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National Qualifications SPECIMEN ONLY

Mark

SQ07/H/01

Chemistry
Section 1 — Answer Grid and Section 2

Date — Not applicable

Duration — 2 hours and 30 minutes

* S Q 0 7 H 0 1 *

Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Number of seat

Date of birth

Day Month Year

Scottish candidate number

Reference may be made to the Chemistry Higher and Advanced Higher Data Booklet.

Total marks — 100

SECTION 1 — 20 marks

Attempt ALL questions.

Instructions for completion of Section 1 are given on *Page two*.

SECTION 2 — 80 marks

Attempt ALL questions

Write your answers clearly in the spaces provided in this booklet. Additional space for answers and rough work is provided at the end of this booklet. If you use this space you must clearly identify the question number you are attempting. Any rough work must be written in this booklet. You should score through your rough work when you have written your final copy.

Use **blue** or **black** ink.

Before leaving the examination room you must give this booklet to the Invigilator; if you do not you may lose all the marks for this paper.

SQA ©

SECTION 1— 20 marks

The questions for Section 1 are contained in the question paper SQ07/H/02.
Read these and record your answers on the answer grid on *Page three* opposite.
DO NOT use gel pens.

1. The answer to each question is **either** A, B, C or D. Decide what your answer is, then fill in the appropriate bubble (see sample question below).

2. There is **only one correct** answer to each question.

3. Any rough working should be done on the additional space for answers and rough work at the end of this booklet.

Sample Question

To show that the ink in a ball-pen consists of a mixture of dyes, the method of separation would be:

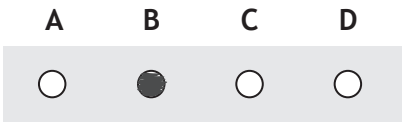
A fractional distillation

B chromatography

C fractional crystallisation

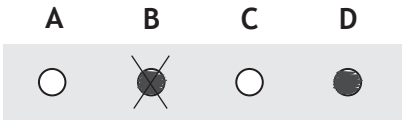
D filtration.

The correct answer is **B**—chromatography. The answer **B** bubble has been clearly filled in (see below).

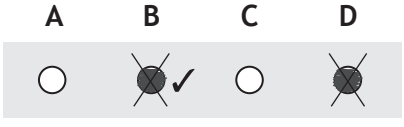


Changing an answer

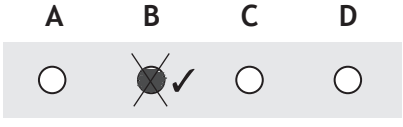
If you decide to change your answer, cancel your first answer by putting a cross through it (see below) and fill in the answer you want. The answer below has been changed to **D**.



If you then decide to change back to an answer you have already scored out, put a tick (✓) to the **right** of the answer you want, as shown below:



or



OBJ20AD1

You must record your answers to Section 1 questions on the answer grid on **Page 3** of your **answer booklet.**

SQ07H0103

MARKS | DO NOT WRITE IN THIS MARGIN

SECTION 2 — 80 marks

Attempt ALL questions

1. Common salt, NaCl, is widely used in the food industry as a preservative and flavour enhancer.

(a) (i) Write the ion-electron equation for the first ionisation energy of sodium. **1**

(ii) **Explain clearly** why the first ionisation energy of sodium is much lower than its second ionisation energy. **3**

(b) The label on a tub of margarine states that 100 g of the margarine contains 0·70 g of sodium. The sodium is present as sodium chloride.

Calculate the mass of sodium chloride, in grams, present in a 10 g portion of the margarine.

The mass of one mole of sodium chloride, NaCl, is 58·5 g. **1**

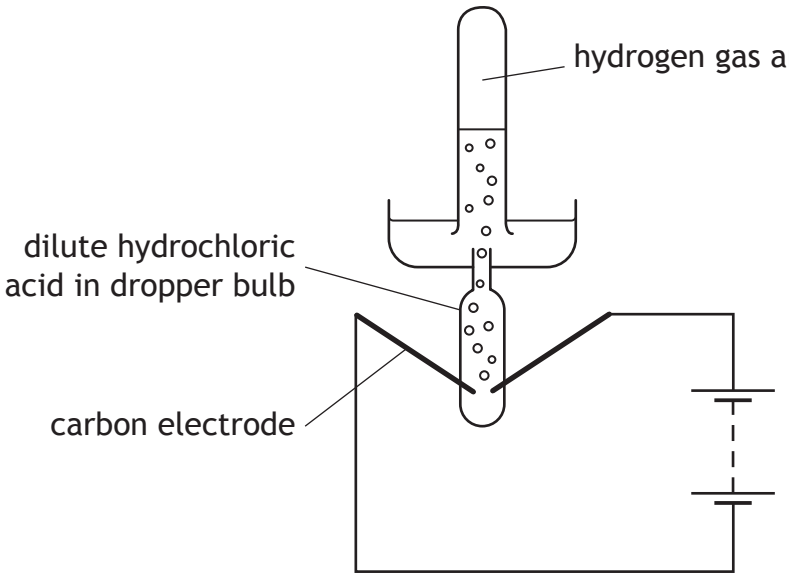
2. (a) Nitrogen dioxide gas and carbon monoxide gas can react when molecules collide.

$$NO_2(g) + CO(g) \rightarrow NO(g) + CO_2(g)$$

State **two** conditions necessary for a collision to be successful. **2**

(b) Hydrogen gas and chlorine gas react explosively in a photochemical reaction. In a demonstration experiment, the reaction was used to fire a table tennis ball across a room.

(i) A mixture of hydrogen gas and chlorine gas was generated by the electrolysis of hydrochloric acid.



