Oxford Cambridge and RSA

Tuesday 13 October 2020 – Morning

AS Level Chemistry B (Salters)

H033/02 Chemistry in depth

Time allowed: 1 hour 30 minutes

You must have:
- the Data Sheet for Chemistry B

You can use:
- a scientific or graphical calculator
- an HB pencil

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Please write clearly in black ink. **Do not write in the barcodes.**

Centre number						Candidate number				

First name(s) ____________________

Last name ____________________

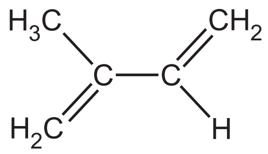
INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

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

ADVICE
- Read each question carefully before you start your answer.

Answer **all** the questions.

1 Natural rubber is a polymer of 2-methylbuta-1,3-diene.



2-methylbuta-1,3-diene

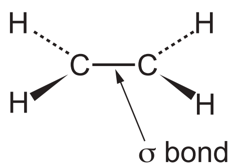
(a) Draw the **skeletal** formula of 2-methylbuta-1,3-diene.

[1]

(b) The carbon-carbon double bond consists of both a sigma(σ) and a pi(π) bond.

(i) The diagram of ethene below shows the position of the sigma(σ) bond between the carbon atoms.

On the diagram sketch the shape and position of the pi(π) bond.



[1]

(ii) Explain the meaning of the wedge bond (▬) in terms of the 3-D shape of ethene.

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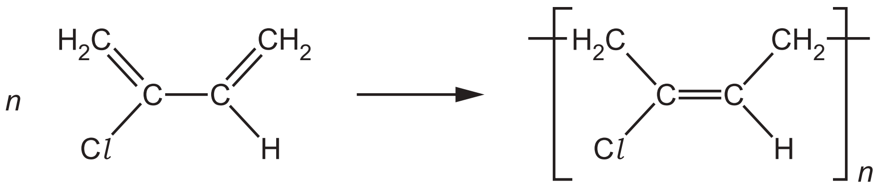
.... **[1]**

(c) 2-chlorobuta-1,3-diene, $CH_2{=}CClCH{=}CH_2$ is made in industry.

It polymerises, as shown in **equation 1.1**.



Equation 1.1

2-chlorobuta-1,3-diene **poly(2-chlorobuta-1,3-diene)**

(i) Polymerisation of buta-1,3-diene, $CH_2{=}CHCH{=}CH_2$, occurs in the same way to form a synthetic rubber.

Draw the structural formula for poly(buta-1,3-diene).

[1]

(ii) The poly(2-chlorobuta-1,3-diene) shown in **equation 1.1** is the *cis*-stereoisomer.

Draw the structure of the *trans*-stereoisomer for poly(2-chlorobuta-1,3-diene).

[1]

(iii) Explain how the two stereoisomers for poly(2-chlorobuta-1,3-diene) occur.

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.... **[2]**

(d) The reaction between 1 mol of buta-1,3-diene and 1 mol of hydrogen bromide is shown below.

CH_2=CHCH=CH_2 + HBr $\rightarrow$ CH_2=CHCHBrCH_3

(i) Name the mechanism of this reaction.

.... **[1]**

(ii) Draw the mechanism for this reaction.

Show curly arrows and full and partial charges.

[3]

2 Solid barium carbonate, $BaCO_3$, is used as a rat poison.

In a rat's stomach, barium carbonate reacts with the hydrochloric acid to produce soluble barium chloride, $BaCl_2$, which is poisonous.

(a) Write an equation for the reaction of solid barium carbonate with hydrochloric acid. Carbon dioxide is produced in the reaction.

Include state symbols.

[2]

(b) (i) Barium carbonate produces carbon dioxide gas when heated strongly. Calcium carbonate is less thermally stable.

Describe an experiment, using limewater, that you could do to show this.

Include a labelled diagram, how you would make it a valid test and what you would observe.

