Higher Chemistry

Past Paper Questions – Book 1

Revised Higher 2013

Revised Higher 2014

2013

(revised)

1. Which of the following elements has the greatest attraction for bonding electrons?

A Lithium

B Chlorine

C Sodium

D Bromine

2. Which of the following elements exists as discrete molecules?

A Boron

B Carbon (diamond)

C Silicon

D Sulfur

3. Which of the following statements is true?

A The potassium ion is larger than the potassium atom.

B The chloride ion is smaller than the chlorine atom.

C The sodium atom is larger than the sodium ion.

D The oxygen atom is larger than the oxide ion.

4. Which type of bonding is **never** found in elements?

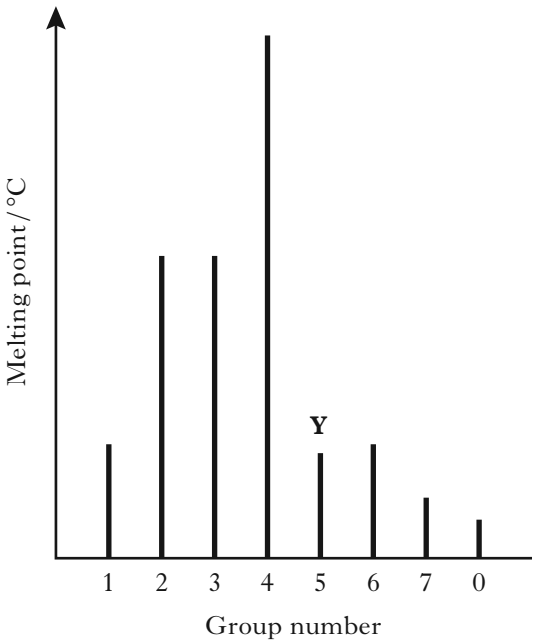
A Metallic

B London dispersion forces

C Polar covalent

D Non-polar covalent

5. The diagram shows the melting points of successive elements across a period in the Periodic Table.



Which of the following is a correct reason for the low melting point of element **Y**?

A It has weak ionic bonds.

B It has weak covalent bonds.

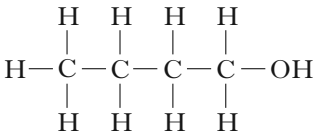
C It has weakly-held outer electrons.

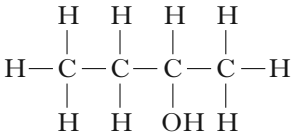
D It has weak forces between molecules.

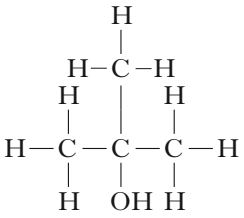
[Turn over

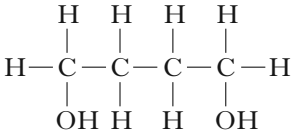
6. The structures for molecules of four liquids are shown below.

Which liquid will be the most viscous?

A 

B 

C 

D 

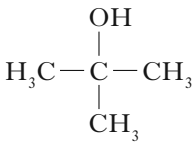
7. Which of the following elements is the strongest reducing agent?

A Lithium

B Bromine

C Fluorine

D Aluminium

8. 

Which of the following compounds is an isomer of the structure shown above?

A Butanal

B Butanone

C Butan-1-ol

D Butanoic acid

9. A compound with molecular formula $C_6H_{12}O_2$, could be

A hexanal

B hexan-2-ol

C hexan-2-one

D hexanoic acid.

10. An ester has the following structural formula

$$CH_3CH_2CH_2COOCH_2CH_3$$

The name of this ester is

A propyl propanoate

B ethyl butanoate

C butyl ethanoate

D ethyl propanoate.

11. Esters are formed by the reaction between which **two** functional groups?

A A hydroxyl group and a carboxyl group

B A hydroxyl group and a carbonyl group

C A hydroxide group and a carboxyl group

D A hydroxide group and a carbonyl group

12. Oils are generally

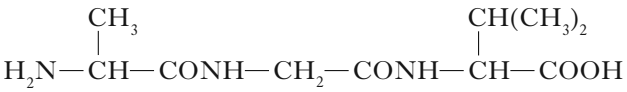
A solid at room temperature and contain a high proportion of unsaturated molecules

B solid at room temperature and contain a high proportion of saturated molecules

C liquid at room temperature and contain a high proportion of unsaturated molecules

D liquid at room temperature and contain a high proportion of saturated molecules.

13. A tripeptide **X** has the structure

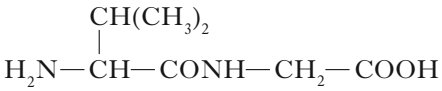


Partial hydrolysis of **X** yields a mixture of dipeptides.

Which of the following dipeptides could be produced on hydrolysing **X**?

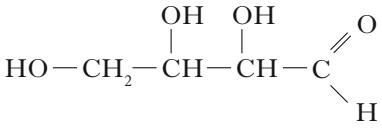
A 

B 

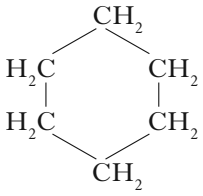
C 

D 

14. Erythrose can be used in the production of a chewing gum that helps prevent tooth decay.

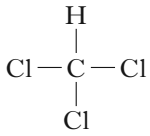


Which of the following compounds will be the **best** solvent for erythrose?

A 

B

C

D 

15. When a protein is denatured

A its overall shape is distorted

B its amide links are hydrolysed

C it is broken into separate peptide fragments

D it decomposes into amino acids.

[Turn over

16. Which **two** isomers would each produce an acid when warmed with acidified potassium dichromate solution?

1 $CH_3—CH_2—CH_2—CH_2—OH$

2 $CH_3—\underset{\displaystyle OH}{\underset{|}{CH}}—CH_2—CH_3$

3 $\begin{array}{l} \quad CH_3 \\ \quad | \\ CH_3—C—OH \\ \quad | \\ \quad CH_3 \end{array}$

4 $\begin{array}{l} CH_3—CH—CH_3 \\ \quad\quad | \\ \quad\quad CH_2—OH \end{array}$

A 1 and 2

B 2 and 3

C 1 and 4

D 3 and 4

17. Which of the following organic compounds is an isomer of hexanal?

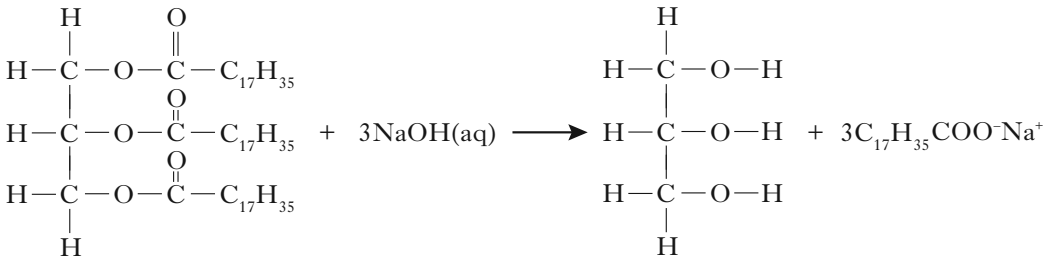
A 2-Methylbutanal

B 3-Methylpentan-2-one

C 2,2-Dimethylbutan-1-ol

D 3-Ethylpentanal

18. Soaps are produced by the following reaction.



This reaction is an example of

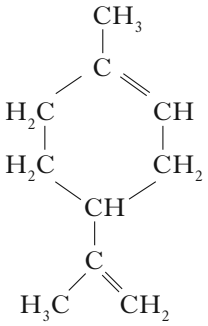
A condensation

B esterification

C hydrolysis

D oxidation.

19. Limonene is one of the terpene molecules responsible for the flavour of lemons.



How many isoprene units are used in the production of one limonene molecule?

A 1

B 2

C 3

D 4

20. A mixture of magnesium bromide and magnesium sulfate is known to contain 3 mol of magnesium and 4 mol of bromide ions.

How many moles of sulfate ions are present?

A 1

B 2

C 3

D 4

21. $2C_2H_2(g) + 5O_2(g) \rightarrow 4CO_2(g) + 2H_2O(\ell)$
ethyne

What volume of gas would be produced by the complete combustion of 100 cm^3 of ethyne gas?

All volumes were measured at atmospheric pressure and room temperature.

A 200 cm^3

B 300 cm^3

C 400 cm^3

D 800 cm^3

22. $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

The equation represents a mixture at equilibrium.

Which line in the table is true for the mixture after a further 2 hours of reaction?

	Rate of forward reaction	**Rate of back reaction**
A	decreases	decreases
B	increases	increases
C	unchanged	decreases
D	unchanged	unchanged

23. In which of the following would an increase in pressure result in the equilibrium position being moved to the left?

A $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

B $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$

C $CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$

D $Fe_2O_3(s) + 3CO(g) \rightleftharpoons 2Fe(s) + 3CO_2(g)$

24. Ammonia is made by the Haber Process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

The equilibrium position lies to the left.

Which line in the table is correct?

	Atom Economy	**Percentage Yield**
A	high	high
B	high	low
C	low	high
D	low	low

[Turn over

25. In which of the following will **both** changes result in an increase in the rate of a chemical reaction?

A A decrease in activation energy and an increase in the frequency of collisions.

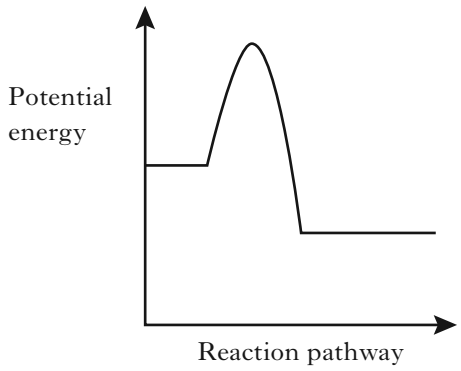
B An increase in activation energy and a decrease in particle size.

C An increase in temperature and an increase in the particle size.

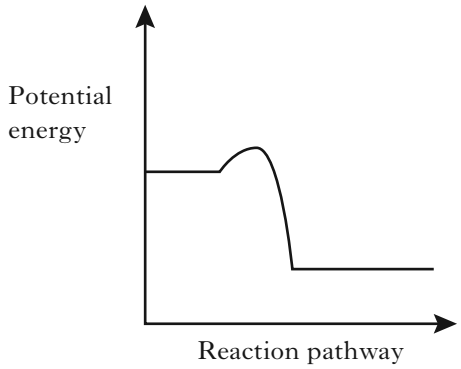
D An increase in concentration and a decrease in the surface area of the reactant particles.

26. Which of the following diagrams represents an exothermic reaction which is most likely to take place at room temperature?

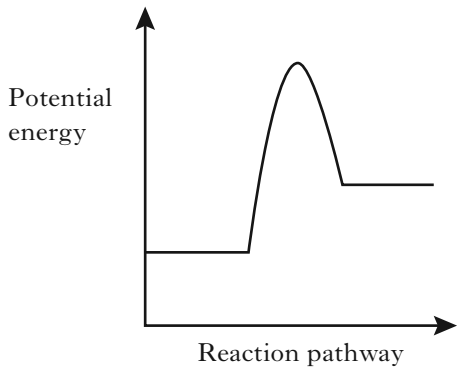
A



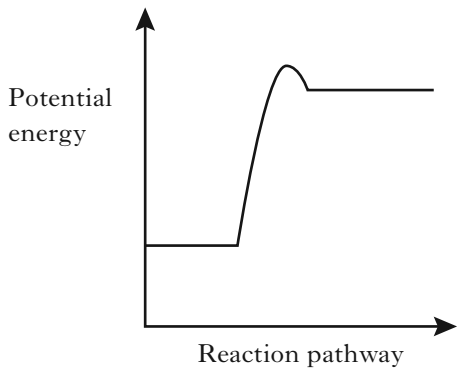
B



C



D



27. The enthalpy of combustion of methanol is $-727\ kJ\ mol^{-1}$.

What mass of methanol has to be burned to produce 72·7 kJ?

A 3·2 g

B 32 g

C 72·7 g

D 727 g

28.

$C(s) + H_2(g) + O_2(g) \rightarrow HCOOH(\ell)$ $\Delta H = a$

$HCOOH(\ell) + \frac{1}{2}O_2(g) \rightarrow CO_2(g) + H_2O(\ell)$ $\Delta H = b$

$C(s) + O_2(g) \rightarrow CO_2(g)$ $\Delta H = c$

$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(\ell)$ $\Delta H = d$

What is the relationship between a, b, c and d?

