UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

6615234962

CHEMISTRY **9701/41**

Paper 4 Structured Questions **October/November 2013**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Section A
Answer **all** questions.

Section B
Answer **all** questions.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.
A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
8	
Total	

This document consists of **16** printed pages and **4** blank pages.

UNIVERSITY of CAMBRIDGE International Examinations

For Examiner's Use

Section A

Answer **all** the questions in the spaces provided.

1 **(a)** Gaseous ammonia reacts with gaseous hydrogen chloride to form solid ammonium chloride.

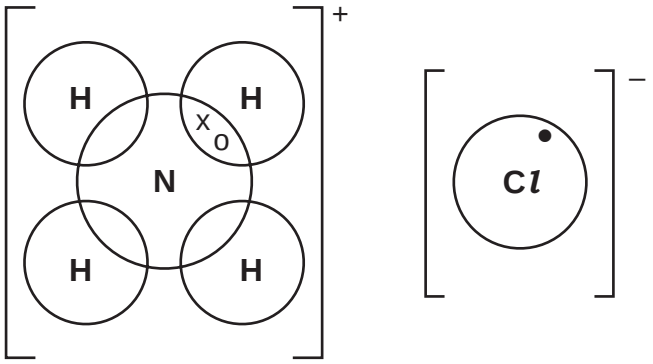
$$NH_3 + HCl \rightarrow NH_4Cl$$

The bonding in ammonium chloride includes ionic, covalent and co-ordinate (dative covalent) bonds.

Complete the following 'dot-and-cross' diagram of the bonding in ammonium chloride. For **each** of the six atoms show **all** the electrons in its outer shell. Three electrons have already been included.

Use the following code for your electrons.

- ● electrons from chlorine
- x electrons from hydrogen
- o electrons from nitrogen



[3]

(b) When a sample of dry ammonia is needed in the laboratory, the gas is passed through a tower containing lumps of solid calcium oxide, CaO.

(i) Suggest why the usual drying agent for gases, concentrated H_2SO_4, is **not** used for ammonia.

.....

(ii) Write an equation for the reaction between CaO and H_2O.

.....

(iii) Suggest why CaO rather than MgO is used to dry ammonia.

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[3]

For Examiner's Use

(c) (i) Write an equation showing the thermal decomposition of calcium nitrate, $Ca(NO_3)_2$.

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(ii) State and explain how the thermal stabilities of the nitrates vary down Group II.

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.....

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[4]

[Total: 10]

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For Examiner's Use

2 **(a)** The melting points of some Group IV elements are given below.

element	melting point / K
C	3925
Si	1683
Ge	1210
Sn	505

Suggest an explanation for each of the following.

(i) The melting point of silicon is less than that of carbon.

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(ii) The melting point of tin is less than that of germanium.

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[2]

(b) Using data from the *Data Booklet* where appropriate, write equations for the following reactions of compounds of Group IV elements.

(i) $SiCl_4(l) + H_2O(l)$

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(ii) the action of heat on $PbCl_4(l)$

.....

(iii) $SnCl_2(aq) + FeCl_3(aq)$

.....

(iv) $SnO_2(s) + NaOH(aq)$

.....

[4]

[Total: 6]

For Examiner's Use

3 **(a)** **(i)** Using the symbol **HZ** to represent a Brønsted-Lowry acid, write equations which show the following substances acting as Brønsted-Lowry bases.

NH_3 + →

CH_3OH + →

(ii) Using the symbol $\mathbf{B}^-$ to represent a Brønsted-Lowry base, write equations which show the following substances acting as Brønsted-Lowry acids.

NH_3 + →

CH_3OH + →

[4]

(b) State briefly what is meant by the following terms.

(i) reversible reaction

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(ii) dynamic equilibrium

.....

.....

[2]

(c) **(i)** Explain what is meant by a *buffer solution*.

.....

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(ii) Explain how the working of a buffer solution relies on a reversible reaction involving a Brønsted-Lowry acid such as **HZ** and a Brønsted-Lowry base such as $\mathbf{Z}^-$.

.....

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[4]

For Examiner's Use

(d) Propanoic acid, $CH_3CH_2CO_2H$, is a weak acid with $K_a = 1.34 \times 10^{-5}$ mol dm^{-3}.

(i) Calculate the pH of a 0.500 mol dm^{-3} solution of propanoic acid.

Buffer solution **F** was prepared by adding 0.0300 mol of sodium hydroxide to 100 cm^3 of a 0.500 mol dm^{-3} solution of propanoic acid.

(ii) Write an equation for the reaction between sodium hydroxide and propanoic acid.

.....

(iii) Calculate the concentrations of propanoic acid and sodium propanoate in buffer solution **F**.

[propanoic acid] = ... mol dm^{-3}

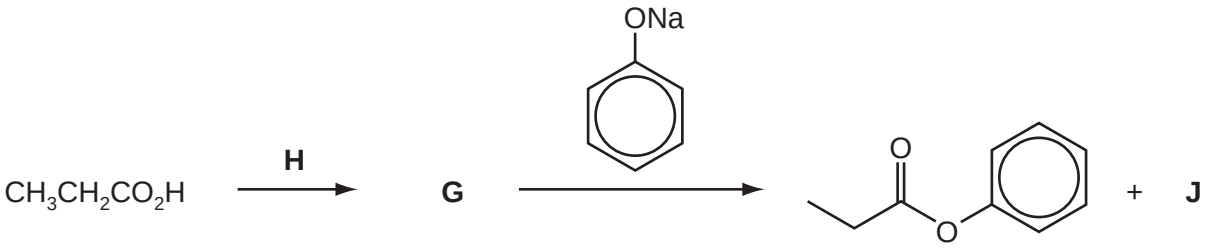
[sodium propanoate] = ... mol dm^{-3}

(iv) Calculate the pH of buffer solution **F**.

pH = ...

[6]

(e) Phenyl propanoate cannot be made directly from propanoic acid and phenol.
Suggest the identities of the intermediate **G**, the reagent **H** and the by-product **J** in the following reaction scheme.



G is .....

H is .....

J is .....

[2]

[Total: 18]

For Examiner's Use

4 **(a)** Explain what is meant by the term *bond energy*.

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.....

[2]

(b) **(i)** Describe and explain the trend in bond energies of the C–X bond in halogenoalkanes, where X = F, C*l*, Br or I.

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.....

(ii) Describe the relationship between the reactivity of halogenoalkanes, RX, and the bond energies of the C–X bond.

.....

.....

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(c) Use the *Data Booklet* to suggest an explanation as to why CFCs such as CF_2Cl_2 are much more harmful to the ozone layer than fluorocarbons such as CF_4 or hydrocarbons such as butane, C_4H_{10}.

.....

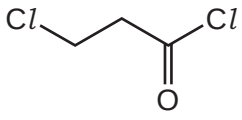
.....

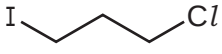
.....

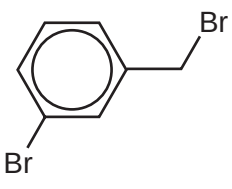
.....

