Higher Chemistry

Past Paper Questions – Book 3

Higher 2016

Higher 2017

2016

SECTION 1 — 20 marks

Attempt ALL questions

1. Particles with the same electron arrangement are said to be isoelectronic.

Which of the following compounds contains ions which are isoelectronic?

A Na_2S

B $MgCl_2$

C KBr

D $CaCl_2$

2. Which line in the table is correct for the polar covalent bond in hydrogen chloride?

	Relative position of bonding electrons	*Dipole notation*
A	H —:— Cl	$\overset{\delta+}{H}—\overset{\delta-}{Cl}$
B	H :— Cl	$\overset{\delta+}{H}—\overset{\delta-}{Cl}$
C	H —:— Cl	$\overset{\delta-}{H}—\overset{\delta+}{Cl}$
D	H :— Cl	$\overset{\delta-}{H}—\overset{\delta+}{Cl}$

3. Which of the following compounds has the greatest ionic character?

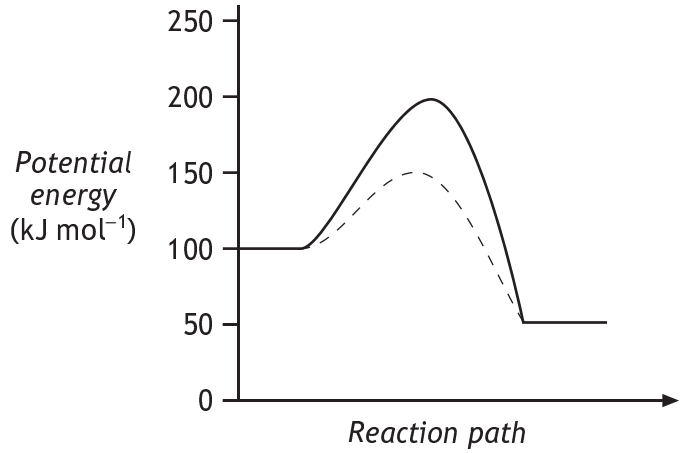
A Caesium fluoride

B Caesium iodide

C Sodium fluoride

D Sodium iodide

4. The diagram below shows the energy profiles for a reaction carried out with and without a catalyst.



What is the enthalpy change, in kJ mol^{-1}, for the catalysed reaction?

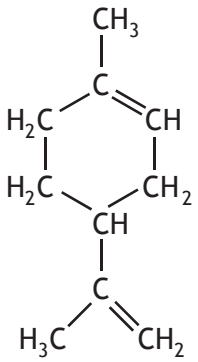
A –100

B –50

C +50

D +100

5. Limonene is a terpene molecule present in lemons.



limonene

How many isoprene units are joined together in a limonene molecule?

A 1

B 2

C 3

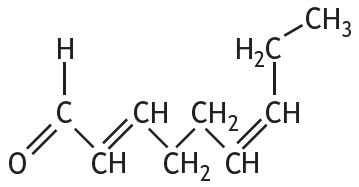
D 4

[Turn over

6. The following molecules give flavour to food.

Which of the following flavour molecules would be most likely to be retained in the food when the food is cooked in water?

A



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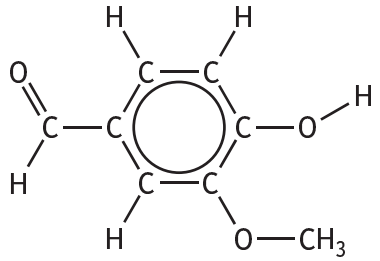

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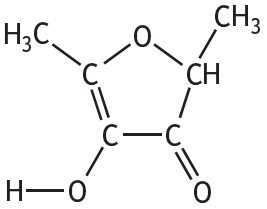
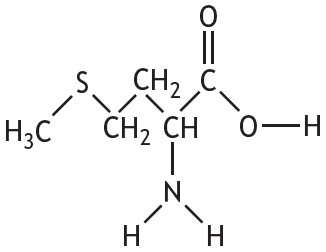


D



7. vegetable oil ⟶ vegetable fat

Which of the following reactions brings about the above change?

A Hydrolysis

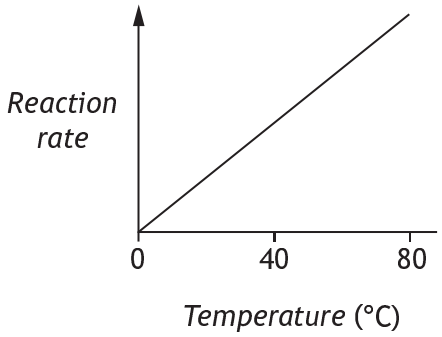
B Condensation

C Hydrogenation

D Dehydrogenation

8. The rate of hydrolysis of protein, using an enzyme, was studied at different temperatures. Which of the following graphs would be obtained?

A



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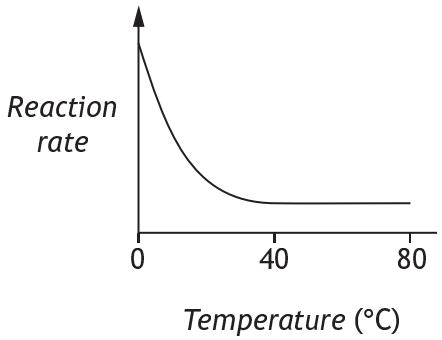
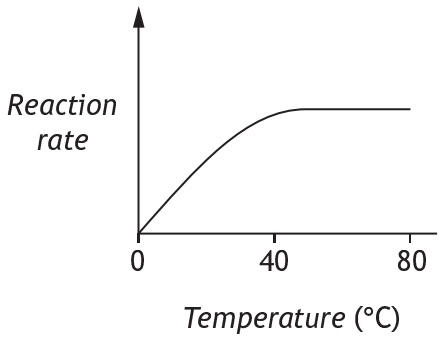
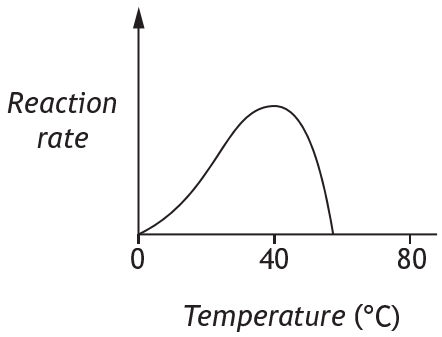


C



D



[Turn over

9. Which of the following is the salt of a long-chain fatty acid?

A Fat

B Oil

C Soap

D Glycerol

10. Emulsifiers for use in food are commonly made by reacting edible oils with

A esters

B glycerol

C fatty acids

D amino acids.

11. The equation for the reduction reaction taking place when ethanal reacts with Tollens' reagent is

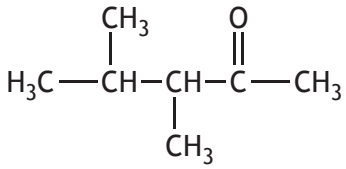
A $Cu^{2+}(aq) + e^- \rightarrow Cu^+(aq)$

B $Ag^+(aq) + e^- \rightarrow Ag(s)$

C $Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(\ell)$

D $MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(\ell)$

12. The name of the compound with structure:



is

A 2,3-dimethylpentan-4-one

B 2,3-dimethylpentan-2-al

C 3,4-dimethylpentan-2-one

D 3,4-dimethylpentan-2-al.

13. $CaCO_3(s) + 2HNO_3(aq) \rightarrow Ca(NO_3)_2(aq) + CO_2(g) + H_2O(\ell)$

Mass of 1 mol = 100 g

Mass of 1 mol = 164 g

2·00 g of calcium carbonate ($CaCO_3$) was reacted with 200 cm^3 of 0·1 mol l^{-1} nitric acid (HNO_3).

Take the volume of 1 mole of carbon dioxide to be 24 litres.

In the reaction

A $CaCO_3$ is the limiting reactant

B an excess of 0·1 mol of nitric acid remains at the end of the reaction

C 1·64 g of calcium nitrate is produced by the reaction

D 480 cm^3 of carbon dioxide is produced by the reaction.

14. The mean bond enthalpy of a C – F bond is 484 kJ mol^{-1}.

In which of the processes is ΔH approximately equal to +1936 kJ mol^{-1}?

A $CF_4(g) \rightarrow C(s) + 2F_2(g)$

B $CF_4(g) \rightarrow C(g) + 4F(g)$

C $CF_4(g) \rightarrow C(g) + 2F_2(g)$

D $CF_4(g) \rightarrow C(s) + 4F(g)$

15. In a reversible reaction, equilibrium is reached when

A molecules of reactants cease to change into molecules of products

B the concentrations of reactants and products are equal

C the concentrations of reactants and products are constant

D the activation energy of the forward reaction is equal to that of the reverse reaction.

16. Which of the following equations represents the enthalpy of combustion of propane?

A $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(\ell)$

B $C_3H_8(g) + \frac{7}{2}O_2(g) \rightarrow 3CO(g) + 4H_2O(\ell)$

C $C_3H_8(g) + 3O_2(g) \rightarrow 3CO_2(g) + 4H_2(g)$

D $C_3H_8(g) + \frac{3}{2}O_2(g) \rightarrow 3CO(g) + 4H_2(g)$

[Turn over

17. An oxidising agent

A gains electrons and is oxidised

B loses electrons and is oxidised

C gains electrons and is reduced

D loses electrons and is reduced.

18. During a redox process in acid solution, chlorate ions, $ClO_3^-(aq)$, are converted into chlorine, $Cl_2(g)$.

$$ClO_3^-(aq) \rightarrow Cl_2(g)$$

The numbers of $H^+(aq)$ and $H_2O(\ell)$ required to balance the ion-electron equation for the formation of 1 mol of $Cl_2(g)$ are, respectively

A 3 and 6

B 6 and 3

C 6 and 12

D 12 and 6.

19. Which of the following ions could be used to oxidise iodide ions to iodine?

$$2I^-(aq) \rightarrow I_2(s) + 2e^-$$

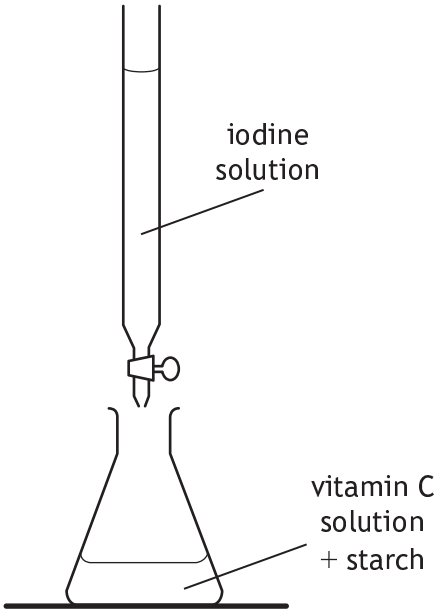
A $SO_4^{2-}(aq)$

B $SO_3^{2-}(aq)$

C $Cr^{3+}(aq)$

D $Cr_2O_7^{2-}(aq)$

20.



A student was carrying out a titration to establish the concentration of vitamin C using iodine solution.

Which of the following would help the student achieve a precise end-point?

A Placing a white tile underneath the conical flask

B Using the bottom of the meniscus when reading the burette

C Repeating titrations

D Carrying out a rough titration first

[END OF SECTION 1. NOW ATTEMPT THE QUESTIONS IN SECTION 2 OF YOUR QUESTION AND ANSWER BOOKLET.]

SECTION 2 — 80 marks

Attempt ALL questions

1. Hydrogen peroxide gradually decomposes into water and oxygen, according to the following equation.

$$2H_2O_2(aq) \rightarrow 2H_2O(\ell) + O_2(g)$$

(a) At room temperature, the reaction is very slow. It can be speeded up by heating the reaction mixture.

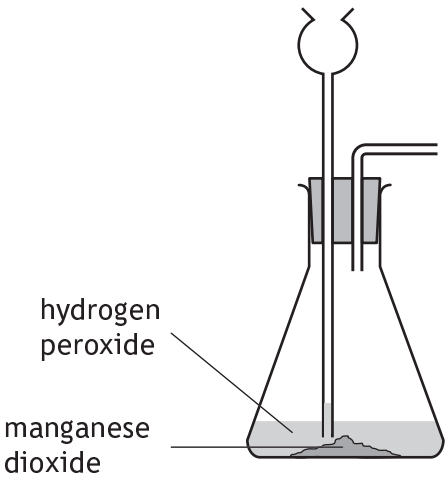
State why increasing the temperature causes an increase in reaction rate. **1**

(b) (i) The reaction can also be speeded up by adding a catalyst, such as manganese dioxide.

To determine the rate of the reaction, the volume of gas produced in a given time can be measured.

Complete the diagram below to show how the gas produced can be collected and measured. **1**

(An additional diagram, if required, can be found on *Page 38*).



1. (b) (continued)

(ii) The concentration of hydrogen peroxide is often described as a volume strength. This relates to the volume of oxygen that can be produced from a hydrogen peroxide solution.

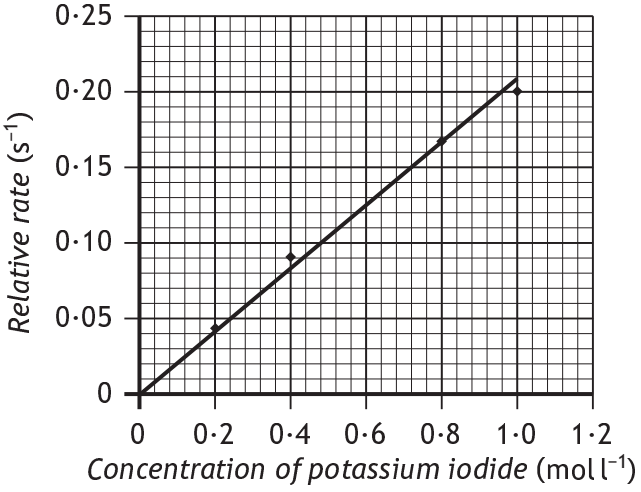
volume of oxygen produced	=	volume strength	×	volume of hydrogen peroxide solution

In an experiment, 74 cm^3 of oxygen was produced from 20 cm^3 of hydrogen peroxide solution.

Calculate the volume strength of the hydrogen peroxide. **1**

(c) Hydrogen peroxide can react with potassium iodide to produce water and iodine.

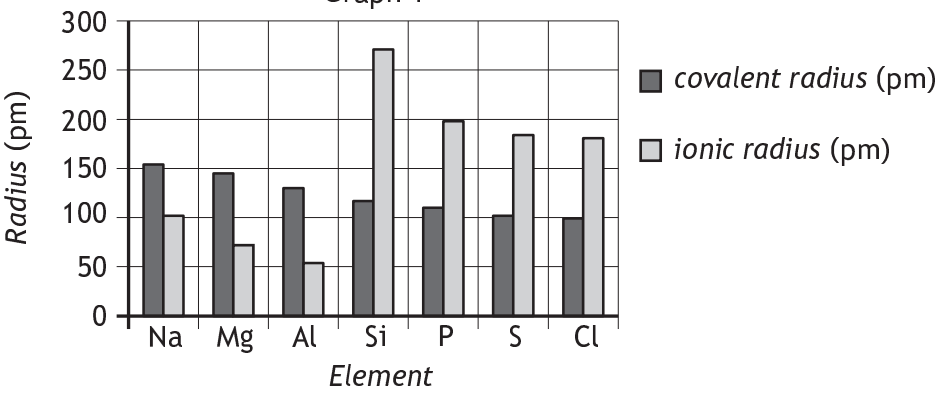
A student carried out an experiment to investigate the effect of changing the concentration of potassium iodide on reaction rate. The results are shown below.



Calculate the time taken, in s, for the reaction when the concentration of potassium iodide used was 0·6 mol l^{-1}. **1**

2. (a) Graph 1 shows the sizes of atoms and ions for elements in the third period of the Periodic Table.

Graph 1



The covalent radius is a measure of the size of an atom.

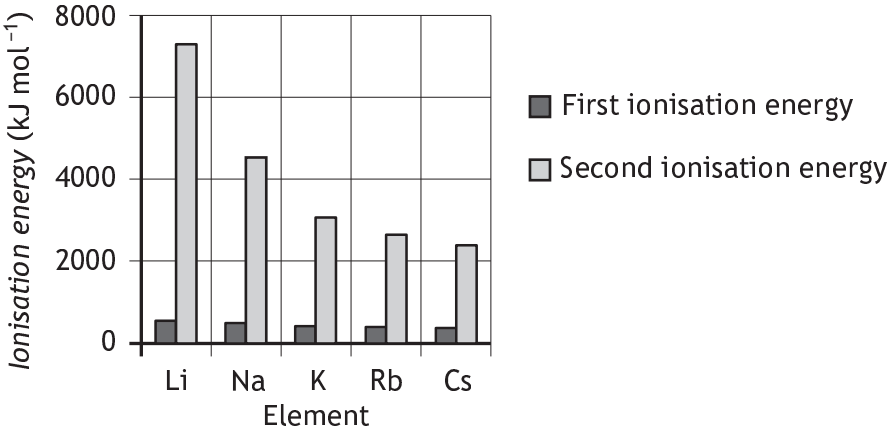
(i) Explain why covalent radius decreases across the period from sodium to chlorine. **1**

(ii) Explain **fully** why the covalent radius of sodium is larger than the ionic radius of sodium. **2**

2. (continued)

(b) Graph 2 shows the first and second ionisation energies of elements in Group 1 of the Periodic Table.