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(ii) A student attempts to explain why the thermal stability of the Group 2 carbonates increases down the Group.

The student says it is because the Group 2 metals increase in chemical reactivity down the group. The carbonates of the more reactive elements decompose less easily when heated.

Discuss the student's explanation, giving the correct chemistry where necessary.

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.... **[3]**

(c) The presence of calcium in its compounds may be identified using a flame test.

(i) Give the flame colour for calcium.

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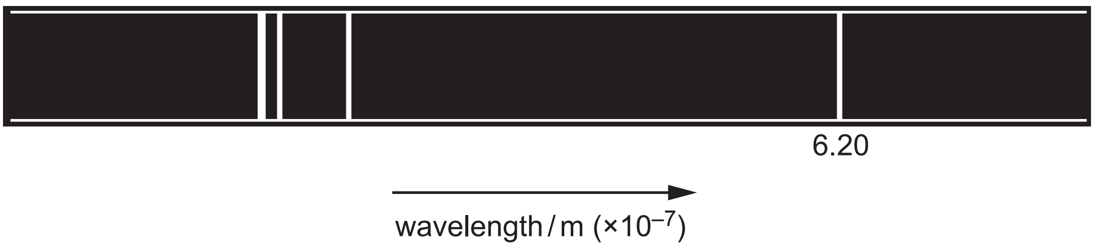
(ii) The visible atomic emission spectrum of an element consists of a series of coloured lines on a black background.

A section of this spectrum for calcium is shown in the diagram.



Calcium can also be identified using its atomic **absorption** spectrum.

Describe the appearance of the visible atomic absorption spectrum of calcium and how it is related to the emission spectrum above.

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.... **[2]**

(iii) Calculate the energy change of an electron, in kJ, that causes the line at 6.20×10^{-7} m in the spectrum of calcium.

energy change = ... kJ **[3]**

(d) A student uses a titration to measure the solubility of calcium hydroxide, $Ca(OH)_2$.

The student uses a volumetric pipette to transfer 25.0 cm^3 of a saturated solution of calcium hydroxide into a conical flask. A saturated solution is used because it contains the maximum mass of solute in a given volume of solution.

(i) The uncertainty in using a 25.0 cm^3 pipette is 0.06 cm^3.

Calculate the percentage uncertainty in using this pipette.

percentage uncertainty = ... % **[1]**

(ii) The student titrates the 25.0 cm^3 of saturated $Ca(OH)_2$ with hydrochloric acid of concentration 0.100 mol dm^{-3}.

$$Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$$

A mean titre of 11.70 cm^3 is obtained.

Calculate the concentration of the saturated calcium hydroxide solution in g dm^{-3}.

concentration = ... g dm^{-3} **[4]**

(e) The titration described in part **(d)** is repeated with 25.0 cm^3 of saturated barium hydroxide solution.

Suggest how the mean titre of 0.100 mol dm^{-3} hydrochloric acid would differ from that for the saturated calcium hydroxide solution. Explain your answer.

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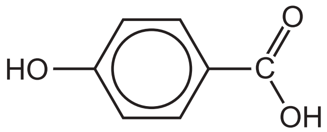
.... **[1]**

3 Parabens are compounds used as preservatives in some cosmetics.

A paraben can be made from the reaction between 4-hydroxybenzoic acid and ethanoic anhydride.

(a) 4-hydroxybenzoic acid has the following structural formula.



4-hydroxybenzoic acid reacts with both sodium hydroxide and sodium carbonate solutions.

The reaction with sodium hydroxide gives a compound with the molecular formula $C_7H_4O_3Na_2$.

The reaction with sodium carbonate gives a compound with the molecular formula $C_7H_5O_3Na$.

Use acid-base chemistry to explain these observations and include the structural formula for the organic product of each reaction.