A $a = c + d - b$

B $a = b - c - d$

C $a = -b - c - d$

D $a = c + b + d$

29. 45 cm^3 of a solution could be most accurately measured out using a

A 50 cm^3 beaker

B 50 cm^3 burette

C 50 cm^3 pipette

D 50 cm^3 measuring cylinder.

30. Aluminium carbonate can be produced by the following reaction.

$2AlCl_3(aq) + 3K_2CO_3(aq) \rightarrow Al_2(CO_3)_3(s) + 6KCl(aq)$

The most suitable method for obtaining a sample of the aluminium carbonate is

A collection over water

B distillation

C evaporation

D filtration.

Candidates are reminded that the answer sheet MUST be returned INSIDE the front cover of this answer book.

[Turn over

DO NOT WRITE IN THIS MARGIN

Marks

SECTION B

All answers must be written clearly and legibly in ink.

1. Attempts have been made to make foods healthier by using alternatives to traditional cooking ingredients.

(*a*) An alternative to common salt contains potassium ions and chloride ions.

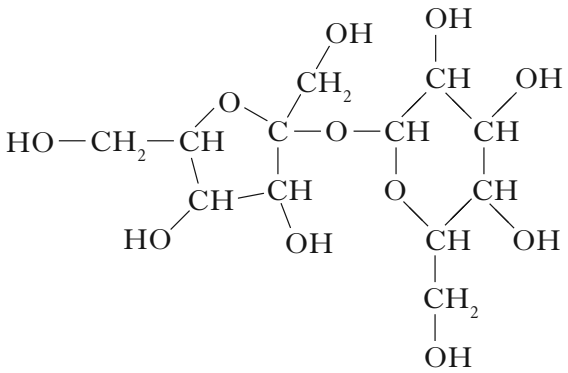
(i) Write an ion-electron equation for the first ionisation energy of potassium.

1

(ii) **Explain clearly** why the first ionisation energy of potassium is smaller than that of chlorine.

3

(*b*) A calorie-free replacement for fat can be made by reacting fatty acids with the hydroxyl groups on a molecule of sucrose. A structural formula for sucrose is shown.



How many fatty acid molecules can react with one molecule of sucrose?

1

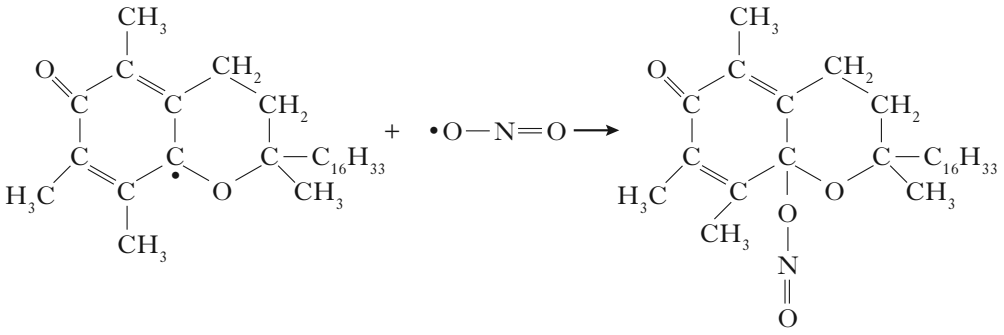
(5)

DO NOT WRITE IN THIS MARGIN

Marks

2. Suncreams contain antioxidants.

(*a*) The antioxidant, compound **A**, can prevent damage to skin by reacting with free radicals such as NO_2•.



Compound **A**

Why can compound **A** be described as a free radical scavenger in the reaction shown above?

1

(*b*) Another antioxidant used in skin care products is vitamin C, $C_6H_8O_6$.

Complete the ion-electron equation for the oxidation of vitamin C.

$$C_6H_8O_6(aq) \rightarrow C_6H_6O_6(aq)$$

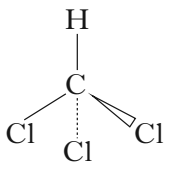
1

(2)

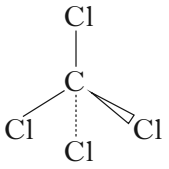
DO NOT WRITE IN THIS MARGIN

Marks

3. The structures below show molecules that contain chlorine atoms.



trichloromethane



tetrachloromethane

(*a*) The compounds shown above are not very soluble in water. Trichloromethane is around ten times more soluble in water than tetrachloromethane.

Explain clearly why trichloromethane is more soluble in water than tetrachloromethane.

Your answer should include the names of the intermolecular forces involved.

3

(*b*) Chloromethane can be produced by the reaction of methane with chlorine.

$$CH_4(g) + Cl_2(g) \rightarrow CH_3Cl(g) + HCl(g)$$

Using bond enthalpies from the data booklet, calculate the enthalpy change, in kJ mol^{-1}, for this reaction.

2

(5)

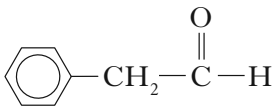
DO NOT WRITE IN THIS MARGIN

Marks

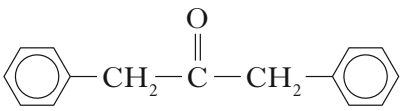
4. Chocolate contains various compounds.

(*a*) Many of the flavour and aroma molecules found in chocolate are aldehydes and ketones.

Two examples are shown below.



phenylethanal



1,3-diphenylpropan-2-one

Phenylethanal can be easily oxidised but 1,3-diphenylpropan-2-one cannot.

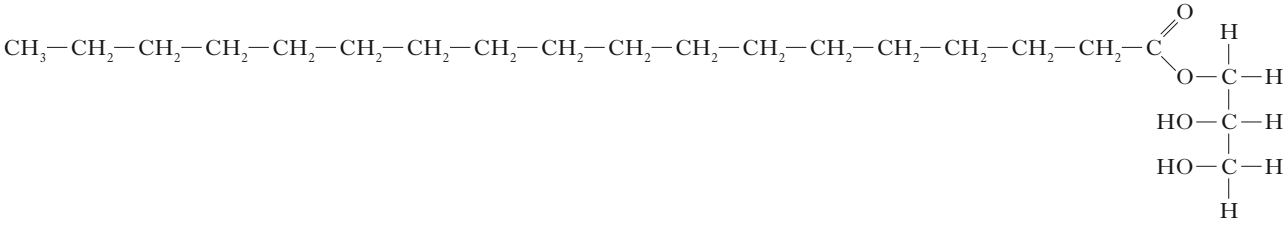
(i) Name a chemical that could be used to distinguish between these two compounds.

1

(ii) Name the type of organic compound formed when phenylethanal is oxidised.

1

(*b*) Glycerol monostearate is an emulsifier used in chocolate.



(i) Why is glycerol monostearate added to chocolate?

1

(ii) Draw a structural formula for glycerol.

1

Marks

4. (continued)

(*c*) Theobromine, a compound present in chocolate, can cause illness in dogs and cats.

To decide if treatment is necessary, vets must calculate the mass of theobromine consumed.

1·0 g of chocolate contains 1·4 mg of theobromine.

Calculate the mass, in mg, of theobromine in a 17 g biscuit of which 28% is chocolate.

Show your working clearly.

2

(*d*) The flavour and texture of chocolate comes from a blend of compounds.

Using your knowledge of chemistry, describe how you could show that there are ionic compounds and covalent compounds present in chocolate.

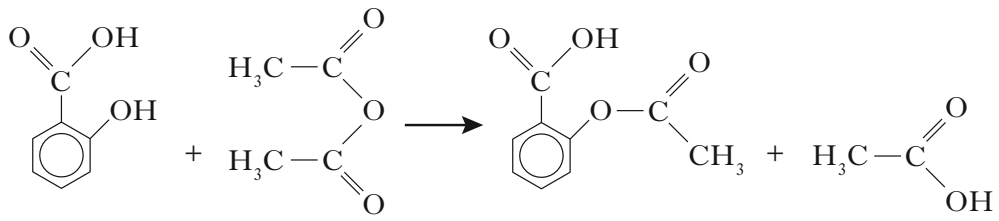
3

(9)

DO NOT WRITE IN THIS MARGIN

Marks

5. Aspirin, a common pain-killer, can be made by the reaction of salicylic acid with ethanoic anhydride.



$C_7H_6O_3$	$C_4H_6O_3$	$C_9H_8O_4$	$C_2H_4O_2$
salicylic acid	ethanoic anhydride	aspirin	ethanoic acid
mass of one mole = 138 g	mass of one mole = 102 g	mass of one mole = 180 g	mass of one mole = 60 g

(*a*) Calculate the atom economy for the formation of aspirin using this method.

Show your working clearly.

2

(*b*) In a laboratory preparation of aspirin, 5·02 g of salicylic acid produced 2·62 g of aspirin.

Calculate the percentage yield of aspirin.

Show your working clearly.

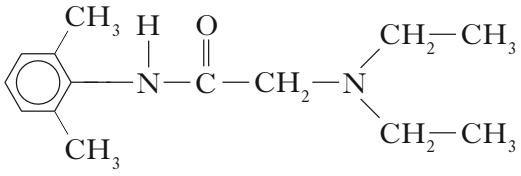
2

(4)

Marks

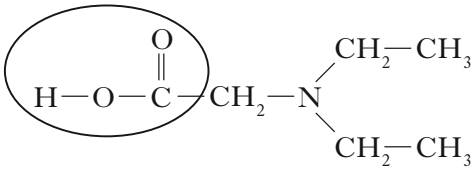
6. Dental anaesthetics are substances used to reduce discomfort during treatment.

(*a*) Lidocaine is a dental anaesthetic.



Lidocaine causes numbness when applied to the gums. This effect wears off as the lidocaine is hydrolysed.

One of the products of the hydrolysis of lidocaine is compound **C**.



compound **C**

(i) Name the functional group circled above.

1

(ii) Draw a structural formula for the other compound produced when lidocaine is hydrolysed.

1

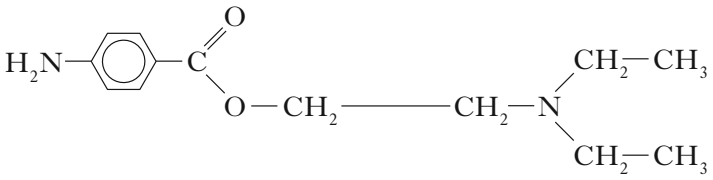
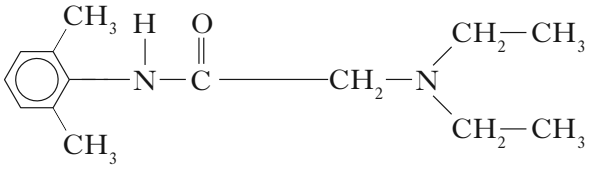
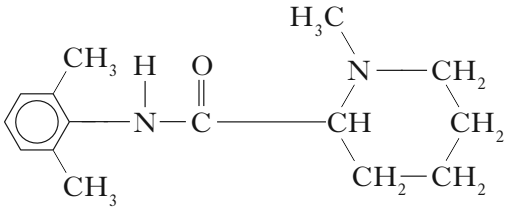
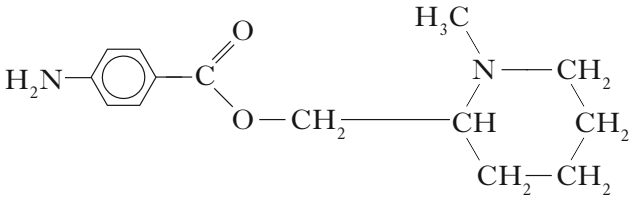
(iii) Draw a structural formula for the organic compound formed when compound **C** reacts with NaOH(aq).

1

Marks

6. (continued)

(*b*) The table below shows the duration of numbness for common anaesthetics.

Name of anaesthetic	Structure	Duration of numbness/ minutes
procaine		7
lidocaine		96
mepivacaine		114
anaesthetic **X**		

Estimate the duration of numbness, in minutes, for anaesthetic **X**.

1

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Marks

6. (continued)

(*c*) The maximum safe dose of lidocaine for an adult is 4·5 mg of lidocaine per kg of body mass.

$1{\cdot}0\ cm^3$ of lidocaine solution contains 10 mg of lidocaine.

Calculate the maximum volume of lidocaine solution that could be given to a 70 kg adult.

Show your working clearly.

