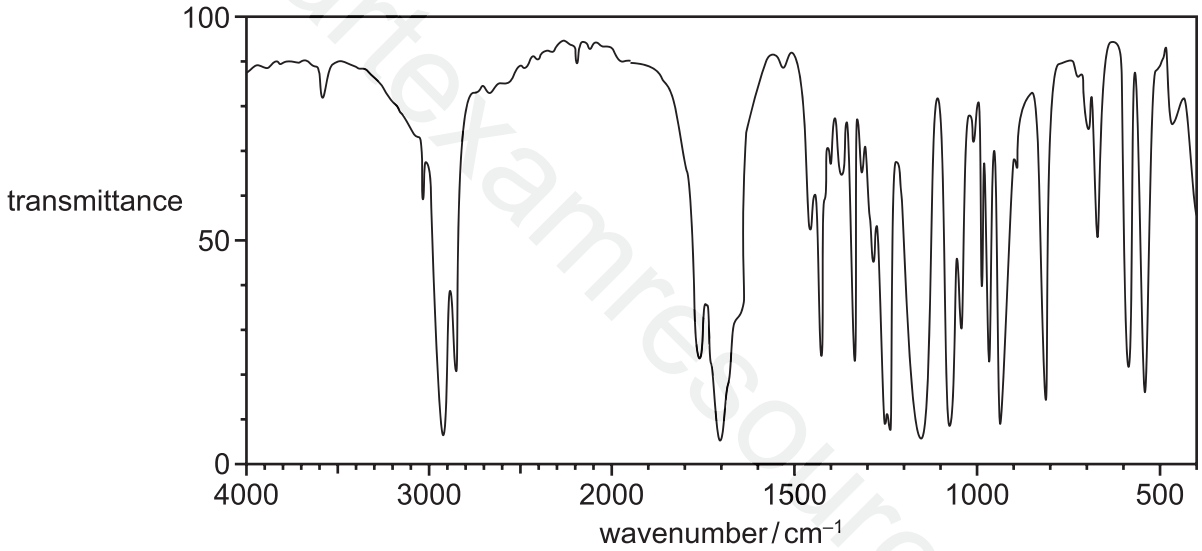
SMART EXAM RESOURCES
9701 CAMBRIDGE AS CHEMISTRY
TOPIC QUESTIONS AND MARK SCHEMES
TOPIC :Analysis
SUB-TOPIC: Infra Red Spectroscopy
SET-1-QP-MS

1 When glycolic acid is heated in the presence of a sulfuric acid catalyst, a new compound, **Y**, $C_4H_4O_4$, is formed.
The equation for the reaction is given.

$$2CH_2(OH)CO_2H \rightarrow C_4H_4O_4 + 2H_2O$$
glycolic acid **Y**

(i) The infra-red spectrum of **Y** is shown.



State how this spectrum differs from an infra-red spectrum of glycolic acid. Explain your answer with particular reference to the peaks within the range 1500–4000 cm^{-1}.

.....

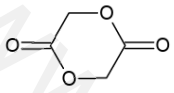
.....

..... [2]

(ii) Suggest a structure for **Y**.

[2]

Mark Scheme:

(i)	**EITHER** Glycolic acid would have: **M1 2500–3000** due to RCO_2-H **M2** range within 3200–3650 due to RO–H **OR** Spectrum Y would NOT have: **M1 2500–3000** due to RCO_2-H **M2** range within 3200–3650 due to RO–H	**2**
(ii)	 **M1** ANY ester group **AND** valid $C_4H_4O_4$ molecule **M2** correct cyclic structure	**2**

2 Trihalomethanes are organic molecules in which three of the hydrogen atoms of methane are replaced by halogen atoms, for example CHF_3.

(a) The equation shows a reaction to produce CHF_3.