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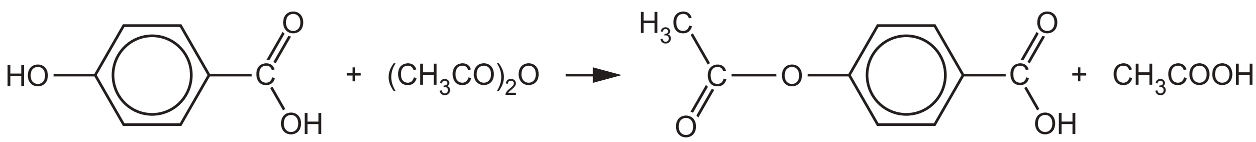
(b) A student makes 4-acetoxybenzoic acid in the laboratory by heating 4-hydroxybenzoic acid and ethanoic anhydride under reflux.



4-hydroxybenzoic acid **4-acetoxybenzoic acid**

(i) Explain why the heating is carried out under reflux.

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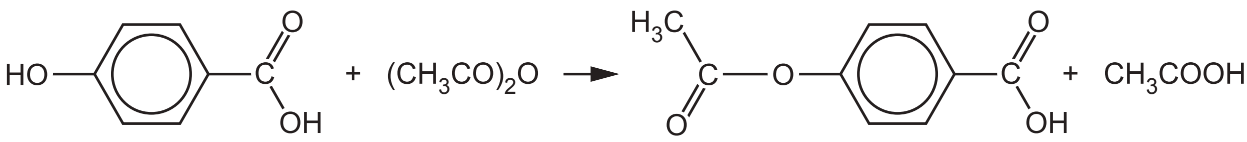
The reaction from **(b)** is shown again here.



4-hydroxybenzoic acid
M_r **= 138**

4-acetoxybenzoic acid
M_r **= 180**

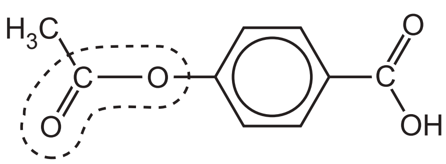
(ii) The student reacts 3.5 g of 4-hydroxybenzoic acid with an excess of ethanoic anhydride. After purifying the crude product the student obtains 2.8 g of 4-acetoxybenzoic acid.

Calculate the percentage yield of 4-acetoxybenzoic acid.

Give your answer to an **appropriate** number of significant figures.

percentage yield = ... % **[3]**

(c) Give the name of the functional group enclosed by the dashed line in the structure of 4-acetoxybenzoic acid.



.... **[1]**

(d) 4-acetoxybenzoic acid has a melting point of 193 °C.

A student explains the high melting point as follows:

- Oxygen is more electronegative than carbon so the carbon-oxygen double bond will be polar.
- Strong permanent dipole-permanent dipole attractions occur between $C^{\delta+}$ and $O^{\delta-}$ atoms at either end of neighbouring molecules.

Discuss the student's statements, giving the correct chemistry where necessary.

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(e) Describe a simple test-tube reaction that would distinguish between 4-hydroxybenzoic acid and 4-acetoxybenzoic acid.

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(f) 4-acetoxybenzoic acid is much more soluble in hot ethanol than cold ethanol.

Using this information, describe how to obtain a pure dry sample of 4-acetoxybenzoic acid from the crude product.

