OCR
Oxford Cambridge and RSA

# A Level Chemistry A

## H432/03 Unified chemistry

# Tuesday 27 June 2017 – Morning

## Time allowed: 1 hour 30 minutes

**You must have:**
- the Data Sheet for Chemistry A (sent with general stationery)

**You may use:**
- a scientific or graphical calculator
- a ruler

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| First name | | | | | | | | | |
| Last name | | | | | | | | | |
| Centre number | | | | | | Candidate number | | | | |

**INSTRUCTIONS**
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

**INFORMATION**
- The total mark for this paper is **70**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **20** pages.

Answer **all** the questions.

**1** Within the permafrost in Arctic regions of the Earth, large amounts of methane are trapped within ice as 'methane hydrate', $CH_4 \cdot xH_2O$. Methane makes up about 13.4% of the mass of 'methane hydrate'.

Scientists are concerned that global warming will melt the permafrost, releasing large quantities of methane into the atmosphere.

tetrahedral 4 bonded pairs → non-linear 2 bonded pairs 2 lone pairs

**(a)** The H–O–H bond angle in ice is about 109° but about 105° in gaseous $H_2O$.

Explain why there is this difference.

ice can form more hydrogen bonds. water ($H_2O$) has 2 bonded pairs and 2 lone pairs: 

lone pairs repel more than bonded pairs hence different bond angles. **[3]**

**(b)** Why are scientists concerned about the release of methane into the atmosphere?

Contributes towards global warming

**[1]**

**(c)** Determine the formula of 'methane hydrate', $CH_4 \cdot xH_2O$.

In the formula, show the value of x to **two** decimal places.

$$\frac{13.4}{(12+4)} = \frac{100}{(12+4)+18x}$$

$$13.4(16+18x) = 100(16)$$

$$214.4 + 241.2x = 1600$$

$$241.2x = 1385.6$$

$$x = 5.74$$

formula = $CH_4 \cdot 5.74H_2O$ **[2]**

**(d)** Calculate the volume of methane, in $dm^3$, that would be released from the melting of each 1.00 kg of 'methane hydrate' at 101 kPa and 0 °C.

Give your answer to **three** significant figures.

$PV = nRT$ R K

Pa $m^3$

moles of $CH_4 \cdot 5.74H_2O$

$$\frac{1 \times 10^3}{12+4+(5.74 \times (2+16))}$$

$= 8.38$ mol

$$V = \frac{nRT}{P}$$

$$V = \frac{8.38 \times 8.314 \times 273}{101 \times 10^3} = 0.188\ m^3$$

$= 188\ dm^3$

volume = ..... 188 ..... $dm^3$ **[4]**

**(e)** Suggest why some industries are interested in the presence of 'methane hydrate' in regions of the Earth.

for fuel / energy .....

.....

..... **[1]**

**2** A student plans to determine the enthalpy change of **reaction 3.1** shown below.

$$Na_2O(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) \qquad \textbf{reaction 3.1}$$

This enthalpy change can be determined indirectly using Hess' Law from the enthalpy changes of **reaction 3.2** and **reaction 3.3** shown below.

$$Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq) \qquad \textbf{reaction 3.2}$$

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l) \quad \Delta_r H = -57.6\,kJ\,mol^{-1} \qquad \textbf{reaction 3.3}$$

The student will determine the enthalpy change of **reaction 3.2** as outlined below.

- Weigh a bottle containing $Na_2O(s)$ and weigh a polystyrene cup.
- Add about $25\,cm^3$ of water to the polystyrene cup and measure its temperature.
- Add the $Na_2O(s)$, stir the mixture, and measure the maximum temperature reached.
- Weigh the empty bottle and weigh the polystyrene cup with the final solution.

**Mass readings**

| | |
|---|---|
| Mass of bottle + $Na_2O(s)$ | = 16.58 g |
| Mass of empty bottle | = 15.34 g |
| Mass of empty polystyrene cup | = 21.58 g |
| Mass of polystyrene cup + final solution | = 47.33 g |

**Temperature readings**

| | |
|---|---|
| Initial temperature of water | = 20.5 °C |
| Maximum temperature of final solution | = 55.5 °C |

The density and specific heat capacity, *c*, of the solution are the same as for water.

