EXAM PAPERS PRACTICE

Boost your performance and confidence with these topic-based exam questions

Practice questions created by actual examiners and assessment experts

Detailed mark scheme

Suitable for all boards

Designed to test your ability and thoroughly prepare you

Time allowed
68 Minutes

Score /57

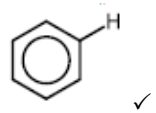
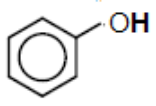
Percentage %

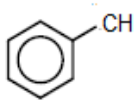
CHEMISTRY

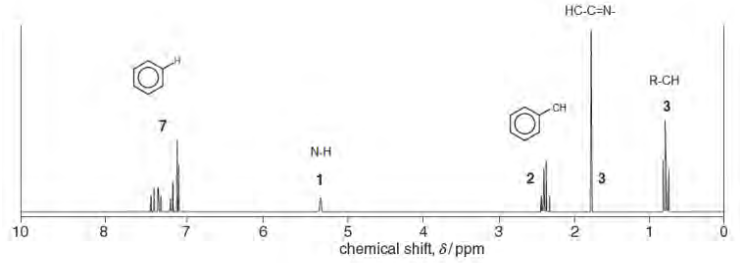
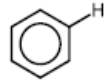
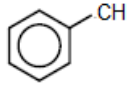
OCR AS & A LEVEL

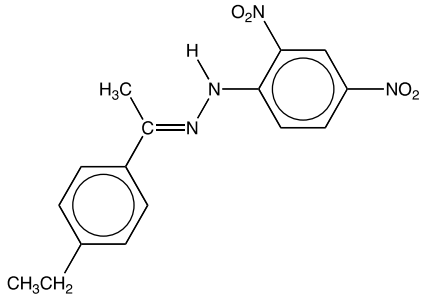
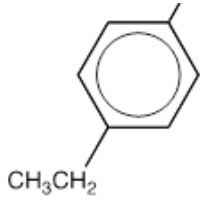
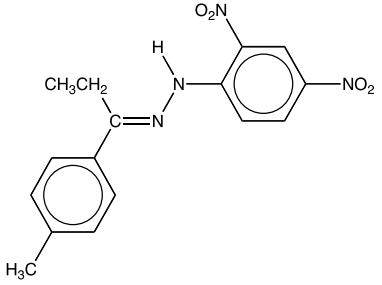
Mark Scheme

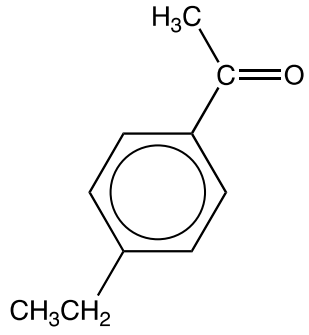
Module 6: Organic chemistry and analysis

Question			Answer	Mark	Guidance
1	(a)		magnetic resonance imaging/providing diagnostic information/body scanners. ✓	1	**ALLOW** MRI/scanning internal structures e.g. brain **ALLOW** detection of tumours/cancer/haemorrhage/aneurysm **IGNORE** reference to drugs, chemicals or functional groups **IGNORE** analysis of blood **DO NOT ALLOW** CT scan/CAT scan
	(b)	(i)	Radio (waves) ✓	1	**ALLOW** a value in the range 60 – 900 MHz
		(ii)	The solvent does not have any hydrogen/H/protons ✓	1	**ALLOW** to prevent (^{1}H nuclei from) the solvent from interfering with the NMR spectrum **ALLOW** does not show on the spectrum **ALLOW** no peak/signal (from solvent) **IGNORE** volatility
4	(c)		14 ✓	1	
	(d)		**NMR analysis** (5 marks) **M1** Peaks between (δ) 7.1 and 7.5 (ppm) **OR** Relative peak area of 7 **OR** Multiplet =  ✓ **M2** Peak at 5.2/5.3	7	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **IGNORE** analysis of ^{13}C spectrum Each peak can be identified from its δ value ± 0.2 ppm **ALLOW** (seven) benzene ring protons **OR** aromatic protons **DO NOT ALLOW** benzene ring without reference to protons **ALLOW** C_6H_6 **IGNORE** 

