Index No.	Name	Form Class	Tutorial Class	Subject Tutor

ANGLO-CHINESE JUNIOR COLLEGE
DEPARTMENT OF CHEMISTRY
Preliminary Examination

CHEMISTRY
Higher 1

8873/02

Paper 2

16 August 2018
2 hours

Candidates answer on the Question Paper

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, index number, form class, tutorial class and subject tutor's 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, glue or correction fluid.

Section A
Answer **all** the questions.

Section B
Answer **one** question.

The use of an approved scientific calculator is expected, where appropriate.

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	
Question no.	**Marks**
Section A	
B7	
B8	
Presentation of answers	
TOTAL	

This document consists of **22** printed pages and **2** blank pages.

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Section A

Answer **all** the questions in this section, in the spaces provided.

1 (a) Hydrogen sulfide, H_2S, is a foul-smelling compound found in the gases from volcanoes. Hydrogen sulfide has a melting point at –85°C and boiling point at –60°C.

(i) State the structure of hydrogen sulfide.

……[1]

(ii) Draw a 'dot-and-cross' diagram to show the structure of H_2S.

[1]

(iii) State and explain the shape of H_2S.

……

……[2]

(iv) Oxygen and sulfur are both in Group 16 of the Periodic Table.

Suggest why the melting and boiling points of water, H_2O, are much higher than those of H_2S.

……

……

……

……

……[3]

(b) Hydrogen sulfide burns with a blue flame in an excess of oxygen to form sulfur dioxide and water.

(i) Write a balanced equation for the complete combustion of H_2S.

……[1]

(ii) What is the change in the oxidation number of sulfur in this reaction?

……[1]

(iii) What volume of oxygen, measured at room temperature and pressure, is required for the complete combustion of 8.65 g of H_2S? Give your answer to two decimal places.

[2]

(c) Hydrogen sulfide is a weak diprotic (dibasic) acid.

(i) What is meant by the term *weak acid*?

……[1]

(ii) Write an equation, with state symbols, for the **first** ionisation of H_2S when it dissolves in water.

……[1]

[Total: 13]

2 (a) In 2010 the Nobel Prize for Physics was awarded to two researchers from Manchester University for their work on preparing graphene from graphite.

(i) Graphene can be prepared from graphite by using sticky tape. Use your knowledge of the bonding in graphite to explain why it is possible to create graphene by this method.

……[1]

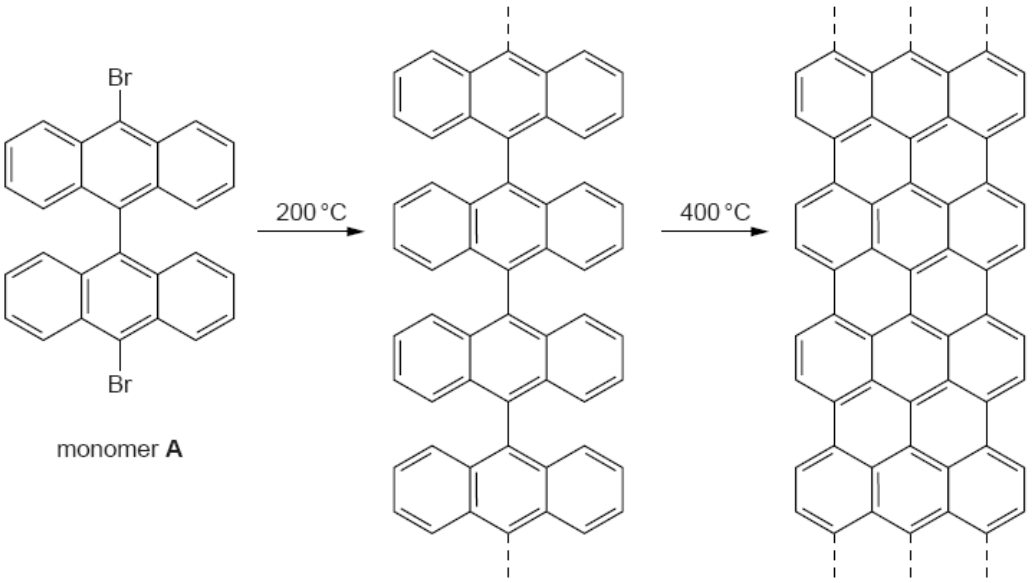
(ii) State one physical property of graphene and explain the reason.

……

……[2]

(b) A graphene sheet is a layer of graphite.

A recent development has been the synthesis of graphene ribbons (reported in *Nature*, 2010). A reaction scheme is shown.



monomer **A**

2 units of polymer **B**

2 units of polymer **C**

(i) When monomer **A** is polymerised to make **B** there is also another product, **X**. Give the molecular formula of **X**.

[1]

(ii) In the transformation of polymer **B** into polymer **C**, another product, **Y**, is produced. Give the molecular formula of **Y**.

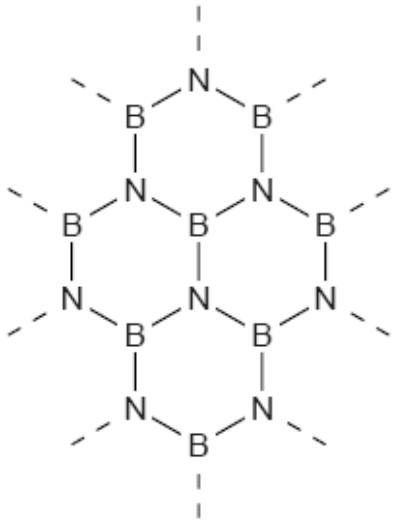
[1]

(iii) Deduce the number of moles of **X** and **Y** produced **per mole of monomer A**.

[2]

(iv) Boron nitride, BN, forms sheets similar to graphene except they contain dative covalent bonds as well as covalent bonds.

Add all the possible dative covalent bonds between the atoms shown in the structure below. [1]



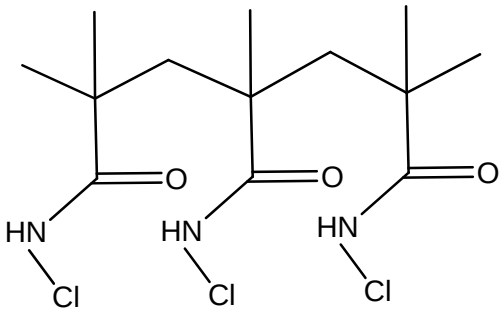
(v) Boron nitride can also form a giant covalent structure in which each atom has four single bonds.

Suggest the name of another substance which has this type of structure.

……[1]

[Total: 9]

3 Chemists have recently found a way of making the strong, light-weight and thermally stable polymer, Kevlar®, to be antibacterial (reported in *Industrial & Engineering Chemistry Research*, 2008). This was achieved by coating it with another polymer, a fragment of which is shown below.



polymer

(a) Draw the repeat unit of the polymer structure shown above.

[1]

(b) The polymer shown above is made by the following reactions:

reaction 1 an addition polymerisation reaction of a monomer known as MAA
reaction 2 the substitution of a hydrogen atom in the polymer with a chlorine atom using bleach

Draw the structure of the monomer MAA.

[1]

(c) Not all the nitrogen atoms in the polymer end up bonded to a chlorine atom. The quantity of chlorine actually present in the polymer can be determined using **reactions 3**, **4** and **5**.

A known mass of polymer (written as **X**CONH–C*l*) is reacted to convert the chlorine content of the polymer to chloric(I) acid, HOC*l*:

reaction 3 **X**CONH–C*l* + H_2O ⟶ $XCONH_2$ + HOC*l*
(where **X** = remainder of polymer)

The chlorine content is then 'converted' to iodine:
reaction 4 HOC*l* + 2KI + H^+ ⟶ I_2 + KC*l* + H_2O + K^+

The quantity of iodine is determined using a titration with sodium thiosulfate:
reaction 5 $I_2 + 2Na_2S_2O_3 \longrightarrow 2NaI + Na_2S_4O_6$

(i) State the oxidation number of the chlorine in HOC*l*.