[3]

(d) Predict the products of the following reactions and draw their structures in the boxes below. The molecular formula of each product is given, where X = C*l*, Br or I.

H_2O +  → $C_3H_5O_2X$

H_2O +  → C_3H_7OX

H_2O +  → C_7H_7OX

[3]

For Examiner's Use

(e) Ethane reacts with chlorine according to the following equation.

$$C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl$$

(i) State the conditions needed for this reaction.

.....

(ii) State the *type of reaction* occurring here.

.....

One of the steps during this reaction is the following process.

$$Cl^{\bullet} + CH_3CH_3 \rightarrow HCl + CH_3CH_2^{\bullet}$$

(iii) Use the *Data Booklet* to calculate the enthalpy change, ΔH, of this step.

ΔH = ... kJ mol^{-1}

(iv) Use the *Data Booklet* to calculate the enthalpy change, ΔH, of the similar reaction:

$$I^{\bullet} + CH_3CH_3 \rightarrow HI + CH_3CH_2^{\bullet}$$

ΔH = ... kJ mol^{-1}

(v) Hence suggest why it is **not** possible to make iodoethane by reacting together iodine and ethane.

.....

(vi) Complete the following equations of some possible steps in the formation of chloroethane.

$Cl_2 \rightarrow$ .....

$Cl^{\bullet} + CH_3CH_3 \rightarrow HCl + CH_3CH_2^{\bullet}$

$CH_3CH_2^{\bullet}$ + ... $\rightarrow$ ..... + ...

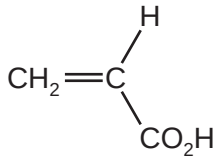
..... + ... $\rightarrow CH_3CH_2Cl$

[8]

[Total: 19]

For Examiner's Use

5 Super-absorbent polymers have the ability to absorb 200-300 times their own mass of water. They are classified as hydrogels and they are widely used in personal disposable hygiene products such as babies' nappies (diapers).
These polymers are commonly made by the polymerisation of compound **K** mixed with sodium hydroxide in the presence of an initiator.



K

(a) (i) Explain what is meant by the term *polymerisation*.

.....

.....

(ii) What type of polymerisation is involved in the formation of hydrogels?

.....

(iii) Describe the changes in chemical bonding that occur during the polymerisation of **K**.

.....

.....
[3]

(b) *Acrylic acid* is the common name for compound **K**.
Suggest the systematic (chemical) name of **K**.

.....
[1]

(c) (i) Draw the structure of at least **two** repeat units of the polymer formed by the above method from acrylic acid, **K**, when mixed with NaOH.

(ii) The C–C–C bond angle in compound **K** changes when the polymer is formed.
State and explain how the C–C–C bond angle differs between a molecule of **K** and the polymer.

angle changes from ..... to .....

explanation .....

.....
[4]

For Examiner's Use

(d) (i) Draw a detailed diagram of a portion of the polymer you have drawn in **(c)(i)** to explain how it can absorb a large volume of water.

(ii) A student added 0.10 g of the polymer to 10 cm^3 of aqueous copper(II) sulfate solution.
Predict, with a reason, what you expect to observe.

.....

.....
[4]

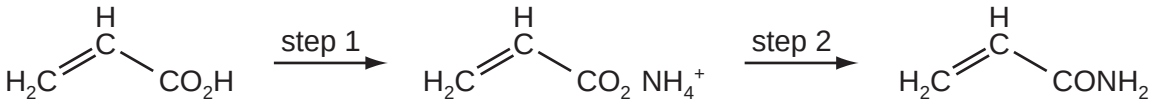
(e) Compound **L**, CH_2=CHCONH$_2$, can also be polymerised to form a super-absorbent polymer.

(i) Name the **two** functional groups in compound **L**.

.....

.....

Compound **K** can be converted into compound **L** by the following two-step route.



K **L**

(ii) Suggest a reagent for step 1.

.....

(iii) What other product is formed in step 2?

.....

(iv) State the reagents and conditions necessary to re-form **K** from **L**.

.....
[5]

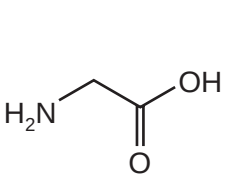
[Total: 17]

For Examiner's Use

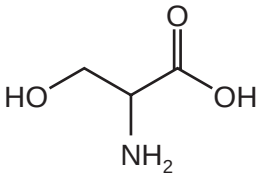
Section B

Answer **all** the questions in the spaces provided.

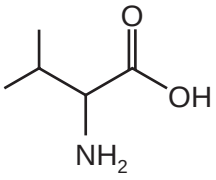
6 **(a)** Protein molecules are formed by the polymerisation of amino acids in the body. The structures of three amino acids are given.



glycine (*gly*)



serine (*ser*)



valine (*val*)

(i) How many different tripeptides can be made using **one** molecule of **each** of the amino acids shown?

.....

(ii) Draw the tripeptide *ser-gly-val*, showing the peptide bonds in displayed form.

(iii) Within the tripeptide, which amino acid provides a hydrophobic side chain?

.....

(iv) Polypeptide chains can form bonds giving proteins their *secondary* and *tertiary* structures.
Using the tripeptide in **(ii)**, state **two** types of bonding that can be formed and the groups in the tripeptide that are involved in this bonding.

bond ..... groups .....

bond ..... groups .....

[6]

(b) Enzymes are particular types of proteins that catalyse chemical reactions. The efficiency of enzymes can be reduced by the presence of other molecules known as inhibitors. Explain how both *competitive* and *non-competitive* inhibitors prevent enzymes from working efficiently.

(i) competitive inhibitors .....

.....

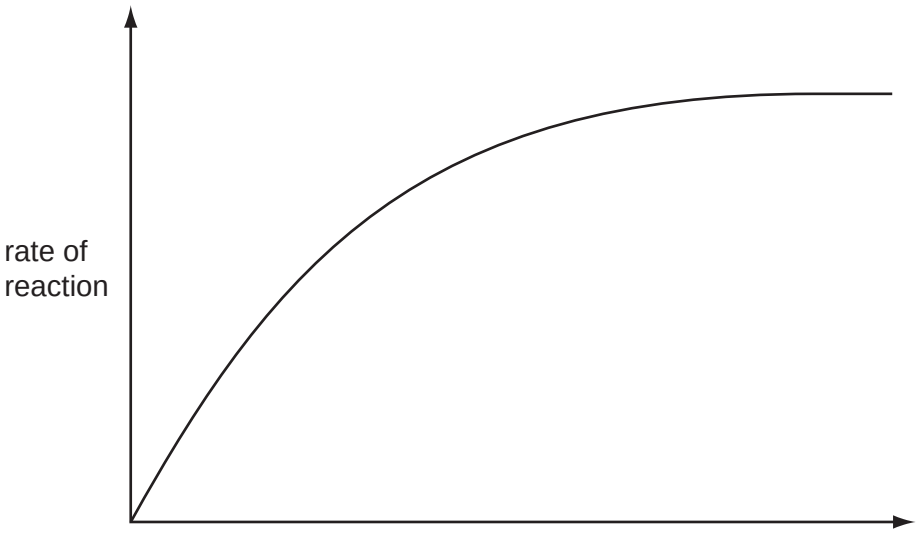
.....