3

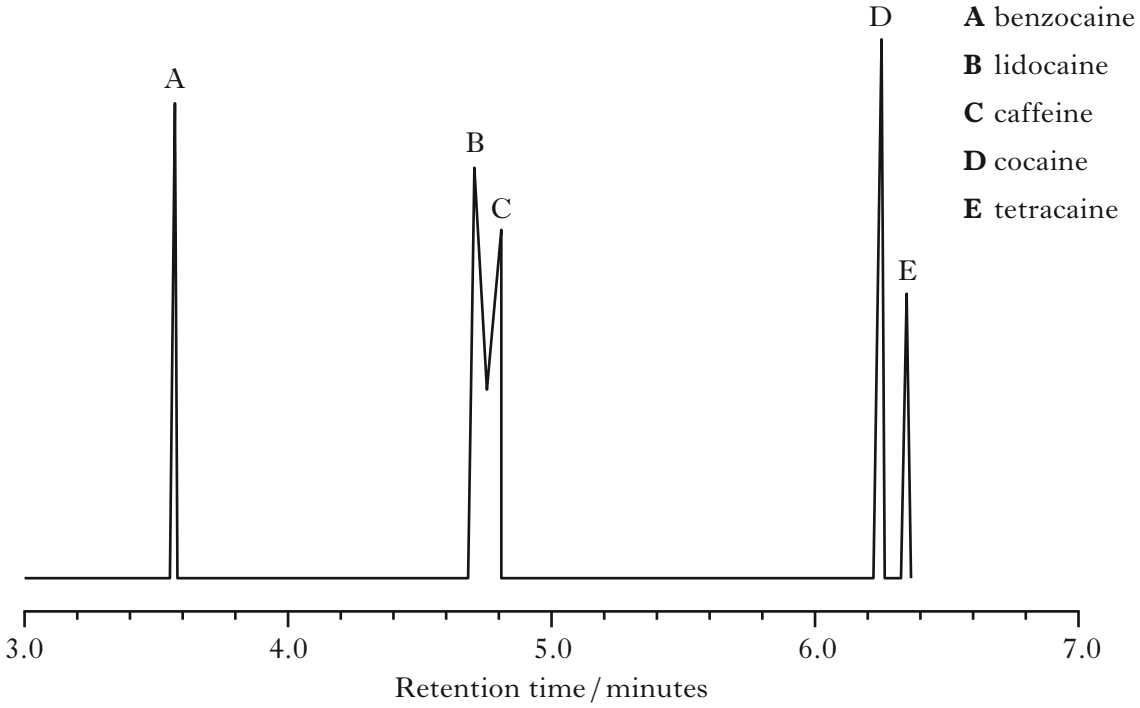
[Turn over

Marks

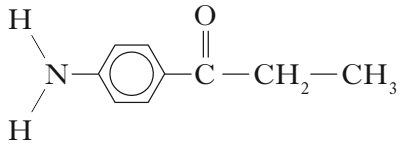
6. (continued)

(*d*) When forensic scientists analyse illegal drugs, anaesthetics such as lidocaine are sometimes found to be present.

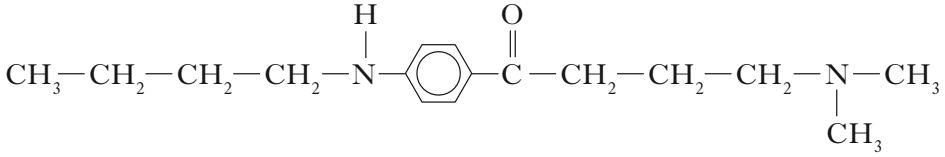
The gas chromatogram below is from an illegal drug.



(i) The structures of benzocaine and tetracaine are shown below.



benzocaine



tetracaine

Suggest why benzocaine has a shorter retention time than tetracaine.

1

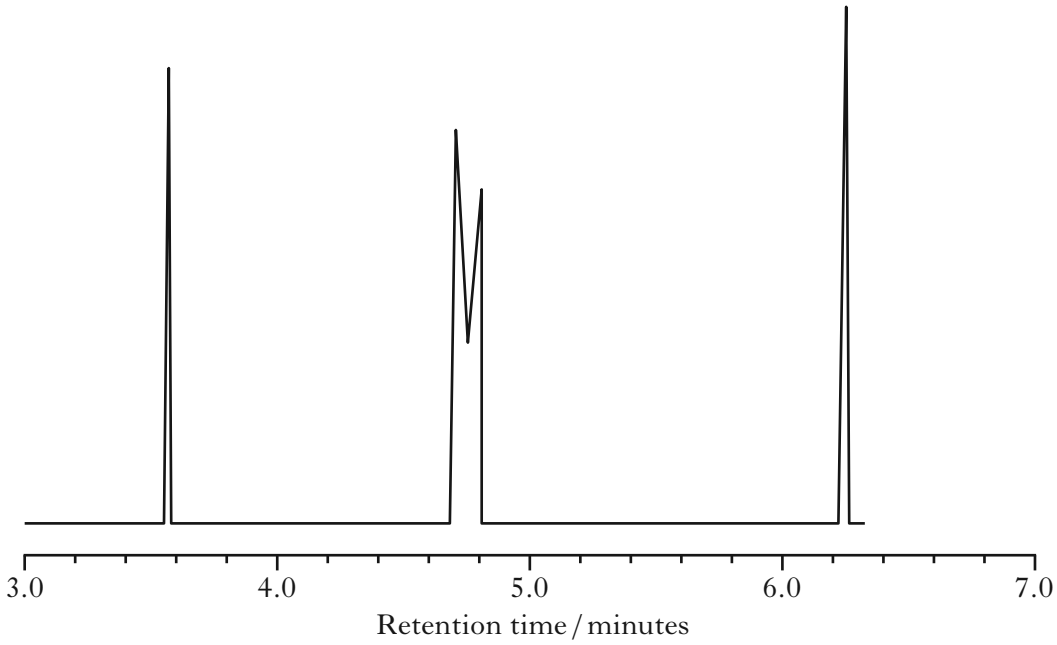
Marks

6. (*d*) (continued)

(ii) Why is it difficult to obtain accurate values for the amount of lidocaine present in a sample containing large amounts of caffeine?

1

(iii) Add a peak to the diagram below to complete the chromatogram for a second sample that only contains half the amount of tetracaine compared to the first.



1

(10)

[Turn over

DO NOT WRITE IN THIS MARGIN

Marks

7. Hydrogen sulfide is a toxic gas with the smell of rotten eggs.

(*a*) Hydrogen sulfide gas can be prepared by the reaction of iron(II) sulfide with excess dilute hydrochloric acid:

$$FeS(s) + 2HCl(aq) \rightarrow FeCl_2(aq) + H_2S(g)$$

(i) Hydrogen sulfide gas is very soluble in water.

Draw a diagram to show an assembled apparatus that could be used to measure the volume of H_2S gas produced when a sample of iron(II) sulfide reacts with hydrochloric acid.

Your diagram should be labelled and should show the names of any chemicals used.

2

(ii) Calculate the mass, in g, of iron(II) sulfide required to produce 79 cm^3 of hydrogen sulfide gas.

(Take the molar volume of hydrogen sulfide to be 24 litres mol^{-1}.)

Show your working clearly.

3

DO NOT WRITE IN THIS MARGIN

Marks

7. (continued)

(*b*) Hydrogen sulfide gas produced from iron(II) sulfide is often contaminated with hydrogen gas and gaseous arsenic compounds.

(i) Arsenic(III) sulfide is an orange-yellow powder which is insoluble in water. Below 310 °C it can sublime, turning from a solid to a gas.

Name the type of bonding and structure present in arsenic(III) sulfide.

1

(ii) To avoid these contaminants, hydrogen sulfide can be made by reacting aluminium sulfide with water. Hydrogen sulfide and aluminium hydroxide are produced.

Write a balanced equation for the production of hydrogen sulfide from aluminium sulfide and water.

2

(8)

[Turn over

DO NOT WRITE IN THIS MARGIN

Marks

8. Mobile phones are being developed that can be powered by methanol.

Methanol can be made by a two-stage process.

(*a*) In the first stage, methane is reacted with steam to produce a mixture of carbon monoxide and hydrogen.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$$

Use the data below to calculate the enthalpy change, in $kJ\,mol^{-1}$, for the forward reaction.

$CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$ $\quad \Delta H = -283\,kJ\,mol^{-1}$

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

$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$ $\quad \Delta H = -803\,kJ\,mol^{-1}$

Show your working clearly.

2

(*b*) In the second stage, the carbon monoxide and hydrogen react to produce methanol.

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

Circle the correct words in the table to show the changes to temperature and pressure that would favour the production of methanol.

(An additional table, if required, can be found on *Page thirty-four*.)

temperature	decrease / keep the same / increase
pressure	decrease / keep the same / increase

1

(3)

DO NOT WRITE IN THIS MARGIN

Marks

9. Dark blue compounds can be made by reacting ammonia with copper ions. To determine the number of ammonia molecules that react with each copper ion, a student prepared the following mixtures and measured their colour intensity.

Mixture	**A**	**B**	**C**	**D**	**E**	**F**
Volume of 0·1 mol l^{-1} Cu^{2+} solution, cm^3	7·5	5·0	2·5	2·0	1·5	1·0
Volume of 0·1 mol l^{-1} NH_3 solution, cm^3	2·5	5·0	7·5	8·0	8·5	
Colour intensity	0·61	1·23	1·83	1·96	1·47	0·98

(An additional table, if required, can be found on *Page thirty-four*.)

(*a*) Complete the table to show the volume of NH_3 solution required for the final experiment. **1**

(*b*) The number of ammonia molecules that react with each copper ion can be found from the mixture with the greatest colour intensity.

How many ammonia molecules react with each copper ion? **1**

(2)

[Turn over

DO NOT WRITE IN THIS MARGIN

Marks

10. Solutions containing iodine are used to treat foot rot in sheep.

The concentration of iodine in a solution can be determined by titrating with a solution of thiosulfate ions.

$$I_2 + \underset{\text{thiosulfate ions}}{2S_2O_3^{2-}} \rightarrow 2I^- + S_4O_6^{2-}$$

(*a*) Write an ion-electron equation for the reaction of the oxidising agent in the titration. **1**

(*b*) Three 20·0 cm^3 samples of a sheep treatment solution were titrated with 0·10 mol l^{-1} thiosulfate solution.

The results are shown below.

Sample	Volume of thiosulfate/cm^3
1	18·60
2	18·10
3	18·20

(i) Why is the volume of sodium thiosulfate used in the calculation taken to be 18·15 cm^3, although this is not the average of the three titres in the table? **1**

DO NOT WRITE IN THIS MARGIN

Marks

10. (*b*) (continued)

(ii) Calculate the concentration of iodine, in mol l^{-1}, in the foot rot treatment solution.

Show your working clearly.

3

(iii) Describe how to prepare 250 cm^3 of a 0·10 mol l^{-1} standard solution of sodium thiosulfate, $Na_2S_2O_3$.

Your answer should include the mass, in g, of sodium thiosulfate required.