……[1]

(ii) State the type of reaction for **reaction 3** and **5**.

……

……[2]

(iii) Write ionic half equations for the oxidation and reduction processes in **reaction 4**.

……

……[2]

In the analysis of a sample of polymer, 1.00 g of the polymer was reacted with steam. (**reaction 3**).

The resulting mixture was reacted with excess acidified potassium iodide (**reaction 4**) and then made up to 250 cm^3 with distilled water.

25.0 cm^3 of this solution reacted with exactly 25.00 cm^3 of sodium thiosulfate solution of concentration 0.100 mol dm^{-3} (**reaction 5**).

(iv) Name a suitable indicator for the titration in **reaction 5** and state the colour change at end point.

……

……[2]

(v) Determine the amount of iodine in the 25.00 cm^3 solution.

[1]

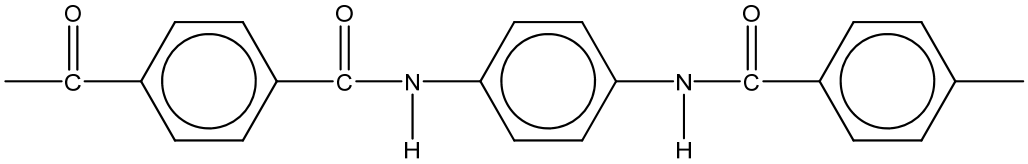
(vi) Determine the mass of chlorine present in the sample of polymer.

[2]

(d) *Kevlar* is a synthetic polymer made from two monomers. It is a registered trademark of DuPont and was discovered in 1965. *Kevlar*'s first commercial use was as a replacement for steel in racing tires.

Kevlar is used to make military equipment such as bulletproof vests, helmets, reinforcements for military vehicles and in making other light weight military equipment.

A portion of its chain is shown below.



(i) What type of polymerisation produces *Kevlar*?

……[1]

(ii) Draw the structural formulae of the monomers from which *Kevlar* is made.

[2]

(iii) With a labelled diagram, suggest a reason why *Kevlar* is much stronger than most other polyamides.

……

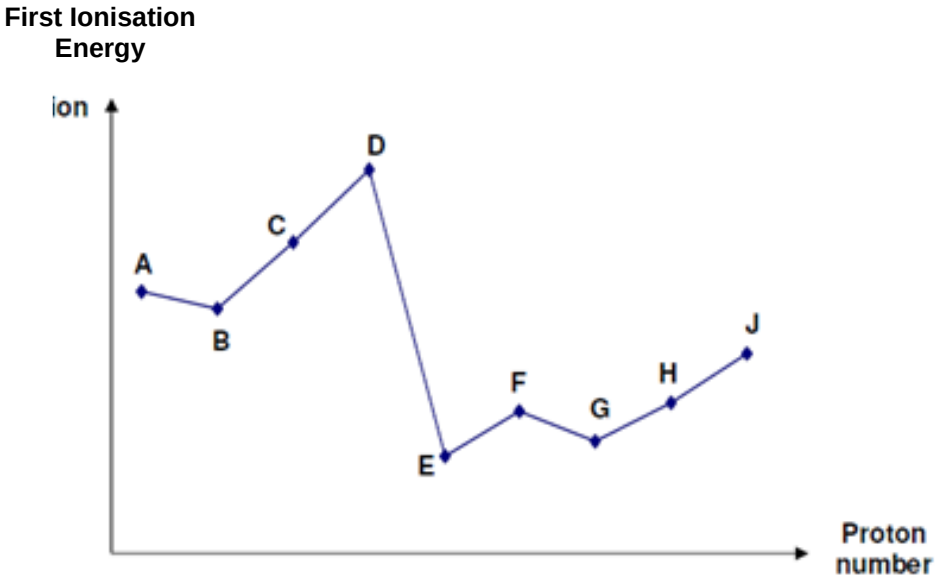
……[2]

(iv) What reaction conditions are needed to break the amide bonds in *Kevlar*?

……[1]

[Total: 18]

4 The first ionisation energies of nine consecutive elements **A** to **J** in Periods 2 and 3 of the Periodic Table are as shown.



(a) **A** and **J** are in the same group. Explain why the first ionisation energy of **J** is lower than that of **A**.

.....

.....

.....[1]

(b) The oxide of **H** is insoluble in water while its chloride reacts completely with aqueous sodium hydroxide to give a resulting mixture of pH close to 7.

(i) To which group does **H** belong?

.....[1]

(ii) Using the symbol **H**, write the formula of the oxide of **H**.

.....[1]

(c) **J** can form different chlorides of **J**Cl_3 and **J**Cl_5.

State the pH of the resultant mixture when the chloride of **G** and one of the chlorides of **J** is added to water separately. Write an equation for each to support your answer.

	chloride of **G**	chloride of **J**
pH of solution formed when added to water		
Equation to show reaction with water (if any)		

[4]

[Total: 7]

5 'Water gas' is an equimolar mixture of hydrogen and carbon monoxide. It is used as an industrial gaseous fuel. It is produced when steam is blown through white-hot coke in the following reaction.

$$H_2O(g) + C(s) \longrightarrow H_2(g) + CO(g)$$

Another widely-used industrial fuel is natural gas, which consists mainly of methane.

The enthalpy changes of combustion of methane, hydrogen and carbon monoxide are –890 kJ mol^{-1}, –242 kJ mol^{-1} and –283 kJ mol^{-1} respectively.

(a) Using the above enthalpy changes, calculate the volume of methane (measured at 20 ^oC and 1 atm) required to produce 1 MJ (1000 kJ) of heat energy when burned.

[2]

(b) Calculate the volume of water gas (measured at 20 ^oC and 1 atm) required to produce the same amount of heat energy.

[2]

(c) Suggest **one** advantage of using natural gas rather than water gas.

.....

.....[1]

(d) An industrially important source of hydrogen is shown in the reaction below.

$$CH_4(g) + 2H_2O(g) \rightleftharpoons CO_2(g) + 4H_2(g)$$

Using the above enthalpy changes of combustion, determine the enthalpy change of this reaction.

[1]

[Total: 6]

6 **K**, **L**, **M** and **N** are consecutive elements of increasing proton number in the Periodic Table.

(a) The successive ionisation energies, in kJ mol^{-1} of element **L** are given below.

1681 3374 6050 8407 11020 15160 17870 92040 106400

To which Group does element **L** belong? Explain your answer.

.....

.....

.....[2]

(b) **K**, **L** and **N** form ions that are isoelectronic with atom **M**.

(i) State the charge on the ions of **K**, **L** and **N**. [2]

K: ……. **L**: ……. **N**: ……..…

(ii) Arrange the ions of **K**, **L** and **N** in *decreasing* order of ionic radius. Explain your answers.

.....

.....

……...

.....

……..[3]

[Total: 7]

Section B

Answer **one** question from this section, in the spaces provided.

7 Acetals are compounds formed when aldehydes are reacted with an alcohol in the presence of an acid catalyst. The reaction between ethanal and methanol was studied in the inert solvent dioxan.

$$\underset{\text{ethanal}}{CH_3CHO} + \underset{\text{methanol}}{2CH_3OH} \overset{H^+}{\rightleftharpoons} \underset{\text{acetal}}{CH_3CH(OCH_3)_2} + H_2O$$

(a) In an experiment, the concentrations of the reactants and products were measured. The results are shown in the table below.

