OXFORD CAMBRIDGE AND RSA EXAMINATIONS

A LEVEL

H432/03

CHEMISTRY A

Unified chemistry

TUESDAY 27 JUNE 2017: Morning

TIME ALLOWED: 1 hour 30 minutes
plus your additional time allowance

MODIFIED ENLARGED 24pt

First name		Last name	

Centre number						Candidate number				

YOU MUST HAVE:
the Data Sheet for Chemistry A
(sent with general stationery)

YOU MAY USE:
a scientific or graphical calculator
a ruler

READ INSTRUCTIONS OVERLEAF

DC (KN/CGW) 149803

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INSTRUCTIONS

Use black ink. You may use an HB pencil for graphs and diagrams.

Complete the boxes on the first page 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.

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 (*).

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', $CH_4 \bullet xH_2O$. 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.

(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.

_____

_____

_____

_____

_____

_____ **[3]**

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

_____

_____

_____ **[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.

formula = _____ [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.

volume = _____ dm^3 [4]

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

_____

_____

_____ [1]

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

$Na_2O(s) + 2HCl(aq) \longrightarrow 2NaCl(aq) + H_2O(l)$ 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.

$Na_2O(s) + H_2O(l) \longrightarrow 2NaOH(aq)$ REACTION 3.2

$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$
$\Delta_r H = -57.6\,kJ\,mol^{-1}$ 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.

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

Show all your working.

[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.

[2]

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

Explain your reasoning.

[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 $NaNO_2$?

_____ [1]

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

Element oxidised _____

Oxidation number change from _____ to _____

Element reduced _____

Oxidation number change from _____ to _____
[2]

(iii) Construct the equation for this reaction.

Equation _____ [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.

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

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 $/10^{-6}\,mol\,dm^{-3}\,s^{-1}$
	$[H_2O_2(aq)]$ $/mol\,dm^{-3}$	$[I^-(aq)]$ $/mol\,dm^{-3}$	$[H^+(aq)]$ $/mol\,dm^{-3}$	
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.

k = _____ units _____ [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*.

[3]

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

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

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

Standard electrode potentials are shown below.

$O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons H_2O_2(aq)$
$E^\ominus = +0.70\,V$

$MnO_2(s) + 4H^+(aq) + 2e^- \rightleftharpoons Mn^{2+}(aq) + 2H_2O(l)$
$E^\ominus = +1.51\,V$

$H_2O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons 2H_2O(l)$
$E^\ominus = +1.78\,V$

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.

[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.**

$$H_2O_2(aq) + CH_3COOH(aq) \rightleftharpoons CH_3COOOH(aq) + H_2O(l)$$

$K_c = 0.37\ dm^3\ mol^{-1}$

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.

amount = _____ mol [3]

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4 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.

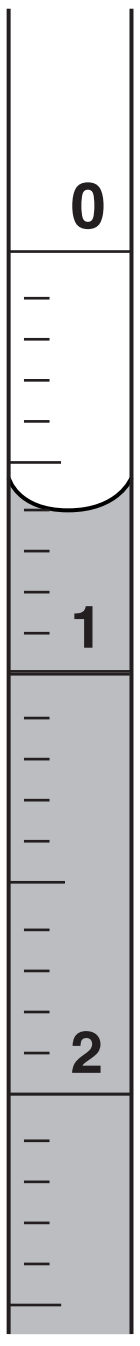
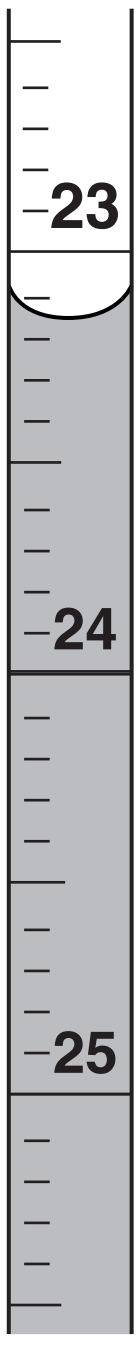
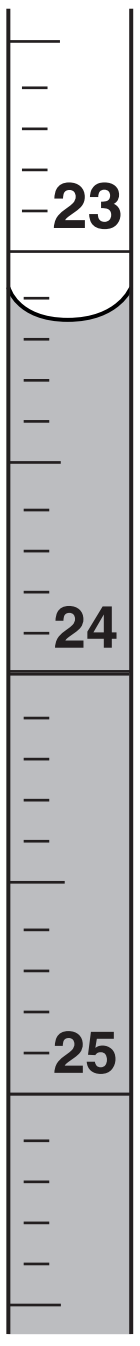
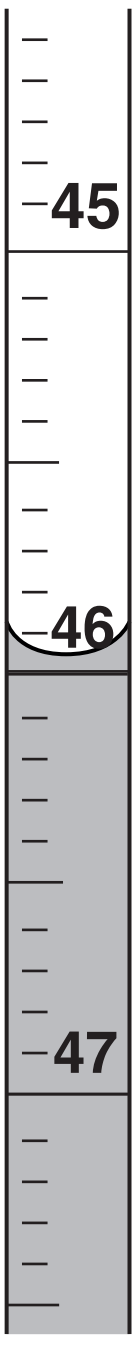
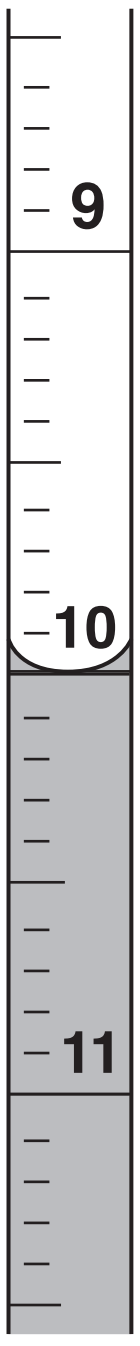
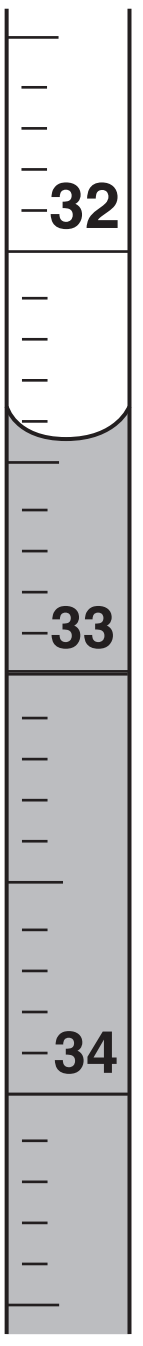
The student carries out a trial, followed by the three further titrations. The diagrams show the initial burette readings and the final burette readings for the student's three FURTHER titrations.