$\Delta H\,3.1 = \Delta H\,3.2 + 2 \times \Delta\,3.3$

5

**(a)*** Calculate the enthalpy change of **reaction 3.2** and the enthalpy change of **reaction 3.1.**

Show all your working.

$mc\Delta T = E$ (joules)

mass of $Na_2O = 16.58 - 15.34$
$= 1.24g$

mass of solution $= 47.33 - 21.58$
$= 25.75g$

$\Delta T = 55.5 - 20.5 = 35°C$

$25.75 \times 4.18 \times 35 = 3767.225J$
$= 3.767225kJ$

exothermic so -ve $\Delta H$ value

$mol = \frac{1.24}{(23\times2)+16} = 0.02 mol$

$\Delta H$ 3.2:

$3.767225 \div 0.02 = 188 kJmol^{-1}$

$\Delta H$ 3.1 $= -188 + (-57.6 \times 2) = -303.2$ $kJmol^{-1}$ **[6]**

**(b)** The uncertainty in each temperature reading is ±0.1 °C.

The uncertainty in each mass reading is ±0.005 g.

Determine whether the mass of $Na_2O$ or the temperature change has the greater percentage uncertainty.

Show all your working.

number of times readings were used

mass: $\frac{0.005 \times 2}{1.24} \times 100 = 0.81\%$

temperature: $\frac{0.1 \times 2}{35} \times 100 = 0.57\%$.

mass has a greater % uncertainty **[2]**

**(c)** Suggest a modification to this experiment, using the **same** apparatus, which would reduce the percentage errors in the measurements.

larger denominator
smaller % uncertainty

Explain your reasoning.

greater mass or greater temperature change ($\Delta T$) to reduce % errors

..... **[2]**

**(d)** Sodium oxide, $Na_2O$, can be prepared by the redox reaction of $NaNO_2$ and sodium metal. Nitrogen gas is also formed.

**(i)** What is the systematic name for $NaNO_2$?

Sodium nitrate ..... **[1]**

**(ii)** Using oxidation numbers, with signs, show the element that is oxidised and the element that is reduced in this reaction.

$2NaNO_2 + 6Na \rightarrow 4Na_2O + N_2$

$+1\ +3\ -2 \quad 0 \quad +1\ -2 \quad 0$

Element oxidised ..... Na .....

Oxidation number change from ..... 0 ..... to ..... +1 .....

Element reduced ..... N .....

Oxidation number change from ..... +3 ..... to ..... 0 .....

**[2]**

**(iii)** Construct the equation for this reaction.

Equation ... $2NaNO_2 + 6Na \rightarrow 4Na_2O + N_2$ ... **[1]**

**3** This question is about reactions of hydrogen peroxide, $H_2O_2$.

**(a)** Hydrogen peroxide, $H_2O_2$, iodide ions, $I^-$, and acid, $H^+$, react as shown in the equation below.

$$H_2O_2(aq) + 2I^-(aq) + 2H^+(aq) \rightarrow I_2(aq) + 2H_2O(l)$$

A student carries out several experiments at the same temperature, using the initial rates method, to determine the rate constant, *k*, for this reaction.

The results are shown below.

| Experiment | Initial concentrations | | | Rate |
|---|---|---|---|---|
| | $[H_2O_2(aq)]$ / mol dm$^{-3}$ | $[I^-(aq)]$ / mol dm$^{-3}$ | $[H^+(aq)]$ / mol dm$^{-3}$ | / $10^{-6}$ mol dm$^{-3}$ s$^{-1}$ |
| 1 | 0.0100 | 0.0100 | 0.100 | 2.00 |
| 2 | 0.0100 | 0.0200 | 0.100 | 4.00 |
| 3 | 0.0200 | 0.0100 | 0.100 | 4.00 |
| 4 | 0.0200 | 0.0100 | 0.200 | 4.00 |

