COMPONENT 2: ORGANIC CHEMISTRY AND ANALYSIS

MARK SCHEME

GENERAL INSTRUCTIONS

Recording of marks

Examiners must mark in red ink.

One tick must equate to one mark, apart from extended response questions where a level of response mark scheme is applied.

Question totals should be written in the box at the end of the question.

Question totals should be entered onto the grid on the front cover and these should be added to give the script total for each candidate.

Extended response questions

A level of response mark scheme is applied. The complete response should be read in order to establish the most appropriate band. Award the higher mark if there is a good match with content and communication criteria. Award the lower mark if either content or communication barely meets the criteria.

Marking rules

All work should be seen to have been marked.

Marking schemes will indicate when explicit working is deemed to be a necessary part of a correct answer.

Crossed out responses not replaced should be marked.

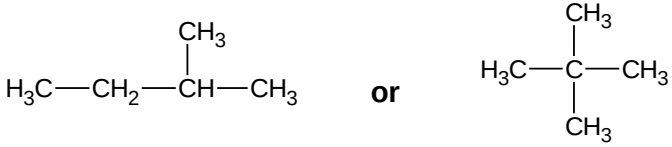
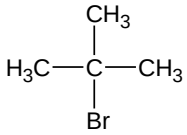
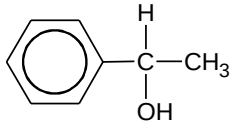
Marking abbreviations

The following may be used in marking schemes or in the marking of scripts to indicate reasons for the marks awarded.

cao = correct answer only
ecf = error carried forward
bod = benefit of doubt

Credit should be awarded for correct and relevant alternative responses which are not recorded in the mark scheme.

Section A

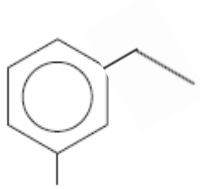
Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
1.				 **or**		1		1		
2.				2-methylbut-1-ene		1		1		
3.				•CH_2F and Cl• accept structural formula for fluoromethyl radical		1		1		
4.						1		1		
5.				one of the carbon atoms of the double bond has two atoms the same		1		1		
6.	*(a)*			the CH(OH) carbon atom is a chiral centre (could be shown on the formula)		1		1		
	(b)			the enantiomers will rotate the plane of polarised light in the opposite direction	1			1		
7.	*(a)*			it contains the CH_2OH group	1			1		
	(b)						1	1		

<table>
<tr><th colspan="4" rowspan="2">Question</th><th rowspan="2">Marking details</th><th colspan="6">Marks available</th></tr>
<tr><th>AO1</th><th>AO2</th><th>AO3</th><th>Total</th><th>Maths</th><th>Prac</th></tr>
<tr><td>8.</td><td>(a)</td><td></td><td></td><td>silver mirror (1)
the aldehyde group acts as a reducing agent and reduces Ag^+ to Ag (1)</td><td>2</td><td></td><td></td><td>2</td><td></td><td>1</td></tr>
<tr><td></td><td>(b)</td><td></td><td></td><td>an aldehyde group is present in the methanoate group and will reduce Ag^+ to Ag</td><td></td><td></td><td>1</td><td>1</td><td></td><td></td></tr>
<tr><td>9.</td><td></td><td></td><td></td><td><table><tr><th>Reagent(s)</th><th>Functional group identified</th><th>Observation</th></tr><tr><td>sodium carbonate</td><td>carboxylic acid</td><td>effervescence</td></tr><tr><td>iron(III) chloride (aq)</td><td>phenol</td><td>purple colouration</td></tr><tr><td>bromine (aq)</td><td>alkene</td><td>bromine decolourised</td></tr></table>(1) for each correct row</td><td>3</td><td></td><td></td><td>3</td><td></td><td>3</td></tr>
<tr><td></td><td></td><td></td><td></td><td>Section A total</td><td>7</td><td>6</td><td>2</td><td>15</td><td>0</td><td>4</td></tr>
</table>