	$[CH_3CHO]$/ mol dm^{-3}	$[CH_3OH]$/ mol dm^{-3}	$[H^+]$/ mol dm^{-3}	[acetal]/ mol dm^{-3}	$[H_2O]$/ mol dm^{-3}
at start	0.20	0.10	0.05	0.00	0.00
change	–0.025				
at equilibrium					

(i) Complete the blanks in the table. [2]

(ii) Write the expression for the equilibrium constant for this reaction, K_c, stating its units.

[2]

(iii) Calculate the value of K_c.

[1]

(iv) State *Le Chatelier's principle*.

.....

.....

.....[1]

(v) Given a fixed temperature, state whether an increase in concentration for the acid catalyst will affect the value of the equilibrium constant.

.....[1]

(b) When the initial rate of this reaction was measured at various starting concentrations of the three reactants, the following results were obtained.

experiment number	$[CH_3CHO]$/ mol dm^{-3}	$[CH_3OH]$/ mol dm^{-3}	$[H^+]$/ mol dm^{-3}	relative rate
1	0.20	0.10	0.05	1.00
2	0.25	0.10	0.05	1.25
3	0.25	0.16	0.05	2.00
4	0.20	0.16	0.10	3.20

(i) Use the data in the table to determine the order with respect to each reactant.

[3]

(ii) Write the rate equation for the reaction.

.....[1]

(iii) State the units of the rate constant in the rate equation given that the rate is expressed in terms of mol dm^{-3} s^{-1}.

[1]

(iv) Explain with the aid of energy profile curves in the same axis how the presence of the acid catalyst will affect the rate constant. Assume that the reaction is exothermic.

.....

.....

.....[4]

(c) Ethanal and methanol can be oxidised using acidified potassium dichromate(VI).

(i) Draw the displayed formulae of the organic products formed.

[2]

(ii) Write equations for both the reactions and state the colour change for the reaction.

[2]

[Total: 20]

8 Blood plasma is a biological fluid that plays an important role in maintaining pH in the body. In the blood plasma, the equilibrium between carbonic acid, $H_2CO_3(aq)$, and hydrogencarbonate ion, $HCO_3^-(aq)$, buffers pH changes.

$$H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

The K_a for this equilibrium is 7.90×10^{-7} mol dm^{-3}.

At body temperature, the pH of the arterial blood plasma is 7.40. If the pH falls below this normal value, a condition termed *acidosis* is produced. If the pH rises above this normal value, the condition is termed *alkalosis*.

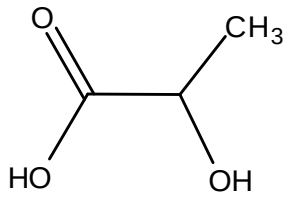
The concentration of $H_2CO_3(aq)$ is controlled by respiration through the lungs. $H_2CO_3(aq)$ is in equilibrium with dissolved CO_2.

$$H_2CO_3(aq) \rightleftharpoons CO_2(aq) + H_2O(l)$$

In the lungs, excess dissolved $CO_2(aq)$ is exhaled as $CO_2(g)$.

$$CO_2(aq) \rightleftharpoons CO_2(g)$$

During heavy exercise, *lactic acid* is released into the blood and is buffered by the blood plasma.



Lactic acid

This eventually leads to an increase in $CO_2(aq)$ concentration and stimulates increased breathing.

(a) (i) Explain what is meant by a *buffer solution* in the context of blood plasma.

.....

……..……..[2]

(ii) Write an equation to show how blood plasma can buffer the pH change when lactic acid is released into the blood.

……..……..[1]

(iii) Write an expression for the acid dissociation constant, K_a, of $H_2CO_3(aq)$ and use it to determine the $[HCO_3^-(aq)]/[H_2CO_3(aq)]$ ratio in the blood plasma.

Comment on this ratio.

[3]

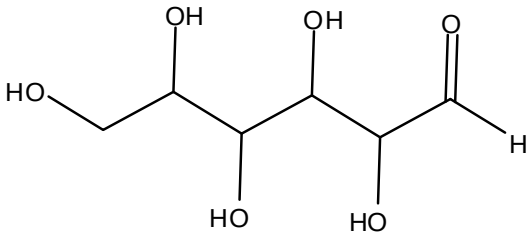
(iv) Using the information given, explain, with the aid of two equations, how the production of lactic acid leads to the increase in rate of breathing.

.....

.....

……..[2]

(b) Lactic acid is converted to *glucose* via gluconeogenesis in the liver.



Glucose

(i) Name the functional group(s) present in glucose.

……[2]

(ii) Draw the skeletal formula of the organic products when *glucose* is added to

(I) $H_2SO_4(aq)$, K_2CrO_7, heat

(II) LiA/H_4, dry ether, reflux

[2]

(iii) Describe a simple chemical test that you could use to distinguish between lactic acid and glucose. You are to include reagents and conditions, observations and balanced equation(s) in each case.

.....

.....

.....

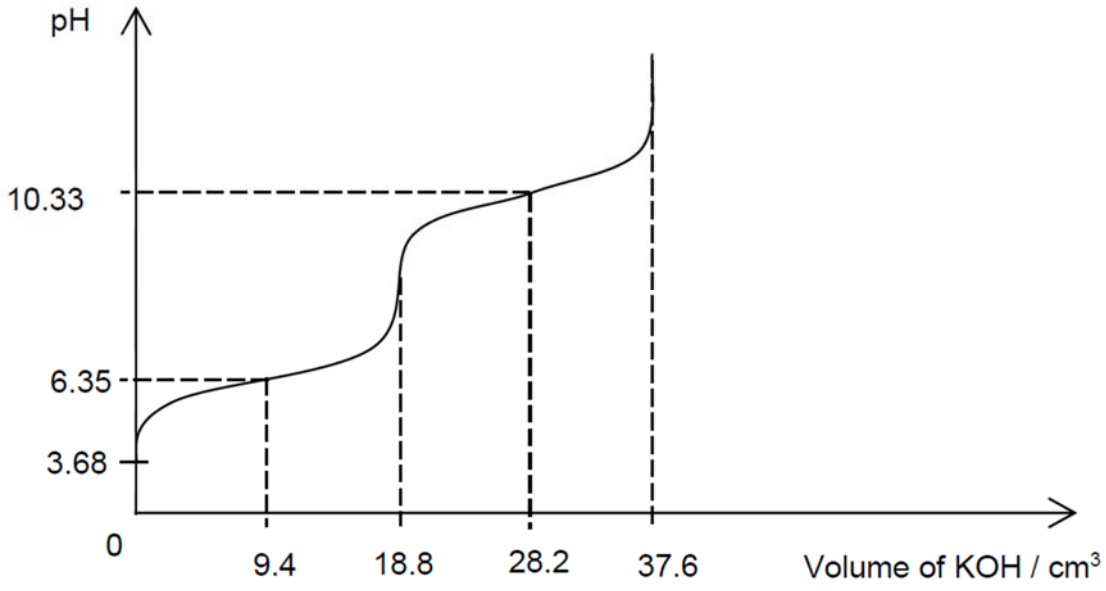
.....

.....[3]

(c) In an experiment, 25 cm^3 of 0.100 mol dm^{-3} H_2CO_3 is titrated with aqueous potassium hydroxide. The titration curve is shown below. The acid dissociation of H_2CO_3 is as shown in the following equations.

$$H_2CO_3 \rightleftharpoons HCO_3^- + H^+$$

$$HCO_3^- \rightleftharpoons CO_3^{2-} + H^+$$



(i) Justify that carbonic acid, H_2CO_3, is a weak acid with relevant calculations.

[2]

(ii) Calculate the concentration of KOH, in mol dm^{-3}, used in the titration.

[1]

(iii) Suggest, with a reason, a suitable indicator for the first end point of this titration.