**(i)** Determine the rate equation and calculate the rate constant, *k*, including units.

rate $= k[H_2O_2]^1[I^-]^1[H^+]^0$

rate $= k[H_2O_2][I^-]$

$\frac{2 \times 10^{-6}}{0.01 \times 0.01} = 0.02$

$\frac{mol\,dm^{-3}\,s^{-1}}{mol\,dm^{-3} \times mol\,dm^{-3}}$

*k* = 0.02 units $mol^{-1}\,dm^3\,s^{-1}$ [3]

**(ii)** The rate constant, *k*, for this reaction is determined at different temperatures, *T*.

Explain how the student could determine the activation energy, $E_a$, for the reaction graphically using values of *k* and *T*.

plot a graph of ln k against 1/T and measure the gradient.

Ea = gradient x -R

$\ln k = -\frac{Ea}{RT} + \ln A$ [3]

**(b)** Solutions of hydrogen peroxide decompose slowly into water and oxygen:

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

This reaction is catalysed by manganese dioxide, $MnO_2(s)$.

Standard electrode potentials are shown below.

| | | | | |
|---|---|---|---|---|
| I | $O_2(g) + 2H^+(aq) + 2e^-$ | $\rightleftharpoons$ | $H_2O_2(aq)$ | $E^\ominus = +0.70\,V$ |
| II | $MnO_2(s) + 4H^+(aq) + 2e^-$ | $\rightleftharpoons$ | $Mn^{2+}(aq) + 2H_2O(l)$ | $E^\ominus = +1.51\,V$ |
| III | $H_2O_2(g) + 2H^+(aq) + 2e^-$ | $\rightleftharpoons$ | $2H_2O(l)$ | $E^\ominus = +1.78\,V$ |

Using the electrode potentials, explain how $MnO_2$ is able to act as a catalyst for the decomposition of hydrogen peroxide.

You answer should include relevant equations.

I+II:

$H_2O_2 + MnO_2 + 2(4H^+ + 2e^-) \rightarrow O_2 + 2H^+ + 2e^- + Mn^{2+} + 2H_2O$

$H_2O_2 + MnO_2 + 2H^+ \rightarrow O_2 + Mn^{2+} + 2H_2O$

II+III:

$Mn^{2+} + 2H_2O + H_2O_2 + 2H^+ + 2e^- \rightarrow MnO_2 + 2(4H^+ + 2e^-) + 2H_2O$

$Mn^{2+} + H_2O_2 \rightarrow MnO_2 + 2H^+$

I more -ve E than II so I moves left. II more -ve E than III moves left. $MnO_2$ is regenerated so acts as a catalyst.

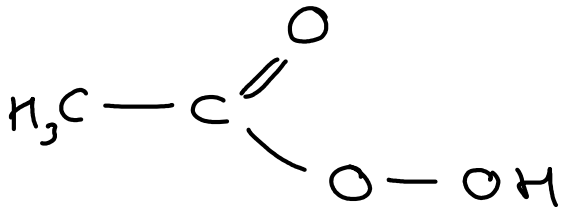
**[4]**

**(c)** Peroxycarboxylic acids are organic compounds with the COOOH functional group.

Peroxyethanoic acid, $CH_3COOOH$, is used as a disinfectant.

**(i)** Suggest the structure for $CH_3COOOH$.

The COOOH functional group must be clearly displayed.



**[1]**

**(ii)** Peroxyethanoic acid can be prepared by reacting hydrogen peroxide with ethanoic acid. This is a heterogeneous equilibrium.

different states

$$H_2O_2(aq) + CH_3COOH(aq) \rightleftharpoons CH_3COOOH(aq) + H_2O(l) \quad K_c = 0.37\,dm^3\,mol^{-1}$$

A $250\,cm^3$ equilibrium mixture contains concentrations of $0.500\,mol\,dm^{-3}$ $H_2O_2(aq)$ and $0.500\,mol\,dm^{-3}$ $CH_3COOH(aq)$.

