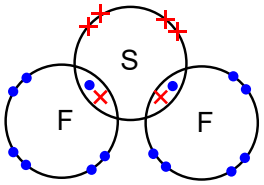
1. Annotations

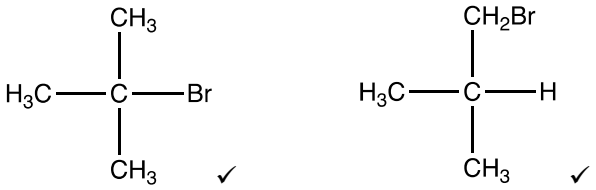
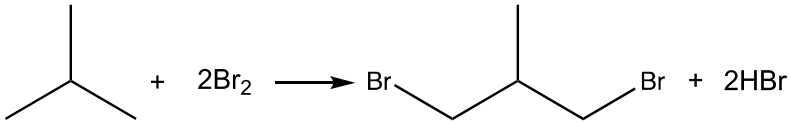
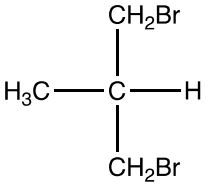
Annotation	Meaning
	Correct response
	Incorrect response
	Omission mark
BOD	Benefit of doubt given
CON	Contradiction
RE	Rounding error
SF	Error in number of significant figures
ECF	Error carried forward
L1	Level 1
L2	Level 2
L3	Level 3
NBOD	Benefit of doubt not given
SEEN	Noted but no credit given
I	Ignore

2. Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

Annotation	Meaning
/	alternative and acceptable answers for the same marking point
✓	Separates marking points
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

Question			Answer	Marks	AO element	Guidance
1	(a)	(i)	(Electrostatic) **attraction** between oppositely charged **ions** ✓	1	AO1.1	**IGNORE** force **IGNORE** references to transfer of electrons
		(ii)	 **Dot and cross** 2 × K shown with either 8 or 0 electrons **AND** S shown with 8 electrons with 2 crosses and 6 dots (or vice versa) ✓ **Charges** Correct charges on K^+ **AND** S^{2-} ions ✓	2	AO2.5 × 2	**ALLOW** separate K^+ ions, i.e.  If 8 electrons are shown around K, 'extra electrons' around S must match symbol chosen for electrons around K, e.g.  Shell circles **NOT** needed **IGNORE** inner shell electrons

Question			Answer	Marks	AO element	Guidance
	(b)		 **Bonded pairs** Electron pairs in covalent bonds shown correctly using dots and crosses in SF_2 molecule ✓ **Lone pairs** Lone pairs correct on S and 2 F atoms ✓	**2**	AO2.5 × 2	Shell circles **NOT** needed **IGNORE** inner shells **ALLOW** Non-bonding electrons shown as unpaired
	(c)		**K_2S**: ionic bonds are strong **OR** has a **giant** ionic lattice ✓ **SF_2**: London forces/ dipole-dipole forces are weak ✓ between molecules ✓	**3**	AO1.1 × 2 AO1.2	 **ALLOW** induced **OR** permanent dipole interactions **ALLOW** intermolecular forces are weak for 2 marks for SF_2 **IGNORE** van der Waals forces, vdW
	(d)	(i)	Octahedral ✓ 90 ° ✓	**2**	AO1.1 × 2	
		(ii)	SF_6 has no overall dipole **OR** is non polar **OR** S–F bonds are strong **OR** SF_6 has no lone pairs ✓	**1**	AO2.1	
			Total	**11**		

Question			Answer	Marks	AO element	Guidance
2	(a)		A species with an unpaired electron ✓	1	AO1.1	**DO NOT ALLOW**: species with **one** electron
	(b)		Homolytic (fission) ✓	1	AO1.1	
	(c)		 ✓ ✓	2	AO2.5 × 2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
	(d)		 Structure of organic product ✓ Complete balanced equation ✓	2	AO2.5 AO2.6	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous, e.g. 
			Total	6		