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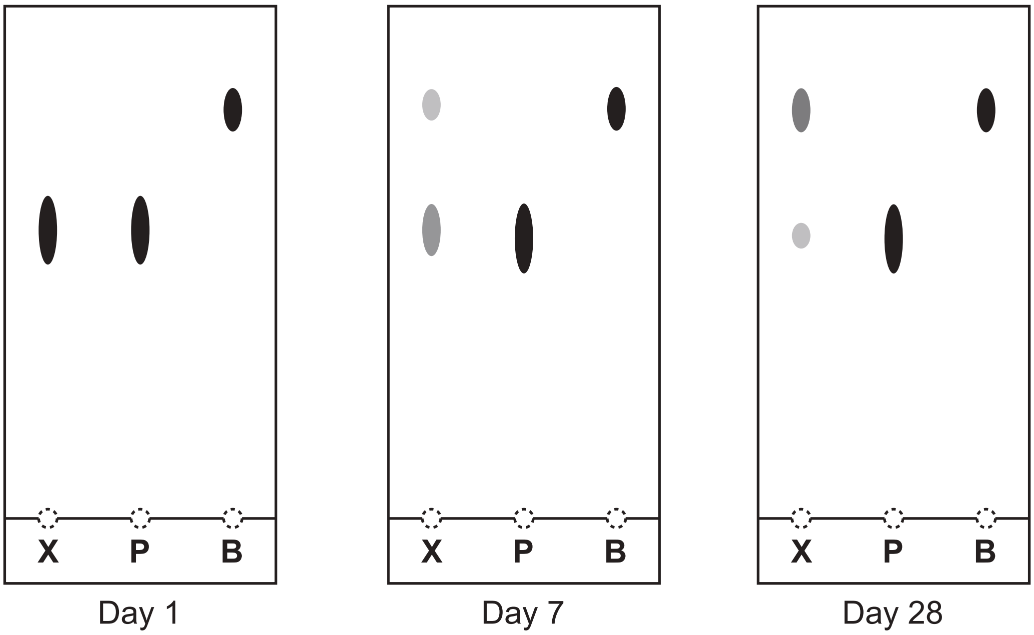
(g)* The hydrolysis of parabens into 4-hydroxybenzoic acid may occur in slightly acidic or slightly alkaline household wastewater.

Some students investigate this hydrolysis. They make 4 solutions:

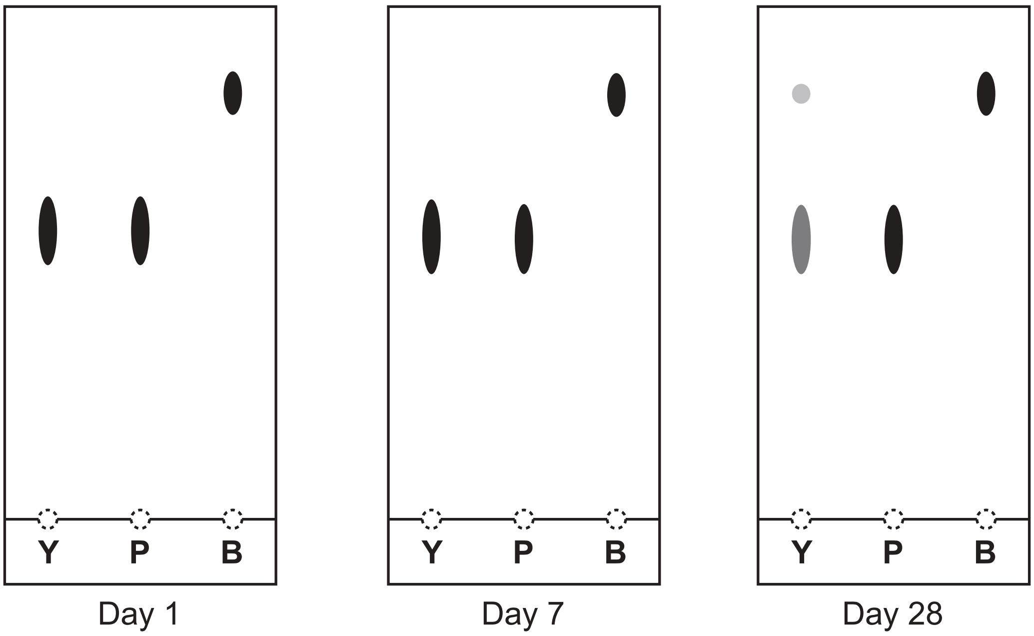
- a slightly alkaline solution of 4-acetoxybenzoic acid, **X**
- a slightly acidic solution of 4-acetoxybenzoic acid, **Y**
- a solution of pure 4-acetoxybenzoic acid, **P**
- a solution of pure 4-hydroxybenzoic acid, **B**

They run thin layer chromatograms of **X**, **P** and **B** (**Fig. 3.1**) and **Y**, **P** and **B** (**Fig. 3.2**).