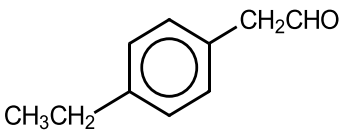
Question			Answer	Mark	Guidance
			OR Relative peak area of 1 = N-**H** ✓		**IGNORE** O-**H** , CON**H** **AND** C=C**H**
			M3 Peak at 2.3/2.4 **OR** Relative peak area of 2 **OR** Quartet =  **OR** $C_6H_5CH_2$ ✓		**ALLOW** quadruplet **IGNORE** C**H**C=O **AND** **H**C-N
			M4 Peak at 0.7/0.8 **OR** Triplet = R-CH **OR** R-CH_3 ✓		**DO NOT ALLOW** triplet = CH_3 **OR** CH_2CH_3
			M5 Triplet (at δ 0.7) **AND** quartet (at δ 2.3) = CH_2CH_3 **OR** triplet at (δ) 0.7 shows (C with) 2 adjacent Hs/protons = CH_2CH_3 **OR** quartet (at δ 2.3) shows (C with) 3 adjacent Hs/protons = CH_2CH_3 ✓		This also scores **M4** if triplet is linked to R-CH_3 **ALLOW** CH_3CH_2 described as R-CH_3 and 2 adjacent H **OR** –CH_2- and 3 adjacent H The information can be presented on the spectrum or in a table.

Question	Answer	Mark	Guidance
	✎ **QWC**: **triplet** or **quartet** spelled correctly in the correct context for **M5**		 Chemical shift/ppm / Relative peak area / Splitting pattern / Type of proton 7.1 – 7.5 / 7 / Multiplet /  5.3 / 1 / Singlet / N-H 2.3/2.4 / 2 / Quartet /  1.7/1.8 / 3 / Singlet / HC-C=N- 0.7/0.8 / 3 / triplet / R-CH/R-CH_3 **IGNORE** peak in the range 1.6–2.2 = HC–C=N– because this information is given in the question. H_3C-C=N- scores one mark for the identification of R^1 or R^2 (see below)

Question	Answer	Mark	Guidance
	Identification of R^1 and R^2 (2 marks) **Orange precipitate L** Correct structure scores 2 marks  **R^1** or **R^2** = -CH_3 ✓ **R^1** or **R^2** =  ✓		**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous Marks are for structure of R^1 and R^2 **IGNORE** errors in the rest of the structure **ALLOW** 1 mark for CH_3 and CH_3CH_2 swapped, i.e. the following structure  **ALLOW** H_3C-C=N- **MUST BE** 1,4-disubstituted (14 carbon environments in the ^{13}C NMR spectrum

Question			Answer	Mark	Guidance
	(e)		**Carbonyl compound K**  ✓	1	**ALLOW ECF** from incorrect compound **L** Must be a correct carbonyl structure
			Total	**12**	

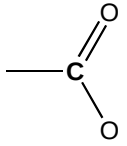
Question			Answer	Mark	Guidance
2	(a)		TMS/tetramethylsilane (which is the) standard (for chemical shift measurements) ✓	1	**ALLOW** $(CH_3)_4Si$ **ALLOW** TMS is the reference **OR** TMS has δ = 0 (ppm) **OR** for calibration **OR** for comparison **IGNORE** solvent, unreactive, volatile, it gives a sharp peak
	(b)		**NMR analysis = 5 marks** **M1:** Peak(s) at (δ) 9.7 = CHO ✓ **M2:** Peak(s) at (δ) 7.1 = C_6H_4 ✓ **M3:** Triplet at (δ) 1.3/peak at 1.3 **AND** quartet (at δ 2.6)/ peak at 2.6 = CH_2CH_3 ✓ **M4:** Triplet at (δ) 9.7/peak at 9.7 **AND** doublet (at δ 3.7)/peak at 3.7 = CH_2CHO ✓	9	**NOTE**: Each peak can be identified from: • its δ value • a range, *e.g.* "the peak between 0.8 and 2.0" • its relative peak area (beware two peaks with 2 protons) • its splitting (beware two triplets) • labelling on the spectrum **ALLOW** CH_2CHO/aldehyde **IGNORE** reference to phenol **ALLOW** (four) benzene ring proton(s) **IGNORE** reference to phenol **M3** and **M4** Look for a clear link (using words or diagrams) between the two peaks

