RAFFLES INSTITUTION
2020 YEAR 6 PRELIMINARY EXAMINATION

Higher 1

CHEMISTRY

8873 / 01

Paper 1 Multiple Choice

24 September 2020

1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not open this question booklet until you are told to do so.

Write in **soft pencil**.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class and index number in the spaces provided on the Answer Sheet unless this has been done for you.

There are **thirty** questions on this paper. Answer **all** questions. For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.
Any rough working should be done in the question booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **14** printed pages.

For examiner's use only

1 *Use of the Data Booklet is relevant to this question.*

Equal masses of four separate samples of the carbonates of calcium, lead, sodium and zinc are decomposed to the respective metal oxides and carbon dioxide gas.

For which compound is there a greatest loss in mass?

A calcium carbonate

B lead(II) carbonate

C sodium carbonate

D zinc carbonate

2 *Use of the Data Booklet is relevant to this question.*

$KMnO_4$ reacts with H_2S as shown in the equation below. The solid products are removed through filtration.

$$2KMnO_4(aq) + 3H_2S(aq) \rightarrow 2MnO_2(s) + 3S(s) + 2KOH(aq) + 2H_2O(l)$$

Which statements about the reaction are correct?

1 The reaction is a redox reaction.

2 Three moles of electrons are gained for every mole of MnO_4^-.

3 Assuming that $KMnO_4$ is the limiting reactant, when 0.1 mol of $KMnO_4$ is used, the mass of the solid products collected is 13.5 g.

A 1 only

B 1 and 2 only

C 2 and 3 only

D 1, 2 and 3

3 *Use of the Data Booklet is relevant to this question.*

In a combustion reaction involving sulfur, 64.9 cm³ of S_xO_y was obtained as a colourless gas at r.t.p. The colourless gas rapidly condensed to form 0.217 g of a dark red solid.

What are the values of x and y?

	x	*y*
A	1	1
B	1	2
C	2	1
D	2	2

4 *Use of the Data Booklet is relevant to this question.*

Which ion contains an unpaired electron?

A Cu^{2+}

B Zn^{2+}

C Se^{2-}

D As^{3-}

5 The boiling points of 2-hydroxybenzoic acid and 4-hydroxybenzoic acid are 158.6 °C and 214.5 °C respectively.

Which statements help to account for the difference in boiling points?

1 2-hydroxybenzoic acid is more polar than 4-hydroxybenzoic acid.

2 4-hydroxybenzoic acid forms stronger covalent bonds than 2-hydroxybenzoic acid.

3 4-hydroxybenzoic acid forms more extensive intermolecular hydrogen bonding than 2-hydroxybenzoic acid.

A 3 only

B 1 and 2 only

C 2 and 3 only

D 1, 2 and 3

6 $CH_3CH_2CH_3$, CH_3CH_2F and CH_3CH_2OH undergoes liquefaction and are converted from the gaseous to the liquid state.

What is the order of their ease of liquefaction?

	increasing ease of liquefaction →		
A	$CH_3CH_2CH_3$	CH_3CH_2F	CH_3CH_2OH
B	$CH_3CH_2CH_3$	CH_3CH_2OH	CH_3CH_2F
C	CH_3CH_2F	CH_3CH_2OH	$CH_3CH_2CH_3$
D	CH_3CH_2OH	CH_3CH_2F	$CH_3CH_2CH_3$

7 Which statement is correct for **all single covalent bonds**?

A A covalent bond cannot be found in ionic compounds.

B A covalent bond can be formed via head-on overlap of p orbitals.

C A covalent bond can only be formed between two non-metal atoms.

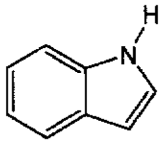
D A covalent bond is formed when each bonding atom contributes a valence electron.

8 Which of the following have giant lattice structures under standard conditions?

1 copper
2 octane
3 aluminium chloride
4 magnesium bromide

A 3 only
B 1 and 4 only
C 1, 3 and 4 only
D 1, 2, 3 and 4

9 Indole is one of the main contributors to the pungent odour in animal faeces.



What is the number of σ and π bonds in a molecule of indole?

	σ	π
A	11	4
B	11	5
C	17	4
D	19	4

10 *Use of the Data Booklet is relevant to this question.*

Which row of the table is correct?

	most exothermic lattice energy	⟶	least exothermic lattice energy
A	calcium oxide	calcium sulfide	magnesium oxide
B	calcium sulfide	calcium oxide	magnesium oxide
C	magnesium oxide	calcium sulfide	calcium oxide
D	magnesium oxide	calcium oxide	calcium sulfide

11 The table below shows the enthalpy change of neutralisation, ΔH_{neut}, for the various acids and bases listed.

acid	base	ΔH_{neut} / kJ mol^{-1}
sulfuric acid	sodium hydroxide	–57.0
ethanoic acid	potassium hydroxide	less exothermic than –57.0
sulfuric acid	X	less exothermic than –57.0
W	potassium hydroxide	–57.0

What are W and X?

	W	X
A	hydrochloric acid	ammonia
B	ethanoic acid	sodium hydroxide
C	ethanoic acid	ammonia
D	hydrochloric acid	sodium hydroxide

12 Xenon-131 is a radioactive isotope which is used in the study of pulmonary function and organ blood flow. It has a half-life of 5.3 days.

Given that radioactive decay is a first-order reaction, what fraction of the isotope has **reacted** after 21.2 days?

A 0.063

B 0.75

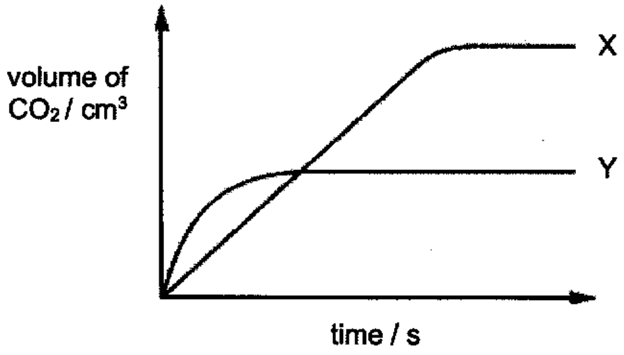
C 0.25

D 0.94

13 0.100 mol of magnesium carbonate was reacted with 100 cm^3 of 0.500 mol dm^{-3} nitric acid. The equation for the reaction is given below.

$$CO_3^{2-} + 2H^+ \rightarrow CO_2 + H_2O$$

The rate of reaction was monitored by collecting the carbon dioxide gas produced. The volume of carbon dioxide produced is plotted against time and the graph labelled X is obtained.



The experiment is repeated using 0.100 mol of the same magnesium carbonate, with a different sample of acid. All other conditions remain the same. Plotting these results gives the graph labelled Y.

Which sample of acid gives graph Y?

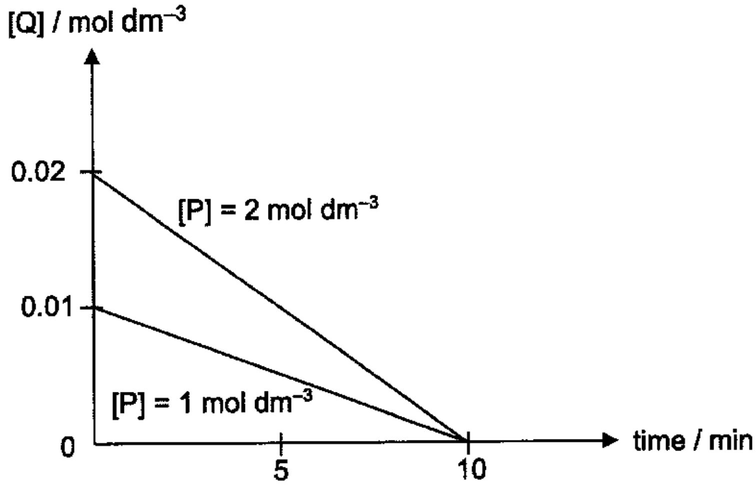
A 50 cm^3 of 1.00 mol dm^{-3} sulfuric acid

B 50 cm^3 of 1.00 mol dm^{-3} nitric acid

C 25 cm^3 of 0.500 mol dm^{-3} nitric acid

D 25 cm^3 of 0.500 mol dm^{-3} sulfuric acid

14 The kinetics of the reaction between compounds P and Q is investigated.



Which statements are correct for this reaction?

1 The rate of reaction is independent of the concentration of Q.

2 The reaction is second order with respect to compound P.

3 The units for the rate constant is min^{-1}.

A 1, 2 and 3

B 1 and 2 only

C 1 and 3 only

D 3 only

15 Consider the following equilibrium system:

$$A(s) + 2B(g) \rightleftharpoons C(g) + 3D(s) \qquad \Delta H^{\ominus} > 0$$

Which of the following is correct?

	change made	position of equilibrium
A	add solid A(s)	shifts to the right
B	reduce the temperature	shifts to the left
C	reduce the concentration of C(g)	shifts to the left
D	increase the volume of the reaction vessel	shifts to the right

16 Contact process is a method of producing high concentrations of sulfuric acid for industrial applications. It involves reacting sulfur dioxide with excess oxygen to form sulfur trioxide.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -196 \text{ kJ mol}^{-1}$$

The reaction is carried out at 450 °C and 1 atm. Vanadium(V) oxide is also used.

Which statement is correct?

A A low pressure of 1 atm is used to increase the percentage of SO_3 in the equilibrium mixture.

B A high temperature of 450 °C is used to increase the rate of the forward reaction to generate a higher yield of SO_3.

C Vanadium(V) oxide is added to decrease the activation energy of the forward reaction.

D Vanadium(V) oxide is added to increase the percentage of SO_3 in the equilibrium mixture.