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

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

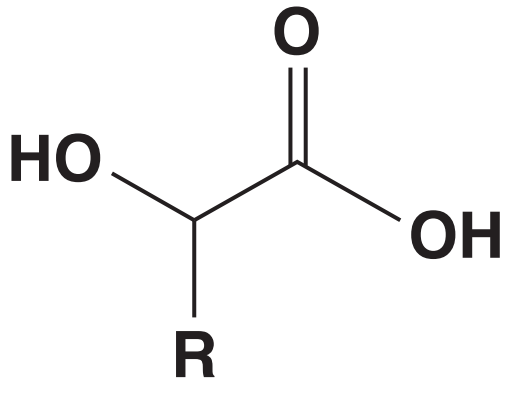
Calculate the mean titre that the student should use for analysing the results.

mean titre = _____ cm^3 [4]

Titration 1		Titration 2		Titration 3	
Initial reading	Final reading	Initial reading	Final reading	Initial reading	Final reading
					

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

COMPOUND A



Compound A has four optical isomers.

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

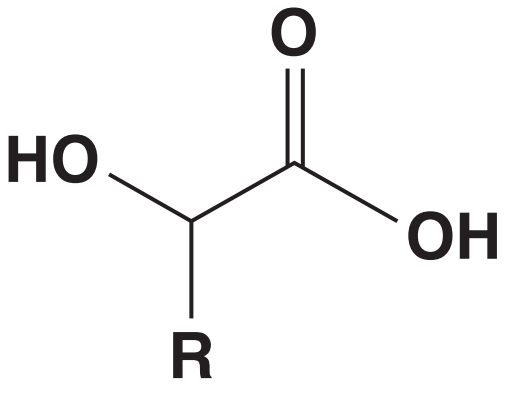
Determine the molar mass of A and the formula of the alkyl group R.

Draw the structure of compound A and label any chiral carbon atoms with an asterisk*.

Show all your working in the space below. [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.

Equation

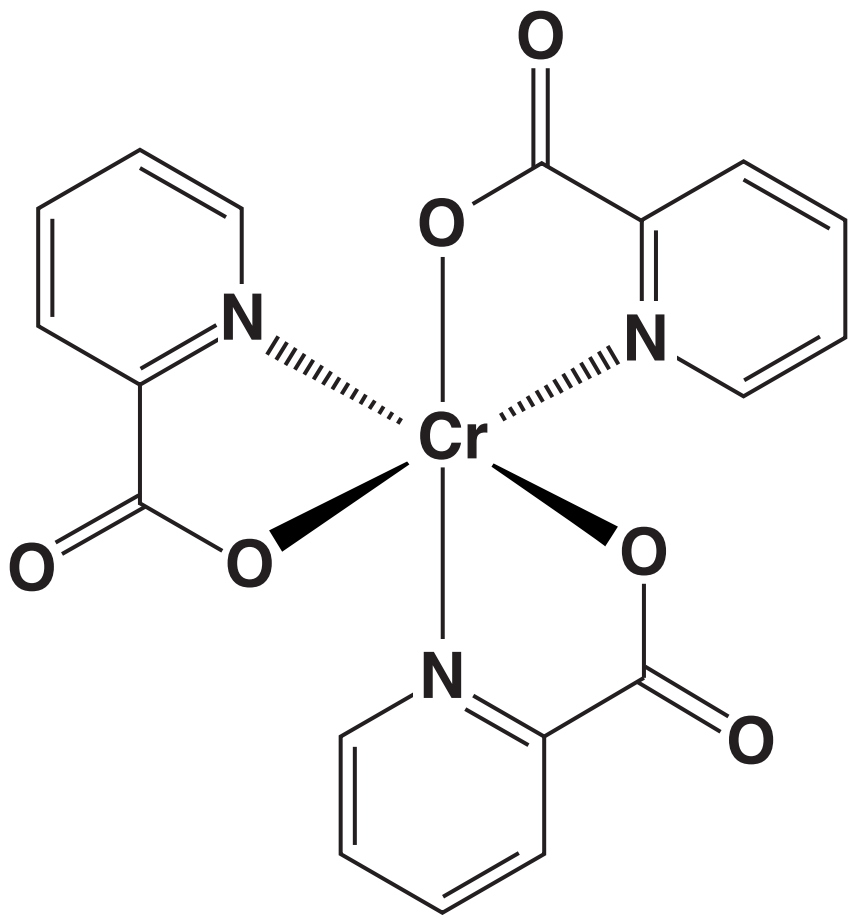
Type of reaction _____ [3]