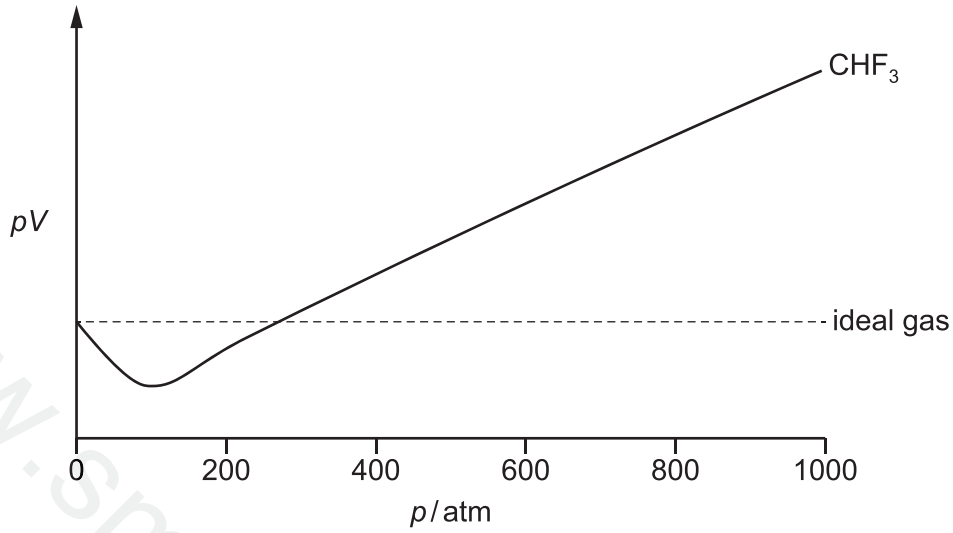
$$CHI_3(s) + 3AgF(s) \rightarrow CHF_3(g) + 3AgI(s)$$

Use the data to calculate the enthalpy change of reaction, ΔH_r, for this formation of CHF_3.

compound	enthalpy change of formation, ΔH_f / kJ mol^{-1}
$CHI_3(s)$	–182.1
$CHF_3(g)$	–692.9
AgF(s)	–204.6
AgI(s)	–61.8

enthalpy change of reaction, ΔH_r = ... kJ mol^{-1} [3]

(b) The graph shows the relationship between pV and p at a given temperature for CHF_3 and an ideal gas.



(i) CHF_3 is not an ideal gas.

State **three** basic assumptions that scientists make about the properties of ideal gases.

1 .....

2 .....

3 .....

[3]

(ii) Explain why CHF_3 deviates from the properties of an ideal gas at pressures greater than 300 atm.

.....

.....

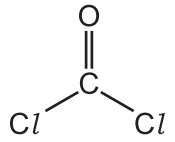
.....

..... [2]

Mark Scheme:

(a)	ΔH_r = (–692.9)+3(–61.8)- (–182.1) –3(–204.6) = –82.4 (kJ mol^{-1}) **M1** ΔH_r = x(–692.9) + y(–61.8) –v(–182.1) –w(–204.6) where x y v and w are integers ⩾1 [1] **M2** use of correct stoichiometry where x =1 y =3 v =1 and w=3 [1] **M3** –82.4 [1]	**3**
b)(i)	1 mark for each bullet, max 3 • particles / molecules have (mass but) negligible size / volume (compared to total volume of gas / container) • no / negligible forces / interactions between particles / molecules • collision between particles / molecules are elastic • gas obeys (all) basic gas laws	**3**
b)(ii)	**M1** particles / molecules are (so) close [1] **M2** particle / molecule size becomes significant [1] OR repulsive forces between particle / molecules become significant	**2**

3 A different trihalomethane, $CHCl_3$, reacts with O_2 to produce carbonyl dichloride. $HCl(g)$ is also released as a product of this reaction.

