EUNOIA JUNIOR COLLEGE
JC2 Preliminary Examination 2020
General Certificate of Education Advanced Level
Higher 1

CHEMISTRY

Paper 1 Multiple Choice

8873/01

18 September 2020

1 hour

Additional Materials: Multiple Choice Answer Sheet
Data Booklet

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, civics group and registration number on the Answer Sheet in the spaces provided 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 this question paper.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **10** printed pages.

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

What do the ions $^{36}S^{2-}$ and $^{37}Cl^{-}$ have in common?

A Both ions have more electrons than neutrons.

B Both ions contain the same number of nucleons in their nuclei.

C Both ions have an outer electronic configuration $2s^2\ 2p^6$.

D Both ions have 20 neutrons in their nuclei.

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

Which particle would, on losing an electron, have a half-filled set of p orbitals?

A C^- **B** N **C** N^- **D** O^+

3 Which of the following species does **not** have the same bond angle as the rest?

A OCl_2 **B** HCN **C** BeH_2 **D** XeF_2

4 Which of the following statements about water are correct?

1 Water can form hydrogen bonds with propanone.

2 Water has a higher density than ice as hydrogen bonds are stronger in water than in ice.

3 Water has a lower boiling point than pentanol as hydrogen bonds are weaker in water than in pentanol.

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

5 Which of the following statements about graphite is **incorrect**?

A All the bond angles in it are 120°.

B Each carbon atom is bonded to three other carbon atoms.

C It is able to conduct electricity due to the presence of delocalised electrons that are free to move within each layer.

D It has low melting point due to the weak instantaneous dipole-induced dipole interactions between the layers.

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

Which of the following contains twice the number of atoms as 16 g of oxygen gas, O_2?

A 2 g of hydrogen gas

B 2 g of helium gas

C 16 g of nitrogen gas

D 16 g of methane gas

7 The percentage by mass of water in a hydrated magnesium sulfate salt, $MgSO_4.xH_2O$ is 51.1%.

What is the value of x?

A 4 **B** 5 **C** 6 **D** 7

8 Dithionite, $S_2O_4^{2-}$ reacts with water under acidic conditions to form thiosulfate, $S_2O_3^{2-}$ and hydrogen sulfite, HSO_3^-.

$$2S_2O_4^{2-} + H_2O \longrightarrow S_2O_3^{2-} + 2HSO_3^-$$

Which of the following statements about the reaction and the species involved is correct?

A H_2O is the reducing agent.

B HSO_3^- is the oxidising agent.

C The oxidation number of sulfur decreases from +3 in $S_2O_4^{2-}$ to +2 in $S_2O_3^{2-}$.

D The oxidation number of hydrogen increases from +1 in H_2O to +2 in HSO_3^-.

9 1 mol of zinc metal was added to 1 mol of VO_3^-. The zinc metal was found to be oxidised by VO_3^- to form Zn^{2+}.

Assuming that all the reactants added were reacted, what is the oxidation number of vanadium in the product?

A +4 **B** +3 **C** +2 **D** +1

10 The first eight ionisation energies, in kJ mol^{-1}, of an unknown element **A** are given below.

420 3100 4400 5900 8000 9600 11400 13300

Which of the following statements about **A** is correct?

A Element **A** is in group 2 of the Periodic Table.

B Element **A** can conduct electricity in the solid state.

C The oxide of **A** is an amphoteric oxide.

D The chloride of **A** hydrolyses in water to give an acidic solution.

11 Which statements concerning the elements in the third period, from sodium to chlorine, are correct?

1 The element that has the lowest melting point is phosphorus.

2 The element with the highest electrical conductivity is aluminium.

3 The element with the smallest anion is chlorine.

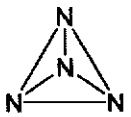
A 2 and 3 **B** 1 and 3 **C** 1 and 2 **D** 2 only

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

Hypothetically, N_4 could be formed from nitrogen gas by the following reaction.

$$2N_2(g) \rightarrow N_4(g) \qquad \Delta H$$

By considering the bonds broken and bonds formed, as well as the structure of N_4 given below, what would be the value of ΔH for the above reaction?