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

Equation

Type of reaction _____ **[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 in the space below.** **[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.
$1\ \mu g = 10^{-6}\ g$.

Give your answer to THREE significant figures.

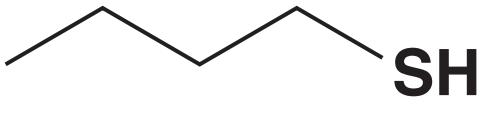
mass = _____ g [2]

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



(i) Thiols are weak acids.

Write the expression for the acid dissociation constant, K_a, for butane-1-thiol below. [1]

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

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

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 below. [1]

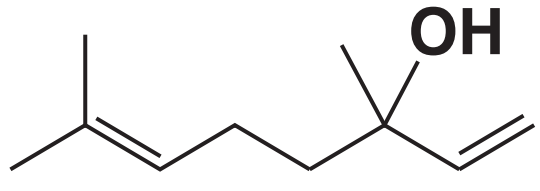
(iv) **Propane-1,3-dithiol reacts with carbonyl compounds in a condensation reaction to form a cyclic organic sulfur product.**

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

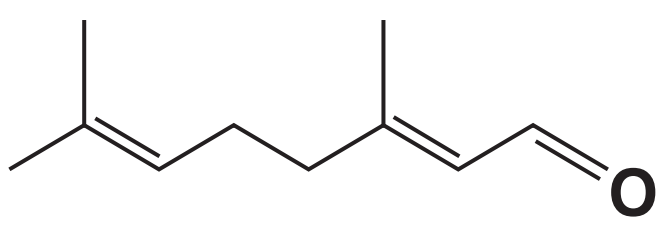
Use structures for organic compounds. [2]

(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.**

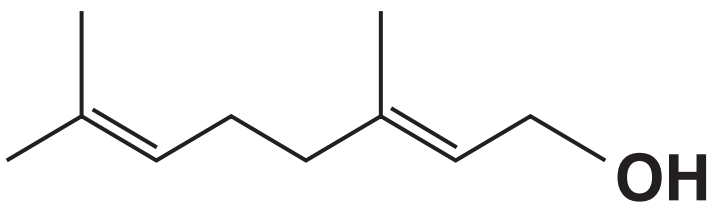
B
(LINALOOL)



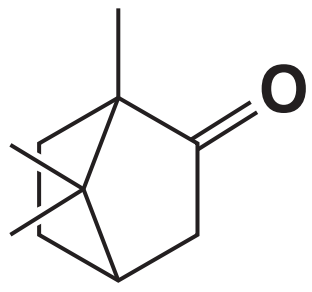
C
(CITRAL)



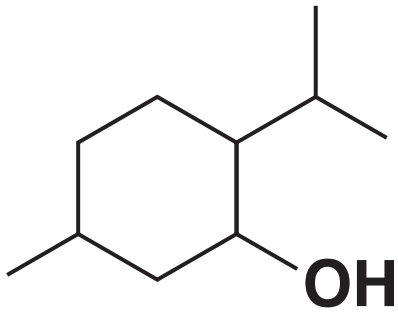
D
(GERANIOL)



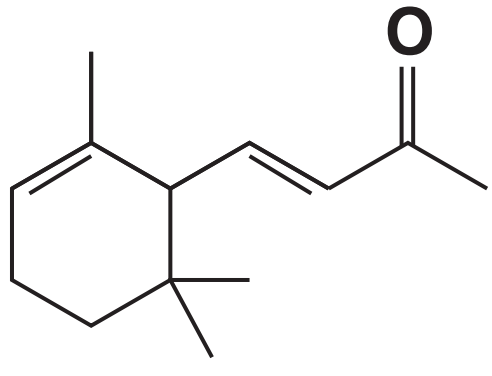
E
(CAMPHOR)



F
(MENTHOL)



G
(IONONE)



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).