Question			Answer	Marks	AO element	Guidance
3	(a)		From colourless to pink ✓	1	AO2.3	
	(b)	(i)	Titre: 18.50, 18.05, 18.20, 18.30 ✓ *All titres with 2 DP and ending with '0'* ***OR*** *'5'*	1	AO2.4	**DO NOT ALLOW** responses given to only 1 decimal place
		(ii)	To estimate the titre ✓	1	AO2.3	**ALLOW** 'getting a rough idea of the titre' (or similar wording)
		(iii)	18.25 cm^3 ✓	1	AO2.4	
		(iv)	% uncertainty = $\frac{0.1}{18.05} \times 100 = 0.55$ % ✓	1	AO2.4	**ALLOW** ECF from incorrect subtraction in (b)(i) or incorrect mean **ALLOW** calculation from other titre values
	(c)		**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 3 AND *M* = 132(,0)…. award 5 marks** --- $n(NaOH) = \frac{18.25 \times 0.240}{1000} = 4.38 \times 10^{-3}$ ✓ n(acid) in 25 $cm^3 = \frac{4.38 \times 10^{-3}}{2} = 2.19 \times 10^{-3}$ (mol) ✓ n(acid) in 250 $cm^3 = 2.19 \times 10^{-2}$ (mol) ✓ M(acid) $= \frac{2.891}{2.19 \times 10^{-2}} = 132(.0)\ldots\ldots$ ($g\ mol^{-1}$) ✓ $M(CH_2)_n$ = 132 – 90 **OR** (132.0…. – 90) **OR** 42 *(seen anywhere)* **AND** $n = \frac{42}{14} = 3$ ✓ **whole number required**	5	AO2.8 ×4 AO3.2	**ALLOW ECF throughout** **ALLOW ECF** from **(b)(iii)** Answers should be to at least 3 significant figures for first 4 marks.

	(d)		The titre would be less ✓ Glutaric acid would be less concentrated/more dilute ✓	**2**	AO3.3 × 2	
			Total	**12**		

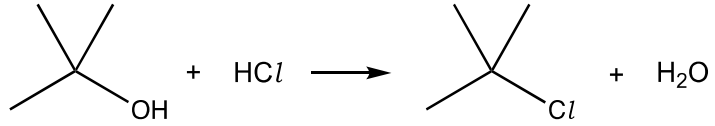
Question			Answer	Marks	AO element	Guidance
4	(a) *		*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Calculates **CORRECT** enthalpy change with correct signs for ΔH_2 for **reaction 2** **AND** ΔH_1 for **reaction 1**. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Calculates a value of ΔH_2 for **reaction 2** from the: Energy change **AND** Amount in mol of $MgCO_3$. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Processes experimental data to obtain the Energy change from $mc\Delta T$ **OR** Amount in moles of $MgCO_3$ *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	6	AO3.1 × 4 AO3.2 × 2	*Indicative scientific points may include:* **1. Processing experimental data** **Energy change from $mc\Delta T$** • Energy in J **OR** kJ *Using 103.01 g or 100.0 g* = **103.01** × 4.18 × 5.0 = 2152.909 (J) **OR** 2.153 (kJ) *3SF or more (2.152909 unrounded)* **OR** **100.0** × 4.18 × 5.0 = 2090 (J) **OR** 2.09 (kJ) --- **Amount in mol of $MgCO_3$** $n(MgCO_3) = \frac{4.215}{84.3} = 0.0500$ (mol) --- **2. ± value of ΔH_2 for reaction 2** From m = 103.01 g $= \pm \frac{2.153}{0.0500} =$ **±43.06** (kJ mol^{-1}) *(–43.05818 unrounded)* From m = 100.0 g $= \pm \frac{2.19}{0.0500} =$ **±41.8** (kJ mol^{-1}) --- **3. CORRECT enthalpy changes for Reaction 1 and Reaction 2 with signs (using 103.01 g ONLY)** **Reaction 2** = **–43.06** (kJ mol^{-1}) *3SF or more with correct – sign* **Reaction 1** $\Delta H_1 = \Delta H_2 - \Delta H_3$ = –43.06 – (–136.1) = **+93.04** (kJ mol^{-1}) *3SF or more with correct – sign* **ALLOW** omission of trailing zeroes, e.g. 93 for 93.0 **NOTE**: If 100 g used, ΔH is incorrect and L3 cannot be attained
			Total	**6**		