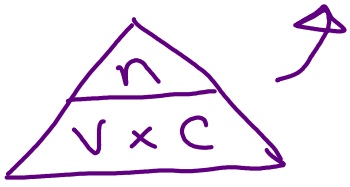
Calculate the amount, in mol, of peroxyethanoic acid in the equilibrium mixture.

square brackets means concentration

$$0.37 = K_c = \frac{[CH_3COOOH]}{[H_2O_2][CH_3COOH]} = \frac{[CH_3COOOH]}{[0.5][0.5]}$$

$$0.37 \times [0.5][0.5] = [CH_3COOOH] = 0.0925\ mol\,dm^{-3}$$

$$0.0925 \times 250 \times 10^{-3} = 0.023125\ mol$$




amount = ..... 0.023 ..... mol **[3]**

**10**

This question is about weak acids.

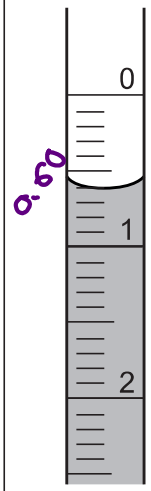
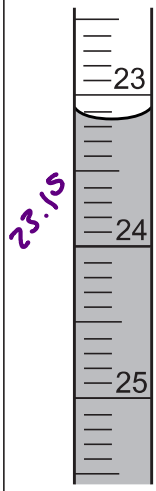
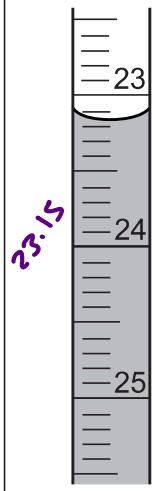
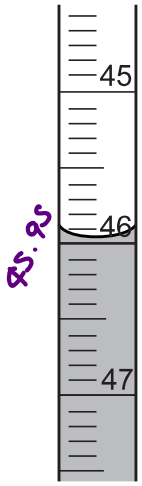
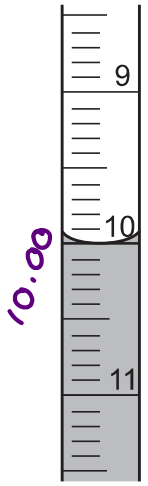
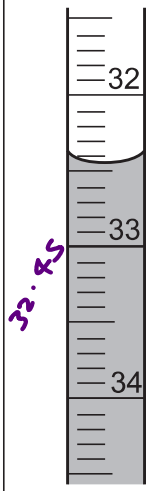
**(a)** Compound **A** is a weak monobasic acid.

A student is supplied with a 250.0 $cm^3$ solution prepared from 2.495 g of **A**.

The student titrates 25.0 $cm^3$ samples of this solution with 0.0840 mol $dm^{-3}$ NaOH in the burette.

The student carries out a trial, followed by the three further titrations. The diagrams show the initial burette readings and the final burette readings for the student's three **further** titrations.

All burette readings are measured to the nearest 0.05 $cm^3$.

| Titration 1 | | Titration 2 | | Titration 3 | |
|---|---|---|---|---|---|
| Initial reading | Final reading | Initial reading | Final reading | Initial reading | Final reading |
|  |  |  |  |  |  |



2dp.

**(i)** Record the student's readings and the titres in an appropriate format.

Calculate the mean titre that the student should use for analysing the results.

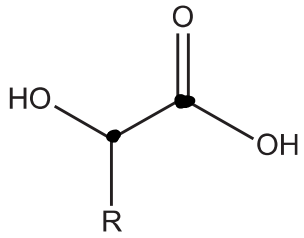
| final ($cm^3$) | initial ($cm^3$) | titre ($cm^3$) |
|---|---|---|
| 23.15 | 0.60 | 22.55 |
| 45.95 | 23.15 | 22.80 |
| 32.45 | 10.00 | 22.45 |

concordant within ± 0.10 $cm^3$

$$\frac{22.55 + 22.45}{2} = 22.50$$

mean titre = 22.50 $cm^3$ **[4]**

**(ii)** The structure of compound **A** is shown below.




**compound A**

C : 2
H : 3
O : 3

$(2 \times 12) + 3 + (16 \times 3)$
$= 75 + R = 131.7$

Compound **A** has four optical isomers.