17 In which reaction is the underlined substance acting as a Brønsted-Lowry base?

A $2\underline{Na}(s) + H_2(g) \rightarrow 2NaH(s)$

B $\underline{NaOH}(s) + aq \rightarrow Na^+(aq) + OH^-(aq)$

C $\underline{CH_3NH_2}(aq) + H_2O(l) \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$

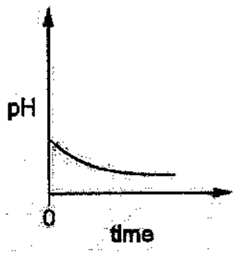
D $\underline{CH_3COOH}(aq) + NaOH(aq) \rightarrow CH_3COO^-Na^+(aq) + H_2O(l)$

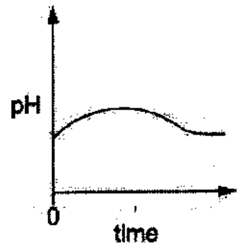
18 Solid lead(II) nitrate is converted into lead(IV) oxide when it is added to a solution of acidified manganate(VII) ions. The nitrate ions do not undergo any chemical reaction.

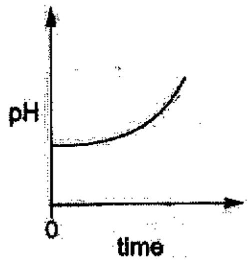
$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$$

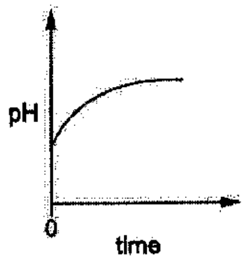
$$Pb^{2+}(aq) + 2H_2O(l) \rightarrow PbO_2(s) + 4H^+(aq) + 2e^-$$

Which graph shows how the pH changes as lead(II) nitrate is added at a constant rate into a well-stirred solution of acidified manganate(VII) ions until its colour just fades?

A


C


B


D


19 Which of the following solutions, when mixed in equal volumes, will produce a buffer solution?

A 0.2 mol dm^{-3} NaOH and 0.1 mol dm^{-3} HC*l*

B 0.2 mol dm^{-3} NaOH and 0.1 mol dm^{-3} CH_3COOH

C 0.1 mol dm^{-3} NaOH and 0.2 mol dm^{-3} H_2SO_4

D 0.1 mol dm^{-3} NaOH and 0.2 mol dm^{-3} CH_3COOH

20 *Use of the Data Booklet is relevant to this question.*

Element X is a Period 3 element.

The oxides of element X are insoluble in water.

The melting point of element X is higher than that of the elements on either side of it in the Periodic Table.

What is the identity of element X?

A Al

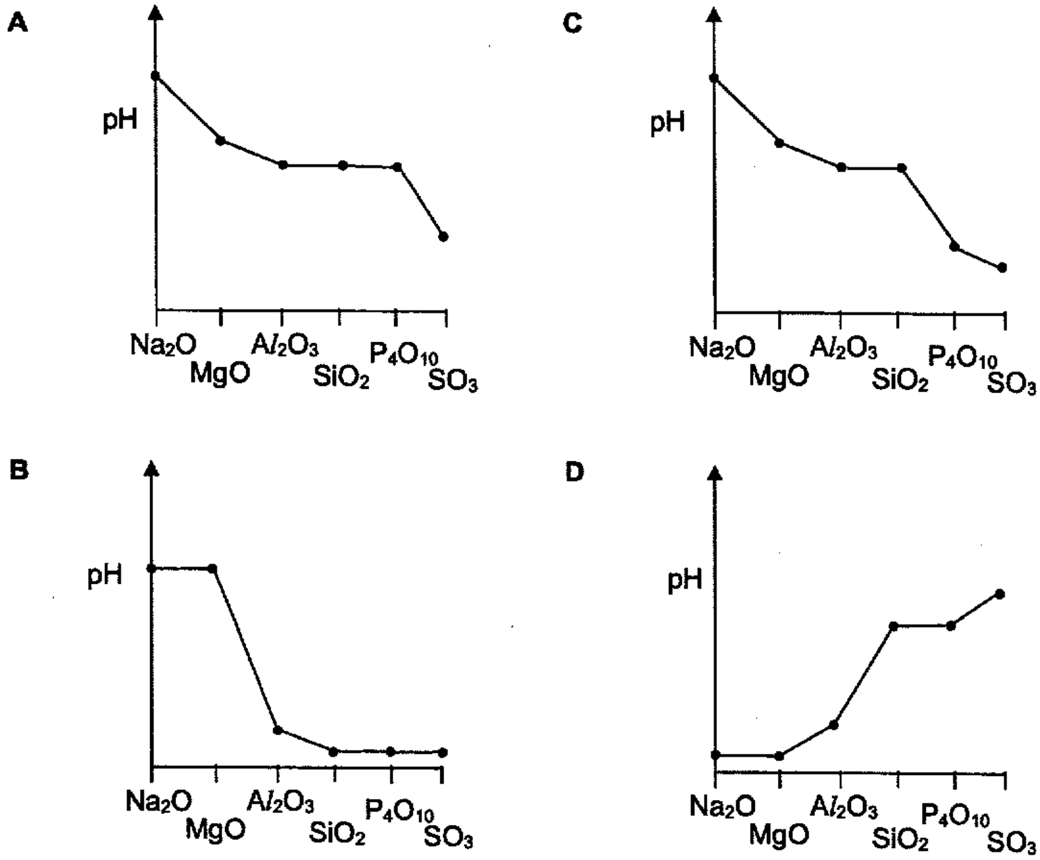
B Cl

C S

D Si

21 The oxides of the elements sodium to sulfur are separately added to water.

Which diagram best represents the pH of the solutions produced?



22 Which of the following statements about the Period 3 chlorides are correct?

1 An aqueous solution of $AlCl_3$ has a lower pH than an aqueous solution of $MgCl_2$ of the same concentration.

2 $NaCl$, $MgCl_2$ and $AlCl_3$ have very high boiling points whereas $SiCl_4$ and PCl_5 have low boiling points.

3 PCl_5 hydrolyses in water to form a strongly acidic solution.

A 1, 2 and 3
B 1 and 3 only
C 2 and 3 only
D 1 only

23 Which statement best explains why HCl has a higher thermal stability than HBr and HI?

A The permanent dipole-permanent dipole interaction between the HCl molecules is the strongest.
B The HCl molecule has the smallest electron cloud.
C The H–Cl bond has the largest bond energy.
D The HCl molecule has the greatest polarity.

24 A monocyclic organic compound has a molecular formula of $C_4H_7O_3N$. It contains a carboxylic acid functional group.

Which other functional groups could be present in this molecule?

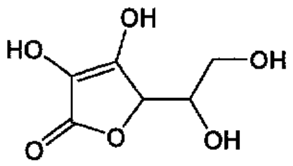
1 aldehyde

2 amine

3 ester

A 1, 2 and 3
B 1 and 2 only
C 1 only
D 2 only

25 Ascorbic acid, also known as vitamin C, is necessary for the growth and repair of body tissues.



ascorbic acid

What is the empirical formula of ascorbic acid?

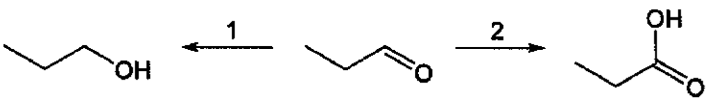
A $C_3H_2O_3$

B $C_3H_4O_3$

C $C_3H_5O_3$

D $C_6H_8O_6$

26 Propanal can undergo different types of reaction.

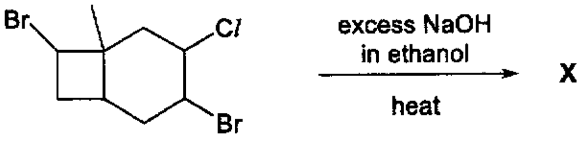


propanal

Which row correctly identifies the type of reaction for reactions 1 and 2?

	reaction 1	reaction 2
A	hydrolysis	oxidation
B	hydrolysis	addition
C	reduction	oxidation
D	reduction	addition

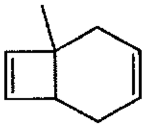
27 Compound **A** is heated with an excess of sodium hydroxide in ethanol. **X** is one of the products formed.



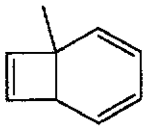
A

What is a possible structure of **X**?

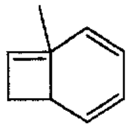
A



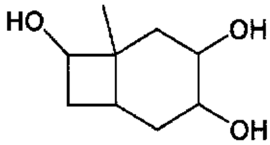
B



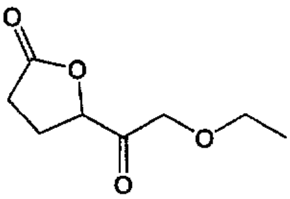
C



D

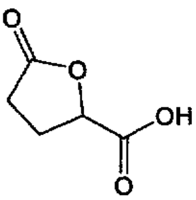


28 An ester is shown.

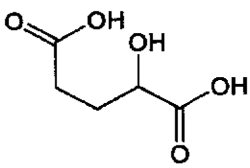


What is the structure of the carboxylic acid formed from the acid hydrolysis of the ester?

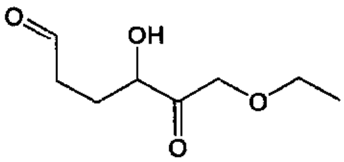
A



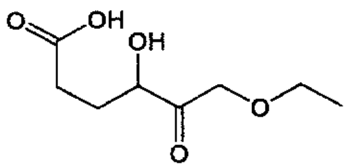
B



C



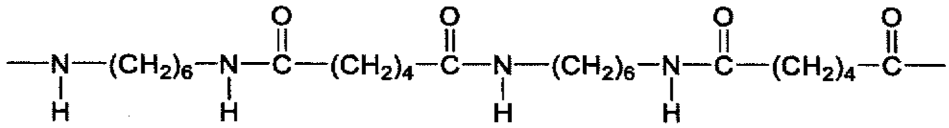
D



29 *Use of the Data Booklet is relevant to this question.*

Nylon 6,6 is a condensation polymer made up of two monomers.

A segment of the Nylon 6,6 polymer chain is shown below.



A typical Nylon 6,6 molecule has a relative molecular mass of 11300.

How many of **each** monomer is used to make this typical Nylon 6,6 molecule?