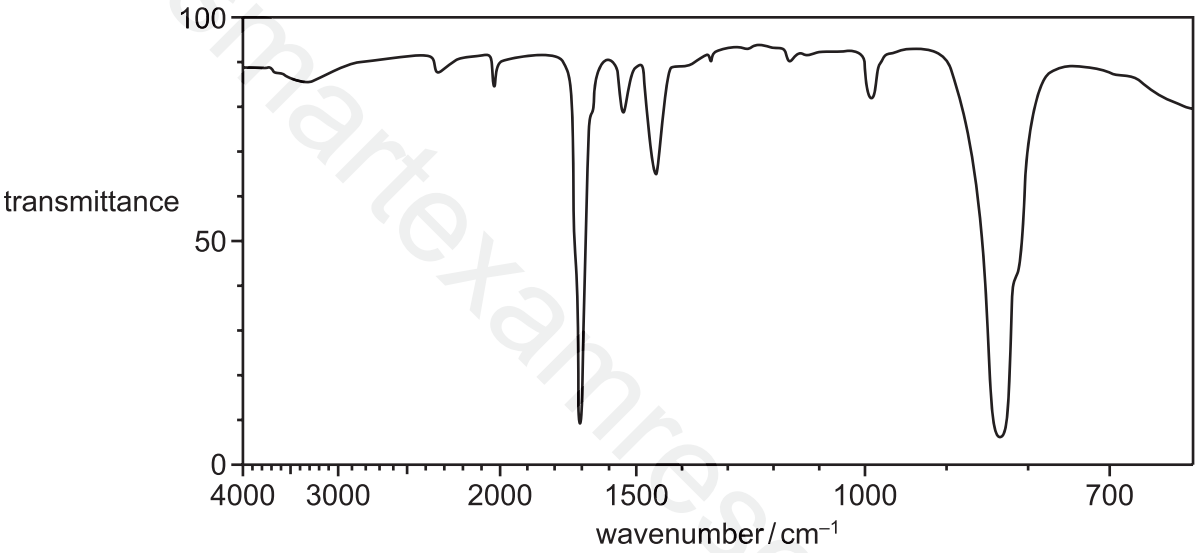


carbonyl dichloride

(i) Write an equation for this reaction of $CHCl_3$ with O_2.

..... [1]

(ii) The conversion of $CHCl_3$ to carbonyl dichloride can be monitored by infra-red spectroscopy. The infra-red spectrum of carbonyl dichloride is shown.



On the infra-red spectrum of carbonyl dichloride identify with an **X** the absorption that would **not** be present in an infra-red spectrum of $CHCl_3$.

Explain your answer.

.....

.....

[2]

(iii) Suggest another difference between the infra-red spectra of $CHCl_3$ and carbonyl dichloride.

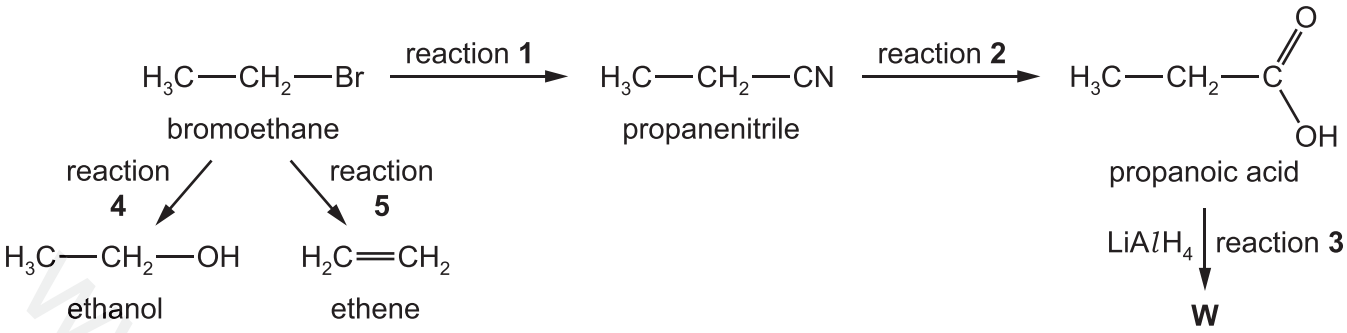
.....