Using this information and the student's results, answer the following.

- Determine the molar mass of **A** and the formula of the alkyl group R.
- Draw the structure of compound **A** and label any chiral carbon atoms with an asterisk*.

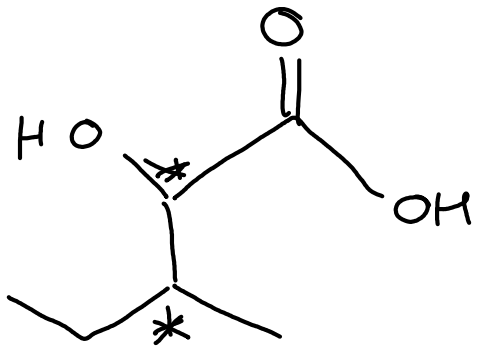
Show all your working.

mol of NaOH : $0.084 \times 22.5 \times 10^{-3} = 1.89 \times 10^{-3}$ mol

250cm$^3$: $1.89 \times 10^{-3} \times 10 = 1.89 \times 10^{-2}$ mol

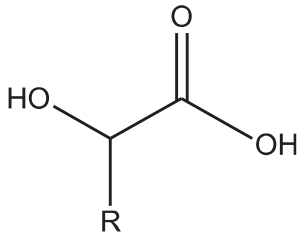
$$\frac{2.495}{1.89 \times 10^{-2}} = 131.7$$

$131.7 - 75 = 56.7 = 57 = C_4H_9$




**[6]**

**(b)** The structural formula of compound **A** is repeated below.




**compound A**

Two reactions of compound **A** are carried out.

Suggest an equation for each reaction and state the type of reaction.

In your equations, draw structures for organic compounds.
You can use R for the alkyl group.

**(i)** Magnesium ribbon is added to a solution of compound **A**.
Gas bubbles are seen and the magnesium slowly dissolves.

salt

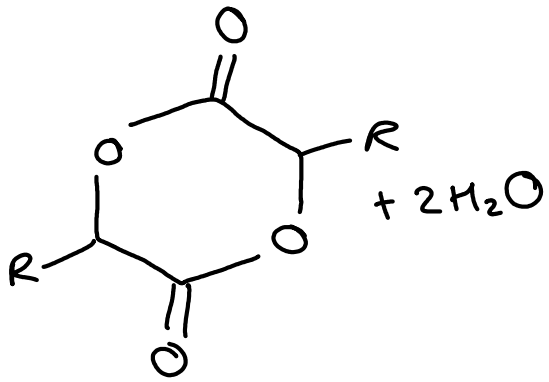
Equation

$2HOCH(R)COOH + Mg \rightarrow 2HOCH(R)COO^{-}Mg^{2+} + H_2$

Type of reaction redox ..... **[3]**

**(ii)** Compound **A** is heated with a few drops of concentrated sulfuric acid as a catalyst.
A cyclic 'dimer' of compound **A** forms.