Graph 2



(i) Explain why the first ionisation energy decreases going down Group 1. **1**

(ii) Explain **fully** why the second ionisation energy is much greater than the first ionisation energy for Group 1 elements. **2**

2. (continued)

(c) The lattice enthalpy is the energy needed to completely separate the ions in one mole of an ionic solid.

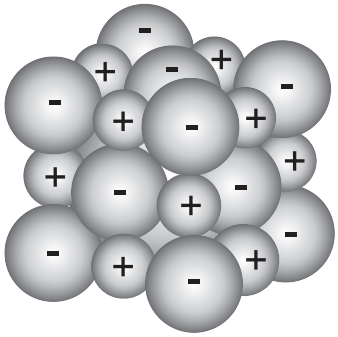


Table 1 shows the size of selected ions.

Table 1

Ion	Li^+	Na^+	K^+	Rb^+	F^-	Cl^-
Ionic radius (pm)	76	102	138	152	133	181

Table 2 shows the lattice enthalpies, in $kJ\,mol^{-1}$, for some Group 1 halides.

Table 2

Ions	F^-	Cl^-
Li^+	1030	834
Na^+	910	769
K^+	808	701
Rb^+		658

(i) Predict the lattice enthalpy, in $kJ\,mol^{-1}$, for rubidium fluoride. **1**

(ii) Write a general statement linking lattice enthalpy to ionic radii. **1**

3. Phosphine (PH_3) is used as an insecticide in the storage of grain.

Phosphine can be produced by the reaction of water with aluminium phosphide

$$AlP(s) + 3H_2O(\ell) \longrightarrow PH_3(g) + Al(OH)_3(aq)$$

(a) State the type of bonding and structure in phosphine. **1**

(b) 2·9 kg of aluminium phosphide were used in a phosphine generator.

Calculate the volume of phosphine gas, in litres, that would have been produced.

(Take the volume of 1 mole of phosphine to be 24 litres). **2**

(c) Carbon dioxide is fed into the phosphine generator to keep the phosphine concentration less than 2·6%. Above this level phosphine can ignite due to the presence of diphosphane, $P_2H_4(g)$, as an impurity.

Draw a structural formula for diphosphane. **1**

4. The viscosity of alcohols depends on a number of factors:

- the strength of intermolecular forces
- the size of the molecule
- temperature

These factors can be investigated using alcohols and apparatus from the lists below.

Alcohols	*Apparatus*
methanol	beakers
ethanol	funnels
propan-1-ol	burettes
ethane-1,2-diol	measuring cylinders
butan-1-ol	plastic syringes
propane-1,3-diol	glass tubing
pentan-1-ol	stoppers
propane-1,2,3-triol	timer
	metre stick
	ball bearing
	clamp stands
	kettle
	thermometer

Using your knowledge of chemistry, identify the alcohols and apparatus that you would select and describe how these could be used to investigate one, or more, of the factors affecting the viscosity of alcohols. **3**

5. When fats and oils are hydrolysed, mixtures of fatty acids are obtained.

(a) Name the other product obtained in this reaction. **1**

(b) The table below shows the percentage composition of the fatty acid mixtures obtained by hydrolysis of coconut oil and olive oil.

Class of fatty acids produced on hydrolysis	*Name of oil*	
	Coconut oil	Olive oil
Saturated	91	14
Monounsaturated	6	72
Polyunsaturated	3	14

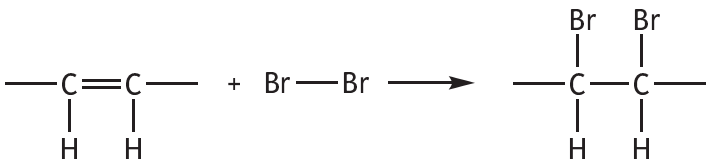
(i) One of the fatty acids produced by the hydrolysis of olive oil is linoleic acid, $C_{17}H_{31}COOH$.

State the class of fatty acid to which linoleic acid belongs. **1**

(ii) Hydrolysed coconut oil contains the fatty acid, caprylic acid, with the formula $CH_3(CH_2)_6COOH$.

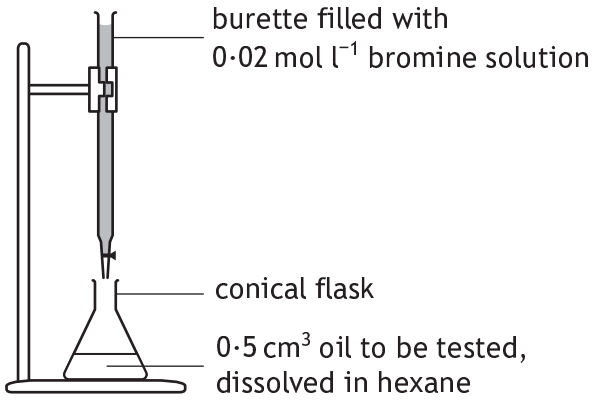
State the systematic name for caprylic acid. **1**

(c) The degree of unsaturation of oil can be tested by adding drops of bromine solution to the oil. Bromine adds across carbon to carbon double bonds in the fatty acid chains.



5. (c) (continued)

The following apparatus can be used to compare the degree of unsaturation of different oils.



(i) Describe how this apparatus could be used to show that olive oil has a greater degree of unsaturation than coconut oil. **2**

(ii) Suggest why hexane is used as the solvent, rather than water. **1**

(iii) Coconut oil has a melting point of 25 °C. Olive oil has a melting point of −6 °C.

Give two reasons why coconut oil has a higher melting point than olive oil. **2**

6. Peptide molecules can be classified according to the number of amino acid units joined by peptide bonds in the molecule.

Type of peptide	*Example of amino acid sequence*
dipeptide	aspartic acid-phenylalanine
tripeptide	isoleucine-proline-proline
tetrapeptide	lysine-proline-proline-arginine
pentapeptide	serine-glycine-tyrosine-alanine-leucine
	alanine-glycine-valine-proline-tyrosine-serine
polypeptide	many amino acids

(a) Complete the table to identify the type of peptide with the following amino acid sequence

alanine-glycine-valine-proline-tyrosine-serine **1**

(b) Partial hydrolysis of another pentapeptide molecule gave a mixture of three smaller peptide molecules with the following amino acid sequences.

leucine-glycine-valine

isoleucine-leucine

glycine-valine-serine

Write the amino acid sequence for the original pentapeptide molecule. **1**

..... – ..... – ..... – ..... – .....

(c) Some amino acids needed to form polypeptides cannot be produced in the human body.

State the term used to describe amino acids that the body cannot make. **1**

6. (continued)

(d) Paper chromatography is often used to analyse the mixtures of amino acids produced when peptides are broken down.

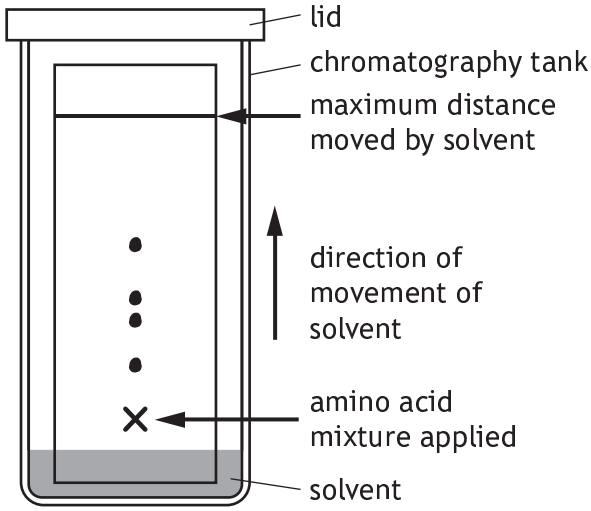
On a chromatogram, the retention factor R_f, for a substance can be a useful method of identifying the substance.

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

The structure of the pentapeptide methionine enkephalin was investigated.

A sample of the pentapeptide was completely hydrolysed into its constituent amino acids and this amino acid mixture was applied to a piece of chromatography paper and placed in a solvent.

The chromatogram obtained is shown below.



(i) Suggest why only four spots were obtained on the chromatogram of the hydrolysed pentapeptide. **1**

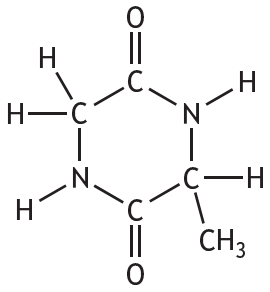
(ii) It is known that this amino acid mixture contains the amino acid methionine. The R_f value for methionine in this solvent is 0·40.

Draw a circle around the spot on the chromatogram that corresponds to methionine. **1**

6. (continued)

(e) Over the last decade several families of extremely stable peptide molecules have been discovered, where the peptide chain forms a ring.

(i) A simple cyclic dipeptide is shown.



Draw a structural formula for one of the amino acids that would be formed on complete hydrolysis of the above cyclic dipeptide. **1**

(ii) Alpha-amanitin is a highly toxic cyclic peptide found in death cap mushrooms. The lethal dose for humans is 100 mg per kg of body mass.

1·0 g of death cap mushrooms contains 250 mg of alpha-amanitin.

Calculate the minimum mass of death cap mushrooms that would contain the lethal dose for a 75 kg adult. **2**

7. Modern shellac nail varnishes are more durable and so last longer than traditional nail polish.

The shellac nail varnish is applied in thin layers to the nails and then the fingers are placed under a UV lamp.

(a) The Skin Care Foundation has recommended that a sun-block is applied to the fingers and hand before using the lamp.

Suggest why the Skin Care Foundation makes this recommendation. **1**

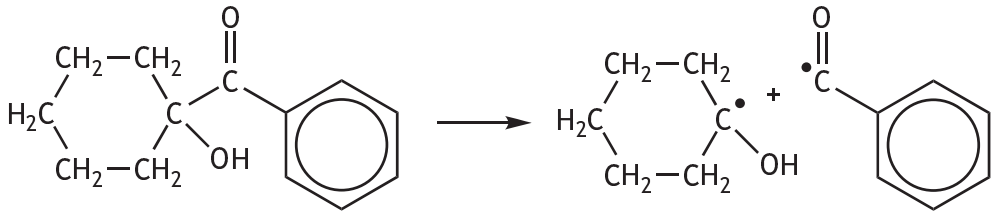
(b) A *free radical* chain reaction takes place and the varnish hardens.

(i) State what is meant by the term *free radical*. **1**

7. (b) (continued)

(ii) The shellac nail varnish contains a mixture of ingredients that take part in the free radical chain reaction.

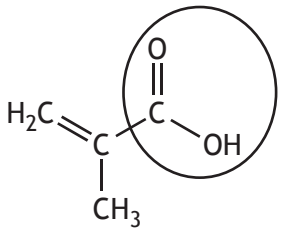
One of the steps in the free radical chain reaction is:



State the term used to describe this type of step in a free radical chain reaction. **1**

(iii) During the free radical chain reaction small molecules join to form large chain molecules.

One example of a small molecule used is



Name the functional group circled above. **1**

(iv) Alcohol wipes are used to finish the varnishing treatment. Alcohol wipes contain the alcohol propan-2-ol.

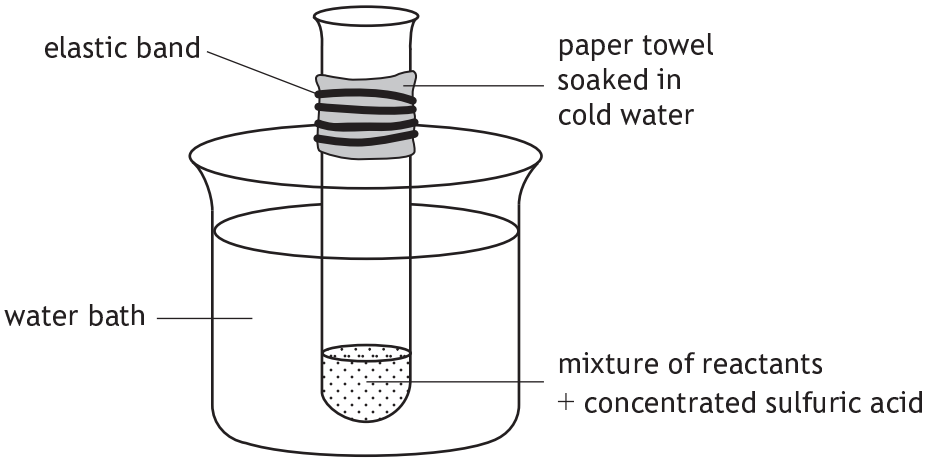
State why propan-2-ol can be described as a secondary alcohol. **1**

7. (continued)

(c) Traditional nail varnishes use ethyl ethanoate and butyl ethanoate as solvents.

(i) Draw a structural formula for butyl ethanoate. **1**

(ii) Ethyl ethanoate can be made in the laboratory using the following apparatus.



Suggest why a wet paper towel is wrapped around the test tube. **1**

7. (c) (continued)

(iii) A student used 2·5 g of ethanol and a slight excess of ethanoic acid to produce 2·9 g of ethyl ethanoate.

ethanol	+	ethanoic acid	⇌	ethyl ethanoate	+	water
mass of one mole = 46·0 g				mass of one mole = 88·0 g		

(One mole of ethanol reacts with one mole of ethanoic acid to produce one mole of ethyl ethanoate.)

Calculate the percentage yield of ethyl ethanoate. **2**

(iv) Name the type of reaction that takes place during the formation of ethyl ethanoate. **1**

[Turn over

8. Methanol (CH_3OH) is an important chemical in industry.

(a) Methanol is produced from methane in a two-step process.

In step 1, methane is reacted with steam as shown.

Step 1: $CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g) \quad \Delta H = +210\,kJ\,mol^{-1}$

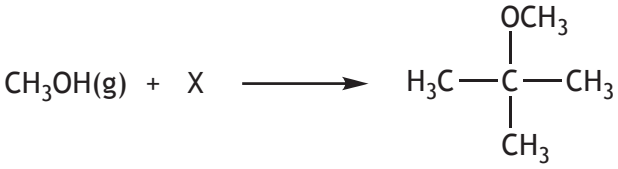
In step 2, hydrogen reacts with carbon monoxide.

Step 2: $2H_2(g) + CO(g) \rightleftharpoons CH_3OH(g) \quad \Delta H = -91\,kJ\,mol^{-1}$

Complete the table to show the most favourable conditions to maximise the yield for each step. **2**

	Temperature (High/Low)	*Pressure* (High/Low)
Step 1		
Step 2		

(b) Methanol reacts with compound X, in an addition reaction, to form methyl tertiary-butyl ether, an additive for petrol.



methyl tertiary-butyl ether

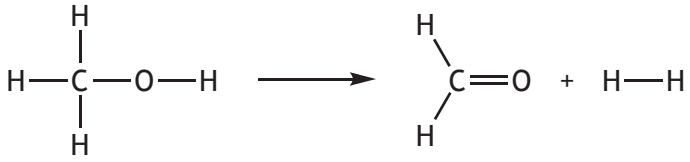
(i) Suggest a structure for compound X. **1**

(ii) The atom economy of this reaction is 100%.

Explain what this means. **1**

8. (continued)

(c) Methanol can be converted to methanal as shown.



Using bond enthalpy and mean bond enthalpy values from the data booklet, calculate the enthalpy change, in $kJ\,mol^{-1}$, for the reaction. **2**

[Turn over

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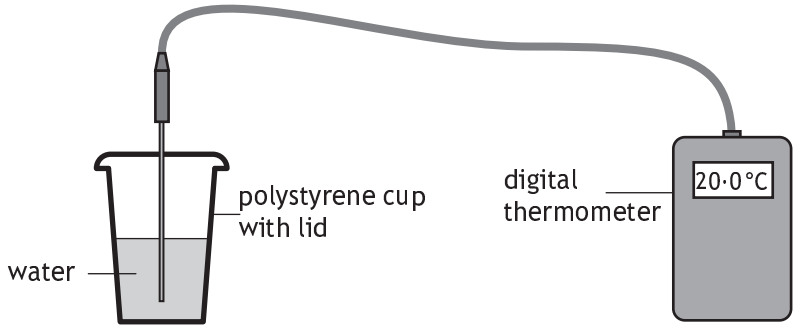
9. A group of students carried out an investigation into the energy changes that take place when metal hydroxides dissolve in water.

The following apparatus was used as a simple calorimeter to determine the change in temperature.



The experiment was carried out as follows.