.....

.....

.....[2]

[Total: 20]

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Section A	
B7	
B8	
TOTAL	

This document consists of **16** printed pages.

Section A

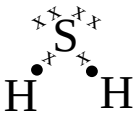
Answer **all** the questions in this section, in the spaces provided.

1 (a) Hydrogen sulfide, H_2S, is a foul-smelling compound found in the gases from volcanoes. Hydrogen sulfide has a melting point at –85 °C and boiling point at –60 °C.

(i) State the structure of hydrogen sulfide. [1]

Simple covalent/ molecular structure

(ii) Draw a 'dot-and-cross' diagram to show the structure of H_2S. [1]



(iii) State and explain the shape of H_2S. [2]

Bent
There are two bond pairs and two lone pairs of electron around the central atom S.

(iv) Oxygen and sulfur are both in Group 16 of the Periodic Table.

Suggest why the melting and boiling points of water, H_2O, are much higher than those of H_2S. [3]

There are stronger hydrogen bonds between H_2O molecules and there are weaker permanent dipole- permanent dipole interactions between H_2S molecules.

More energy is needed to overcome the stronger hydrogen bonds between water molecules compared to the pd-pd interactions.

(b) Hydrogen sulfide burns with a blue flame in an excess of oxygen to form sulfur dioxide and water.

(i) Write a balanced equation for the complete combustion of H_2S. [1]

$2H_2S + 3O_2 \rightarrow 2H_2O + 2SO_2$

OR $H_2S + 3/2\ O_2 \rightarrow H_2O + SO_2$

(ii) What is the change in the oxidation number of sulfur in this reaction? [1]

-2 to +4 OR +6 OR increase the oxidation state by +6

(iii) What volume of oxygen, measured at room temperature and pressure, is required for the complete combustion of 8.65 g of H_2S? Give your answer to two decimal places. [2]

Amount of H_2S = 8.65/ 34.1 = 0.25367 mol

Mole ratio of H_2S: O_2 = 2:3

Amount of oxygen= 3/2 x 0.025367 = 0.380499 mol

Volume of oxygen = 0.380499 x 24 = 9.13 dm^3

(c) Hydrogen sulfide is a weak diprotic (dibasic) acid.

(i) What is meant by the term *weak acid*? [1]

A weak acid undergoes partial dissociation in water to give H^+ ions/ proton donor.

(ii) Write an equation, with state symbols, for the **first** ionisation of H_2S when it dissolves in water. [1]

$H_2S(g) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HS^-(aq)$
or
$H_2S(aq) \rightleftharpoons H^+(aq) + HS^-(aq)$

[Total: 13]

2 (a) In 2010 the Nobel Prize for Physics was awarded to two researchers from Manchester University for their work on preparing graphene from graphite.

(i) Graphene can be prepared from graphite by using sticky tape. Use your knowledge of the bonding in graphite to explain why it is possible to create graphene by this method. [1]

Weak id-id interactions between graphene sheets in graphite

(ii) State one physical property of graphene and explain the reason. [2]

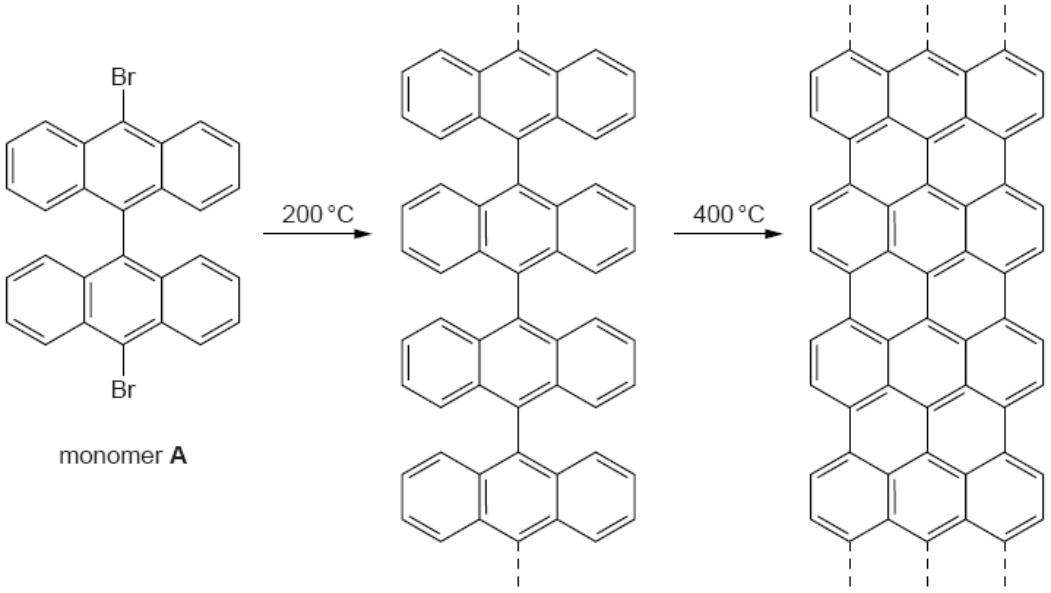
- High tensile strength (reason: strong covalent bonds between atom)

OR

- Excellent electrical conductivity (reason: p electron per carbon atom)

(b) A graphene sheet is a layer of graphite.

A recent development has been the synthesis of graphene ribbons (reported in *Nature*, 2010). A reaction scheme is shown.



monomer **A**

2 units of polymer **B**

2 units of polymer **C**

(i) When monomer **A** is polymerised to make **B** there is also another product, **X**. Give the molecular formula of **X**. [1]

Br_2

(ii) In the transformation of polymer **B** into polymer **C**, another product, **Y**, is produced. Give the molecular formula of **Y**. [1]

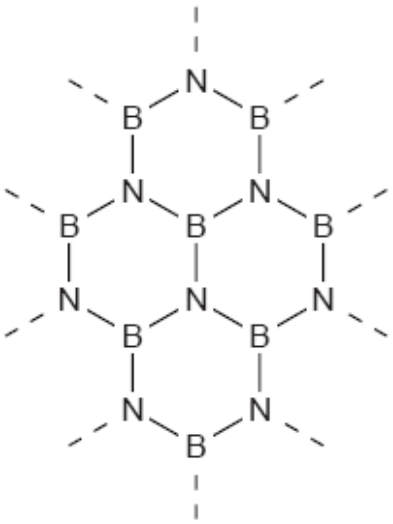
H_2

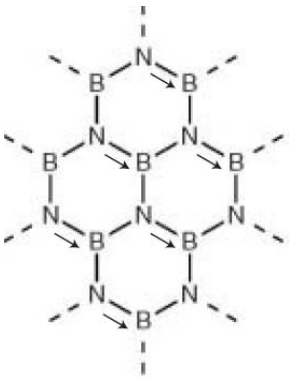
(iii) Deduce the number of moles of **X** and **Y** produced **per mole of monomer A**. [2]

No. of moles of X = 1
No. of moles of Y = 4

(iv) Boron nitride, BN, forms sheets similar to graphene except they contain dative covalent bonds as well as covalent bonds.

Add all the possible dative covalent bonds between the atoms shown in the structure below. [1]





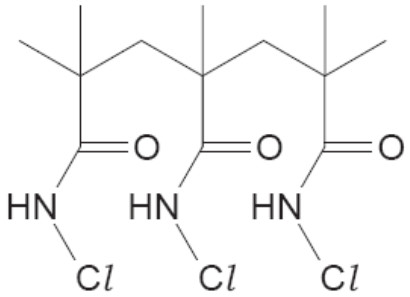
(v) Boron nitride can also form a giant covalent structure in which each atom has four single bonds.