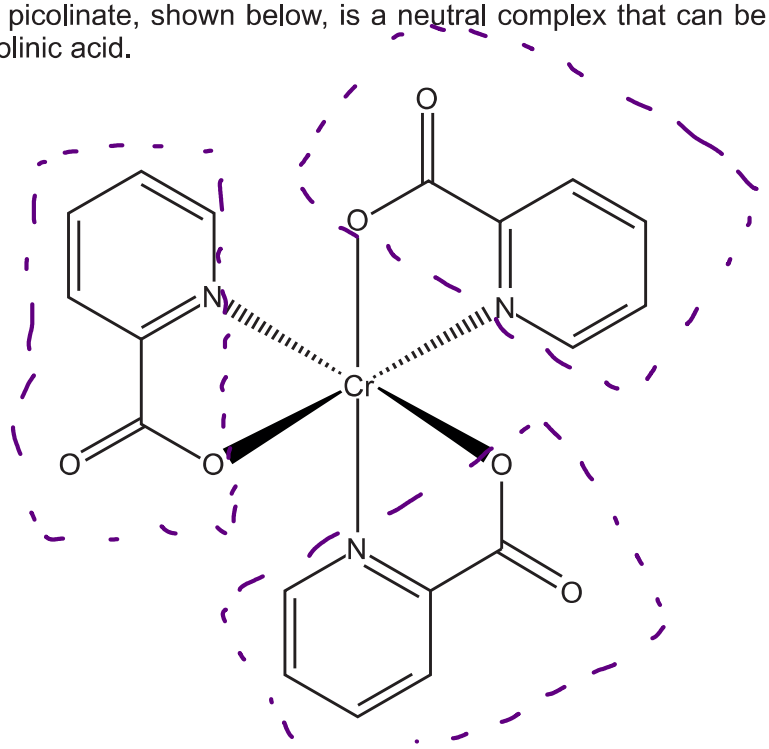
Equation

$2HOCH(R)COOH \rightarrow$  $+ 2H_2O$

compound consisting of 2 identical parts

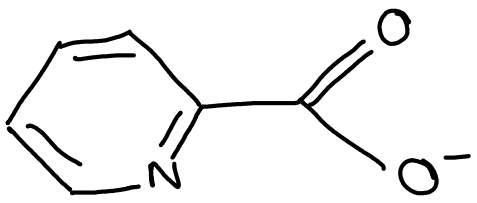
Type of reaction esterification ..... **[3]**

**(c)** Chromium(III) picolinate, shown below, is a neutral complex that can be prepared from the weak acid, picolinic acid.




Chromium(III) picolinate is used in tablets as a nutritional supplement for chromium.

**(i)** Draw the structure of the ligand in chromium(III) picolinate.




**[1]**

**(ii)** A typical tablet of chromium(III) picolinate contains 200 μg of chromium.

Calculate the mass, in g, of chromium(III) picolinate in a typical tablet.
1 μg = $10^{-6}$ g.

Give your answer to **three** significant figures.

C:6
H:4
O:2
N:1
} RFM = (12×6) + 4 + 14 + ((6×2)
= 122

(122 × 3) + 52 = 418 RFM of Chromium (III) picolinate

$\frac{200 \times 10^{-6}}{52} = 3.85 \times 10^{-6}$

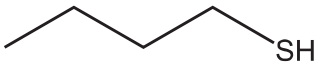
$3.85 \times 10^{-6} \times 418 = 1.61 \times 10^{-3}$

mass = 1.61 × 10⁻³ g **[2]**

**5** This question is about organic molecules that have a strong smell.

**(a)** Thiols are foul-smelling, organic sulfur compounds with the functional group –SH.

Butane-1-thiol, shown below, contributes to the strong smell of skunks.




**butane-1-thiol**

$K_a = \frac{[H^+][A^-]}{[HA]}$

**(i)** Thiols are weak acids.

Write the expression for the acid dissociation constant, $K_a$, for butane-1-thiol.