3

(8)

DO NOT WRITE IN THIS MARGIN

Marks

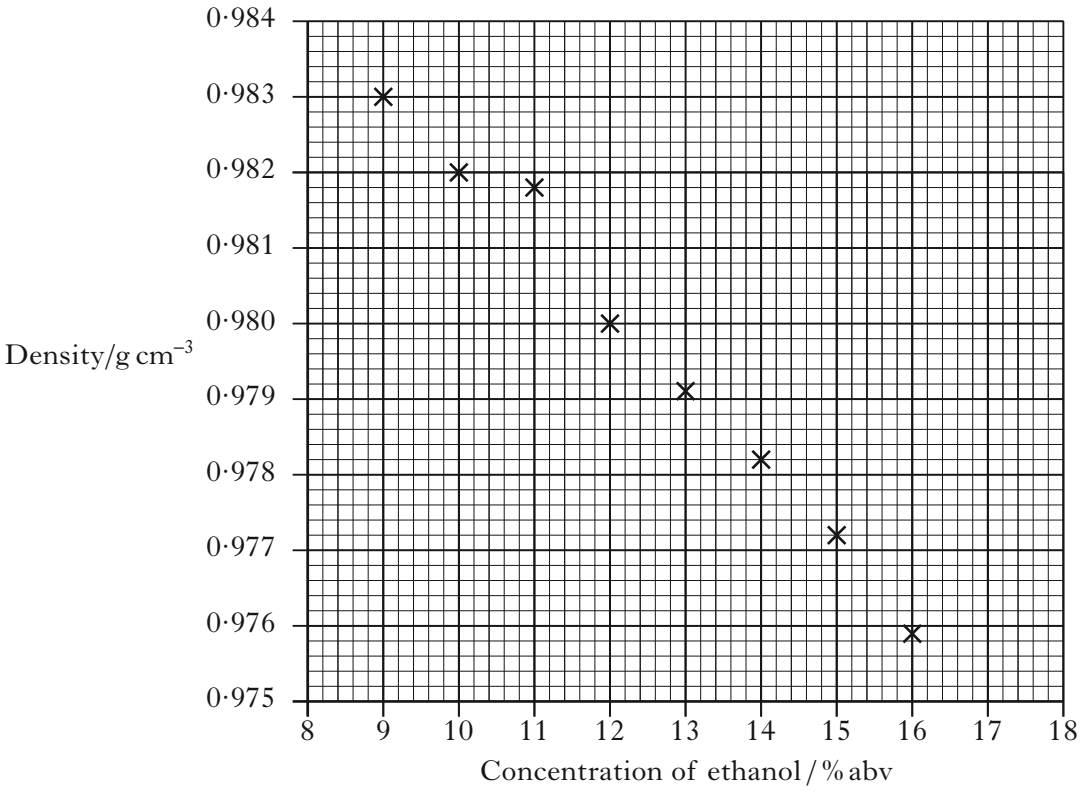
11. Ethanol has many uses.

(*a*) Ethanol is found at relatively low concentrations in wine.

(i) Name the chemical reaction that produces ethanol in wine.

1

(ii) Standard ethanol solutions were used to produce a graph of density against concentration of ethanol, given as a percentage of alcohol by volume (% abv).



What is the concentration of ethanol, in units of % abv, in a solution of density 0·9818 g cm^{-3}?

1

Marks

11. (continued)

(*b*) Whisky contains a higher concentration of ethanol.

(i) Before 1980, the concentration of alcohol in drinks was measured in terms of degrees proof.

The concentration of alcohol in two drinks is shown in the table below, both as % abv and degrees proof.

Sample	**Alcohol concentration / % abv**	**Alcohol concentration / degrees proof**
Wine	14·0	24·5
Sherry	20·0	35·0

A cask strength whisky has an alcohol concentration of 65% abv.

Calculate the alcohol concentration of this whisky in degrees proof.

1

(ii) A barrel containing 195 litres of cask strength whisky costs £1300.

The cask strength whisky is diluted with water to reduce the concentration of alcohol from 65% abv to 46% abv before it is bottled.

Calculate the cost of the cask strength whisky needed to produce a 0·70 litre bottle.

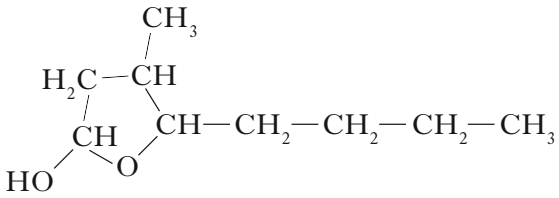
Show your working clearly.

2

Marks

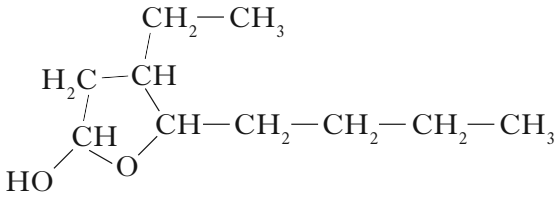
11. (*b*) (continued)

(iii) 5-Butyl-4-methyltetrahydrofuran-2-ol is a flavour compound found in whisky stored in oak barrels.



5-butyl-4-methyltetrahydrofuran-2-ol

Write the systematic name for the compound shown below.



1

(*c*) Ethanol, for use in industrial processes, can be produced by reacting ethene gas with steam.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g)$$

(i) What name is given to this type of chemical reaction?

1

(ii) What would happen to the equilibrium position if a catalyst was used?

1

(8)

DO NOT WRITE IN THIS MARGIN

Marks

12. Cooking involves many chemical reactions. Proteins, fats, oils and esters are some examples of compounds found in food. A chemist suggested that cooking food could change compounds from being fat-soluble to water-soluble.

Use your knowledge of chemistry to comment on the accuracy of this statement.

(3)

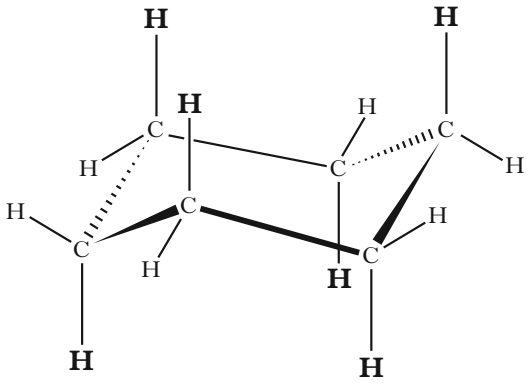
[Turn over

DO NOT WRITE IN THIS MARGIN

Marks

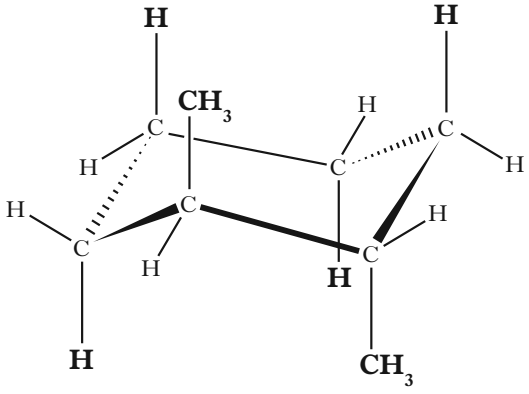
13. Cycloalkanes are found in nature.

A representation of cyclohexane is shown below.



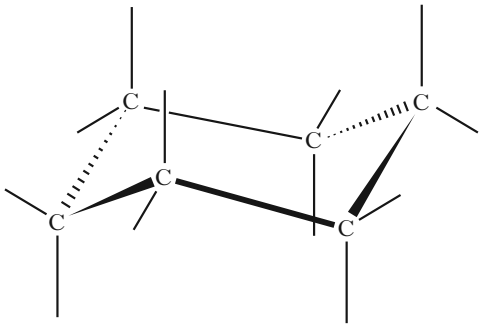
The six hydrogen atoms marked in **bold** are said to be in axial positions.

In the molecule of **1,2-**dimethylcyclohexane shown below, two methyl groups are in axial positions.



(*a*) Complete the structure shown below to show a molecule of **1,3-**dimethylcyclohexane in which both the methyl groups are in axial positions.

(An additional diagram, if required, can be found on *Page thirty-four*.)



1

Marks

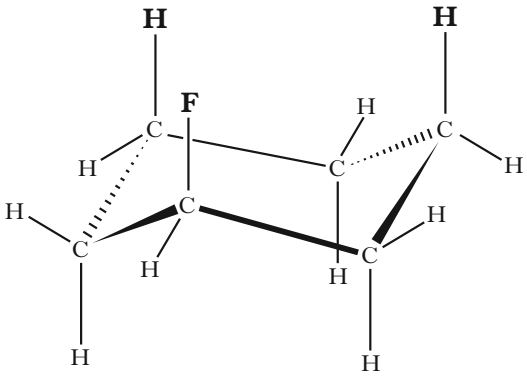
13. (continued)

(*b*) Axial groups **on the same side** of a cyclohexane ring can repel each other. The strength of the repulsion is known as the "steric strain".

The table below shows values which allow the steric strain to be calculated.

Axial groups	**Steric strain /kJ mol^{-1}**
H and H	0·0
H and F	0·5
H and Br	1·0
H and CH_3	3·8
H and $(CH_3)_3C$	11·4

For example:



Steric strain = 2 × (Steric strain between **H** and **F**)

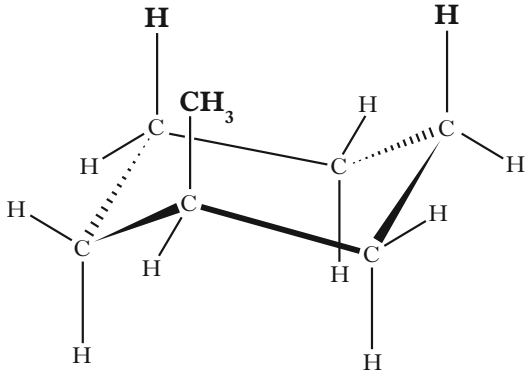
= 2 × 0·5

= 1·0 kJ mol^{-1}

(i) Write a general statement, linking the size of the steric strain to the type of axial group present.

1

(ii) Calculate, in kJ mol^{-1}, the steric strain for the molecule shown below.



Steric strain =

1

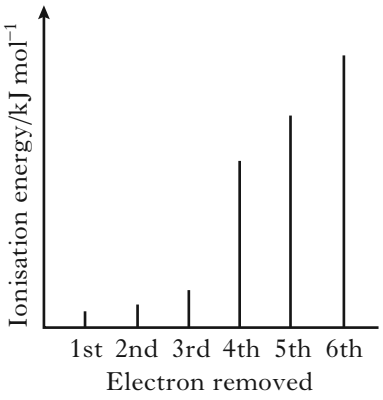
(3)

[*END OF QUESTION PAPER*]

2014

(revised)

1. The spike graph shows the variation in successive ionisation energies of an element, **Z**.



In which group of the Periodic Table is element **Z**?

A 1

B 3

C 4

D 6

2. For elements in Group 7 of the Periodic Table, which of the following statements is true as the group is descended?

A The boiling point decreases.

B The covalent radius decreases.

C The electronegativity decreases.

D The strength of London dispersion forces decreases.

3. Which of the following chlorides is likely to have **least** ionic character?

A $BeCl_2$

B $CaCl_2$

C LiCl

D CsCl

4. Which of the following elements would have the strongest London dispersion forces?

A Argon

B Chlorine

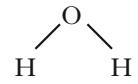
C Nitrogen

D Oxygen

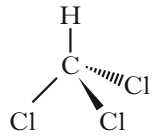
5. The shapes of some common molecules are shown below and each contains at least one polar bond.

Which molecule is non-polar?

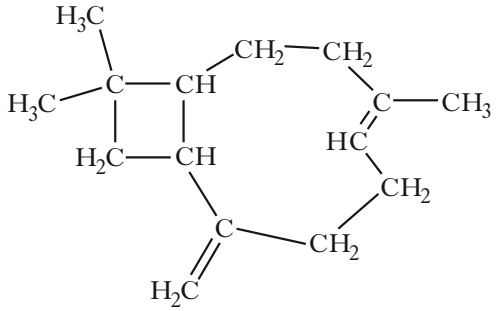
A O = C = O

B 

C H — Cl

D 

6. Caryophyllene is a natural product which can be extracted from clove oil using a solvent.



caryophyllene

Which of the following would be the best solvent for extracting caryophyllene?

A Hexane

B Hexanal

C Hexan-2-ol

D Hexan-3-one

7. Which of the following is the strongest oxidising agent?

A $Li^+(aq)$

B Li(s)

C $F^-(aq)$

D $F_2(g)$

8. Silver jewellery discoloured by tarnish (Ag_2S) can be cleaned by placing the item in an aluminium pot containing salt solution. The reaction occurring is shown below.

$3Ag_2S + 2Al \rightarrow 6Ag + Al_2S_3$

Which of the following statements is true?

A Aluminium metal is a reducing agent.

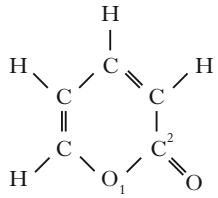
B Silver metal is an oxidising agent.

C Silver ions are acting as electron donors.

D Sulfide ions are acting as electron acceptors.

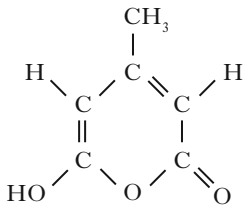
9. 4-Hydroxy-6-methyl-2-pyrone is a cyclic ester responsible for the smell of chocolate.

The number 2 identifies the position of the carbonyl group in the pyrone ring counting from the oxygen atom within the ring.

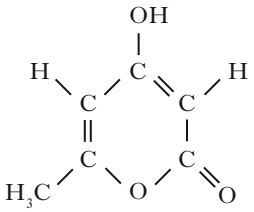


What is the structure of 4-hydroxy-6-methyl-2-pyrone?