A +140 kJ mol^{-1} **B** +928 kJ mol^{-1} **C** −140 kJ mol^{-1} **D** −928 kJ mol^{-1}

13 The enthalpy change of reaction between calcium and water, ΔH_r, can be measured in the laboratory.

$$Ca(s) + 2H_2O(l) \rightarrow Ca(OH)_2(s) + H_2(g) \qquad \Delta H_r$$

What other data is needed in order to calculate the enthalpy change of formation of $Ca(OH)_2(s)$?

A Lattice energy of calcium hydroxide

B Enthalpy change of formation of calcium

C Enthalpy change of combustion of hydrogen

D First and second ionisation energies of calcium

14 A commercial pharmaceutical drug has a constant half-life of 2 h. The drug will lose its effectiveness in the human body once its concentration in the patient's bloodstream falls below 40 mg dm^{-3}.

Given that when a patient first consumes the drug, the concentration of the drug in his bloodstream increases to 320 mg dm^{-3}, how often should he take his prescription in order to maintain the effectiveness of this drug in his body?

A every 2 h **B** every 4 h **C** every 6 h **D** every 8 h

15 The reactants **D** and **E** react in the presence of a dilute acid as follows:

$$\mathbf{D}(aq) + \mathbf{E}(aq) \rightarrow \mathbf{G}(aq) + \mathbf{J}(aq)$$

It is found that the rate equation for the reaction is $\text{rate} = k[\mathbf{D}]^2[H^+]$.

Which of the following statements is **not** correct?

A The magnitude of k increases with temperature.

B H^+ lowers the activation energy of the reaction.

C Doubling of **[E]** at constant temperature causes a doubling of the reaction rate.

D Doubling of $[H^+]$ at constant temperature causes a doubling of the reaction rate.

16 In which of the following reactions is the underlined species behaving as a base?

A $\underline{N_2} + 3H_2 \rightleftharpoons 2NH_3$

B $\underline{NH_4^+} + H_2O \rightleftharpoons NH_3 + H_3O^+$

C $\underline{CH_3CONH_2} + OH^- \longrightarrow CH_3COO^- + NH_3$

D $\underline{CH_3CH_2NH_2} + H_3O^+ \longrightarrow CH_3CH_2NH_3^+ + H_2O$

17 Which of the following statements about the titration involving 25.0 cm^3 of 0.001 mol dm^{-3} $CH_3COOH(aq)$ and 0.002 mol dm^{-3} $NaOH(aq)$ is correct?

A The initial pH is 3.

B The equivalence volume is 25.00 cm^3.

C The solution obtained at equivalence point is acidic.

D After adding 6.00 cm^3 of $NaOH(aq)$, a buffer solution is obtained.

18 Consider a reaction for which the equilibrium constant is independent of temperature. Which of the following statements about this reaction is correct?

A The enthalpy change of reaction is zero.

B Its rate constant does not vary with temperature.

C There are equal amounts of reactants and products.

D The activation energies for both the forward and reverse reactions are zero.

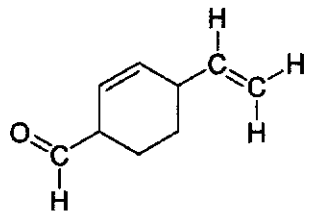
19 Myoglobin, Mb, is an oxygen-carrier protein that exists in the muscle fibres of most mammals. Each Mb molecule will bind to one O_2 molecule, according to the following equation.

$$Mb(aq) + O_2(aq) \rightleftharpoons MbO_2(aq) \qquad K_c = 1 \times 10^6 \text{ mol}^{-1} \text{ dm}^3$$

Given that the equilibrium concentration of O_2 is 6.5×10^{-6} mol dm^{-3}, what is the percentage of MbO_2 in the Mb-MbO_2 mixture at equilibrium?

A 50.5 % **B** 65.0 % **C** 86.7 % **D** 88.4 %

20 Compound **L** was reacted with hydrogen gas in the presence of platinum catalyst. How many sigma and pi bonds will be found in the product formed?



	number of sigma bonds	number of pi bonds
A	21	3
B	25	2
C	26	1
D	28	0

21 Compound **M** has a straight-chain structure with a molecular formula of C_5H_8O.

Which functional groups may be present in an isomer of compound **M**?

