



Oxford Cambridge and RSA

Monday 18 October 2021 – Morning

A Level Chemistry B (Salters)

H433/03 Practical skills in chemistry

Time allowed: 1 hour 30 minutes



You must have:

- the Practical Insert (inside this document)
- the Data Sheet for Chemistry B

You can use:

- a scientific or graphical calculator
- an HB pencil



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

Centre number

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Candidate number

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First name(s)

Last name

StemUp Model Solution

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 **60**.
- 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 **16** pages.

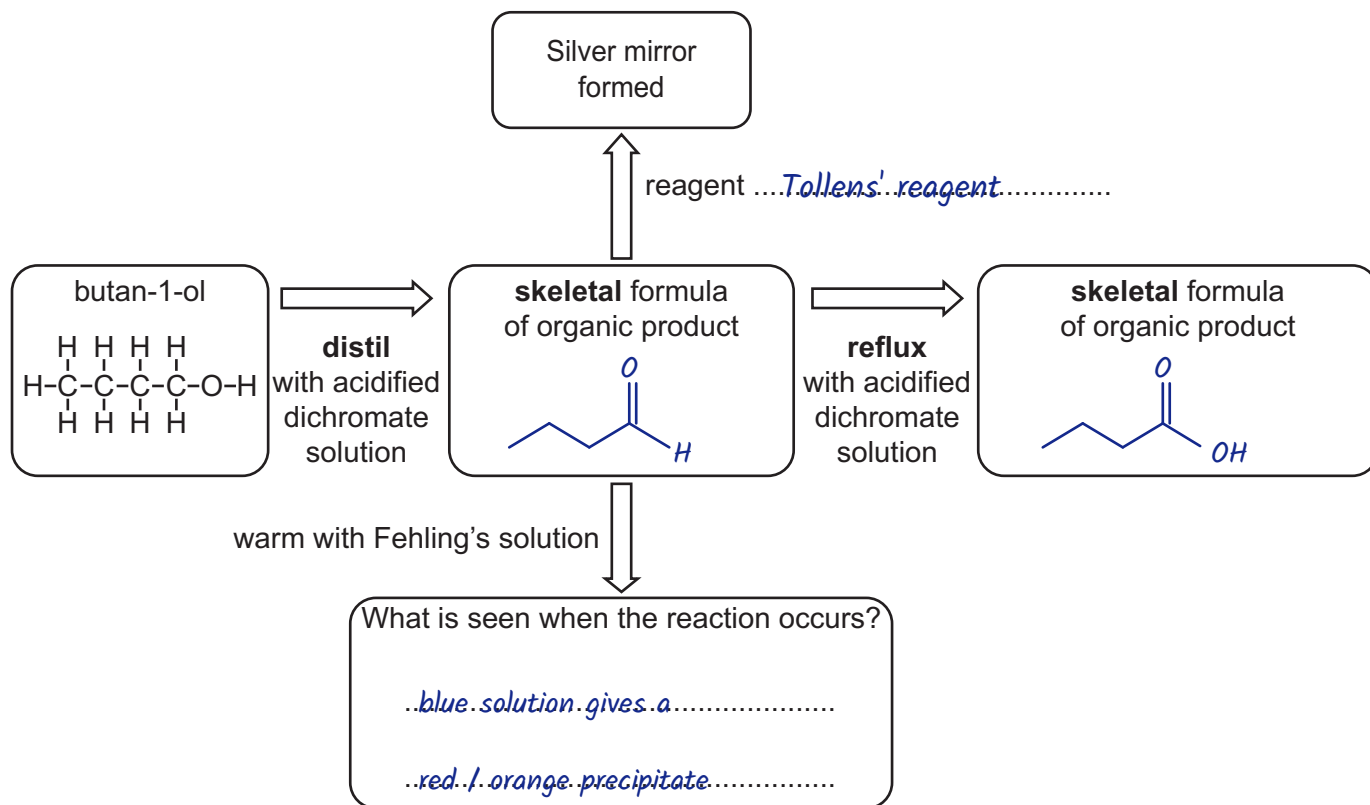
ADVICE

- Read each question carefully before you start your answer.

Answer **all** the questions.

- 1 Alcohols are useful intermediates and react to give a variety of products.
For example, butan-1-ol can be oxidised to other useful products as shown below.

- (a) Complete the flow diagram by writing on the dotted lines and drawing skeletal formulae in the empty boxes.



[4]

- (b) Butan-2-ol is an isomer of butan-1-ol.

