Oxford Cambridge and RSA

Tuesday 10 June 2025 – Morning

A Level Chemistry B (Salters)

H433/01 Fundamentals of Chemistry

Time allowed: 2 hours 15 minutes

You must have:
- 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 | | | | | | Candidate number | | | | |

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 page 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 **110**.
- 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 **28** pages.

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

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Section A

You should spend a **maximum** of **40 minutes** on this section.

Write your answer to each question in the box provided.

1 Part of a protein structure can be represented as:

–CONHCH(CH_3)CONHCH_2CONHCH(CH_3)–

What is correct about this part of the protein structure?

A All its amino acids show optical isomerism.

B It has three peptide links.

C It is an addition polymer.

D It is made from three different amino acids.

Your answer B **[1]**

2 What is correct about the greenhouse effect?

A Greenhouse gas bonds vibrate more when warmed by infrared radiation.

B Greenhouse gases reflect infrared radiation back to Earth.

C The Earth emits mostly ultraviolet radiation.

D The principal radiation from the Sun is infrared.

Your answer A **[1]**

3 An organic compound **A** is oxidised to a different compound which forms a silver mirror with Tollens' reagent.

Which could be compound **A**?

A propanal

B propan-1-ol

C propan-2-ol

D propanone

Your answer B **[1]**

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4 Which statement about transition metals is correct?

A Copper(II) ions form an octahedral complex with chloride ions.

B Most manganese compounds have Mn in the oxidation state of +2, +4 or +7.

C Nickel is used as a catalyst in the hydration of alkenes.

D The dichromate ion is often used as a reducing agent.

Your answer B **[1]**

5 Which statement about the element astatine, At, is likely to be correct?

A It displaces iodine from sodium iodide.

B It is a gas at room temperature.

C It is a weaker oxidising agent than chlorine.

D It is colourless.

Your answer C **[1]**

6 Which of the following pairs can be structural isomers?

A acid anhydrides and aldehydes

B amines and amides

C carboxylic acids and esters

D diols and esters

Your answer C **[1]**

7 Which row shows the correct electron configurations of Cr and Cr^{3+}?

	Cr	**Cr^{3+}**
A	[Ar] $3d^4\ 4s^2$	[Ar] $3d^3$
B	[Ar] $3d^4\ 4s^2$	[Ar] $3d^1\ 4s^2$
C	[Ar] $3d^5\ 4s^1$	[Ar] $3d^3$
D	[Ar] $3d^5\ 4s^1$	[Ar] $3d^1\ 4s^2$

Your answer C **[1]**

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8 What is an advantage of **both** ethanol **and** hydrogen as alternatives to petrol?

A Their only product of combustion is water.

B They can be produced by fermentation.

C They do **not** produce nitrogen oxides in the engine.

D They do **not** produce oxides of sulfur on combustion.

Your answer D **[1]**

9 What is correct about chlorine radicals in the atmosphere?

A They act as homogeneous catalysts that increase ozone depletion.

B They are formed by heterolytic fission of CFCs.

C They are formed by homolytic fission of CFCs by infrared radiation.

D They are heterogeneous catalysts that increase the rate of ozone formation.

Your answer A **[1]**

10 A colorimeter is used to measure the concentration of a copper(II) sulfate solution.

What is correct?

A A blue filter is used.

B A calibration curve of copper ion concentration against time is used.

C The absorption increases as the concentration of copper ions increases.

D The transmission decreases as the concentration of copper ions decreases.

Your answer C **[1]**

11 Which statement about all sodium compounds is correct?

A They are less reactive than potassium compounds.

B They dissolve in water to give alkaline solutions.

C They form giant structures.

D They give a red flame test.

Your answer C **[1]**

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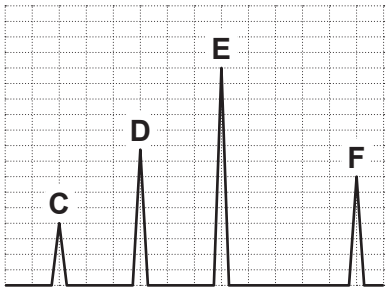
12 A scientist runs a mixture of four hydrocarbons through a gas-liquid chromatography apparatus. The chromatogram obtained is:



What is correct?

A Compound **C** emerges from the apparatus first.

B Compound **E** has the longest retention time.

C Compound **F** is held least well by the column.

D The x-axis label should be 'abundance'.

Your answer A **[1]**

13 Chlorine is added to water to prevent the spread of bacterial diseases.

Why must the levels of chlorine in the water be carefully monitored?

A Chlorine is a green gas.

B Chlorine is a halogen.

C Chlorine is toxic.

D Chlorine prevents the spread of cholera.

Your answer C **[1]**

14 Which row has ammonia, methane and water in order of **increasing** boiling point?

A	ammonia	<	methane	<	water
B	methane	<	ammonia	<	water
C	methane	<	water	<	ammonia
D	water	<	ammonia	<	methane

Your answer B **[1]**

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15 Which pair will react to produce brown vapours?

A NaC*l* and concentrated H_3PO_4

B NaC*l* and concentrated H_2SO_4

C NaBr and concentrated H_2SO_4

D NaI and concentrated H_3PO_4

Your answer C **[1]**

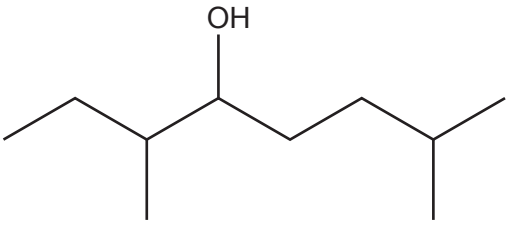
16 Modern petrol cars have catalytic converters.