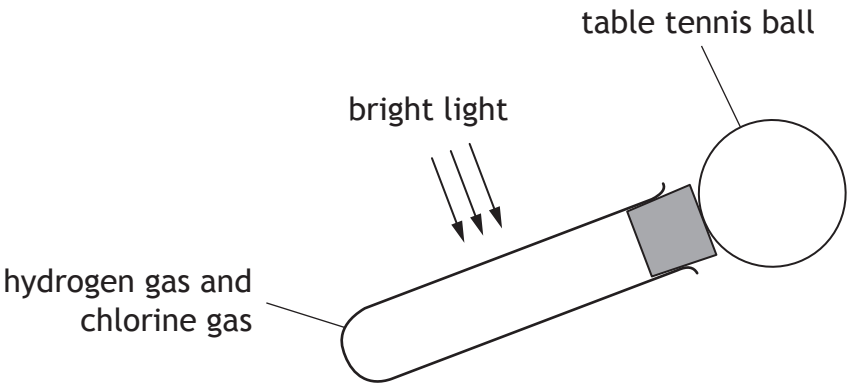
$$2HCl(aq) \rightarrow H_2(g) + Cl_2(g)$$

Calculate the number of moles of hydrochloric acid required to completely fill a 10 cm^3 test tube with the hydrogen gas and chlorine gas mixture.

(Take the molar volume of a gas to be 24 litres mol^{-1}) **2**

2. (b) **(continued)**

(ii) The filled test tube was fitted with a stopper to which a table tennis ball was attached. When a bright light was directed at the test tube, the gas mixture exploded and the ball was fired across the room.



Chlorine reacts with hydrogen in a free radical chain reaction. Some steps in the chain reaction are shown in the table.

Reaction step	*Name of step*
$Cl_2 \rightarrow 2Cl\bullet$	
$Cl\bullet + H_2 \rightarrow HCl + H\bullet$ $H\bullet + Cl_2 \rightarrow HCl + Cl\bullet$	propagation
	termination

Complete the table by:

A inserting the missing name for the first step; **1**

B showing a possible termination step. **1**

2. (b) (continued)

(iii) The production of hydrogen chloride from hydrogen and chlorine is exothermic.

$$H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$$

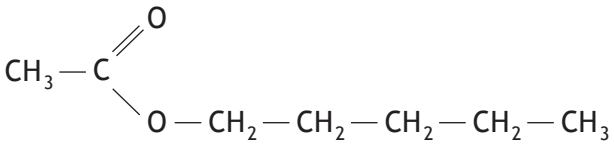
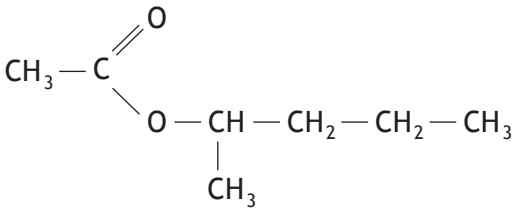
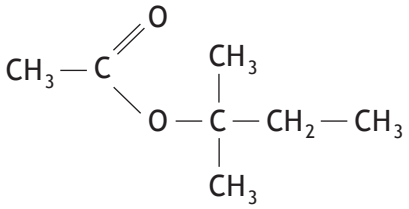
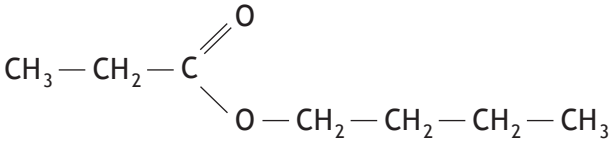
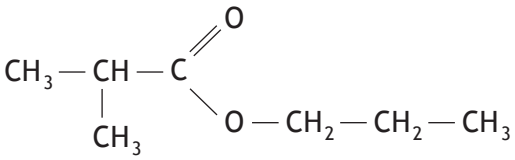
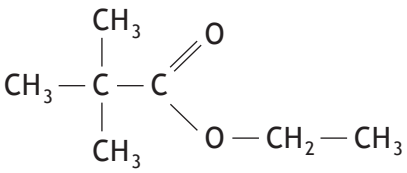
Using bond enthalpy values, calculate the enthalpy change, in kJ, for the reaction.

Show your working clearly. **2**

3. A team of chemists is developing a fragrance for use in a shower gel for men.

(a) To give the gel a fruity smell the chemists are considering adding an ester.

They synthesise six isomeric esters. Volunteers smell each ester and give it a rating out of one hundred depending on how fruity the smell is.

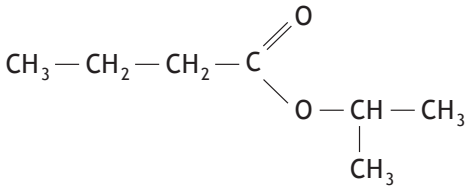
Structure	*Fruit-smell rating*
	100
	34
	0
	92
	44
	32

(i) Name the ester with the fruit-smell rating of 92. **1**

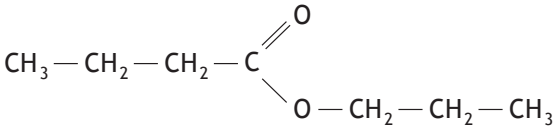
3. (a) (continued)

(ii) Shown below are the structures of three more isomers.

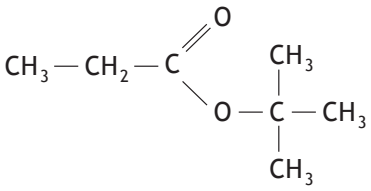
Ester **A**



Ester **B**



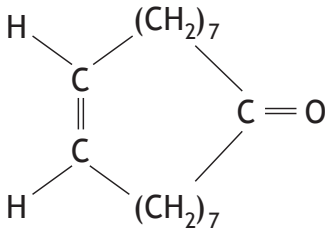
Ester **C**



Arrange these esters in order of **decreasing** fruit-smell rating.