(ii) non-competitive inhibitors .....

.....

.....

(iii) The graph shows the rate of an enzyme-catalysed reaction against the substrate concentration in the absence of an inhibitor.



On the same axes, sketch a graph showing the rate of this reaction if a *non-competitive inhibitor* was present.

[4]

[Total: 10]

For Examiner's Use

7 Electrophoresis is a technique which can be used to separate amino acids or peptide fragments present in a mixture.

(a) Draw a diagram to show the apparatus used to carry out electrophoresis. You should label each of the relevant parts of the apparatus.

[4]

(b) How far an amino acid will travel during electrophoresis depends on the pH of the solution. For a given potential difference, state **two other** factors that will affect how far a given amino acid travels in a fixed time during electrophoresis.

1. .....

.....

2. .....

.....

[2]

(c) A number of analytical and separation techniques rely on substances having different partition coefficients.

State what is meant by the term *partition coefficient*.

.....

.....

.....

[1]

For Examiner's Use

(d) The partition coefficient of **X** between ethoxyethane and water is 40.0.
A solution contains 4.00 g of **X** dissolved in 0.500 dm^3 of water.

Calculate the mass of **X** that can be extracted from this aqueous solution by shaking it with

(i) 0.050 dm^3 of ethoxyethane,

(ii) two successive portions of 0.025 dm^3 of ethoxyethane.

[4]

[Total: 11]

[Turn over

For Examiner's Use

8 In a world with a rapidly increasing population, access to clean drinking water is critical. For many countries, groundwater sources, rather than stored rainwater or river-water, are vital. *Groundwater* is water that exists in the pore spaces and fractures in rock and sediment beneath the Earth's surface. The World Health Organisation (WHO) provides maximum recommended concentrations for different ions present in drinking water.

(a) The geological nature of the soil determines the chemical composition of the groundwater. The table shows some ions which may contaminate groundwater.

ion present	WHO maximum permitted concentration / mg dm^{-3}
Ba^{2+}	0.30
Cl^{-}	250.00
NO_3^{-}	50.00
Pb^{2+}	0.01
Na^{+}	20.00
SO_4^{2-}	500.00

(i) Nitrate, NO_3^{-}, ions are difficult to remove from groundwater.
What is the reason for this?

.....

(ii) State which ions in the table above are likely to be removed from the water by treatment with powdered limestone, $CaCO_3$, giving reasons for each of your answers.

.....

.....

.....
[4]

(b) Nitrates and phosphates can enter water courses such as rivers or streams as a result of human activity. Both of these ions are nutrients for algae.

(i) What is the origin of these nitrates?

.....

For Examiner's Use

(ii) Suggest an origin for the phosphates found in water courses.

.....

(iii) What effect do nitrates and phosphates have on water courses?

.....

.....

[3]

(c) Acid rain can have a major impact on natural waters, particularly lakes. In recent years there has been a worldwide effort to reduce the amount of acid rain produced.

(i) Write equations to show the production of acid rain from sulfur dioxide, SO_2.

.....

.....

(ii) The use of fossil fuels is one major source of sulfur dioxide.
Name another major industrial source.

.....

[2]

[Total: 9]

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General Certificate of Education Advanced Level

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CENTRE NUMBER

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5507470235

CHEMISTRY **9701/42**

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For Examiner's Use

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The bonding in ammonium chloride includes ionic, covalent and co-ordinate (dative covalent) bonds.

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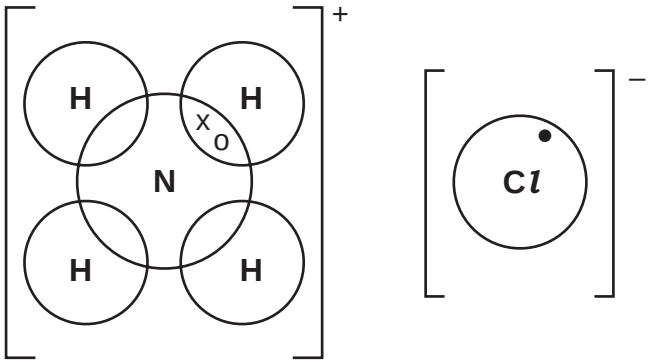

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(b) When a sample of dry ammonia is needed in the laboratory, the gas is passed through a tower containing lumps of solid calcium oxide, CaO.

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[3]

For Examiner's Use

(c) (i) Write an equation showing the thermal decomposition of calcium nitrate, $Ca(NO_3)_2$.

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(ii) State and explain how the thermal stabilities of the nitrates vary down Group II.

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Suggest an explanation for each of the following.

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(ii) The melting point of tin is less than that of germanium.

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(ii) the action of heat on $PbCl_4(l)$

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[4]

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For Examiner's Use

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(ii) Explain how the working of a buffer solution relies on a reversible reaction involving a Brønsted-Lowry acid such as **HZ** and a Brønsted-Lowry base such as $\mathbf{Z}^-$.

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.....

[4]

For Examiner's Use

(d) Propanoic acid, $CH_3CH_2CO_2H$, is a weak acid with $K_a = 1.34 \times 10^{-5}$ mol dm^{-3}.

(i) Calculate the pH of a 0.500 mol dm^{-3} solution of propanoic acid.

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(ii) Write an equation for the reaction between sodium hydroxide and propanoic acid.

.....

(iii) Calculate the concentrations of propanoic acid and sodium propanoate in buffer solution **F**.

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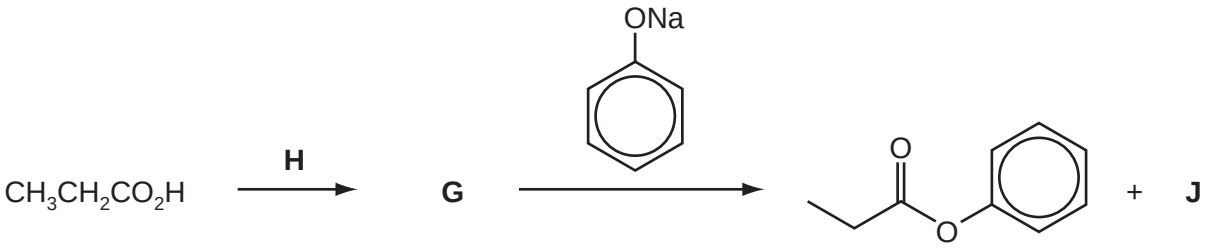

G is .....

H is .....

J is .....

[2]

[Total: 18]

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[2]

(b) **(i)** Describe and explain the trend in bond energies of the C–X bond in halogenoalkanes, where X = F, C*l*, Br or I.

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(ii) Describe the relationship between the reactivity of halogenoalkanes, RX, and the bond energies of the C–X bond.

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.....

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.....