A 25

B 50

C 75

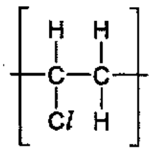
D 100

30 Which statement about poly(vinyl chloride), PVC, is **not** correct?

A It is able to form hydrogen bonds with water molecules.

B Combustion of PVC produces a highly acidic gas.

C It is a thermoplastic that can be recycled.

D The repeat unit is .

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RAFFLES INSTITUTION
2020 YEAR 6 PRELIMINARY EXAMINATION

Higher 1

CANDIDATE NAME

CLASS

INDEX NUMBER

CHEMISTRY

8873/02

Paper 2 Structured Questions

15 September 2020

2 hours

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Do not open this question booklet until you are told to do so.

Write your name, class and index number in the spaces provided at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answer **all** the questions.

Section B
Answer **one** question.

For Examiner's Use		
Section A	**1**	**/ 11**
	2	**/ 12**
	3	**/ 13**
	4	**/ 4**
	5	**/ 20**
Section B (Please circle the question you have attempted)	**6**	**/ 20**
	7	**/ 20**
Total		**/ 80**

The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided. Do not write anything in it.

You are reminded of the need for good English and clear presentation in your answers.

The number of marks is given in brackets [ ] at the end of each question or part question.

This document consists of **26** printed pages and **3** blank pages.

Section A

For examiner's use

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

1 *Use of the Data Booklet is relevant to this question.*

X^- is isoelectronic with H_3O^+.

(a) **(i)** State the number of electrons and protons in X^-. Hence, deduce the identity of X^-.

number of electrons ....

number of protons ....

identity of X^- .... [2]

(ii) Fig. 1.1 shows the third ionisation energies of eight consecutive elements in the Periodic Table. These elements have atomic numbers less than 20. One of the eight elements is element X.

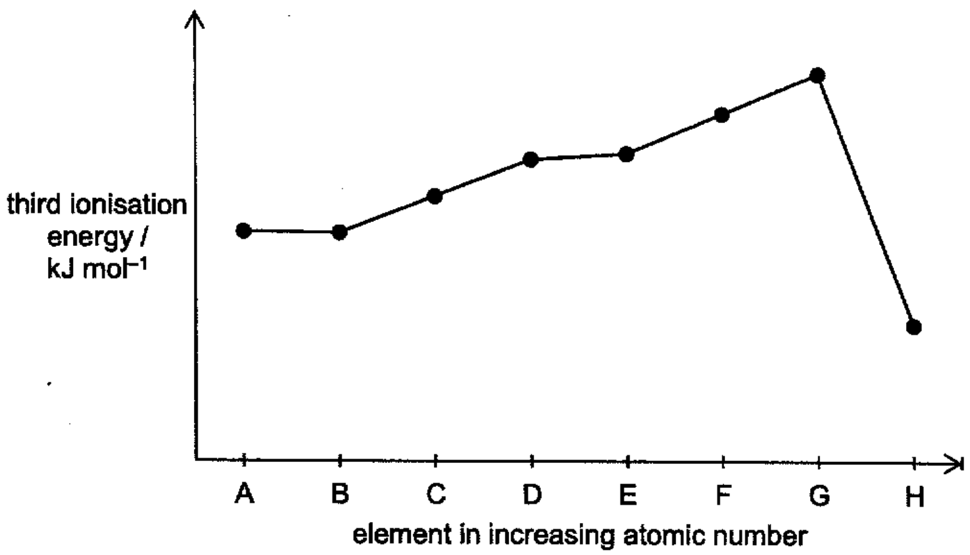

Fig. 1.1

With reference to Fig. 1.1, state the element which represents element X and explain your answer.

....

....

....

....

....

....[3]

For examiner's use

(b) Fig. 1.2 shows an experimental setup used to measure the angle of deflection of charged particles.

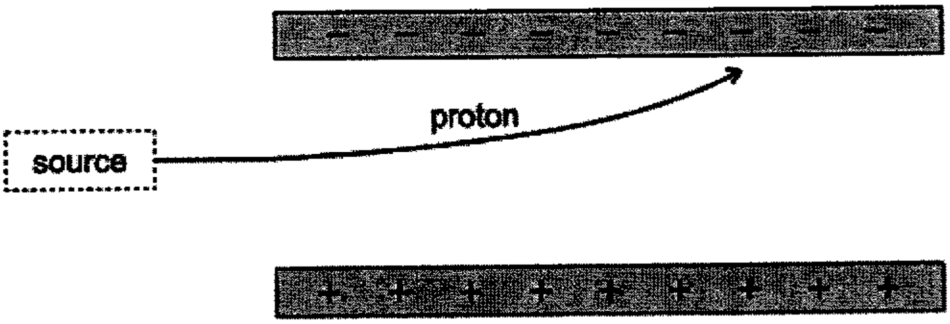

Fig. 1.2

The angle of deflection of a beam of protons was found to be +20°.

(i) Under identical conditions, a beam of **isotope** of O^{2-} was deflected by an angle of –2.20°. Determine the number of neutrons in an ion of O^{2-}.

[2]

(ii) State the electronic configurations of $_{8}O^{2-}$ and $_{13}Al$.

$_{8}O^{2-}$ $1s^2$ ....

$_{13}Al$ $1s^2$ ....
[2]

(iii) $_{13}Al$ can be oxidised by losing electrons to form $_{13}Al^{3+}$.
Name the orbitals from which the electrons are removed and describe their shapes.

....

....[2]

[Total: 11]

2 ▯ *Use of the Data Booklet is relevant to this question.*

For examiner's use▯

(a) Lithium and sodium are Group 1 metals which are reducing agents.

When a small piece of sodium is added to ethanoic acid, a rapid flow of bubbles was seen. Lithium will react with ethanoic acid in a similar way.

Write an equation for the reaction of lithium with ethanoic acid. State and explain how the observations differ when lithium metal is used in place of sodium metal in the above reaction.

....

....

....

....

....

....

....

....

....

....[3]

(b) Borohydrides, such as $LiBH_4$, $NaBH_4$ and KBH_4, are often used as reducing agents in organic chemistry.

(i) The greater the charge density of the metal cation, the stronger the reducing power of the borohydrides.

Identify the weakest reducing agent among the three Group 1 borohydrides listed above and explain your answer.

weakest reducing agent ....

explanation ....

....

....[2]

For examiner's use

(ii) $LiBH_4$ can be used to reduce ethyl ethanoate to form ethanol as the only product.

Using [H] to represent the $LiBH_4$ reducing agent, write an equation for this reaction.

....[1]

(c) (i) Iodine can react with chlorine to form iodine monochloride, ICl.

The boiling points of ICl and chlorine are 97.4 °C and –34.0 °C respectively. Explain why the boiling points are different with reference to the type of bonding involved.

....

....

....

....

....

....[2]

(ii) At higher temperatures, iodine can react with excess chlorine to form I_xCl_y. The percentage by mass of iodine in I_xCl_y is 54.3%.

Determine the empirical formula of I_xCl_y.

[1]

(iii) The relative molecular mass of I_xCl_y is 466.8. Determine x and y.

[1]

For examiner's use

(d) When chlorine is added to a solution containing Mn^{2+} ions, a black precipitate of MnO_2 is formed.

$$Cl_2 + Mn^{2+} + 2H_2O \rightarrow 2Cl^- + MnO_2 + 4H^+$$

(i) Explain why this is a redox reaction, in terms of oxidation numbers.

....

....[1]

(ii) There is no redox reaction when bromine is added to a solution containing Mn^{2+} ions. Explain the difference in observations between chlorine and bromine with Mn^{2+}.

....[1]

[Total: 12]

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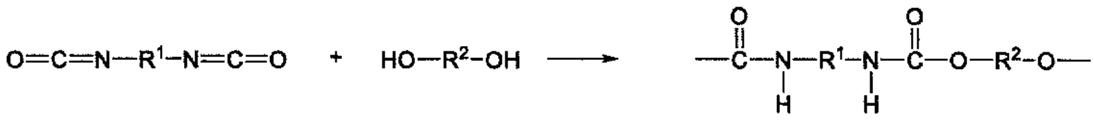
For examiner's use

3 (a) Polyurethanes are widely used polymers that have a wide range of properties. It can be soft and elastic or tough and rigid.

Polyurethanes are thermosetting polymers and can be formed from the reaction between a diisocyanate and a diol, as shown in Fig. 3.1. R^1 and R^2 are hydrocarbon groups.



diisocyanate diol polyurethane

Fig. 3.1

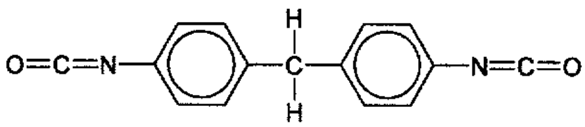
(i) With reference to the structure in Fig. 3.1, suggest two possible factors why polyurethanes can be made soft and elastic or tough and rigid.

factor 1 ....

factor 2 ....

[2]

Lycra® is a polyurethane formed from the diisocyanate **P** and $HOCH_2CH_2OH$.



P

(ii) Draw a repeat unit of Lycra®.

[2]

(iii) Fibres of Lycra® are strong due to the intermolecular forces between the polymer chains. Complete the table below to identify two intermolecular forces responsible for this property and the corresponding group(s) involved.

intermolecular forces	group(s) involved

[2]

For examiner's use

(iv) Suggest why Lycra® cannot be recycled.

....

....[1]

(b) An addition polymer made from two different alkene monomers is called a co-polymer. A section of a polyalkene co-polymer is shown in Fig. 3.2.

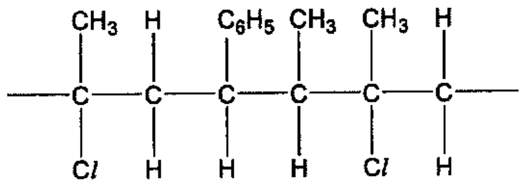


Fig. 3.2

Draw the structure of the two alkene monomers used to produce the co-polymer in Fig. 3.2.

[2]

(c) When choosing a polymer for a specific use, the properties of the polymer must be considered carefully.

For examiner's use

Table 3.1 shows properties of four polymers labelled A to D.