Which row shows a pollutant removed by these catalytic converters and the environmental problem the pollutant causes?

	Pollutant removed by catalytic converters	**Problem caused**
A	CFCs	Ozone depletion
B	CO	Toxic
C	CO_2	Global warming
D	O_3	Photochemical smog

Your answer B **[1]**

17 An organic compound is shown:



What is the correct name for this compound?

A 1,1,5-trimethylheptan-4-ol

B 2-methyl-6-methyloctan-5-ol

C 2-ethyl-6-methylheptan-3-ol

D 3,7-dimethyloctan-4-ol

Your answer D **[1]**

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18 In which of the following reactions is the hydrogen halide acting as a reducing agent?

A $2HBr + 2Na \rightarrow 2NaBr + H_2$

B $HCl + AgNO_3 \rightarrow HNO_3 + AgCl$

C $HCl + NaOH \rightarrow NaCl + H_2O$

D $8HI + H_2SO_4 \rightarrow H_2S + 4H_2O + 4I_2$

Your answer D **[1]**

19 2.00 g of an oxide of copper contains 1.78 g of copper.

What is the oxidation state of the copper in the oxide?

A –1

B 0

C +1

D +2

Your answer C **[1]**

20 The cracking of one molecule of compound **H** produces but-1-ene, propene and butane in a 2:2:1 mol ratio.

What is the M_r of compound **H**?

A 154

B 156

C 250

D 254

Your answer D **[1]**

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21 A gaseous mixture contains 3.803×10^{-5} moles of Cl_2 molecules per dm^3.
$1.00\,dm^3$ of the mixture has a mass of 1.35 g.

What is the concentration of Cl_2 molecules in this mixture, in parts per million, ppm?

A 28

B 500

C 1000

D 2000

Your answer D **[1]**

22 In a saturated solution of MgF_2, the fluoride ion concentration is $2.4 \times 10^{-3}\,mol\,dm^{-3}$.

What is the solubility product of MgF_2 in $mol^3\,dm^{-9}$?

A 1.7×10^{-9}

B 3.5×10^{-9}

C 6.9×10^{-9}

D 1.4×10^{-8}

Your answer C **[1]**

23 A scientist studies the reaction:

J $\rightarrow$ **K**

After 24 minutes there is $\frac{1}{8}$th as much **J** left as at the start.

What is the half-life of the reaction in minutes?

A 4

B 6

C 8

D 12

Your answer C **[1]**

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24 Iodine is much more soluble in hexane than in water.

What is a reason for this?

A Hydrogen bonds between water molecules are stronger than the instantaneous dipole–induced dipole bonds that iodine would form with water.

B I–I bonds are stronger than the hydrogen bonds in water.

C Iodine is an ionic solid that forms ion–dipole bonds with water that are stronger than the hydrogen bonds broken.

D The I–I bonds that are broken by hexane are weaker than the C–C bonds in hexane.

Your answer A **[1]**

25 At a certain pH, the amino acid glycine exists as:

$NH_2CH_2COO^-$

What is correct about this structure?

A It exists at acid pHs.

B It is a zwitterion.

C It is the conjugate base of NH_2CH_2COOH.

D It will react with NaOH.

Your answer C **[1]**

26 A scientist measures the wavelengths of light from a distant star.

One wavelength measured is 6.56×10^{-11} m.

What is the energy (in J) transferred by a photon at this wavelength?

A 1.45×10^{-52}

B 1.30×10^{-35}

C 3.03×10^{-15}

D 2.61×10^{7}

Your answer C **[1]**

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27 A sample of strontium contains two isotopes, strontium-86 and strontium-88.
The relative atomic mass of the sample is 87.82.

What is the % abundance of the strontium-86 isotope?

A 9%

B 18%

C 90%

D 91%

Your answer A **[1]**

28 An organic compound is yellow.

Which statement(s) is / are correct?

1 The compound absorbs blue light.

2 The electron energy levels in the molecule have a separation ΔE so that the frequency given by $\Delta E / h$ is in the visible range.

3 The compound emits yellow light.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer B **[1]**

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29 A student has high-resolution and low-resolution mass spectra for a gas sample that might be either N_2 or CO.

What would help the student decide which gas was in the sample?

1 The fragmentation pattern at low resolution.

2 The high resolution M^+ value.

3 The low resolution M^+ value.

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer B **[1]**

30 Which of the following compounds is/are able to form a polymer with $ClOCC_6H_4COCl$?

1 $NH_2CH_2CH_2NH_2$

2 $CH_3CHOHCH_2COOH$

3 $CH_2NH_2CH_2CH_2OH$

A 1, 2 and 3

B Only 1 and 2

C Only 1 and 3

D Only 3

Your answer C **[1]**

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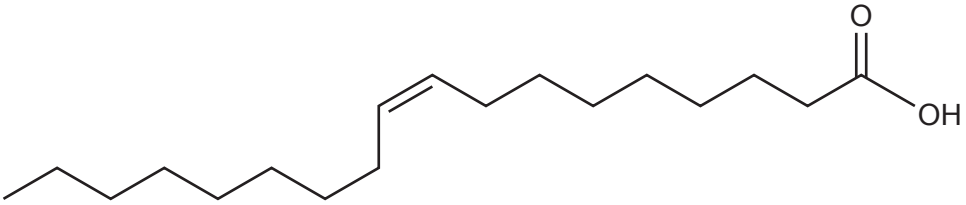
Section B

31 Oleic acid, $C_{17}H_{33}COOH$, is an unsaturated carboxylic acid found in many vegetable oils.



(a) Oleic acid contains a carboxylic acid group, COOH.

