For each question there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

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

The relative abundance of the isotopes of a sample of germanium is given in the table below.

relative isotopic mass	70	72	74
relative abundance	20.5	27.5	36.5

What is the relative atomic mass of germanium in this sample?

A 70.9 **B** 71.9 **C** 72.4 **D** 73.1

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

A solution of manganate(VII) ions is titrated against a solution containing 0.004 mol of sodium iodide. 20.0 cm^3 of 0.05 mol dm^{-3} manganate(VII) solution is required to oxidise iodide ions to iodine. What is the final oxidation state of manganese?

A +3 **B** +4 **C** +5 **D** +6

3 Which of the following reactions has the underlined species as being oxidised?

A $3\underline{N}O_2 + H_2O \rightarrow 2HNO_3 + \underline{N}O$

B $2\underline{As} + 3I_2 \rightarrow 2\underline{As}I_3$

C $\underline{H}Cl + NH_3 \rightarrow N\underline{H}_4Cl$

D $SbF_3 + \underline{F}_2 \rightarrow Sb\underline{F}_5$

4 When a $^{4}_{2}He^{2+}$ particle is passed through an electric field, the angle of deflection is +9°. Which of the following ions will be deflected to the same extent but in the opposite direction?

A $^{1}_{1}H^{+}$ **B** $^{1}_{1}H^{-}$ **C** $^{2}_{1}H^{-}$ **D** $^{4}_{2}He^{-}$

5 Which particle would have a half-filled set of p orbitals when it loses an electron?

A C^{-} **B** N^{-} **C** Si^{+} **D** P^{+}

6 Which statement explains why the first ionisation energy of magnesium is higher than that of aluminium?

A Magnesium has a larger metallic character than aluminium.
B Magnesium atom is smaller than aluminium atom.
C Aluminium can form a more highly charged cation.
D The electron that is to be lost from aluminium is of a higher energy level than that from magnesium.

7 Which of the following pairs have a smaller bond angle for the first species than the second species?

1 CCl_4, $SiCl_4$
2 NF_3, NH_3
3 SO_3^{2-}, CO_3^{2-}

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

8 Which of the following, in the solid state, exists as discrete molecules?

A aluminium fluoride
B beryllium chloride
C carbon dioxide
D silicon dioxide

9 Hex-3-ene exists as a pair of cis-trans isomers. *cis*-hex-3-ene has a lower melting point than *trans*-hex-3-ene.

Which of the following statements is correct about hex-3-ene?

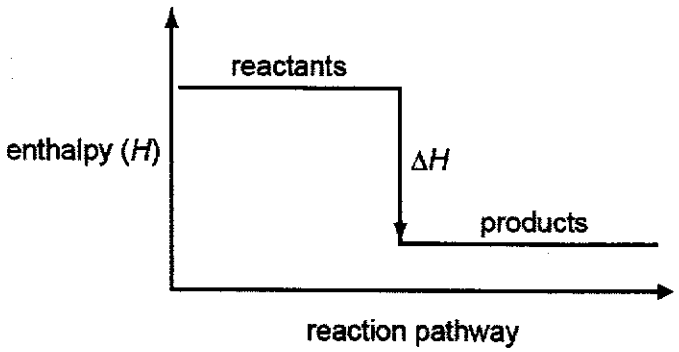
1 *Trans*-hex-3-ene has a higher melting point because there is no net dipole moment in the molecule.
2 In the solid state, *cis*-hex-3-ene is less dense than *trans*-hex-3-ene.
3 Hex-3-ene has low melting point because little amount of energy is required to overcome the covalent bonds.

A 1 only
B 2 only
C 1 and 3 only
D All of the above

10 Which of the following molecules will **not** form a hydrogen bond with another of its own molecule?

A CH_3NH_2
B CH_3COCH_3
C CH_3CONH_2
D CH_3OH

11 Which enthalpy change could not be correctly represented by the enthalpy diagram shown below?



A standard enthalpy change of combustion

B standard enthalpy change of neutralisation

C bond energy

D lattice energy

12 Antimony pentachloride is prepared in the manner as shown by the equation below.

$$SbCl_3(s) + Cl_2(g) \rightarrow SbCl_5(l) \qquad \Delta H^{\ominus} = -58 \text{ kJ mol}^{-1}$$

Given the $\Delta H_f^{\ominus}$ of $SbCl_3(s)$ is -382 kJ mol^{-1}, what is the standard enthalpy change of formation of $SbCl_5(l)$?

A +324 kJ mol^{-1} **B** -324 kJ mol^{-1}

C +440 kJ mol^{-1} **D** -440 kJ mol^{-1}

13 The kinetics of the reaction $X_2 + 2Y \longrightarrow 2XY$ was studied by the method of initial rates and the experimental results obtained are shown in the table below.

Experiment	Volume of X_2 / cm^3	Volume of Y / cm^3	Volume of H_2O / cm^3	Time/ min
1	20	20	10	2
2	20	15	15	2
3	10	10	30	4
4	**a**	5	5	1

What is the value of **a**?

A 5 **B** 10 **C** 20 **D** 40

14 A catalytic converter reduces the amount of nitrogen oxides and carbon monoxide found in the exhaust gases given out by a car. Which modifications would reduce the amount of nitrogen oxides and carbon monoxides in the exhaust gases?

1 Increase the temperature of the engine

2 Increase the surface area of the catalyst in the converter

3 Increase the rate of flow of gases through the catalytic converter

A 1 only **B** 2 only

C 1 and 2 only **D** 2 and 3 only

15 Methanol is produced in the industry through the following reaction in the presence of a copper catalyst and under the operating conditions of 100 atm and 250°C.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H^{\ominus} = -92 \text{ kJ mol}^{-1}$$

Which of the following would increase the value of K_c?

A Addition of nickel catalyst

B Remove the methanol produced

C Decreasing the temperature

D Decreasing the pressure

16 Which of the following can increase the equilibrium yield of $NO_2(g)$ in the following reaction?

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \quad \Delta H^{\ominus} = +58 \text{ kJ mol}^{-1}$$

1 Increase the pressure of the reaction vessel

2 Increase the amount of N_2O_4 in the mixture

3 Increase the temperature of the mixture

A 1 and 2 only **B** 1 and 3 only

C 2 and 3 only **D** All of the above

17 6 moles of ethanoic acid and 6 moles of ethanol were mixed in a 3 dm^3 reaction vessel. The mixture was found to reach equilibrium when 4.67 moles of ethyl ethanoate is formed. The equation is as follows:

$$CH_3COOH(l) + CH_3CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_3(l) + H_2O(l)$$

What is the value of K_c?

A 0.08 **B** 0.3 **C** 3.5 **D** 12.3

18 Which of the following are conjugate acid-base pairs?

1 NO_3^-/HNO_3

2 HPO_4^{2-}/H_3PO_4

3 $CH_3OH/CH_3OH_2^+$

A 1 only **C** 2 only

C 3 only **D** 1 and 3 only

19 Which of the following will give an acidic buffer solution when dissolved in 10 dm^3 of water?

1 1 mol of CH_3COOH and 1 mol of HCl

2 1 mol of HCl and 1 mol of CH_3COONa

3 1 mol of CH_3COOH and 1 mol of CH_3COONa

A 1 and 2 only **B** 2 and 3 only

C 1 only **D** 3 only

20 What is the pH of the resultant solution at 25°C when 50 cm^3 of 0.20 mol dm^{-3} NaOH and 20 cm^3 of 0.15 mol dm^{-3} HC*l* are added together?

A 1.0 **B** 2.2 **C** 11.8 **D** 13.0

21 Which of the following statements are correct?

1 The ionic radii of Period 3 metals decrease across the period.

2 The pH of Period 3 oxides in water generally decreases across the period.

3 The electrical conductivity of Period 3 elements decreases across the period.

A 1 only **B** 3 only

C 1 and 2 only **D** 1, 2 and 3

22 Which of the following statements is **not true** for Group 17 elements and its compounds?

A Iodine is soluble in organic solvents because it can form instantaneous dipole-induced dipole with organic solvents.

B Oxidising power of the halogens increases down the group.

C Thermal stability of hydrogen halides decreases down the group.

D Volatility of the halogens decreases down the group.

23 **X** and **Y** are elements in Period 3 of the Periodic Table. **X** forms a chloride that has a high melting point. The oxide of **X** does not react with alkalis. **Y** forms a soluble oxide that does not react with acids. The chloride of both **X** and **Y** forms a solution in water that turns blue litmus paper red.

Which of the following could be elements **X** and **Y**?

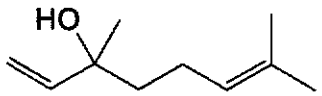
	X	**Y**
A	Na	S
B	Mg	P
C	A*l*	S
D	Na	P

24 An organic compound, $C_3H_8O_2$, is used as a precursor to the production of polymers. It contains 2 alcohol groups. Upon reaction with excess MnO_4^- and H^+, it forms compound **A** which also has 3 carbon atoms.

Which of the following could be the molecular formula of compound **A**?

A $C_3H_8O_4$ **B** $C_3H_6O_4$ **C** $C_3H_4O_4$ **D** $C_3H_4O_2$

25 Linalool is an alcohol found in many flowers and gives out a distinct scent.

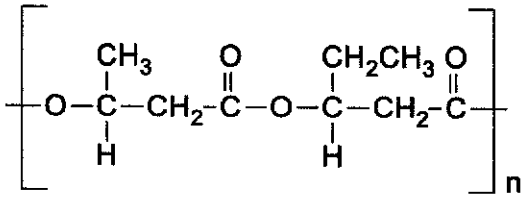


Linalool

How many σ and π bonds are there in linalool?

	σ	π
A	26	2
B	26	4
C	28	2
D	28	4

26 The structure of a copolymer PHBV is given below.



PHBV

Which of the following is one of the monomers of PHBV?

A $HOCH(CH_3)CH_2CH_2OH$

B $HOCH(CH_3)CH_2CHO$

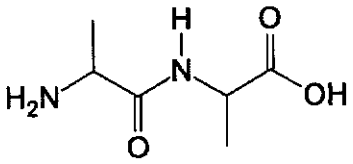
C $HOOCCH(CH_2CH_3)CH_2COOH$

D $HOCH(CH_2CH_3)CH_2COOH$

27 Epoxy resin and nylon are both polymers. Epoxy resin is a hard plastic and becomes black when heated, while nylon melts upon heating.
Which of the following statements is true about the polymers?