1 alcohol
2 aldehyde
3 ester

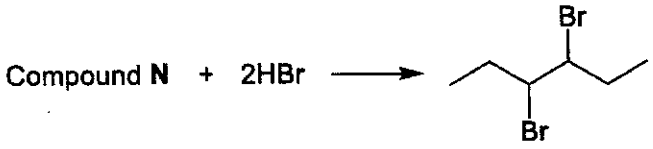
A 1, 2 and 3 **B** 1 and 2 only **C** 1 only **D** 2 only

22 $(CH_3CH_2)_3CH$ can react with chlorine under *uv* light to produce monochloro-compounds.

How many possible constitutional isomers of monochloro-compounds can it produce?

A 2 **B** 3 **C** 6 **D** 7

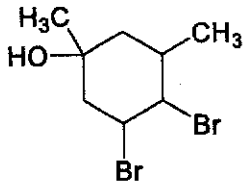
23 Compound **N** reacts with 2 mol of HBr at room temperature in the following reaction:



Given that there are no adjacent carbon-carbon double bonds in **N**, what is the total number of *cis-trans* isomers that **N** can have?

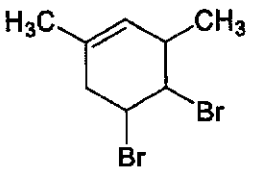
A 1 **B** 2 **C** 3 **D** 4

24 The following compound was heated with ethanolic sodium hydroxide.

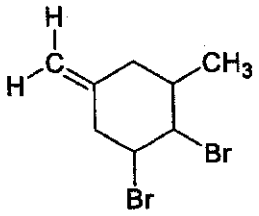


Which of the following represents the structure of the organic product?

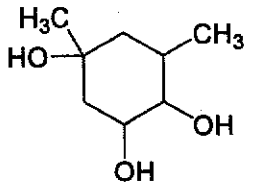
A



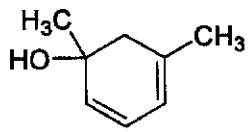
B



C



D



25 2-methylbuta-1,3-diene, $CH_2=C(CH_3)–CH=CH_2$, is used as a monomer in the manufacture of synthetic rubbers.

Which compound will **not** produce this monomer on treatment with excess concentrated sulfuric acid at 170 °C?

A $(CH_3)_2C(OH)CH(OH)CH_3$

B $HOCH_2CH(CH_3)CH_2CH_2OH$

C $HOCH_2CH(CH_3)CH(OH)CH_3$

D $HOCH_2C(CH_3)(OH)CH_2CH_3$

26 **P**, **Q** and **R** are three isomeric alcohols.

P $CH_3CH_2CH_2CH_2CH_2OH$

Q $CH_3CH_2CH(OH)CH_2CH_3$

R $(CH_3)_2C(OH)CH_2CH_3$

Two or more of these alcohols react with acidified potassium dichromate(VI).
One of these alcohols, upon oxidation, produces an organic product **S** that reacts with sodium carbonate to give carbon dioxide.

Which row is correct?

	reacts with acidified potassium dichromate(VI)	forms **S** which reacts with sodium carbonate
A	**P** and **Q** only	**P** only
B	**P** and **Q** only	**Q** only
C	**P**, **Q** and **R**	**P** only
D	**P**, **Q** and **R**	**Q** only

27 Reaction **I** shows two ethanal molecules combining to form an aldol. Reaction **II** shows the reaction of the aldol when heated.

I $2CH_3CHO \rightarrow \underset{\text{aldol}}{CH_3CH(OH)CH_2CHO}$

II $CH_3CH(OH)CH_2CHO \rightarrow CH_3CH{=}CHCHO + H_2O$

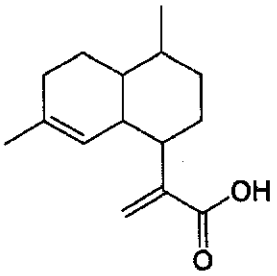
Which of the following correctly describes reactions **I** and **II**?