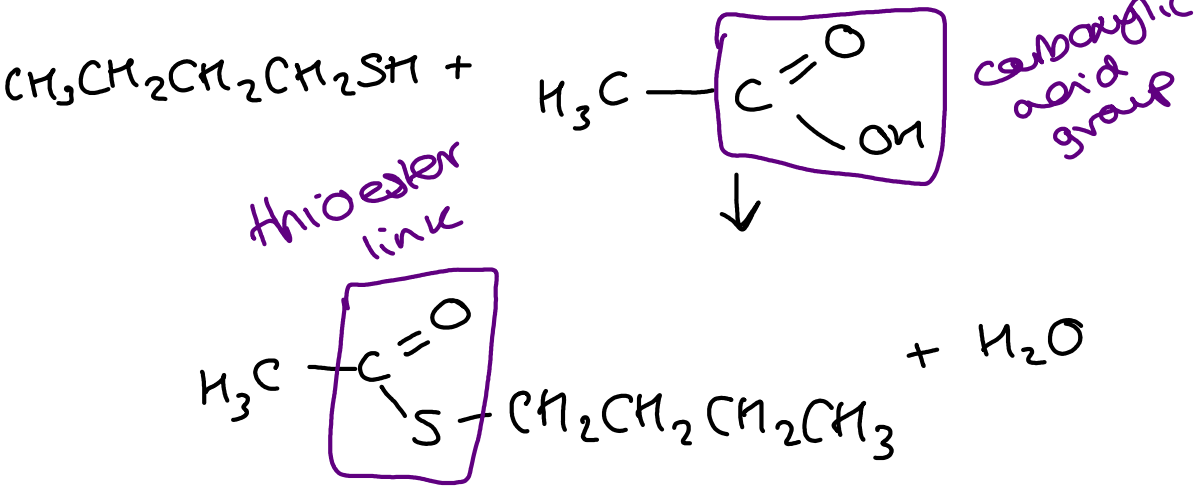
$K_a = \frac{[H^+][C_4H_9S^-]}{[C_4H_9SH]}$

**[1]**

**(ii)** Thiols react with carboxylic acids to form thioesters.

Write an equation for the reaction of butane-1-thiol with ethanoic acid.

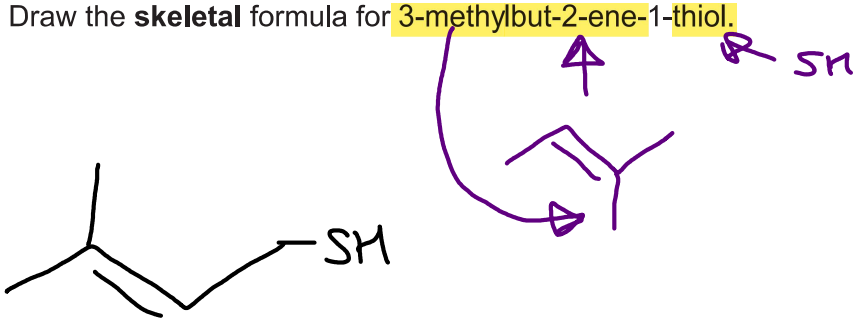
Use structures for all organic compounds with the functional groups clearly displayed.




**[2]**

**(iii)** When beer is exposed to light, 3-methylbut-2-ene-1-thiol is formed, which gives an unpleasant smell and flavour to the beer.

Draw the **skeletal** formula for 3-methylbut-2-ene-1-thiol.

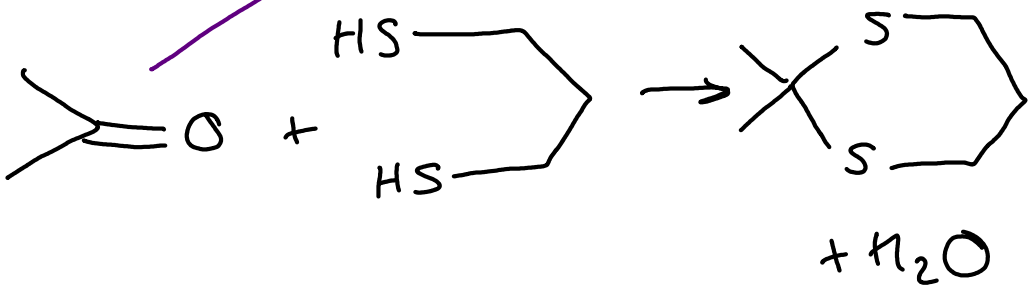



**[1]**

**(iv)** Propane-1,3-dithiol reacts with carbonyl compounds in a condensation reaction to form a cyclic organic sulfur product.