..... [1]

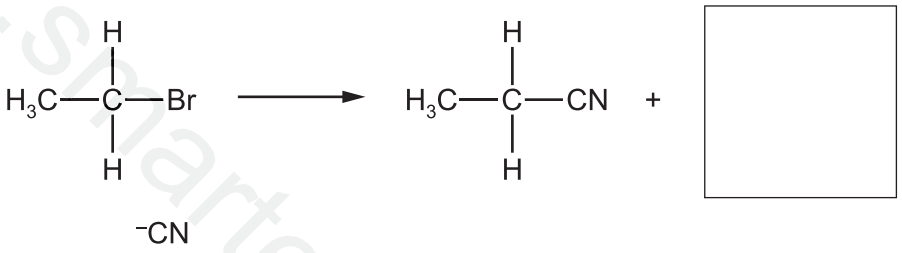
Mark Scheme:

)(i)	$CHCl_3 + ½O_2 \rightarrow COCl_2 + HCl$	**1**
(ii)	**M1 X** marked on peak at 1670–1740 cm^{-1} [1] **M2** $CHCl_3$ has no C=O [1]	**2**
(iii)	(It / $CHCl_3$ has a) peak at 2850–2950 (cm^{-1}) OR carbonyl dichloride spectrum has no peak 2850–2950 (cm^{-1})	**1**

4 A reaction sequence is shown.



(a) Complete the diagram to show the mechanism of reaction **1**. Include all necessary charges, partial charges, lone pairs and curly arrows.

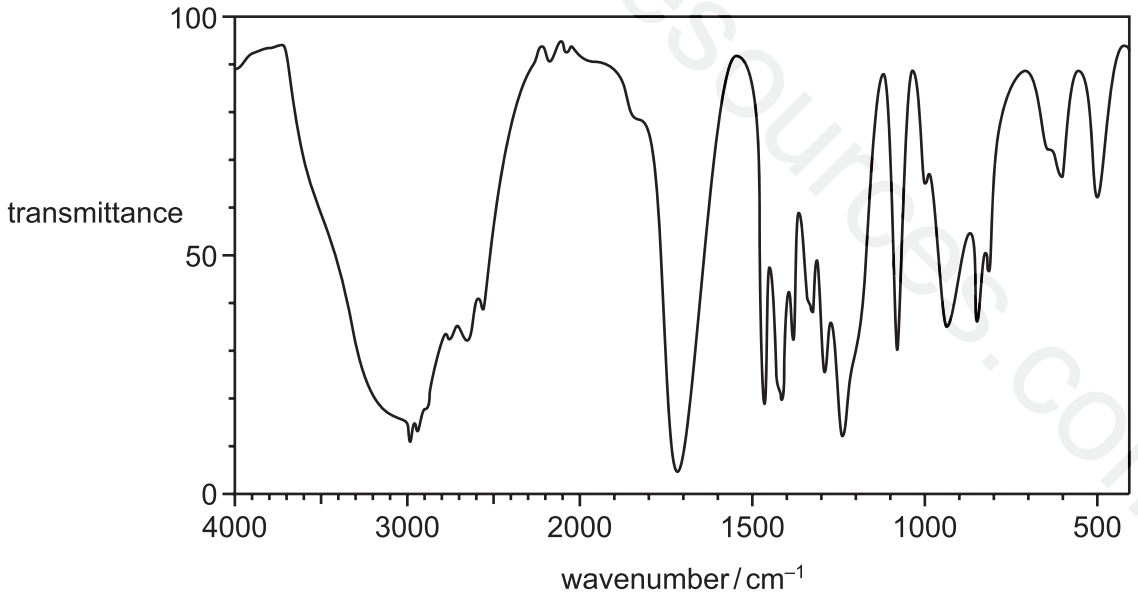


[2]

(b) (i) Give the name of the type of reaction involved in reaction **3**.

..... [1]

The infra-red spectrum of the propanoic acid produced by reaction **2** is shown.



(ii) Describe and explain the main difference between the infra-red spectrum of **W** and that of propanoic acid.

.....

..... [2]

(c) **(i)** Reactions **4** and **5** use the same reagent.

