

GCE

Chemistry B

H433/02: Scientific literacy in chemistry

Advanced 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.

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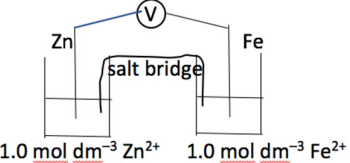
1. Annotations

Annotation	Meaning
	Correct response
	Incorrect response
	Omission mark
	Benefit of doubt given
	Contradiction
	Rounding error
	Error in number of significant figures
	Error carried forward
	Level 1
	Level 2
	Level 3
	Benefit of doubt not given
	Noted but no credit given
	Ignore

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

Annotation	Meaning
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	Mark	AO	Guidance
1	a	i	inert/unreactive ✓	1	1.2	
1	a	ii	high-boiling liquid ✓ porous support ✓	2	2 x 1.2	
1	b	i	mass spectroscopy/spectrometry ✓	1	2.7	ALLOW compare retention times with data book
1	b	ii	(compound) 1/ methylbenzene/ $C_6H_5CH_3$ ✓	1	1.1	ALLOW C_7H_8
1	c		(compound) 4/ octane ✓ Least/no branching/chains can get close (ORA) ✓ most Van der Waals forces (ORA) ✓	3	3 x 2.3	ALLOW London/id-id
1	d		$C_8H_{18} \rightarrow C_4H_8 + C_4H_{10}$ ✓	1	2.5	
1	e		no/lack of rotation about $C=C$ ✓ two different groups on each C ✓	2	2 x 1.2	ALLOW 2 diagrams to illustrate E/Z isomers
1	f		Bromine/solution decolourised/ goes (from brown/yellow/orange to) colourless ✓ $\begin{array}{c} \text{-(CH-CH-)}_n \\ \quad \\ \text{CH}_3 \quad \text{CH}_3 \end{array}$ ✓ $\begin{array}{cccc} \text{H} & \text{H} & \text{H} & \text{H} \\ & & & \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ & & & \\ \text{H} & \text{OH} & \text{H} & \text{H} \end{array}$ ✓ (sulfuric) acid and (potassium) dichromate/formulae ✓ heat/reflux ✓	5	1.2 2.3 2.3 1.2 1.2	If starting colour of bromine is given it must be brown/yellow/orange ALLOW 'decolourised' on its own as bromine named in stem of Question ALLOW any unambiguous structural formula IGNORE brackets or 'n' ALLOW 'OH' rather than 'O-H'
1	g		CHECK ANSWER ON ANSWER LINE If answer is C_3H_8 award 3 marks amount $CO_2 = 11/44 = 0.25$ mol and amount $H_2O = 6/18 = 0.33$ mol ✓ Ratio = 3:4 or C:H 3:8 ✓ Hydrocarbon is C_3H_8 ✓	3	3 x 2.6	ALLOW ecf Eg If $nCO_2 = 0.25$ AND $nH_2O = 0.3$ then the formula for the Hydrocarbon is C_5H_{12} and scores 2 marks If no other marks scored a formula of C_3H_4 scores 1 mark
				19		