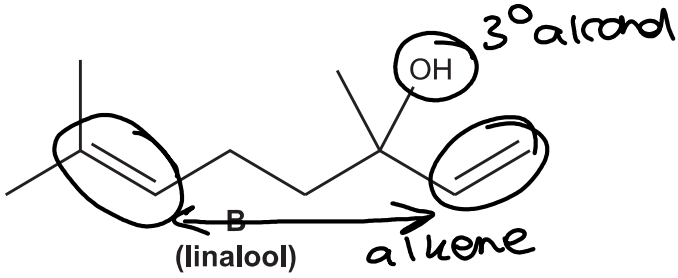
Write an equation for the reaction of propane-1,3-dithiol with propanone.

Use structures for organic compounds.

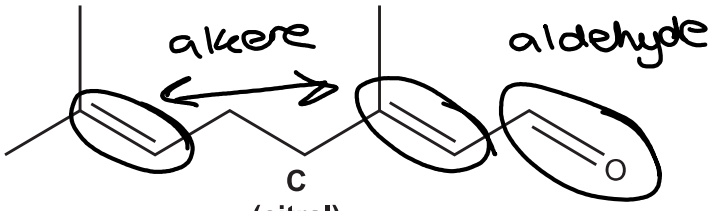



**[2]**

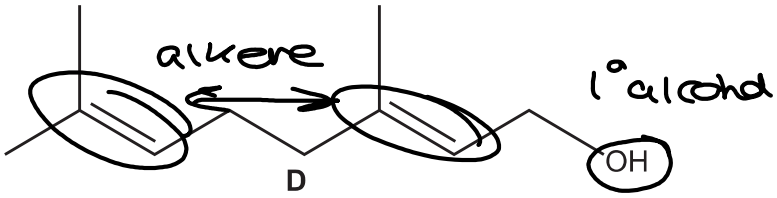
**(b)*** The structures for six naturally occurring organic compounds with pleasant smells, **B–G**, are shown below. The common names in brackets relate to their source and smell.



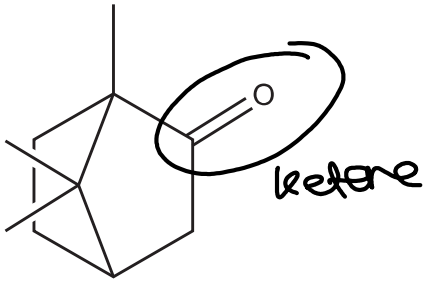

**(linalool)**



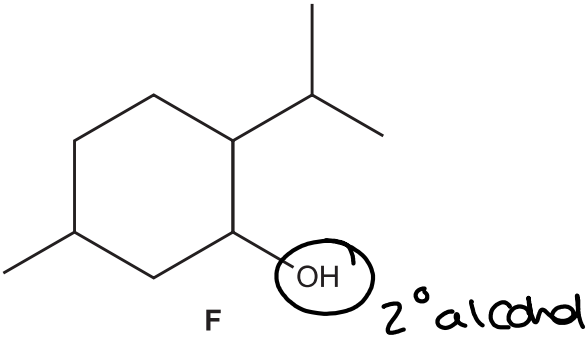

**(citral)**



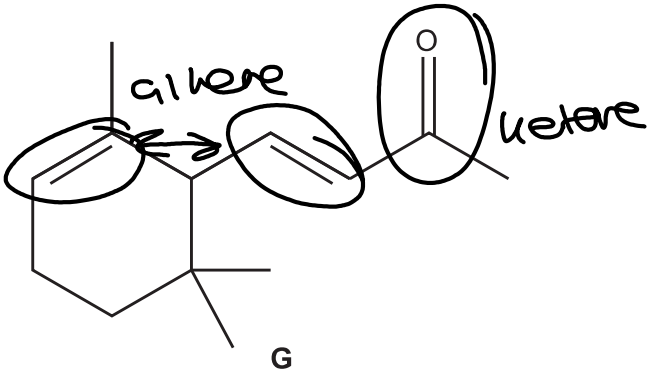

**(geraniol)**




**(camphor)**




**(menthol)**




**(ionone)**

**17**

Explain how chemical tests would allow each compound to be distinguished from the other compounds.

In your answer, include essential details for all test procedures and observations.

Details of apparatus and quantities are **not** required.


**[6]**

**END OF QUESTION PAPER**

## ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).