[3]

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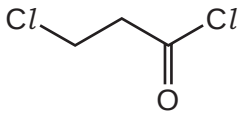
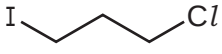
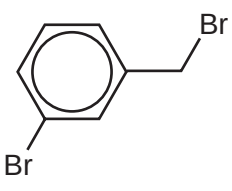
H_2O +  → $C_3H_5O_2X$

H_2O +  → C_3H_7OX

H_2O +  → C_7H_7OX

[3]

(e) Ethane reacts with chlorine according to the following equation.

$$C_2H_6 + Cl_2 \rightarrow C_2H_5Cl + HCl$$

(i) State the conditions needed for this reaction.

.....

(ii) State the *type of reaction* occurring here.

.....

One of the steps during this reaction is the following process.

$$Cl^{\bullet} + CH_3CH_3 \rightarrow HCl + CH_3CH_2^{\bullet}$$

(iii) Use the *Data Booklet* to calculate the enthalpy change, ΔH, of this step.

ΔH = ... kJ mol^{-1}

(iv) Use the *Data Booklet* to calculate the enthalpy change, ΔH, of the similar reaction:

$$I^{\bullet} + CH_3CH_3 \rightarrow HI + CH_3CH_2^{\bullet}$$

ΔH = ... kJ mol^{-1}

(v) Hence suggest why it is **not** possible to make iodoethane by reacting together iodine and ethane.

.....

(vi) Complete the following equations of some possible steps in the formation of chloroethane.

$Cl_2 \rightarrow$ .....

$Cl^{\bullet} + CH_3CH_3 \rightarrow HCl + CH_3CH_2^{\bullet}$

$CH_3CH_2^{\bullet}$ + ... $\rightarrow$ ..... + ...

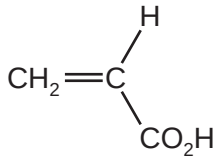
..... + ... $\rightarrow CH_3CH_2Cl$

[8]

[Total: 19]

For Examiner's Use

5 Super-absorbent polymers have the ability to absorb 200-300 times their own mass of water. They are classified as hydrogels and they are widely used in personal disposable hygiene products such as babies' nappies (diapers).
These polymers are commonly made by the polymerisation of compound **K** mixed with sodium hydroxide in the presence of an initiator.



K

(a) (i) Explain what is meant by the term *polymerisation*.

.....

.....

(ii) What type of polymerisation is involved in the formation of hydrogels?

.....

(iii) Describe the changes in chemical bonding that occur during the polymerisation of **K**.

.....

.....
[3]

(b) *Acrylic acid* is the common name for compound **K**.
Suggest the systematic (chemical) name of **K**.

.....
[1]

(c) (i) Draw the structure of at least **two** repeat units of the polymer formed by the above method from acrylic acid, **K**, when mixed with NaOH.

(ii) The C–C–C bond angle in compound **K** changes when the polymer is formed.
State and explain how the C–C–C bond angle differs between a molecule of **K** and the polymer.

angle changes from ..... to .....

explanation .....

.....
[4]

For Examiner's Use

(d) (i) Draw a detailed diagram of a portion of the polymer you have drawn in **(c)(i)** to explain how it can absorb a large volume of water.

(ii) A student added 0.10 g of the polymer to 10 cm^3 of aqueous copper(II) sulfate solution.
Predict, with a reason, what you expect to observe.

.....

.....
[4]

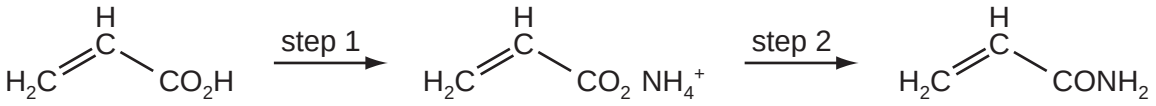
(e) Compound **L**, CH_2=CHCONH$_2$, can also be polymerised to form a super-absorbent polymer.

(i) Name the **two** functional groups in compound **L**.

.....

.....

Compound **K** can be converted into compound **L** by the following two-step route.



K **L**

(ii) Suggest a reagent for step 1.

.....

(iii) What other product is formed in step 2?

.....

(iv) State the reagents and conditions necessary to re-form **K** from **L**.

.....
[5]

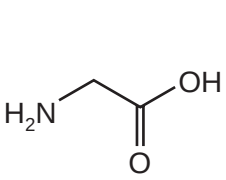
[Total: 17]

For Examiner's Use

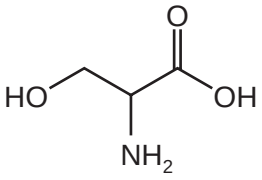
Section B

Answer **all** the questions in the spaces provided.

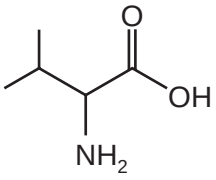
6 **(a)** Protein molecules are formed by the polymerisation of amino acids in the body. The structures of three amino acids are given.



glycine (*gly*)



serine (*ser*)



valine (*val*)

(i) How many different tripeptides can be made using **one** molecule of **each** of the amino acids shown?

.....

(ii) Draw the tripeptide *ser-gly-val*, showing the peptide bonds in displayed form.

(iii) Within the tripeptide, which amino acid provides a hydrophobic side chain?

.....

(iv) Polypeptide chains can form bonds giving proteins their *secondary* and *tertiary* structures.
Using the tripeptide in **(ii)**, state **two** types of bonding that can be formed and the groups in the tripeptide that are involved in this bonding.

bond ..... groups .....

bond ..... groups .....

[6]

(b) Enzymes are particular types of proteins that catalyse chemical reactions. The efficiency of enzymes can be reduced by the presence of other molecules known as inhibitors. Explain how both *competitive* and *non-competitive* inhibitors prevent enzymes from working efficiently.

(i) competitive inhibitors .....

.....

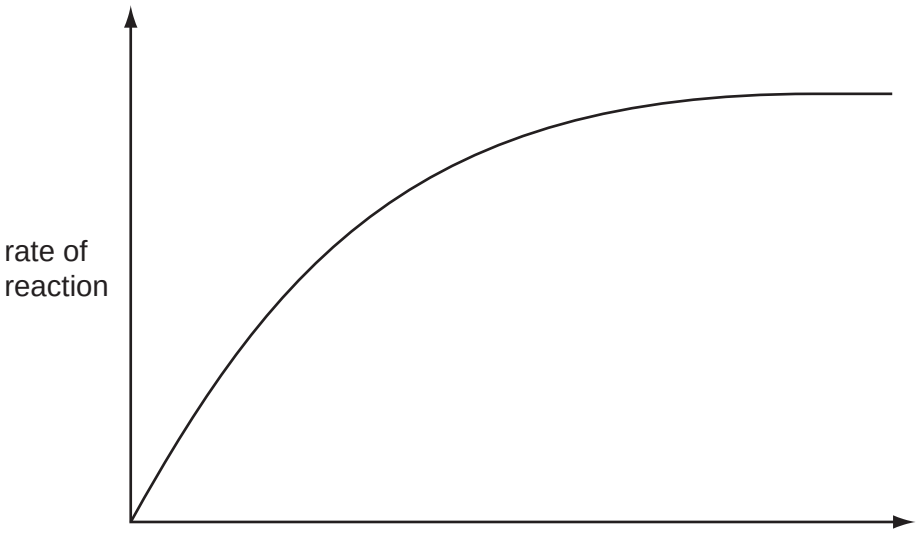
.....