Name and explain the shape around the carbon atom in the carboxylic acid group.

Trigonal planar, with bond angles of 120°.

The carbon atom has three regions (areas) of electron density around it (the C=O, C–O and C–C bonds) and no lone pairs. These regions of electrons repel each other and arrange themselves as far apart as possible to minimise repulsion, giving 120°. **[3]**

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(b)

(i) The double bond in oleic acid consists of a σ bond and a π bond.

Describe how π bonds are formed.

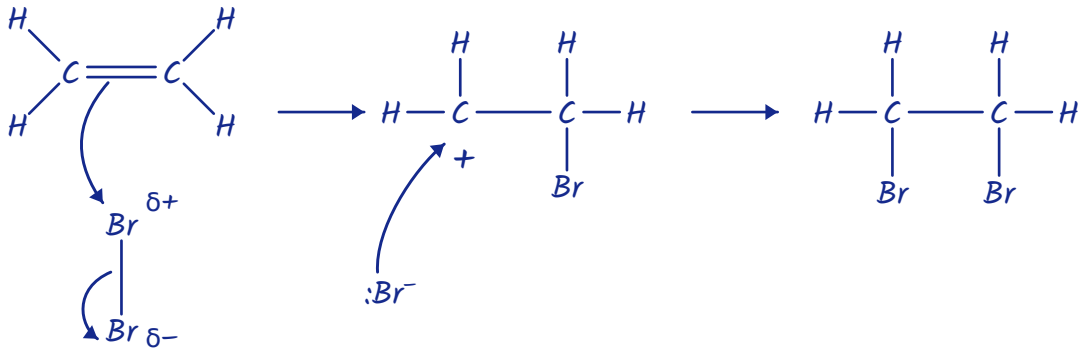
By sideways overlap of p orbitals on adjacent carbon atoms, giving electron density above and below the plane of the atoms.

[1]

(ii) The presence of the double bond in oleic acid can be shown by its reaction with bromine.

Draw the mechanism of the reaction of **ethene** with bromine.

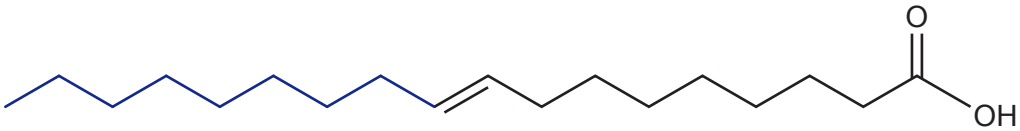
Show curly arrows, partial and full charges and the product.



[3]

(iii) Oleic acid is a *cis* isomer.

Complete the diagram below to show the skeletal formula of the *trans* isomer of oleic acid.



[1]

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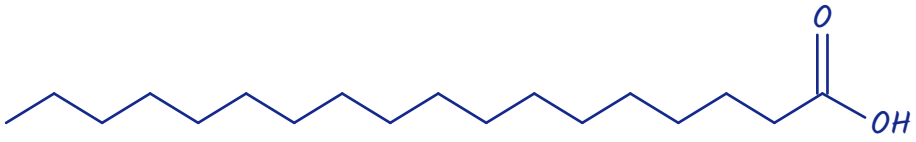
(c) Oleic acid reacts with hydrogen in the presence of a nickel catalyst.

(i) Give the **skeletal** formula of the product of this hydrogenation.



[1]

(ii) In this hydrogenation reaction, nickel is acting as a heterogeneous catalyst.

Explain how a heterogeneous catalyst lowers the activation enthalpy of a reaction.

The reactants (H_2 and oleic acid) are adsorbed onto the surface of the nickel catalyst, at active sites.

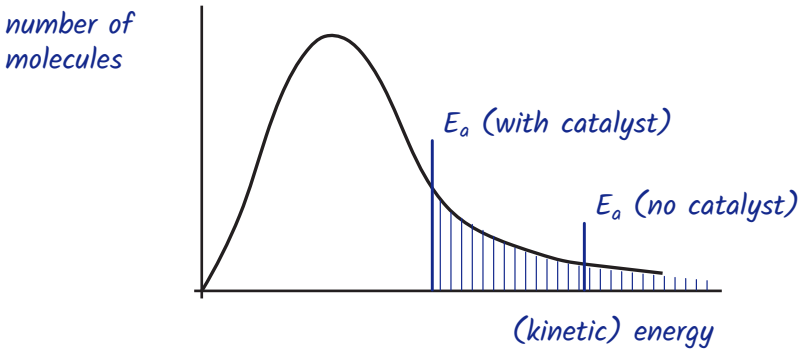
This weakens the covalent bonds in the reactant molecules (H–H and C=C), so less energy is needed to break them and the reactants are held close together to react.

The product is then desorbed and diffuses away from the catalyst surface. **[3]**

(iii) Catalysis can be explained using a Boltzmann distribution.

Use the diagram to explain how a catalyst speeds up a reaction.

Label the diagram and write on the lines below.



The catalyst provides an alternative pathway with a lower activation enthalpy, so E_a moves to the left.