Question			Answer	Mark	AO	Guidance
2	a	i	0.5/ $\frac{1}{2}$ ✓ 2 ✓	2	2 x 2.6	ALLOW 'multiples'
2	a	ii	$(\frac{1}{2})\text{O}_2$ ✓ oxidation state goes from 0 to -2 ✓	2	2 x 2.1	ALLOW 'oxygen' IGNORE 'O'
2	b	i	 1.0 mol dm⁻³ Zn²⁺ 1.0 mol dm⁻³ Fe²⁺ both electrodes and solutions ✓ salt bridge and voltmeter ✓ 1.0 mol dm⁻³ and 298 K ✓	3	3 x 3.3	IGNORE composition of salt bridge IGNORE concentrations for first mark If concentrations not given, then '(aq)' or 'solution' must be there for first mark.
2	b	ii	0.32 (V) ✓	1	2.4	
2	c		(Student is incorrect) – electrons flow from Zn to Fe ✓ Reason – E_{Zn} more negative than E_{Fe} ✓ (Student is incorrect) Half-equation 2 is not reversed/occurs in forward direction (as E_{Fe} is more positive than E_{Zn}). ✓ (Student is incorrect) The sea-water acts as the salt bridge ✓	4	3.2 3.1 3.1 3.2	Electrons flow from more negative Zn to less negative Fe scores MP1 and MP2 DO NOT ALLOW ' E_{Zn} less/lower than E_{Fe} ' ALLOW half equation 1 is reversed
2	d		$\text{Fe}(\text{OH})_2(\text{s}) + \frac{1}{4} \text{O}_2(\text{g}) + \frac{1}{2} \text{H}_2\text{O}(\text{l}) \rightarrow \text{Fe}(\text{OH})_3(\text{s})$ correct formulae ✓ equation correctly balanced ✓ all ss correct ✓	3	3 x 2.7	ALLOW multiples ALLOW even if equation/balancing incorrect
2	e		amount $\text{Fe}_2\text{O}_3 \cdot 2\text{H}_2\text{O} = 5/195.6 (= 0.0256) \text{ mol}$ ✓ mass water = $0.0256 \times 2 \times 18 = 0.92 \text{ g}$ so students incorrect ✓	2	3.1 3.2	ALLOW ecf OR amount of $\text{Fe}_2\text{O}_3 = 4/159.6 = 0.025$ ✓ Amount of water = $1/18 = 0.056$, so ratio is 1:2.2, so student is incorrect ✓ OR amount of water = $1/18 = 0.056 \text{ mol}$ ✓ Expected mass of $\text{Fe}_2\text{O}_3 \cdot 2\text{H}_2\text{O} = 0.5 \times 0.056 \times 195.6 = 5.47 \text{ g}$, so students incorrect ✓ If incorrect Mr for $\text{Fe}_2\text{O}_3 \cdot 2\text{H}_2\text{O}$ used leading to a calculation giving mass water = 1g then allow MP2 via ecf
				17		

Question			Answer	Mark	AO	Guidance
3	a		107: M+1 peak / C ₆ ¹³ CH ₆ O ⁽⁺⁾ ✓ 77: C ₆ H ₅ ⁺ ✓	2	2 x 2.2	Clear indication of C ¹³ within the parent ion '+' sign not essential for first mark but must be somewhere for second mark.
3	b		Rings(AW) (of electron density/delocalised electrons) ✓ above and below (plane of) benzene/carbon ring ✓	2	2 x 1.2	
3	c		benzene has (electrophilic) substitution and ethene has (electrophilic) addition ✓	1	2.1	
3	d	i	complementary colour/blue-violet is absorbed ✓ (Student incorrect because molecule) does not emit light ✓ yellow colour is what is left after absorption(AW) ✓	3	3 x 3.1	ALLOW yellow is the colour transmitted/reflected
3		ii	CHECK ANSWER ON ANSWER LINE 5.7 x 10⁻⁵ (cm) scores 3 marks Use of $\lambda = hc/E$ ✓ $E = 6.63 \times 10^{-34} \times 3 \times 10^8 / 3.5 \times 10^{-19} = 5.7 \times 10^{-7} \text{ m}$ ✓ Convert to cm 5.7 x 10 ⁻⁵ (cm) ✓	3	3 x 2.6	ALLOW ecf ALLOW 2 or more sf ALLOW use of $E = h\nu$ and $c = \lambda\nu$ with subsequent rearrangement to calculate the value of λ $\nu = E/h = 3.5 \times 10^{-19} / 6.63 \times 10^{-34} = 5.28 \times 10^{14} \text{ ✓}$ $\lambda = c/\nu = 3 \times 10^8 / 5.28 \times 10^{14} = 5.7 \times 10^{-7} \text{ ✓}$ convert to cm giving 5.7 x 10 ⁻⁵ ✓ Units not required but if given they must be correct.
3	e	i	 attack by CN ⁻ ✓ intermediate and attack by H ⁺ ✓	2	1.2	IGNORE partial charges and product Curly arrows must start (if projected) on lone pair on C (or negative charge if no lone pair) or double bond and end (if projected) on the appropriate atom ALLOW negative charge on either atom of cyanide ion.
3	e	ii	cyan(o)hydrin/hydroxynitrile ✓	1	1.1	