A There are crosslinks in both epoxy and nylon.
B Epoxy resin can be recycled but nylon cannot be recycled.
C Epoxy resin has high tensile strength.
D Epoxy resin is made up of linear polymers.

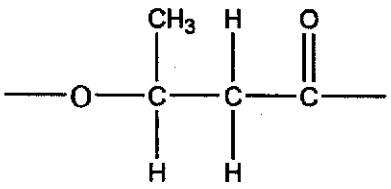
28 An amide is given below.



What are the reagents that can be used to produce this amide?

A $H_2NCH(CH_3)COOH$, concentrated H_2SO_4
B $H_2NCH(CH_3)NH_2$, $HOOCCH(CH_3)COOH$
C $H_2NCH(CH_3)COOH$, DCC
D $H_2NCH(CH_3)CH_2OH$, $H_2NCH(CH_3)COOH$

29 The polymer having the repeat unit shown occurs in bacteria as cell storage material.



Which deductions about this substance can be made from this structure?

1 It is a condensation polymer.

2 Hydrogen bonding is formed between two polymer chains.

3 It can be made when a diol and a dicarboxylic undergo polymerisation.

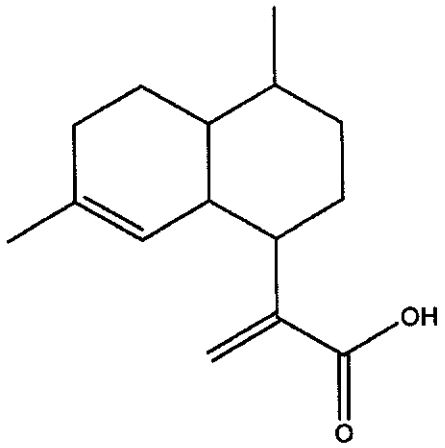
A 1 only

B 1 and 2 only

C 1 and 3 only

D 2 and 3 only

30 Artemisinic acid is a useful intermediate for making the anti-malarial drug, artemisin.



artemisinic acid

Which statement about this compound is **not** correct?

A It can be esterified by ethanol, in the presence of H^+ ions.

B It can exhibit cis-trans isomerism around a double bond .

C It has a molecular formula of $C_{15}H_{22}O_2$.

D It can undergo condensation with ethylamine, in the presence of DCC.

END OF PAPER

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NATIONAL JUNIOR COLLEGE
SH2 PRELIMINARY EXAMINATION
Higher 1

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

CHEMISTRY
Paper 2 Structured Questions

8873/02

Monday 14 September 2020

Candidates answer on the Question Paper.

Additional Materials: Data Booklet

2 hours

READ THESE INSTRUCTIONS FIRST

Write your subject class, registration number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answers **all** the questions.

Section B
Answer **one** question.

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

For Examiner's Use	
Section A	
1	/16
2	/15
3	/10
4	/10
5	/9
Section B	
6 OR 7	/20
P2 Total	/80

This document consists of **22** printed pages and **0** blank pages.

Section A

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

1 In the Periodic Table, the p block contains elements whose outer electrons are found in the p subshell.

(a) Elements in the p block show a general increase in first ionisation energy as the atomic number increases.

(i) Draw the shape of a p orbital

[1]

(ii) Write an equation to show the first ionisation energy of silicon.

.....[1]

(iii) Explain why there is a general increase in first ionisation energies of the elements across Period 3.

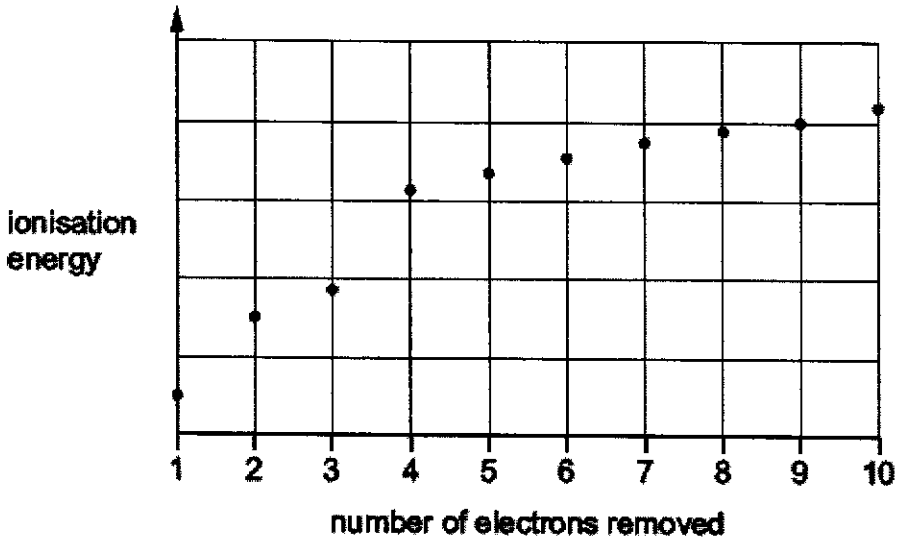
.....

.....

..... [2]

(iv) Element **A** is in the p block.

The graph shows the successive ionisation energies for the removal of the first ten electrons of **A**.



State and explain the group of the Periodic Table that elements **A** belongs to

group number .....

explanation .....

.....

.....

[2]

(b) Silicon is found in many compounds in the Earth's crust. Silicon has only three naturally occurring isotopes, ^{28}Si, ^{29}Si and ^{30}Si.

(i) The table shows data for ^{28}Si, ^{29}Si and ^{30}Si.

	^{28}Si	^{29}Si	^{30}Si
Relative isotopic mass	28.0	29.0	30.0

A sample of silicon contains 92.2% ^{28}Si. The total percentage abundance of ^{29}Si and ^{30}Si in the sample is 7.8%.

The relative atomic mass, A_r, of silicon in the sample is 28.09.

Calculate the percentage abundance of ^{30}Si.

Give your answer to **one** decimal place.

percentage abundance of ^{30}Si = ...% [3]

(ii) Silicon reacts with nitrogen gas to form Si_3N_4.

Si_3N_4 is a solid with a melting point of 1900°. It is insoluble in water and does not conduct electricity when molten.

Suggest the type of bonding in **and** structure of Si_3N_4. Explain your answer.

.....

.....

.....

.....

.....[3]

(c) SO_2 can react with ozone, O_3, to form SO_3 in two different reactions.

(i) In one reaction, SO_2 reacts with O_3 until a dynamic equilibrium is established.

$$SO_2(g) + O_3(g) \rightleftharpoons SO_3(g) + O_2(g)$$

State and explain the effect of an increase in pressure on the composition of the equilibrium mixture.

.....

.....

.....[2]

(ii) In the other reaction, a different equilibrium is established at 300k as shown.

$$3SO_2(g) + O_3(g) \rightleftharpoons 3SO_3(g) \qquad \Delta H = +462.3 \text{ kJmol}^{-1}$$

Suggest a temperature needed to increase the yield of SO_3 at equilibrium.

Explain your answer.

.....

.....

.....[2]

[Total: 16]

2 Magnesium silicide, Mg_2Si, is a compound made by heating magnesium with sand.

(a) Draw a 'dot-and-cross' diagram to show the arrangement of outer electrons present in a formula unit of Mg_2Si. Assume magnesium silicide is an ionic compound.

[2]

(b) When solid Mg_2Si is added to water, silane gas, SiH_4 is a gas at room temperature.

Construct the equation for this reaction. Include state symbols.

.....[2]

(c) Suggest, with reference to structure and bonding, why SiH_4 is a gas at room temperature.

.....

.....

.....[2]

(d) The table shows the electronegativity values of carbon, hydrogen and silicon.

element	carbon	hydrogen	silicon
electronegativity	2.5	2.1	1.8

(i) C-H and Si-H bonds have weak dipoles.

Use the electronegativity values in the table to show the polarity of the C-H and Si-H bonds

C----H Si----H

[2]

(ii) Explain why methane, CH_4, has overall dipole moment.

.....

.....

.....[2]

(e) SiH_4 reacts in air without heating but CH_4 must be ignited before combustion occurs.

$$SiH_4 + 2O_2 \longrightarrow SiO_2 + 2H_2O$$

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

Suggest, with reference to bond energies from the *Data Booklet*, why SiH_4 reacts in air without heating but CH_4 must be ignited.

.....

.....

.....[2]

(f) Silicon dioxide reacts with hot, concentrated sodium hydroxide.

(i) Identify the **two** products formed during this reaction.

.....

.....[2]

(ii) Describe the behaviour of the silicon dioxide during this reaction.

.....[1]

[Total: 15]

3 (a) Chlorate(I) ions undergo the following reaction under aqueous conditions.

$$2NH_3 + ClO^- \longrightarrow N_2H_4 + Cl^- + H_2O$$

A series of experiments was carried out at different concentrations of ClO^- and NH_3.

The table shows the results obtained.

Experiment	$[ClO^-]$ /mol dm^{-3}	$[NH_3]$ /mol dm^{-3}	initial rate /mol dm^{-3} s^{-1}
1	0.200	0.100	0.256
2	0.400	0.200	2.05
3	0.400	0.400	8.2

(i) Use the data in the table to determine the order with respect to each reactant, ClO^- and NH_3.

Show your reasoning.

.....

.....

.....

.....

.....[2]

(ii) Write the rate equation for this reaction.

Rate: .....[1]

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

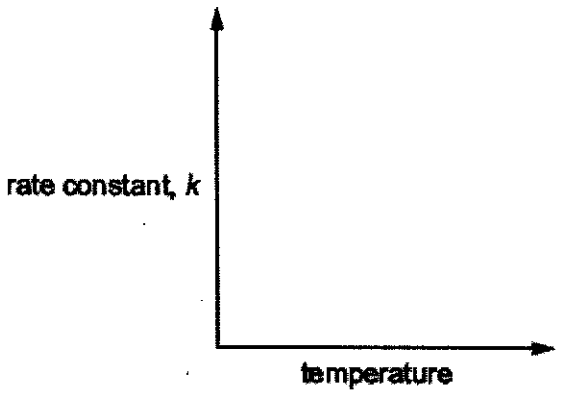
k = ...

units = ...