Give the reagent and conditions needed for reaction **4**.

reagent .....

conditions ..... [2]

(ii) Give the conditions needed for reaction **5**.

..... [1]

(d) Under appropriate conditions, ethanol and propanoic acid undergo a condensation reaction.

(i) State the condition necessary for the reaction.

..... [1]

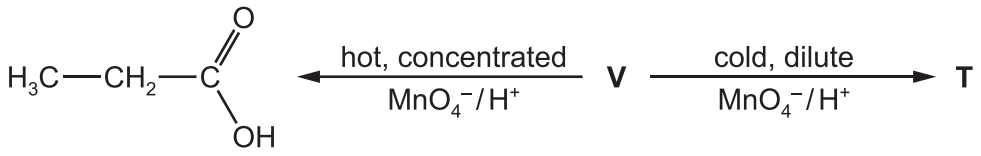
(ii) Draw the skeletal formula of the organic product of this reaction.

[1]

(iii) Name the organic product of this reaction.

..... [1]

(e) **V** reacts with acidified manganate(VII) ions in two different ways depending on the conditions, as shown in the reaction sequence below.



propanoic acid

V decolourises bromine water.

When the acidified manganate(VII) is hot and concentrated, propanoic acid is the only organic product.

When the acidified manganate(VII) is cold and dilute, the organic product is **T** which has two chiral centres.

(i) Give the structural formulae of **V** and **T**.

V ..... **T** .....

[2]

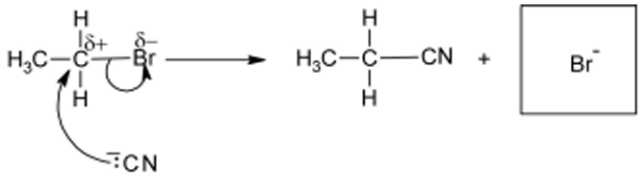
(ii) Identify the types of stereoisomerism shown by **V** and **T**.

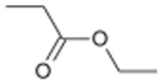
V ..... **T** .....

[2]

[Total: 15]

Mark Scheme:

(a)	 M1 = lone pair on C of CN− AND curly arrow from lone pair to C of C—Br M2 = correct dipole on C—Br, curly arrow from C—Br bond to Br AND Br^-	[1] [1]	[2]
(b) (i)	reduction	[1]	[1]
(ii)	disappearance of peak / dip / trough / absorption at 1680–1730 due to (loss of) C=O OR peak at 3200–3650 due to (alcohol) O—H (formation)	[1] [1] [1] [1]	[2]
(c) (i)	sodium/potassium hydroxide aqueous	[1] [1]	[2]

(ii)	ethanol	[1]	[1]
(d) (i)	(conc) H^+ / (conc) acid / (conc)H_2SO_4 / (conc)H_3PO_4	[1]	[1]
(ii)		[1]	[1]
(iii)	ethyl propanoate	[1]	[1]
(e) (i)	**V** = $CH_3CH_2CHCHCH_2CH_3$ / $CH_3CH_2CH{=}CHCH_2CH_3$ **T** = $CH_3CH_2CH(OH)CH(OH)CH_2CH_3$	[1] [1]	[2]
(ii)	**V** = geometric(al) / *cis-trans* / *E–Z* **T** = optical	[1] [1]	[2]
			[15]

5 Acetoin, $CH_3COCH(OH)CH_3$, and diacetyl, $CH_3COCOCH_3$, are two of the compounds that give butter its characteristic flavour. Their skeletal formulae are shown.

acetoin diacetyl

(a) Give the systematic name for acetoin.