Table 3.1

polymer	reaction with water	strength to weight ratio	rigidity
A	resistant	medium	high
B	soluble	high	medium
C	resistant	high	medium
D	soluble	low	low

You are to design a waterproof swimming bag to store the belongings of children during lessons. The swimming bag should be foldable to fit into a small locker.

State which polymer would be most suitable for making the swimming bag. Explain your choice by considering each of the three properties listed in Table 3.1.

....

....

....

....

....

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....

....

....

....

....

....

....[4]

[Total: 13]

For examiner's use

4 Boron nitride and graphite are similar in their structures. The empirical formula for boron nitride is BN.

It is a slip modifier which is often added to lipsticks and eye shadows so that they can be applied smoothly onto the skin. It is a good lubricant.

Boron nitride can also be used in electrical insulating coatings.

(a) Use the information above to suggest one property in which boron nitride and graphite are **similar**. Explain your answer in terms of structure and bonding.

property ....

explanation ....

....

.... [2]

(b) Use the information above to suggest one property in which boron nitride and graphite are **different**. Explain your answer in terms of structure and bonding.

property ....

explanation ....

....

.... [2]

[Total: 4]

For examiner's use

5 Methanol is a highly versatile chemical widely used for industrial purposes. It is also an energy resource used in the automotive sector and is an emerging renewable energy resource.

(a) A student used the apparatus shown in Fig. 5.1 to determine the enthalpy change of combustion of methanol, $\Delta H_c(CH_3OH)$.

equation 1 $CH_3OH(l) + \frac{3}{2}O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$ $\Delta H_c(CH_3OH)$

The energy released from the combustion of methanol is used to heat up the water and the copper calorimeter.

The heat absorbed by the copper calorimeter can be calculated using the equation given below.

$$\text{heat absorbed by copper calorimeter} = C \times \Delta T$$

where C represents the heat capacity of the calorimeter. This is the amount of heat required to raise the temperature of the copper calorimeter by 1 °C.

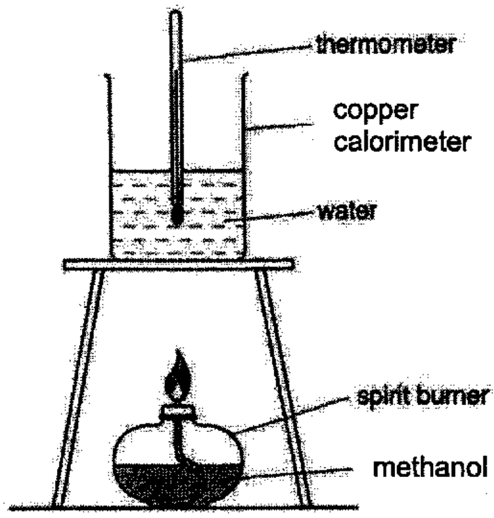


Fig. 5.1

The measurements recorded by the student are shown in Table 5.1.

Table 5.1

mass of water / g	250.0
initial temperature of water and copper calorimeter / °C	31.0
final temperature of water and copper calorimeter / °C	50.5
initial mass of spirit burner / g	65.38
final mass of spirit burner / g	63.97

The heat capacity of the copper calorimeter is 38.5 J °C^{-1}.

For examiner's use

(i) Define the term *standard enthalpy change of combustion*.

....

....

....[1]

(ii) Calculate the enthalpy change of combustion of methanol, $\Delta H_c(CH_3OH)$, using relevant information from the *Data Booklet* and the data from Table 5.1.

[4]

(iii) The same apparatus in Fig. 5.1 can be used to determine and compare the enthalpy change of combustion of different alcohols.

Identify two variables that must be controlled to determine and compare the enthalpy change of combustion of different alcohols. Suggest a reason for each variable.

variable 1 ....

reason..

....

variable 2 ....

reason..

....

[4]

For examiner's use

(b) Bond energies can also be used to calculate the $\Delta H_c(CH_3OH)$.

(i) Using equation 1 and suitable bond energies from the *Data Booklet*, calculate the $\Delta H_c(CH_3OH)$.

[2]

(ii) One of the reasons why $\Delta H_c(CH_3OH)$ obtained from **(b)(i)** is different from the theoretical value of the $\Delta H_c^{\ominus}(CH_3OH)$ is that the bond energy values are only average values.

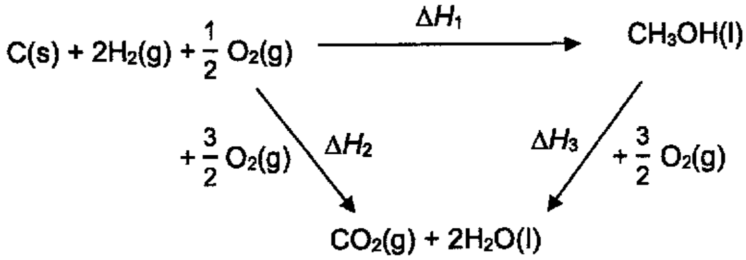
Suggest another reason for this difference.

....

....[1]

For examiner's use

(c) The diagram below shows an energy cycle involving methanol.



(i) In the energy cycle above, what enthalpy change is represented by ΔH_1?

....[1]

(ii) Use the energy cycle and the following data to calculate the standard enthalpy change of combustion of methanol, $\Delta H_c^{\ominus}(CH_3OH)$.

$\Delta H_c^{\ominus}$ (carbon) $= -393$ kJ mol^{-1}
$\Delta H_c^{\ominus}$ (hydrogen) $= -286$ kJ mol^{-1}
ΔH_1 $= -238$ kJ mol^{-1}

[2]

For examiner's use

(d) The student is also interested to determine the concentration of methanol in a sample provided by his teacher.

10.0 cm^3 of the sample was mixed with dilute sulfuric acid and made up to a volume of exactly 250.0 cm^3 in a volumetric flask.

A 25.0 cm^3 portion of this diluted solution was pipetted into a conical flask and heated. A few drops of N-phenylanthranilic acid indicator were added to the flask. 0.01 mol dm^{-3} aqueous potassium dichromate(VI) was run from the burette into the conical flask until a distinct colour change was observed. The titration was repeated to obtain two consistent results (i.e. at least two titres that are within 0.10 cm^3 of each other).

The results are shown in Table 5.2.

Table 5.2

titration number	1	2	3
initial burette reading / cm^3	0.00	21.40	0.00
final burette reading / cm^3	21.40	43.35	21.50
titre / cm^3			

(i) Complete Table 5.2 and obtain the average volume of aqueous potassium dichromate(VI) to be used in your calculations. Show clearly how you obtained this volume.

Use the result obtained to calculate the amount of potassium dichromate(VI) required to react with the methanol present in 25.0 cm^3 of the diluted solution.

average titre ....cm^3

amount of potassium dichromate(VI) ....mol

[2]

(ii) Under the conditions of the experiment, methanol is oxidised to methanoic acid by the acidified solution of dichromate(VI) ions during this titration.

$$CH_3OH + H_2O \rightarrow HCOOH + 4H^+ + 4e^-$$

The dichromate(VI) ions, $Cr_2O_7^{2-}$, are reduced to Cr^{3+}.

Construct a balanced ionic equation for the reaction between methanol and the acidified dichromate(VI) ions.

Use of the Data Booklet is relevant to this question.

....[1]

For examiner's use

(iii) Use your answers to **(d)(i)** and **(d)(ii)** to calculate the concentration of methanol in the sample provided by the teacher.

[2]

[Total: 20]

Section B

For examiner's use

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

6 Boron trifluoride, BF_3, is an important catalyst used in organic synthesis. It forms adducts with a variety of nitrogen compounds such as ammonia and amines.

(a) In one scientific study, it was found that one molecule of BF_3 reacts with one molecule of hydrazine, N_2H_4, to form a $BF_3 \cdot N_2H_4$ adduct.

(i) Draw a 'dot-and-cross' diagram for a molecule of hydrazine, showing all of the valence electrons. Suggest the shape of the molecule with respect to each central N atom.

shape of molecule with respect to each central N atom ....

[2]

(ii) Explain why BF_3 is able to form an adduct with N_2H_4 in a 1:1 ratio.

....

....

....

....

....[1]

(iii) Draw the structure to illustrate the bonding in $BF_3 \cdot N_2H_4$.

[1]

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(b) The boiling points of BF_3 and N_2H_4 are –100 °C and 114 °C respectively. Explain why the boiling points are different in terms of structure and bonding.

For examiner's use

....

....

....

....

....

....

....[3]

(c) The titration curve for the acid-base reaction between hydrazine and hydrochloric acid is shown in Fig. 6.1.

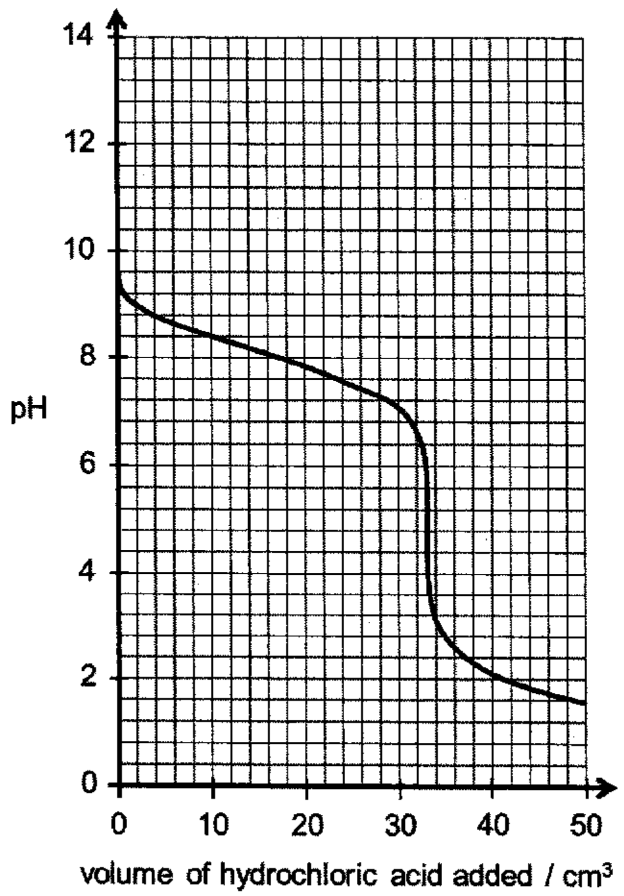

Fig. 6.1

(i) Using Fig 6.1, deduce the volume of hydrochloric acid required to reach the equivalence point for this titration.

volume of hydrochloric acid ....[1]

(ii) Table 6.1 shows some acid-base indicators.