[2]

....

(iv) On the axes sketch a graph to show how the value of k changes as temperature is increased.



[1]

(b) In another experiment, the reaction between chlorate(I) ions and iodide ions in aqueous alkali was investigated.

A solution of iodide ions in aqueous alkali was added to a large excess of chlorate(I) ions and $[I^-]$ was measured at regular intervals.

(i) Describe how the results of this experiment can be used to confirm that the reaction is first-order with respect to $[I^-]$.

.....

.....

.....[2]

A three-step mechanism for this reaction is shown.

step 1: $ClO^- + H_2O \rightarrow HClO + OH^-$

step 2: $I^- + HClO \rightarrow HIO + Cl^-$

step 3: $HIO + OH^- \rightarrow H_2O + IO^-$

(ii) Use this mechanism to deduce the overall equation for this reaction.

.....[1]

(iii) Identify a step that involves a redox reaction. Explain your answer

.....

.....[1]

[Total: 10]

4 Methylpropane, $(CH_3)_2CHCH_3$, is an isomer of butane, $CH_3(CH_2)_2CH_3$.

(a) (i) Explain why methylpropane and butane are a pair of isomers.

.....

.....[2]

(ii) Identify the type of isomerism shown by methylpropane and butane.

.....[1]

(b) When a sample of butane is heated to 373 K, in the presence of a catalyst, and allowed to reach equilibrium the following reaction occurs.

$$CH_3(CH_2)_2CH_3(g) \rightleftharpoons (CH_3)_2CHCH_3(g) \qquad \Delta H = -8.0 \text{ kJmol}^{-1}$$

State and explain the effect on the composition of this equilibrium mixture when the temperature is increased to 473 K.

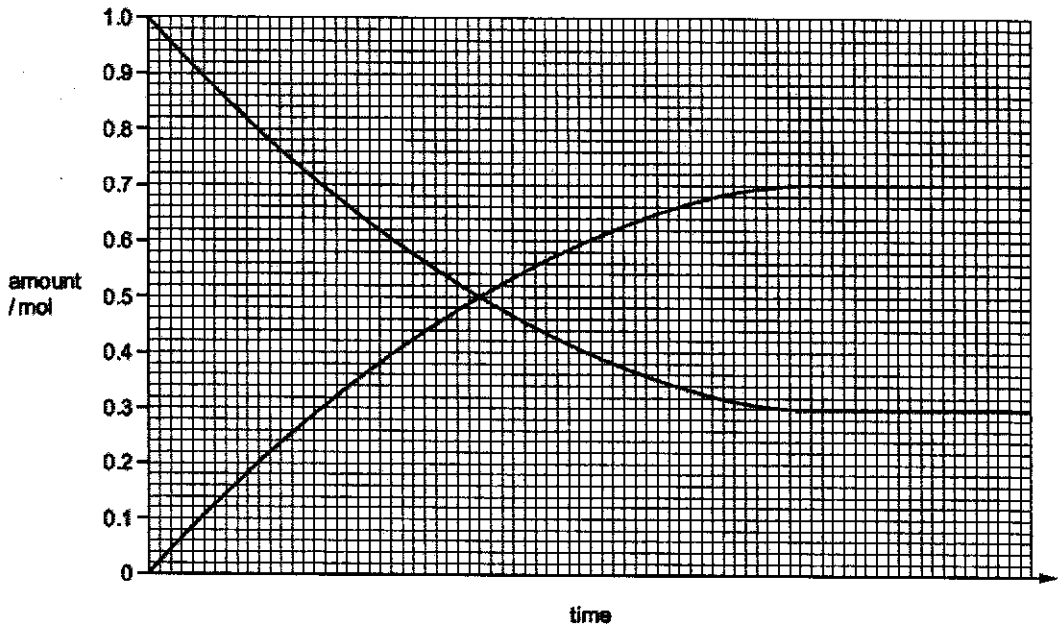
.....

.....

.....

.....[2]

(c) 1 mole of butane gas was added to a 1 dm^3 closed system, at a constant temperature and pressure. The amount of butane and methylpropane was measured at regular time intervals.



(i) Label the graph with a *t* to show the time taken to reach dynamic equilibrium. [1]

(ii) Use the graph to find the concentration of butane and methylpropane in the mixture at equilibrium.

concentration of butane = ... mol dm^{-3}

concentration of methylpropane = ...mol dm^{-3}

[1]

(iii) Write an expression for K_c for this reaction.

[1]

(iv) Calculate a value for K_c and state its units.

K_c = ... units = ...[2]

[Total: 10]

5 The increasing awareness of the diminishing supply of crude oil has resulted in a number of initiatives to replace oil-based polymers with those derived from natural products. One such polymer, 'polyactide' or PLA, is produced from corn starch and has a range of applications.

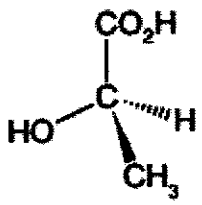
(a) The raw material for the polymer, lactic acid (2-hydroxypropanoic acid), is formed by the fermentation of corn starch using enzymes from bacteria.

(i) Calcium hydroxide is added to the fermentation tanks to prevent the production of lactic acid from slowing down.
Why might high acidity reduce the effectiveness of the enzymes?

.....

.....[1]

(ii) The structure of lactic acid is shown



What type of reaction takes place in this polymerisation?

.....[1]

(b) One of the reasons PLA has attracted so much attention is that is biodegradable. This does, however, restrict some potential uses. The simple polymer has a melting point of around 175°C, but softens between 60 – 80°C. However, its thermoplastic properties enable it to have a range of uses in fibres and in food packaging.

(I) Explain why PLA would **not** be a suitable packaging material for foods pickled in vinegar.

.....

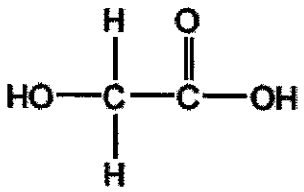
.....[1]

(ii) PLA containers are not used for hot drinks. Suggest why.

.....

.....[1]

(c) Lactic acid can also be co-polymerised with glycolic acid.



glycolic acid

(i) Draw a section of the co-polymer showing one repeat unit.

[2]

(ii) Suggest what type(s) of bonding will occur between chains of this co-polymer, indicating the groups involved.

.....

.....

.....[2]

(iii) Suggest one property in which the co-polymer differs from PLA

.....

.....[1]

[Total: 9]

Section B

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

6 **(a)** Crude oil is a natural source of hydrocarbons that are used as fuels

Hydrocarbons with low relative molecular mass, M_r, are use as fuels in industry, in the home and for transport.

There is a high demand for the hydrocarbons with low M_r.

(i) Name the process by which long-chain hydrocarbons are broken down into shorter-chain hydrocarbons.

.....[1]

(ii) Give one reason why hydrocarbons with low M_r are suitable for use as fuels.

.....[1]

(ii) Incomplete combustion of hydrocarbons can release carbon monoxide, CO, into the atmosphere.

Write an equation for the formation of CO from the incomplete combustion of butane, C_4H_8.

.....[1]

(b) Thiophene, $C_4H_4S(l)$, is an organic compound that is found as a contaminant in crude oil.

(i) A student carries out an experiment to determine the enthalpy change of combustion of $C_4H_4S(l)$.

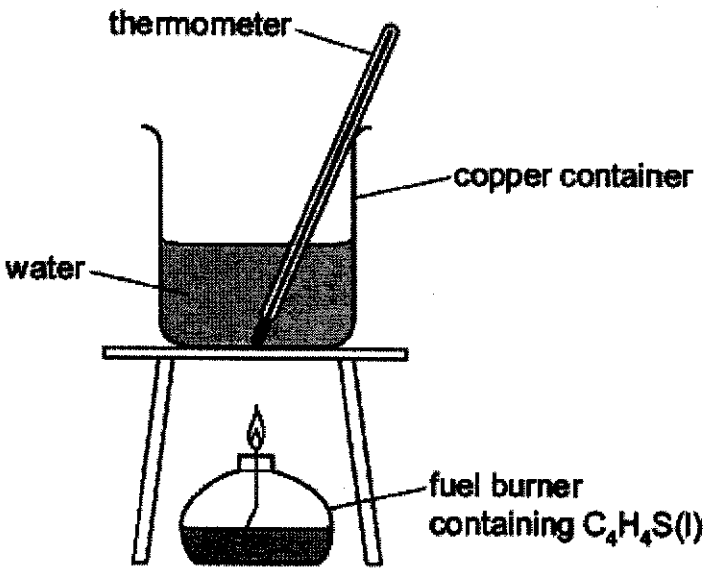
Explain the meaning of the term *enthalpy change of combustion*.

.....

.....

.....[2]

(ii) The students uses the following apparatus in the experiment.



mass of water in copper container / g	200
initial temperature of water / °C	18.5
highest temperature of water / °C	37.5

Calculate the heat energy released, in J, by the reaction.

Assume that 4.18 J of heat energy changes the temperature of 1.0 cm^3 of water by 1.0°C.

Assume no heat is lost to the surroundings.

heat energy released = ... J
[2]

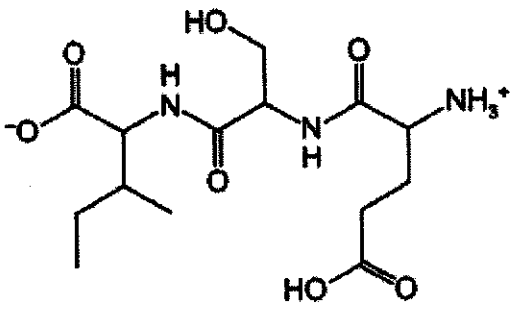
(iii) The student used 0.63 g of $C_4H_4S(l)$ in the experiment.

Calculare the enthalpy change of combustion of thiophene, $\Delta H_c(C_4H_4S(l))$. Include a sign in your answer.