Question			Answer	Marks	AO element	Guidance
5	(a)		$K_c = \frac{[CH_3OH]}{[CO] \times [H_2]^2}$ ✓	1	AO1.2	Multiplication sign is not required **DO NOT ALLOW** curved brackets
	(b)	(i)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer =** 1.4…….. **(mol dm^{-3}) award 2 marks** --- $[CH_3OH] = 15.4 \times 0.57 \times 0.40^2$ ✓ $= 1.40448$ (mol dm^{-3}) ✓	2	AO2.2 × 2	**ALLOW ECF** from incorrect expression in **(a)** **ALLOW** 1.4 up to calculator value of 1.40448
		(ii)	To the right ✓	1	AO1.1	**ALLOW** towards the product/CH_3OH
	(c)		Less fossil fuel used ✓ Reduction in CO_2 (emissions) ✓	2	AO3.2 ×2	**ALLOW** Less energy used
	(d)	(i)	d-block ✓	1	AO1.1	
		(ii)	$1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^1$ ✓ *Look carefully at $1s^2 2s^2 2p^6 3s^2 3p^6$ – there may be a mistake*	1	AO1.2	**ALLOW** 4s **AND/OR** $4p^1$ before 3d, e.g. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^1$ **ALLOW** $1s^2$ after answer prompt (*ie* $1s^2$ twice) **ALLOW** upper case D, etc and subscripts, e.g. ……$4S_2 3D_8$ **DO NOT ALLOW** [Ar] as shorthand for $1s^2 2s^2 2p^6 3s^2 3p^6$

Question			Answer	Marks	AO element	Guidance
	(e)		Element **A** is silicon/Si ✓ **AND** A large increase between the 4rd and 5th IE 5th electron is removed from shell closer to the nucleus **OR** there are 4 electrons in the outer shell ✓	**2**	AO3.1 AO3.2	**ALLOW** an indication of a different shell (from removal of 5th electron)
			Total	**10**		

Question			Answer	Marks	AO element	Guidance
6	(a)		Best fit curve ✓ Tangent drawn at approximately t = 50 s ✓ Gradient calculated: 0.44 ± 0.2 ($cm^3\ s^{-1}$) ✓	3	AO1.2 AO2.4 × 2	**DO NOT ALLOW** interpolation (taking a direct reading from graph), answer must be derived from taking a gradient **ALLOW** ECF from incorrectly drawn tangent
	(b)		Advantage: no loss of gas ✓ Disadvantage: small loss in mass ✓	2	AO3.4 × 2	**IGNORE** easier to set up
	(c)	(i)	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 0.41 (g) award 2 marks** --- n(Ba) = $\frac{0.26}{87.6}$ **OR** 2.9…….. × 10^{-3} **OR** 3 × 10^{-3} ✓ mass Ba = 137.3 × 2.9…….. × 10^{-3} = 0.41 g ✓ **2 DP required**	2	AO3.3 ×2	**ALLOW** ECF from incorrect moles of Ba Calculator: 2.96803653 × 10^{-3} **NOTE** 3 × 10^{-3} also gives 0.41 g
		(ii)	Steeper initial gradient **AND** levels off earlier ✓ Same volume of gas produced ✓	2	AO3.1 × 2	