Suggest the name of another substance which has this type of structure. [1]

Diamond or silicon or silicon dioxide

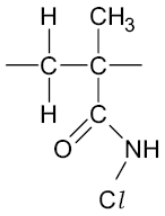
[Total: 9]

3 Chemists have recently found a way of making the strong, light-weight and thermally stable polymer, Kevlar®, to be antibacterial (reported in *Industrial & Engineering Chemistry Research*, 2008). This was achieved by coating it with another polymer, a fragment of which is shown below.



polymer

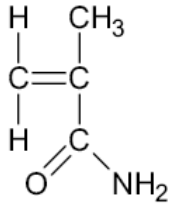
(a) Draw the repeat unit of the polymer structure shown above. [1]



(b) The polymer shown above is made by the following reactions:

reaction 1 an addition polymerisation reaction of a monomer known as MAA
reaction 2 the substitution of a hydrogen atom in the polymer with a chlorine atom using bleach

Draw the structure of the monomer MAA. [1]



(c) Not all the nitrogen atoms in the polymer end up bonded to a chlorine atom. The quantity of chlorine actually present in the polymer can be determined using **reactions 3**, **4** and **5**.

A known mass of polymer (written as **X**CONH–C*l*) is reacted to convert the chlorine content of the polymer to chloric(I) acid, HOC*l*:

reaction 3 **X**CONH–C*l* + H_2O ⟶ $XCONH_2$ + HOC*l*
(where **X** = remainder of polymer)

The chlorine content is then ‘converted’ to iodine:

reaction 4 $HOCl + 2KI + H^+ \longrightarrow I_2 + KCl + H_2O + K^+$

The quantity of iodine is determined using a titration with sodium thiosulfate:
reaction 5 $I_2 + 2Na_2S_2O_3 \longrightarrow 2NaI + Na_2S_4O_6$

(i) State the oxidation number of the chlorine in HOC*l*. [1]

+1

(ii) State the type of reaction for **reaction 3** and **5**. [2]

Reaction 3 – hydrolysis
Reaction 5 – redox

(iii) Write ionic half equations for the oxidation and reduction processes in **reaction 4**. [2]

Oxidation: $2I^- \rightarrow I_2 + 2e^-$

Reduction: $ClO^- + 2H^+ + 2e^- \rightarrow Cl^- + H_2O$
Or $HOCl + H^+ + 2e^- \rightarrow Cl^- + H_2O$

In the analysis of a sample of polymer, 1.00 g of the polymer was reacted with steam. (**reaction 3**).
The resulting mixture was reacted with excess acidified potassium iodide (**reaction 4**) and then made up to 250 cm^3 with distilled water.

25.0 cm^3 of this solution reacted with exactly 25.00 cm^3 of sodium thiosulfate solution of concentration 0.100 mol dm^{-3} (**reaction 5**).

(iv) Name a suitable indicator for the titration in **reaction 5** and state the colour change at end point. [2]

Starch
dark-blue to colourless

(v) Determine the amount of iodine in the 25.00 cm^3 solution. [1]

Amount of thiosulfate = 25.0/1000 × 0.100 = 0.0025 mol

$I_2 + 2Na_2S_2O_3 \rightarrow 2NaI + Na_2S_4O_6$

Amount of iodine in 25.0 cm^3 = 0.0025 mol / 2 = 0.00125 mol

(vi) Determine the mass of chlorine present in the sample of polymer. [2]

Amount of iodine in 250 cm^3 = 0.00125 x 10 = 0.0125 mol

$XCONH–Cl + H_2O \rightarrow XCONH_2 + HOCl$
$HOCl + 2KI + H^+ \rightarrow I_2 + KCl + H_2O + K^+$

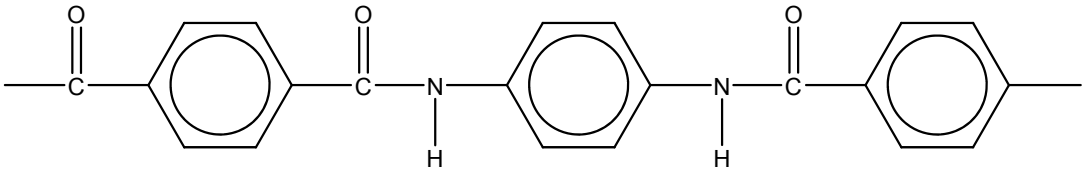
Amount of chlorine = 0.0125 mol

Mass of chlorine = 0.0125 × 35.5 = 0.444 g

(d) *Kevlar* is a synthetic polymer made from two monomers. It is a registered trademark of DuPont and was discovered in 1965. *Kevlar*'s first commercial use was as a replacement for steel in racing tires.

Kevlar is used to make military equipment such as bulletproof vests, helmets, reinforcements for military vehicles and in making other light weight military equipment.

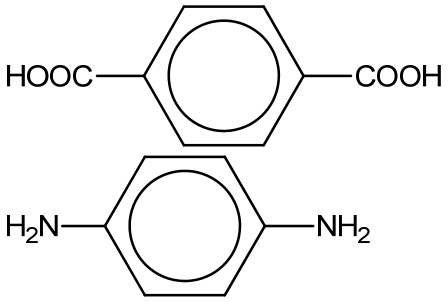
A portion of its chain is shown below.



(i) What type of polymerisation produces *Kevlar*? [1]

Condensation

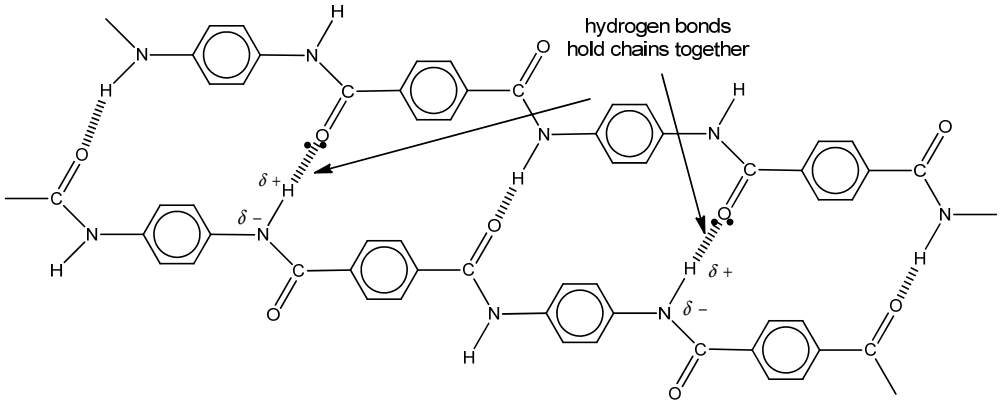
(ii) Draw the structural formulae of the monomers from which *Kevlar* is made. [2]



(iii) With a labelled diagram, suggest a reason why *Kevlar* is much stronger than most other polyamides. [2]

Kevlar is strong as there are intermolecular forces between the chains due to hydrogen bonds. This leads to compact packing or polymers are closely packed.

The chains of rigid, linear molecules line up together parallel to one another, held together by hydrogen bonds which leads to sheets of molecules.