	I	**II**
A	elimination	reduction
B	substitution	elimination
C	addition	reduction
D	addition	elimination

28 Which of the following molecules can react with both acidified potassium dichromate(VI) and sodium borohydride, $NaBH_4$?

A CH_3CH_2OH **B** CH_3CHO **C** CH_3COCH_3 **D** $CH_3CH(OH)CH_3$

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



artemisinic acid

Which statement about this compound is **incorrect**?

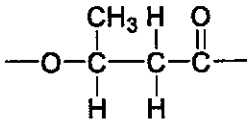
A 15 mol of CO_2 is formed upon complete combustion of 1 mol of it.

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

C In the presence of H^+ ions, it can form esters with ethanol.

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

30 The polymer having the repeat unit shown below occurs in bacteria as a 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

EUNOIA JUNIOR COLLEGE
JC2 Preliminary Examination 2020
General Certificate of Education Advanced Level
Higher 1

CANDIDATE NAME							
CIVICS GROUP	1	9	–			INDEX NUMBER	

CHEMISTRY

8873/02

Paper 2 Structured Questions

02 September 2020
2 hours

Candidates answer on the Question Paper

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, civics group, index number on all the work you hand in.
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.

The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided.

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

For Examiner's Use	
Section A	
1	/ 8
2	/ 10
3	/ 10
4	/ 12
5	/ 8
6	/ 12
Section B	
7 / 8	/ 20
Total	/ 80

This document consists of **23** printed pages and **1** blank page.

[Turn Over

Section A

For Examiner's Use

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

1 (a) Beams of particles travelling at the same speed are subjected to an electric field. Fig 1.1 shows the experimental set-up in which protons are found to be deflected through an angle of $+x°$.

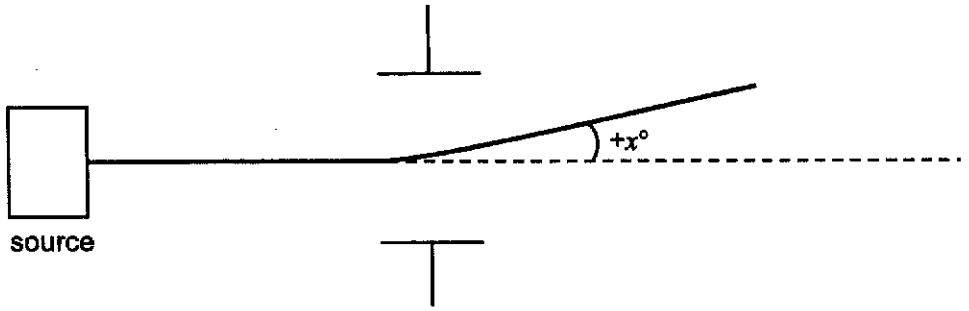


Fig 1.1

(i) Indicate in Fig 1.1, the polarity of the plates and explain your answer.

.....

.....

..... [2]

(ii) Assuming an identical set of experimental conditions, state and explain the **angle** and **direction** of deflection in terms of $x°$ for the following particles.

I: ^{4}He nuclei

.....

.....

..... [2]

II: ^{2}H atom

.....

..... [1]

(b) With reference to the electronic configurations, explain why the first ionisation energy of fluorine is smaller compared to that of neon.

For Examiner's Use

Electronic configuration of fluorine: .....

Electronic configuration of neon:.....

.....

.....

.....

.....

.....

.....

..... [3]

[Total: 8]

For Examiner's Use

2 Ascorbic acid ($C_6H_8O_6$), or more commonly known as Vitamin C, is an important component of our diet. Vitamin C pills are widely available in the market as dietary supplements, with about 1000 mg or 500 mg of Vitamin C in each pill.

To determine the amount of Vitamin C in a pill, a titration involving the following steps can be carried out.

Step 1: IO_3^- is reacted with I^- to produce a known amount of I_2:

$$IO_3^- + 6H^+ + 5I^- \longrightarrow 3I_2 + 3H_2O$$

Step 2: A Vitamin C pill is dissolved in deionised water.