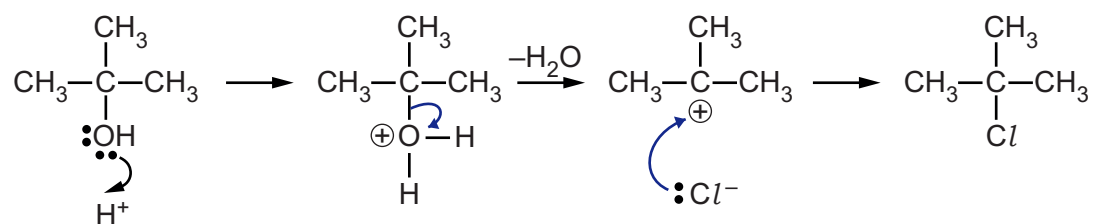
Alcohols can be categorised as primary, secondary or tertiary.
Which is the correct category for butan-2-ol?

Explain your answer.

..Secondary.. The carbon atom bonded to the OH group is attached to two
..other carbon atoms (two R groups) and has only one hydrogen atom on it..

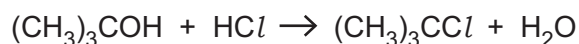
.....

..... [2]



[2]

(d)* A student prepares a pure sample of $(\text{CH}_3)_3\text{CCl}$ by the reaction from (c):



The preparation involves two parts.

Part A The student shakes about 10 cm^3 of the alcohol with 20 cm^3 of concentrated hydrochloric acid in a stoppered conical flask. The reaction occurs quickly at room temperature.

Part B The student then separates the layers formed, removes the acid and dries and purifies the organic product.

The student uses data as shown in the table below.

Compound	Does it mix with water?	Density / g cm^{-3}
$(\text{CH}_3)_3\text{COH}$	yes	0.78
$(\text{CH}_3)_3\text{CCl}$	no	0.85

Describe and explain the student's procedure in **part B**.

[6]

Pour the mixture into a separating funnel. $(\text{CH}_3)_3\text{CCl}$ does not mix with water, so two layers form. It is less dense (0.85 g cm^{-3}) than the aqueous acid layer, so the chloroalkane is the top layer. Run off the lower aqueous layer and discard it; unreacted alcohol mixes with water so most of it is removed here too.

To remove the acid impurity, add sodium hydrogencarbonate solution to the organic layer in the funnel, a small volume at a time. Stopper, shake and invert, opening the tap often to release the pressure of CO_2 gas. Keep adding until there is no more effervescence (all the HCl is neutralised), then run off and discard the lower aqueous layer again.

To remove water, run the upper organic layer into a dry conical flask and add anhydrous sodium sulfate (a drying agent). Swirl and leave until the liquid is clear, then decant (or filter) the dried liquid off the solid into a distillation flask.

Additional answer space if required.

Finally, distil the liquid and collect the fraction that distils over at the boiling point of $(\text{CH}_3)_3\text{CCl}$, which gives the pure product and leaves any remaining impurities behind.

- 2 Our bodies contain many proteins, including enzymes.
These proteins have individual molecular shapes.

- (a) A protein can be described in terms of its primary, secondary and tertiary structure.
Explain the terms primary, secondary and tertiary in this context.

Primary *the sequence (order) of amino acids*
in the polypeptide chain, joined by peptide bonds.

Secondary *folding of the primary structure into α -helices and β -pleated*
sheets, held by hydrogen bonds.

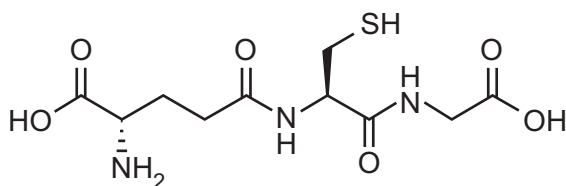
Tertiary *further folding of the secondary structure (helices and sheets) into*
the overall 3D shape of the protein.

[3]

- (b) Peptides and proteins are condensation polymers formed from amino acid monomers.

The tripeptide glutathione is an antioxidant found in the body.

The skeletal structure of glutathione is:



- (i) Explain the significance of the dashed line and the wedge shown on the structure.

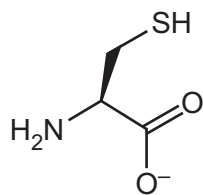
Dashed line: the bond goes behind (into) the plane of the paper.

Wedge: the bond comes out in front of the plane of the paper.