For examiner's use

Table 6.1

indicator	colour in acid	colour in alkali	pH range of colour change of indicator
alizarin yellow	yellow	orange	10.1 – 13.0
methyl orange	red	yellow	3.1 – 4.4
phenolphthalein	colourless	pink	8.2 – 10.0

Suggest which of the above indicators should be used for this titration.

State the colour change of your chosen indicator at the end-point of this titration.

indicator ....

colour change ....

[2]

(d) Hydrazine is a monoacidic base which can react with another acid, butanoic acid, $CH_3CH_2CH_2COOH$, in an acid-base reaction.

Write an equation for the reaction between N_2H_4 and $CH_3CH_2CH_2COOH$.
Label the conjugate acid and conjugate base in your equation.

....

....[2]

(e) Butanoic acid can be synthesised from 1-chlorobutane as shown in Fig. 6.2.

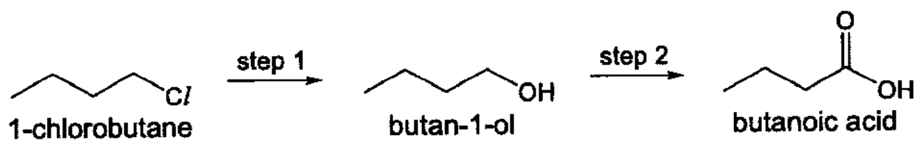

Fig. 6.2

State the reagents and conditions for step 1.

....[1]

(f) In step 2 of Fig. 6.2, butan-1-ol was heated under reflux with acidified potassium dichromate(VI) to form butanoic acid.

For examiner's use

There are three other isomeric **alcohols** with the same molecular formula as butan-1-ol.

Name and draw the structure of the isomer which does **not** turn hot acidified potassium dichromate(VI) from orange to green.

name of isomer: .... [2]

For examiner's use

(g) A series of experiments was carried out at different concentrations of 1-chlorobutane and sodium hydroxide. The experimental data are shown in Table 6.2.

Table 6.2

experiment	[1-chlorobutane] / mol dm^{-3}	[NaOH] / mol dm^{-3}	initial rate / mol dm^{-3} min^{-1}
1	0.015	0.010	0.0024
2	0.030	0.040	0.0192
3	0.015	0.020	0.0048

(i) Use the data in Table 6.2 to determine the order of reaction with respect to each reactant, 1-chlorobutane and NaOH.

Show your reasoning.

....

....

....

....

....

....

....

order of reaction with respect to 1-chlorobutane = ... [1]

order of reaction with respect to NaOH = ... [1]

(ii) Write the rate equation for this reaction.

....[1]

(iii) Use the data of experiment 1 to calculate the rate constant, *k*, for this reaction. Include the units of *k*.

k = ... [1]

units = ... [1]

[Total: 20]

For examiner's use

7 (a) Nail polish is mainly composed of the nitrocellulose polymer. It is commonly dissolved in organic solvents such as butyl ethanoate which gives nail polish its characteristic smell.

The structure of nitrocellulose is shown in Fig. 7.1.

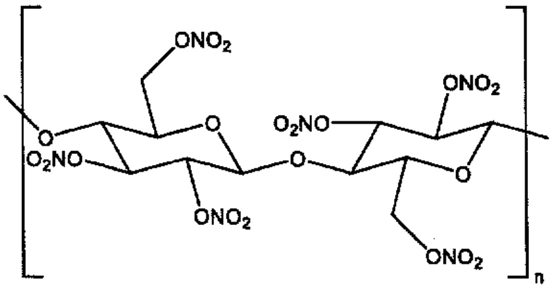

Fig. 7.1

(i) Explain why nitrocellulose is soluble in butyl ethanoate.

....

....

....[1]

(ii) The time taken for the nail polish to dry depends on the volatility of the solvent, and this allows different design effects to be achieved. The cracked nail polish effect, for example, is achieved from the rapid evaporation of a more volatile solvent, ethanol.

Suggest why ethanol is more volatile than butyl ethanoate in terms of structure and bonding.

....

....

....

....

....

....

....[3]

(iii) Plasticisers are often added to increase the distance between the polymer chains.

Suggest how plasticisers prevent nail polish from chipping.

....

....[1]

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For examiner's use

(b) Butyl ethanoate is synthesised from the condensation of ethanoic acid with butanol. A dynamic equilibrium is established.

$$CH_3COOH(l) + CH_3(CH_2)_3OH(l) \rightleftharpoons CH_3COO(CH_2)_3CH_3(l) + H_2O(l) \quad \Delta H > 0$$

(i) State the reagents and conditions for the above reaction.

....[1]

(ii) Write the expression for the equilibrium constant, K_c.

[1]

In an experiment, a mixture of ethanoic acid, butanol and butyl ethanoate were allowed to reach equilibrium in a 2 dm³ closed vessel. Fig. 7.2 shows how the amount of butanol and butyl ethanoate in the reaction mixture changes with time.

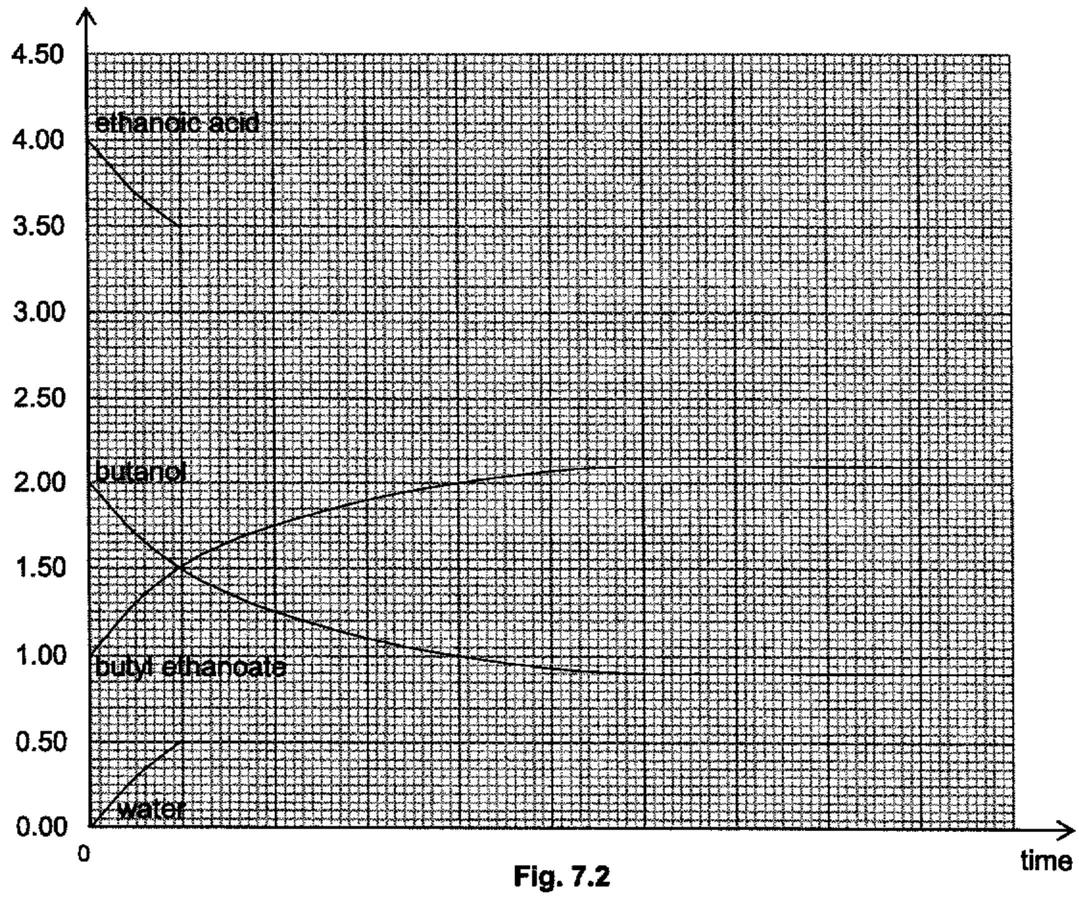


Fig. 7.2

(iii) Complete the graphs for ethanoic acid and water in Fig. 7.2. [2]

For examiner's use

(iv) Hence, calculate the value of K_c.

value of K_c ....
[1]

(v) Using Le Chatelier's Principle, state and explain how the equilibrium composition would change when the temperature decreases.

....

....

....

....

....[2]

(vi) Sketch a labelled reaction pathway diagram to illustrate the effect of a catalyst on the reaction.

[2]

(c) Protein buffers account for two-thirds of the buffering power of blood. Amino acids, which are monomers of proteins, are responsible for this buffering ability of proteins.

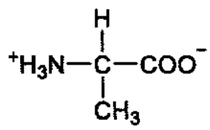
For examiner's use

(i) Define the term *buffer solution.*

....

....[1]

Alanine is an amino acid that is abundant in haemoglobin, a protein buffer in blood. In aqueous solutions, alanine exists as a zwitterion.



zwitterion of alanine

(ii) Write equations to show the buffering action of alanine when small amount of H^+ or OH^- is added.

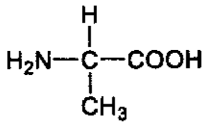
On addition of H^+: ....

On addition of OH^-: ....[2]

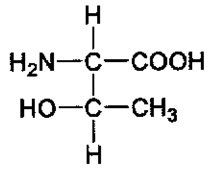
For examiner's use

(d) Amino acids can react with each other in the presence of a suitable catalyst to form a variety of products which are structural isomers.