The area under the curve to the right of E_a is the number of molecules with enough energy to react on collision. This area is bigger for E_a (with catalyst), so more collisions are successful per second and the rate increases. **[3]**

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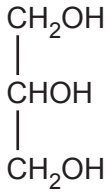
(d) Oleic acid and glycerol (propane-1,2,3-triol) react together to form a triglyceride oil.



Glycerol

(i) State the **type** of reaction that occurs between oleic acid and glycerol.

Esterification (condensation) **[1]**

(ii) Write a balanced equation for the reaction between oleic acid, $C_{17}H_{33}COOH$, and glycerol.

$3C_{17}H_{33}COOH + C_3H_5(OH)_3$

$\rightarrow C_3H_5(C_{17}H_{33}COO)_3 + 3H_2O$

[2]

(iii) Hydrogenation reactions convert vegetable oils into solid fats.
Fats have higher melting points than oils because fats have more flexible molecules.

Explain in terms of intermolecular forces why fats have higher melting points than oils.

Fats are saturated, so their chains have no cis C=C kinks and the molecules pack more closely together than in oils, with more points of contact.
So there are more (stronger) instantaneous dipole-induced dipole forces between fat molecules.
So more energy is needed to overcome them. **[3]**

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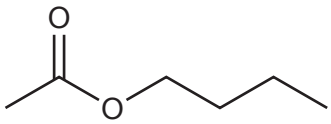
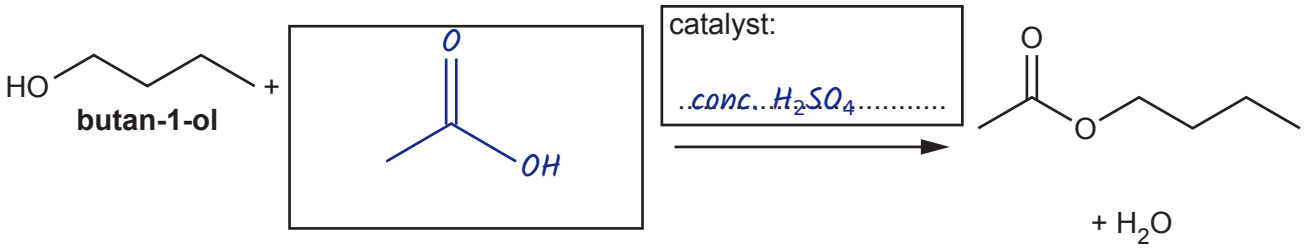
32 Butyl ethanoate is an ester found in apples.



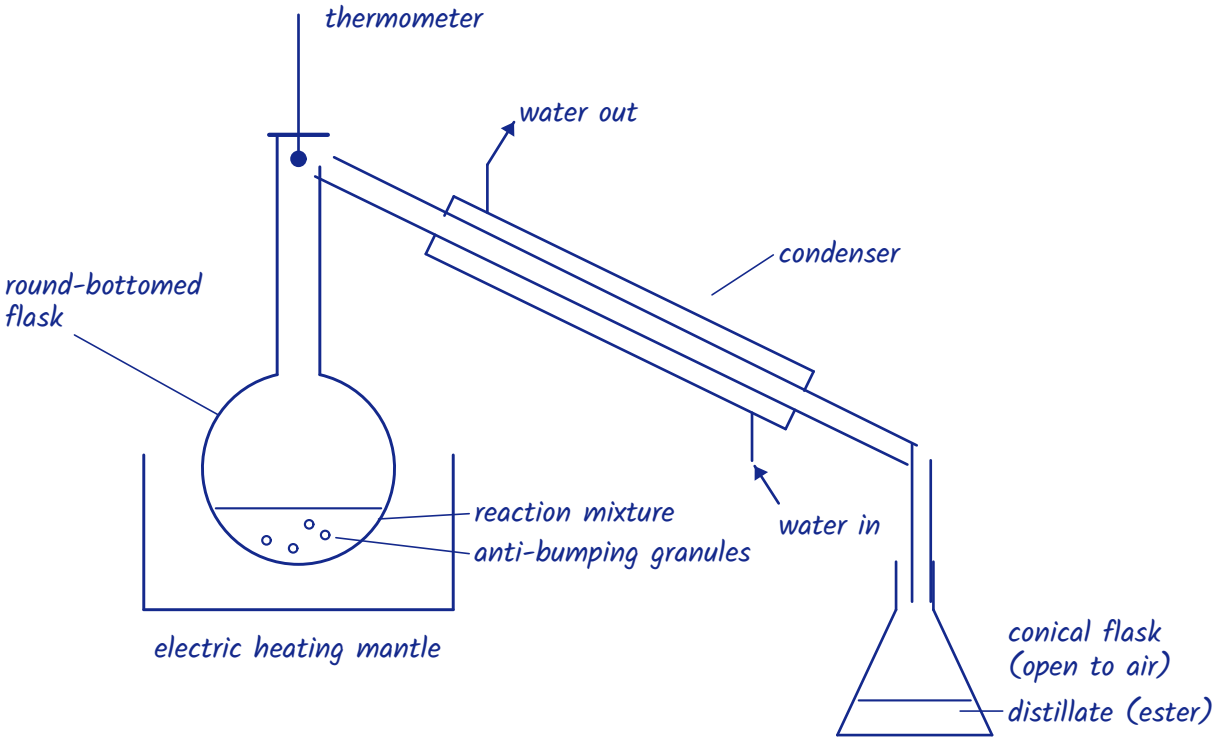
(a) Butyl ethanoate can be made by reacting butan-1-ol with a carboxylic acid.