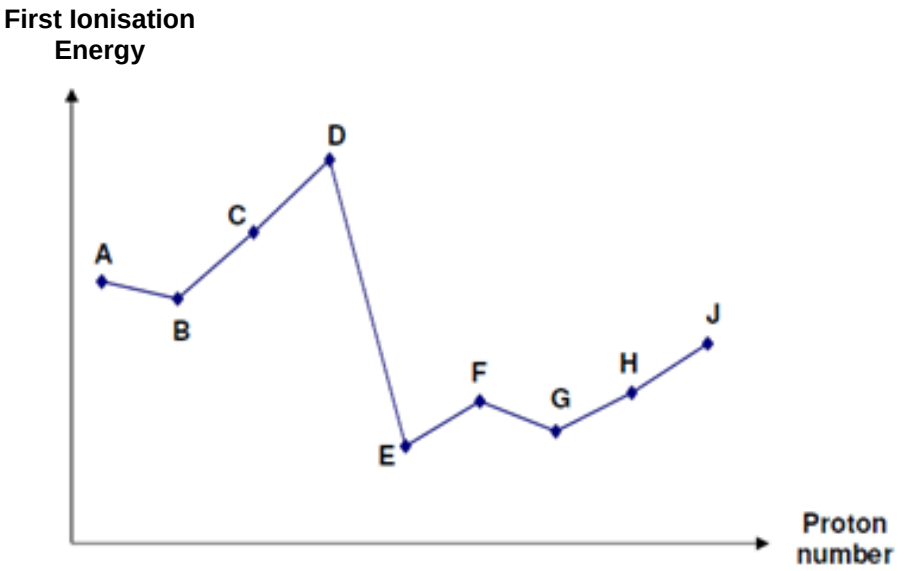


(iv) What reaction conditions are needed to break the amide bonds in *Kevlar*? [1]

Heat/ warm with aq/dilute H_2SO_4/ H^+ or OH^-/ NaOH

[Total: 18]

4 The first ionisation energies of nine consecutive elements **A** to **J** in Periods 2 and 3 of the Periodic Table are as shown.



(a) **A** and **J** are in the same group. Explain why the first ionisation energy of **J** is lower than that of **A**. [1]

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J has an extra quantum shell; the valence electrons are further away from nucleus and less strongly attracted and thus a lower IE.

(b) The oxide of **H** is insoluble in water while its chloride reacts completely with aqueous sodium hydroxide to give a resulting mixture of pH close to 7.

(i) To which group does **H** belong? [1]

14

(ii) Using the symbol **H**, write the formula of the oxide of **H**. [1]

HO_2 OR SiO_2

(c) **J** can form different chlorides of **J**C*l*$_3$ and **J**C*l*$_5$.

State the pH of the resultant mixture when the chloride of **G** and one of the

chlorides of **J** is added to water separately. Write an equation for each to support your answer. [4]

	Chloride of **G**	Chloride of **J**
pH of solution formed when added to water		
Equation to show reaction with water (if any)		

	Chloride of **G**	Chloride of **J**
pH of solution formed when added to water	**3**	**1 or 2**
Equation to show reaction with water (if any)	$\mathbf{GCl_3 + 6H_2O \rightarrow [G(H_2O)_6]^{3+} + 3Cl^-}$ $\mathbf{[G(H_2O)_6]^{3+} \rightleftharpoons [G(H_2O)_5OH]^{2+} + H^+}$ or $\mathbf{GCl_3 + 3H_2O \rightarrow G(OH)_3 + 3HCl}$	$\mathbf{JCl_3 + 3H_2O \rightarrow H_3JO_3 + 3HCl}$ $\mathbf{JCl_5 + 4H_2O \rightarrow H_3JO_4 + 5HCl}$

[Total: 7]

5 'Water gas' is an equimolar mixture of hydrogen and carbon monoxide. It is used as an industrial gaseous fuel. It is produced when steam is blown through white-hot coke in the following reaction.

$$H_2O(g) + C(s) \rightarrow H_2(g) + CO(g)$$

Another widely-used industrial fuel is natural gas, which consists mainly of methane.

The enthalpy changes of combustion of methane, hydrogen and carbon monoxide are –890 kJ mol^{-1}, –242 kJ mol^{-1} and –283 kJ mol^{-1} respectively.

(a) Using the above enthalpy changes, calculate the volume of methane (measured at 20 ^{o}C and 1 atm) required to produce 1 MJ (1000 kJ) of heat energy when burned. [2]

No. of moles of methane needed to produce 1000 kJ of heat
= 1000 / 890 = 1.124 mol

Volume of methane required = 1.124 x 24 = <u>27.0 dm^3</u>

(b) Calculate the volume of water gas (measured at 20 ^oC and 1 atm) required to produce the same amount of heat energy. [2]

1 mol of water gas contains ½ mol of H_2 and ½ mol of CO.

Amount of heat given off when 1 mol of water gas is burnt
= ½ (242) + ½ (283) = 262.5 kJ

amt of water gas needed to produce 1000 kJ of heat
= 1000 / 262.5 = 3.81 mol

Volume of water gas required = 3.81 x 24 = <u>91.4 dm^3</u>

(c) Suggest **one** advantage of using natural gas rather than water gas. [1]

Natural gas is cheaper to use as it is found naturally. Water gas has to be manufactured by passing steam over white hot coke.
OR
Natural gas releases more energy per unit volume than water gas.

OR

Natural gas is not toxic while CO is toxic.

(d) An industrially important source of hydrogen is shown in the reaction below.

$$CH_4(g) + 2H_2O(g) \rightleftharpoons CO_2(g) + 4H_2(g)$$

Using the above enthalpy changes of combustion, determine the enthalpy change of this reaction. [1]

Enthalpy change of reaction = –890 – 4(–242)
= **<u>+78.0 kJ mol^{-1}</u>**

[Total: 6]

6 **K**, **L**, **M** and **N** are consecutive elements of increasing proton number in the Periodic Table.

(a) The successive ionisation energies, in kJ mol^{-1} of element **L** are given below.

1681 3374 6050 8407 11020 15160 17870 92040 106400

To which Group does element **L** belong? Explain your answer. [2]

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.....

.....

Group 17 as the highest jump in ionisation energies is between 7th and 8th electron. 8th electron is found in the inner quantum shell and need more energy to remove it.

(b) **K**, **L** and **N** form ions that are isoelectronic with atom **M**.

(i) State the charge on the ions of **K**, **L** and **N**. [2]

K: …… **L**: …… **N**: ……..…

K: **2– L**: **1– N**: **1+**

(ii) Arrange the ions of **K**, **L** and **N** in *decreasing* order of ionic radius. Explain your answers. [3]

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Ionic radius: $K^{2-} > L^{-} > N^{+}$
All 3 ions are <u>isoelectronic</u> while the <u>nuclear charges increases</u> from K^{2-} to L^{-} to N^{+}; thus stronger forces of attraction between valence e's and nucleus.

[Total: 7]

Section B

Answer **one** question from this section, in the spaces provided.

7 Acetals are compounds formed when aldehydes are reacted with an alcohol in the presence of an acid catalyst. The reaction between ethanal and methanol was studied in the inert solvent dioxan.

$$\underset{\text{ethanal}}{CH_3CHO} + 2\underset{\text{methanol}}{CH_3OH} \overset{H^+}{\rightleftharpoons} \underset{\text{acetal}}{CH_3CH(OCH_3)_2} + H_2O$$

(a) In an experiment, the concentrations of the reactants and products were measured. The results are shown in the table below.

	$[CH_3CHO]$/ mol dm^{-3}	$[CH_3OH]$/ mol dm^{-3}	$[H^+]$/ mol dm^{-3}	[acetal]/ mol dm^{-3}	$[H_2O]$/ mol dm^{-3}
at start	0.20	0.10	0.05	0.00	0.00
change	**-0.025**	-0.05	0	+0.025	+0.025
at equilibrium	0.175	0.05	0.05	0.025	0.025

(i) Complete the blanks in the table. [2]

(ii) Write the expression for the equilibrium constant for this reaction, K_c, stating its units. [2]

$$CH_3CHO + 2CH_3OH \rightleftharpoons CH_3CH(OCH_3)_2 + H_2O$$

$$K_c = \frac{[\text{acetal}][H_2O]}{[\text{ethanal}][\text{methanol}]^2}$$

Units: $mol^{-1}\ dm^3$

(iii) Calculate the value of K_c. [1]

$K_c = \frac{[0.025][0.025]}{[0.175][0.05]^2} = 1.43$

(iv) State *Le Chatelier's principle*. [1]

Le Chatelier's Principle states that if a system in dynamic equilibrium is subjected to a change which disturbs the equilibrium, the system responds in such a way to counteract the effect of the change.