Results with the slightly alkaline sample

Fig. 3.1



Results with the slightly acidic sample

Fig. 3.2

The chromatograms shown in **Fig. 3.1** and **Fig. 3.2** are for samples taken from the 4 solutions on day 1, day 7 and day 28.

Describe how to produce one of these thin layer chromatograms and explain what all the results show. **[6]**

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4 Sodium hydrogencarbonate is used in baking powder. When it is heated above about 80 °C it begins to break down as shown in **equation 4.1**.

$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(l)$ ΔH_1 **Equation 4.1**

The enthalpy change for the thermal decomposition of sodium hydrogencarbonate, ΔH_1, is difficult to determine directly by experiment.

Instead the enthalpy change for the reaction is determined indirectly using Hess' law.

The enthalpy changes ΔH_2 and ΔH_3 are determined separately.

$NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + CO_2(g) + H_2O(l)$ ΔH_2 **Equation 4.2**

$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$ ΔH_3 **Equation 4.3**

(a) Suggest why it is difficult to measure ΔH_1 directly.

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.... **[1]**

(b) A student does an experiment to measure ΔH_2.

The student adds 7.50×10^{-2} mol of $NaHCO_3$ to $50.00\,cm^3$ (an excess) of $2.00\,mol\,dm^{-3}$ HCl. The temperature **decreases** by 7.50 °C.

Use this data to calculate ΔH_2 in kJ per mol of $NaHCO_3$.

Assume the density and the specific heat capacity of the solution are the same as those of water.

ΔH_2 = ... $kJ\,mol^{-1}$ **[2]**

(c)* Another student does an experiment to measure ΔH_3.

The student uses a measuring cylinder to place 50 cm^3 (an excess) of 2.00 mol dm^{-3} HCl into a glass beaker.

The student measures the temperature of the acid using a thermometer, taking readings to the nearest degree °C.

3.0 g of Na_2CO_3 is added to the acid. The temperature increases slowly and the student records the temperature every minute.

The student uses the highest temperature reached (an increase of 5 °C) to calculate ΔH_3.

The student wants to repeat the experiment to get a more accurate measurement of ΔH_3.

Describe how measurement uncertainties and the effects of 'heat loss' can be reduced in the experiment. **[6]**

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(d) In separate accurately performed experiments the following enthalpy changes were determined.

$NaHCO_3(s) + HCl(aq) \longrightarrow NaCl(aq) + CO_2(g) + H_2O(l)$ $\Delta H_2 = +23\,kJ\,mol^{-1}$

$Na_2CO_3(s) + 2HCl(aq) \longrightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$ $\Delta H_3 = -30\,kJ\,mol^{-1}$

Draw a Hess' law enthalpy cycle and use these values for ΔH_2 and ΔH_3 to calculate a value for ΔH_1.

$2NaHCO_3(s) \longrightarrow Na_2CO_3(s) + CO_2(g) + H_2O(l)$ ΔH_1

enthalpy change ΔH_1 = ... $kJ\,mol^{-1}$ **[4]**

(e) Bond enthalpies can be used in some calculations involving ΔH values.
Use the data below to calculate a value for the bond enthalpy of the H–O bond.

$2H_2(g) + O_2(g) \rightarrow 2H_2O(g) \quad \Delta H = -484\,kJ\,mol^{-1}$

Bond	**Bond enthalpy / $kJ\,mol^{-1}$**
H–H	+436
O=O	+498

bond enthalpy of H–O = ... $kJ\,mol^{-1}$ **[2]**

(f) Why can bond enthalpies **not** be used to estimate ΔH_1?

$2NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(l) \qquad \Delta H_1$

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.... **[1]**

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).