(i) Complete the equation below by drawing the **skeletal** formula of a suitable carboxylic acid and suggesting a suitable catalyst.



[2]

(ii) After synthesis, the ester can be separated from the reaction mixture by distillation.
Draw a labelled diagram to show how equipment is set up for distillation.



[3]

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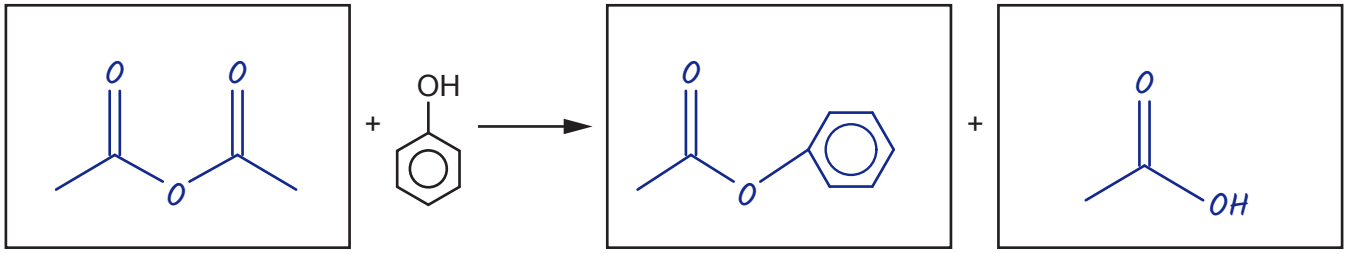
(b) Phenols share some of their reactions with alcohols.

(i) They react with acid anhydrides to form esters.

Ethanoic anhydride reacts with phenol to form an ester and one other product.

Show the structures of these compounds in the boxes below



ethanoic anhydride **phenol** **ester** **other product**

[3]

(ii) Sodium phenoxide can be made from phenol.

Explain whether sodium carbonate or sodium hydroxide should be used for this synthesis.

Sodium hydroxide: phenol is too weak an acid to react with sodium carbonate, so it only reacts with NaOH. **[1]**

(c) Butan-1-ol can be dehydrated to make but-1-ene.

(i) Give suitable conditions for this reaction.

Heat under reflux with concentrated H_2SO_4 (or concentrated H_3PO_4). **[1]**

(ii) State the **type** of reaction that occurs during the dehydration of an alcohol.

Elimination **[1]**

(iii) The dehydration of butan-2-ol also makes but-1-ene.

Suggest, with reasons, whether butan-1-ol or butan-2-ol would be better for making but-1-ene.

Butan-1-ol is better, as it gives only one product, but-1-ene.
Butan-2-ol gives a mixture of but-1-ene and but-2-ene (E and Z), as H can be lost from C1 or C3.
So butan-1-ol gives a greater yield of but-1-ene and no separation is needed. **[3]**