Ester ☐ > Ester ☐ > Ester ☐ **1**

(b) To create a fragrance for men, the compound civetone is added.

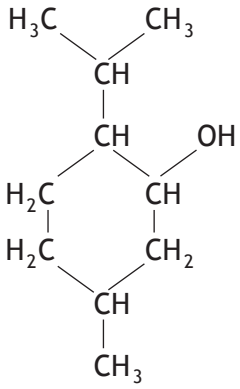


civetone

Draw a structural formula for the alcohol that can be oxidised to form civetone. **1**

3. (continued)

(c) To make the shower gel produce a cold, tingling sensation when applied to the skin, menthol is added.



Like terpenes, menthol is formed from isoprene (2-methylbuta-1,3-diene).

Circle an isoprene unit on the menthol structure above. **1**

4. Cooking changes the appearance and composition of foods.

Using your knowledge of chemistry, comment on the changes to food that may occur during cooking. **3**

MARKS | DO NOT WRITE IN THIS MARGIN

5. 2-Methylpropan-1-ol and ethanol are renewable fuels that are used as alternatives to petrol in car engines.

(a) A car was fuelled with 15 litres of ethanol. The ethanol burned to produce 351 000 kJ of energy.

Use the data in the table to calculate the volume of 2-methylpropan-1-ol that would burn to release the same energy.

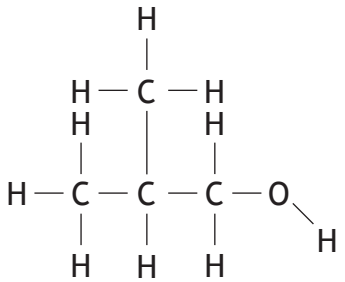
Volume of 1 g of 2-methylpropan-1-ol	1·25 cm^3
Energy from 1 g of 2-methylpropan-1-ol	3·61 kJ

3

(b) Fuels containing alcohols have a tendency to absorb water, which can cause the engine to rust.

Water is absorbed by alcohols due to hydrogen bonds forming between the alcohol and water molecules.

In the box below, use a dotted line to show a hydrogen bond between a water molecule and 2-methylpropan-1-ol. **1**



5. (continued)

(c) 2-Methylpropan-1-ol can also be converted to produce diesel and jet fuel.

The first step in the process is the production of 2-methylpropene.

$$\underset{\text{2-methylpropan-1-ol}}{C_4H_{10}O(\ell)} \rightarrow \underset{\text{2-methylpropene}}{C_4H_8(g)} + H_2O(g)$$

Using the data below, calculate the enthalpy change, in kJ mol^{-1}, for the production of 2-methylpropene from 2-methylpropan-1-ol.

$4C(s) + 5H_2(g) + \frac{1}{2}O_2(g) \rightarrow C_4H_{10}O(\ell) \quad \Delta H = -335 \text{ kJ mol}^{-1}$

$4C(s) + 4H_2(g) \rightarrow C_4H_8(g) \quad \Delta H = -17 \text{ kJ mol}^{-1}$

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(g) \quad \Delta H = -242 \text{ kJ mol}^{-1}$ **2**

(d) If the viscosity of a fuel is not within a certain range then it can result in damage to the fuel pump and engine.

A student was asked to design an experiment to compare the viscosity of some fuels. Suggest an experiment that could be done to compare viscosities.

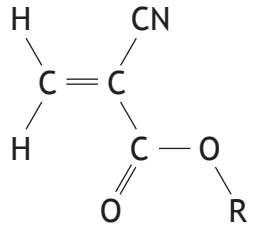
(You may wish to use a diagram to help with your description.) **2**

MARKS | DO NOT WRITE IN THIS MARGIN

6. Cyanoacrylate adhesives are a range of high performance "super glues".

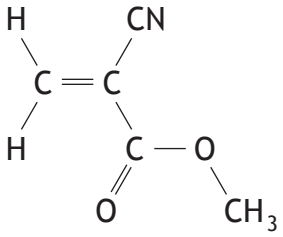
In its liquid form, super glue consists of cyanoacrylate monomers that rapidly polymerise in the presence of water to form a strong resin that joins two surfaces together.

Cyanoacrylates have the general structure



where R is a hydrocarbon group, eg $-CH_3$.

(a) Some super glues contain methyl 2-cyanoacrylate.

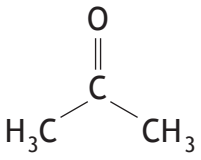


Circle the ester link in this structure. **1**

(b) If used incorrectly, super glue can rapidly cause your fingers to stick together.

(i) Suggest why super glue reacts rapidly on the surface of the skin. **1**

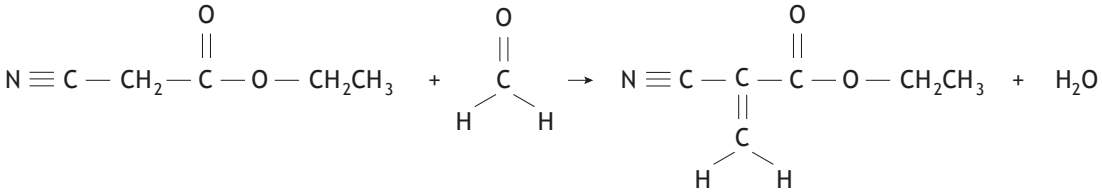
(ii) Super glue can be removed from the skin using propanone as a solvent.