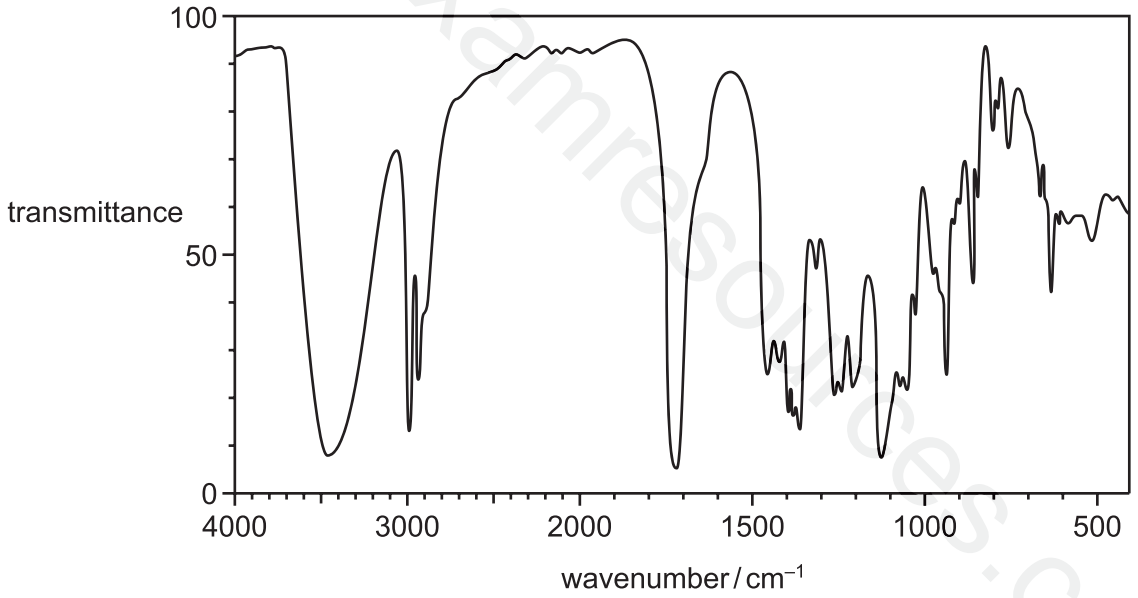
..... [1]

(b) Identify the reagents and conditions necessary for the conversion of acetoin into diacetyl.

.....

..... [2]

(c) The infra-red spectrum for acetoin is shown.



(i) Explain the main features of this spectrum, with reference to the peaks with wavenumbers greater than 1500 cm^{-1}.

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..... [3]

(ii) State and explain how the infra-red spectrum for diacetyl would differ from the infra-red spectrum for acetoin.

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..... [2]

(d) If a sample of acetoin is reacted with concentrated sulfuric acid, a single product is formed that does **not** exhibit stereoisomerism.

However, if a sample of acetoin is reacted with HBr, a mixture of a pair of stereoisomers is produced.

(i) Give the structural formula of the product of the reaction of acetoin with concentrated sulfuric acid.

..... [1]

(ii) Explain why the product in **(i)** does **not** exhibit stereoisomerism.

.....

.....

..... [2]

(iii) Explain why the product of reaction of acetoin with HBr **does** exhibit stereoisomerism.

.....

.....

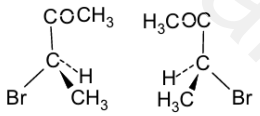
..... [1]

(iv) Draw the two stereoisomers from **(iii)** using the conventional representation.

[2]

[Total: 14]

Mark Scheme:

(a)	3-hydroxybutan(-2-)one	[1]	[1]
(b)	H_2 / $Cr_2O_7^{2-}$ or names heat / reflux / warm	[1] [1]	[2]
(c) (i)	absorption at 1670–1740 C (=) O absorption at 2850–3000 C (-) H absorption at 3200–3650 O (-) H	[1] [1] [1]	[3]
(ii)	no absorption at 3200–3650 O-H disappears / no O-H bond in diacetyl	[1] [1]	[2]
(d) (i)	$CH_3COCH(=)CH_2$	[1]	[1]
(ii)	one of the double-bonded C atoms / first C has 2H atoms attached **ora** so no cis-trans / *E-Z* / geometric(al) isomerism possible OR no chiral C so mirror images superimposable / molecule not asymmetric	[1] [1]	[2]
(iii)	asymmetric / chiral C atom / carbon with four different groups / atoms attached	[1]	[1]
(iv)		[1+1]	[2]
			[14]