Question			Answer	Mark	Guidance
			M5: (n+1 rule) Any one of the following • triplet at (δ) 1.3 shows (C with) 2 adjacent Hs/protons **OR** adjacent CH_2 *(because of splitting: so triplet)* • quartet at (δ 2.6 shows) (C with) 3 adjacent Hs/protons **OR** adjacent CH_3 • triplet at (δ) 9.7 shows (C with) 2 adjacent Hs/protons **OR** adjacent CH_2 • doublet at (δ 3.7 shows) (C with) 1 adjacent H/proton **OR** adjacent CH ✓ ✎ **QWC**: **triplet** spelled correctly in the correct context once		**ALLOW** a response that implies a splitting into three for a triplet/into two for a doublet etc. **ALLOW** "neighbouring" Hs for "adjacent to" Hs **IGNORE** other comments about splitting once **M5** has been awarded **DO NOT ALLOW** one of **M3** or **M4 or M5** if triplet not seen
			Aldehyde structure = 4 marks  ✓✓✓✓		**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous **IF** structure contains C_6H_4 ✓ **IF** structure contains C_6H_4 **AND** the organic structure contains CH_3CH_2 directly attached to the benzene ring **OR** contains CH_2CHO directly attached to the benzene ring ✓✓ **IF** structure has formula $C_{10}H_{12}O$ **AND** structure contains C_6H_4 **AND** the structure contains CH_3CH_2 **AND** contains CH_2CHO **AND** 1,2 **OR** 1,3 substituted ✓✓✓

Question			Answer	Mark	Guidance
					IF structure has formula $C_{10}H_{12}O$ **AND** structure contains C_6H_4 **AND** the structure contains CH_3CH_2 **AND** contains CH_2CHO **AND** 1,4 substituted ✓✓✓✓ (use of ^{13}C data)
			Total	**10**	

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>3</td><td>(a)</td><td></td><td>
<table>
<tr><td></td><td>C</td><td></td><td>O</td></tr>
<tr><td>%</td><td>73.15%</td><td></td><td>19.48%</td></tr>
<tr><td>mol</td><td>6.10</td><td></td><td>1.22</td></tr>
<tr><td>ratio</td><td>5</td><td></td><td>1</td></tr>
</table>
molar ratio (C:H:O) = 6.10 : 7.37 : 1.22 OR = 5:6:1
OR empirical formula = C_5H_6O ✓
M_r is 164 so molecular formula = $C_{10}H_{12}O_2$ ✓
</td><td>2</td><td>
ALLOW alternative method
73.15% × 164 = 120 } ratio = 10 OR 5
7.37% × 164 = 12.1 } 12 OR 6
19.48% × 164 = 31.9 } 2 OR 1
✓ ✓

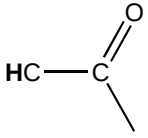
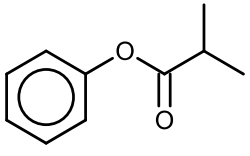
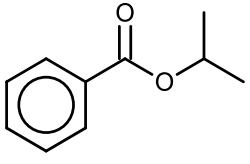
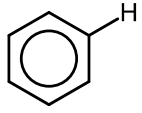
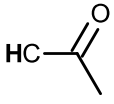
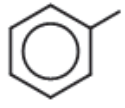
This mark is for some evidence of using M_r, which is twice the value that you would obtain from the empirical formula
</td></tr>
<tr><td></td><td>(b)</td><td></td><td>seven ✓</td><td>1</td><td></td></tr>
<tr><td></td><td>(c)</td><td>(i)</td><td>TMS is the standard (for chemical shift measurements) ✓</td><td>1</td><td>ALLOW TMS is the reference OR for calibration
IGNORE unreactive / volatile / it gives a sharp peak
ALLOW TMS = 0 ppm / TMS is used for comparison</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>(relative) number of protons/hydrogens in each environment / peak / region
OR three proton environments with protons in ratio 5:1:6 ✓</td><td>1</td><td>ALLOW (relative) number of each type of proton/hydrogen
IGNORE number of protons in the compound</td></tr>
<tr><td></td><td></td><td>(iii)</td><td>^{13}C NMR Analysis (1 mark)

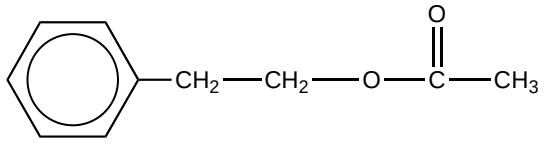
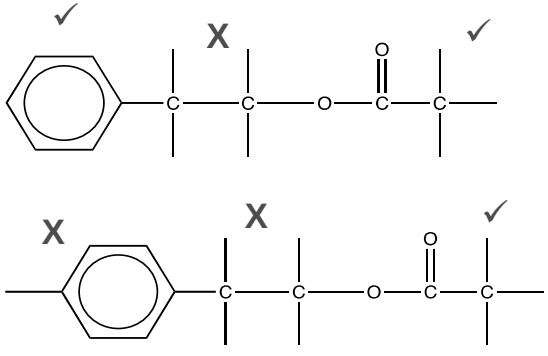
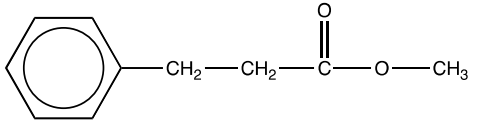
The peak at 185ppm suggests an ester group /
 