Name the main type of van der Waals' forces that would be formed between propanone and super glue. **1**

6. (continued)

(c) Ethyl 2-cyanoacrylate is synthesised from ethyl 2-cyanoethanoate by a process based on the Knovenagel reaction.



ethyl 2-cyanoethanoate mass of one mole = 113 g	reactant **A** mass of one mole = 30 g	ethyl 2-cyanoacrylate mass of one mole = 125 g	water mass of one mole = 18 g

(i) Name reactant **A**. **1**

(ii) Name this **type** of chemical reaction. **1**

(iii) Calculate the atom economy for the formation of ethyl 2-cyanoacrylate using this process.

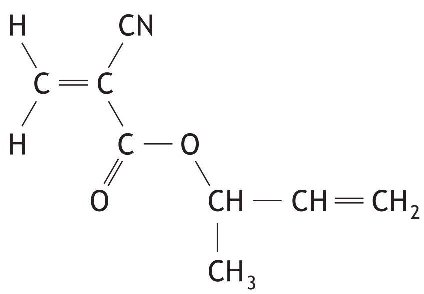
Show your working clearly. **2**

6. (continued)

(d) The adhesive strength of super glue can be altered by introducing different alkyl groups to the monomer.

Hydrocarbon group	*Shearing adhesive strength*/N cm^{-2}
$-CH_3$	1800
$-CH_2-CH_3$	1560
$-CH_2-CH_2-CH_3$	930
$-CH_2-CH_2-CH_2-CH_3$	270
$-CH_2(CH_3)-CH_2-CH_3$	420
$-CH_2-CH=CH_2$	1240
$-CH_2-C\equiv CH$	1670
$-CH(CH_3)-C\equiv CH$	1140

Estimate the adhesive strength of super glue that contains the monomer shown below. **1**



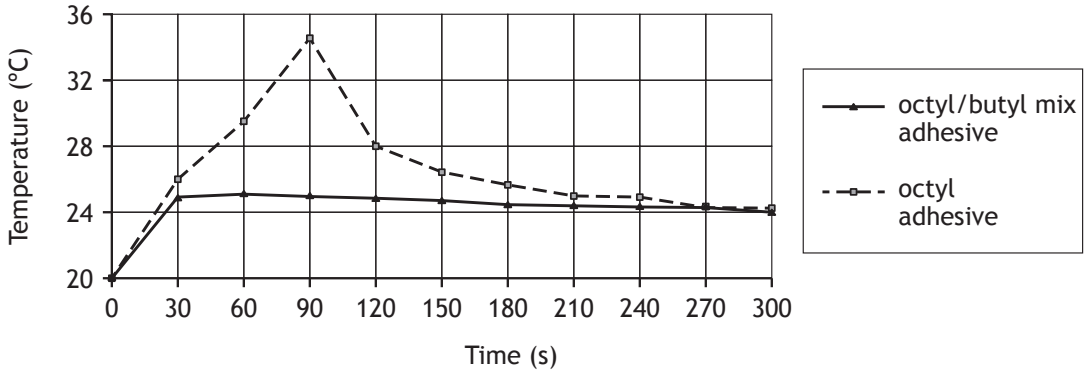
6. (continued)

(e) Super glues have been developed for medical applications.

(i) Medical tissue adhesive, containing octyl 2-cyanoacrylate, can be used for wound closures instead of sutures or stitches.

Draw a structural formula for octyl 2-cyanoacrylate. **1**

(ii) The graph below compares the temperature change during the polymerisation reaction for two different brands of medical tissue adhesive.



Suggest an advantage to the patient of using the octyl/butyl mix adhesive. **1**

MARKS | DO NOT WRITE IN THIS MARGIN

7. A student analysed a local water supply to determine fluoride and nitrite ion levels.

(a) The concentration of fluoride ions in water was determined by adding a red coloured compound that absorbs light to the water samples. The fluoride ions reacted with the red compound to produce a colourless compound. Higher concentrations of fluoride ions produce less coloured solutions which absorb less light.

The student initially prepared a standard solution of sodium fluoride with fluoride ion concentration of 100 mg l^{-1}.

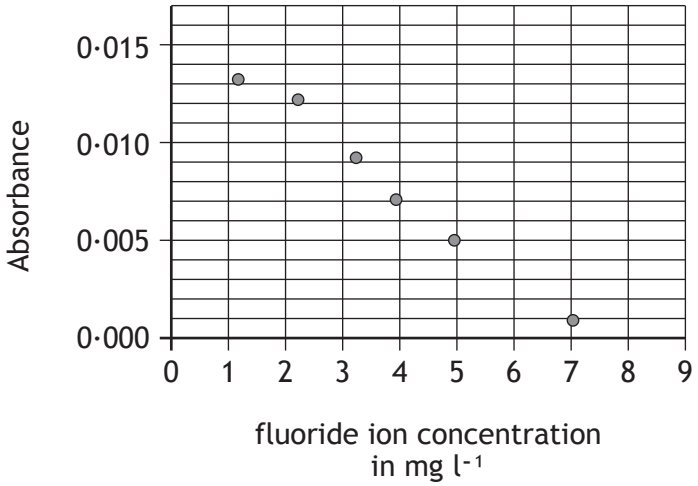
(i) State what is meant by the term **standard solution**. **1**

(ii) Describe how the standard solution is prepared from a weighed sample of sodium fluoride. **2**

(iii) Explain why the student should use distilled or deionised water rather than tap water when preparing the standard solution. **2**

7. (a) (continued)

(iv) The student prepared a series of standard solutions of fluoride ions and reacted each with a sample of the red compound. The light absorbance of each solution was measured and the results graphed.