Section B

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
10.	*(a)*			angle 1 C–Ĉ–H ~120° (1) angle 2 H–Ĉ–H ~109.5° (1)	2			2		
	(b)			acidified (sodium/potassium) dichromate / H^+, $Cr_2O_7^{2-}$ **or** acidified potassium manganate(VII) / H^+, MnO_4^-	1			1		1
	(c)	(i)		SeO_2 +4 Se 0 (1) oxidation number becoming less positive is reduction (1)	1	1		2		
		(ii)		SeO_2 only oxidises to an aldehyde / SeO_2 does not produce a carboxylic acid			1	1		
		(iii)		M_r CH_3CHO 44.04 / 44 M_r CHO–CHO 58.0 / 58 (1) moles of ethanal = $\frac{22.0}{44.04}$ = 0.500 moles of ethanedial = $\frac{20.0}{58.0}$ = 0.345 (1) (mole ratio is 1:1) % yield = $\frac{0.345 \times 100}{0.500}$ = 69.0 (1) award (3) for correct answer only (cao) error carried forward (ecf) possible		3		3	1 1	
	(d)	(i)		nucleophilic addition-elimination / condensation	1			1		
		(ii)		the melting temperature cannot be higher than the book value ∴ compound **A** cannot be propanal or cyclopentanone (1) if impure the compound will melt at a lower temperature than the expected value (1) and over a range of temperatures (1)		3		3		3

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(e)			test it with I_2 / NaOH **or** NaOCl / KI (1) yellow precipitate / solid (1)		2		2		2
	(f)			any three for (1) each up to max 3 • the temperature / pressure at which the system operates (1) • how the ethanal is separated from the other products / catalyst (1) • if the use of a heterogenous catalyst is feasible (1) • how the catalyst is recovered (1) • the nature of the corrosion proof reactor lining (1) accept other sensible answers			3	3		
				Question 10 total	**5**	**9**	**4**	**18**	**2**	**6**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
11.	*(a)*	(i)		chloroethane / bromoethane		1		1		
		(ii)		 or in position 2 with respect to methyl group		1		1		
		(iii)		correct value of M_r from the graph (190) (1) correct deduction of 'M_r' of R group (43.1) (1) correct formula of R group ($CH_3CH_2CH_2$ / $(CH_3)_2CH$) (1) no ecf		1 1	1	3	1	
		(iv)	I	electrical heating / oil bath (1) to avoid danger of fire / boiling temperature is greater than 100 °C so a water bath cannot be used (1)	2			2		2
			II	acid chlorides are hydrolysed by moisture	1			1		1
	(b)	(i)		$C_2H_5NH_2 + CH_3COOH \rightarrow C_2H_5NH_3^+CH_3COO^-$ (1) $C_6H_5NH_2 + H_2SO_4 \rightarrow C_6H_5NH_3^+HSO_4^-$ **or** $2C_6H_5NH_2 + H_2SO_4 \rightarrow (C_6H_5NH_3^+)_2\,SO_4^{2-}$ (1) (accept if charges omitted)		2		2		

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
11.	*(b)*	(ii)		they all act as bases by donating lone pair to H^+ (1) the more available the lone pair, the stronger the base (1) sensible comment on the order e.g. lone pair on nitrogen in phenylamine is delocalised to the ring electron system / ethyl group is electron releasing (1)	1 1	 1		 3		
	(c)	(i)		the phenol needs to be in alkaline solution (1) the temperature needs to be 10 °C or less (1)	 2			 2		2
		(ii)	I	the yellow dye contains a phenolic OH group and this acidic group is neutralised by aqueous sodium hydroxide (1) giving the (soluble) anion / ~~~ O^-Na^+ (1)		 2		 2		
			II	when the solution becomes acidic, the (soluble) anion is replaced by the OH group to restore the insoluble yellow dye		1		1		
				Question 11 total	**7**	**10**	**1**	**18**	**1**	**5**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
12.	*(a)*			dipoles shown i.e. $C^{\delta+}$ and $Cl^{\delta-}$ (1) curly arrow shown from OH^- to $C^{\delta+}$ (1) curly arrow from bond to Cl (1) products are propan-1-ol and Cl^- (1)	4			4		
	(b)			nucleophilic substitution	1			1		
	(c)			Indicative content • The concentration of the sodium hydroxide solution in each case needs to be kept constant, otherwise the rate of substitution will be affected by the [OH] present • The temperature of each reaction must be kept the same as reaction rate changes markedly with changes in temperature • The bonding between the carbon and halogen atom in each compound is covalent but each bond is a polar covalent bond • Polarisation for the C-Cl bond is the greatest suggesting that 1-chloropropane should react most quickly • The C-I bond is the weakest is terms of bond enthalpy suggesting that 1-iodopropane should react most quickly • The overriding factor in these reactions is the bond enthalpy	2	2	2	6		