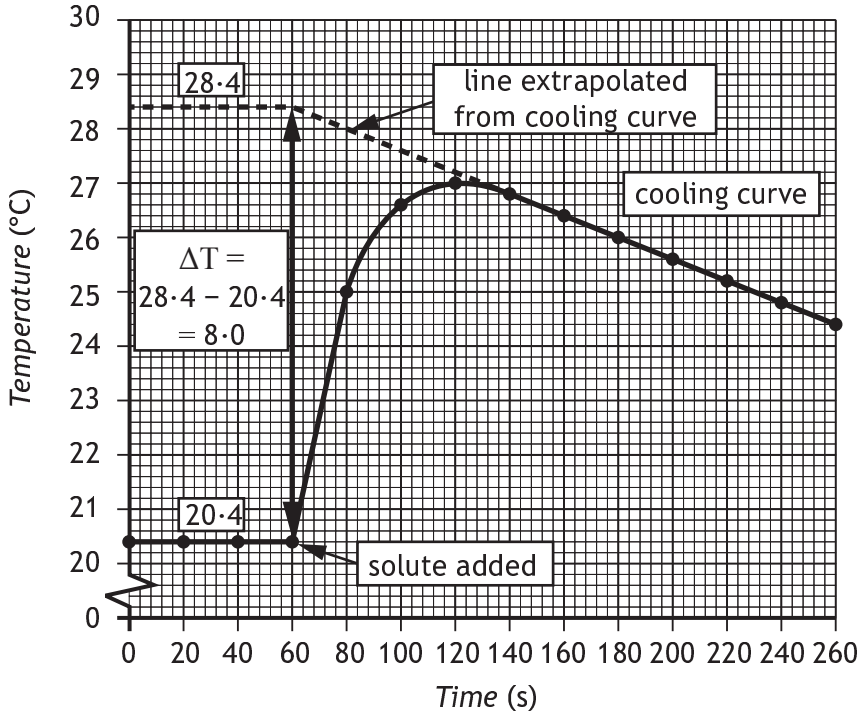
Step 1: 100 cm^3 of deionised water was added to the cup.

Step 2: The stop-clock was started, the water stirred continuously and the temperature recorded every 20 seconds.

Step 3: After 60 seconds, an accurately weighed mass of the metal hydroxide was added to the water and the temperature recorded every 20 seconds.

Graph 1 shows the group's results for lithium hydroxide.

Graph 1 – Lithium hydroxide



The heat energy transferred to the water can be calculated as shown.

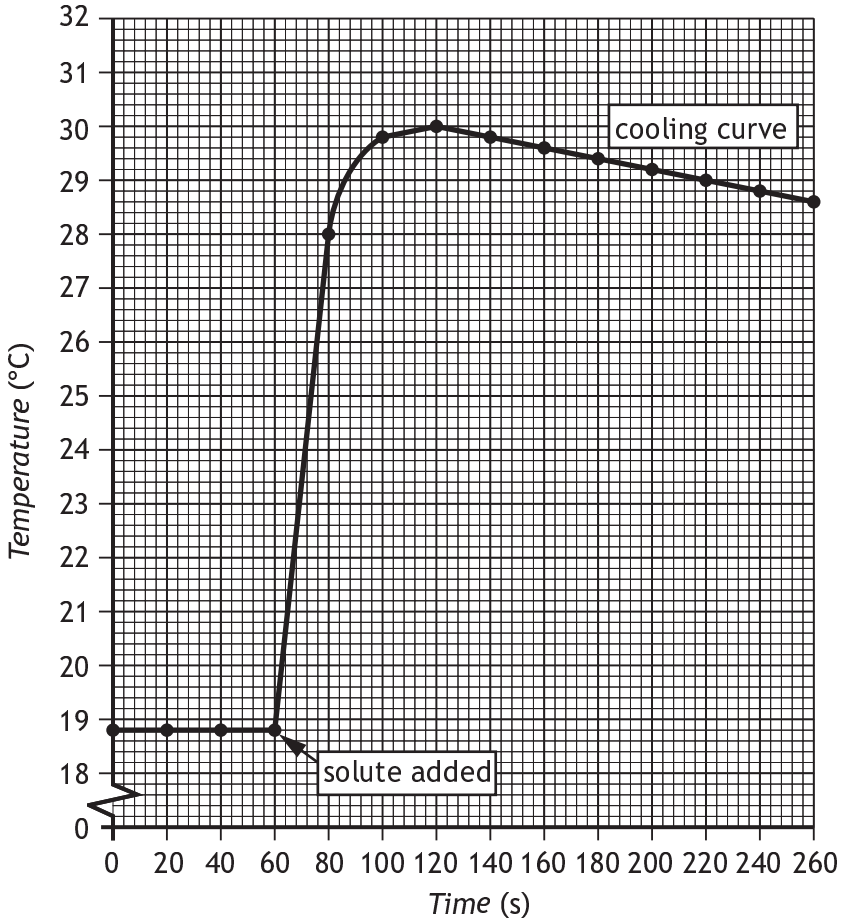
$$E_h = cm\Delta T$$
$$= 4{\cdot}18 \times 0{\cdot}10 \times 8{\cdot}0$$
$$= 3{\cdot}3 \text{ kJ}$$

MARKS | DO NOT WRITE IN THIS MARGIN

(a) The experiment was repeated using sodium hydroxide.

Graph 2 shows the results of this experiment.

Graph 2 – Sodium Hydroxide



(i) Using Graph 2 calculate the heat energy transferred to the water, in kJ, when the sodium hydroxide dissolved. **2**

(ii) Suggest why the experiment was carried out in a polystyrene cup with a lid. **1**

9. (a) (continued)

(iii) **In another experiment** the students found that 5·61 g of potassium hydroxide (KOH) released 5·25 kJ of heat energy on dissolving.

Use this information to calculate the energy released, in kJ mol^{-1}, when one mole of potassium hydroxide dissolves in water. **1**

(b) Calcium hydroxide solution can be formed by adding calcium metal to excess water.

Solid calcium hydroxide would form if the exact molar ratio of calcium to water is used. The equation for the reaction is

$$Ca(s) + 2H_2O(\ell) \rightarrow Ca(OH)_2(s) + H_2(g)$$

Calculate the enthalpy change, in kJ mol^{-1}, for the reaction above by using the data shown below.

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(\ell)$ $\quad \Delta H = -286$ kJ mol^{-1}

$Ca(s) + O_2(g) + H_2(g) \rightarrow Ca(OH)_2(s)$ $\quad \Delta H = -986$ kJ mol^{-1} **2**

10. The chemical industry creates an immense variety of products which impact on virtually every aspect of our lives. Industrial scientists, including chemical engineers, production chemists and environmental chemists, carry out different roles to maximise the efficiency of industrial processes.

Using your knowledge of chemistry, comment on what industrial scientists can do to maximise profit from industrial processes and minimise impact on the environment. **3**

11. Soft drinks contain a variety of sugars. A student investigated the sugar content of a soft drink.

(a) The density of the soft drink can be used to estimate its total sugar concentration. Solutions of different sugars, with the same concentration, have similar densities.

The first experiment was to determine the total sugar concentration of the soft drink by comparing the density of the drink with the density of standard sucrose solutions.

(i) This firstly involved producing standard sucrose solutions of different concentrations.

The standard sucrose solutions were made up in volumetric flasks.

Draw a diagram of a volumetric flask. **1**

(ii) The density of each standard sucrose solution was then determined. In order to determine the density of each solution, the student accurately measured the mass of 10·0 cm^3 of each sucrose solution.

Describe **fully** a method that the student could have used to accurately measure the mass of 10·0 cm^3 of each sucrose solution. **2**

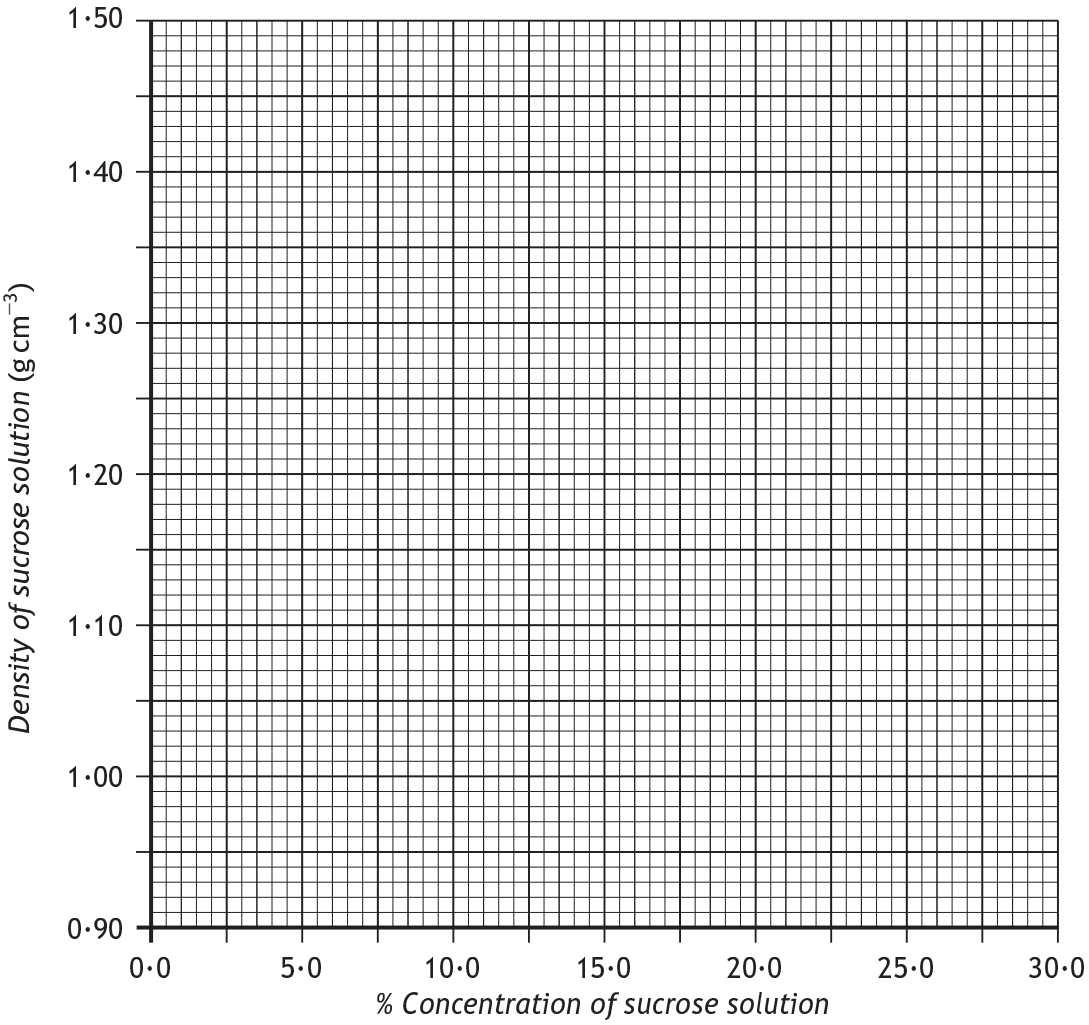
11. (a) (continued)

(iii) The results that the student obtained for the density of the standard solutions of sucrose are shown in the table.

% Concentration of sucrose solution	*Density of sucrose solution* ($g\ cm^{-3}$)
0·0	1·00
5·0	1·10
10·0	1·19
15·0	1·31
20·0	1·41

Draw a line graph using the student's results. **2**

(Additional graph paper, if required, can be found on *Page 38*.)



11. (a) (continued)

(iv) The student used the line graph to obtain the relationship between the concentration of sugars in solution and the density of the solution.

This equation shows the relationship.

density of sugar in g cm^{-3} = (0·0204 × % concentration of sugars in solution) + 1·00

The student then determined the density of a soft drink. In order to ensure that the drink was flat, all the gas had been allowed to escape.

(A) Suggest a reason why the soft drink needed to be flat before its density was determined. **1**

(B) The soft drink tested had a density of 1·07 g cm^{-3}.

Using the equation, calculate the % concentration of sugars present in the soft drink. **1**

(v) A different soft drink is found to contain 10·6 grams of sugar in 100 cm^3.

Calculate the total mass of sugar present, in grams, in a 330 cm^3 can of this soft drink. **1**

(b) The second experiment in the investigation was to determine the concentration of specific types of sugar called reducing sugars. This was carried out by titration with Fehling's solution.

(i) Reducing sugars contain an aldehyde functional group.

Draw this functional group. **1**

11. (b) (continued)

(ii) The overall reaction that occurs with Fehling's solution and a reducing sugar is shown.

$$C_6H_{12}O_6 + 2Cu^{2+} + H_2O \rightarrow C_6H_{12}O_7 + 2Cu^{+} + 2H^{+}$$

reducing sugar — Fehling's solution

Write the ion-electron equation for the oxidation reaction. **1**

(iii) State the colour change that would be observed when reducing sugars are reacted with Fehling's solution. **1**

(iv) For the titrations, the student diluted the soft drink to improve the accuracy of results.

$25{\cdot}0\,cm^3$ samples of the diluted soft drink were titrated with Fehling's solution which had a Cu^{2+} concentration of $0{\cdot}0250\,mol\,l^{-1}$.

The average volume of Fehling's solution used in the titrations was $19{\cdot}8\,cm^3$.

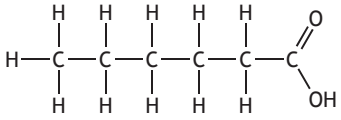
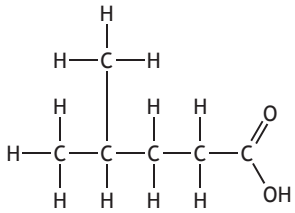
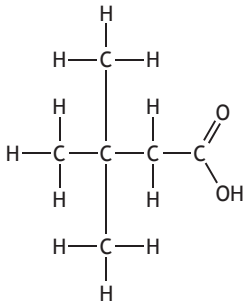
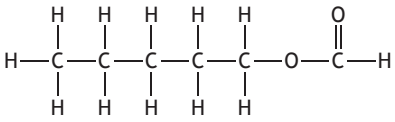
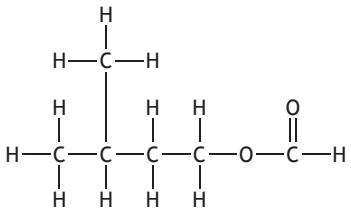
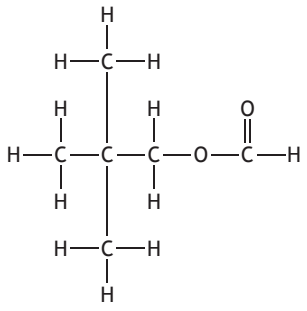
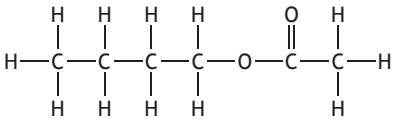
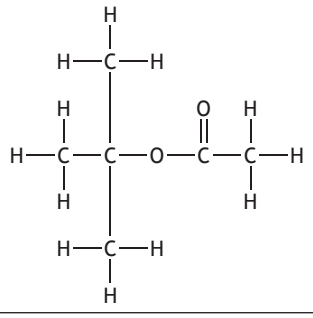
$$C_6H_{12}O_6 + 2Cu^{2+} + H_2O \rightarrow C_6H_{12}O_7 + 2Cu^{+} + 2H^{+}$$

reducing sugar — Fehling's solution

Calculate the concentration, in $mol\,l^{-1}$, of reducing sugars present in the diluted sample of the soft drink. **3**

12. (a) The table shows the boiling points and structures of some isomers with molecular formula $C_6H_{12}O_2$.

DO NOT WRITE IN THIS MARGIN

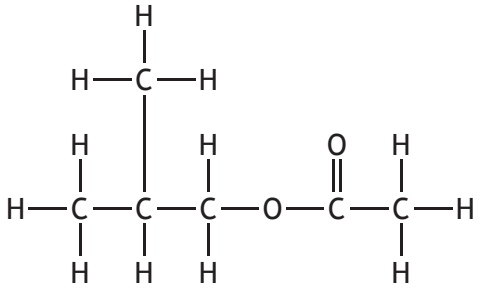
Isomer	*Structure*	*Boiling point* (°C)
1		205
2		201
3		187
4		132
5		125
6		119
7		126
8		98

12. (a) (continued)

(i) Name the intermolecular force which accounts for the higher boiling points of isomers 1, 2 and 3. **1**

(ii) Using the information in the table, describe **two** ways in which differences in structure affect the boiling points of isomeric esters 4–8. **2**

(iii) Predict the boiling point, in °C, for the isomer shown below. **1**



[Turn over

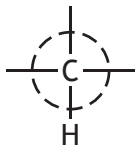
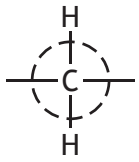
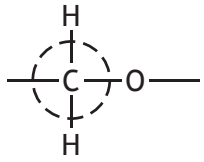
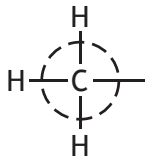
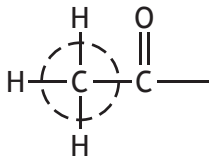
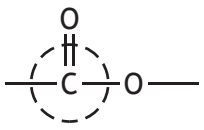
12. (continued)

(b) Carbon-13 NMR spectroscopy is a technique that can be used in chemistry to determine the structure of organic molecules such as esters.