$\Delta H_c(C_4H_4S(l))$ = ... kJ mol^{-1} [2]

(c) Proteins are natural polymers. When one particular protein is partially hydrolysed the product mixture includes tripeptide **E**.

tripeptide E



(i) Describe the conditions that could be used to hydrolyse **E** to produce a mixture of three amino acids.

.....[1]

(ii) Draw the structures of the three amino acids produced by this hydrolysis reaction.

The three amino acids should be shown in the correct form for the conditions you have chosen in **(c)(i)**.

[3]

(iii) If a pure sample of **E** is obtained in aqueous solution, several different types of intermolecular forces are possible between pairs of **E** molecules.

Name two different types of intermolecular force that exist between pairs of **E** molecules, stating the group on the molecules where the forces are acting.

type of force/bond	pair of groups responsible

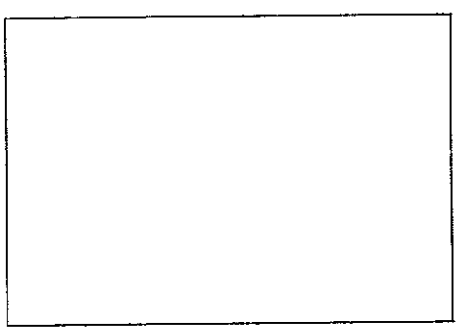
[2]

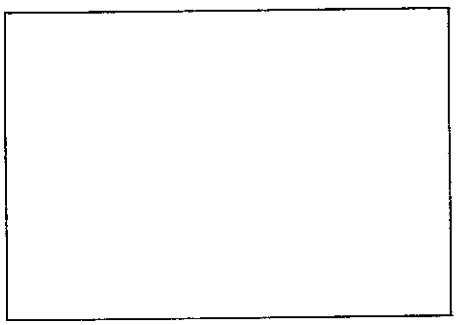
(d) Polyesters and polyamides are two important types of condensation polymer.

(i) Draw the structure of a compound that can polymerise to produce a polyamide, without the need for a second monomer.

[1]

(ii) Draw the structures of two different compounds that can polymerise together to produce a polyester with **four** carbon atoms per repeat unit. Name the two compounds.



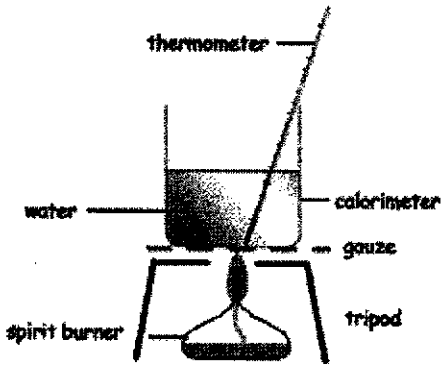


name ..... name .....

[4]

[Total: 20]

7 (a) Methanol is used to calibrate the heat capacity of the calorimeter set up as shown below.



(i) Given that standard enthalpy change of combustion of methanol is -732 kJ mol^{-1}, determine the heat capacity of the calorimeter when 2.00 g of methanol raises the temperature of the calorimeter by 8.0 °C.

[2]

(ii) A student carries out an experiment to determine the enthalpy change of combustion of ethanol.

Explain the meaning of the term *enthalpy change of combustion.*

.....

.....

.....[2]

(iii) Determine the enthalpy change of combustion of ethanol given the following data:

Mass of spirit lamp before combustion: 5.445 g
Mass of spirit lamp after combustion: 3.585 g
Initial temperature: 29.5 °C
Final temperature: 36.5 °C

[2]

(b) The chemical equation for the combustion of propene is as shown below.

$$C_3H_6\,(g) + \frac{9}{2}\,O_2\,(g) \rightarrow 3CO_2\,(g) + 3H_2O\,(l)$$

The table below shows the standard enthalpy changes of formation of the compounds involved in reaction.

Compound	$C_3H_6\,(g)$	$CO_2\,(g)$	$H_2O\,(l)$	$O_2\,(g)$
ΔH_f^{θ} / kJ mol^{-1}	+20	-394	-286	0

(i) Explain why the standard enthalpy of formation, ΔH_f^{θ}, of oxygen is zero.

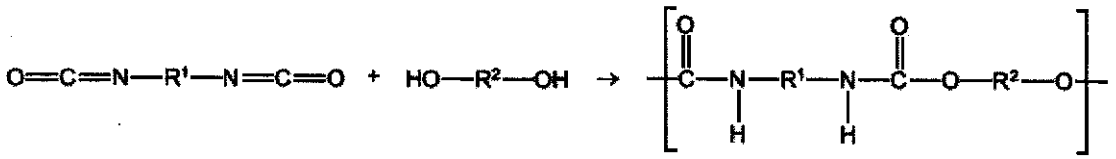
.....

.....[1]

(ii) Use the data from the table above to calculate the standard enthalpy of combustion of propene

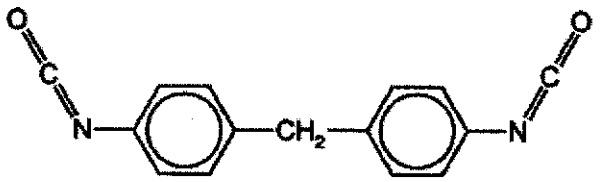
[2]

(c) Polyurethanes are polymers made by the reaction of a diisocyanate with a diol as shown. R^1 and R^2 are hydrocarbon groups.



a diisocyanate a diol a polyurethane

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



P

(i) Give the molecular formula for **P**.

.....[1]

(ii) Draw the repeat unit of Lycra®.

[2]

(iii) Fibres of Lycra® are strong due to the intermolecular forces between the polymer chains.

Complete the table to identify two intermolecular forces responsible for this property and the group(s) involved.

intermolecular force	group(s) involved

[2]

(iv) Name **one** example of each of the following types of polymer.

type of polymer	example
water soluble polymer	
chemical resistant polymer	

[1]

(d) (i) A metal chloride **A**, has the formula MCl_x. When 3.0×10^{-3} mol of sodium hydroxide is reacted completely with 1.0×10^{-3} mol of **A**, 0.078g of a white precipitate, **B** is formed. When **B** is heated, water is lost, leaving a white residue **C**. **C** is of high melting point and is not soluble in water.

Deduce the identities of **A**, **B** and **C**.

[3]

(ii) Compound **C**, Na_2O and SO_3 are separately added to acid and alkali. Write equations, with state symbols, for possible reactions that occur.

Na_2O :.....

SO_3: .....

[2]
[Total: 20]

For each question there are four possible answers, **A**, **B**, **C**, and **D**. Choose the **one** you consider to be correct.

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

The relative abundance of the isotopes of a sample of germanium is given in the table below.

relative isotopic mass	70	72	74
relative abundance	20.5	27.5	36.5

What is the relative atomic mass of germanium in this sample?

A 70.9 **B** 71.9 **C** 72.4 **D** 73.1

[(20.5 x 70) + (27.5 x 72) + (36.5 x 74)] / 84.5 = 72.4

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

A solution of manganate(VII) ions is titrated against a solution containing 0.004 mol of sodium iodide. 20.0 cm^3 of 0.05 mol dm^{-3} manganate(VII) solution is required to oxidise iodide ions to iodine. What is the final oxidation state of manganese?

A +3 **B** +4 **C** +5 **D** +6

$MnO_4^- + 8H^+ + xe^- \rightarrow Mn^{(7-x)+} + 4H_2O$

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

Amount of MnO_4^- = 0.001 mol

Amount of e^- gained = 0.004 mol

x = 4

final oxidation state of Mn = +3

3 Which of the following reactions has the underlined species as being oxidised?

A $3\underline{N}O_2 + H_2O \rightarrow 2HNO_3 + \underline{N}O$

B $2\underline{As} + 3I_2 \rightarrow 2\underline{As}I_3$

C $\underline{H}Cl + NH_3 \rightarrow N\underline{H}_4Cl$

D $SbF_3 + \underline{F}_2 \rightarrow Sb\underline{F}_5$

Option A: +4 to +2 (reduction)
Option B: 0 to +3 (oxidised)
Option C: +1 to +1
Option D: 0 to -1 (reduction)

4 When a $^4_2He^{2+}$ particle is passed through an electric field, the angle of deflection is +9°. Which of the following ions will be deflected to the same extent but in the opposite direction?

A $^1_1H^+$ B $^1_1H^-$ **B** $^2_1H^-$ D $^4_2He^-$

Angle of deflection ∝ charge/mass
Angle of deflection of $^4_2He^{2+}$ particle ∝ 2/4 = ½
Option C: Angle of deflection of $^2_1H^-$ particle ∝ 1/2 = ½
Since $^2_1H^-$ particle is negatively charged, it will deflect towards the positive plate, which is the opposite direction as $^4_2He^{2+}$ particle.

5 Which particle would have a half-filled set of p orbitals when it loses an electron?

A C^- **B** N^- C Si^+ D P^+

Option B:
N^- loses an electron forms N.
Electronic configuration of N: $1s^22s^22p^3$

6 Which statement explains why the first ionisation energy of magnesium is higher than that of aluminium?

A Magnesium has a larger metallic character than aluminium.
B Magnesium atom is smaller than aluminium atom.
C Aluminium can form a more highly charged cation.
B The electron that is to be lost from aluminium is of a higher energy level than that from magnesium.

7 Which of the following pairs have a smaller bond angle for the first species than the second species?

1 CCl_4, $SiCl_4$
2 NF_3, NH_3
3 SO_3^{2-}, CO_3^{2-}

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

Option 1: Central carbon in CCl_4 is more electronegative than central Si in $SiCl_4$. Hence, bond pair – bond pair repulsion is greater in CCl_4 resulting in a larger bond angle.
Option 2: peripheral atom F in NF_3 is more electronegative than H in NH_3. Hence, bond pair – bond pair repulsion is smaller in NF_3 resulting in a smaller bond angle.
Option 3: SO_3^{2-} has 3 bond pairs 1 lone pair while CO_3^{2-} has 3 bond pairs zero lone pair. Lone pair – bond pair repulsion causes the bond angle in SO_3^{2-} to be smaller.