3	e	iii	CHECK ANSWER ON ANSWER LINE Answer rounding to 88% scores 3 marks amount benzaldehyde = $5/106$ (= 0.0472 mol) ✓ amount mandelic acid = $6.3/152$ (= 0.0414 mol) ✓ yield = $0.0414 \times 100/0.0472 = 88\%$ ✓ OR Amount benzaldehyde = $5/107$ (=0.0467) ✓ Amount mandelic acid = $6.3/153$ (=0.0412) ✓ Yield = $0.0412 \times 100/0.0467 = 88\%$ ✓	3	3 x 2.8	ALLOW 88 to 2 or more sf. Alternative method: <i>Mr</i> values 106 and 152 ✓ max mass of mandelic acid = $5 \times 152/106 = 7.17\text{g}$ ✓ % = $6.3 \times 100/7.17 = 88\%$ ✓ use of parent ion <i>Mr</i> = 107 giving <i>Mr</i> mandelic acid as 153 and subsequent evaluation $5 \times 153/107 = 7.15\text{ g}$, ✓ so % = $6.3 \times 100/7.15 = 88\%$ ✓
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3	f*	Refer to marking instructions on page 5 of mark scheme for guidance on marking this question. Level 3 (5-6 marks) Correct structure/identity for both A and B deduced and most evidence related to each structure is provided from both spectra. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3-4 marks) Correctly identifies one compound with most evidence for that compound OR Correctly identifies both compounds with some supporting evidence <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1-2 marks) Correctly identifies one compound with no valid evidence OR Structure/identity not given or incorrect for both compounds, but some correct evidence from at least one spectrum. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant and correct.</i> Level 0 (0 marks) No response or nothing worthy of credit.	6	4 x 3.1 2 x 3.2 Indicative scientific points include: AO3.1 Analysis: IR • A has OH 3200-3600 (broad) • A has no C=O around 1700 • B has C=O at 1700 • B has carboxylic O-H at 2500-3300 (broad) • Both have aromatic C=C peaks in range 1450-1650 ¹³C-NMR • A has aromatic carbons 120 – 140 • A has C-O at 65 • B has aromatic carbons 'around 130' (AW) • B has C=O at 175 If no relevant analysis given in text look at the spectra for any identification of bonds. AO3.2 Evaluation • A is C₆H₅CH₂OH/phenylmethanol/correct structure drawn • B is C₆H₅COOH/benzoic acid/correct structure drawn IGNORE references to number of C atoms(given in question) IGNORE remarks relating structure of A and B to benzaldehyde (question asks for analysis of spectra)
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Question			Answer	Mark	AO	Guidance
4	a	i	measure water using measuring cylinder ✓ insulated cup ✓ measure initial temp ✓ add solid and measure final temp <u>when all dissolved/when temperature (change) becomes constant</u> ✓	4	3.4 3.4 3.3 3.3	Eg polystyrene, polythene, styrofoam etc. (must be clear that this is before the addition of the solid)
4	a	ii	CHECK ANSWER ON ANSWER LINE +33 (kJ mol⁻¹) scores 4 marks 150 x 4.18 x 5.3 = 3.3(23) kJ/3323 J ✓ 10.1/101 = 0.1 mol ✓ 3.3(23)/0.1 = 33 kJ mol ⁻¹ ✓ 2sf and '+' sign ✓	4	2.8 2.8 2.8 3.1	Allow any number of sf for MP1 to MP3 1. calculates Q using mcθ 2. calculate amount of KNO ₃ 3. converts to kJ per mol (any sign or no sign) 4. converts to 2sf and includes '+' sign
4	b	i	Entropy is no. of ways of arranging particles / a measure of randomness/disorder / associated energy quanta ✓ (KIO ₃) solid/ (ionic) lattice has lower entropy than (ions in) solution (ora) ✓	2	2 x 2.7	ALLOW +ve sign shows that particles <u>in solution</u> are in a <u>more random arrangement</u> than in a solid with a higher entropy for 2 marks +ve sign shows that particles have become more disordered/random for 1 mark
4	b	ii	Use of $\Delta_{\text{tot}}S = \Delta_{\text{sys}}S - \Delta H/T$ ✓ Converts ΔH from kJ to J ✓ calculates $\Delta_{\text{tot}}S = 0$ at 434K ✓ Student is correct/reaction is not feasible as $\Delta_{\text{tot}}S$ would be negative below this temp/434K ✓	4	4 x 3.1	Recall equation Insert values and evaluates correctly ALLOW reaction is not feasible if $T < 434$ since $\Delta_{\text{tot}}S$ will have a -ve value
4	c	i	same number/two of moles (of gas) on each side (of the equation) ✓	1	2.6	