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
				5-6 marks: Each point included; clear understanding of link between observations and conclusion *The candidate constructs a relevant, coherent and logically structured account including all key elements of the indicative content. A sustained and substantiated line of reasoning is evident and scientific conventions and vocabulary are used accurately throughout.* **3-4 marks:** Effect of at least one of general factors affecting rate included; reference to bond polarity and bond strength; attempt at comparison of their effect on rate *The candidate constructs a coherent account including most of the key elements of the indicative content and little irrelevant material. Some reasoning is evident in the linking of key points and use of scientific conventions and vocabulary is generally sound.* **1-2 marks:** Reference to one general factor affecting rate; conclusion in terms of bond enthalpy *The candidate attempts to link at least two relevant points from the indicative content. Coherence is limited by omission and/or inclusion of irrelevant material. There is some evidence of appropriate use of scientific conventions and vocabulary.* **0 marks:** *The candidate does not make any attempt or give an answer worthy of credit.*						

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(d)	(i)		sodium / potassium hydroxide in ethanol	1			1		1
		(ii)		elimination / dehydrohalogenation	1			1		
		(iii)		(mass of required product ÷ total mass of reactants) × 100 **or** (82 ÷ 118.5) × 100 (1) = 69.2 % (1) award (2) for cao ecf possible if error in calculating one of masses		2		2		
		(iv)		Reasons in *(a)* – carbon is not δ+ since electrons from chlorine pulled towards delocalised ring / C—Cl bond is strengthened since electrons from chlorine pulled towards delocalised ring (1) Reasons in *(d)* – there is no suitable hydrogen atom (to allow elimination of HCl) (1)		1	1	2		
				Question 12 total	**9**	**5**	**3**	**17**	**0**	**1**

Question				Marking details	Marks available					
					AO1	**AO2**	**AO3**	**Total**	**Maths**	**Prac**
13.				**Mass spectrum**						
				M_r is 86 (1)		1				
				link between mass and identity of any fragment e.g. 43 is CH_3CO / C_3H_7 (1)			1			
				IR spectrum						
				peak at ~ 1700 cm^{-1} due to C=O (1)		1				
				no O-H peak (1)		1				
				compound **T** is a carbonyl compound / aldehyde / ketone (not a carboxylic acid) (1)			1			
				^{13}C NMR						
				four different carbon environments (1)		1				
				^{1}H NMR						
				three different hydrogen environments (1)		1				
				ratio of peak areas / hydrogen environments is 6:3:1 (1)		1				
				any two for (1) each up to max 2 • splitting shows → 1 H on C next to C with multiple hydrogen atoms (1) • 6 protons on C next to C with 1 proton (1) • 3 protons on C next to C with no protons (1)			2			
				Conclusion						
				compound **T** is 3-methylbutanone (1)			1	11		
				Question 13 total	**0**	**6**	**5**	**11**	**0**	**0**

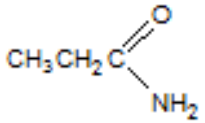
Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
14.	*(a)*	(i)		any alkene molecules produced would react with hydrogen (forming the corresponding alkane)			1	1		
		(ii)		$n = \frac{pV}{RT} = \frac{(101000 \times 0.96)}{8.31 \times 323}$ (1)	1				1	
				n = 36.1 (1)		1			1	
				M = 57.9 (1)		1			1	
				methylpropane / $CH_3CH(CH_3)CH_3$ (1)			1	4		
	(b)	(i)		relative peak area α-terpinene = 8 total relative peak area = 64 both required (1) $\therefore$ percentage of α-terpinene $= \frac{8 \times 100}{64} = 12.5$ (1)			2	2		
		(ii)		total percentage of α-terpinene in the citrus oil $= \frac{95 \times 12.5}{100} = 11.9$ (1) mass of α-terpinene in the citrus oil $= \frac{11.9 \times 3.2}{100} = 0.38$ g (1) award (2) for cao ecf possible from (ii)		2		2	2	

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
14.	*(c)*	(i)		1,2,3-tribromocyclohexane cannot be a product as addition of bromine / Br_2 is taking place and the only possible products are 1,2-dibromocyclohexane or 1,2,3,4-tetrabromocyclohexane (1) the percentage of bromine in the tetrabromo-compound is 80.0 and for the dibromo-compound it is 66.7 (1) one conclusion is that not every double bond has been brominated (and the product is a mixture of the dibromo- and tetrabromo- compounds) (1)			3	3		
		(ii)		answers based on **any** of the following techniques infrared (absorption) spectroscopy (1) look for C = C at 1620-1670 cm^{-1} (1) proton NMR spectroscopy (1) look for HC = CH protons at ~4.8 δ (1) GLC / HPLC (1) compare retention times with standard materials (1) mass spectroscopy (1) look for fragmentation pattern / M^+ signals (1)	1	1		2		2
				Question 14 total	**2**	**5**	**7**	**14**	**5**	**2**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
15.	*(a)*			dehydration / elimination	1			1		
	(b)			(concentrated) sulfuric acid / (concentrated) phosphoric acid	1			1		1
	(c)			methanol contains a (polar) $O^{\delta-}$— $H^{\delta+}$ bond (could be shown in a formula) (1)		1				
				the 'H' of the OH group acts as an electrophile (1)		1				
				reacting with the alkene to give the 2-methyl-2-propyl carbocation / tertiary carbocation (1)		1				
				if 1-methoxy-2-methylpropane was the product, then the intermediate carbocation would be the 2-methyl-1-propyl carbocation which is a primary carbocation (1)			1			
				less stable / not so easily formed as the tertiary 2-methyl-2-propyl carbocation (1)			1	5		
	(d)			the alcohol can hydrogen bond between its molecules but MTBE cannot (1)						
				more energy is needed to break these hydrogen bonds therefore a relatively higher boiling temperature (1)		2		2		