Step 3: The I_2 produced in Step 1 is reacted with the Vitamin C solution from Step 2:

$$C_6H_8O_6 + I_2 \longrightarrow C_6H_6O_6 + 2I^- + 2H^+$$

Step 4: The **unreacted** I_2 from Step 3 will be titrated against $S_2O_3^{2-}$:

$$I_2 + 2S_2O_3^{2-} \longrightarrow 2I^- + S_4O_6^{2-}$$

(a) (i) Write half-equations to show the oxidation and reduction processes that occur in Step 1.

oxidation .....

reduction ..... [2]

In Step 1, 5.00 g of KIO_3 (M_r = 214.0) was first dissolved in 10 cm^3 of deionised water. The solution was then acidified and made up to 250 cm^3. 25.0 cm^3 of the resulting solution was pipetted out. 2.50 g of KI was added and stirred to ensure complete reaction.

(ii) Calculate the amount of KIO_3 in 25.0 cm^3 of solution.

[1]

For Examiner's Use

(iii) Hence, calculate the amount of iodine formed in Step 1.

[3]

(b) Is Vitamin C, $C_6H_8O_6$, acting as a reducing agent or an oxidising agent in Step 3? Explain your answer in terms of the change in oxidation numbers.

.....

..... [1]

(c) In Step 3, the solution of I_2 obtained in **(a)(iii)** was mixed with a solution of Vitamin C. The unreacted I_2 from Step 3 required 20.85 cm^3 of 0.400 mol dm^{-3} $S_2O_3^{2-}$ for complete reaction in Step 4.

(i) Calculate the amount of I_2 that has reacted with $S_2O_3^{2-}$ in Step 4.

[1]

(ii) Using your answer in **(a)(iii)**, calculate the amount of I_2 reacted with Vitamin C in Step 3.

[1]

(iii) Hence, calculate the mass of Vitamin C in the pill.

[1]

[Total: 10]

For Examiner's Use

3 Nitrogen can form a few hydrides such as NH_3 and N_2H_4.

(a) Draw a 'dot-and-cross' diagram to show the bonding in N_2H_4. State the shape of the molecule about each nitrogen atom.

shape .....

[2]

(b) The boiling points of three compounds are given in the table below.

compound	boiling point / °C
NH_3	–33
N_2H_4	114
C_2H_4	–103

Explain the difference between the boiling points of:

(i) N_2H_4 and C_2H_4

.....

.....

.....

.....

..... [2]

(ii) NH_3 and N_2H_4

.....

.....

.....

..... [1]

For Examiner's Use

(c) When NH_3 is reacted with HC*l*, a white solid of NH_4Cl with a melting point of 338 °C can be obtained upon heating to dryness. The melting point of the NaC*l* solid obtained after a similar reaction between NaOH and HC*l* is found to be much higher at 801 °C.

Explain why this is so with reference to their structure and bonding.

.....

.....

.....

.....

.....

.....

..... [3]

(d) (i) NH_3 reacts with BH_3 to form ammonia borane, NH_3BH_3.

Draw a 'dot-and-cross' diagram to show the bonding in NH_3BH_3.

[1]

(ii) Is ammonia borane a polar molecule? Explain your answer clearly.

.....

..... [1]

[Total: 10]

For Examiner's Use

4 (a) An experiment was carried out to determine the relative oxidising power of three unknown halogens X_2, Y_2 and Z_2. Table 4.1 shows the results of experiments in which the halogens X_2, Y_2 and Z_2 were added to separate aqueous solutions containing X^-, Y^- and Z^- ions.

	X^- (aq)	Y^- (aq)	Z^- (aq)
X_2		no reaction	no reaction
Y_2	brown solution formed		orange solution formed
Z_2	brown solution formed	no reaction	

Table 4.1

(i) Using the results given in Table 4.1, suggest the identity of X_2, Y_2 and Z_2.

X_2: .....

Y_2: .....

Z_2: .....

[2]

(ii) Hence, state the most powerful oxidising agent among the halogens.

..... [1]

(iii) Explain, in terms of ease of gaining electrons, why the element you have identified in **(a)(ii)** is the most powerful oxidising agent.

.....

.....

..... [2]

(b) Describe what happens when separate samples of magnesium oxide and aluminium oxide are added to water. Give equations for any reactions that occur.

For Examiner's Use

What is the effect of adding universal indicator to each resulting solution?

.....

.....