8 Which of the following, in the solid state, exists as discrete molecules?

A aluminium fluoride
B beryllium chloride
C carbon dioxide
D silicon dioxide

Option A: aluminium fluoride exists as ions
Option B: beryllium chloride exists as a polymer chain
Option C: molecules
Option D: atoms

9 Hex-3-ene exists as a pair of cis-trans isomers. *cis*-hex-3-ene has a lower melting point than *trans*-hex-3-ene.

Which of the following statements is correct about hex-3-ene?

1 *Trans*-hex-3-ene has a higher melting point because there is no net dipole moment in the molecule.

2 In the solid state, *cis*-hex-3-ene is less dense than *trans*-hex-3-ene.

3 Hex-3-ene has low melting point because little amount of energy is required to overcome the covalent bonds.

A 1 only **B** 2 only

C 1 and 3 only **D** All of the above

Statement 1 is incorrect: *trans*-hex-3-ene has a higher melting point because of the closer packing between the molecules.

Statement 2 is correct: *In the solid state, trans*-hex-3-ene has a closer packing than *cis*-hex-3-ene, thus *cis*-hex-3-ene is less dense than *trans*-hex-3-ene.

Statement 3 is incorrect: during melting, energy is used to overcome the intermolecular forces of attraction between hex-3-ene molecules, not the covalent bonds.

10 Which of the following molecules will **not** form a hydrogen bond with another of its own molecules?

A CH_3NH_2

B CH_3COCH_3

C CH_3CONH_2

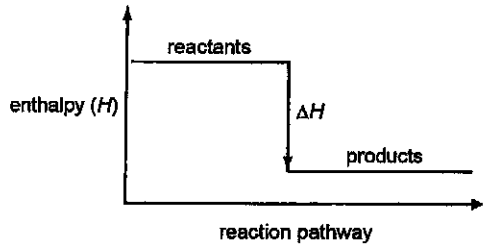
D CH_3OH

Option A and C: both molecules consist of at least one H bonded to the electronegative N, and the N atom has a lone pair of electrons to form a hydrogen bond with another of its own molecule.

Option B: CH_3COCH_3 is a ketone and does not contain a H bonded to the electronegative O, so it cannot form a hydorgen bond with another molecule of its own.

Option D: CH_3OH has a H bonded to the electronegative O, and the O atom has a lone pair of electrons to form a hydrogen bond with another of its own molecule.

11 Which enthalpy change could not be correctly represented by the enthalpy diagram shown below?



A standard enthalpy change of combustion

B standard enthalpy change of neutralisation

C bond energy

D lattice energy

Since the diagram shows an exothermic reaction, the only possible incorrect enthalpy change is bond energy (option C) because bond energy is the energy taken in (endothermic) to break 1 mole of covalent bond.

12 Antimony pentachloride is prepared in the manner as shown by the equation below.

$$SbCl_3(s) + Cl_2(g) \rightarrow SbCl_5(l) \quad \Delta H^{\ominus} = -58 \text{ kJ mol}^{-1}$$

Given the $\Delta H_f^{\ominus}$ of $SbCl_3(s)$ is -382 kJ mol^{-1}, what is the standard enthalpy change of formation of $SbCl_5(l)$?

A +324 kJ mol^{-1} **B** -324 kJ mol^{-1}

C +440 kJ mol^{-1} **D** -440 kJ mol^{-1}

$\Delta H^{\ominus} = \Delta H_f^{\ominus}(SbCl_5(s)) - \Delta H_f^{\ominus}(SbCl_3(s))$

$-58 = \Delta H_f^{\ominus}(SbCl_5(s)) - (-382)$

$\Delta H_f^{\ominus}(SbCl_5(s)) = -440$ kJ mol^{-1}

13 The kinetics of the reaction $X_2 + 2Y \longrightarrow 2XY$ was studied by the method of initial rates and the experimental results obtained are shown in the table below.

Experiment	Volume of X_2 / cm^3	Volume of Y / cm^3	Volume of H_2O / cm^3	Time/ min
1	20	20	10	2
2	20	15	15	2
3	10	10	30	4
4	a	5	5	1

What is the value of a?

A 5 B 10 C 20 **D** 40

Comparing expt 1 and 2, when volume of Y decreases, the rate of reaction remains constant, order of reaction w.r.t. Y is zero. Compaing expt 1 and 4, when volume of X_2 changes, rate increases from ½ to 1. Hence, volume of X_2 must have doubled.

14 A catalytic converter reduces the amount of nitrogen oxides and carbon monoxide found in the exhaust gases given out by a car. Which modifications would reduce the amount of nitrogen oxides and carbon monoxides in the exhaust gases?

1 Increase the temperature of the engine
2 Increase the surface area of the catalyst in the converter
3 Increase the rate of flow of gases through the catalytic converter

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

Catalytic converter in a car is an example of heterogeneous catalysis. An increase in the surface area of the catalyst in the converter allows for a larger amount of nitrogen oxides and carbon monoxide to be converted.

15 Methanol is produced in the industry through the following reaction in the presence of a copper catalyst and under the operating conditions of 100 atm and 250°C.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H^{\ominus} = -92 \text{ kJ mol}^{-1}$$

Which of the following would increase the value of K_c?

A Addition of nickel catalyst
B Remove the methanol produced
C Decreasing the temperature
D Decreasing the pressure

Only temperature would change the value of K_c.
By LCP, when temperature decreases, position of equilibrium shifts to the left to favour the endothermic reaction so that excess heat is absorbed. Hence, K_c decreases.

16 Which of the following can increase the equilibrium yield of $NO_2(g)$ in the following reaction?

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H^{\ominus} = +58 \text{ kJ mol}^{-1}$$

1 Increase the pressure of the reaction vessel
2 Increase the amount of N_2O_4 in the mixture
3 Increase the temperature of the mixture

A 1 and 2 only B 1 and 3 only
C 2 and 3 only D All of the above

Option 1: when the pressure of the reaction vessel increases, position of equilibrium shifts to the left to decrease the pressure since the number of gaseous particles increases from reactant to product. Hence, equilibrium yield of $NO_2(g)$ decreases.

Option 2: when the amount of N_2O_4 in the mixture increases, position of equilibrium shifts to the right to decrease the amount of N_2O_4. Hence, equilibrium yield of $NO_2(g)$ increases.

Option 3: when the temperature of the mixture increases, position of equilibrium shifts to the right to absorb the excess heat, favouring the endothermic reaction. Hence, equilibrium yield of $NO_2(g)$ increases.

17 6 moles of ethanoic acid and 6 moles of ethanol were mixed in a 3 dm^3 reaction vessel. The mixture was found to reach equilibrium when 4.67 moles of ethyl ethanoate is formed. The equation is as follows:

$$CH_3COOH(l) + CH_3CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_3(l) + H_2O(l)$$

What is the value of K_c?

A 0.08 B 0.3 C 3.5 ■ 12.3

$K_c = [(4.67/3)^2]/[(1.33/3)^2]$
$= 12.3$

18 Which of the following are conjugate acid-base pairs?

1 NO_3^-/HNO_3
2 HPO_4^{2-}/H_3PO_4
3 $CH_3OH/CH_3OH_2^+$

A 1 only C 2 only
C 3 only ■ 1 and 3 only

Option 1: acid – HNO_3 ; conjugate base – NO_3^-
Option 2: not conjugate acid-base pair
Option 3: acid - $CH_3OH_2^+$; conjugate base – CH_3OH

19 Which of the following will give an acidic buffer solution when dissolved in 10 dm^3 of water?

1 1 mol of CH_3COOH and 1 mol of HCl
2 1 mol of HCl and 1 mol of CH_3COONa
3 1 mol of CH_3COOH and 1 mol of CH_3COONa

A 1 and 2 only B 2 and 3 only
C 1 only ■ 3 only

Acidic buffer includes a weak acid and its salt.
Option 1: no weak acid nor salt
Option 2: no weak acid
Option 3: weak acid - CH_3COOH ; salt - CH_3COONa

20 What is the pH of the resultant solution at 25°C when 50 cm^3 of 0.20 mol dm^{-3} NaOH and 20 cm^3 of 0.15 mol dm^{-3} HCl are added together?

A 1.0 B 2.2 C 11.8 ■ 13.0

Amount of NaOH = 0.01 mol
Amount of HCl = 0.003 mol
HCl is the limiting reagent.
Amount of excess NaOH = 0.01 -0.003 = 0.007 mol
pOH = -log(0.007/(70/1000)) = 1
pH = 14 – 1 = 13.0

21 Which of the following statements are correct?

1 The ionic radii of Period 3 metals decrease across the period.
2 The pH of Period 3 oxides in water generally decreases across the period.
3 The electrical conductivity of Period 3 elements decreases across the period.

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

Option 3: electrical conductivity increases from Na to Al before it decreases. Hence, the statement is incorrect.

22 Which of the following statements is **not true** for Group 17 elements and its compounds?

A Iodine is soluble in organic solvents because it can form instantaneous dipole-induced dipole with organic solvents.
■ Oxidising power of the halogens increases down the group.
C Thermal stability of hydrogen halides decreases down the group.
D Volatility of the halogens decreases down the group.

Option B: ability of halogens to accept an electron decreases down the group due to the longer distance between the nucleus and valence shell electrons. Thus oxidising power of the halogens decreases down the group.

[Turn over

23 X and Y are elements in Period 3 of the Periodic Table. X forms a chloride that has a high melting point. The oxide of X does not react with alkalis. Y forms a soluble oxide that does not react with acids. The chloride of both X and Y forms a solution in water that turns blue litmus paper red.

Which of the following could be elements X and Y?

	X	Y
A	Na	S
B	Mg	P
C	Al	S
D	Na	P

Since oxide of X does not react with alkalis, Al is eliminated. Since chloride of X and Y forms a solution in water that turns blue litmus paper red, X cannot be Na as NaCl is neutral. Hence, option B is the answer.

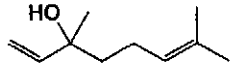
24 An organic compound, $C_3H_8O_2$, is used as a precursor to the production of polymers. It contains 2 alcohol groups. Upon reaction with excess MnO_4^- and H^+, it forms compound A which also has 3 carbon atoms.

Which of the following could be the molecular formula of compound A?

A $C_3H_8O_4$ B $C_3H_6O_4$ C $C_3H_4O_4$ D $C_3H_4O_2$

Both OH groups in $C_3H_8O_2$ are primary alcohols. Upon oxidation, they become –COOH and there is a removal of 2 hydrogens for every –OH oxidation to –COOH.