(ii) non-competitive inhibitors .....

.....

.....

(iii) The graph shows the rate of an enzyme-catalysed reaction against the substrate concentration in the absence of an inhibitor.



On the same axes, sketch a graph showing the rate of this reaction if a *non-competitive inhibitor* was present.

[4]

[Total: 10]

For Examiner's Use

7 Electrophoresis is a technique which can be used to separate amino acids or peptide fragments present in a mixture.

(a) Draw a diagram to show the apparatus used to carry out electrophoresis. You should label each of the relevant parts of the apparatus.

[4]

(b) How far an amino acid will travel during electrophoresis depends on the pH of the solution. For a given potential difference, state **two other** factors that will affect how far a given amino acid travels in a fixed time during electrophoresis.

1. .....

.....

2. .....

.....

[2]

(c) A number of analytical and separation techniques rely on substances having different partition coefficients.

State what is meant by the term *partition coefficient*.

.....

.....

.....

[1]

For Examiner's Use

(d) The partition coefficient of **X** between ethoxyethane and water is 40.0.
A solution contains 4.00 g of **X** dissolved in 0.500 dm^3 of water.

Calculate the mass of **X** that can be extracted from this aqueous solution by shaking it with

(i) 0.050 dm^3 of ethoxyethane,

(ii) two successive portions of 0.025 dm^3 of ethoxyethane.

[4]

[Total: 11]

[Turn over

For Examiner's Use

8 In a world with a rapidly increasing population, access to clean drinking water is critical. For many countries, groundwater sources, rather than stored rainwater or river-water, are vital. *Groundwater* is water that exists in the pore spaces and fractures in rock and sediment beneath the Earth's surface. The World Health Organisation (WHO) provides maximum recommended concentrations for different ions present in drinking water.

(a) The geological nature of the soil determines the chemical composition of the groundwater. The table shows some ions which may contaminate groundwater.

ion present	WHO maximum permitted concentration / mg dm^{-3}
Ba^{2+}	0.30
Cl^{-}	250.00
NO_3^{-}	50.00
Pb^{2+}	0.01
Na^{+}	20.00
SO_4^{2-}	500.00

(i) Nitrate, NO_3^{-}, ions are difficult to remove from groundwater.
What is the reason for this?

.....

(ii) State which ions in the table above are likely to be removed from the water by treatment with powdered limestone, $CaCO_3$, giving reasons for each of your answers.

.....

.....

.....
[4]

(b) Nitrates and phosphates can enter water courses such as rivers or streams as a result of human activity. Both of these ions are nutrients for algae.

(i) What is the origin of these nitrates?

.....

For Examiner's Use

(ii) Suggest an origin for the phosphates found in water courses.

.....

(iii) What effect do nitrates and phosphates have on water courses?

.....

.....

[3]

(c) Acid rain can have a major impact on natural waters, particularly lakes. In recent years there has been a worldwide effort to reduce the amount of acid rain produced.

(i) Write equations to show the production of acid rain from sulfur dioxide, SO_2.

.....

.....

(ii) The use of fossil fuels is one major source of sulfur dioxide.
Name another major industrial source.

.....

[2]

[Total: 9]

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UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
General Certificate of Education Advanced Level

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

6208133357

CHEMISTRY **9701/43**

Paper 4 Structured Questions **October/November 2013**

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Section A
Answer **all** questions.

Section B
Answer **all** questions.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.
A Data Booklet is provided.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
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6	
7	
8	
9	
Total	

This document consists of **18** printed pages and **2** blank pages.

UNIVERSITY of CAMBRIDGE International Examinations

For Examiner's Use

Section A

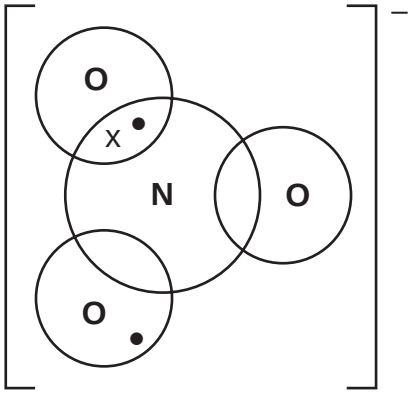
Answer **all** the questions in the spaces provided.

1 **(a)** The nitrate ion, NO_3^-, contains a dative covalent bond.

Complete the following 'dot-and-cross' diagram of the bonding in the nitrate ion. For **each** of the four atoms show **all** the electrons in its outer shell. Three electrons have already been included.

Use the following code for your electrons.

- ● electrons from oxygen
- x electrons from nitrogen
- □ added electron(s) responsible for the overall negative charge



[3]

(b) **(i)** Write an equation showing the action of heat on magnesium nitrate, $Mg(NO_3)_2$.

.....

(ii) Describe and explain the trend that is observed in the thermal stabilities of the Group II nitrates.

.....

.....

.....

.....

[4]

(c) When concentrated nitric acid, HNO_3, is added to copper turnings, a brown gas is evolved. Use data from the *Data Booklet* to construct an ionic equation for this reaction.

.....

.....

[2]

[Total: 9]

For Examiner's Use

2 **(a)** State **two** assumptions of the kinetic theory of gases, as applied to ideal gases.

.....

.....

[2]

(b) **(i)** State the conditions of temperature and pressure under which real gases behave **least** like an ideal gas.

.....

(ii) Explain why real gases do **not** behave ideally under these conditions.

.....

.....

[2]

(c) Gaseous aluminium chloride is dimeric at low temperatures, but the dimer dissociates on heating.

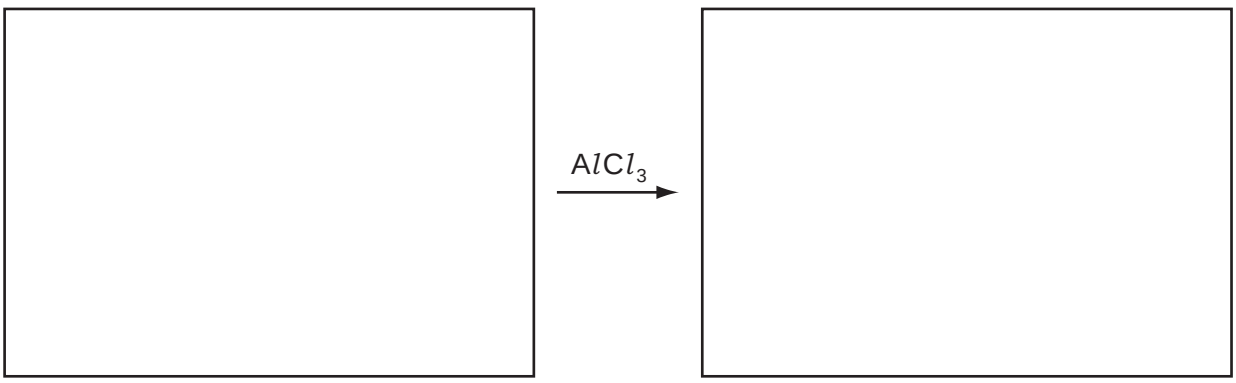
$$Al_2Cl_6(g) \rightleftharpoons 2AlCl_3(g)$$

(i) State whether this dissociation is endothermic or exothermic. Explain your answer.