4	c*	ii	Refer to marking instructions on page 5 of mark scheme for guidance on marking this question. Level 3 (5-6 marks) Explains how temperature and pressure affect both rate and yield, giving most fine detail and makes at least one related recommendation about the process. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3-4 marks) Explains how rate or yield is affected by both temperature and pressure, with some fine detail, and makes at least one recommendation about the process or Explains how both rate and yield, are affected by either temperature or pressure, with some fine detail, and makes one related recommendation about the process <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1-2 marks) Attempts to explain how rate and yield are affected by temperature or pressure or Attempts to explain how rate or yield is affected by both temperature and pressure <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> Level 0 (0 marks) No response or nothing worthy of credit.	6	1.2 x 2 3.1 x 1 3.2 x 3	Indicative scientific points may include: (fine detail in <i>italic</i>) AO 1.2 Knowledge and Understanding • high temperature increases rate/ORR • <i>As a greater frequency of collisions have $E \geq E_A$</i> • rate would be higher at higher P/ORR • <i>collisions are more frequent</i> AO3.1 Analysis • A higher temperature would give a greater yield • <i>Reaction is endothermic</i> • Yield does not depend on pressure • <i>Equal moles on each side (AW)</i> • <i>explanations in terms of Le Chatelier</i> AO3.2 Recommendations • Suggests optimum conditions of high temperature and low pressure (Approx. 1 – 2 atm and 500K) to maximise yield • <i>high temperature would be limited by cost/safety (AW)</i> • <i>high pressure would be limited by cost/safety (AW).</i>
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Question			Answer	Mark	AO	Guidance
5	a	i	f-(block)	1	2.1	
5	b	i	Bright/ coloured lines on a black background ✓	1	1.2	
5	b	ii	when electrons fall energy levels, energy is released ✓ $\Delta E = h\nu$ / energy proportional to frequency ✓ electrons in elements have different energy levels – different lines in spectrum ✓	3	1.2 1.2 2.5	
	c	i	104.5 $\pm$ 1 ✓	1	1.2	
5	c	ii	Four areas of electron density (around O) ✓ repel as far apart as possible/ minimise repulsion ✓ (two) lone pairs repel more than bonding pairs ✓	3	3x 1.2	ALLOW four electron pairs (around O) – can be shown on a suitable diagram OR as a description such as 2 bp and 2 lp.
5	d		Both have covalent bonding Si–O ✓ Gorilla has (in addition) Al–O bonds ✓ and ionic bonds ✓	3	3 x 3.1	ALLOW both based on Silicon Dioxide/contain silicon and oxygen IGNORE references to amorphous/crystalline ALLOW Gorilla contains aluminosilicate anions / sodium ions / potassium ions
5	e		Both form 1+ ions / ions have the same charge ✓ K has more electrons/shells than Na ✓	2	2 x 1.1	
5	f		Al: 2 x +3 and Si: 14 x +4 = 62 ✓ O: 32 x 2 = 64, so x = (-)2 ✓	2	2 x 2.2	
5	g	i	In ³⁺ (since In in Group 13/3) ✓ gives In ₂ O ₃ with O ²⁻ ✓	2	2 x 2.2	ALLOW any reasoned explanation using oxidation states or ionic charges
	g	ii	In:Si:O :: 53/114.8: 28/118.7; 19/16 :: 0.46:0.24:1.19 ✓ :: 2: 1: 5 is SnO ₂ + In ₂ O ₃ ✓	2	2 x 2.6	IGNORE In ₂ SnO ₅
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