25 Linalool is an alcohol found in many flowers and gives out a distinct scent.

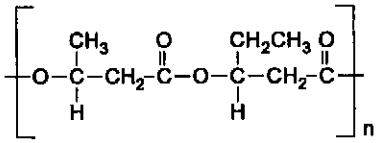


Linalool

How many σ and π bonds are there in linalool?

	σ	π
A	26	2
B	26	4
C	28	2
D	28	4

26 The structure of a copolymer PHBV is given below.



PHBV

Which of the following is one of the monomers of PHBV?

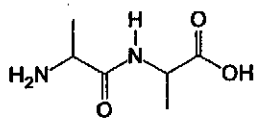
A $HOCH(CH_3)CH_2CH_2OH$
B $HOCH(CH_3)CH_2CHO$
C $HOOCCH(CH_2CH_3)CH_2COOH$
D $HOCH(CH_2CH_3)CH_2COOH$

This is a condensation polymerisation between a carboxylic acid and an alcohol. Each of the monomer units consists of the –COOH and –OH groups. The individual monomer units present are $HOCH(CH_3)CH_2COOH$ and $HOCH(CH_2CH_3)CH_2COOH$.

27 Epoxy resin and nylon are both polymers. Epoxy resin is a hard plastic and becomes black when heated, while nylon melts upon heating. Which of the following statements is true about the polymers?

A There are crosslinks in both epoxy and nylon.
B Epoxy resin can be recycled but nylon cannot be recycled.
C Epoxy resin has high tensile strength.
D Epoxy resin is made up of linear polymers.

28 An amide is given below.

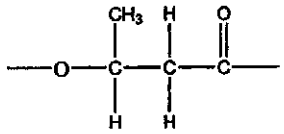


What are the reagents that can be used to produce this amide?

A $H_2NCH(CH_3)COOH$, concentrated H_2SO_4
B $H_2NCH(CH_3)NH_2$, $HOOCCH(CH_3)COOH$
C $H_2NCH(CH_3)COOH$, DCC
D $H_2NCH(CH_3)CH_2OH$, $H_2NCH(CH_3)COOH$

$H_2NCH(CH_3)COOH + H_2NCH(CH_3)COOH$ forms the product under DCC.

29 The polymer having the repeat unit shown occurs in bacteria as cell storage material.



Which deductions about this substance can be made from this structure?

1 It is a condensation polymer.

2 Hydrogen bonding is formed between two polymer chains.

3 It can be made when a diol and a dicarboxylic undergo polymerisation.

C 1 only

B 1 and 2 only

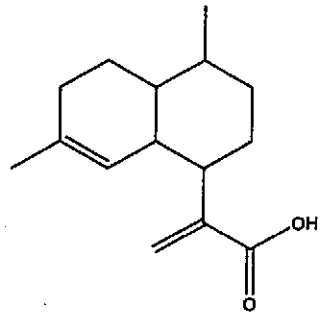
C 1 and 3 only

D 2 and 3 only

Ans: A

- The structure shows a condensation polymer (polyester).
- The polymer does not satisfy the requirements of hydrogen bonding.
- it can be made from $HOCH(CH_3)CH_2COOH$ and not between a dicarboxylic acid and diol.

30 Artemisinic acid is a useful intermediate for making the anti-malarial drug, artemisin.



artemisinic acid

Which statement about this compound is **not** correct?

A It can be esterified by ethanol, in the presence of H^+ ions.

C It can exhibit cis-trans isomerism around a double bond .

C It has a molecular formula of $C_{15}H_{22}O_2$.

D It can undergo condensation with ethylamine, in the presence of DCC.

[Turn over

Ans: B

A → it contains a carboxylic acid , thus it can react with ethanol to form esters

B → cis-trans isomerism requires each C on the double bond to have two different atoms/ groups. However the alkene is RR' – C = CH_2 and alkene in the ring can only exhibit cis configuration. Thus it CANNOT exhibit cis-trans isomerism

C → There are 15 C atoms, 22 H atoms and 2 O atoms.

D → Carboxylic acid can undergo condensation with amine group in the presence of DCC to form an amide

NATIONAL JUNIOR COLLEGE
SH2 PRELIMINARY EXAMINATION
Higher 12

CANDIDATE NAME: **Answer**

SUBJECT CLASS:

REGISTRATION NUMBER:

CHEMISTRY **8873/02**
Paper 2 Structured Questions

Monday 14 September 2020

Candidates answer on the Question Paper.

2 hours

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your subject class, registration number and name on all the work you hand in.
Write in dark blue or black pen.
You may use a HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Section A
Answers **all** the questions.

Section B
Answer **one** question.

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

For Examiner's Use	
Section A	
1	/16
2	/15
3	/10
4	/10
5	/9
Section B	
	/20
P2 Total	/80

This document consists of **22** printed pages and **0** blank pages.

Section A

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

1 In the Periodic Table, the p block contains elements whose outer electrons are found in the p subshell.

(a) Elements in the p block show a general increase in first ionisation energy as the atomic number increases.

(i) Draw the shape of a p orbital

[1]

(ii) Write an equation to show the first ionisation energy of silicon.

$Si(g) \rightarrow Si^{+}(g) + e^{-}$

[1]

(iii) Explain why there is a general increase in first ionisation energies of the elements across Period 3.

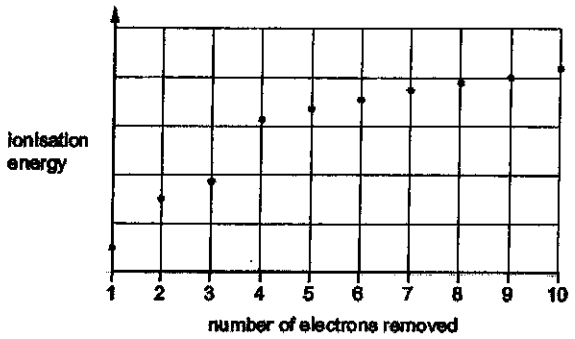
Similar shielding AND increase in proton number/atomic number/nuclear charge

Increased nuclear attraction

[2]

(iv) Element A is in the p block.

The graph shows the successive ionisation energies for the removal of the first ten electrons of A.



State and explain the group of the Periodic Table that elements A belongs to

group number: 13

explanation: large increase between third and fourth ionisation energies OR large increase after third electron removed.

[2]

(b) Silicon is found in many compounds in the Earth's crust. Silicon has only three naturally occurring isotopes, ^{28}Si, ^{29}Si and ^{30}Si.

(i) The table shows data for ^{28}Si, ^{29}Si and ^{30}Si.

	^{28}Si	^{29}Si	^{30}Si
Relative isotopic mass	28.0	29.0	30.0

A sample of silicon contains 92.2% ^{28}Si. The total percentage abundance of ^{29}Si and ^{30}Si in the sample is 7.8%.

The relative atomic mass, A_r, of silicon in the sample is 28.09.

Calculate the percentage abundance of ^{30}Si.

Give your answer to **one** decimal place.

$$\frac{(92.2 \cdot 28) + (^{29}Si \cdot 29) + (^{30}Si \cdot 30)}{100} = 28.09$$

(x =) 6.6 OR 28.09 = 28.078 + x (where x = abundance of Si-29)

7.8 – 6.6 = 1.2%

percentage abundance of ^{30}Si = 1.2 %

[3]

(ii) Silicon reacts with nitrogen gas to form Si_3N_4.

Si_3N_4 is a solid with a melting point of 1900°. It is insoluble in water and does not conduct electricity when molten.

Suggest the type of bonding in and structure of Si_3N_4. Explain your answer.

Giant molecular

Strong covalent bond between atoms

There is no mobile charged carriers

[3]

(c) SO_2 can react with ozone, O_3, to form SO_3 in two different reactions.

(i) In one reaction, SO_2 reacts with O_3 until a dynamic equilibrium is established.

$$SO_2(g) + O_3(g) \rightleftharpoons SO_3(g) + O_2(g)$$

State and explain the effect of an increase in pressure on the composition of the equilibrium mixture.

No effect/none

Equal moles of gas on both sides

[2]

(ii) In the other reaction, a different equilibrium is established at 300k as shown.

$$3SO_2(g) + O_3(g) \rightleftharpoons 3SO_3(g) \quad \Delta H = +462.3 \text{ kJmol}^{-1}$$

Suggest a temperature needed to increase the yield of SO_3 at equilibrium.

Explain your answer.

Forward reaction is endothermic

Any temperature higher than 300K

[2]

[Total: 16]

2 Magnesium silicide, Mg_2Si, is a compound made by heating magnesium with sand.

(a) Draw a 'dot-and-cross' diagram to show the arrangement of outer electrons present in a formula unit of Mg_2Si. Assume magnesium silicide is an ionic compound.

$[Mg]^{2+}$ 

[2]

(b) When solid Mg_2Si is added to water, silane gas, SiH_4 is a gas at room temperature.

Construct the equation for this reaction. Include state symbols.

$Mg_2Si(s) + 4H_2O \rightarrow 2Mg(OH)_2(aq) + SiH_4(g)$

[2]

(c) Suggest, with reference to structure and bonding, why SiH_4 is a gas at room temperature.

Simple covalent/ molecular

Weak temporary dipole – induced dipole interaction between SiH_4 molecules.

[2]

(d) The table shows the electronegativity values of carbon, hydrogen and silicon.

element	carbon	hydrogen	silicon
electronegativity	2.5	2.1	1.8

(i) C-H and Si-H bonds have weak dipoles.

Use the electronegativity values in the table to show the polarity of the C-H and Si-H bonds

$C^{\delta-}$----$H^{\delta+}$ $Si^{\delta+}$----$H^{\delta-}$

[2]

(ii) Explain why methane, CH_4, has overall dipole moment.

Tetrahedral (molecule)

Individual bonds dipoles/partical charges cancel

[2]

(e) SiH_4 reacts in air without heating but CH_4 must be ignited before combustion occurs.

$$SiH_4 + 2O_2 \longrightarrow SiO_2 + 2H_2O$$

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

Suggest, with reference to bond energies from the *Data Booklet*, why SiH_4 reacts in air without heating but CH_4 must be ignited.