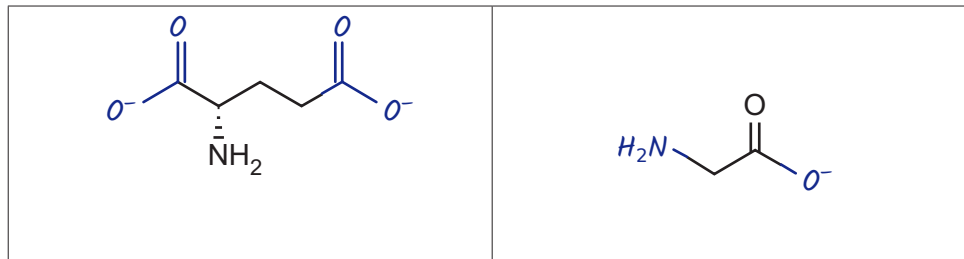
[1]

- (ii) There are **three** organic products from the **alkaline** hydrolysis of glutathione.

The skeletal structure of one of the organic products is shown below.



Complete the skeletal structures of the other two organic products in the boxes below.



[2]

- (c) Many medicinal molecules, including glutathione, show stereoisomerism and interact with active sites on protein molecules in the body.

- (i) Salbutamol and salmeterol are medicines used in the treatment of asthma.

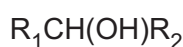
They contain the same **pharmacophore**.

Explain the term **pharmacophore**.

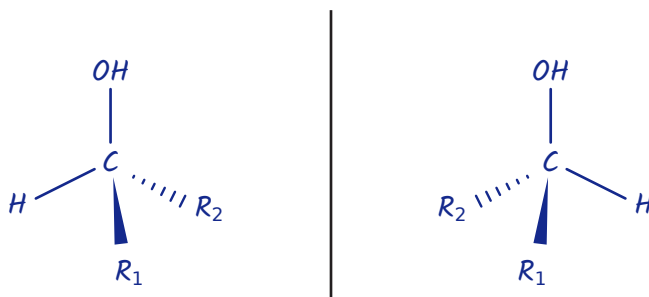
The part of a molecule (its shape and groups) that is responsible for its biological / pharmacological activity. [1]

- (ii) Salbutamol and salmeterol are both chiral molecules and have enantiomers.

The structure of salbutamol can be represented as shown below.



Use this representation to draw appropriate structural diagrams of salbutamol to explain the terms **chiral** and **enantiomer**.



Chiral: the C has four different groups (R_1 , R_2 , OH, H), so the molecule is asymmetric.

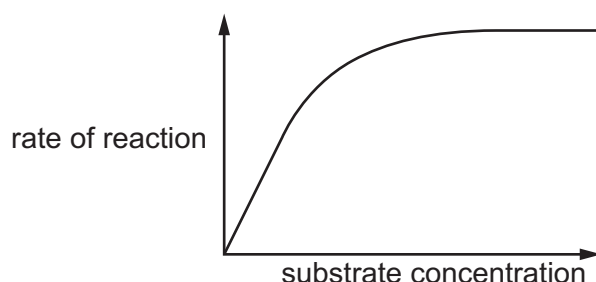
Enantiomers: non-superimposable mirror images. [3]

- (iii) One of the enantiomers of salbutamol is nearly seventy times more effective at treating asthma than the other.

Suggest why this is the case.

The receptor / active site (a protein) is also chiral, so only one enantiomer has the right 3D shape to fit and bind to it; the other cannot fit / interact with the receptor site well. [2]

- (d) An investigation into the effect of changing substrate concentration on the rate of an enzyme catalysed reaction gave the following graphical results.



A student suggested that the graph showed that the reaction is first order with respect to the substrate.

Comment on the student's suggestion, using the shape of the graph to help explain your reasoning.

The student is only partly correct. At low substrate concentrations the graph is a straight line through the origin, so rate is proportional to concentration: the reaction is first order only at the start. At high substrate concentrations the graph flattens (levels off), so rate no longer depends on substrate concentration: it is zero order, as all the enzyme active sites are occupied. [3]

- 3 Brine is a solution of mainly sodium chloride in water. There is also some iodine present as the iodide ion, I^- .

I^- ions are oxidised to I_2 commercially using chlorine.

- (a) Some students investigate this process.

They react aqueous chlorine with aqueous potassium iodide.

They then shake the resulting solution with an equal volume of cyclohexane.

They see a brown layer and a purple layer.

- (i) Write an ionic equation for the reaction.