.....

.....

(ii) Choose **one** reaction in organic chemistry that is catalysed by $AlCl_3$, and write the structural formulae of the reactants and products in the boxes below.



[3]

[Total: 7]

For Examiner's Use

3 **(a)** Write equations, with state symbols, to define the following.

(i) the C–Br bond energy in CH_3Br

.....

(ii) the A*l*–C*l* bond energy in A*l*C*l*$_3$

.....

[3]

(b) **(i)** Describe and explain the trend in bond energies of the bonds in C*l*$_2$, Br_2 and I_2.

.....

.....

.....

(ii) Fluorine, F_2, does **not** follow this trend.
Suggest a possible reason why.

.....

.....

[3]

(c) **(i)** Use data from the *Data Booklet* to calculate the enthalpy change of the following reaction.

$$H_2(g) + X_2(g) \rightarrow 2HX(g)$$

when X = C*l*

ΔH = ... kJ mol^{-1}

when X = I

ΔH = ... kJ mol^{-1}

(ii) Use these results to describe and explain the trend in the thermal stabilities of the hydrides of Group VII.

.....

.....

.....

[5]

For Examiner's Use

(d) Bromine reacts with hot NaOH(aq) to give a solution which on cooling produces white crystals of compound **A**.
A has the following percentage composition by mass: Na, 15.2; O, 31.8; Br, 53.0.

The remaining solution contains mostly NaBr, with a little of compound **A**.

(i) Calculate the empirical formula of **A**.

(ii) Construct an equation for the reaction between Br_2 and hot NaOH(aq).

.....
[4]

[Total: 15]

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For Examiner's Use

4 **(a)** The electrical conductivities of some Group IV elements are given below.

element	electrical conductivity / Ω^{-1} cm^{-1}
C (graphite)	6.1×10^{2}
Si	2.5×10^{-6}
Ge	1.5×10^{-2}
Sn	9.2×10^{4}

From a consideration of the structures, suggest reasons for the following.

(i) The electrical conductivity of silicon is less than that of graphite.

.....

.....

(ii) The electrical conductivity of tin is more than that of germanium.

.....

.....

[2]

(b) Using data from the *Data Booklet* where appropriate, write equations for the following reactions of compounds of Group IV elements.

(i) the action of heat on PbO_2(s)

.....

(ii) PbO_2(s) + HCl(aq)

.....

(iii) SnO(s) + NaOH(aq)

.....

(iv) GeCl_4(l) + H_2O(l)

.....

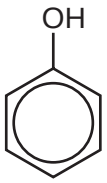
[4]

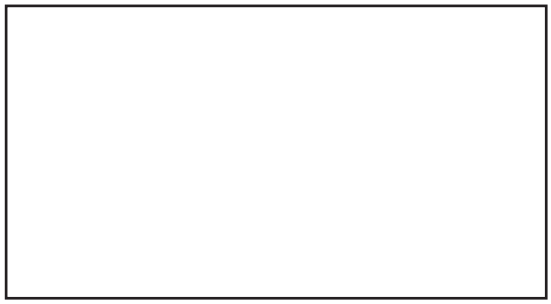
[Total: 6]

For Examiner's Use

5 **(a)** Bromine reacts with a variety of organic compounds.
For each of the following reactions,

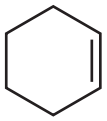
- complete and **balance the equation**, including the structural formula of the organic product,
- state the specific conditions (if any) under which the reaction takes place and the *type of reaction* that occurs.

(i) .....Br_2 + 



reaction conditions .....

type of reaction .....

(ii) .....Br_2 + 

reaction conditions .....

type of reaction .....

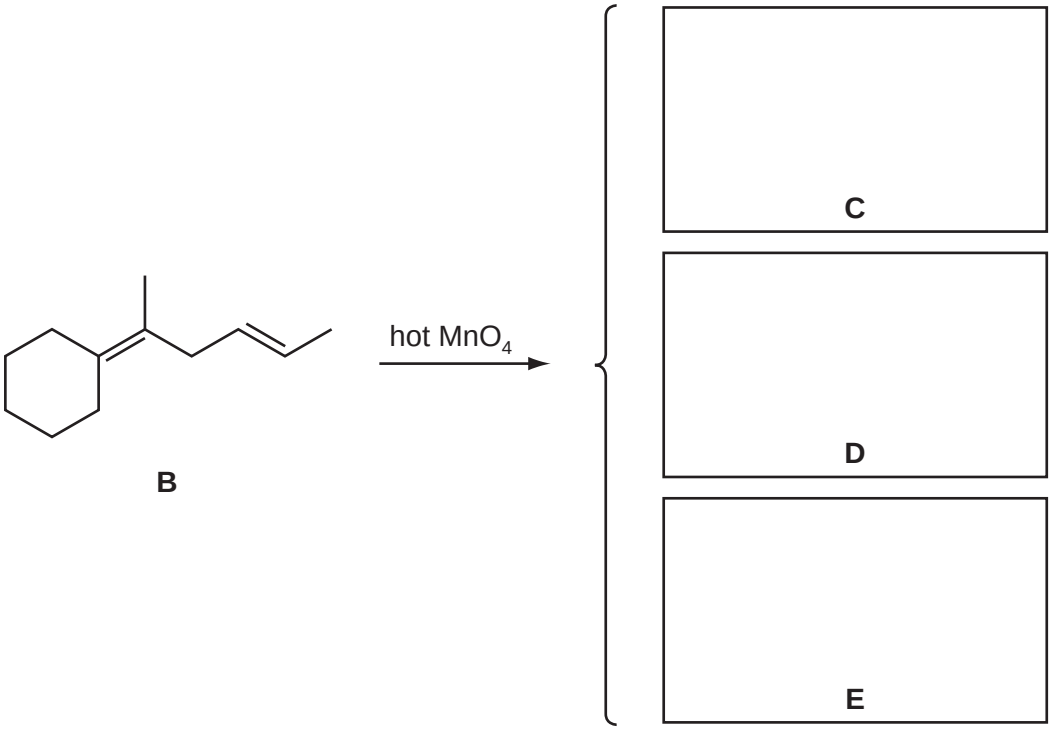
(iii) .....Br_2 + 

reaction conditions .....

type of reaction .....

[10]

(b) When hydrocarbon **B** is heated with concentrated manganate(VII) ions, three organic compounds, **C**, **D** and **E**, are formed.



B

(i) Suggest the identities of compounds **C**, **D** and **E**, drawing their structures in the boxes above.

(ii) Use the relevant letter, **C**, **D** or **E**, to identify which of your compounds will react with each of the following reagents.
Each reagent may react with more than one of **C**, **D** and **E**, in which case state **all** the compounds that may react with each reagent.

- 2,4-dinitrophenylhydrazine .....
- alkaline aqueous iodine .....
- aqueous sodium hydroxide .....