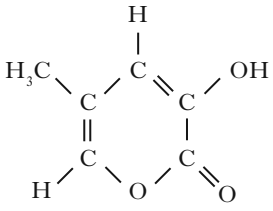
A



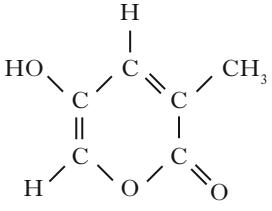
B



C



D



10. Which of the following consumer products is **least** likely to contain esters?

A Solvents

B Perfumes

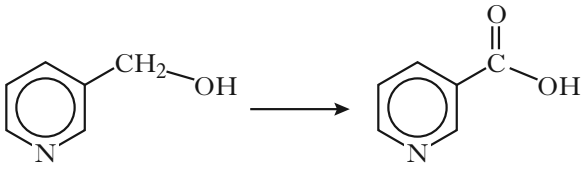
C Toothpastes

D Flavourings

11. Which line in the table shows correct functional groups for aldehydes and ketones and fats and oils?

	Aldehydes and ketones	**Fats and oils**
A	carbonyl	hydroxyl
B	carboxyl	hydroxyl
C	carboxyl	ester link
D	carbonyl	ester link

12. A step in the synthesis of nicotinic acid (vitamin B_3) is shown.



nicotinyl alcohol nicotinic acid

The type of reaction taking place in this step is

A hydration

B oxidation

C reduction

D condensation.

13. Which type of bond is broken when a protein is denatured?

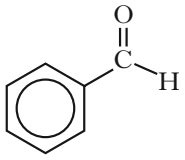
A Ionic

B Polar covalent

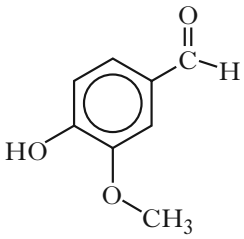
C Hydrogen

D Non-polar covalent

14. Benzaldehyde and vanillin are examples of flavour molecules.



benzaldehyde



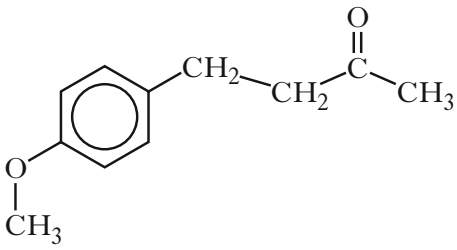
vanillin

Vanillin is soluble in water and is fairly volatile.

Which line in the table correctly compares benzaldehyde to vanillin?

	Solubility in water	**Relative volatility**
A	greater than vanillin	greater than vanillin
B	greater than vanillin	less than vanillin
C	less than vanillin	less than vanillin
D	less than vanillin	greater than vanillin

15. A compound with the following structure is used in perfumes to help provide a sweet, fruity fragrance.



This compound could be classified as

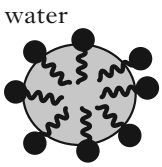
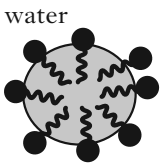
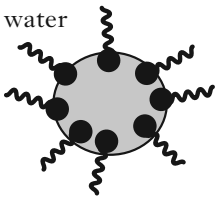
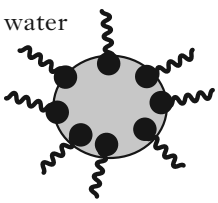
A an aldehyde

B a carboxylic acid

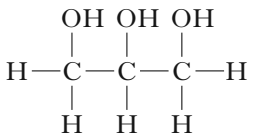
C an ester

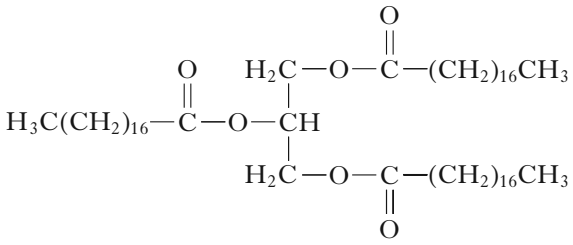
D a ketone.

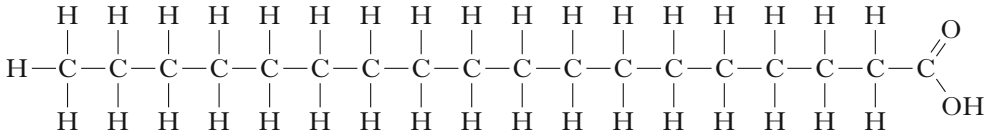
16. Which of the following diagrams and explanations best describes a step in the cleansing action of soap?

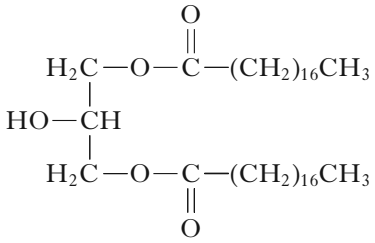
	Diagram	**Explanation**
A		Hydrophobic head dissolves in water. Hydrophilic tail dissolves in oil droplet.
B		Hydrophilic head dissolves in water. Hydrophobic tail dissolves in oil droplet.
C		Hydrophobic head dissolves in oil droplet. Hydrophilic tail dissolves in water.
D		Hydrophilic head dissolves in oil droplet. Hydrophobic tail dissolves in water.

17. Which of the following could act as an emulsifier?

A 

B 

C 

D 

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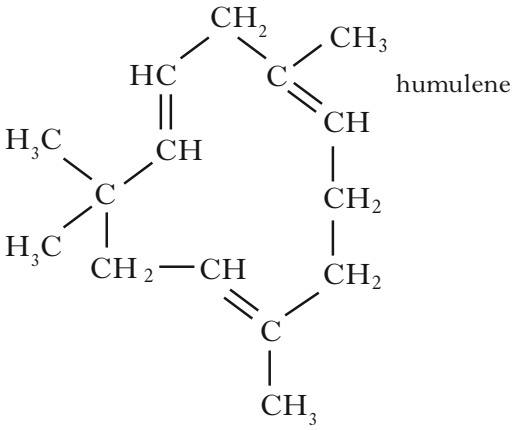
18. Humulene is a terpene which contributes to the aroma of beer.



humulene

How many isoprene units were used to form a humulene molecule?

A 2

B 3

C 4

D 5

19. Which of the following gases has the same volume as 128·2 g of sulfur dioxide?

(All volumes are measured under the same conditions of temperature and pressure)

A 2·0 g hydrogen

B 8·0 g helium

C 32·0 g oxygen

D 80·8 g of neon.

20. Which line in the table describes dynamic equilibrium?

	Concentration of reactants and products	**Forward and reverse reaction rates**
A	constant	equal
B	constant	not equal
C	not constant	equal
D	not constant	not equal

21. The following reaction takes place in a blast furnace:

$CO_2(g) + C(s) \rightleftharpoons 2CO(g) \quad \Delta H = +174\,kJ\ mol^{-1}$

Which conditions of pressure and temperature would favour the production of carbon monoxide?

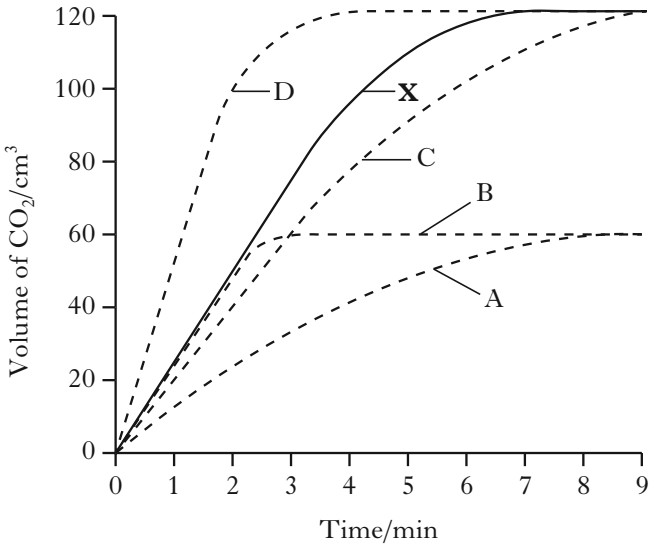
A Low pressure and low temperature

B High pressure and low temperature

C Low pressure and high temperature

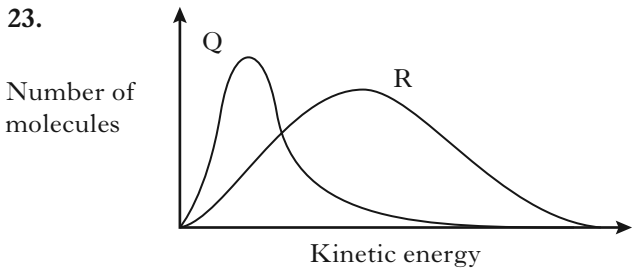
D High pressure and high temperature

22. Graph **X** was obtained when 1 g of calcium carbonate powder reacted with excess dilute hydrochloric acid at 20 °C.



Which curve would best represent the reaction of 0·5 g lump calcium carbonate with excess of the same dilute hydrochloric acid?

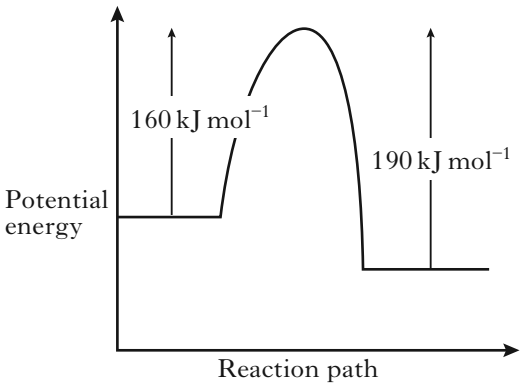
23.



Which line in the table is correct for curves **Q** and **R** in the above graph?

	Curve Q	**Curve R**
A	1 mol of O_2 at 50 °C	2 mol of O_2 at 100 °C
B	1 mol of O_2 at 100 °C	2 mol of O_2 at 100 °C
C	2 mol of O_2 at 50 °C	1 mol of O_2 at 100 °C
D	2 mol of O_2 at 100 °C	1 mol of O_2 at 100 °C

24.



When a catalyst is used, the activation energy of the forward reaction is reduced to 35 kJ mol^{-1}.

What is the activation energy of the catalysed reverse reaction?

A 30 kJ mol^{-1}

B 35 kJ mol^{-1}

C 65 kJ mol^{-1}

D 190 kJ mol^{-1}

[Turn over

25. Excess iron was added to 100 cm^3 of 1·0 $mol\,l^{-1}$ copper(II) sulfate solution releasing 3·1 kJ of energy.

$Fe(s) + CuSO_4(aq) \rightarrow Cu(s) + FeSO_4(aq)$

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

A −0·31

B −3·1

C −31

D −310

26. The enthalpy of combustion of an alcohol is always the enthalpy change for

A the alcohol burning in 1 mole of oxygen

B the alcohol burning to produce 1 mole of water

C 1 mole of the alcohol burning completely in oxygen

D 1 mole of the alcohol burning to produce 1 mole of carbon dioxide.

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

$C(diamond) + O_2(g) \rightarrow CO_2(g) \quad \Delta H = -395\,kJ\,mol^{-1}$

What is the enthalpy change, in $kJ\,mol^{-1}$, for the conversion of one mole of graphite into one mole of diamond?

A +789

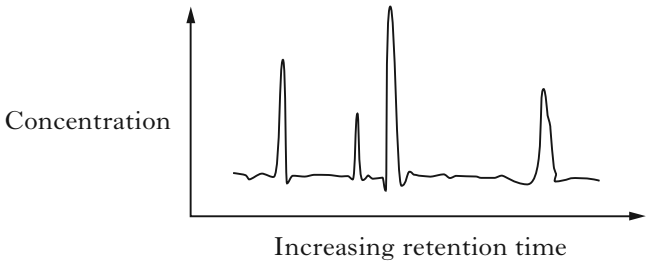
B +1

C −1

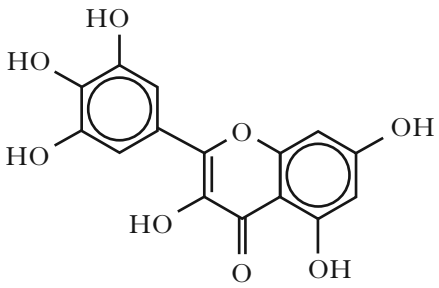
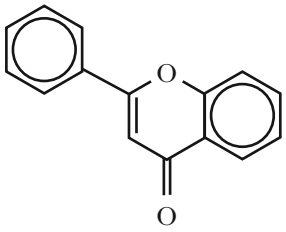
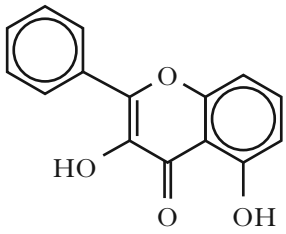
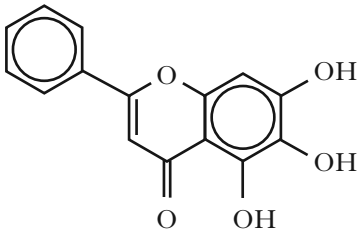
D −789

28. A chemist analysed a mixture of four dyes A, B, C and D using gas-liquid chromatography.

When a polar column was used the following chromatogram was obtained.