(v) Given a fixed temperature, state whether an increase in concentration for the acid catalyst will affect the value of the equilibrium constant. [1]

No effect on the equilibrium constant.

(b) When the initial rate of this reaction was measured at various starting concentrations of the three reactants, the following results were obtained.

experiment number	$[CH_3CHO]$/ mol dm^{-3}	$[CH_3OH]$/ mol dm^{-3}	$[H^+]$/ mol dm^{-3}	relative rate
1	0.20	0.10	0.05	1.00
2	0.25	0.10	0.05	1.25
3	0.25	0.16	0.05	2.00
4	0.20	0.16	0.10	3.20

(i) Use the data in the table to determine the order with respect to each reactant. [3]

Comparing expt 1 and 2, increasing $[CH_3CHO]$ by 1.25 and keeping the $[H^+]$ and $[CH_3OH]$ constant, the relative rate also increases by 1.25. Hence first order with respect to CH_3CHO.

Comparing expt 2 and 3, increasing $[CH_3OH]$ by 1.6, keeping the $[H^+]$ and $[CH_3CHO]$ constant, the relative rate increases by 1.6. Hence first order with respect to CH_3OH.

Comparing expt 1 and 4, increasing $[CH_3OH]$ by 1.6 and increasing $[H^+]$ by 2, keeping $[CH_3CHO]$ constant, the relative rate increases by 3.2. Hence first order with respect to H^+.

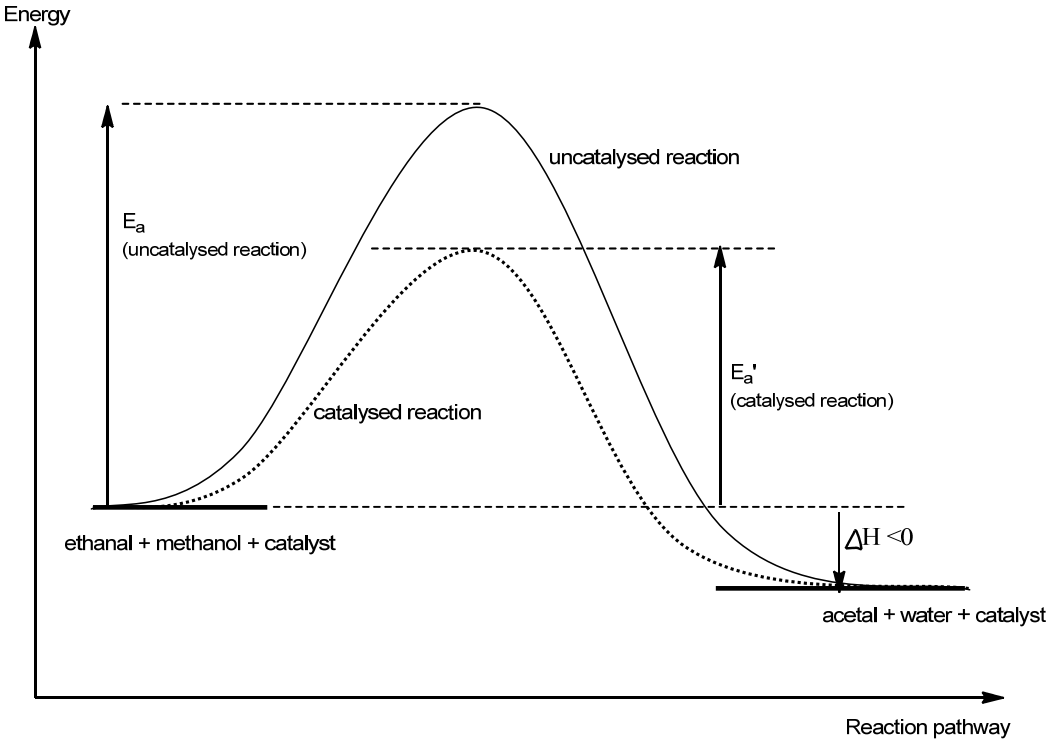
(ii) Write the rate equation for the reaction. [1]

rate = $k[CH_3CHO][CH_3OH][H^+]$

(iii) State the units of the rate constant in the rate equation given that the rate is expressed in terms of mol dm^{-3} s^{-1}. [1]

rate = $k[CH_3CHO][CH_3OH][H^+]$
mol dm^{-3} s^{-1} = k (mol dm^{-3})^3
units of rate constant = mol^{-2} dm^6 s^{-1}

(iv) Explain with the aid of energy profile curves in the same axis how the presence of the acid catalyst will affect the rate constant. Assume that the reaction is exothermic. [4]



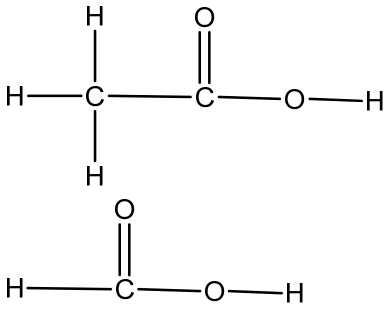
Arrhenius equation is given as:

$$k = Ae^{-\frac{E_a}{RT}}$$

Rate constant is increased. An acid catalyst will decrease activation energy, E_a More particles with energy ≥ E_a increase and frequency of effective collisions increase and increase the rate constant.

(c) Ethanal and methanol can be oxidised using acidified potassium dichromate(VI).

(i) Draw the displayed formulae of the organic products formed. [2]



(ii) Write the equations for the reaction and state the colour change for the reaction. [2]

$CH_3CHO + [O] \rightarrow CH_3COOH$
$CH_3OH + 2[O] \rightarrow HCOOH + H_2O$
Colour change: orange to green

[Total: 20]

8 Blood plasma is a biological fluid that plays an important role in maintaining pH in the body. In the blood plasma, the equilibrium between carbonic acid, $H_2CO_3(aq)$, and hydrogencarbonate ion, $HCO_3^-(aq)$, buffers pH changes.

$$H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

The K_a for this equilibrium is 7.90×10^{-7} mol dm^{-3}.

At body temperature, the pH of the arterial blood plasma is 7.40. If the pH falls below this normal value, a condition termed *acidosis* is produced. If the pH rises above this normal value, the condition is termed *alkalosis*.

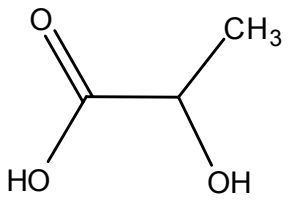
The concentration of $H_2CO_3(aq)$ is controlled by respiration through the lungs. $H_2CO_3(aq)$ is in equilibrium with dissolved CO_2.

$$H_2CO_3(aq) \rightleftharpoons CO_2(aq) + H_2O(l)$$

In the lungs, excess dissolved $CO_2(aq)$ is exhaled as $CO_2(g)$.

$$CO_2(aq) \rightleftharpoons CO_2(g)$$

During heavy exercise, *lactic acid* is released into the blood and is buffered by the blood plasma.



Lactic acid

This eventually leads to an increase in $CO_2(aq)$ concentration and stimulates increased breathing.

(a) (i) Explain what is meant by a *buffer solution* in the context of blood plasma. [2]

Blood plasma contains buffer solution that is made up of a large reservoir of weak acid $H_2CO_3(aq)$ and its conjugate base, $HCO_3^-(aq)$ which maintains a fairly constant pH when a small amount of acid or base is added.