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
15.	*(e)*			Indicative content • 2-methylpropan-1-ol / the alcohol is treated with HCl / hydrogen chloride in the presence of (anhydrous) zinc chloride • to give 1-chloro-2-methylpropane / $(CH_3)_2CHCH_2Cl$ • this chloro-compound then reacts with potassium cyanide / KCN • giving 3-methylbutanenitrile / $(CH_3)_2CHCH_2CN$ • this is then hydrolysed by, for example, aqueous sulfuric acid (to give the carboxylic acid) **5-6 marks:** Each step included in the correct order; reagents and intermediate products identified *The candidate constructs a relevant, coherent and logically structured account including all key elements of the indicative content. A sustained and substantiated line of reasoning is evident and scientific conventions and vocabulary are used accurately throughout.* **3-4 marks:** General description of each stage; reagents/products identified for two stages *The candidate constructs a coherent account including most of the key elements of the indicative content and little irrelevant material. Some reasoning is evident in the linking of key points and use of scientific conventions and vocabulary is generally sound.*	2	2	2	6		6

				1-2 marks: Description or reagents given for one step; one intermediate product identified *The candidate attempts to link at least two relevant points from the indicative content. Coherence is limited by omission and/or inclusion of irrelevant material. There is some evidence of appropriate use of scientific conventions and vocabulary.* **0 marks:** *The candidate does not make any attempt or give an answer worthy of credit.*						
				Question 15 total	**4**	**7**	**4**	**15**	**0**	**7**

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
16.	*(a)*	(i)		moles of NaOH used = $\frac{1.25 \times 50.00}{1000}$ = 0.0625 (1) moles of HCl used = $\frac{1.00 \times 30.50}{1000}$ = 0.0305 (1) since 1 mol of HCl reacts with 1 mol of NaOH moles of NaOH that reacted with the amide = 0.0625 – 0.0305 = 0.0320 (1) since 1 mol of NaOH reacts with 1 mol of the amide moles of the amide present = 0.0320 ∴ M_r of the amide = $\frac{\text{mass}}{\text{moles}} = \frac{2.34}{0.032}$ = 73.1 (1) ecf possible up to this point but not for incorrect alkyl group 'M_r' $CONH_2$ = 12 + 16 + 2.02 = 44.02 'M_r' R = 73.1 – 44.02 = 29.08 → an alkyl group ∴ C_2H_5 formula of the amide is  (1)		5		5	4	5

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
16.	*(a)*	(ii)		M_r of benzamide is 121 (the value obtained is too high) (1) not all the ammonia had been expelled (1) ∴ more HCl was used to neutralise this ∴ the titration indicated that apparently relative less of the NaOH reacted with the amide ∴ number of moles is apparently less ∴ M_r higher (1) (accept 'some HCl reacted with the ammonia' as a weaker answer for the second point) mass used was **lower** than the recorded mass (2) [**incorrect** recording of the mass of amide used (1)]		1 2 2	5		5
	(b)			add $NaHCO_3$ (1) effervescence (1) **or** universal indicator (1) turns red (1)	2			2		2
				Question 16 total	**2**	**6**	**4**	**12**	**4**	**12**

COMPONENT 2: ORGANIC CHEMISTRY AND ANALYSIS

SUMMARY OF MARKS ALLOCATED TO ASSESSMENT OBJECTIVES

Question	AO1	AO2	AO3	Total	Maths	Prac
Section A	7	6	2	15	0	4
10.	5	9	4	18	2	6
11.	7	10	1	18	1	5
12.	9	5	3	17	0	1
13.	0	6	5	11	0	0
14.	2	5	7	14	5	2
15.	4	7	4	15	0	7
16.	2	6	4	12	4	12
Totals	**36**	**54**	**30**	**120**	**12**	**37**