[6]

[Total: 16]

For Examiner's Use

6 Naturally-occurring α-amino acids, $RCH(NH_2)CO_2H$, can be classified as *amphiprotic* substances. An amphiprotic substance is one which can act as both a Brønsted-Lowry acid and base.

α-amino acid	R group
alanine	CH_3–
aspartic acid	HO_2CCH_2–
glycine	H–
lysine	$H_2N(CH_2)_4$–
threonine	$CH_3CH(OH)$–
serine	$HOCH_2$–

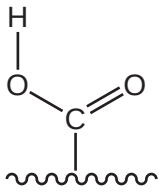
(a) What is the Brønsted-Lowry definition of an acid?

.....

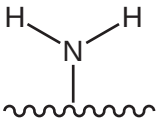
.....

[1]

(b) **(i)** All α-amino acids are soluble in water since they can form hydrogen bonds with water molecules and can also exist as zwitterions.
Draw diagrams to show how the carboxylic acid and amino groups of alanine can form hydrogen bonds with water molecules.



carboxylic acid



amino group

(ii) Draw the structure of the zwitterionic form of glycine.

[5]

(c) The amino acid alanine can be formed by the reaction of $CH_3CHCl CO_2H$ with an excess of ammonia.
Outline a mechanism for this reaction using curly arrows.

[3]

(d) Amino acids can form different ions at different pH values.
Suggest the structures of the ions formed from the α-amino acids below at the respective pH value.

lysine at pH 1	aspartic acid at pH 14

[2]

(e) **(i)** How many different **di**peptides is it possible to synthesise, each containing two of the three amino acids alanine, serine and lysine?

.....

(ii) Write the structural formula of one of these dipeptides incorporating serine and alanine.

[3]

(f) Most naturally-occurring amino acids have a chiral centre and exhibit stereoisomerism.

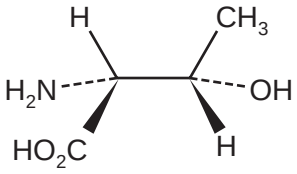
(i) Define the term *stereoisomerism*.

.....

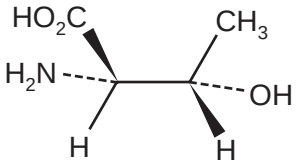
.....

There are **four** optical isomers of threonine.

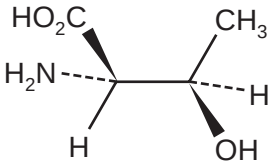
Some of these optical isomers are drawn below.



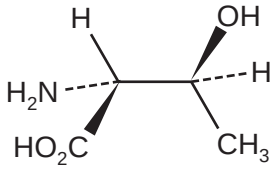
F



G



H



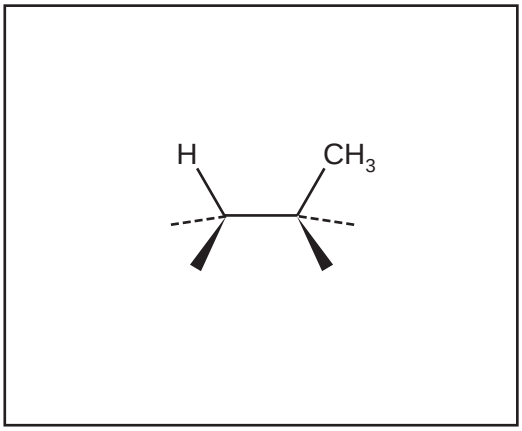
J

When answering this question, remember that completely free rotation about a C–C single bond occurs in these compounds.

(ii) Which of the structures **G**, **H** or **J** is identical to structure **F**? .....

(iii) The other two of the structures **G**, **H** or **J** represent **two** of the **three** other possible optical isomers of threonine.

Complete the following partial structure of the **fourth** optical isomer.



[3]

[Total: 17]

PLEASE TURN OVER FOR SECTION B

For Examiner's Use

Section B

Answer **all** the questions in the spaces provided.

7 **(a)** Enzymes are particular types of proteins that catalyse chemical reactions. The efficiency of enzymes can be reduced by the presence of other substances known as inhibitors.

(i) State **one** example of a substance that can act as a *non-competitive* inhibitor in enzyme reactions.

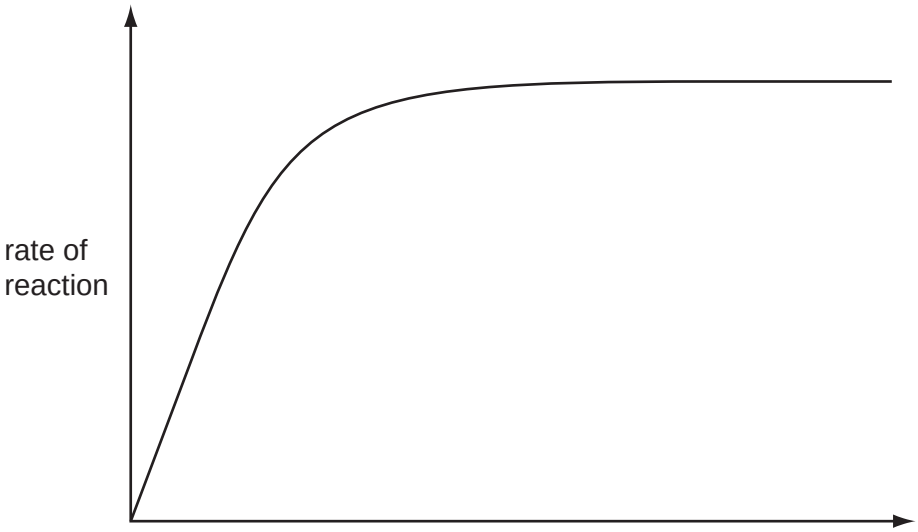
.....

(ii) For the inhibitor you have identified, explain why it is a non-competitive inhibitor.

.....

.....

(iii) The graph shows the rate of an enzyme-catalysed reaction against the substrate concentration in the absence of an inhibitor.



On the same axes, sketch a graph showing the rate of this reaction if a *competitive inhibitor* was present.

[4]

For Examiner's Use

(b) DNA is responsible for encoding the amino acid sequence to produce proteins.

Ribosome, tRNA and mRNA are all involved in the process of protein synthesis.

(i) Write ribosome, tRNA and mRNA in the boxes below to show the correct sequence in which they are involved.

(ii) Sequences of three bases code for specific amino acids. The code UGA however does not usually code for an amino acid. Suggest its use.

.....

[3]

(c) Much of the energy used in biochemical reactions is provided by the hydrolysis of the molecule ATP.

(i) What are the breakdown products of the hydrolysis of ATP?

.....

(ii) Give **two** uses for the energy released by ATP hydrolysis in cells.

1. .....

2. .....

[3]

[Total: 10]

For Examiner's Use

8 Instrumental analysis plays an increasingly important role in modern chemistry. Two important techniques are NMR spectroscopy and X-ray crystallography.

(a) Both techniques use part of the electromagnetic spectrum.
Which technique uses radiation with the longer wavelength, and in which part of the spectrum is it found?