(ii) Write an equation to show how blood plasma can buffer the pH change when lactic acid is released into the blood. [1]

$H^+(aq) + HCO_3^-(aq) \rightarrow H_2CO_3(aq)$

(iii) Write an expression for the acid dissociation constant, K_a, of $H_2CO_3(aq)$ and use it to determine the $[HCO_3^-(aq)]/[H_2CO_3(aq)]$ ratio in the blood plasma.

Comment on this ratio. [3]

$$K_a = \frac{[HCO_3^-][H^+]}{[H_2CO_3]}$$

pH = 7.4 ⇒ $[H^+]$ = $10^{-7.4}$ mol dm^{-3}
= 3.98 x 10^{-8} mol dm^{-3}

$$7.90\times10^{-7} = \frac{[HCO_3^-](10^{-7.40})}{[H_2CO_3]}$$

$$\frac{[HCO_3^-]}{[H_2CO_3]} = \frac{7.90\times10^{-7}}{3.98\times10^{-8}} = 19.8$$

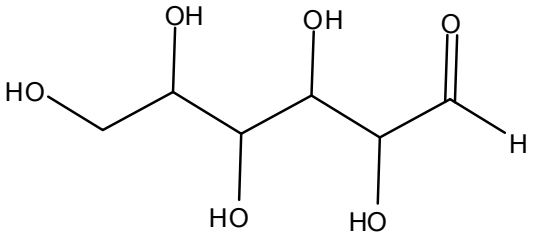
The ratio is high as HCO_3^- is needed to remove lactic acid in the blood during heavy exercises.

(iv) Using the information given, explain, with the aid of two equations, how the production of lactic acid leads to the increase in rate of breathing. [2]

When lactic acid is removed,
$H_2CO_3(aq) \rightleftharpoons CO_2(aq) + H_2O(l)$ ----- (1)
When $[H_2CO_3]$ increases, the equilibrium position in (1) shifts right. Thus, more $CO_2(aq)$ is formed.

$CO_2(aq) \rightleftharpoons CO_2(g)$ ----- (2)
When $[CO_2(aq)]$ increases, the equilibrium position in (2) shifts right, forming more $CO_2(g)$ and thus the rate of breathing increases.

(b) Lactic acid is converted to *glucose* via gluconeogenesis in the liver.



Glucose

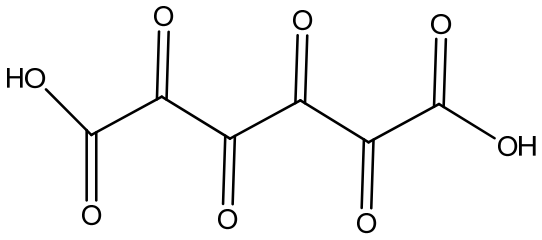
(i) Name the functional group(s) present in glucose. [2]

Aldehyde, primary alcohol and secondary alcohol

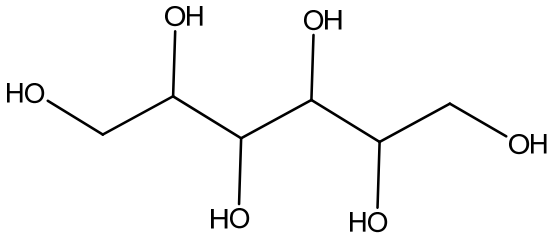
(ii) Draw the skeletal formula of the organic products when *glucose* is added to

[2]

(I) H_2SO_4 (aq), K_2CrO_7, heat

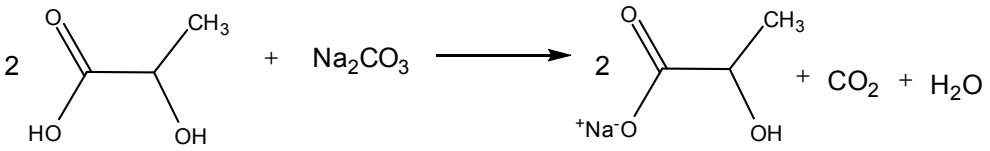


(II) $LiAlH_4$, dry ether, reflux



(iii) Describe a simple chemical test that you could use to distinguish between lactic acid and glucose. You are to include reagents and conditions, observations and balanced equation(s) in each case. [3]

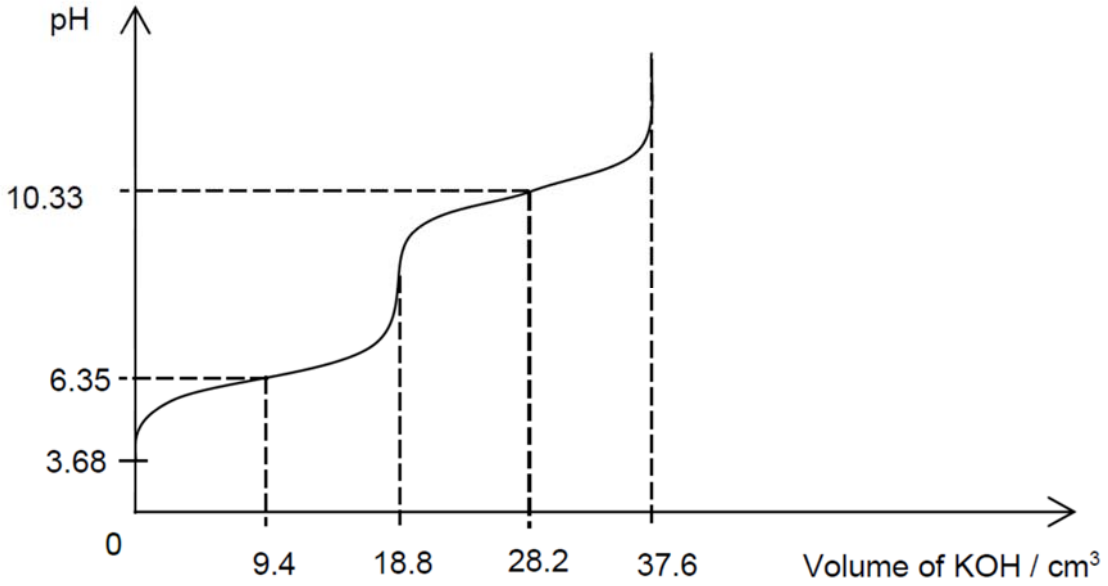
r/c: Na_2CO_3 (aq)
Observation:
Lactic acid- effervescence observed. colourless odourless gas gives white ppt in limewater.
Glucose. No effervescence observed. No white ppt formed in limewater.



(c) In an experiment, 25 cm^3 of 0.100 mol dm^{-3} H_2CO_3 is titrated with aqueous potassium hydroxide. The titration curve is shown below. The acid dissociation of H_2CO_3 is as shown in the following equations.

$$H_2CO_3 \rightleftharpoons HCO_3^- + H^+$$

$$HCO_3^- \rightleftharpoons CO_3^{2-} + H^+$$



(i) Justify that carbonic acid, H_2CO_3, is a weak acid with relevant calculations. [2]

Initial $[H^+(aq)] = 10^{-3.68} = 2.09 \times 10^{-4}$ mol dm^{-3} < 0.100 mol dm^{-3}
H_2CO_3 is partially/ weakly dissociated. Hence, H_2CO_3 is a <u>weak acid</u>.

(ii) Calculate the concentration of KOH, in mol dm^{-3}, used in the titration. [1]

[KOH] = 25/18.8 x 0.100 = 0.133 mol dm^{-3}

(iii) Suggest, with a reason, a suitable indicator for the first end point of this titration. [2]

Phenolphthalein OR thymol blue as the first equivalence point lies within the working range of the indicator of pH 8-10.

[Total: 20]