Which of the following compounds was present in greatest concentration?

Dye	Structure
A	
B	
C	
D	

29. The correct method of filling a $20\,cm^3$ pipette is to draw the liquid into the pipette

A doing it slowly at the end, until the top of the meniscus touches the mark

B doing it slowly at the end, until the bottom of the meniscus touches the mark

C to above the mark and then release liquid from the pipette until the top of the meniscus touches the mark

D to above the mark and then release liquid from the pipette until the bottom of the meniscus touches the mark.

30. A $0{\cdot}10\ mol\ l^{-1}$ solution could be prepared most accurately from a $1{\cdot}0\ mol\ l^{-1}$ solution using

A a $1\,cm^3$ dropping pipette and a $10\,cm^3$ measuring cylinder

B a $10\,cm^3$ measuring cylinder and a $100\,cm^3$ volumetric flask

C a $25\,cm^3$ pipette and a $250\,cm^3$ volumetric flask

D a $50\,cm^3$ burette and a $500\,cm^3$ measuring cylinder.

Candidates are reminded that the answer sheet MUST be returned INSIDE the front cover of this answer book.

[Turn over

DO NOT WRITE IN THIS MARGIN

Marks

SECTION B

All answers must be written clearly and legibly in ink.

1. Information about four elements from the third period of the Periodic Table is shown in the table.

Element	aluminium	silicon	phosphorus	sulfur
Bonding		covalent		covalent
Structure	lattice		molecular	

(*a*) Complete the table to show the bonding and structure for each element. **2**

(*b*) Why is there a decrease in the size of atoms across the period from aluminium to sulfur? **1**

(*c*) Argon is also in the third period. Argon is a very useful gas and each year 750 000 tonnes of argon are extracted from liquid air.

(i) Suggest how argon could be extracted from liquid air. **1**

(ii) Air contains 1·3% argon by mass. Calculate the mass of liquid air needed to obtain 750 000 tonnes of argon. **1**

(iii) Argon is used in the manufacture of magnesium powder. A jet of liquid argon is blown at a stream of molten magnesium producing fine droplets of metal. These cool to form the powder.

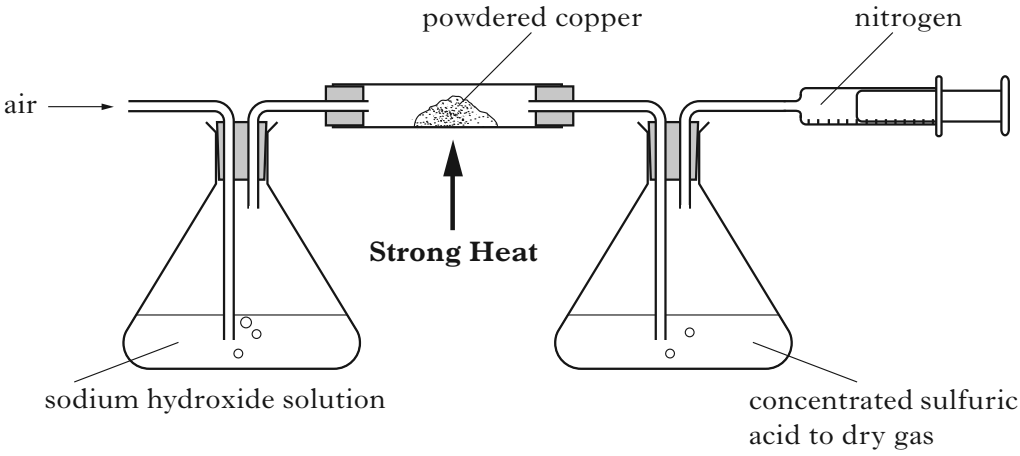
Why can liquid air not be used to make magnesium powder? **1**

1. (*c*) continued

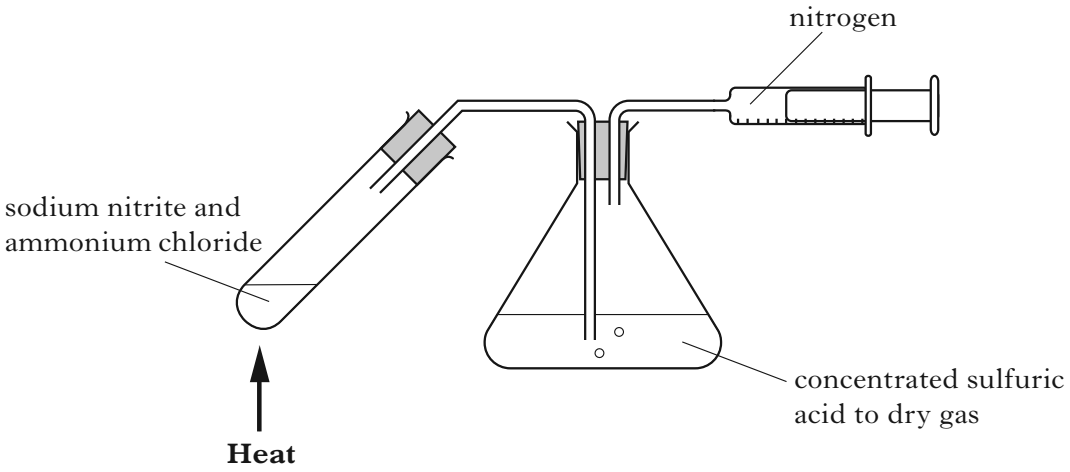
(iv) Argon was discovered in 1890's when samples of nitrogen prepared by different methods were compared. The element name was derived from the Greek *argos*, which means "lazy one".

Two samples of nitrogen can be prepared as shown.

Method 1 Removing carbon dioxide and oxygen from the air.



Method 2 Reaction of sodium nitrite with ammonium chloride.



$$NaNO_2(s) + NH_4Cl(s) \rightarrow NaCl(s) + N_2(g) + 2H_2O(\ell)$$

Heated magnesium metal can react with nitrogen gas to give magnesium nitride.

$$3Mg(s) + N_2(g) \rightarrow Mg_3N_2(s)$$

DO NOT WRITE IN THIS MARGIN

Marks

1. (*c*) continued

Using your knowledge of chemistry, comment on the discovery and naming of argon.

3

(9)

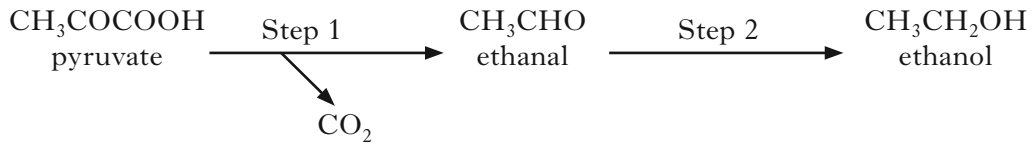
[Turn over

DO NOT WRITE IN THIS MARGIN

Marks

2. (*a*) In some countries, ethanol is used as a substitute for petrol. This ethanol is produced by fermentation of glucose, using yeast enzymes.

During the fermentation process, glucose is first converted into pyruvate. The pyruvate is then converted to ethanol in a two-step process.



(i) **Step 1** is catalysed by an enzyme. Enzymes are proteins that can act as catalysts because they have a specific shape.

Why, when the temperature is raised above a certain value, does the rate of reaction decrease?

1

(ii) Why can Step 2 be described as a reduction reaction?

1

(iii) The overall equation for the fermentation of glucose is

$C_6H_{12}O_6$	$\rightarrow$	$2C_2H_5OH$	+	$2CO_2$
mass of one mole = 180 g		mass of one mole = 46 g		

Calculate the percentage yield of ethanol if 445 g of ethanol is produced from 1·0 kg of glucose.

Show your working clearly

3

Marks

2. (continued)

(*b*) The energy density value of a fuel is the energy released when one kilogram of the fuel is burned.

The enthalpy of combustion of ethanol is $-1367\ kJ\ mol^{-1}$.

Calculate the energy density value, in $kJ\ kg^{-1}$, of ethanol.

1

(*c*) The quantity of alcohol present after a fermentation reaction is called the % alcohol by volume.

This can be calculated from measurements taken using an instrument called a hydrometer. The hydrometer is floated in the liquid sample, before and after fermentation, to measure its specific gravity.

% alcohol by volume = change in specific gravity of liquid x ***f***

where ***f*** is a conversion factor, which varies as shown in the table.

Change in specific gravity of liquid	***f***
Up to 6·9	0·125
7·0 – 10·4	0·126
10·5 – 17·2	0·127
17·3 – 26·1	0·128
26·2 – 36·0	0·129
36·1 – 46·5	0·130
46·6 – 57·1	0·131

The hydrometer readings taken for a sample are shown on *Page sixteen*.

[Turn over

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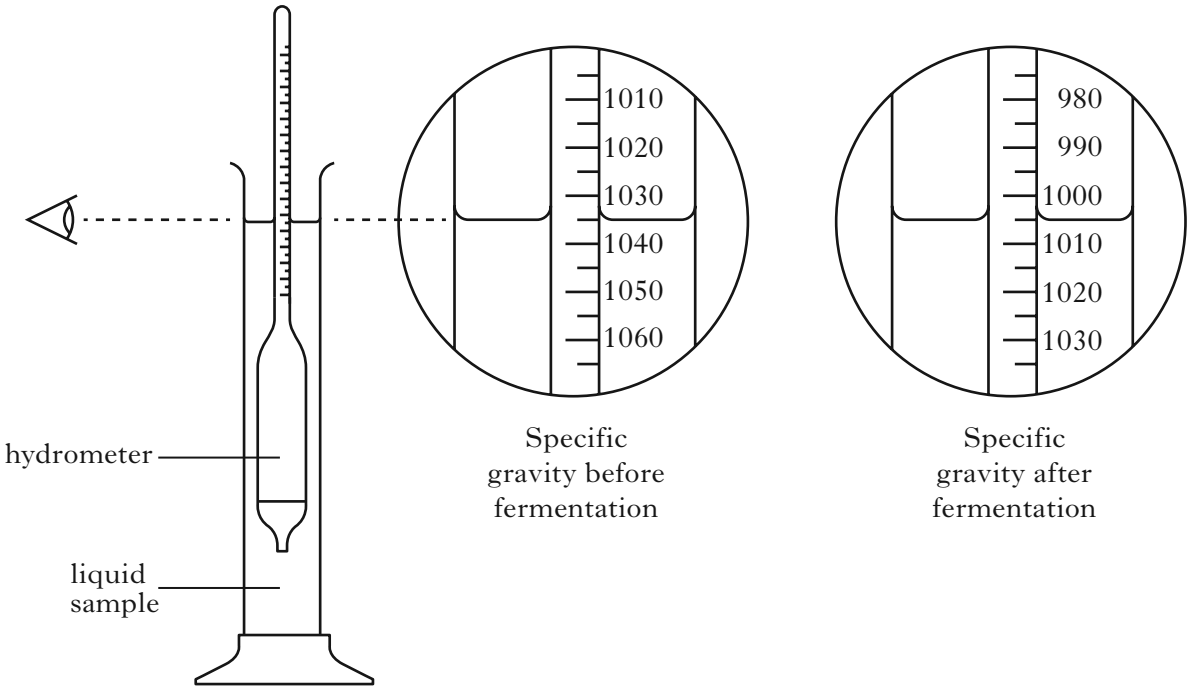
Marks

2. (*c*) continued



Calculate the % alcohol by volume for this sample.

2

(8)

Marks

3. (*a*) Hydrogen and fluorine can react explosively to form hydrogen fluoride gas.