AND one of the following:

The peaks between 120ppm and 160ppm indicate a benzene ring
OR the peaks at 18ppm AND 36ppm suggest C-C ✓</td><td>7</td><td>FULL ANNOTATIONS WITH TICKS, CROSSES,CON ETC MUST BE USED

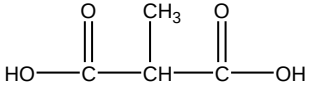
Inclusion of an incorrectly assigned ^{13}C peak CONS M1</td></tr>
</table>

Question	Answer	Marks	Guidance
	^{1}H ANALYSIS (4 marks) Doublet / peak at 1.2 shows R-C**H AND** 6 H's / 2 CH_3 (in this environment) ✓ Multiplet / septet / heptet / peak split into 7 / peak at 2.7ppm indicates  ✓ The doublet suggests that two CH_3 groups are attached to a CH **OR** the multiplet / septet / heptet suggests that the CH group is attached to two CH_3 groups ✓ ✎ **QWC** must spell **one** of *multiplet*, *septet*, *heptet* **OR** *doublet correctly* Peak at 7.3ppm indicates a benzene ring **AND** 5 H's ✓ **Compound identification (2 marks)** **IF** identified as  then **two** marks ✓✓ **IF** identified as  then **one** mark ✓		Candidates may quote δ values as ranges taken from Data Sheet, so **ALLOW** tolerance (ppm) eg 6.5–8 aromatic  2.0–2.9 carboxyl  0.7–2.0 alkyl R—C**H** **ALLOW** peaks labelled on the spectrum If **QWC** word is not used, MAX 3 for proton NMR **ALLOW** C_6H_5 **IGNORE** reference to phenol Allow  as C_6H_5 if they state that the benzene ring has 5 H's
	Total	**12**	

Question			er	Marks	Guidance
4	(a)	(i)	(number of esters) from number of peaks/retention times **AND** (proportions) from (relative) peak areas ✓	1	**BOTH** points for 1 mark **ALLOW** peak heights **OR** sizes of peaks
		(ii)	(Some esters may have) same retention time ✓	1	**ALLOW** (very) similar retention times **ALLOW** some esters come out at same time
	(b)		**Ester structure 3 marks**  ✓✓ **STICKS** IF there are sticks are shown in CH_2CH_2 **OR** in CH_3 **DO NOT AWARD** when first seen **DO NOT ALLOW** sticks on the benzene ring, *Sticks on benzene ring **must** be interpreted as methyl groups* e. 	3	***ANNOTATIONS MUST BE USED*** --- **ALLOW** correct structural **OR** displayed **OR** skeletal formula **ALLOW** combination of formulae as long as unambiguous **NO ECF** for structure --- **IF** the structure is **NOT** fully correct, award the following marks: **IF ESTER** shown **AND** contains **ONE** of the following: C_6H_5 **OR** $CH_3C{=}O$ **OR** CH_2CH_2 1 mark ✓ **IF ESTER** shown **AND** contains **TWO** of the following: C_6H_5 **OR** $CH_3C{=}O$ **OR** CH_2CH_2 2 marks ✓✓ **IF ESTER** contains **C_6H_5 AND** CH_2CH_2 **BUT** ester link is reversed 2 marks ✓✓  **DO NOT ALLOW** CH_2CH_2 with H on any adjacent Cs e.g. **DO NOT ALLOW** $CH_2CH_2CH_3$, $CH_2CH_2CH_2$, etc. **IGNORE** any name