Determine the concentration of fluoride ions in a solution with absorbance 0·012. **1**

7. (continued)

(b) The concentration of nitrite ions in the water supply was determined by titrating water samples with acidified permanganate solutions.

(i) An average of $21{\cdot}6\,cm^3$ of $0{\cdot}015\,mol\,l^{-1}$ acidified permanganate solution was required to react completely with the nitrite ions in a $25{\cdot}0\ cm^3$ sample of water.

The equation for the reaction taking place is

$$2MnO_4^-(aq) + 5NO_2^-(aq) + 6H^+(aq) \rightarrow 2Mn^{2+}(aq) + 5NO_3^-(aq) + 3H_2O(\ell)$$

Calculate the nitrite ion concentration, in $mol\,l^{-1}$, in the water.

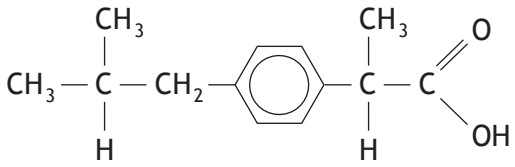
Show your working clearly. **3**

(ii) During the reaction the nitrite ion is oxidised to the nitrate ion. Complete the ion-electron equation for the oxidation of the nitrite ion.

$NO_2^-(aq)$ [ ] $\rightarrow$ $NO_3^-(aq)$ [ ]

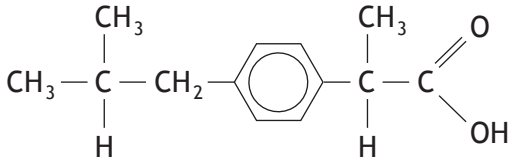
MARKS | DO NOT WRITE IN THIS MARGIN

8. Ibuprofen is one of the best-selling pain killers in the UK.



(a) Ibuprofen tablets should not be taken by people who suffer from acid indigestion. Name the functional group present in ibuprofen that makes this drug unsuitable for these people. **1**

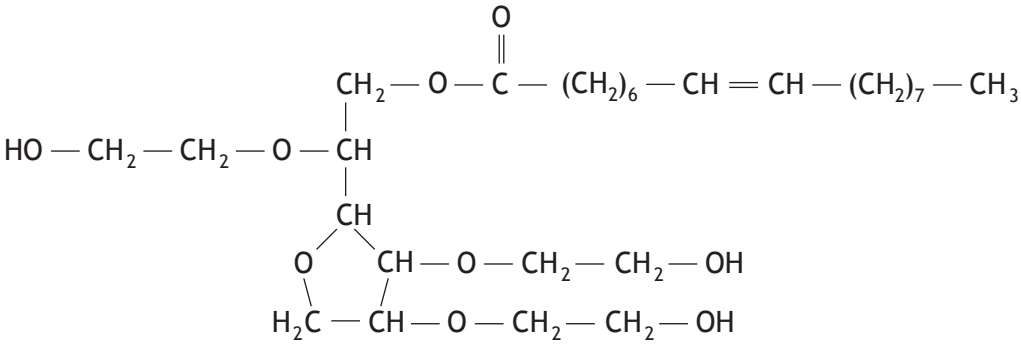
(b) Ibuprofen is normally taken as tablets or pills and it is only slightly soluble in water.



(i) Suggest why ibuprofen is only slightly soluble in water. **1**

(ii) Ibuprofen is also available as an "infant formula" emulsion for young children.

The emulsifier used is polysorbate 80. Its structure is shown below.



Circle the part of the polysorbate 80 molecule that is hydrophobic. **1**

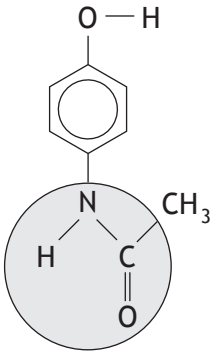
MARKS | DO NOT WRITE IN THIS MARGIN

(iii) The emulsion contains 2·0 g of ibuprofen in every 100 cm^3 of emulsion.

The recommended dose for treating a three month old baby is 0·050 g.

Calculate the volume, in cm^3, of "infant formula" needed to treat a three month old baby. **1**

(c) Paracetamol is another widely used painkiller. Its structure is shown below.

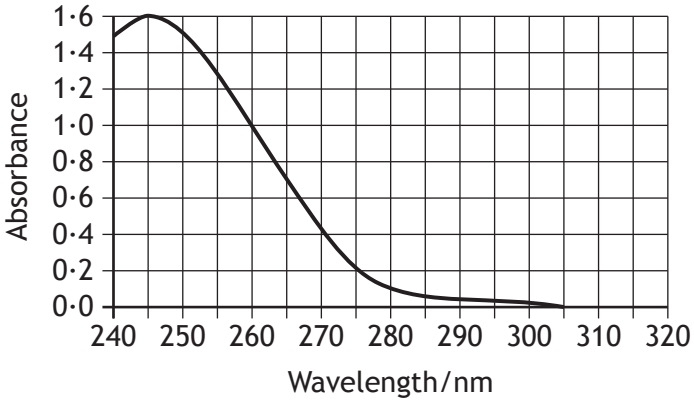


(i) Name the functional group shaded in the structure. **1**

8. (b) (continued)

(ii) The concentration of paracetamol in a solution can be determined by measuring how much UV radiation it absorbs. The quantity of UV radiation absorbed is directly proportional to the concentration of paracetamol.

The graph shows how the absorbance of a sample containing $0{\cdot}040\,g\,l^{-1}$ paracetamol varies with wavelength.