.....

[1]

(b) NMR spectroscopy provides detailed information about protons, but X-ray crystallography is unable to detect them. Explain these facts.

.....

.....

.....

.....

[2]

(c) The protein found in hair contains the amino acid cysteine, $C_3H_7SNO_2$. Crystalline cysteine was examined using X-ray crystallography. State which atom produced the strongest reflection, explaining your answer.

.....

.....

[1]

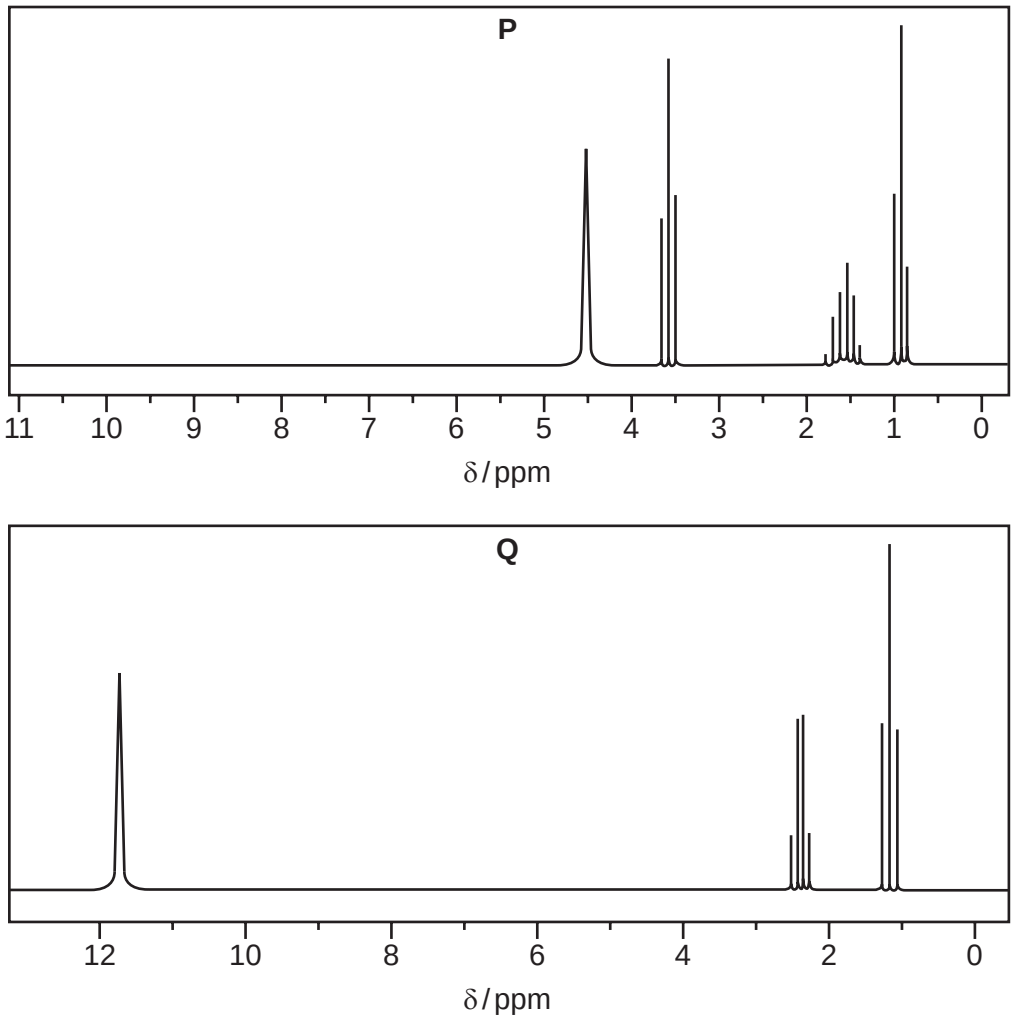
(d) Compound **P** is an alcohol that can be converted into compound **Q** in the following reaction sequence.

$$\mathbf{P} \rightarrow C_xH_6O \rightarrow \mathbf{Q}$$

Spectral analyses of **P** and **Q** were carried out.

(i) The mass spectrum of **P** shows an M : M+1 peak ratio of 4.5 : 0.15.
Calculate the number of carbon atoms in **P**.

The NMR spectra of **P** and **Q** are shown below.



(ii) In the spectrum of **P**, clearly label the peak due to the –OH group with an **X**.

(iii) State how many different proton environments are present in compound **Q**.

.....

(iv) What evidence is there in these spectra that **P** is a primary rather than a secondary alcohol?

.....

.....

.....

(v) Draw a structure for **Q**.

[6]

[Total: 10]

For Examiner's Use

9 Until 1985, carbon was thought to exist in only two structural forms or *allotropes*. In 1985 another form, buckminsterfullerene, was discovered, in which the carbon exists as spherical molecules.

(a) The other two forms of carbon have very different structures.

(i) Name these two forms.

..... and .....

(ii) Give **three** differences in physical properties between these two forms.

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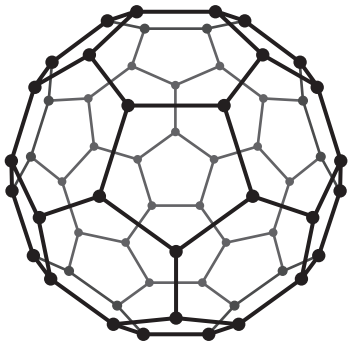
[4]

(b) The diagram shows the structure of buckminsterfullerene.



buckminsterfullerene

The molecule of buckminsterfullerene contains 60 carbon atoms. Suggest a reason why buckminsterfullerene reacts with hydrogen under suitable conditions and give a formula for the product.

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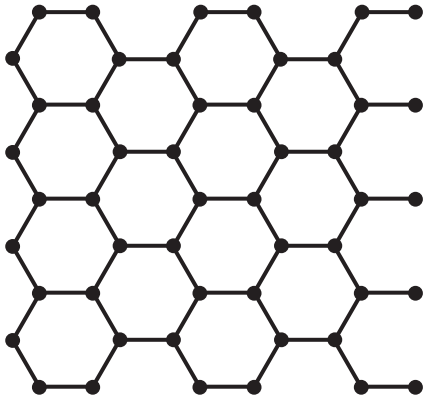
[2]

(c) In 2010, two scientists from the University of Manchester were awarded the Nobel Prize for Physics for their work on graphene, a new structural form of carbon. Graphene is one of the new 'nano-materials' being developed for commercial uses in the next 10 years.



graphene

(i) Graphene is in the form of sheets of carbon one atom thick. Calculate the number of carbon atoms present in a sheet of graphene with a mass of one thousandth of a gram (0.001 g).

The number of hexagons in a large sheet of graphene can be assumed to be one half of the number of carbon atoms. Each hexagon has an area of 690 nm^2.

(ii) Calculate the area of the sheet of graphene in **(i)**.

area of sheet = ... nm^2

(iii) Would you expect samples of graphene and buckminsterfullerene to be electrical conductors? Explain your answers.

graphene .....

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buckminsterfullerene .....

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[4]

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