Question			er	Marks	Guidance
			Mass spectrum 164 linked directly to molecular formula of $C_{10}H_{12}O_2$ **OR** an ester structure with formula $C_{10}H_{12}O_2$ ✓ *This direct link could be seen anywhere in the response* e.g. 164 is $C_{10}H_{12}O_2$ e.g. $C_{10}H_{12}O_2$ = 120 + 12 + 32 = 164 e.g. (164 – 44/COO) = 120; 120 = C_9H_{12} --- **NMR analysis** **QWC** *Triplet must be spelled correctly and used in correct context* Triplet at 2.8 ppm shows an adjacent CH_2 **AND** Triplet at 4.4 ppm shows an adjacent CH_2 ✓ Peak at 2.2 shows C**H$_3$**–C=O **OR** Peak at 2.2 shows HC–C=O **AND 3** Hs of this type **OR** Peak at 2.2 shows HC–C=O **AND** adjacent to (C with) no Hs✓ Peak at 7.3 shows **5 aromatic Hs OR** shows C_6**H$_5$** ✓ *5Hs required* Peak at 2.8 shows C_6H_5–C**H OR** C_6H_5–C**H$_2$** ✓ *Just require C_6H_5–CH as testing environment here* Peak at 4.4 due to **H**C–O **OR H$_2$**C–O ✓ *Just require HC–O as testing environment here*	1 -------- 5	***Check back for any responses added to spectrum*** ***Credit responses throughout provided that it is clear which peaks are being referred to*** --- **ALLOW** tolerance on δ values: ± 0.2 ppm Throughout**, ALLOW** for H: proton **OR** H^+ For adjacent CH_2, **ALLOW** (C) adjacent to 2 Hs **ALLOW** There are 2 triplets **AND** triplet shows an adjacent CH_2 For peak at (δ =) 2.2 **ALLOW** singlet **OR** peak labelled 3 For peak at (δ =) 7.3 **ALLOW** peak labelled 5 **OR** multiplet **OR** quintet **OR** hextet **OR** heptet For peak at (δ =) 2.8 **ALLOW** triplet at 2.8 For peak at (δ =) 4.4 **ALLOW** triplet at 4.4
			Total	**11**	

Question			Answer	Mark	Guidance
5	(a)		idea of separating (the components/compounds) ✓ idea of (identifying compounds) by comparison with a (spectral) database ✓	2	**ALLOW** (identifies compounds) using fragmentation (patterns)/fragment ions (but **IGNORE** molecular ions) ✓ **Note**: Each marking point does **not** need to be linked to GC or MS (The question asks about GC–MS as a combined technique)
	(b)	(i)	54.2% of 118 **OR** 54.2/118 x 100 = 64/63.96 (hence there are 4 oxygens) ✓ 118 – 64 = 54 hence 4 carbon (48) and 6 hydrogen (6) ✓	2	**IGNORE** calculation that proves that $C_4H_6O_4$ has a molar mass of 118 (ie 12 x 4 + 6 x 1 + 16 x 4) **ALLOW** 64/118 x 100 = 54.2% for 1st mark **IGNORE** method using empirical formula **ALLOW** any reasonable working leading to 4C **Note**: 54.2(%) ÷ 16 would **not** get the 1st mark but the answer could be used to get the 2nd mark
		(ii)	carboxyl group **OR** carboxylic acid ✓ must be **name** (in question)	1	**IGNORE** working, e.g. O–H, C=O, C–O on IR spectrum

Question			er	Mark	Guidance
5	(c)	(i)	***Chemical shifts*** Any **two** peaks identified for **1 mark** ✓ peak at δ = 0.8 ppm due to R–C**H** / CH_3CH peak at δ = 3.4 ppm due to **H**C–C=O peak at δ = 11 ppm due to COO**H** / carboxylic acid ***Splitting*** quartet shows adjacent CH_3 **OR** 3 adjacent Hs ✓ doublet shows adjacent CH **OR** 1 adjacent H ✓ ***Identification***  ✓	**1** **2** **1**	***ANNOTATIONS MUST BE USED*** **CHECK SPECTRUM** for responses **ANNOTATE** with '^' For peak at (δ =) 0.8 (ppm), **ALLOW** doublet and vice versa For peak at (δ =) 3.4 (ppm), **ALLOW** quartet ' and vice versa For peak at (δ =) 11 (ppm), **ALLOW** singlet and vice versa **ALLOW** peak at δ = 2.4 ppm for peak at δ = 3.4 ppm **ALLOW** tolerance on δ values: ± 1 ppm For quartet, **ALLOW** quadruplet **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous)
		(ii)	$(CD_3)_2SO$ / D / It does **not** absorb **OR** does not give a peak ✓	**1**	**ALLOW** $(CD_3)_2SO$ / does **not** contain H **ALLOW** undeuterated solvents would absorb **OR** give peaks **ALLOW** responses in terms of $(CH_3)_2SO$ producing peaks …… **but IGNORE** number of peaks
		(iii)	TMS is the standard (for chemical shift measurements) ✓	**1**	**ALLOW** TMS is the reference **OR** TMS has δ = 0 (ppm) **OR** for calibration **IGNORE** unreactive, volatile, it gives a sharp peak
		(iv)	peak at δ = 11.0 (ppm) disappears ✓	**1**	**ALLOW** COOH (peak) disappears **ALLOW** OH (peak) disappears
			Total	**12**	