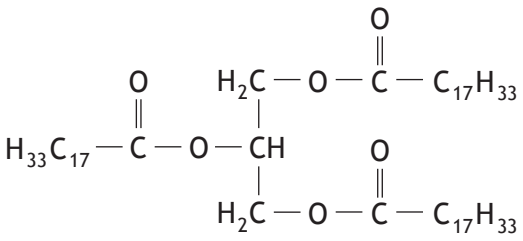
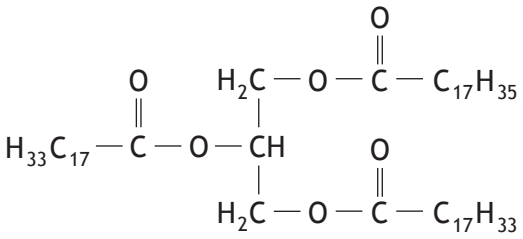
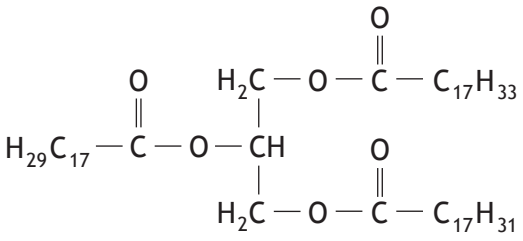
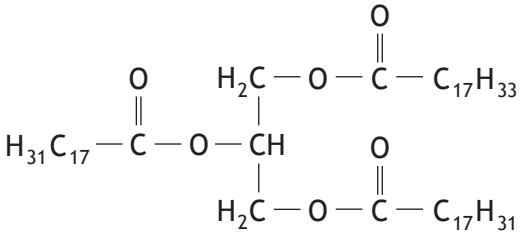


The absorbance of a second sample of paracetamol solution measured at 245 nm was 0·90.

Determine the concentration, in $g\,l^{-1}$, of this second paracetamol solution. **1**

9. A student carried out some experiments using different fats and oils.

(a) The first experiment allowed the iodine number to be calculated. The iodine number is the mass of iodine, in grams, that will react with 100 g of the fat or oil. The student's results are shown.

Fat or oil	*Iodine number*	*Typical molecule found in the fat or oil*
Olive oil	84	
Shea butter	43	
Linseed oil	172	
Sunflower oil		

(i) Shea butter is a solid at room temperature.

Explain why the melting point of shea butter is higher than room temperature. **2**

MARKS | DO NOT WRITE IN THIS MARGIN

9. (a) (continued)

(ii) Predict the iodine number of sunflower oil. **1**

(iii) Name the substance that reacts with oils to turn them rancid. **1**

(b) In the second experiment some oils were used to make soap. The oil, triolein, was reacted with sodium hydroxide.

$(C_{17}H_{33}COO)_3C_3H_5 + 3NaOH \rightarrow 3C_{17}H_{33}COONa + X$

triolein — mass of one mole = 884 g

sodium oleate — mass of one mole = 304 g

(i) Name product **X**. **1**

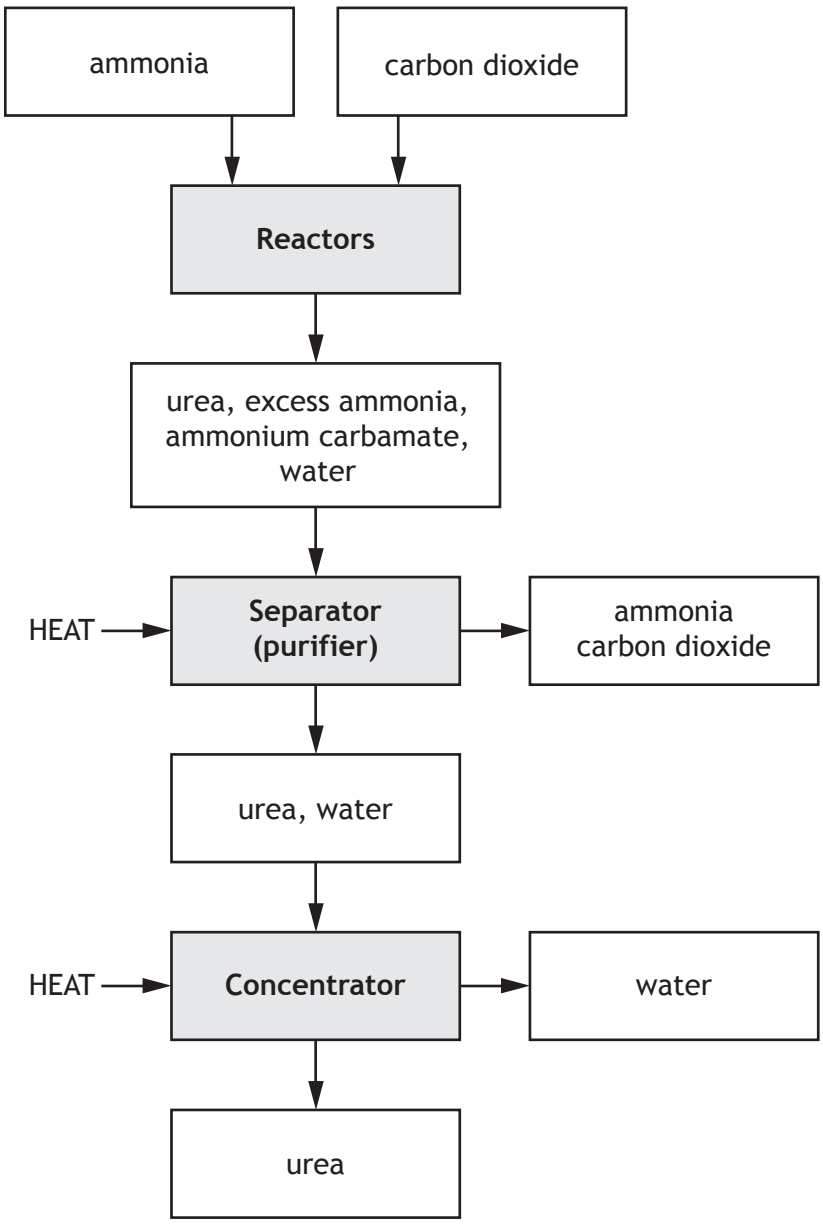
(ii) 5·0 g of triolein was dissolved in ethanol and placed in a test tube with excess sodium hydroxide. The mixture was heated to 80 °C.

State a suitable method for heating the reaction mixture. **1**

(iii) The experiment produced 1·28 g of sodium oleate.

Calculate the percentage yield. **2**

10. Urea, $(NH_2)_2CO$, is an important industrial chemical that is mainly used in fertilisers. It is made by the Bosch-Meiser process.



10. (continued)

(a) (i) In the reactors, the production of urea involves two reversible reactions.

In the first reaction ammonium carbamate is produced.

$$2NH_3(g) + CO_2(g) \rightleftharpoons H_2NCOONH_4(g)$$

In the second reaction the ammonium carbamate decomposes to form urea.

$$H_2NCOONH_4(g) \rightleftharpoons (NH_2)_2CO(g) + H_2O(g)$$

A chemical plant produces 530 tonnes of urea per day.

Calculate the theoretical mass, in tonnes, of ammonia required to produce 530 tonnes of urea. **2**

(ii) An undesirable side reaction is the production of biuret, a compound that can burn the leaves of plants.

$$2(NH_2)_2CO(aq) \rightleftharpoons \underset{\text{biuret}}{NH_2CONHCONH_2(aq)} + NH_3(g)$$

State why having an excess of ammonia in the reactors will decrease the amount of biuret produced. **1**

10. (a) (continued)

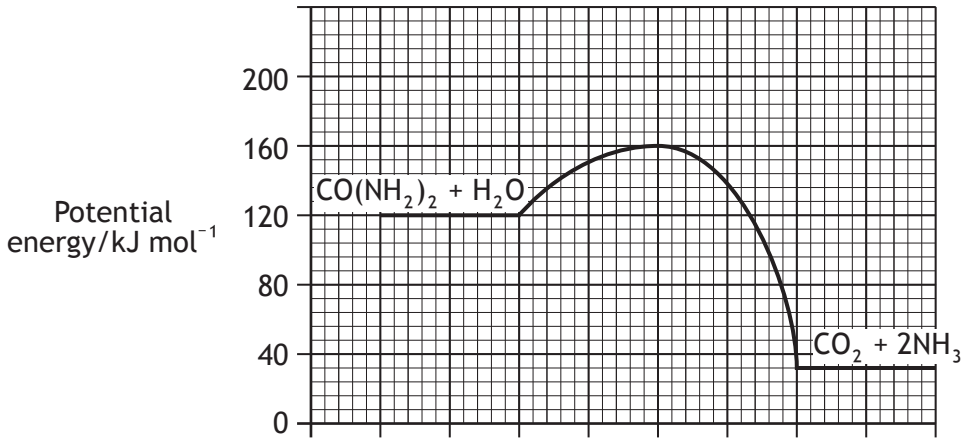
(iii) In the separator the ammonium carbamate from the reactors decomposes to form ammonia and carbon dioxide.

$$NH_2COONH_4(aq) \rightleftharpoons 2NH_3(g) + CO_2(g)$$

Explain clearly why a low pressure is used in the separator. **2**

(iv) Add a line to the flow chart, to show how the Bosch-Meiser process can be made more economical. **1**

(b) Soil bacteria are mainly responsible for releasing nitrogen in urea into the soil so that it can be taken up by plants. The first stage in the process is the hydrolysis of urea using the enzyme urease.



(i) Determine the enthalpy change, in kJ mol^{-1}, for the reaction. **1**

(ii) Acid is a less effective catalyst than urease for this reaction. Add a curve to the potential energy diagram to show the change in potential energy when acid is used as the catalyst. **1**

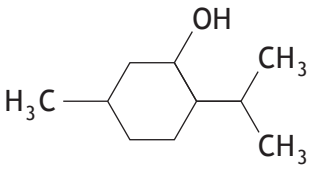
MARKS | DO NOT WRITE IN THIS MARGIN

11. A TV programme was reproducing a pharmacy from the 19th century and planned to use the original 19th century pharmacy jars that had been kept in a museum. The TV company wanted to know what compounds the jars were likely to contain now.

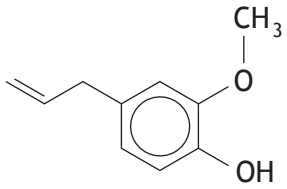
Substances used in pharmacies over a hundred years ago included:

- Essential oils dissolved in ethanol.

  Some molecules included in these essential oils were:

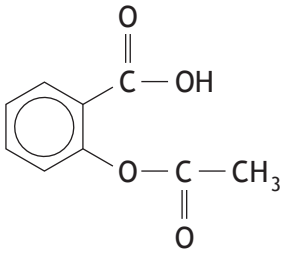


menthol



eugenol

- Aspirin.



- Ointments that contained animal fats like lard, beef fat or beeswax.

Using your knowledge of chemistry, comment on what compounds the old pharmacy jars might contain now. **3**

MARKS | DO NOT WRITE IN THIS MARGIN

12. Proteins are an important part of a healthy diet because they provide essential amino acids.

(a) State what is meant by an **essential amino acid**. **1**

(b) Eggs and fish are good dietary sources of the essential amino acid, methionine.