Draw the three structural isomers, each with molecular formula $C_7H_{14}N_2O_4$, that can be formed when alanine, $C_3H_7NO_2$, reacts with threonine, $C_4H_9NO_3$.



alanine



threonine

isomer 1

isomer 2

isomer 3

[3]

[Total: 20]

For examiner's use

Suggested Answers for 2020 Y6 H1 Chemistry Preliminary Examination

Paper 1:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A	D	C	A	A	A	B	B	C	D	A	D	D	C	B	C	C	A	D	D

21	22	23	24	25	26	27	28	29	30
C	B	C	D	B	C	B	D	B	A

Worked solutions for Paper 1

Q1
For all compounds, the loss in mass is due to the formation of $CO_2(g)$. The mole ratio between metal carbonate and CO_2 is 1:1 for all options.

Let assume the mass of each carbonate to be 2.0 g

Option A:
$CaCO_3 \rightarrow CaO + CO_2$
$n(CaCO_3) = n(CO_2) = \frac{2.0}{100.1} = 1.9980 \times 10^{-3}$ mol
M_r of CO_2 = 12.0 + 16.0 + 16.0 = 44.0 g mol^{-1}
mass of CO_2 = $1.9980 \times 10^{-3} \times 44.0 = 0.879$ g

Option B:
$PbCO_3 \rightarrow PbO + CO_2$
$n(PbCO_3) = n(CO_2) = \frac{2.0}{267.2} = 7.4850 \times 10^{-3}$ mol
M_r of CO_2 = 12.0 + 16.0 + 16.0 = 44.0 g mol^{-1}
mass of CO_2 = $7.4850 \times 10^{-3} \times (44.0) = 0.329$ g

Option C:
$Na_2CO_3 \rightarrow Na_2O + CO_2$
$n(Na_2CO_3) = n(CO_2) = \frac{2.0}{106} = 1.8868 \times 10^{-3}$ mol
M_r of CO_2 = 12.0 + 16.0 + 16.0 = 44.0 g mol^{-1}
mass of CO_2 = $1.8868 \times 10^{-3} \times 44.0 = 0.830$ g

Option D:
$ZnCO_3 \rightarrow ZnO + CO_2$
$n(ZnCO_3) = n(CO_2) = \frac{2.0}{125.4} = 1.5949 \times 10^{-3}$ mol
M_r of CO_2 = 12.0 + 16.0 + 16.0 = 44.0 g mol^{-1}
mass of CO_2 = $1.5949 \times 10^{-3} \times 44.0 = 0.702$ g

$CaCO_3$ has the greatest loss in mass.

Ans: A

Q2
Option 1 is correct. Since MnO_4^- (oxidation number of Mn = +7) is reduced to MnO_2 (oxidation number of Mn = +4) while H_2S (oxidation number of S = –2) is oxidised to S (oxidation number of S = 0), it is a redox reaction.

Option 2 is correct. Based on the reduction half-equation (can be found in Data Booklet),
$MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O$
For every mole of MnO_4^-, 3 moles of e^- was gained.

Option 3 is correct.
$n(MnO_2) = 0.1$ mol

Mass of MnO_2 = 0.1 × (54.9 + 32.0) = 8.69 g

Mass of S = $0.1 \times \frac{3}{2} \times 32.1 = 4.815$ g
mass of solid products = 8.69 + 4.815
= 13.505 ≈ 13.5 g

Ans: D (1, 2 and 3)

Q3
$n(S_xO_y) = \frac{64.9}{1000} \div 24 = 2.7042 \times 10^{-3}$ mol
M_r of $S_xO_y = \frac{0.217}{0.0027042} = 80.247$
$32.1x + 16y \approx 80.247$
x = 2; y = 1

Ans: C

Q4
Cu^{2+}: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9$ (unpaired electron present)
Zn^{2+}: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$
Se^{2-}: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$
As^{3-}: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6$

Ans: A

Q5
Statement 1 does not help to account for the higher boiling point of 4-hydroxybenzoic acid as it would prove that 2-hydroxybenzoic acid will have a higher boiling point if it is more polar.

Statement 2 is incorrect. During boiling, intermolecular forces between molecules is overcome and not covalent bonds between atoms.

Statement 3 is correct as the close proximity between the COOH and OH groups in 2-hydroxybenzoic acid results in intramolecular hydrogen bonding. There will be lesser sites available for intermolecular hydrogen bonding and hence forms less extensive intermolecular hydrogen bonding than 4-hydroxybenzoic acid. Less energy is required to overcome the less extensive intermolecular hydrogen bonding in 2-hydroxybenzoic acid and hence it has a lower boiling point.

Ans: A (3 only)

Q6
Ease of liquefaction ∝ strength of IMF ∝ boiling point
Thus, the higher the boiling point, the easier it is to liquefy a gas.

All three compounds have simple molecular structure.

$CH_3CH_2CH_3$	instantaneous dipole-induced dipole interactions
CH_3CH_2F	permanent dipole-permanent dipole interactions
CH_3CH_2OH	hydrogen bonding

Hence, boiling point of
$CH_3CH_2CH_3 < CH_3CH_2F < CH_3CH_2OH$

Ease of liquefaction:
$CH_3CH_2CH_3 < CH_3CH_2F < CH_3CH_2OH$

Ans: A

Q7
Option A: incorrect. Polyatomic ions, such as sulfate ions (SO_4^{2-}), consists of covalent bonds between the S and O atoms.

Option B: correct. Fluorine is an example where the covalent bonds are formed via head-on overlap of p orbitals.

Option C: incorrect. Aluminium chloride is an example of a molecule with covalent bonds between metals and non-metals.

Option D: incorrect. A dative covalent bond is formed when the shared pair of electrons is provided by only one of the bonding atoms.

Ans: B

Q8
Option 1: Copper is a metal and has a <u>giant metallic lattice structure</u>.

Option 2: Octane exists as <u>small discrete molecules</u> with covalent bonds between the C and H atoms.

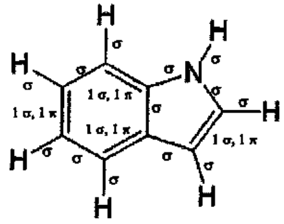
Option 3: Aluminium chloride exist as <u>small discrete molecules</u> with covalent bonds between the *Al* and *Cl* atoms.

Option 4: Magnesium bromide is an ionic compound which has a <u>giant ionic lattice structure</u>.

Ans: B (1 and 4 only)

Q9
As there are 4 C=C bonds, there are 4 π bonds in total.

There are 6 C–H bonds, 8 C–C bonds, 2 N–C bonds and 1 N–H bond. So, the number of σ bonds = 6 + 8 + 2 + 1 = 17



Ans: C

Q10

$$|LE| \propto \left|\frac{q_+q_-}{r_+ + r_-}\right|$$

Since Mg^{2+} has a smaller cationic radius than Ca^{2+}, and O^{2-} also has a smaller anionic radius than S^{2-}, the interionic distance in MgO is the smallest and CaS has the largest interionic distance.

Therefore, lattice energy of MgO is the most exothermic and lattice energy of CaS is the least exothermic.

Ans: D

Q11

acid	base	ΔH_{neu} / kJ mol^{-1}
sulfuric acid (strong acid)	sodium hydroxide (strong base)	–57.0
ethanoic acid (weak acid)	potassium hydroxide (strong base)	less exothermic than –57.0
sulfuric acid (strong acid)	X (weak base)	less exothermic than –57.0
W (strong acid)	potassium hydroxide (strong base)	–57.0

Hence X must be ammonia, and W must be hydrochloric acid.

Ans: A

Q12

Since half–life of Xenon-131 is 5.3 days,
$\frac{21.2}{5.3} = 4$ half-lives have passed after 21.2 days.
% remaining after 21.2 days = $\left(\frac{1}{2}\right)^4 = 0.0625$.
Therefore, fraction of isotope reacted
= 1 – 0.0625 = 0.9375 ≈ 0.94

Ans: D

Q13

$CO_3^{2-} + 2H^+ \rightarrow CO_2 + H_2O$

$n(H^+) = \frac{100}{1000} \times 0.5 = 0.0500$ mol

$n(MgCO_3) = 0.100$ mol (from question)

⇒ HNO_3 is the limiting reagent

$n(CO_2) = n(H^+) = \frac{0.0500}{2} = 0.0250$ mol

0.100 mol of $MgCO_3$ reacts with 100 cm^3 of 0.500 mol dm^{-3} nitric acid to produce 0.025 mol of CO_2.

The amount of CO_2 produced can be calculated:

$CO_3^{2-} + 2H^+ \rightarrow CO_2 + H_2O$

Option A:	0.1000	0.0500
Option B:	0.0500	0.0250
Option C:	0.0125	0.00625
Option D:	0.0250	0.0125

For graph Y to be plotted, the acid must produce less than 0.025 mol of CO_2 (thus option A and B is rejected) and has a concentration higher than 0.500 mol dm^{-3} of H^+ (shown by steeper gradient at the start of reaction).

↑ higher concentration of H^+
→ reactant particles come closer together
→ frequency of effective collisions increases
→ rate of reaction increases
→ gradient of the graph plotted steeper

$[H^+]$ for option C = 0.500 mol dm^{-3}
$[H^+]$ for option D = 0.500 × 2 = 1.000 mol dm^{-3}

Ans: D

Q14

The graph of [Q] against time is a straight line, which indicates the rate of reaction is constant as [Q] changes, hence the order of reaction w.r.t. Q is zero.

When [P] is doubled, the gradient of the graph (which represents rate) also doubled. Since order of reaction w.r.t. Q is zero, it can be deduced that the order of reaction w.r.t. P is 1.

rate = k[P]

$$\text{unit of k} = \frac{\text{unit of rate}}{\text{unit of [P]}} = \frac{\text{mol dm}^{-3}\text{min}^{-1}}{\text{mol dm}^{-3}} = \text{min}^{-1}$$

Therefore, statement 2 is incorrect and statements 1 and 3 are correct.

Ans: C (1 and 3)

Q15

$A(s) + 2B(g) \rightleftharpoons C(g) + 3D(s) \quad \Delta H^\ominus > 0$

Forward reaction is endothermic.