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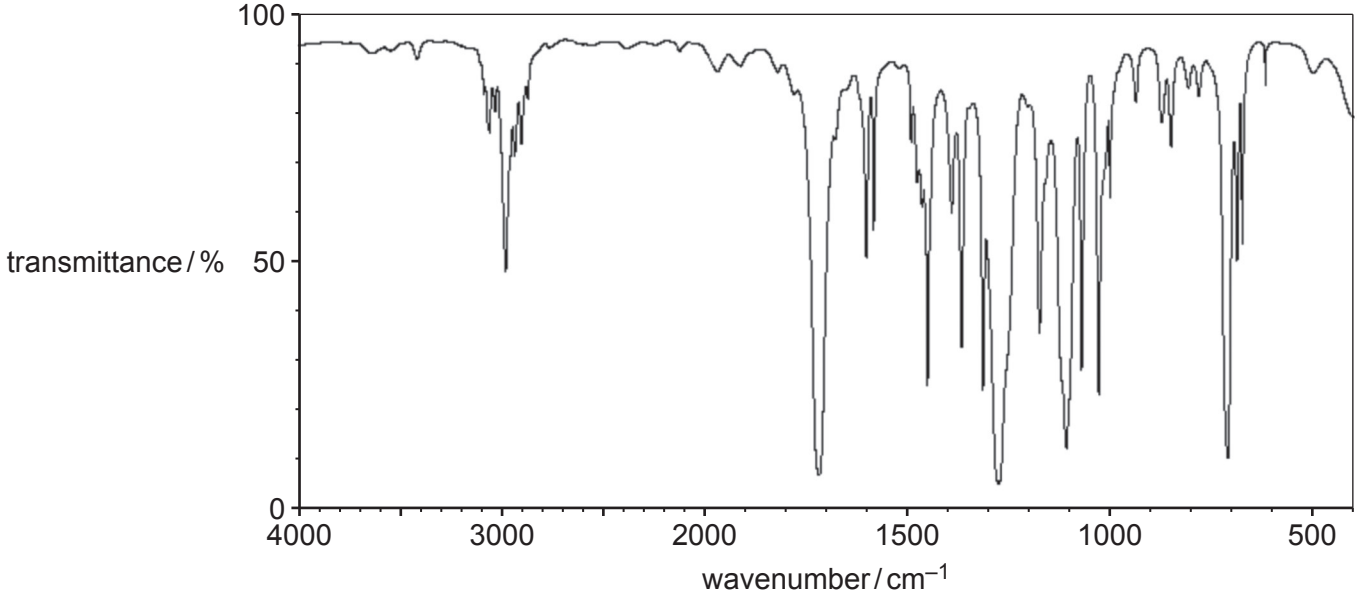
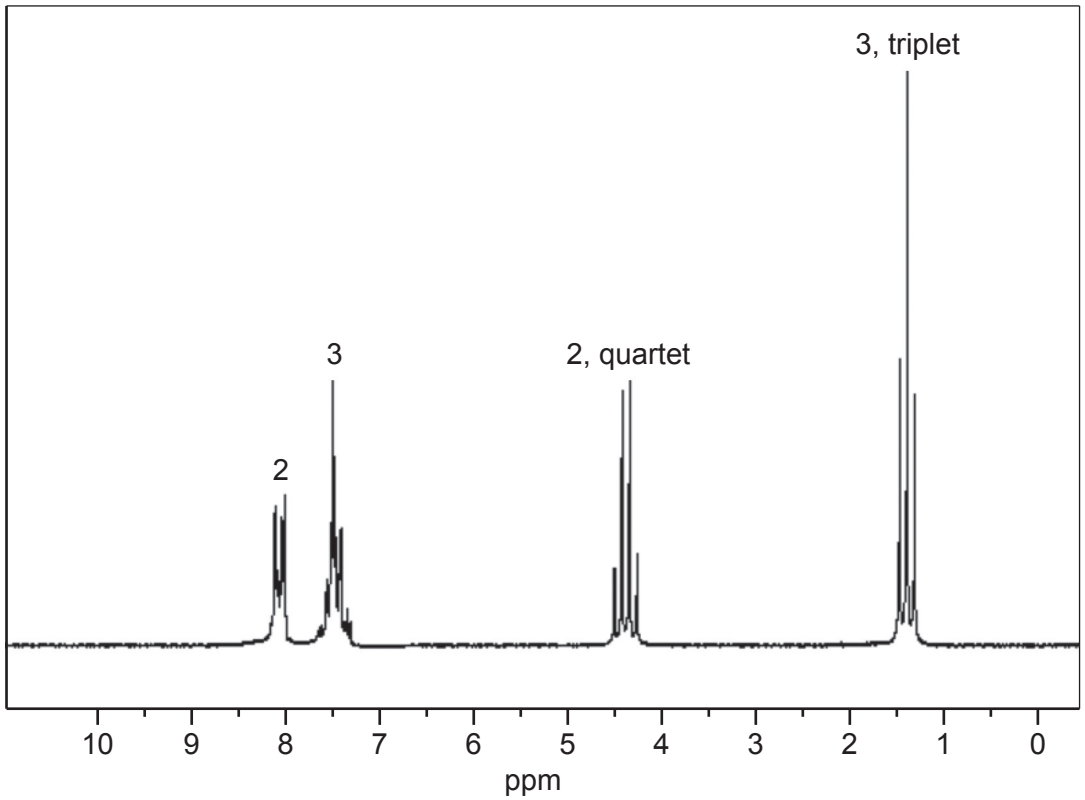
(d)* A scientist extracts an aromatic compound from cherries, which contains 72.0% C, 6.7% H and 21.3% O by mass. The scientist analyses the compound by IR and ^{1}H NMR spectroscopy.

IR spectrum



^{1}H NMR spectrum



The numbers by the peaks are the relative peak areas and the splitting is shown where appropriate.

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Use the percentage composition data and the spectra to identify the aromatic compound, showing your reasoning.

Formula: C: 72.0 ÷ 12.0 = 6.00; H: 6.7 ÷ 1.0 = 6.7; O: 21.3 ÷ 16.0 = 1.33.

Dividing by 1.33: C : H : O = 4.5 : 5 : 1 = 9 : 10 : 2, so the formula is $C_9H_{10}O_2$ (M_r = 150).

IR: the strong peak at about 1720 cm^{-1} shows a C=O bond and the strong peak at about 1280 cm^{-1} shows a C–O bond. There is no broad peak at 2500 to 3300 cm^{-1}, so there is no O–H group: it is not a carboxylic acid (or alcohol).

C=O and C–O with no O–H means it is an ester (COO group).

NMR: there are 4 peaks, so 4 different proton environments, with relative areas 2 : 3 : 2 : 3 = 10 H in total, which supports $C_9H_{10}O_2$. The peaks at δ = 7.4 to 8.1 (areas 2 + 3 = 5) are aromatic H, so there is a C_6H_5 ring with only one substituent.

The triplet (area 3) at δ = 1.4 is a CH_3 group; it is a triplet by the n + 1 rule, so it is next to a CH_2. The quartet (area 2) at δ = 4.4 is a CH_2 next to a CH_3 (3 + 1 = 4), so there is an ethyl group, CH_2CH_3. The high shift of 4.4 shows the CH_2 is bonded to the O of the ester group (H–C–O). **[6]**

Extra space if required.

So the compound is the ester ethyl benzoate, $C_6H_5COOCH_2CH_3$, with the benzene ring on the C=O side and the ethyl group on the O side, which fits all the data.

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33 Ammonium nitrate, NH_4NO_3, is a compound that can be used in cold packs.

A student wants to measure the cooling effect of ammonium nitrate.

The student carries out an experiment using the method below.

The student:

- Measures 100 cm^3 of deionised water in a measuring cylinder.
- Pours the water into a polystyrene cup.
- Records the mass of an empty weighing bottle.
- Adds about 10 g of ammonium nitrate to the weighing bottle.
- Records the mass of the weighing bottle containing the ammonium nitrate.
- Subtracts the mass of the empty weighing bottle.
- Records the initial temperature of the water and adds the ammonium nitrate.
- Stirs the mixture and records the minimum temperature of the water.