Si—H bond is much weaker than C—H bond

Lower activation energy required

[2]

(f) Silicon dioxide reacts with hot, concentrated sodium hydroxide.

(I) Identify the two products formed during this reaction.

Na_2SiO_3

H_2O

[2]

(II) Describe the behaviour of the silicon dioxide during this reaction.

Acidic [1]

[Total: 15]

3 (a) Chlorate(I) ions undergo the following reaction under aqueous conditions.

$$2NH_3 + ClO^- \longrightarrow N_2H_4 + Cl^- + H_2O$$

A series of experiments was carried out at different concentrations of ClO^- and NH_3.

The table shows the results obtained.

Experiment	$[ClO^-]$ /mol dm^{-3}	$[NH_3]$ /mol dm^{-3}	initial rate /mol dm^{-3} s^{-1}
1	0.200	0.100	0.256
2	0.400	0.200	2.05
3	0.400	0.400	8.2

(I) Use the data in the table to determine the order with respect to each reactant, ClO^- and NH_3.

Show your reasoning.

Using expt 2 and 3, $[NH_3]$ x 2, rate x 4 so order with respect to $[NH_3] = 2$

Using expt 1 and 2, $[ClO^-]$ x 2 and $[NH_3]$ x 2, as rate x 8 ($=2^2$ x) so order with respect to $[ClO^-] = 1$.

[2]

(II) Write the rate equation for this reaction.

Rate = $k[NH_3]^2[ClO^-]$

[1]

(III) Use the results of experiment 1 to calculate the rate constant, k, for this reaction. Include the units of k.

$k = 0.256/(0.200 \times 0.100^2)$ $k = 128$

Units: $dm^6mol^{-2}s^{-1}$

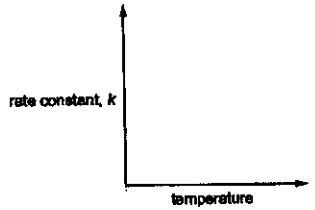
k = ...

units = ...

[2]

(iv) On the axes sketch a graph to show how the value of *k* changes as temperature is increased.

Curve/line showing *k* increasing as temperature increases



[1]

(b) In another experiment, the reaction between chlorate(I) ions and iodide ions in aqueous alkali was investigated.

A solution of iodide ions in aqueous alkali was added to a large excess of chlorate(I) ions and $[I^-]$ was measured at regular intervals.

(i) Describe how the results of this experiment can be used to confirm that the reaction is first-order with respect to $[I^-]$.

Plot a graph of $[I^-]$ against time

Constant half-lives

[2]

A three-step mechanism for this reaction is shown.

step 1: $ClO^- + H_2O \rightarrow HClO + OH^-$

step 2: $I^- + HClO \rightarrow HCO + Cl^-$

step 3: $HIO + OH^- \rightarrow H_2O + IO^-$

(ii) Use this mechanism to deduce the overall equation for this reaction.

$ClO^- + I^- \rightarrow IO^- + Cl^-$

[1]

(iii) Identify a step that involves a redox reaction. Explain your answer

Step 2

Cl is reduced/oxidised number decreases/oxidation number +1 to -1
I is oxidised/oxidation number increases/ oxidation number -1 to +1

[1]
[Total: 10]

4 Methylpropane, $(CH_3)_2CHCH_3$, is an isomer of butane, $CH_3(CH_2)_2CH_3$.

(a) (i) Explain why methylpropane and butane are a pair of isomers.

C_4H_{10}/same molecular formula

OR

Same number of carbon (atoms) and hydrogen (atoms)

[2]

(ii) Identify the type of isomerism shown by methylpropane and butane.

Structural

[1]

(b) When a sample of butane is heated to 373 K, in the presence of a catalyst, and allowed to reach equilibrium the following reaction occurs.

$$CH_3(CH_2)CH_3(g) \rightleftharpoons (CH_3)_2CHCH_3(g) \qquad \Delta H = -8.0\ kJmol^{-1}$$

State and explain the effect on the composition of this equilibrium mixture when the temperature is increased to 473 K.

Forward reaction is exothermic reaction

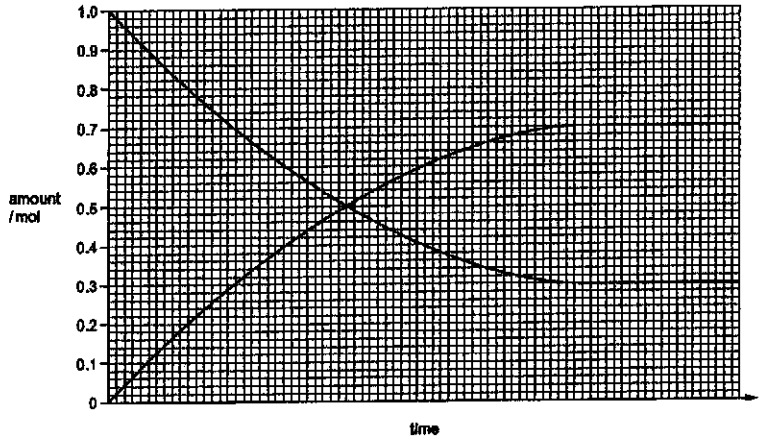
The proportion of methylpropane/product decreases

OR

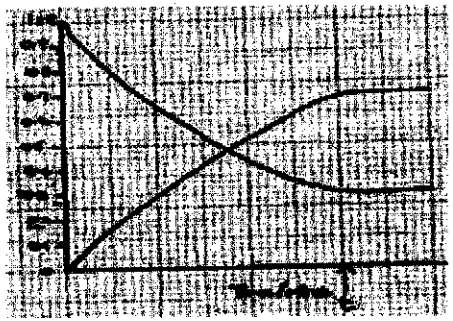
The proportion of butane/reactant increases.

[2]

(c) 1 mole of butane gas was added to a 1 dm^3 closed system, at a constant temperature and pressure. The amount of butane and methylpropane was measured at regular time intervals.



(i) Label the graph with a *t* to show the time taken to reach dynamic equilibrium.



[1]

(ii) Use the graph to find the concentration of butane and methylpropane in the mixture at equilibrium.

concentration of butane = **0.3** mol dm^{-3}

concentration of methylpropane = **0.7** mol dm^{-3}

[1]

(iii) Write an expression for K_c for this reaction.

K_c = [methylpropane] / [butane]

[1]

(iv) Calculate a value for K_c and state its units.

K_c = value of methylpropane in (ii) / value of butane in (ii)

= 0.7/0.3

= 2.33

K_c = ... units = ...[2]

[Total: 10]

5 The increasing awareness of the diminishing supply of crude oil has resulted in a number of initiatives to replace oil-based polymers with those derived from natural products. One such polymer, 'polyactide' or PLA, is produced from corn starch and has a range of applications.

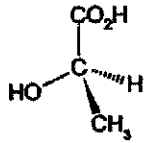
(a) The raw material for the polymer, lactic acid (2-hydroxypropanoic acid), is formed by the fermentation of corn starch using enzymes from bacteria.

(i) Calcium hydroxide is added to the fermentation tanks to prevent the production of lactic acid from slowing down.
Why might high acidity reduce the effectiveness of the enzymes?

It could denature(destroy) the enzyme.

[1]

(ii) The structure of lactic acid is shown



What type of reaction takes place in this polymerisation?

Condensation [1]

(b) One of the reasons PLA has attracted so much attention is that is biodegradable. This does, however, restrict some potential uses. The simple polymer has a melting point of around 175°C, but softens between 60 – 80°C. However, its thermoplastic properties enable it to have a range of uses in fibres and in food packaging.

(i) Explain why PLA would **not** be a suitable packaging material for foods pickled in vinegar.

(Acid present would) hydrolyse the ester (linkage).

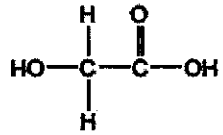
[1]

(ii) PLA containers are not used for hot drinks. Suggest why.

(Hot water would) soften the container.

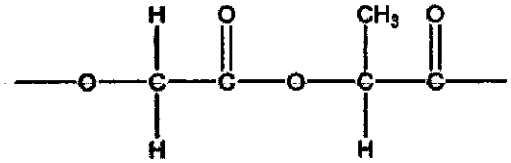
[1]

(c) Lactic acid can also be co-polymerised with glycolic acid.



glycolic acid

(i) Draw a section of the co-polymer showing one repeat unit.



Ester linkage shown
Rest of repeat unit correct

[2]

(ii) Suggest what type(s) of bonding will occur between chains of this co-polymer, indicating the groups involved.

Temporary-induced dipole interaction between methyl group

Permanent dipole-dipole interaction between ester group [2]

(iii) Suggest one property in which the co-polymer differs from PLA

Different melting point or different density or different solubility

[1]
[Total: 9]

Section B

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

6 (a) Crude oil is a natural source of hydrocarbons that are used as fuels

Hydrocarbons with low relative molecular mass, M_r, are use as fuels in industry, in the home and for transport.

There is a high demand for the hydrocarbons with low M_r.

(i) Name the process by which long-chain hydrocarbons are broken down into shorter-chain hydrocarbons.

Cracking

[1]

(ii) Give one reason why hydrocarbons with low M_r are suitable for use as fuels.

Enthalpy change of combustion is high/large energy release (per mole / per unit mass)

Or Combust/burn easily

[1]

(ii) Incomplete combustion of hydrocarbons can release carbon monoxide, CO, into the atmosphere.

Write an equation for the formation of CO from the incomplete combustion of butane, C_4H_8.

$C_4H_8 + 4O_2 \rightarrow 4CO + 4H_2O$

[1]

(b) Thiophene, $C_4H_4S(l)$, is an organic compound that is found as a contaminant in crude oil.

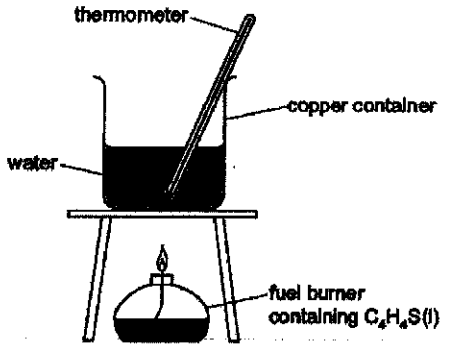
(i) A student carries out an experiment to determine the enthalpy change of combustion of $C_4H_4S(l)$.