A	adding solid does not shift the P.O.E.
B	decreasing the temperature favours the backward exothermic reaction by releasing heat to increase temperature. Hence P.O.E shift left.
C	reducing the concentration of product C(g) will cause the P.O.E to shift right
D	increasing the volume of reaction vessel will reduce the concentration of all species. The P.O.E will shift left to favour the production of more gaseous particles to increase concentration.

Ans: B

Q16

Option A is incorrect. A pressure of 1 atm (atmospheric pressure) is considered to be low. To increase the percentage of SO_3, a higher pressure should be used.

Option B is incorrect. This is because high temperature favours the backward reaction, and it will lead to a decrease in the yield of SO_3.

Option C is correct. Vanadium(V) oxide is a catalyst and it reduces the activation energy of both the forward and backward reaction.

Option D is incorrect. Catalyst only increases the rate of reaction but not the yield.

Ans: C

Q17

A Brønsted-Lowry base is a proton acceptor.

Option A is a redox reaction in which Na is oxidised to Na^+ while H_2 is reduced to H^-.

Option B shows an Arrhenius base. Arrhenius base is a compound that produces OH^- in aqueous solution.

Option C shows a Brønsted-Lowry base. CH_3NH_2 accepts H^+ from water to form $CH_3NH_3^+$.

Option D is a neutralisation reaction in which ethanoic acid behaves as Brønsted-Lowry acid.

Ans: C

Q18

Combining both half-equations:

$2MnO_4^-(aq) + 5Pb^{2+}(aq) + 2H_2O(l)$
$\rightarrow 2Mn^{2+}(aq) + 5PbO_2(s) + 4H^+(aq)$

There is a net production of $H^+(aq)$, causing the solution to be more acidic with time. This results in pH decreases with time.

Ans: A

Q19

A buffer must contain a weak acid (or base) with its conjugate base (or acid).

Options A and C do not contain any weak acids or bases, thus they do not produce buffers.

Option B: The weak acid is limiting. Upon mixing, the solution contains a salt and excess NaOH → not a buffer.

Option D: Upon mixing, the mixture contains CH_3COO^- and CH_3COOH → buffer

Ans: D

Q20

SiO_2 is insoluble in water as it exists in a giant molecular structure where Si and O atoms are held together by strong covalent bonds.

Silicon has a higher melting point compared to both aluminium and phosphorus.

Ans: D

Q21

When dissolved in water, sodium oxide and magnesium oxide gives alkaline solution. (pH > 7)

Aluminium oxide and silicon dioxide are not soluble in water and hence both solution are neutral. (pH ≈ 7)

P_4O_{10} and SO_3 gives acidic solutions (pH < 7) when dissolved in water.

Hence option C gives the best representation.

Ans: C

Q22

Option 1 is correct. Al^{3+} has a higher charge density than Mg^{2+}, hence it undergoes hydrolysis in water to a greater extent to produce higher concentration of H^+ ions.

Option 2 is incorrect as $AlCl_3$ is a simple molecule with a low boiling point.

Option 3 is correct due to the formation of HCl.
$PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$

Ans: B (1 and 3 only)

Q23

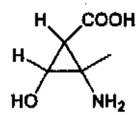
Polarity of the molecule, pd-pd interaction between the molecules and size of electron cloud affects the melting and boiling point of the substance. Hence option A, B and D are incorrect.

Thermal stability of hydrogen halide is related to the H–X bond strength. Hence option C is correct.

Ans: C

Q24

By drawing a structure with a ring structure and carboxylic acid group, the rest of the structure must not have any double bonds (otherwise the number of hydrogen atoms will be too few). An example is shown below.



An ester cannot be present too due to the insufficient number of oxygen atoms.

Ans: D (2 only)

Q25

The molecular formula of ascorbic acid is $C_6H_8O_6$.
Therefore, the empirical formula is $C_3H_4O_3$.

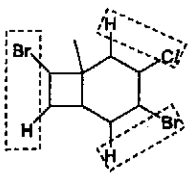
Ans: B

Q26

Reaction 1: Aldehyde reduced to primary alcohol.
Reaction 2: Aldehyde oxidised to carboxylic acid.

Ans: C

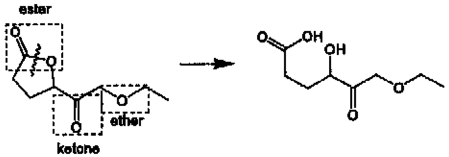
Q27
Hot NaOH in ethanol results in elimination reactions.
Note: the halogen atom will be eliminated with a hydrogen atom from an adjacent carbon atom.



Ans: B

Q28
Upon acid hydrolysis, the ester group forms a carboxylic acid and an alcohol.

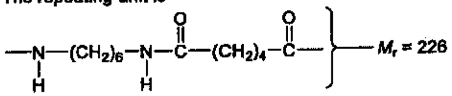
Note: The bottom right chain does not contain an ester group. It is a ketone and ether.



Ans: D

Q29

The repeating unit is



Based on the M_r of 11300, there are $\frac{11300}{226}$ = 50 repeat units in the polymer. Since the repeating unit is made up of one monomer each, there would be 50 of each monomer present in the nylon 6,6 molecule.

Ans: B

Q30

PVC is unable to form hydrogen bonds as it has only C,H and C*l*.

Ans: A

Suggested Answers for 2020 Y6 H1 Chemistry Preliminary Examination

Paper 2

1(a)(i)
Since X^- is isoelectronic with H_3O^+, both species contain the same number of electrons.
Number of electrons in H_3O^+ = 10
Number of electrons in X^- = 10
Number of protons in X^- = 9

Identity of X^- is F^-.

1(a)(ii)
There is a large decrease in the third ionisation energy between G and H.

This indicates that significantly less energy is needed to remove the 3rd electron from H. Thus, this 3rd electron in H is located in the valence shell that is further away from the nucleus and is less attracted by the nucleus.

Therefore, H has 3 valence electrons. H belongs to Group 13 of the Periodic Table.

Since the elements differs by one proton number, elements **G**, **F**, **E** and **D** should have 2, 1, 8 and 7 valence electrons respectively. Thus, D is element X which belongs to Group 17.

1(b)(i)
If H^+ where $\frac{q}{m} = 1$ gives θ of +20°,
since $\theta = k\left(\frac{q}{m}\right)$, k = 20

For O^{2-}: $-2.20 = 20 \times \frac{-2}{m}$
m = 18.18

number of neutrons = 18.18 – 8 = 10.18 ≈ 10

1(b)(ii)
$_8O^{2-}$ $1s^22s^22p^6$
$_{13}Al$ $1s^2\,2s^2\,2p^6\,3s^2\,3p^1$

1(b)(iii)
3s orbital has a spherical shape.
$3p_x$ or $3p_y$ or $3p_z$ orbital has a dumbbell shape.

2(a)
Li + CH_3COOH → $CH_3COO^-Li^+$ + ½ H_2
The rate of bubbles formed with lithium is slower/ less vigorous.

The valence electron in lithium is closer to the nucleus compared to the valence electron in sodium. Thus, it is more difficult for lithium metal to lose electron to form cation and lithium is less reactive than sodium.

2(b)(i)
weakest reducing agent: KBH_4

explanation: Among the Group 1 cations, all 3 ions have the same charge of +1 but K^+ has the largest ionic radius. Hence K^+ has the smallest charge density and KBH_4 is the weakest reducing agent.

2(b)(ii)
$CH_3COOCH_2CH_3$ + 4[H] → $2CH_3CH_2OH$

2(c)(i)
Chlorine has a lower boiling point because the non-polar molecules are held by weaker instantaneous dipole – induced dipole interactions (id-id). Hence lesser energy is required to overcome the weak id-id interactions.

IC*l* has a higher boiling point because the polar molecules are held by additional permanent dipole – permanent dipole interactions (pd-pd) and stronger id-id interactions ~~due to a larger and more polarisable electron cloud~~. Hence more energy is required to overcome the stronger intermolecular interactions in IC*l*.

2(c)(ii)
% by mass of chlorine = 100 – 54.3 = 45.7%

Mole ratio of iodine : chlorine
(54.3/126.9) : (45.7/35.5)
0.428 : 1.287
1 : 3

Hence empirical formula of iodine chloride is ICl_3.

2(c)(iii)
n(126.9 + 3 x 35.5) = 466.8
n = 2

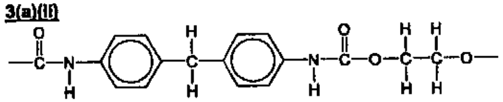
Hence the molecular formula is I_2Cl_6.
x = 2 and y = 6

2(d)(i)
oxidation number of C*l* : 0 to –1
oxidation number of Mn: +2 to +4

2(d)(ii)
Chlorine is a stronger oxidising agent compared to bromine.

3(a)(i)
factor 1: amount of cross-link
factor 2: the length of the polymer chains

3(a)(ii)

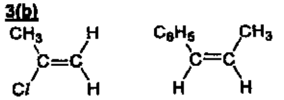


3(a)(iii)

Intermolecular force	group(s) involved
Permanent dipole-permanent dipole	COO
hydrogen bonding	NH, CO (lpe on O) or amide
Instantaneous dipole-induced dipole interactions	$-C_6H_4CH_2$ (allow benzene/aromatic rings)

3(a)(iv)
It is a thermoset which cannot be remolded.

3(b)



3(c)
Explanation:
(1) Being water resistant allows it to be dry/waterproof when used in the swimming pool.

(2) A polymer with high strength to weight ratio allows it to be strong enough to carry large weights and yet itself is lightweight.

(3) Low or medium rigidity allows it to be folded when the bag is not in use and minimises storage space.

Hence, polymer C would be the most suitable polymer.

4(a)
property: It is soft.

explanation: There is weak instantaneous dipole-induced dipole interactions between the different layers as the layers can glide/slide over each other.

4(b)
property: Boron nitride is an insulator but graphite is an electrical conductor.

explanation: There is delocalisation of π–electron cloud in both boron nitride and graphite. However, N is more electronegative than B, the electrons in the π bond tend to stay with N rather than delocalise throughout the π-electron cloud.

5(a)(i)
Standard enthalpy change of combustion ($\Delta H_c^\ominus$) of a substance is the energy released when one mole of the substance is completely burnt in excess oxygen at 298 K and 1 bar.