[1]

- (ii) Identify the coloured layers.

purple: iodine dissolved in cyclohexane; brown: iodine dissolved in water.....

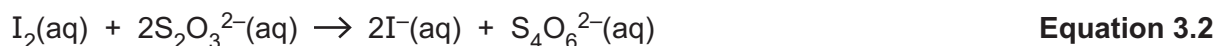
(aqueous iodine)..... [1]

- (b) One way to determine the amount of iodine in brine is to react the brine with an excess of aqueous Cu^{2+} ions.

This produces molecular iodine along with a precipitate of copper(I) iodide.



The iodine, I_2 , produced can then be quantitatively measured using titration with aqueous thiosulfate ions, $S_2O_3^{2-}$.



- (i) Analysis of 25.0 cm^3 of a sample of brine by this method gave an average titre of 14.20 cm^3 of $1.00 \times 10^{-3}\text{ mol dm}^{-3}$ aqueous $S_2O_3^{2-}$.

Calculate the concentration of iodine in the brine in mg dm^{-3} .

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

$$n(S_2O_3^{2-}) = (14.20 \div 1000) \times 1.00 \times 10^{-3} = 1.42 \times 10^{-5} \text{ mol}$$

$$n(I_2) = 1.42 \times 10^{-5} \div 2 = 7.10 \times 10^{-6} \text{ mol}$$

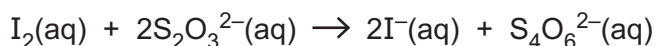
$$n(I^-) \text{ in } 25.0 \text{ cm}^3 = 4 \times 7.10 \times 10^{-6} = 2.84 \times 10^{-5} \text{ mol}$$

$$[I^-] = 2.84 \times 10^{-5} \times (1000 \div 25.0) = 1.136 \times 10^{-3} \text{ mol dm}^{-3}$$

$$\text{mass conc.} = 1.136 \times 10^{-3} \times 126.9 = 0.1442 \text{ g dm}^{-3} = 144 \text{ mg dm}^{-3} \text{ (3 s.f.)}$$

concentration of iodine = ...144..... mg dm^{-3} [4]

- (ii) The reaction in **Equation 3.2** is a redox reaction.



Equation 3.2

The thiosulfate ion, $\text{S}_2\text{O}_3^{2-}$, is oxidised by the iodine.
Use oxidation numbers to explain why this is an oxidation.

In $\text{S}_2\text{O}_3^{2-}$ the oxidation state of S is +2; in $\text{S}_4\text{O}_6^{2-}$ it is +2½ (+2.5).
The oxidation state of S increases, and an increase in oxidation state
(number) is oxidation (loss of electrons).
 [2]

- (c) The element iodine is much less soluble in water than potassium iodide, KI.

State the structures of iodine and potassium iodide.

Suggest why potassium iodide is more water-soluble than iodine.

Iodine: simple molecular structure of small diatomic I_2 molecules (weak id-id
forces between them).
Potassium iodide: giant ionic lattice of K^+ and I^- ions.
Polar water molecules are attracted to the positive and negative ions in KI
($\delta^- \text{O}$ to K^+ , $\delta^+ \text{H}$ to I^-), so the ions are hydrated.
Non-polar I_2 molecules have little interaction with water (only weak id-id
forces), so do not dissolve well.
 [4]

- 4 This question refers to the **Practical Insert** that is provided as an insert to this paper.

For propanoic acid, $\text{C}_2\text{H}_5\text{COOH}$, $K_a = 1.3 \times 10^{-5} \text{ mol dm}^{-3}$.

- (a) (i) Investigate, by **calculation**, whether the starting pH of 2.5 recorded for the propanoic acid solution is the expected value.

$$[\text{H}^+] = \sqrt{K_a \times [\text{C}_2\text{H}_5\text{COOH}]} = \sqrt{(1.3 \times 10^{-5} \times 0.50)}$$

$$[\text{H}^+] = 2.55 \times 10^{-3} \text{ mol dm}^{-3}$$

$$\text{pH} = -\log(2.55 \times 10^{-3}) = 2.59 = 2.6$$

Expected pH is 2.6, not 2.5, so the recorded value is not quite as expected.

[2]

- (ii) A student says that the pH of propanoic acid with the added HCl(aq) is the same as if the 20 cm^3 of $0.05 \text{ mol dm}^{-3} \text{ HCl(aq)}$ had been diluted with 30 cm^3 water.

Carry out a calculation to see whether this is so.

$$[\text{HCl}] = (20 \times 0.050) \div 50 = 0.020 \text{ mol dm}^{-3}$$

$$\text{pH} = -\log(0.020) = 1.7$$

This equals the recorded pH of 1.7, so the student is correct.

[2]

- (b) Explain, using an appropriate equation, why the sodium propanoate solution is alkaline.

In your explanation you should identify the species behaving as a base and identify its conjugate acid.



The propanoate ion, $\text{C}_2\text{H}_5\text{COO}^-$, accepts a proton (H^+) from water, so it is

behaving as a base. This produces OH^- ions, so the solution is alkaline.

Its conjugate acid is propanoic acid, $\text{C}_2\text{H}_5\text{COOH}$ (molecule).

[3]

- (c) Investigate, by **calculation**, whether the starting pH of 5.1 recorded for the solution of propanoic acid with dissolved sodium propanoate is the expected value.

$$n(\text{C}_2\text{H}_5\text{COONa}) = 2.4 \div 96.0 = 0.025 \text{ mol}; \quad n(\text{acid}) = 0.50 \times 0.030 = 0.015 \text{ mol}$$

$$[\text{H}^+] = K_a \times [\text{acid}] \div [\text{salt}]$$

$$[\text{H}^+] = 1.3 \times 10^{-5} \times (0.015 \div 0.025) = 7.8 \times 10^{-6} \text{ mol dm}^{-3}$$

$$\text{pH} = -\log(7.8 \times 10^{-6}) = 5.1$$

This matches the recorded starting pH of 5.1, so it is the expected value.

[4]

- (d)* One of the solutions in the table is a buffer solution.

Choose the buffer solution, giving evidence from the students' results, and explain, with equations, why this solution acts as a buffer solution while the other two do not.

Solution C (propanoic acid with sodium propanoate) is the buffer. Its pH stays at 5.1 on dilution with water and on adding HCl, and only rises to 5.2 on adding NaOH; it resists changes in pH.

A (acid alone) changes from 2.5 to 1.7 with acid and to 3.7 with alkali, and B (salt alone) changes from 9.3 to 6.0 and 12.5, so neither is a buffer.

C contains large amounts of both the weak acid $\text{C}_2\text{H}_5\text{COOH}$ and its conjugate base $\text{C}_2\text{H}_5\text{COO}^-$. $\text{C}_2\text{H}_5\text{COOH} \rightleftharpoons \text{C}_2\text{H}_5\text{COO}^- + \text{H}^+$

Added H^+ reacts with the conjugate base: $\text{C}_2\text{H}_5\text{COO}^- + \text{H}^+ \rightarrow \text{C}_2\text{H}_5\text{COOH}$

Added OH^- reacts with the acid: $\text{C}_2\text{H}_5\text{COOH} + \text{OH}^- \rightarrow \text{C}_2\text{H}_5\text{COO}^- + \text{H}_2\text{O}$

As $[\text{H}^+] = K_a \times [\text{acid}] \div [\text{salt}]$ and both concentrations are large, the ratio hardly changes, so the pH stays almost constant (dilution does not [6]

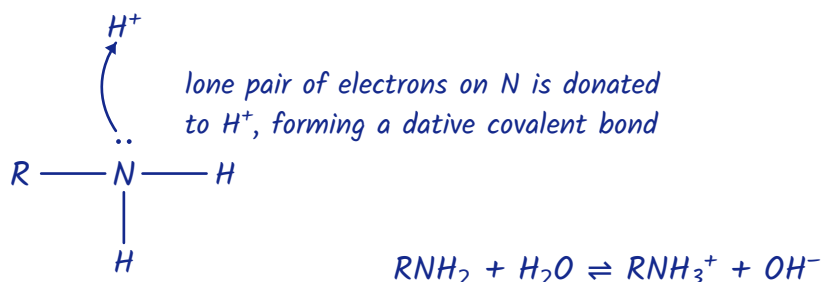
Additional answer space if required.

change the ratio either).

A has very little $\text{C}_2\text{H}_5\text{COO}^-$ to remove added H^+ , and B has very little $\text{C}_2\text{H}_5\text{COOH}$ to remove added OH^- , so their pH changes.

- (e) Buffer solutions can also be prepared using weak bases in solution such as amines, RNH_2 .

Explain, in terms of their electronic structure, why amines behave as bases in aqueous solution. You should draw a labelled diagram of the amine structure to help explain your answer.



The N atom has a lone pair of electrons which it donates to H^+ , so amines are proton (H^+) acceptors. [2]

END OF QUESTION PAPER

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