The equation for the reaction is shown.

$$H_2(g) + F_2(g) \rightarrow 2HF(g)$$

Using bond enthalpy values from the data booklet, calculate the enthalpy change for this reaction.

2

(*b*) The boiling point of hydrogen fluoride, HF, is much higher than the boiling point of F_2.

H — F	F — F
boiling point: 19·5 °C	boiling point: −188 °C

Explain fully why the boiling point of hydrogen fluoride is much higher than the boiling point of fluorine.

In your answer you should mention the intermolecular forces involved and how they arise.

3

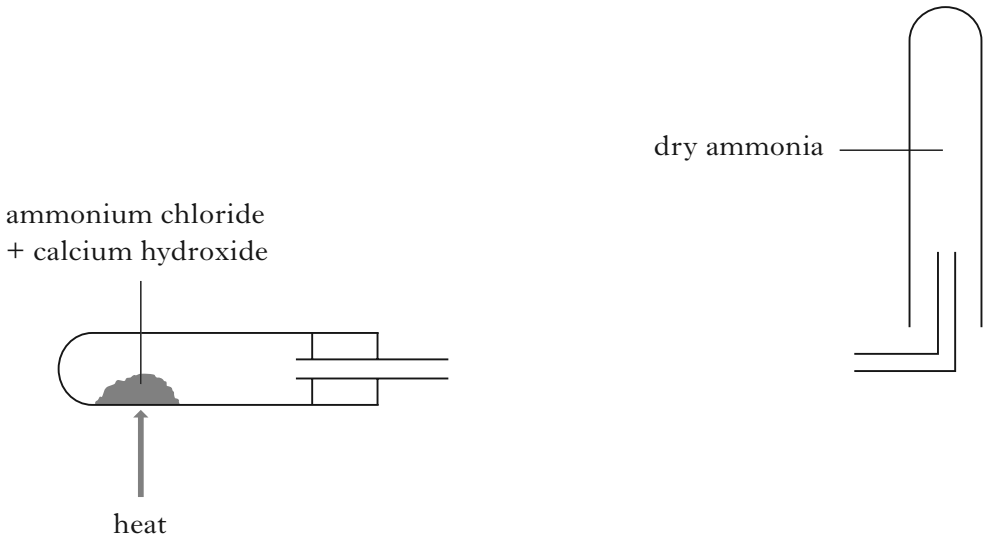
(5)

Marks

4. (*a*) A small sample of ammonia can be prepared in the laboratory by heating a mixture of ammonium chloride and calcium hydroxide. The ammonia is dried by passing it through small lumps of calcium oxide and collected by the downward displacement of air.

Complete the diagram to show how ammonia gas can be dried before collection.

(An additional diagram, if required, can be found on *Page thirty-six*.)

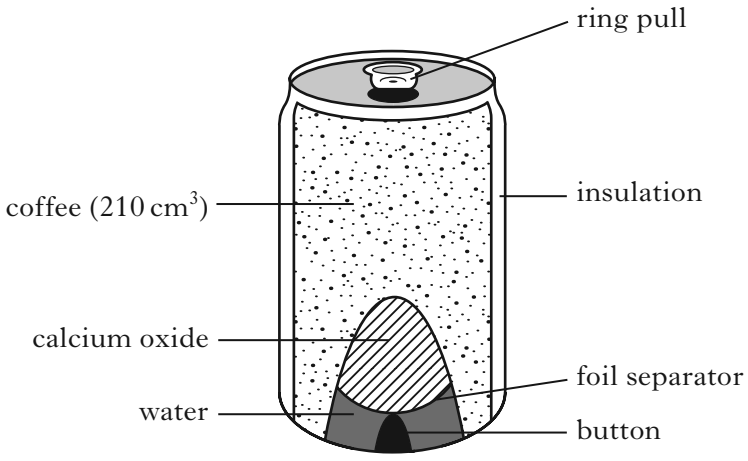


1

(*b*) Self-heating cans may be used to warm drinks such as coffee.

When the button on the can is pushed, a seal is broken, allowing water and calcium oxide to mix and react.

The reaction produces solid calcium hydroxide and releases heat.



The equation for this reaction is:

$$CaO(s) + H_2O(\ell) \rightarrow Ca(OH)_2(s) \qquad \Delta H = -65\ kJ\ mol^{-1}$$

Marks

4. (*b*) continued

(i) Calculate the mass, in grams, of calcium oxide required to raise the temperature of 210 cm^3 of coffee from 20 °C to 70 °C.

Show your working clearly.

3

(ii) If more water is used the calcium hydroxide is produced as a solution instead of as a solid.

The equation for the reaction is:

$$CaO(s) + H_2O(\ell) \rightarrow Ca(OH)_2(aq)$$

Using the following data, calculate the enthalpy change, in kJ mol^{-1}, for this reaction.

$Ca(s) + \frac{1}{2}O_2(g) \rightarrow CaO(s)$ $\quad \Delta H = -635\,kJ\ mol^{-1}$

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

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

$Ca(OH)_2(s) \rightarrow Ca(OH)_2(aq)$ $\quad \Delta H = -82\,kJ\ mol^{-1}$

Show your working clearly.

2

(6)

Marks

5. Some fruit drinks claim to be high in antioxidants such as vitamin C.

(*a*) The vitamin C content in a fruit drink can be determined by titrating it with iodine.

The redox reaction which takes place is shown.

$$\underset{\text{vitamin C}}{C_6H_8O_6(aq)} + I_2(aq) \rightarrow C_6H_6O_6(aq) + 2H^+(aq) + 2I^-(aq)$$

(i) Write the ion-electron equation for the oxidation reaction taking place.

1

(ii) Some students carried out an investigation of fruit drinks to determine their vitamin C content. The following steps were followed in each experiment.

Step 1 A 20·0 cm^3 sample of fruit drink was transferred to a conical flask by pipette.

Step 2 A burette was filled with a standard iodine solution.

Step 3 The fruit drink sample was titrated with the iodine.

Step 4 Titrations were repeated until concordant results were obtained.

The burette, pipette and conical flask were all rinsed before they were used.

Tick the appropriate boxes below to show which solution should be used to rinse each piece of glassware.

Glassware used	**Rinse with water**	**Rinse with iodine**	**Rinse with fruit drink**
pipette			
burette			
conical flask			

2

DO NOT WRITE IN THIS MARGIN

Marks

5. (*a*) continued

(iii) Titrating a whole carton of fruit drink would require large volumes of iodine solution.

Apart from this disadvantage, give another reason for titrating several smaller samples of fruit drink.

1

(iv) An average of $25{\cdot}4\,cm^3$ of $0{\cdot}00125\ mol\,l^{-1}$ iodine solution was required for the complete titration of the vitamin C in a $20{\cdot}0\,cm^3$ sample of fruit drink.

Calculate the mass, in grams, of vitamin C in the 1 litre carton of fruit drink.

(mass of 1 mole vitamin C = 176 g)

Show your working clearly.

3

(*b*) The recommended daily allowance (RDA) for vitamin C is 60 mg.

A one litre carton of an orange fruit drink contains 240 mg of vitamin C.

What percentage of the RDA is provided by $200\,cm^3$ of this drink?

2

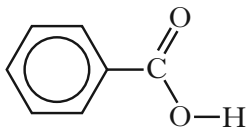
(9)

[Turn over

DO NOT WRITE IN THIS MARGIN

Marks

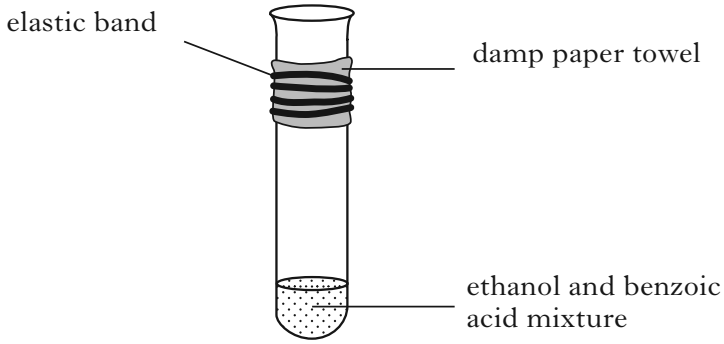
6. Benzoic acid, C_6H_5COOH, is an important feedstock in the manufacture of chemicals used in the food industry.



benzoic acid

(*a*) The ester ethyl benzoate is used as food flavouring.

Ethyl benzoate can be prepared in the laboratory by an esterification reaction. A mixture of ethanol and benzoic acid is heated, with a few drops of concentrated sulfuric acid added to catalyse the reaction.



(i) Suggest a suitable method for heating the reaction mixture.

1

(ii) During esterification the reactant molecules join by eliminating a small molecule. What name is given to this type of chemical reaction?

1

(iii) Draw a structural formula for ethyl benzoate.

1

DO NOT WRITE IN THIS MARGIN

Marks

6. (continued)

(*b*) Sodium benzoate is used in the food industry as a preservative. It can be made by reacting benzoic acid with a concentrated solution of sodium carbonate.

$2C_6H_5COOH$	+	Na_2CO_3	→	$2C_6H_5COONa$	+	CO_2	+	H_2O
mass of 1 mole = 122 g		mass of 1 mole = 106 g		mass of 1 mole = 144 g		mass of 1 mole = 44 g		mass of 1 mole = 18 g

Calculate the atom economy for the production of sodium benzoate.

2

(5)

[Turn over

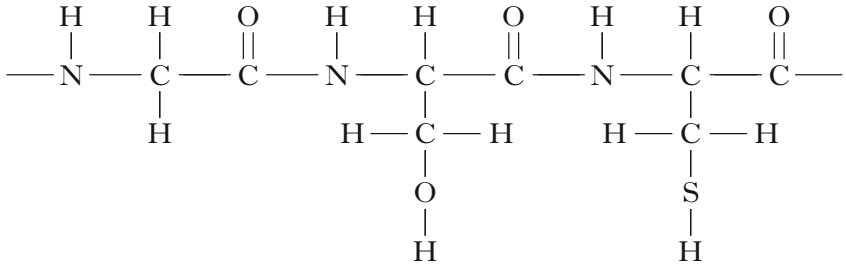
DO NOT WRITE IN THIS MARGIN

Marks

7. Proteins are made from monomers called amino acids.

Human hair is composed of long strands of a protein called keratin.

(*a*) Part of the structure of a keratin molecule is shown.

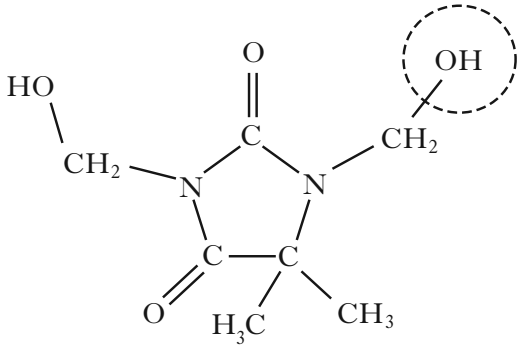


Circle a peptide link in the structure. **1**

(*b*) Hair products contain a large variety of different chemicals.

Chemicals called hydantoins are used as preservatives in shampoos to kill any bacteria.

A typical hydantoin is shown.



Name the functional group circled.

1

(*c*) Some hair conditioners contain the fatty acid, behenic acid, $CH_3(CH_2)_{19}CH_2COOH$.

Behenic acid is produced by hydrolysing the edible oil, ben oil.

(i) Name the compound, other than fatty acids, which is produced by hydrolysing the edible oil, ben oil.

1

DO NOT WRITE IN THIS MARGIN

Marks

7. (*c*) (continued)

(ii) 5·0 g of behenic acid can be obtained from 50·0 cm^3 of ben oil.

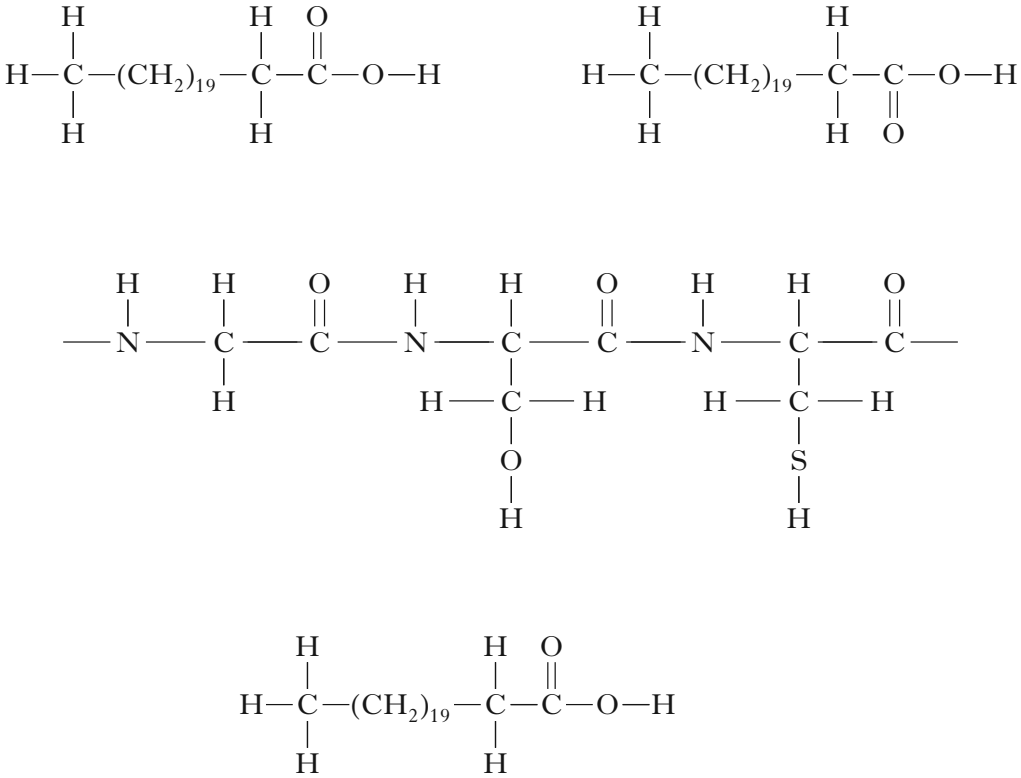
1 litre of ben oil costs £90.

How much would it cost to buy sufficient ben oil to produce 20·0 g of behenic acid?

1

(iii) When conditioner containing behenic acid is applied to hair, the behenic acid molecules make strong intermolecular hydrogen bonds to the keratin protein molecules.

On the diagram below use a dotted line to show **one** hydrogen bond that could be made between a behenic acid molecule and the keratin.



1

Marks

7. (continued)

(*d*) Blocked drains can be very unpleasant. Common causes of blocked drains in homes are fats, hair and food waste.

Using your knowledge of chemistry, comment on chemical methods that might be used to unblock drains.

3

(8)

DO NOT WRITE IN THIS MARGIN

Marks

8. (*a*) Carbon monoxide gas is produced as a result of the incomplete combustion of fuels.

The amount of carbon monoxide in the atmosphere is controlled by a series of free radical reactions.

(i) What is meant by the term *free radical*?

1

(ii) Why do free radicals form in the atmosphere?

1

(iii) The equation shows one of the steps in the free radical chain reaction which controls the level of carbon monoxide.

$$CO + HO\bullet \rightarrow CO_2 + H\bullet$$

What term describes this type of step in the free radical chain reaction

1

(*b*) Carbon monoxide can be used to produce the gas tricarbon dioxide, C_3O_2, a substance used to bind dyes to natural fur.

Draw a structural formula for tricarbon dioxide.

1

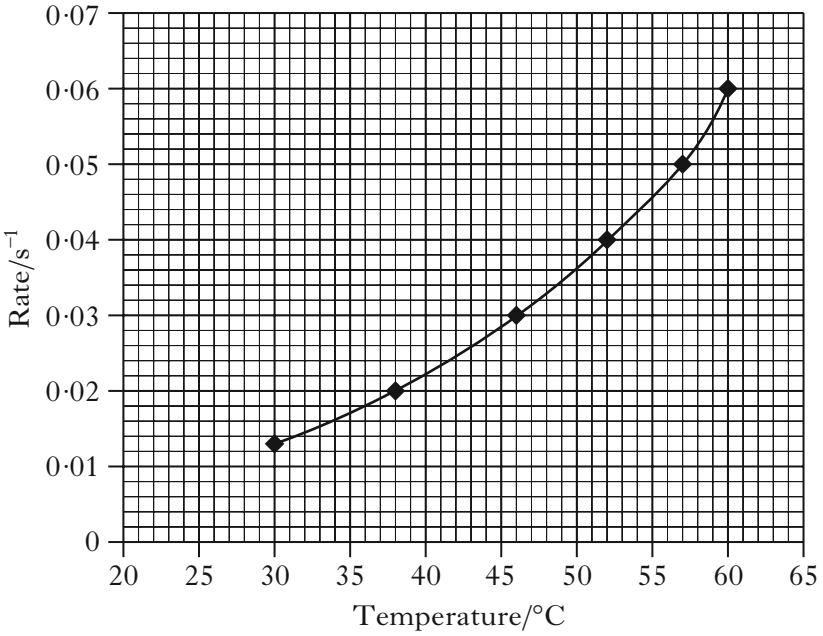
(4)

DO NOT WRITE IN THIS MARGIN

Marks

9. A student investigated the effect of changing temperature on the rate of chemical reaction.

The results from the investigation are shown in the graph below.



(*a*) Use the graph to determine the temperature rise required to double the rate of reaction.

1

(*b*) Collision theory can be used to explain reaction rates.

Collision theory states that for two molecules to react, they must first collide with one another.

State **two** conditions necessary for the collisions to result in the formation of products.

2

(3)

DO NOT WRITE IN THIS MARGIN

10. The table shows the boiling points of some alcohols.

Alcohol	Boiling point/°C
$CH_3CH_2CH_2CH_2OH$	118
$CH_3CH_2CH(OH)CH_3$	98
$CH_3CH(CH_3)CH_2OH$	108
$CH_3CH_2CH_2CH_2CH_2OH$	137
$CH_3CH_2CH_2CH(OH)CH_3$	119
$CH_3CH_2CH(CH_3)CH_2OH$	128
$CH_3CH_2C(OH)(CH_3)CH_3$	101
$CH_3CH_2CH_2CH_2CH_2CH_2OH$	159
$CH_3CH_2CH_2CH(CH_3)CH_2OH$	149
$CH_3CH_2CH_2C(OH)(CH_3)CH_3$	121

Marks

(*a*) Using information from the table, describe **two** ways in which differences in the structures affect boiling point of **isomeric alcohols**.

2

(*b*) Predict a boiling point for hexan-2-ol.

1

(3)

DO NOT WRITE IN THIS MARGIN

Marks

11. Some types of steel contain manganese.

The manganese content of a steel can be determined by converting the manganese into permanganate ions.

The steel is reacted with nitric acid giving manganese ions in solution. These are converted into permanganate ions by reaction with periodate ions.

$Mn(s) \rightarrow Mn^{2+}(aq) \rightarrow MnO_4^-(aq)$

During the reaction the periodate ions, $IO_4^-(aq)$, are reduced to iodate ions, $IO_3^-(aq)$.

(*a*) Complete the ion-electron equation for this reduction reaction -

$IO_4^-(aq) \rightarrow IO_3^-(aq)$ **1**

(*b*) When light is shone through a permanganate solution some of the light is absorbed.

The concentration of a permanganate solution can be found by measuring the amount of light absorbed and comparing this with the light absorbed by solutions of known concentration.

(i) To obtain solutions of known concentration a stock solution of accurately known concentration is first prepared.

Describe how a stock solution of accurately known concentration could be prepared from a weighed sample of potassium permanganate crystals.

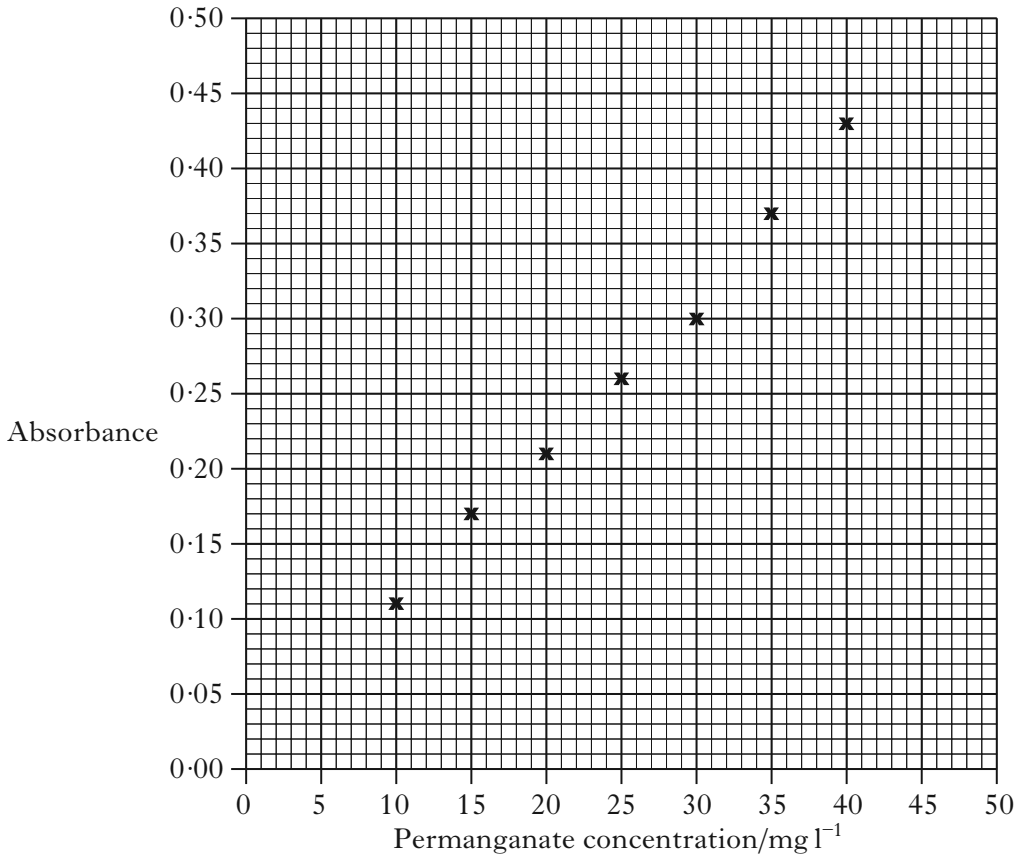
2

DO NOT WRITE IN THIS MARGIN

Marks

11. (b) (continued)

The graph was plotted using the absorbance of different permanganate solutions.



(ii) A sample of steel was reacted to give one litre of solution containing permanganate ions. The absorbance of the solution was 0·30.

Use your graph to determine the mass of manganese in the steel sample.

(1 mole of manganese gives 1 mole of permanganate ions.)

3

(6)

[Turn over

Marks

12. A chemical explosion is the result of a very rapid reaction that generates a large quantity of heat energy and, usually, a large quantity of gas.

(*a*) The explosive RDX, $C_3H_6N_6O_6$, is used in the controlled demolition of disused buildings.

During the reaction it decomposes as shown.

$$C_3H_6O_6N_6(s) \rightarrow 3CO(g) + 3H_2O(g) + 3N_2(g)$$

Calculate the volume, in litres, of gas released when 1·0 g of RDX decomposes.

Take the molar volume of the gases to be 24 litres mol^{-1}.

3

Marks

12. (continued)

(*b*) The products formed when an explosive substance decomposes can be predicted by applying the Kistiakowsky-Wilson rules. These rules use the number of oxygen atoms in the molecular formula to predict the products.

In the example below these rules are applied to the decomposition of the explosive RDX, $C_3H_6N_6O_6$

Rule Number	Rule	Atoms available in $C_3H_6N_6O_6$	Apply Rule to show products
1	Using oxygen atoms from the formula convert any carbon atoms in the formula to carbon monoxide.	3 × C	3CO formed
2	If any oxygen atoms remain convert H atoms in the formula to water.	3 × O remain	$3H_2O$ formed
3	If any oxygen atoms still remain then convert CO formed to CO_2.	No more oxygen left	No CO_2 formed
4	Convert any nitrogen atoms in the formula to N_2.	6 × N	$3N_2$ formed

Decomposition equation:

$C_3H_6N_6O_6(s) \rightarrow 3CO(g) + 3H_2O(g) + 3N_2(g)$

By applying the same set of rules, complete the equation for the decomposition of the explosive PETN, $C_5H_8N_4O_{12}$.

$C_5H_8N_4O_{12}(s) \rightarrow$ **1**

(4)

[*END OF QUESTION PAPER*]