5(a)(ii)
amount of heat released from the combustion of methanol
= amount of heat absorbed by water
+ amount of heat absorbed by copper calorimeter

$= m_{water} \times c_{water} \times \Delta T + C \times \Delta T$

$= 250 \times 4.18 \times (50.5 - 31.0) + 38.5 \times (50.5 - 31.0)$

$= 20377.5 + 750.75$

$= 21128.25$ J

Amount of methanol burned $= \dfrac{65.38 - 63.97}{12.0 + 4 \times 1.0 + 16.0} = 0.04406$ mol

$\Delta H_c(\text{methanol}) = -\dfrac{21128.25 \times 10^{-3}}{0.04406} = \underline{-480 \text{ kJ mol}^{-1}}$

5(a)(iii)
variable: Distance between the flame and the calorimeter
reason: To ensure that the percentage/amount of heat transfer to the calorimeter is the same for both experiments. (or words to the same effect)

variable: The calorimeter used
reason: To ensure that same amount of heat is required to raise the temperature of calorimeter by 1 °C.

Or
variable: The thermometer used
reason: To ensure that the thermometer has the same sensitivity to heat / the precision of the temperature reading is the same for both experiments.

5(b)(i)
$CH_3OH\ (l) + \frac{3}{2}O_2(g) \rightarrow CO_2\ (g) + 2H_2O\ (l)$

Bonds broken		Bonds formed	
3 C–H	3(410)	2 C=O in CO_2	2(805)
C–O	360	4 O–H	4(460)
O–H	460		
3/2 O=O	3/2(496)		

ΔH_c = ΣBE of bonds broken in reactants – ΣBE of bonds formed in products

$\Delta H_c = [3(410) + 360 + 460 + 3/2(496)] - [2(805) + 4(460)]$

$= -656$ kJ mol^{-1} (3 s.f.)

5(b)(ii)
When using the bond energies method in (b)(i), all the reactants and products should be in gaseous state (in accordance with the definition of bond energy). However, the methanol and water are in the liquid state and the enthalpy change value obtained in (b)(i) will be different from the theoretical value of the $\Delta H_c^\ominus(CH_3OH)$.

Or
The ΔH_c calculated makes use of data which was collected under non-standard conditions e.g. T not at 298 K.

5(c)(i)
(standard) enthalpy change of formation of methanol

5(c)(ii)
$\Delta H_f^\ominus(CH_3OH) = \Delta H_3$

$\Delta H_3 = \Delta H_2 - \Delta H_1$
$= -393 + 2(-286) - (-238)$

$\Delta H_f^\ominus(CH_3OH) = \Delta H_3 = -727$ kJ mol^{-1}

5(d)(i)

titration number	1	2	3
initial burette reading / cm³	0.00	21.40	0.00
Final burette reading / cm³	21.40	43.35	21.50
titre / cm³	21.40	21.95	21.50

average volume of $Cr_2O_7^{2-}$ used = (21.40+21.50)/2 = 21.45 cm³

Amt of $Cr_2O_7^{2-}$
= (21.45/1000) x 0.01 = 2.15 x 10^{-4} mol

5(d)(ii)
[O]: $CH_3OH + H_2O \rightarrow HCOOH + 4H^+ + 4e^-$ x3
[R]: $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$ x2

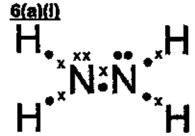
Overall balanced equation:
$3CH_3OH + 2Cr_2O_7^{2-} + 16H^+ \rightarrow 3HCOOH + 4Cr^{3+} + 11H_2O$

5(d)(iii)
amount of CH_3OH in 25.0 cm³ solution
= 2.145 x 10^{-4} x 3/2
= 3.2175 x 10^{-4} mol

amount of CH_3OH in 250 cm³ solution
= Amount of CH_3OH in 10 cm³ sample
= 3.2175 x 10^{-4} x 10
= 3.2175 x 10^{-3} mol

concentration of CH_3OH in 10 cm³ sample
= 3.2175 x 10^{-4} x 1000/10
= 0.322 mol dm^{-3} (3 s.f.)

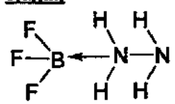
6(a)(i)



shape = trigonal pyramidal

6(a)(ii)
BF_3 contains a vacant low-lying orbital/energetically accessible orbital that can accept a lone-pair electrons from either of the nitrogen atom in hydrazine to form a dative covalent bond.

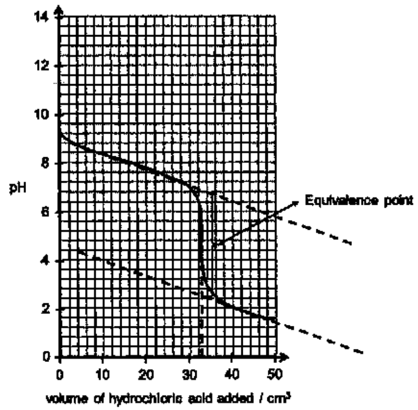
6(a)(iii)



6(b)
Both BF_3 and N_2H_4 exist as simple molecular structures. There are instantaneous dipole - induced dipole interactions between non-polar BF_3 molecules.

There are hydrogen bonds between N_2H_4 molecules. More energy is needed to overcome the stronger hydrogen bonds between N_2H_4 molecules.

6(c)(i)



volume of hydrochloric acid = 33.00 ± 1.0 cm³

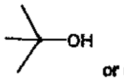
6(c)(ii)
indicator: methyl orange
colour change: from yellow to orange

6(d)
$N_2H_4 + CH_3CH_2CH_2COOH \rightarrow N_2H_5^+ + CH_3CH_2CH_2COO^-$

conjugate acid: $N_2H_5^+$
conjugate base: $CH_3CH_2CH_2COO^-$

6(e)
reagents and conditions for Step 1:
NaOH(aq), heat

6(f)



or $(CH_3)_3COH$

2-methylpropan-2-ol

6(g)(i)
Comparing experiments 1 and 3,
when [NaOH] × 2, initial rate × 2.
⇒ reaction is first order with respect to NaOH.

Comparing experiments 1 and 2,
when [1-chlorobutane] × 2 and [NaOH] × 4,
initial rate × 8.
Since reaction is first order with respect to NaOH,
⇒ reaction is first order with respect to 1-chlorobutane.

6(g)(ii)
rate = k[1-chlorobutane][NaOH]

6(g)(iii)
$k = 0.0024 / (0.015 \times 0.010) = 16.0$
units = $mol^{-1}\,dm^3\,min^{-1}$

7(a)(i)
Nitrocellulose is able to form favourable permanent dipole-permanent dipole interactions between the polar –COO group of butyl ethanoate with the polar $-ONO_2$ group of nitrocellulose, enabling dissolution.

Or
Nitrocellulose is able to form favourable instantaneous dipole-induced dipole interactions between the non-polar hydrocarbon chains of both butyl ethanoate and nitrocellulose.

7(a)(ii)
Both ethanol and butyl ethanoate have simple molecular structure. As butyl ethanoate has more electrons / a larger and more polarisable electron cloud, more energy is required to overcome the stronger instantaneous dipole-induced dipole interactions in butyl ethanoate than the weaker hydrogen bonding between ethanol molecules. Thus, ethanol has a lower boiling point and is more volatile.

7(a)(iii)
Plasticisers increases the distance between the polymer chains and reduces the inter-chain interactions.

This increases the flexibility of nail polish, making it less brittle/rigid and prevents it from chipping.

7(b)(i)
concentrated sulfuric acid, heat

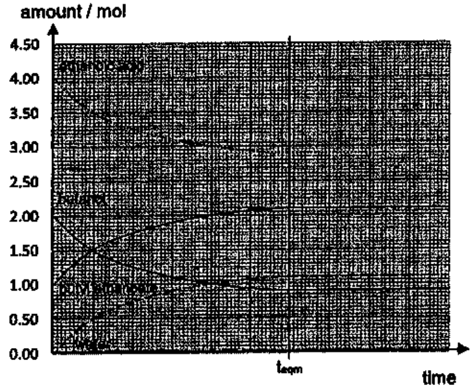
7(b)(ii)

$$K_c = \frac{[CH_3COO(CH_2)_3CH_3][H_2O]}{[CH_3COOH][CH_3(CH_2)_3OH]}$$

7(b)(iii)

$CH_3COOH(l) + CH_3(CH_2)_3OH(l) \rightleftharpoons CH_3COO(CH_2)_3CH_3(l) + H_2O(l)$

initial/mol	4	2	1	0
change/mol	-1.1	-1.1	+1.1	+1.1
eqm/mol	2.9	0.9 (from graph)	2.1(from graph)	1.1

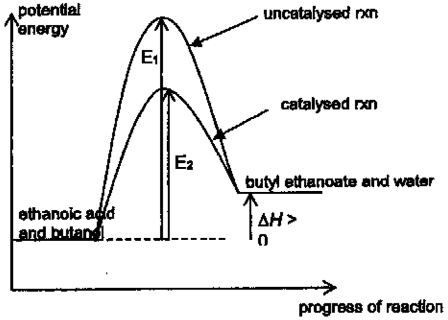


7(b)(iv)

$$K_c = \frac{\frac{2.1}{2} \times \frac{1.1}{2}}{\frac{0.9}{2} \times \frac{2.9}{2}} = 0.885$$

7(b)(v)
By LCP, a decrease in temperature would shift the position of equilibrium to the left to favour the backward exothermic reaction that releases heat to increase temperature. The new equilibrium mixture would contain more ethanoic acid and butanol and less butyl ethanoate and water.

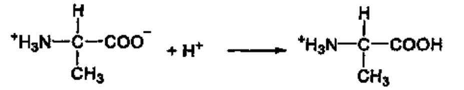
7(b)(vi)



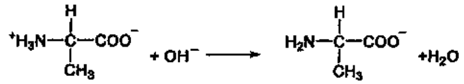
7(c)(i)
A buffer solution is a solution which is able to resist pH changes upon the addition of a small amount of acid or base.

7(c)(ii)

on addition of H^+:



on addition of OH^-:



7(d)
The three isomers are: