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.

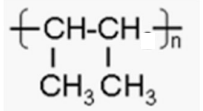
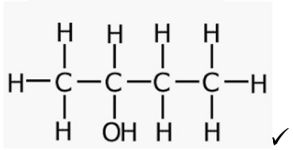
Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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
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 x1.2	
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 decolorised/ goes (from brown/yellow/orange to) colourless ✓  ✓  ✓ (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
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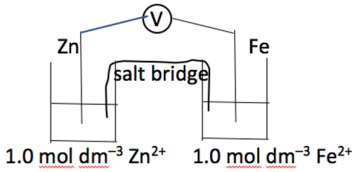
Question			Answer	Mark	AO	Guidance
2	a	i	0.5/ ½✓ 2 ✓	2	2 x 2.6	**ALLOW** 'multiples'
2	a	ii	(½)O_2 ✓ oxidation state goes from 0 to -2 ✓	2	2 x 2.1	**ALLOW** 'oxygen' **IGNORE** 'O'
2	b	i	 both electrodes and solutions ✓ salt bridge and voltmeter ✓ 1.0 mol dm^{-3} and 298 K ✓	3	3 x 3.3	**IGNORE** composition 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 **in**correct) 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		$Fe(OH)_2(s) + ¼ O_2 (g) + ½H_2O(l) \rightarrow Fe(OH)_3(s)$ correct formulae ✓ equation correctly balanced ✓ all ss correct ✓	3	3 x 2.7	**ALLOW** multiples **ALLOW** even if equation/balancing incorrect
2	e		amount $Fe_2O_3•2H_2O$ = 5/195.6 (= 0.0256) mol ✓ mass water = 0.0256 x 2 x 18 = 0.92 g so students incorrect ✓	2	3.1 3.2	**ALLOW** ecf **OR** amount of Fe_2O_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 mol ✓ Expected mass of $Fe_2O_3•2H_2O$ = 0.5 x 0.056 x 195.6 = 5.47 g, so students incorrect ✓ If incorrect Mr for $Fe_2O_3•2H_2O$ used leading to a calculation giving mass water = 1g then allow MP2 via ecf
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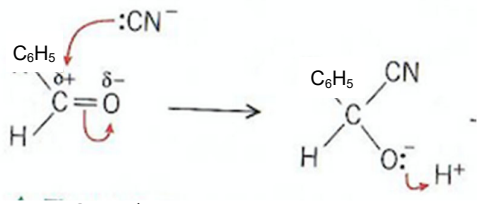
Question			Answer	Mark	AO	Guidance
3	a		107: M+1 peak / $C_6{}^{13}CH_6O^{(+)}$ ✓ 77: $C_6H_5^+$ ✓	2	2 x 2.2	Clear indication of C^{13} within the parent ion '+' sign not essential for first mark but must be somewhere for second mark.
3	b		Rings(AW) (of electron density/delocalised electrons) ✓ above 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 becausemolecule) 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 $\lambda = hc/E$ ✓ $E = 6.63 \times 10^{-34} \times 3 \times 10^8 / 3.5 \times 10^{-19} = 5.7 \times 10^{-7}$ m✓ Convert to cm 5.7×10^{-5} (cm) ✓	3	3 x 2.6	**ALLOW** ecf **ALLOW** 2 or more sf **ALLOW** use of $E = h\gamma$ and $c = \lambda\gamma$ with subsequent rearrangement to calculate the value of λ $\gamma = E/h = 3.5 \times 10^{-19}/6.63 \times 10^{-34} = 5.28 \times 10^{14}$ ✓ $\lambda = c/\gamma = 3 \times 10^8 / 5.28 \times 10^{14} = 5.7 \times 10^{-7}$ ✓ convert to cm giving 5.7×10^{-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 x 100/0.0472 = 88% ✓ OR Amount benzaldehyde = 5/107 (=0.0467) ✓ Amount mandelic acid = 6.3/153 (=0.0412) ✓ Yield = 0.0412 x 100/0.0467 = 88% ✓	**3**	**3 x 2.8**	**ALLOW** 88 to 2 or more sf. Alternative method: *M*r values 106 and 152 ✓ max mass of mandelic acid = 5 x 152/106 = 7.17g✓ % = 6.3 x 100/ 7.17 = 88% ✓ use of parent ion Mr = 107 giving Mr mandelic acid as 153 and subsequent evaluation 5 x 153/107 = 7.15 g, ✓ so % = 6.3 x 100/7.15 = 88%✓

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. *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)** Correctly identifies one compound with most evidence for that compound **OR** Correctly identifies both compounds with some supporting evidence *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)** 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. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant and correct.* **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 **^{13}C-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 $C_6H_5CH_2OH$/phenylmethanol/correct structure drawn • **B** is C_6H_5COOH/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 $\Delta_{tot}S = \Delta_{sys}S - \Delta H/T$ ✓ Converts ΔH from kJ to J ✓ calculates $\Delta_{tot}S = 0$ at 434K✓ Student is correct/reaction is not feasible as Δ_{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 Δ_{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. *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)** 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 *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)** 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 *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **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 italic)* **AO 1.2 Knowledge and Understanding** • high temperature increases rate/ORA • *As a greater frequency of collisions have E≥ E_A* • rate would be higher at higher P/ORA • *collisions are more frequent* **AO3.1 Analysis** • A higher temperature would give a greater yield • *Reaction is endothermic* • Yield does not depend on pressure • *Equal moles on each side* (**AW**) • *explanations in terms of Le Chatelier* **AO3.2 Recommendations** • Suggests optimum conditions of high temperature and low pressure (Approx. 1 – 2 atm and 500K) to maximise yield • *high temperature would be limited by cost/safety (AW)* • *high pressure would be limited by cost/safety (AW).*
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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 ✓ $\Delta E = hv$/ 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 ±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_2O_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_2O_3 ✓	2	2 x 2.6	**IGNORE** In_2SnO_5
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