Explain the meaning of the term *enthalpy change of combustion*.

The energy release when 1 mol of a substance is completely burn in excess oxygen.

[2]

(ii) The students uses the following apparatus in the experiment.



mass of water in copper container / g	200
initial temperature of water / °C	18.5
highest temperature of water / °C	37.5

Calculate the heat energy released, in J, by the reaction.

Assume that 4.18 J of heat energy changes the temperature of 1.0 cm^3 of water by 1.0°C.

Assume no heat is lost to the surroundings.

m = 200 and $\Delta T = 37.5 - 18.5$

$Q = mc\Delta T = 200 \times 4.18 \times (37.5 - 18.5) = 15\,884 J$

heat energy released = ... J

[2]

(iii) The student used 0.63 g of $C_4H_4S(l)$ in the experiment.

Calculate the enthalpy change of combustion of thiophene, $\Delta H_c(C_4H_4S(l))$. Include a sign in your answer.

Mol of thiophene used = 0.63 / 84.1

$\Delta H_c = -(ii)/1000 \div n = -(ii)/21000 \div (0.63/84.1)$

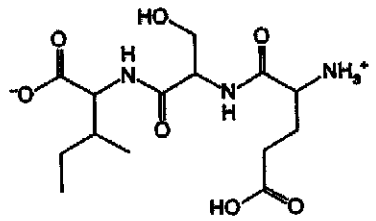
$= -2120 kJ mol^{-1}$

$\Delta H_c(C_4H_4S(l))$ = ... $kJ mol^{-1}$

[2]

(c) Proteins are natural polymers. When one particular protein is partially hydrolysed the product mixture includes tripeptide **E**.

tripeptide E



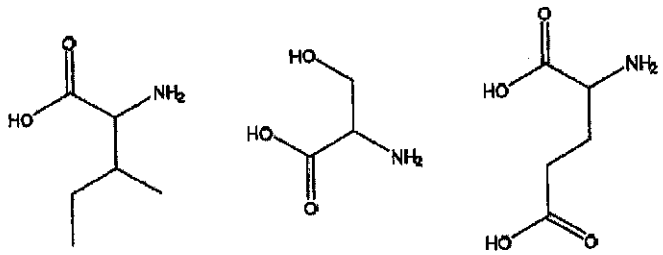
(i) Describe the conditions that could be used to hydrolyse **E** to produce a mixture of three amino acids.

any one from:

- OH^-/NaOH; aqueous/dilute; heat under reflux
- H^+/HCl/H_2SO_4, aqueous/dilute; heat under reflux [1]

(ii) Draw the structures of the three amino acids produced by this hydrolysis reaction.

The three amino acids should be shown in the correct form for the conditions you have chosen in **(c)(i)**.



[3]

(iii) If a pure sample of **E** is obtained in aqueous solution, several different types of intermolecular forces are possible between pairs of **E** molecules.

Name two different types of intermolecular force that exist between pairs of **E** molecules, stating the group on the molecules where the forces are acting.

any two

type of force/bond	pair of groups responsible
Permanent dipole-diople	CO, NH, COOH, OH
Hydrogen bonds	NH, OH and another with lone pair (NH, COOH, OH, $CONH_2$)
Ionic bonding	NH_3^+ AND COO^-

[2]

(d) Polyesters and polyamides are two important types of condensation polymer.

(i) Draw the structure of a compound that can polymerise to produce a polyamide, without the need for a second monomer.

Any structure containing one COOH/COCl AND NH_2 groups in the same molecule.

[1]

(ii) Draw the structures of two different compounds that can polymerise together to produce a polyester with **four** carbon atoms per repeat unit. Name the two compounds.

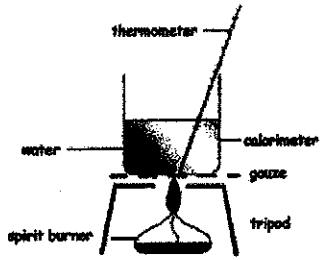
$HOCH_2CH_2OH$ HO_2CCOOH or ClOCCOCl

name: ethane-1, 2-diol name: ethanedioic acid or ethanedioyl chloride

[4]

[Total: 20]

7 (a) Methanol is used to calibrate the heat capacity of the calorimeter set up as shown below.



(i) Given that standard enthalpy change of combustion of methanol is -732 kJ mol^{-1}, determine the heat capacity of the calorimeter when 2.00 g of methanol raises the temperature of the calorimeter by 8.0 °C.

$$\Delta q_{surrounding} = C\Delta T_{surrounding}$$
$$\Delta q_{reaction} = -\Delta q_{surrounding}$$

$$\Delta H_c = \frac{\Delta q_{reaction}}{n_{substance\ burnt}}$$

$$\eta_{methanol} \times \Delta H_c = -C\Delta T$$
$$\frac{2}{22} \times -732000 = -C(8)$$
$$C = 5720 JK^{-1} (3sf)$$

[2]

(ii) A student carries out an experiment to determine the enthalpy change of combustion of ethanol.

Explain the meaning of the term *enthalpy change of combustion.*

The energy release when 1 mol of a substance is completely burn in excess oxygen.

[2]

(iii) Determine the enthalpy change of combustion of ethanol given the following data:

Mass of spirit lamp before combustion: 5.445 g
Mass of spirit lamp after combustion: 3.585 g
Initial temperature: 29.5 °C
Final temperature: 36.5 °C

$$\eta_{ethanol} \times \Delta H_c = -C\Delta T$$
$$\frac{5.445 - 3.585}{(15+14+17)} \times \Delta H_c = -5720 \times (36.5 - 29.5)$$
$$\Delta H_c = -990 kJmol^{-1} (3sf)$$

[2]

(b) The chemical equation for the combustion of propene is as shown below.

$$C_3H_8(g) + \tfrac{9}{2} O_2(g) \rightarrow 3CO_2(g) + 3H_2O(l)$$

The table below shows the standard enthalpy changes of formation of the compounds involved in reaction.

Compound	C_3H_8 (g)	CO_2 (g)	H_2O (l)	O_2 (g)
ΔH_f^θ / kJ mol^{-1}	+20	-394	-286	0

(i) Explain why the standard enthalpy of formation, ΔH_f^θ, of oxygen is zero.

$O_2(g) \rightarrow O_2(g)$
Initial state = final state, ∴ there is no change in the energy level, hence ΔH_f^θ = zero .
ΔH_f^θ = zero for any elements in their standard states and most stable allotrope.

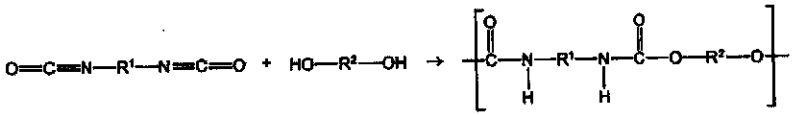
[1]

(ii) Use the data from the table above to calculate the standard enthalpy of combustion of propene

ΔH_c^θ = 3(–394) + 3(–242) – (20) – 4½ (0) = –1928 kJ mol^{-1}

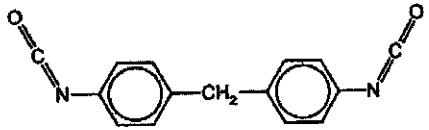
[2]

(c) Polyurethanes are polymers made by the reaction of a diisocyanate with a diol as shown. R^1 and R^2 are hydrocarbon groups.



a diisocyanate a diol a polyurethane

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



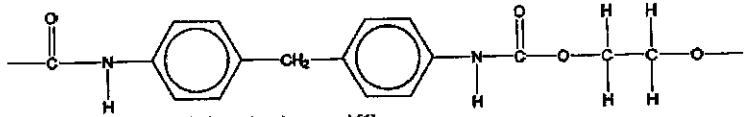
P

(i) Give the molecular formula for **P**.

$C_{15}H_{10}N_2O_2$

[1]

(ii) Draw the repeat unit of Lycra®



-NH-CO-O- linkage [1] whole molecule correct [1]

(iii) Fibres of Lycra® are strong due to the intermolecular forces between the polymer chains.

Complete the table to identify two intermolecular forces responsible for this property and the group(s) involved.

intermolecular force	group(s) involved
Hydrogen bonding	NH
Temporary dipole-induced dipole	$-C_6H_4CH_2-$

[2]

(iv) Name **one** example of each of the following types of polymer.

type of polymer	example
water soluble polymer	Poly(vinyl alcohol) PVA
chemical resistant polymer	PET

[3]

(d) (i) A metal chloride **A**, has the formula MCl_x. When 3.0×10^{-3} mol of sodium hydroxide is reacted completely with 1.0×10^{-3} mol of **A**, 0.078g of a white precipitate, **B** is formed. When **B** is heated, water is lost, leaving a white residue **C**. **C** is of high melting point and is not soluble in water.

Deduce the identities of **A**, **B** and **C**.

3 moles of OH^- reacts with 1 mole of MCl_x to give **B**. Therefore, **A** could be group 13 element, **A** could be MCl_3.

$$3NaOH + MCl_3 \rightarrow M(OH)_3 + 3\,NaCl$$
$$A \qquad B$$

No. of moles of **A** = 1.0×10^{-3}
No. of moles of **B** = 1.0×10^{-3}
M_r of **B** = $0.078 / 1.0 \times 10^{-3}$
= 78.0
$\Rightarrow A_r$ of M = 78.0 – (3 × 17.0)
= 27.0
∴ M is Al. [1]

A is $AlCl_3$
B is $Al(OH)_3$
C is Al_2O_3 [2] all correct

[3]

(ii) Compound **C**, Na_2O and SO_3 are separately added to acid and alkali. Write equations, with state symbols, for possible reactions that occur.

Na_2O : $Na_2O(s) + 2HCl(aq) \longrightarrow 2NaCl(aq) + H_2O(l)$ [1]

SO_3: $SO_3(l) + 2NaOH(aq) \longrightarrow Na_2SO_4(aq) + H_2O(l)$ [1]

[2]
[Total: 20]