(a) The student uses an incorrect method for measuring the mass of ammonium nitrate.

Explain what the student should do to correctly measure the mass of ammonium nitrate.

After tipping the ammonium nitrate into the water, reweigh the empty weighing bottle (some solid may be left in it). Subtract this mass from the mass of the bottle plus ammonium nitrate to find the mass actually added. **[2]**

(b) The student corrects this error and obtains the following results:

Mass of ammonium nitrate	10.10 g
Initial temperature of water	20.5 °C
Minimum temperature of water	14.0 °C

(i) Another student says this method only gives a small temperature change and this will cause a large percentage uncertainty.
The thermometer has an uncertainty of 0.5 °C.

Calculate the percentage uncertainty in the temperature **change**.

$\Delta T = 20.5 - 14.0 = 6.5$ °C; uncertainty in $\Delta T = 2 \times 0.5 = 1.0$ °C

% uncertainty $= 1.0 \div 6.5 \times 100 = 15.4\%$

Percentage uncertainty = 15.4 % **[1]**

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(ii) Suggest **one** change the student could make to the method (apart from changing the thermometer) to reduce this percentage uncertainty.

Explain why this change will reduce the percentage uncertainty.

Use a larger mass of ammonium nitrate (e.g. 20 g) in the same volume of water.

The temperature decrease will be greater, so the same 1.0 °C uncertainty is a smaller percentage of the temperature change.

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

(c) Use the student's results to calculate a value for the enthalpy change of solution, $\Delta_{solution}H$, for ammonium nitrate, NH_4NO_3, in kJ mol^{-1}.

Assume that the solution weighs 110.10 g and has a specific heat capacity the same as that of water.

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

$n(NH_4NO_3) = 10.10 \div 80.0 = 0.12625$ mol

$q = mc\Delta T = 110.10 \times 4.18 \times 6.5 = 2991.4$ J

$\Delta_{solution}H = +2991.4 \div 0.12625 = +23\ 694$ J mol^{-1}

$= +23.7$ kJ mol^{-1}

Positive as endothermic (temperature fell); ΔT has 2 s.f., so 2 s.f.

$\Delta_{solution}H$ = ...+24..... kJ mol^{-1} **[4]**

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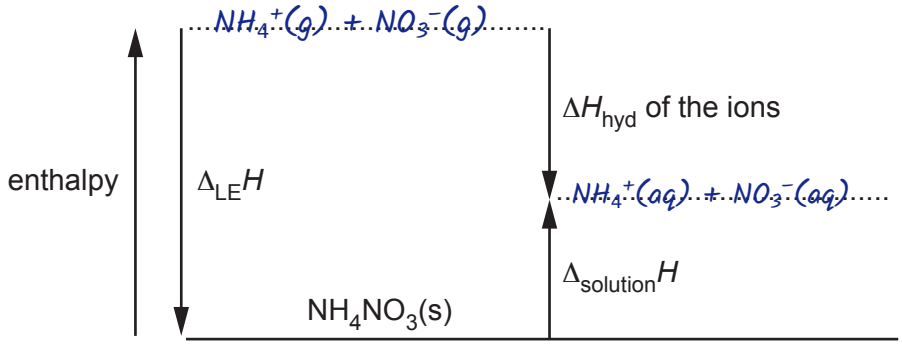
(d) The student looks up data and uses an enthalpy cycle to work out a value for $\Delta_{solution}H$.

(i) NH_4NO_3 is dissolved in water.

Complete the enthalpy cycle for this by adding ions and their state symbols on the dotted lines.



[2]

(ii) Use the data in the table below to calculate the theoretical value for the enthalpy change of solution of NH_4NO_3.

Enthalpy change	Value / kJ mol^{-1}
$\Delta_{hyd}H$ NH_4^+	–307
$\Delta_{hyd}H$ NO_3^-	–314
$\Delta_{LE}H$ NH_4NO_3	–646

$$\Delta_{solution}H = -\Delta_{LE}H + \Delta_{hyd}H(NH_4^+) + \Delta_{hyd}H(NO_3^-)$$

$$= +646 + (-307) + (-314) = +25 \text{ kJ mol}^{-1}$$

$\Delta_{solution}H$ = ...+25.... kJ mol^{-1} **[1]**

(e) The lattice enthalpy of sodium nitrate, $NaNO_3$, is –755 kJ mol^{-1}.

Suggest why the lattice enthalpy for NH_4NO_3 is less exothermic than the lattice enthalpy for $NaNO_3$.

The NH_4^+ ion is larger than the Na^+ ion (same charge), so NH_4^+ has a smaller charge density. So there are weaker electrostatic attractions between NH_4^+ and NO_3^- ions than between Na^+ and NO_3^- ions. **[2]**

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34 This question is about acids and buffers.

(a) Lateral flow tests can be used to test for viral infections in people.

These tests involve a sample being taken from the inside of a person's nose. A phosphate buffer is then added to this sample.

One type of lateral flow test uses phosphate buffers with the following reaction:

$H_2PO_4^- \rightleftharpoons HPO_4^{2-} + H^+$

(i) Explain why this equation shows that $H_2PO_4^-$ is a **weak** acid.

The ⇌ sign shows the reaction is reversible (an equilibrium), so $H_2PO_4^-$ only partially dissociates. **[1]**

(ii) Write the formula of the conjugate acid of $H_2PO_4^-$.