In a carbon-13 NMR spectrum, a carbon atom in a molecule is identified by its **chemical shift**. This value depends on the other atoms bonded to the carbon atom, which is known as the "chemical environment" of the carbon-13 atom.

Carbon-13 chemical shift values are shown in the table below.

The carbon-13 atom in each chemical environment has been circled.

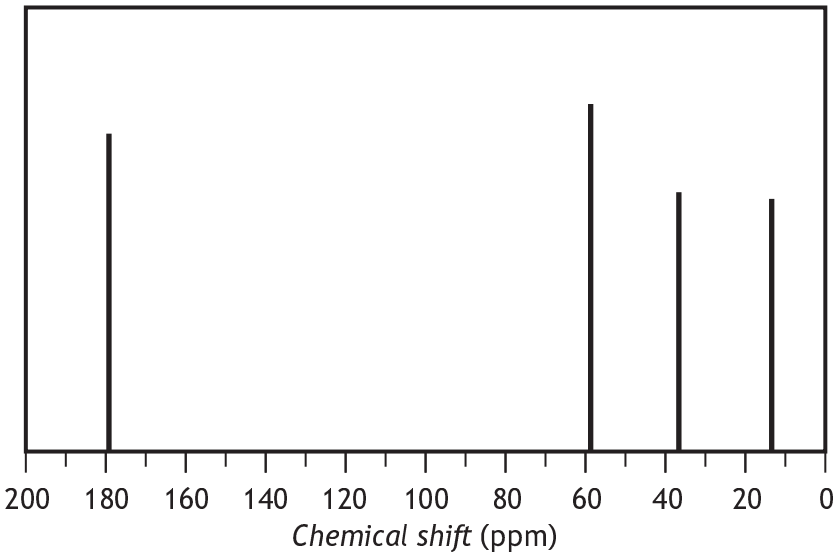
Chemical environment	*Chemical shift* (ppm)
	25–35
	16–25
	50–90
	10–15
	20–50
	170–185

The **number** of peaks in a carbon-13 NMR spectrum corresponds to the number of carbon atoms in different chemical environments within the molecule.

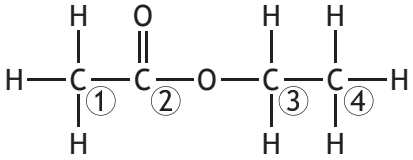
The **position** of a peak (the chemical shift) indicates the type of carbon atom.

12. (b) (continued)

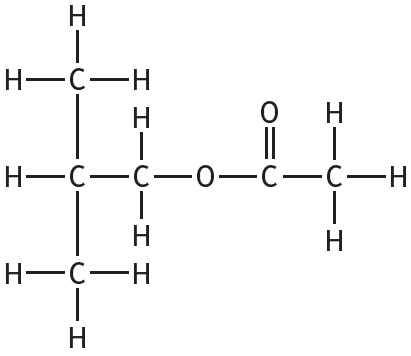
The spectrum for ethyl ethanoate is shown below.



(i) Label each peak in the ethyl ethanoate spectrum with a number to match the carbon atom in ethyl ethanoate, shown below. **1**



(ii) Determine the number of peaks that would be seen in the carbon-13 NMR spectrum for the ester shown below. **1**



Number of peaks in carbon-13 NMR spectrum

= _____

[END OF QUESTION PAPER]

2017

SECTION 1 — 20 marks

Attempt ALL questions

1. Which of the following bonds is the **least** polar?

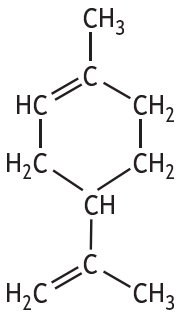
A C — I

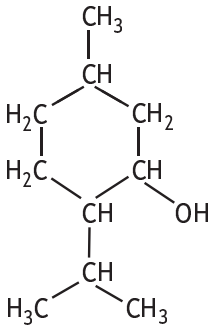
B C — F

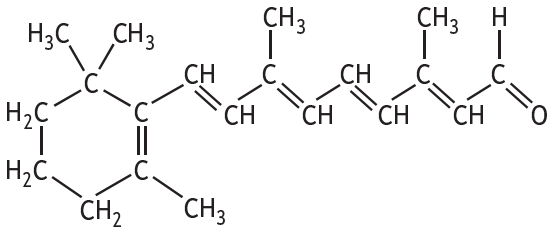
C C — Cl

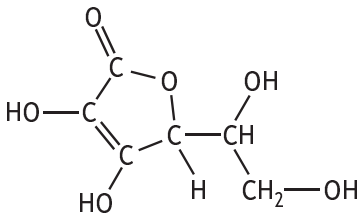
D C — Br

2. Which of the following compounds would be the **most water** soluble?

A 

B 

C 

D 

3. Which of the following atoms has the greatest attraction for bonding electrons?

A Sulfur

B Silicon

C Nitrogen

D Hydrogen

4. Which type of structure is found in phosphorus?

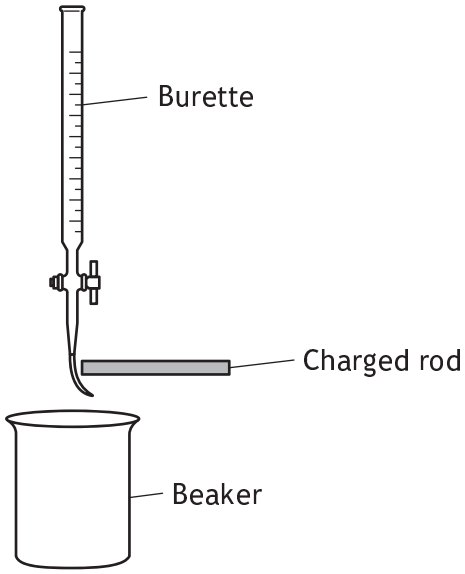
A Covalent network

B Covalent molecular

C Monatomic

D Metallic lattice

5. The polarity of molecules can be investigated using a charged rod. The charged rod will attract a stream of polar liquid flowing from a burette.



Which of the following liquids would **not** be attracted?

A Water

B Propanone

C Propanol

D Hexane

[Turn over

6. $x P_2H_4 + y O_2 \rightarrow P_4O_{10} + z H_2O$

The equation is balanced when

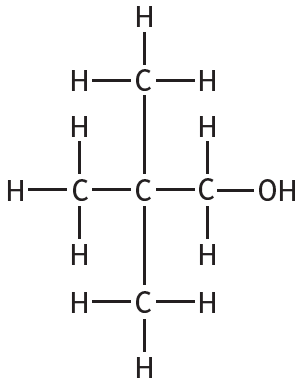
A $x = 1, y = 5, z = 4$

B $x = 4, y = 6, z = 2$

C $x = 2, y = 7, z = 4$

D $x = 2, y = 5, z = 2$

7. What is the systematic name for the compound below?



A 2,2,2-trimethylethanol

B 2,2-dimethylpropan-1-ol

C 2,2-dimethylpropan-3-ol

D 2,2-dimethylpentan-1-ol

8. Which of the following fatty acids is the most unsaturated?

A $C_{15}H_{29}COOH$

B $C_{15}H_{31}COOH$

C $C_{17}H_{31}COOH$

D $C_{17}H_{35}COOH$

9. Which of the following is **not** a step in a free radical chain reaction?

A Activation
B Initiation
C Propagation
D Termination

10. Which of the following is an isomer of ethyl propanoate ($CH_3CH_2COOCH_2CH_3$)?

A Methyl propanoate
B Pentan-2-one
C Pentanoic acid
D Pentane-1,2-diol

11. Essential oils are

A non-water soluble, non-volatile compounds
B non-water soluble, volatile compounds
C water soluble, non-volatile compounds
D water soluble, volatile compounds.

12. The enthalpy of combustion of a hydrocarbon is the enthalpy change when

A one mole of a hydrocarbon burns to give one mole of water
B one mole of a hydrocarbon burns to give one mole of carbon dioxide
C one mole of a hydrocarbon burns completely in oxygen
D one mole of a hydrocarbon burns in one mole of oxygen.

13. Which of the following is the strongest reducing agent?

A Fluorine
B Lithium
C Calcium
D Iodine

[Turn over

14.

$TiCl_4$	+	2Mg	→	$2MgCl_2$	+	Ti
mass of one mole = 189·9 g		mass of one mole = 24·3 g		mass of one mole = 95·3 g		mass of one mole = 47·9 g

The atom economy for the production of titanium in the above equation is equal to

A $\dfrac{47{\cdot}9}{189{\cdot}9+24{\cdot}3}\times 100$

B $\dfrac{47{\cdot}9}{189{\cdot}9+(2\times 24{\cdot}3)}\times 100$

C $\dfrac{95{\cdot}3+47{\cdot}9}{189{\cdot}9+24{\cdot}3}\times 100$

D $\dfrac{(2\times 47{\cdot}9)}{189{\cdot}9+24{\cdot}3}\times 100$

15. The vitamin C content of a carton of orange juice was determined by four students. Each student carried out the experiment three times.

	Experiment 1 (mg/100 cm^3)	*Experiment 2* (mg/100 cm^3)	*Experiment 3* (mg/100 cm^3)
Student A	30·0	29·0	28·0
Student B	26·4	26·6	26·8
Student C	26·9	27·0	26·9
Student D	26·9	26·5	26·9

The most reproducible results were obtained by

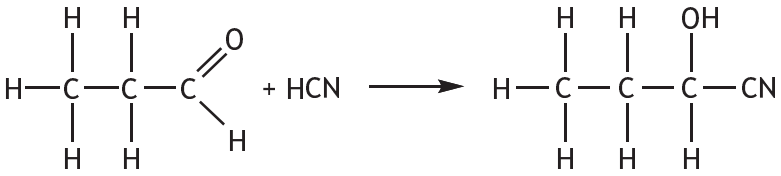
A Student A

B Student B

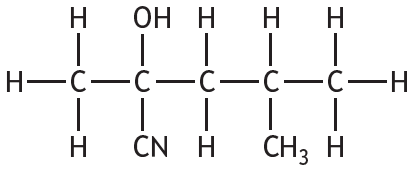
C Student C

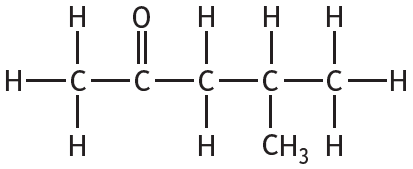
D Student D.

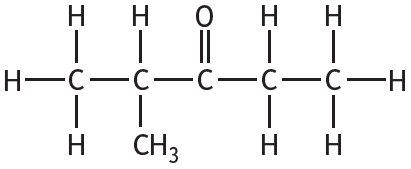
16. Cyanohydrin compounds can be made from carbonyl compounds by reacting the carbonyl compound with hydrogen cyanide (HCN).

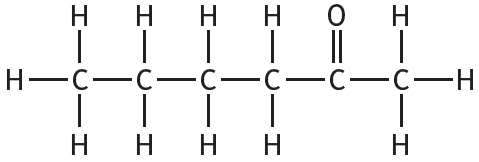


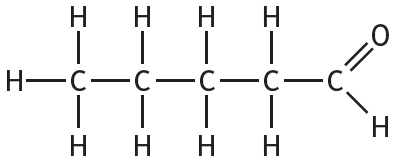
Which carbonyl compound would react with hydrogen cyanide (HCN) to form the following compound?



A 

B 

C 

D 

[Turn over

17. Chemical reactions are in a state of dynamic equilibrium only when

A the reaction involves no enthalpy change

B the concentrations of reactants and products are equal

C the activation energies of the forward and backward reactions are equal

D the rate of the forward reaction equals that of the backward reaction.

18. Bromine and hydrogen react together to form hydrogen bromide.

$$H_2(g) + Br_2(g) \rightarrow 2HBr(g)$$

Bonds broken	Bonds made
H—H	2 × H—Br
Br—Br	

Bond	Bond enthalpy (kJ mol^{-1})
H—H	436
Br—Br	194
H—Br	366

The enthalpy change for this reaction, in kJ mol^{-1}, is

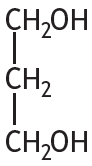
A −102

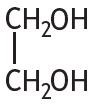
B +102

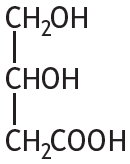
C −264

D +264.

19. Which of the following is a structural formula for glycerol?

A


B


C


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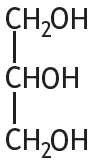


20. Which line in the table best describes the effect of adding a catalyst to the following reaction?

$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -ve$

	Position of equilibrium	*Rate of forward reaction*
A	unchanged	unchanged
B	unchanged	increased
C	moves to right	unchanged
D	moves to right	increased

[END OF SECTION 1. NOW ATTEMPT THE QUESTIONS IN SECTION 2 OF YOUR QUESTION AND ANSWER BOOKLET.]

SECTION 2 — 80 marks

Attempt ALL questions

1. The elements sodium to argon make up the third period of the Periodic Table.

Na	Mg	Al	Si	P	S	Cl	Ar

(a) Name the element from the third period that exists as a covalent network. **1**

(b) Ionisation energy changes across the period.

(i) Explain why the first ionisation energy increases across the period. **1**

(ii) Write an equation, including state symbols, for the **second** ionisation energy of magnesium. **1**

(iii) The table shows the values for the first four ionisation energies of aluminium.

Ionisation energies (kJ mol^{-1})			
First	Second	Third	Fourth
578	1817	2745	11 577

Explain why there is a large difference between the third and fourth ionisation energies. **1**

1. (continued)

(c) The boiling point of chlorine is much higher than that of argon.

Explain **fully**, in terms of structure and the type of van der Waals forces present, why the boiling point of chlorine is higher than that of argon. **3**

2. Reactions involving iodine are commonly used to investigate rates of reaction.

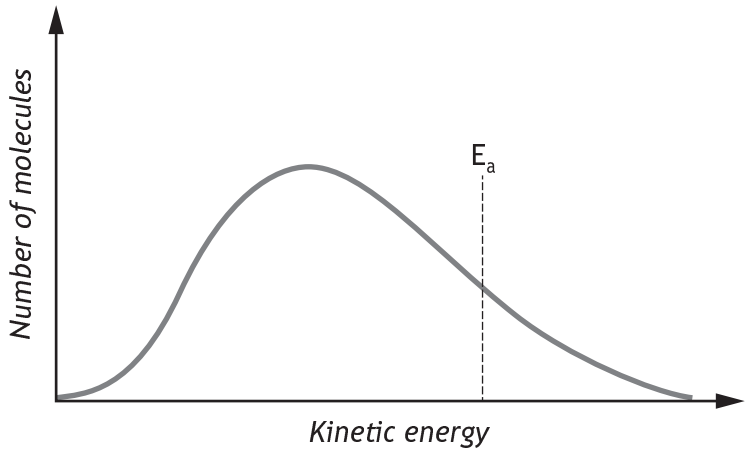
(a) One reaction involves hydrogen and iodine reacting together to form hydrogen iodide.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

(i) This reaction is thought to occur by initially breaking bonds in one of the reactants.

Explain, using bond enthalpies, which bond is more likely to break first during this reaction. **1**

(ii) The graph shows the distribution of kinetic energies of reactant molecules in the gas mixture at 300 °C.



Add a second curve to the graph to show the distribution of kinetic energies at 400 °C. **1**

(An additional graph, if required, can be found on *Page 35*)

2. (a) (continued)

(iii) The reaction to produce hydrogen iodide is exothermic.

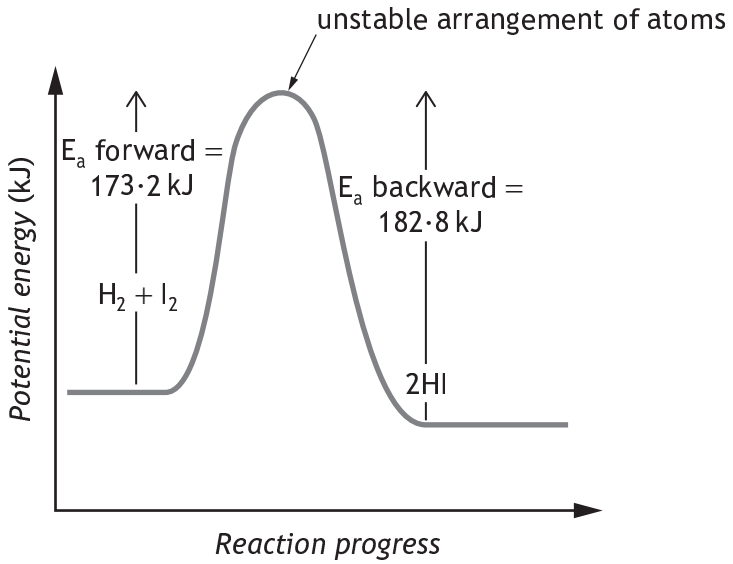
$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

(A) State the effect of increasing temperature on the position of equilibrium. **1**

(B) State why changing the pressure has no effect on this equilibrium reaction. **1**

2. (a) (continued)

(iv) The potential energy diagram for the reaction between hydrogen and iodine is shown.



(A) State the term for the unstable arrangement of atoms. **1**

(B) Calculate the enthalpy change, in kJ, for the forward reaction. **1**

(C) Platinum can be used as a catalyst for this reaction.

State the effect that platinum would have on the activation energy for the reaction. **1**

2. (continued)

(b) The reaction between iodide ions, $I^-(aq)$, and persulfate ions, $S_2O_8^{2-}(aq)$, is used to investigate the effect of changing concentration on rate of reaction. The relative rate of the reaction is determined by mixing the reactants in a beaker and recording the time taken for the mixture to change colour.

The results of the investigation are shown in the table.

Experiment	*Concentration of $I^-(aq)$* (mol l^{-1})	*Concentration of $S_2O_8^{2-}(aq)$* (mol l^{-1})	*Time* (s)	*Relative rate* (s^{-1})
1	0·04	0·05	241	0·00415
2	0·06	0·05	180	0·00556
3	0·08	0·05		0·00819
4	0·1	0·05	103	0·00971

(i) The instructions state that a dry beaker must be used for each experiment.

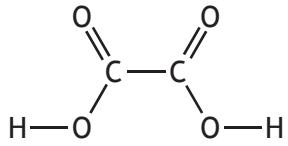
Suggest a reason why the beaker should be dry. **1**

(ii) Calculate the time, in seconds, for the reaction in experiment 3. **1**

(iii) Explain why decreasing the concentration of iodide ions lowers the reaction rate. **1**

3. The leaves of the rhubarb plant are considered poisonous because they contain high levels of oxalic acid.

Oxalic acid is a white, water-soluble solid. It is a dicarboxylic acid that has the structural formula shown.



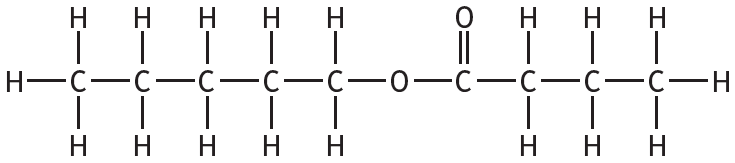
Oxalic acid reacts with bases to form salts.

It can also be oxidised by strong oxidising agents to form carbon dioxide gas. The oxidation equation for oxalic acid is shown.

$$H_2C_2O_4 \rightarrow 2CO_2 + 2e^- + 2H^+$$

Using your knowledge of chemistry, comment on how the mass of oxalic acid in a rhubarb leaf could be determined. **3**

4. Pentyl butanoate is responsible for some of the flavour in apricots and strawberries.



(a) Hydrolysis of pentyl butanoate using sodium hydroxide produces an alcohol and the salt of the carboxylic acid.

(i) Name the alcohol that would be formed when pentyl butanoate is hydrolysed. **1**

(ii) Draw a structural formula for the sodium salt of the carboxylic acid that would be formed. **1**

(b) Fats and oils belong to the same class of compounds as pentyl butanoate.

(i) Name this class of compounds. **1**

(ii) When a fat is hydrolysed using sodium hydroxide, sodium salts of fatty acids are produced.

State a use for sodium salts of fatty acids. **1**

4. (b) (continued)

(iii) Hydrolysis of fats using hydrochloric acid produces fatty acids. Stearic acid is a fatty acid that can be made from hydrolysis of beef fat. It is a fuel sometimes found in fireworks.

During combustion, stearic acid ($C_{17}H_{35}COOH$) produces 623 kJ of energy **per mole of CO_2 produced.**

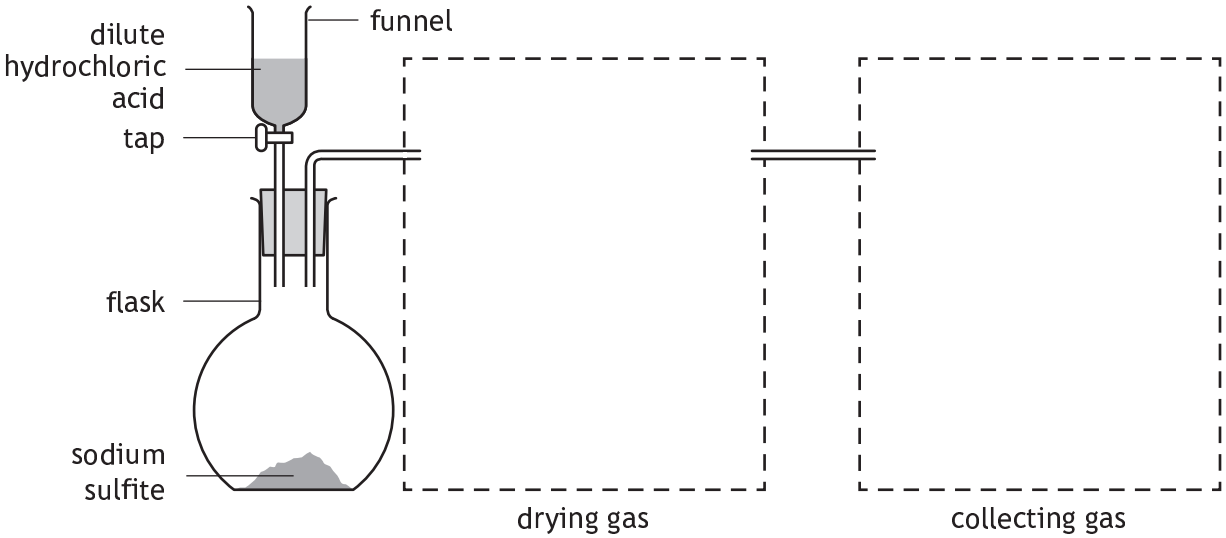
$$C_{17}H_{35}COOH + 26O_2 \rightarrow 18CO_2 + 18H_2O$$

mass of one mole = 284 g

Calculate the energy released, in kJ, by combustion of 10 grams of stearic acid. **2**

5. Sulfur dioxide is a colourless, toxic gas that is soluble in water and more dense than air.

(a) One laboratory method for preparation of sulfur dioxide gas involves adding dilute hydrochloric acid to solid sodium sulfite. The sulfur dioxide gas produced is dried by bubbling the gas through concentrated sulfuric acid. The sulfur dioxide gas can then be collected.



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(i) Complete the diagram by drawing:

in the first box, apparatus suitable for drying the sulfur dioxide gas;

in the second box, apparatus suitable for collecting the gas. **2**

(An additional diagram, if required, can be found on *Page 35*)

5. (a) (continued)

(ii) 0·40 g of sodium sulfite, Na_2SO_3, is reacted with 50 cm^3 of dilute hydrochloric acid, concentration 1·0 mol l^{-1}.

$$Na_2SO_3(s) + 2HCl(aq) \rightarrow H_2O(\ell) + 2NaCl(aq) + SO_2(g)$$

mass of one mole = 126·1 g

Show, by calculation, that sodium sulfite is the limiting reactant. **2**

(b) Another reaction that produces sulfur dioxide gas involves combustion of carbon disulfide in the reaction shown.

$$CS_2(\ell) + 3O_2(g) \rightarrow CO_2(g) + 2SO_2(g)$$

Calculate the enthalpy change, in kJ mol^{-1}, for this reaction using the following information. **2**

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\quad \Delta H = -393{\cdot}5$ kJ mol^{-1}

$S(s) + O_2(g) \rightarrow SO_2(g)$ $\quad \Delta H = -296{\cdot}8$ kJ mol^{-1}

$C(s) + 2S(s) \rightarrow CS_2(\ell)$ $\quad \Delta H = +87{\cdot}9$ kJ mol^{-1}

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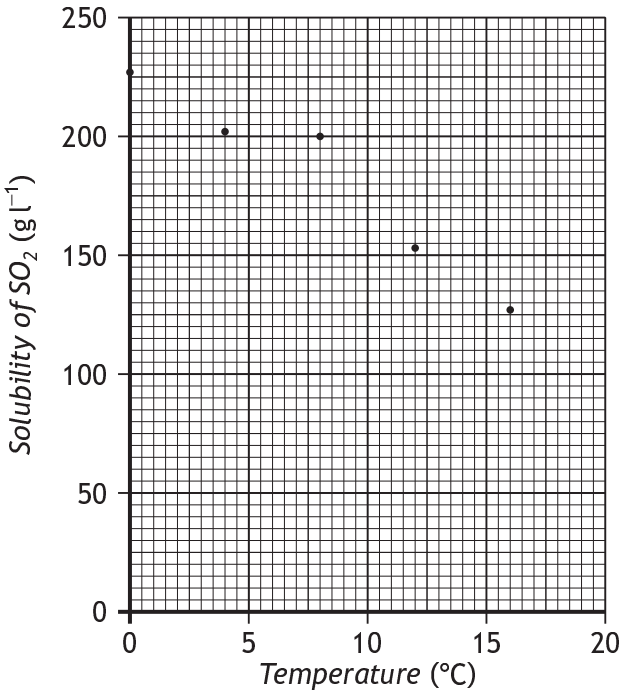
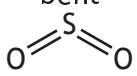
(c) The graph shows results for an experiment to determine the solubility of sulfur dioxide in water.



(i) Determine the solubility of sulfur dioxide, in g l^{-1}, in water at 10 °C. **1**

(ii) Information about sulfur dioxide and carbon dioxide is shown in the table.

	Shape of molecule	*Electronegativity difference between elements*	*Solubility in water at 25 °C* (g l^{-1})
carbon dioxide	linear O=C=O	1·0	1·45
sulfur dioxide	bent 	1·0	94

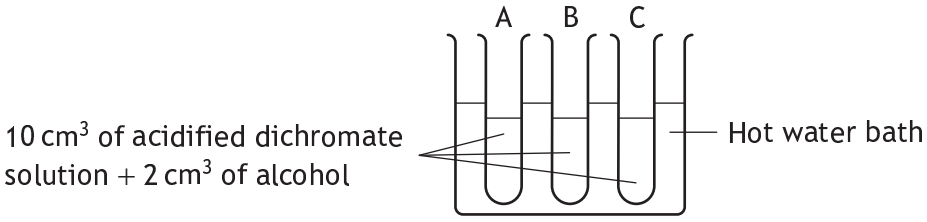
Explain **fully** why carbon dioxide is much less soluble in water than sulfur dioxide is in water. **2**

6. A student was carrying out an investigation into alcohols, aldehydes and ketones.

(a) The student was given three alcohols labelled as **A**, **B** and **C**. These alcohols were all isomers with the formula C_4H_9OH.

(i) Draw a structural formula for the secondary alcohol with the formula C_4H_9OH. **1**

(ii) The student set up the following experiment.



Alcohol	*Observation*
A	Colour change
B	No change
C	Colour change

(A) Suggest why a water bath is an appropriate method of heating the reaction mixture. **1**

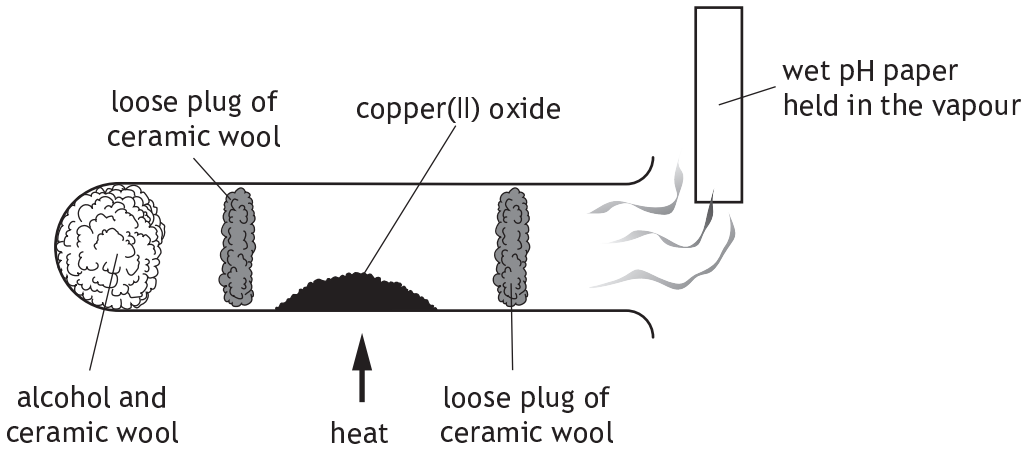
(B) Describe the colour change that would have been observed with alcohols **A** and **C**. **1**

(C) Alcohol **B** is not oxidised.

State the **type** of alcohol which cannot be oxidised by acidified dichromate solution. **1**

6. (a) (continued)

(iii) The student set up a second experiment with alcohol **A**.



Hot copper(II) oxide is an oxidising agent.

(A) When alcohol **A** (C_4H_9OH) is oxidised the product turns the pH paper red.

Suggest a name for the product. **1**

(B) Complete the ion-electron equation for the oxidation reaction. **1**

$C_4H_9OH \rightarrow C_4H_8O_2$

MARKS

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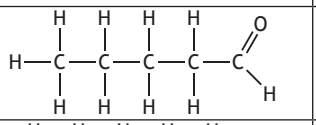
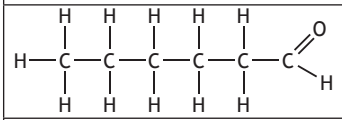
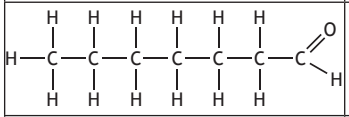
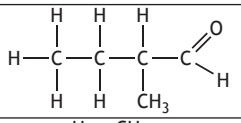
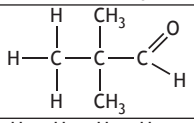
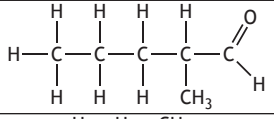
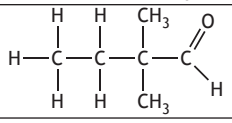
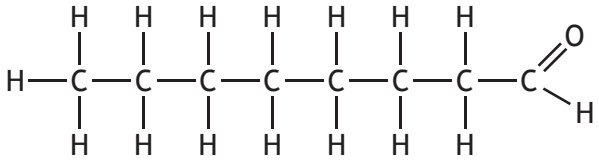
(b) The student found the following information about the boiling points of some aldehydes.

Aldehyde	*Molecular formula*	*Boiling point* (°C)
	$C_5H_{10}O$	102
	$C_6H_{12}O$	130
	$C_7H_{14}O$	153
	$C_5H_{10}O$	95
	$C_5H_{10}O$	75
	$C_6H_{12}O$	119
	$C_6H_{12}O$	111

(i) Name the aldehyde that has a boiling point of 119 °C. **1**

(ii) Predict the boiling point, in °C, of the following molecule. **1**



6. (b) (continued)

(iii) Using information from the table, describe one way in which differences in structure affect the boiling point of **isomeric** aldehydes. **1**

(iv) State what would be observed when an aldehyde is gently heated with Tollens' reagent. **1**

(c) Ketones contain a carbonyl group.

Name the type of intermolecular interaction between ketone molecules. **1**

7. Some people take iron tablets as a dietary supplement. Iron tablets may contain iron(II) sulfate.

(a) A student was investigating the iron(II) content of iron tablets. A work card gave the following instructions for preparing an iron tablet solution.

1. Add five iron tablets to about 50 cm^3 of dilute sulfuric acid in a small beaker and stir to dissolve.
2. Transfer quantitatively to a 100 cm^3 volumetric flask.
3. Make up the solution to the graduation mark on the volumetric flask.
4. Stopper the flask and then invert it to mix the solution.

To 'transfer quantitatively' means that **all** of the iron tablet solution must be transferred into the volumetric flask.

Describe how this is carried out in practice. **1**

(b) The concentration of iron(II) ions (Fe^{2+}) in this iron tablet solution can be determined by a redox titration with permanganate (MnO_4^-) solution.

$$5Fe^{2+}(aq) + 8H^+(aq) + MnO_4^-(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(\ell)$$

(i) Suggest why it is **not** necessary to add an indicator to this titration. **1**

7. (b) (continued)

(ii) Suggest why the titration must be carried out under acidic conditions. **1**

(iii) Three 25·0 cm^3 samples of the iron tablet solution were titrated with a standard solution of 0·020 mol l^{-1} permanganate (MnO_4^-). The results are shown below.

Sample	*Volume of permanganate* (cm^3)
1	14·9
2	14·5
3	14·6

(A) State why the volume of permanganate used in the calculation was taken to be 14·55 cm^3, although this is not the average of the three titres in the table. **1**

(B) Calculate the concentration, in mol l^{-1}, of iron(II) ions in the iron tablet solution. **3**

$$5Fe^{2+}(aq) + 8H^+(aq) + MnO_4^-(aq) \rightarrow 5Fe^{3+}(aq) + Mn^{2+}(aq) + 4H_2O(\ell)$$

7. (b) (iii) (continued)

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

(D) Name an appropriate piece of apparatus which could be used to measure 25·0 cm^3 samples of iron tablet solution. **1**

(c) In a different experiment, five iron tablets were found to contain 0·00126 moles of iron(II) ions.

Calculate the average mass, in **mg**, of iron present in **one** tablet. **1**

(d) It is recommended an adult female takes in 14·8 mg of iron per day.

100 g of a breakfast cereal contains 12·0 mg of iron.

Calculate the percentage of the recommended daily amount of iron provided for an adult female by a 30 g serving. **2**

8. Skin care products contain a mixture of polar covalent, non-polar covalent and ionic compounds. The compounds need to stay mixed within the product.

Skin care products also need to spread easily and remain on the skin for a period of time, as well as provide physical and chemical protection from the sun. In order to do this, skin care products contain a range of chemicals including water, fats and oils, antioxidants, minerals and sun block.

Using your knowledge of chemistry, explain the role of different chemicals in skin care products. **3**

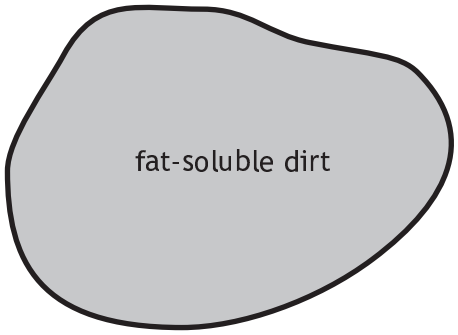
9. Dishwasher tablets contain chemicals which remove dirt from dishes.

(a) Dishwasher tablets include detergents. These molecules act like soaps to allow mixing of fat-soluble dirt and water.

(i) During the cleaning process, the detergent molecules combine with fat-soluble dirt.

A simplified diagram of a detergent molecule is shown.

Complete the diagram below to show how detergent molecules combine with fat-soluble dirt. **1**



(An additional diagram, if required, can be found on *Page 36*)

(ii) State the term used to describe the non-polar, hydrocarbon tail of a detergent molecule. **1**

9. (continued)

(b) Dishwasher tablets produce the bleach hydrogen peroxide, H_2O_2. One action of this oxidising agent is to oxidise food.

(i) Suggest another action of the bleach produced by the dishwasher tablets. **1**

(ii) Hydrogen peroxide decomposes to form water and oxygen.

$$2H_2O_2(\ell) \rightarrow 2H_2O(\ell) + O_2(g)$$

A dishwasher tablet produces 0·051 g of hydrogen peroxide (mass of one mole = 34 g).

Calculate the volume of oxygen that would be produced when 0·051 g of hydrogen peroxide decomposes. **3**

Take the volume of 1 mole of oxygen gas to be 24 litres.

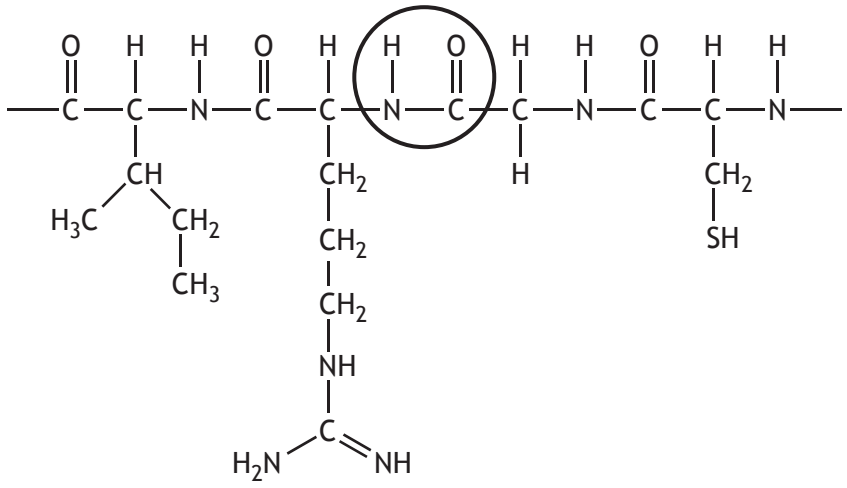
(c) Enzymes are commonly added to dishwasher tablets. These are used to break down proteins.

(i) The proteins are broken down into small, water-soluble molecules.

Name the small, water-soluble molecules made when proteins are broken down completely. **1**

9. (c) (continued)

(ii) The structure of a section of protein chain found in egg white is shown.



(A) Name the functional group circled. **1**

(B) Draw a structural formula for **one** of the molecules that would be made when this section of egg white protein chain is completely broken down. **1**

(iii) As part of the program in the dishwasher, the conditions in the dishwasher change so that the enzyme molecules no longer work because they change shape.

(A) State the term used to describe the change in shape of enzyme molecules. **1**

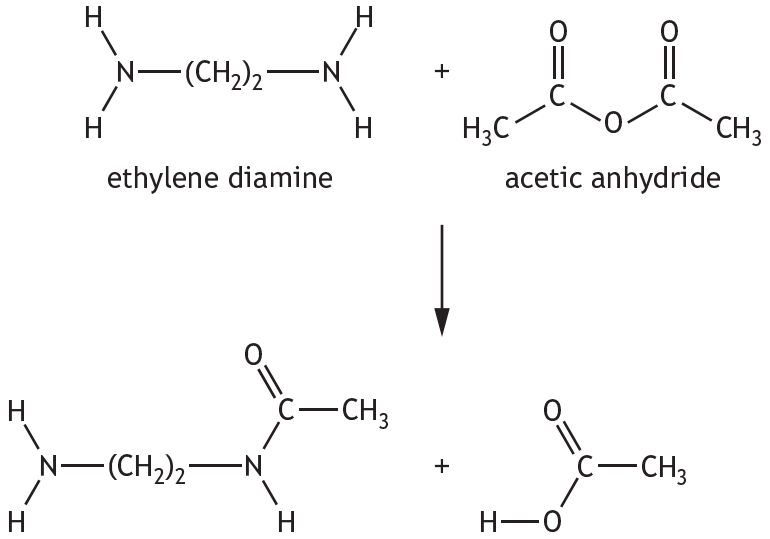
(B) Suggest a change in conditions which would cause the enzyme molecules to change shape. **1**

9. (continued)

(d) A bleach activator is frequently added to dishwasher tablets to speed up the bleaching reaction. One common bleach activator is TAED.

TAED could be produced in a process which involves a number of stages.

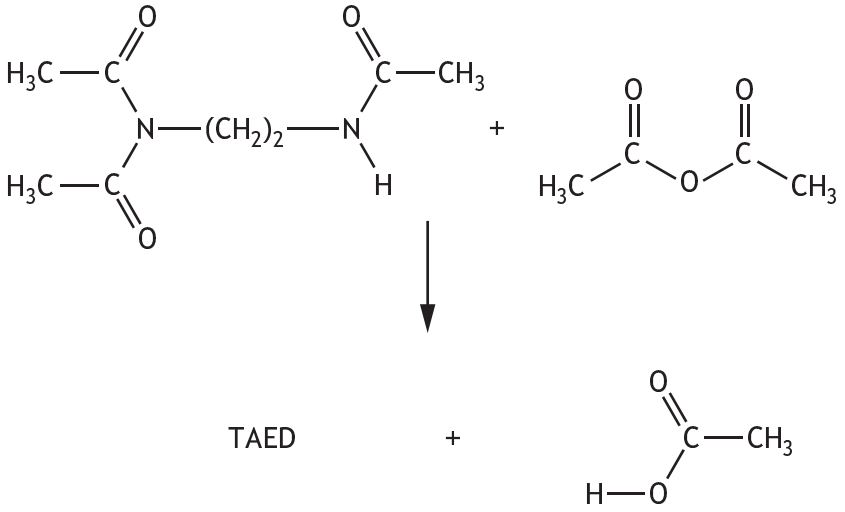
(i) The first stage in producing TAED is shown below.



Suggest a name for this type of reaction. **1**

9. (d) (continued)

(ii) The final stage in the process producing TAED is shown below.



Draw a structural formula for TAED. **1**

10. Essential oils from the lavender plant are used in aromatherapy.

MARKS

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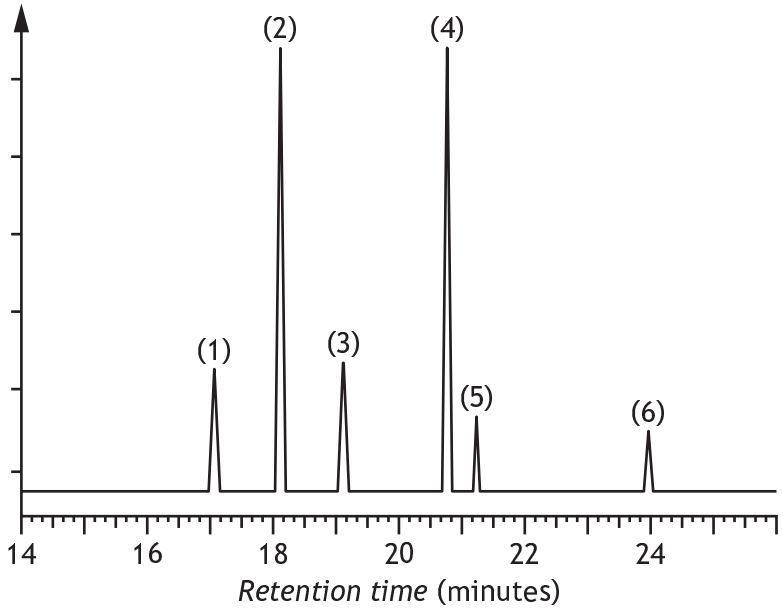
(a) Gas chromatography can be used to separate and identify the organic compounds in lavender oils.

Chromatogram 1 - Lavender oil **A**



Peak	*Component*	*Component peak area*
1	1,8-cineole	7432
2	linalool	31 909
3	camphor	7518
4	linalyl acetate	27 504
5	geranyl acetate	3585
6	farnesene	1362

Total peak area = 79 310

The relative concentration of each component can be calculated using the following formula.

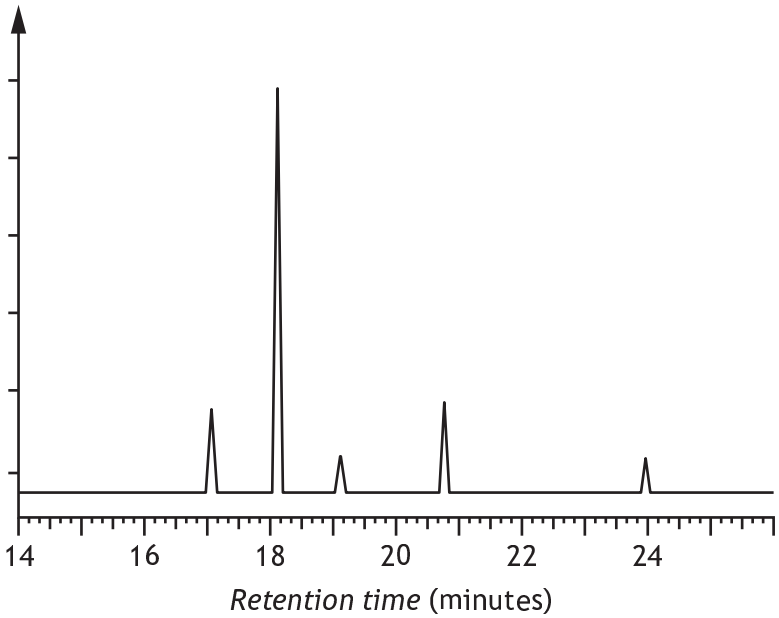
$$\text{Relative concentration} = \frac{\text{Component peak area}}{\text{Total peak area}} \times 100\ (\%)$$

(i) Calculate the relative concentration of linalool in lavender oil **A**. **1**

10. (a) (continued)

(ii) Different varieties of lavender oils have different compositions.

Chromatogram 2 – Lavender oil **B**



Identify the component found in lavender oil **A** that is missing from lavender oil **B**. **1**

(b) A brand of mouthwash contains the component 1,8-cineole at a concentration of 0·92 mg per cm^3. The cost of 1 kg of 1,8-cineole is £59·10.

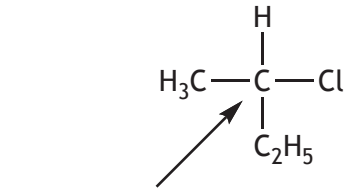
Calculate the cost, in pence, of 1,8-cineole that is present in a 500 cm^3 bottle of this brand of mouthwash. **2**

10. (continued)

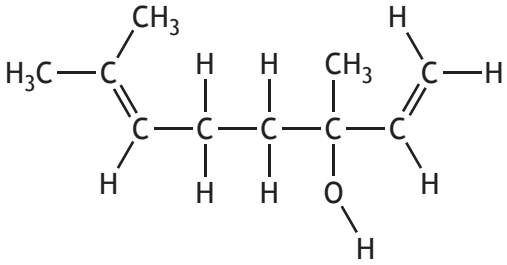
(c) The component molecules found in lavender oils are terpenes or terpenoids.

(i) A chiral carbon is a carbon atom attached to **four** different atoms or groups of atoms.

An example is shown below.



A molecule of the terpenoid linalool has a chiral carbon. Linalool has the following structure.



Circle the chiral carbon atom in the linalool structure. **1**

(An additional diagram, if required, can be found on *Page 36*)

(ii) Farnesene is a terpene consisting of **three** isoprene units (2-methylbuta-1,3-diene) joined together.

Write the molecular formula of farnesene. **1**

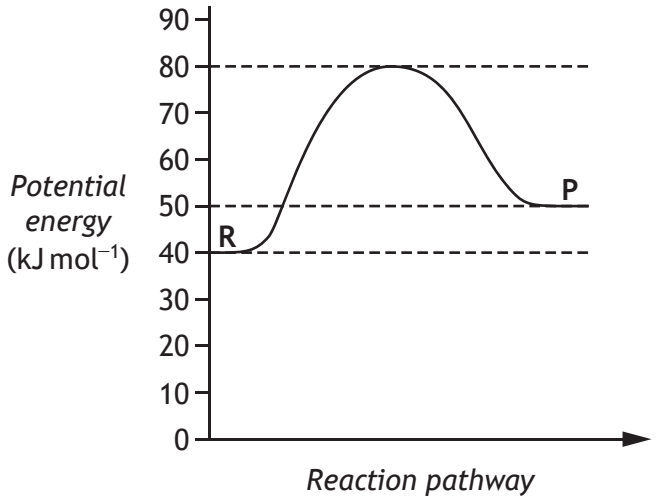
[END OF QUESTION PAPER]

2018

SECTION 1 — 20 marks

Attempt ALL questions

1. The potential energy diagram below refers to the reversible reaction involving reactants **R** and products **P**.



What is the enthalpy change, in kJ mol^{-1}, for the **reverse** reaction?

A −40

B −10

C +10

D +30

2. The relative rate of a reaction which reached completion in 1 minute 40 seconds is

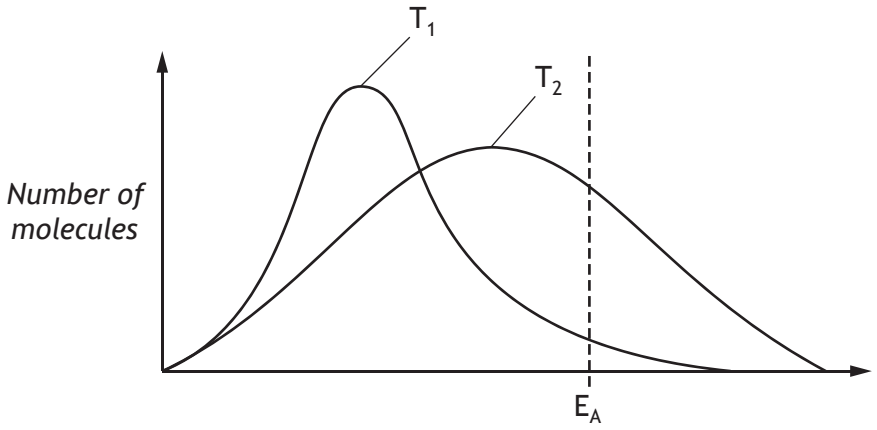
A 0·010 s^{-1}

B 0·714 s^{-1}

C 0·010 min^{-1}

D 0·714 min^{-1}.

3.



Which of the following is the correct interpretation of the above energy distribution diagram for a reaction as the temperature **decreases** from T_2 to T_1?

	Activation energy (E_A)	*Number of successful collisions*
A	remains the same	increases
B	decreases	decreases
C	decreases	increases
D	remains the same	decreases

4. The table shows the first three ionisation energies of aluminium.

Ionisation energy (kJ mol^{-1})		
First	*Second*	*Third*
578	1817	2745

Using this information, what is the enthalpy change, in kJ mol^{-1}, for the following reaction?

$$Al^{+}(g) \rightarrow Al^{3+}(g) + 2e^{-}$$

A 1817

B 2395

C 4562

D 5140

[Turn over

5. An element contains covalent bonding and London dispersion forces.

The element could be

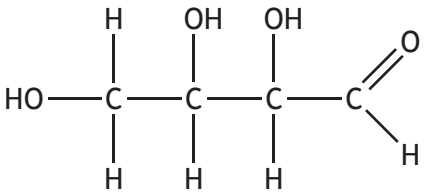
A boron

B neon

C sodium

D sulfur.

6. Erythrose is a chemical that is known to kill cancer cells.



erythrose

The two functional groups present in erythrose are

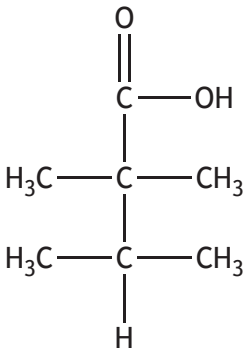
A carboxyl and ester

B carbonyl and ester

C carbonyl and hydroxyl

D carboxyl and hydroxyl.

7.



The name of the above compound is

A 2,2,3-trimethylbutanoic acid

B 2,3,3-trimethylbutanoic acid

C 1,1,2,2-tetramethylpropanoic acid

D 2,2,3,3-tetramethylpropanoic acid.

8. Which of the following is an isomer of pentan-3-ol?

A $CH_3CH_2CH(OH)CH_2CH_3$

B $CH_3CHCHCH_2CH_2OH$

C $CH_3CHCHCH(OH)CH_3$

D $CH_3CH(CH_3)CH_2CH_2OH$

9. Oxidation of 4-methylpentan-2-ol to the corresponding ketone results in the alcohol

A losing 2 g per mole

B gaining 2 g per mole

C losing 16 g per mole

D gaining 16 g per mole.

10. Essential amino acids are defined as the amino acids which

A are necessary for building proteins

B humans must acquire through their diet

C plants cannot synthesise for themselves

D are produced when any protein is hydrolysed.

11. A mixture of carbon monoxide and hydrogen can be converted into water and a mixture of hydrocarbons.

$\mathbf{n}\ CO + (\mathbf{2n} + \mathbf{1})\ H_2 \rightarrow \mathbf{n}\ H_2O +$ hydrocarbons

What is the general formula for the hydrocarbons produced?

A C_nH_{2n-2}

B C_nH_{2n}

C C_nH_{2n+1}

D C_nH_{2n+2}

12. A mixture of sodium chloride and sodium sulfate is known to contain 0·6 mol of chloride ions and 0·2 mol of sulfate ions.

How many moles of sodium ions are present?

A 0·4

B 0·5

C 0·8

D 1·0

13. Under the same conditions of temperature and pressure, which of the following gases would occupy the largest volume?

A 0·20 g of hydrogen

B 0·44 g of carbon dioxide

C 0·60 g of neon

D 0·80 g of argon

14. $3CuO + 2NH_3 \rightarrow 3Cu + N_2 + 3H_2O$

What volume of gas, in cm^3, would be obtained by reaction between 100 cm^3 of ammonia gas and excess copper(II) oxide?

All volumes are measured at atmospheric pressure and 20 °C.

A 50

B 100

C 200

D 400

15. $Cl_2(g) + H_2O(\ell) \rightleftharpoons Cl^-(aq) + ClO^-(aq) + 2H^+(aq)$

The addition of which of the following substances would move the above equilibrium to the right?

A Hydrogen

B Hydrogen chloride

C Sodium chloride

D Sodium hydroxide

16. When 3·6 g of butanal (mass of one mole = 72 g) was burned, 124 kJ of energy was released.

What is the enthalpy of combustion of butanal, in kJ mol^{-1}?

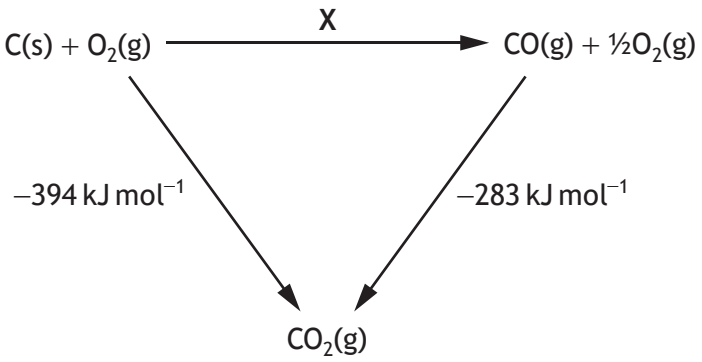
A −6·2

B +6·2

C −2480

D +2480

17. Consider the reaction pathways shown below.



According to Hess's Law, the enthalpy change, in kJ mol^{-1}, for reaction **X** is

A +111

B −111

C −677

D +677.

18. $SO_3^{2-}(aq) + H_2O(\ell) \rightarrow SO_4^{2-}(aq) + 2H^+(aq) + 2e^-$

Which of the following ions could be used to oxidise sulfite ions to sulfate ions?

A $Cr^{3+}(aq)$

B $Al^{3+}(aq)$

C $Fe^{3+}(aq)$

D $Sn^{4+}(aq)$

19. During a redox reaction nitrate ions, NO_3^-, are converted to nitrogen monoxide, NO.

$$NO_3^- \rightarrow NO$$

Which line in the table correctly completes the ion-electron equation?

	Reactants	*Products*
A	$6H^+ + 5e^-$	$3H_2O$
B	$4H^+ + 3e^-$	$2H_2O$
C	$6H^+$	$3H_2O + 5e^-$
D	$4H^+$	$2H_2O + 3e^-$

20. $ICl(\ell) + Cl_2(g) \rightleftharpoons ICl_3(s) \quad \Delta H = -106 kJ\,mol^{-1}$

Which line in the table identifies correctly the changes that will cause the greatest increase in the proportion of solid in the above equilibrium mixture?

	Temperature	*Pressure*
A	decrease	decrease
B	decrease	increase
C	increase	decrease
D	increase	increase

[END OF SECTION 1. NOW ATTEMPT THE QUESTIONS IN SECTION 2 OF YOUR QUESTION AND ANSWER BOOKLET.]

SECTION 2 — 80 marks

Attempt ALL questions

1. The elements of group 7 in the periodic table are known as the halogens.

(a) Going down group 7 the electronegativity of the halogens decreases.

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

(ii) Explain why electronegativity values decrease going down group 7. **1**

(b) Explain **fully** why the boiling points of the halogens increase going down group 7.

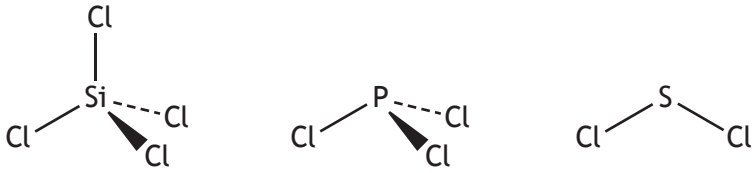
In your answer you should name the intermolecular forces involved. **3**

2. The elements sodium to argon form the third period of the periodic table.

(a) Explain the decrease in atom size going across the third period from sodium to argon. **1**

(b) Elements in the third period of the periodic table form chlorides.

The structures of three of these chlorides are shown.



(i) Circle the structure of the molecule above that contains **bonds** with the lowest polarity. **1**

(An additional diagram, if required, can be found on *page 37*).

(ii) Explain **fully** why, of these three chlorides, silicon tetrachloride is the most soluble in hexane. **2**

[Turn over

2. (continued)

(c) Silicon tetrachloride can be used to make silicon nitride (Si_3N_4), a compound found in many cutting tools.

(i) Silicon nitride has a melting point of 1900 °C and does not conduct electricity when molten.

Explain **fully**, in terms of structure and bonding, why silicon nitride has a high melting point. **2**

(ii) An equation for the formation of silicon nitride is shown.

$3SiCl_4$	+	$16NH_3$	→	Si_3N_4	+	$12NH_4Cl$
mass of one mole = 170·1 g		mass of one mole = 17·0 g		mass of one mole = 140·3 g		mass of one mole = 53·5 g

Calculate the atom economy for the formation of silicon nitride. **2**

2. (continued)

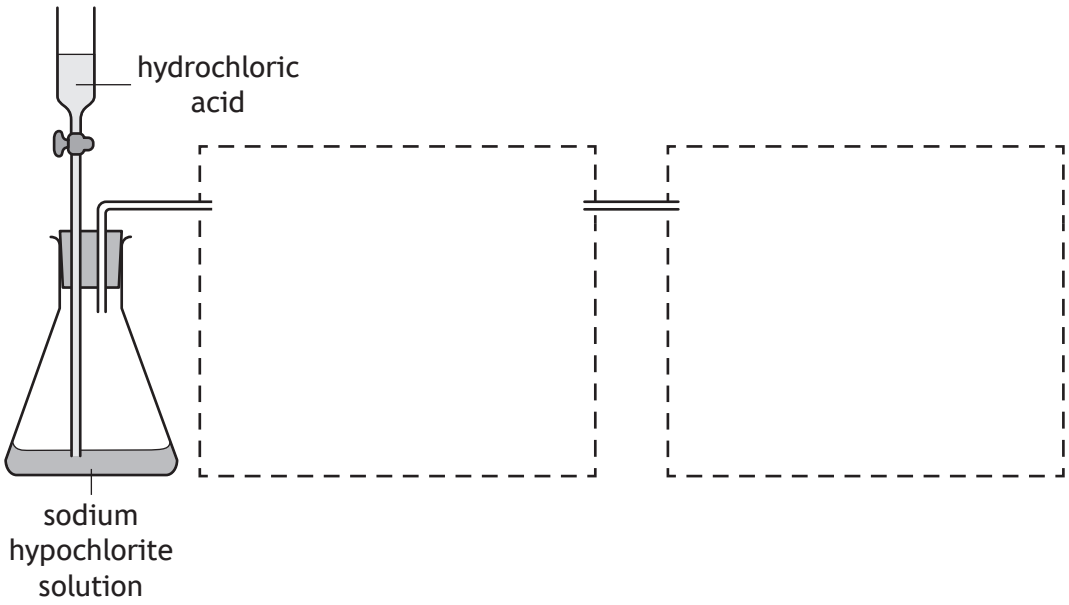
(d) Aluminium, another element in the third period, also forms a chloride. Aluminium chloride is prepared by reacting aluminium metal and chlorine gas.

Chlorine gas is produced by the reaction between hydrochloric acid and sodium hypochlorite. The chlorine is then passed over heated aluminium foil, forming aluminium chloride as a hot gas. The hot aluminium chloride gas and unreacted chlorine gas are passed into a flask where the aluminium chloride cools to a fine white powder.

For safety it is important that any unreacted chlorine gas can escape from the flask.

(i) Complete a labelled diagram to show an apparatus suitable for carrying out this preparation. **2**

(An additional diagram, if required, can be found on *page 37*).

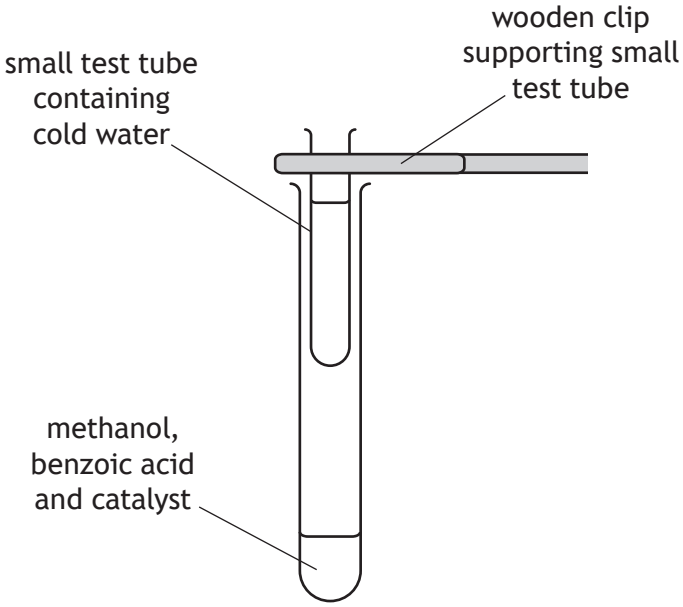


(ii) Explain why the aluminium foil needs to be heated at the start of the preparation, despite the reaction being highly exothermic. **1**

[Turn over

3. Methyl benzoate is commonly added to perfumes as it has a pleasant smell.

A student carries out a reaction to produce methyl benzoate using the following apparatus.



(a) The reaction mixture needs to be heated.

Describe a safe method of heating a flammable mixture. **1**

(b) Suggest a reason why there is a small test tube filled with cold water in the neck of the tube containing the reaction mixture. **1**

3. (continued)

(c) The chemical reaction involved in the experiment is shown.

$C_6H_5COOH(s)$	+	$CH_3OH(\ell)$	→	$C_6H_5COOCH_3(\ell)$	+	**X**
benzoic acid				methyl benzoate		
mass of one mole = 122 g		mass of one mole = 32 g		mass of one mole = 136 g		

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

(ii) In a laboratory experiment, a student used 5·0 g of benzoic acid and 2·5 g of methanol to produce methyl benzoate.

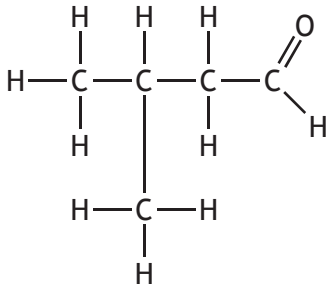
Explain why benzoic acid is the limiting reactant.

You must include calculations in your answer. **2**

(iii) The student produced 3·1 g of methyl benzoate from 5·0 g of benzoic acid. Benzoic acid costs £39·80 for 500 g.

Calculate the cost, in £, of the benzoic acid needed to make 100 g of methyl benzoate using the student's method. **2**

4. 3-Methylbutanal is a compound that is found in low concentrations in many types of food. The structure of 3-methylbutanal is shown.



(a) Draw a structural formula for a ketone that is an isomer of 3-methylbutanal. **1**

(b) Name a reagent which could be used to distinguish between 3-methylbutanal and a ketone. **1**

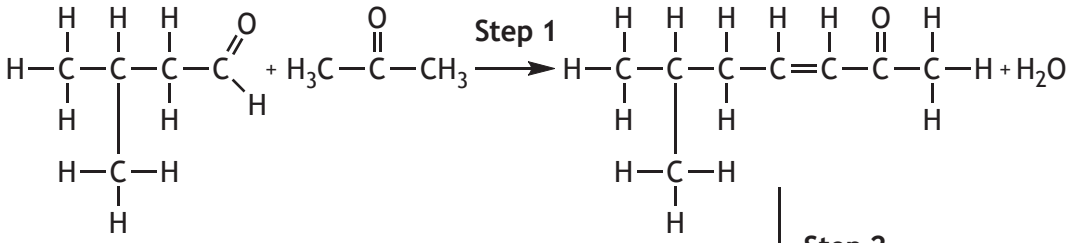
(c) Name the strongest intermolecular force that occurs between 3-methylbutanal molecules. **1**

4. (continued)

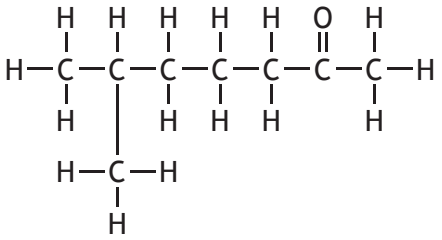
(d) 3-Methylbutanal is found in olive oil. **2**

Explain **fully** what can happen to 3-methylbutanal that will cause the olive oil to develop an unpleasant taste.

(e) 3-Methylbutanal can be used as a reactant in the production of other compounds. One reaction scheme involving 3-methylbutanal is shown.



3-methylbutanal propanone



product A

(i) Explain why **step 1** is described as a condensation reaction. **1**

(ii) Give the systematic name for **product A**. **1**

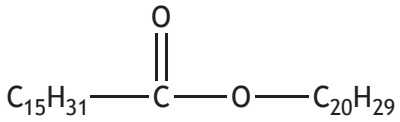
5. Many chemical compounds are related to each other by their structural features, the way they are made and how they are used.

Using your knowledge of chemistry, describe the relationships between fats, oils, detergents, soaps and emulsifiers. **3**

6. Skin creams contain many different chemicals.

(a) Retinol (vitamin A) promotes cell regeneration.

One method of supplying retinol to the skin is by using a skin cream containing the compound retinyl palmitate.



retinyl palmitate

Retinyl palmitate is absorbed into the skin and then broken down to form retinol.

(i) Name the type of reaction that occurs when retinyl palmitate is broken down to form retinol. **1**

(ii) Write a molecular formula for retinol. **1**

(b) Skin creams often contain vitamin E to prevent damage to the skin caused by free radicals.

(i) Describe how free radicals are formed. **1**

6. (b) (continued)

(ii) Hydroxyl free radicals (•OH) can attack fatty acids present in cell membranes. One step in the chain reaction is shown below.

$$C_{18}H_{31}O_2 \quad + \quad \bullet OH \quad \rightarrow \quad C_{18}H_{30}O_2\bullet \quad + \quad H_2O$$

State the name given to this step in the chain reaction. **1**

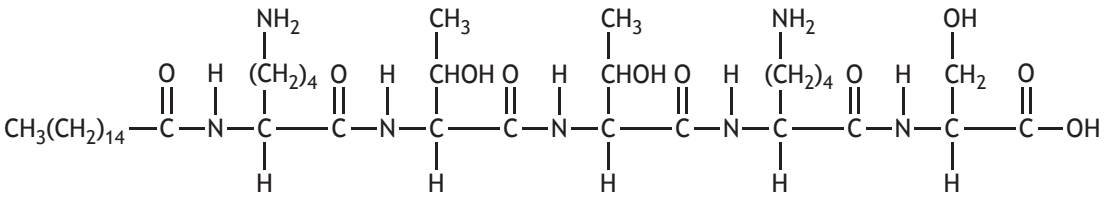
(iii) The antioxidant vitamin E is a free radical scavenger.

State how free radical scavengers prevent further chain reactions. **1**

[Turn over

6. (continued)

(c) Palmitoyl pentapeptide-4 is also used in skin creams.



(i) Circle a peptide link in the above structure. **1**

(An additional diagram, if required, can be found on *page 37*).

(ii) Palmitoyl pentapeptide-4 is formed from palmitic acid and three different amino acids.

Molecule	*Number of molecules used to form one molecule of palmitoyl pentapeptide-4*
palmitic acid	1
threonine	2
serine	1
lysine	2

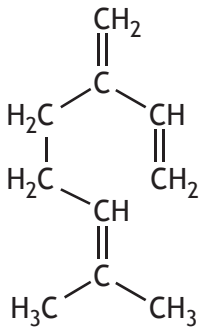
Draw a structural formula for the amino acid serine. **1**

7. Terpenes consist of joined isoprene units (2-methylbuta-1,3-diene). They are classified by the number of isoprene units in the molecule.

Class of terpene	*Number of isoprene units*
hemiterpene	1
monoterpene	2
sesquiterpene	3
diterpene	4
triterpene	6

(a) Myrcene and humulene are terpenes present in hops which give beer its characteristic flavour and aroma.

(i) Circle an isoprene unit on the myrcene structure below. **1**



(An additional diagram, if required, can be found on *page 38*).

(ii) Humulene has the molecular formula $C_{15}H_{24}$.

Name the class of terpene to which humulene belongs. **1**

[Turn over

7. (continued)

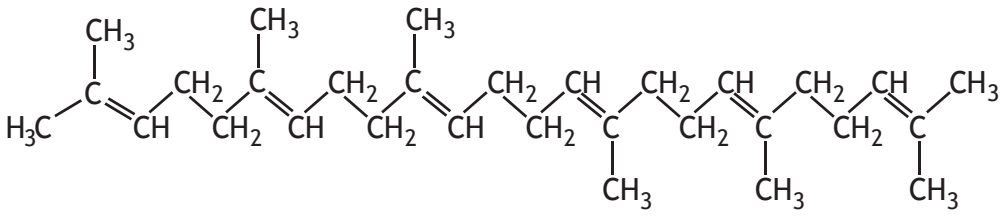
(b) (i) Squalene, a triterpene, is included in some flu vaccines to enhance the body's immune response. A single dose of flu vaccine contains 10·69 mg of squalene.

Calculate the mass of squalene required to produce a batch of 500 000 doses of flu vaccine.

Your answer must be given in kg. **2**

(ii) Squalane is a fully saturated hydrocarbon used in skin moisturising cream.

Squalane can be made by the reaction of squalene with hydrogen.

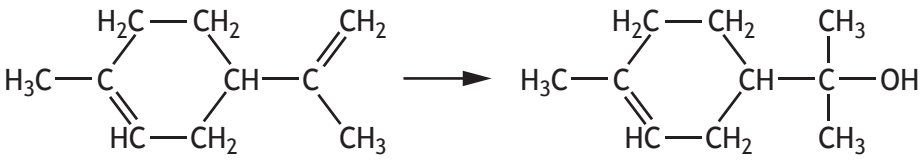


squalene

State the number of moles of hydrogen needed to fully saturate one mole of squalene to produce one mole of squalane. **1**

7. (continued)

(c) The monoterpene limonene, found in lemon oil, can be converted into the alcohol, terpineol.



limonene terpineol

(i) Name the type of reaction taking place. **1**

(ii) When terpineol is heated with copper(II) oxide, no reaction takes place.

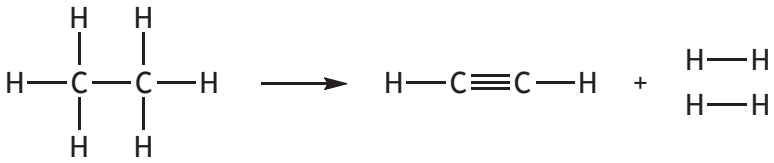
Explain why no reaction takes place. **1**

[Turn over

8. The alkynes are a homologous family of hydrocarbons.

(a) The simplest member of the family is ethyne, C_2H_2, used in welding torches.

Ethyne can be produced from ethane.



Using bond enthalpies and mean bond enthalpies from the data book, calculate the enthalpy change, in kJ mol^{-1}, for this reaction. **2**

(b) Hess's Law can be used to calculate the enthalpy change for reactions that do not normally take place, such as the formation of propyne from its elements.

$$3C(s) + 2H_2(g) \rightarrow C_3H_4(g)$$

Calculate the enthalpy change, in kJ mol^{-1}, for this reaction using the following information. **2**

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\quad \Delta H = -394$ kJ mol^{-1}

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(\ell)$ $\quad \Delta H = -286$ kJ mol^{-1}

$C_3H_4(g) + 4O_2(g) \rightarrow 3CO_2(g) + 2H_2O(\ell)$ $\quad \Delta H = -1939$ kJ mol^{-1}

8. (continued)

(c) Propyne, C_3H_4 (1 mole = 40 g), has been suggested as a possible rocket fuel.

(i) The enthalpy of combustion of propyne is $-1939\ kJ\ mol^{-1}$.

Calculate the energy released, in kJ, when 1 kg of propyne is burned completely. **1**

(ii) The mass of air required to burn 1 g of fuel can be calculated using the relationship shown.

Mass of air, in g = 4·3 × mass of oxygen, in g, for complete combustion of 1 g of fuel

Calculate the mass of air, in g, required to burn 1 g of propyne. **2**

$$C_3H_4(g) + 4O_2(g) \rightarrow 3CO_2(g) + 2H_2O(\ell)$$

8. (c) (continued)

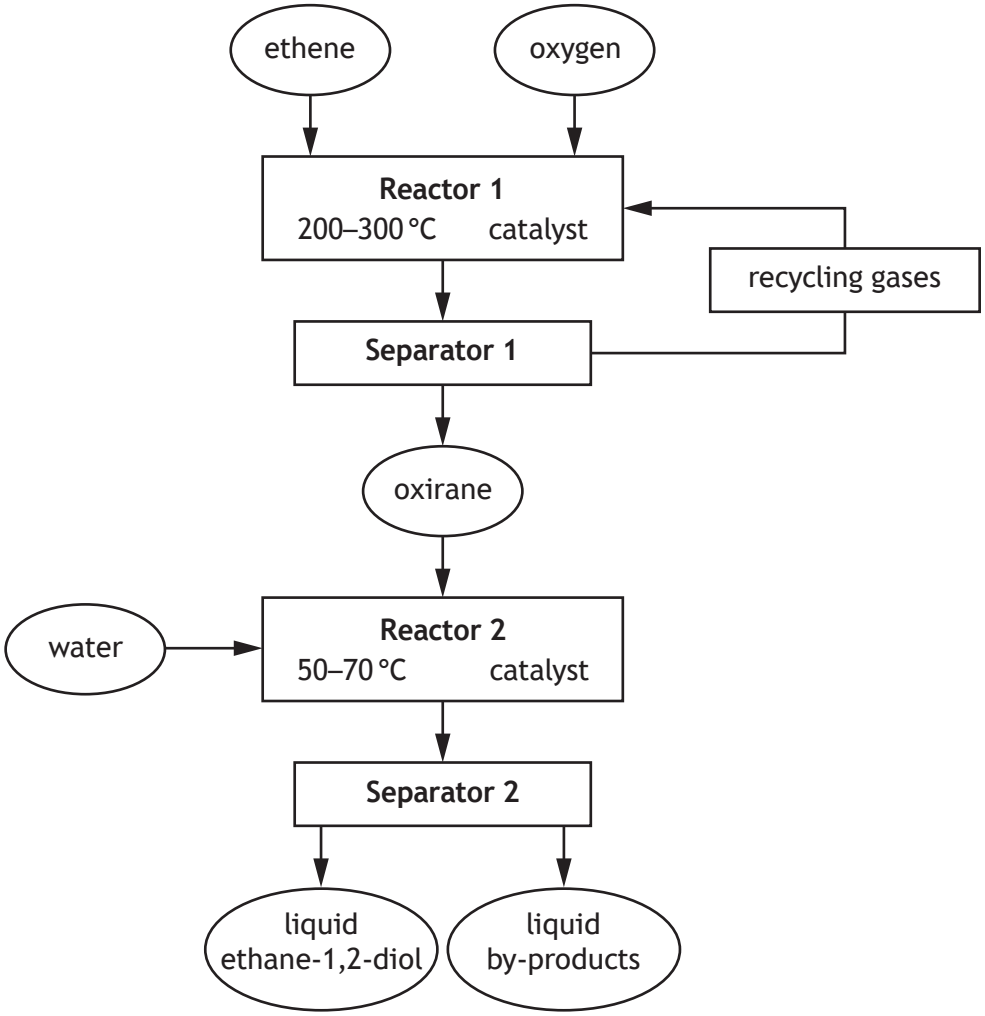
(iii) The table shows the mass of air required to burn 1 g of different fuels.

Fuel	*Mass of 1 mole (g)*	*Mass of air required to burn 1 g*
ethane	30	16·1
propane	44	15·6
methanol	32	6·5
ethanol	46	9·0

Suggest why methanol and ethanol, compared to the other fuels, require less air to burn 1 g. **1**

9. Ethane-1,2-diol can be made from ethene.

(a) The flow chart of an industrial process to produce ethane-1,2-diol is shown.



(i) Industrial processes are designed to maximise profit.

Using the flowchart, suggest two ways to maximise profit in this industrial process. **2**

9. (a) (continued)

(ii) Name the process used in **Separator 2** to separate ethane-1,2-diol from the larger liquid by-products. **1**

(b) Explain fully why ethane-1,2-diol is more viscous than propan-1-ol. **2**

(c) Draw a structural formula for a diol that contains three carbon atoms. **1**

[Turn over

9. (continued)

(d) Ethane-1,2-diol has been found to be harmful to animals. Treatment for affected animals involves using a 20% ethanol solution.

(i) The 20% ethanol solution is prepared by accurately measuring 20 cm^3 of ethanol and then making up to exactly 100 cm^3 with water.

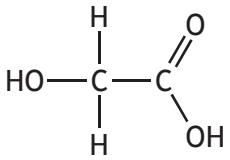
Describe the procedure which should be used to prepare 100 cm^3 of the 20% ethanol solution. **2**

(ii) An affected animal must be treated with 9 doses of 20% ethanol solution. Each dose contains 5 cm^3 of the ethanol solution for every kilogram body mass of the animal.

Calculate the total volume, in cm^3, of the 20% ethanol solution needed to treat a 3·5 kg animal. **1**

9. (d) (continued)

(iii) Ethane-1,2-diol is harmful because it is oxidised in the body to form glycolic acid.



glycolic acid

(A) Draw a structural formula for another possible product of oxidation of ethane-1,2-diol. **1**

(B) Glycolic acid can be neutralised by sodium hydroxide to form sodium glycolate.

Give a formula for sodium glycolate. **1**

[Turn over

10. The molar volume (in units of litres per mole) is the same for all gases at the same temperature and pressure.

Using your knowledge of chemistry, suggest how the molar volume of gases could be measured and compared. Any suitable chemicals and apparatus can be used. Some suggested chemicals and apparatus are given below. **3**

Chemicals	*Apparatus*
hydrochloric acid	gas syringe
zinc	measuring cylinder
magnesium	delivery tube
calcium	stoppers
water	500 cm^3 flask
sodium carbonate	vacuum pump
calcium carbonate	balance
cylinder of nitrogen	cork ring
cylinder of hydrogen	burette
cylinder of carbon dioxide	filter funnel

10. (continued)

[Turn over

11. Iodine is required for a healthy diet. Food grown in certain parts of the world is low in iodine. To prevent iodine deficiency in people's diets, table salt can be 'iodised' by the addition of very small quantities of potassium iodide, KI.

The number of moles of iodide in a sample of salt can be determined by the following procedure.

Step 1

Prepare a standard salt solution by dissolving an accurately weighed sample of iodised salt (50·0 g) in water to give a final volume of 250 cm^3.

Step 2

Transfer 50 cm^3 of salt solution to a conical flask and add excess bromine solution to convert the iodide ions to iodine.

Step 3

Titrate the iodine (I_2) released with sodium thiosulfate solution ($Na_2S_2O_3$).

(a) Describe a procedure to accurately weigh out a 50·0 g sample of iodised table salt. **1**

(b) The overall equation for the reaction of bromine solution with iodide ions is shown.

$$2I^-(aq) + Br_2(aq) \rightarrow I_2(aq) + 2Br^-(aq)$$

Write the ion-electron equation for the oxidation reaction. **1**

11. (continued)

(c) Three samples were prepared as described in **step 2**. Each sample was titrated with 0·0010 mol l^{-1} sodium thiosulfate solution.

The results are shown below.

Sample	*Volume of sodium thiosulfate* (cm^3)
1	10·0
2	9·4
3	9·6

(i) Calculate the average volume, in cm^3, of sodium thiosulfate solution that should be used to determine the number of moles of iodine released. **1**

(ii) Calculate the number of moles of iodine released from 50 cm^3 of the standard salt solution. **2**

$$I_2(aq) + 2Na_2S_2O_3(aq) \rightarrow 2NaI(aq) + Na_2S_4O_6(aq)$$

[Turn over

12. Many modern antiseptics are based on phenol. The table shows the germ-killing power of some phenol compounds.

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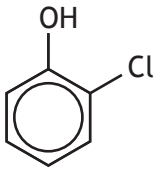
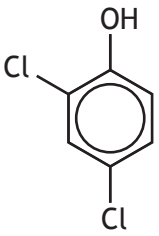
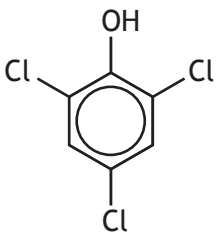
(a)

Compound	*Structure*	*Germ-killing power (relative to phenol)*
phenol		1·0
4-methylphenol		2·5
2-chlorophenol		3·6
4-ethylphenol		7·5
2,4-dichlorophenol		13·0
4-propylphenol		20·0
2,4,6-trichlorophenol		23·0

12. (a) (continued)

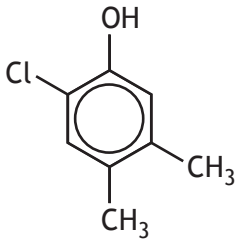
(i) Suggest two ways in which structural features increase germ-killing power of phenol compounds. **2**

(ii) The names of the phenol compounds in the table are derived from their structures using the following rules.

Phenol is used as the parent name for the compound.

1. The –OH functional group is assigned as being on carbon 1 of the ring.
2. The ring can be numbered clockwise or anticlockwise to assign numbers to the other atoms or groups. The numbers should be assigned so that the lowest possible numbers are used.
3. If two or more identical atoms or groups are present, use one of the prefixes di, tri or tetra.
4. The names of the atoms or groups attached to the ring are listed alphabetically (ignoring the prefixes for alphabetical purposes).

Using these rules, name this molecule.



1

[Turn over

12. (continued)

(b) There are different methods of producing phenol.

(i) In the early 1900s, phenol was produced by the following reaction.

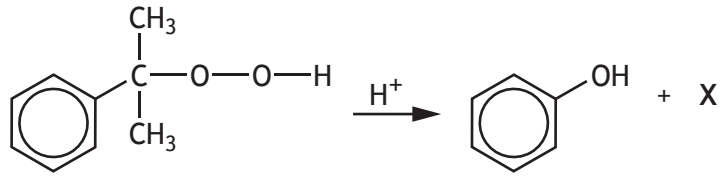
$$\underset{\text{benzene}}{C_6H_6} + H_2SO_4 + 2NaOH \rightarrow \underset{\text{phenol}}{C_6H_5OH} + Na_2SO_3 + 2H_2O$$

mass of one mole = 78·0 g

mass of one mole = 94·0 g

Calculate the mass of phenol, in kg, produced from 117 kg of benzene if the percentage yield is 90%. **2**

(ii) Phenol is now usually produced by the Cumene Process.



cumene hydroperoxide

phenol

Name the other product, **X**, formed in the Cumene Process. **1**

[END OF QUESTION PAPER]