Question			Answer	Marks	AO element	Guidance
		(iii)	**Reactivity** Ba is more reactive (than Sr) ✓ **Atomic radius** Ba has a **greater** atomic radius (than Sr) **OR** Ba has **more** shells **OR** Ba has **more** shielding ✓ **Attraction** Nuclear attraction is less in Ba **OR** (outer) electrons in Ba are less attracted (to nucleus) **OR** Increased distance / shielding in Ba outweighs increased nuclear charge ✓ **Ionisation energy** Ionisation energy of Ba is less **OR** easier to remove (outer) electrons in Ba ✓	**4**	AO1.1 × 4	Comparison required throughout **ORA** throughout For **more** shells**, ALLOW** higher energy level **IGNORE** more orbitals **OR** more sub-shells **IGNORE** 'different shell' or 'new shell' **ALLOW** Ba has less nuclear pull' **OR** 'Ba electrons are less tightly held' **IGNORE** less effective nuclear charge' **IGNORE** 'nuclear charge' for 'nuclear attraction' **ALLOW** easier to oxidise Ba
			Total	**13**		

Question			Answer	Marks	AO element	Guidance
7	(a)		 Correct skeletal formulae for organic compounds ✓ Complete balanced equation ✓	2	AO2.5 × 2	Skeletal formulae needed for 1st marking point. For complete balanced equation, **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous, e.g. $(CH_3)_3COH + HCl \rightarrow (CH_3)_3CCl + H_2O$

Question	Answer	Marks	AO element	Guidance
(b) *	*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Explains the purification steps with most fine detail. **AND** Calculates correct mass of 2-chloro-2-methylpropane, $(CH_3)_3CCl$ *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Describes some purification steps, with some detail. **AND** Calculates the mass of $(CH_3)_3CCl$ with some errors. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Describes few purification steps. **OR** Attempts to calculate the mass of $(CH_3)_3CCl$ with little progress. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	**6**	AO1.2 × 2 AO2.7 × 2 AO3.3 × 2	**Indicative scientific points may include:** **<u>Main purification stages</u>** • Separating funnel to remove organic layer from aqueous layer • Anhydrous salt to dry organic layer • Distillation to purify the product **Fine detail** • Organic layer is the top layer • Name of a drying agent e.g. anhydrous $MgSO_4$ or $CaCl_2$ • Collect fraction at 50 °C **IGNORE** washing with carbonate/water *not in spec.* **<u>Calculation of mass of $(CH_3)_3CCl$</u>** • $n((CH_3)_3COH) = \frac{7.70}{74.0} = 0.10405$ (mol) • *expected* $n((CH_3)_3CCl)$ $= 0.10405 \times \frac{76}{100} = 0.0791$ (mol) • expected mass = 0.0791 × 92.5 = 7.315 g **ALLOW** 7.31–7.32 for small slip/rounding **Using mass** • Theoretical mass $(CH_3)_3CCl$ $= 7.70 \times \frac{92.5}{74.0} = 9.625$ g • Mass of $(CH_3)_3CCl = 9.625 \times \frac{76}{100}$ = **7.315** g

Question			Answer	Marks	AO element	Guidance
						NOTE: Incorrect inverse ratio of $\frac{100}{76}$ gives: • $0.10405 \times \frac{76}{100} = 0.137$ (mol) • Mass = $92.5 \times 0.137 = 12.7$ g
	(c)	**(i)**	Butan-2-ol ✓	**1**	AO1.2	
		(ii)	$(CH_3)_2CHCH_2OH + 2[O] \rightarrow (CH_3)_2CHCOOH + H_2O$ **B** as reactant: $(CH_3)_2CHCH_2OH$ ✓ $(CH_3)_2CHCOOH$ as product ✓ Correct equation with 2[O] and H_2O ✓	**3**	AO2.5 × 2 AO2.6	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous If structure of **B** is a different primary or secondary alcohol, **ALLOW ECF** for product and equation
			Total	**12**		

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