The recommended daily allowance of methionine for an adult is 15 mg per kg of body mass.

Tuna contains 755 mg of methionine per 100 g portion.

Calculate the mass, in grams, of tuna that would provide the recommended daily allowance of methionine for a 60 kg adult. **2**

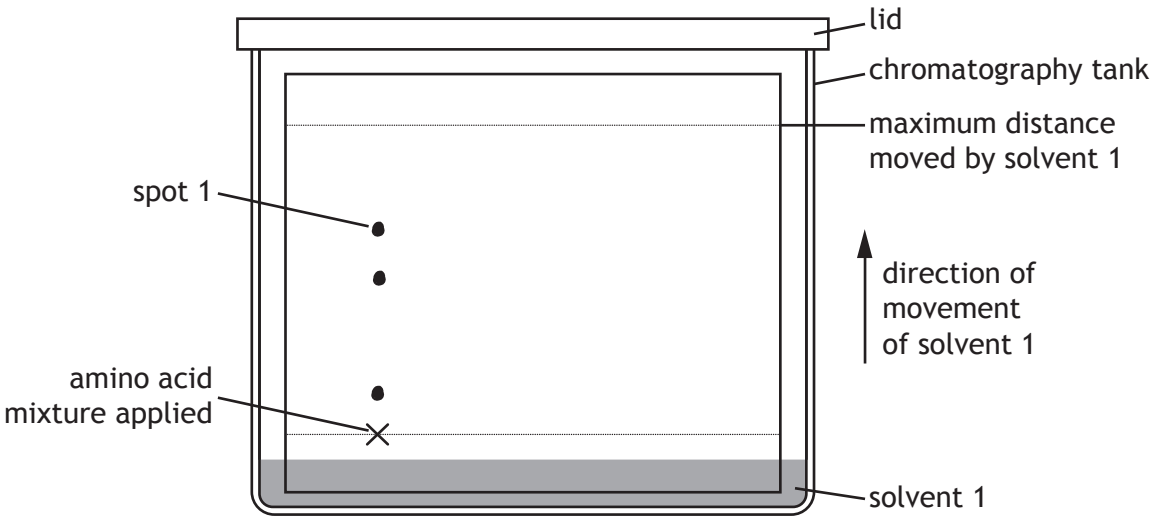
12. (continued)

(c) Mixtures of amino acids can be separated using paper chromatography. On a chromatogram, the retention factor, R_f, for a substance can be a useful method of identifying the substance.

$$R_f = \frac{\text{distance moved by the substance}}{\text{maximum distance moved by the solvent}}$$

(i) A solution containing a mixture of four amino acids was applied to a piece of chromatography paper that was then placed in solvent 1.

Chromatogram 1 is shown below.



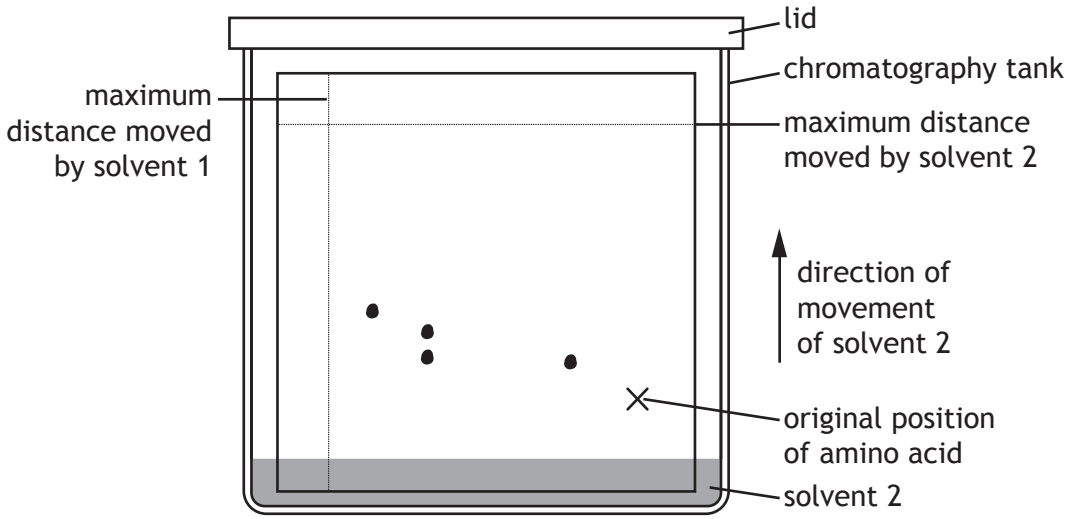
Amino Acid	R_f (*solvent 1*)
alanine	0·51
arganine	0·16
threonine	0·51
tyrosine	0·68

Identify the amino acid that corresponds to spot 1 on the chromatogram. **1**

12. (c) **(continued)**

(ii) The chromatogram was dried, rotated through 90° and then placed in solvent 2.

Chromatogram 2 is shown below.



Amino Acid	R_f (*solvent 2*)
alanine	0·21
arganine	0·21
threonine	0·34
tyrosine	0·43

The retention factors for each of the amino acids in solvent 2 are shown in the table.

Draw a circle around the spot on chromatogram 2 that corresponds to the amino acid alanine. **1**

(iii) Explain why only three spots are present in chromatogram 1 while four spots are present in chromatogram 2. **2**

[END OF SPECIMEN QUESTION PAPER]

ADDITIONAL SPACE FOR ANSWERS AND ROUGH WORK

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