H_3PO_4 **[1]**

(iii) Explain how this buffer works.

A buffer resists changes in pH when small amounts of acid or alkali are added.

When acid is added, HPO_4^{2-} removes the added H^+, forming $H_2PO_4^-$: the equilibrium shifts to the left.

When alkali is added, OH^- removes H^+, so $H_2PO_4^-$ dissociates to give H^+: the equilibrium shifts to the right.

There are large concentrations of both the weak acid, $H_2PO_4^-$, and its conjugate base (salt), HPO_4^{2-}, so their ratio hardly changes and $[H^+]$ (pH) stays almost constant. **[4]**

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(iv) This type of lateral flow test only works at a pH around 7.4.

A scientist wants to make a buffer of pH 7.40, using NaH_2PO_4 and Na_2HPO_4.

$H_2PO_4^- \rightleftharpoons HPO_4^{2-} + H^+$ $\quad pK_a = 7.20$

Calculate the mass of NaH_2PO_4 that must be added to 2.0 dm^3 of 0.020 mol dm^{-3} Na_2HPO_4 to make a buffer with pH 7.40.

Assume that the total volume of the solution stays at 2.0 dm^3.

$[H^+] = 10^{-7.40} = 3.98 \times 10^{-8}$ mol dm^{-3}

$K_a = 10^{-7.20} = 6.31 \times 10^{-8}$ mol dm^{-3}

$K_a = [H^+][HPO_4^{2-}] \div [H_2PO_4^-]$

$6.31 \times 10^{-8} = 3.98 \times 10^{-8} \times 0.020 \div [H_2PO_4^-]$

$[H_2PO_4^-] = (3.98 \times 10^{-8} \times 0.020) \div (6.31 \times 10^{-8}) = 0.01262$ mol dm^{-3}

$n(NaH_2PO_4) = 0.01262 \times 2.0 = 0.02524$ mol; $M_r(NaH_2PO_4) = 120.0$

mass $= 0.02524 \times 120.0 = 3.03$ g

Mass = ...3.0..... g **[5]**

(b) Hydrochloric acid is a strong acid.

(i) Complete the equation for the reaction of hydrochloric acid with water.

$HCl + H_2O \rightarrow H_3O^+ + Cl^-$

[1]

(ii) Calculate the pH of 0.050 mol dm^{-3} hydrochloric acid.

$pH = -\log[H^+] = -\log(0.050) = 1.30$

pH = ...1.30..... **[1]**

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35 This question is about halides.

(a) Iodide ions react with BrO_3^- ions in acid solution to form iodine, water and bromide ions.

(i) Give the systematic name of the BrO_3^- ion.

bromate(V) ..... **[1]**

(ii) Write a balanced ionic equation for the reaction.

$6I^- + BrO_3^- + 6H^+ \rightarrow 3I_2 + Br^- + 3H_2O$

[2]

(iii) A chemist measures the rate constant for this reaction at two temperatures.
The chemist's results are shown in the table.

	T **/ K**	**ln *k***
Temperature 1	313	4.777
Temperature 2	296	3.645

The expression below can be derived from the Arrhenius equation.

$$\ln k_1 - \ln k_2 = \frac{E_a}{R}(1/T_2 - 1/T_1)$$

Use this expression and the chemist's results to calculate a value for the activation enthalpy, E_a, in kJ mol^{-1}.

$\ln k_1 - \ln k_2 = 4.777 - 3.645 = 1.132$

$1/T_2 - 1/T_1 = 1/296 - 1/313 = 1.835 \times 10^{-4}\ K^{-1}$

$E_a = (1.132 \times 8.314) \div (1.835 \times 10^{-4}) = 51\ 290\ J\ mol^{-1}$

$= 51.3\ kJ\ mol^{-1}$

E_a = ...51.3..... kJ mol^{-1} **[3]**

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(b)* A student wishes to identify three unlabelled salts.

The student has been told:
- the cations in the three salts are ammonium, copper(II) and iron(II) respectively.
- the anions present (one per salt) are chloride, bromide and iodide.

Describe the chemical tests that the student could carry out to identify the salts.

Include the observations from positive tests and equations for the reactions that occur.

Dissolve a small sample of each salt in distilled water to make solutions, and use a separate portion for each test.

Cations: add sodium hydroxide solution. Copper(II) gives a blue precipitate: $Cu^{2+}(aq) + 2OH^-(aq) \rightarrow Cu(OH)_2(s)$. Iron(II) gives a green precipitate: $Fe^{2+}(aq) + 2OH^-(aq) \rightarrow Fe(OH)_2(s)$. The ammonium salt gives no precipitate, but on warming gives ammonia gas, which turns damp red litmus paper blue: $NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(g) + H_2O(l)$.

Anions: add dilute nitric acid, then silver nitrate solution. Chloride gives a white precipitate, bromide a cream precipitate and iodide a yellow precipitate: $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$; $Ag^+(aq) + Br^-(aq) \rightarrow AgBr(s)$; $Ag^+(aq) + I^-(aq) \rightarrow AgI(s)$.

To confirm, add ammonia solution: AgCl dissolves in dilute ammonia, AgBr dissolves only in concentrated ammonia and AgI does not dissolve.

Matching each salt's cation result with its anion result identifies all three salts.

[6]

Extra space if required:

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EXTRA ANSWER SPACE

If you need extra space use this lined page. You must write the question numbers clearly in the margin.

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