.....

.....

..... [3]

(c) Describe the reactions of the chlorides of magnesium and phosphorus with water. Include the approximate pH value of any resulting solutions and write equations for any reactions that occur.

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

..... [4]

[Total: 12]

For Examiner's Use

5 Ammonia, NH_3 is commonly used as a household cleaner to remove greasy dirt in ovens. It is also used to clean windows as it evaporates quickly and does not leave stains on glass.

25.0 cm^3 of 0.500 mol dm^{-3} NH_3 was titrated against 0.500 mol dm^{-3} HCl. Fig. 5.1 shows the pH changes during the titration.

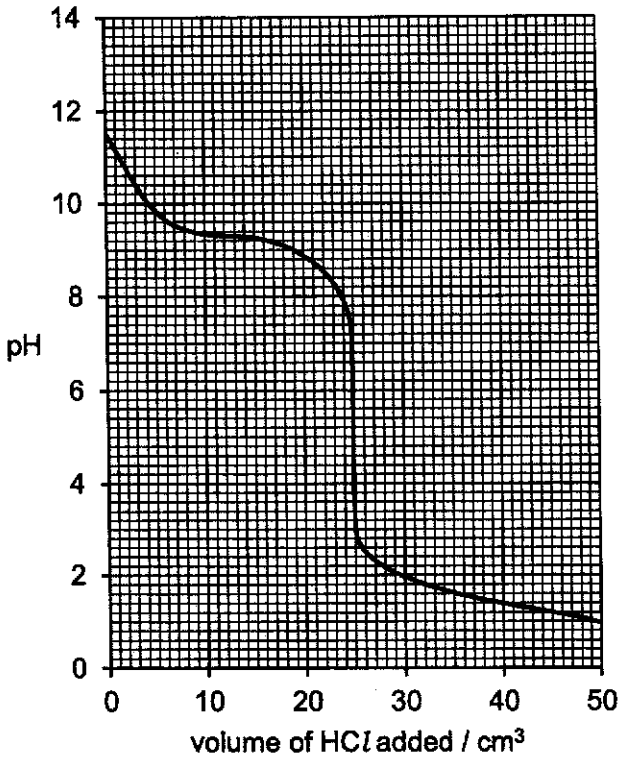


Fig. 5.1

(a) (i) Using the pH from the graph, calculate the concentration of hydroxide ions, in mol dm^{-3}, in the 25.0 cm^3 of 0.500 mol dm^{-3} solution of NH_3.

[2]

(ii) Explain how your answer in **(a)(i)** indicates that NH_3 is a weak base.

.....

.....

..... [1]

For Examiner's Use

(b) During the addition of the first 15.0 cm^3 of HC*l*, the mixture is behaving as a buffer.

(i) State what is meant by the term *buffer solution.*

.....

..... [1]

(ii) Explain how the mixture is behaving as a buffer at this stage of the titration. Include an equation in your answer.

.....

.....

..... [2]

(c) A student proposes using phenolphthalein as the indicator to determine the end-point of this titration. Using information from Fig. 5.1 and Table 5.1, explain why the student's proposal is not valid, and suggest a more suitable indicator.

indicator	colour in acid	colour in alkali	pH range over which the colour change occurs
alizarin	yellow	orange	10.1–13.0
bromocresol green	yellow	blue	3.8–5.4
gentian violet	yellow	violet	0.0–1.6
phenolphthalein	colourless	pink	8.2–10.0

Table 5.1

.....

.....

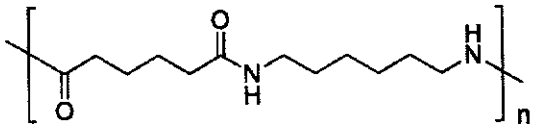
..... [2]

[Total: 8]

For Examiner's Use

6 (a) The two most common types of nylon used in textile and plastic industries are nylon-6 and nylon-6,6.

The structure of nylon-6,6 is shown below.



nylon-6,6

(i) Define the term *polymer*.

.....

..... [1]

(ii) Ropes made of nylon-6,6 are chosen for its high tensile strength. Ropes made from polyesters such as poly(ethylene terephthalate) (PET) are about 90% as strong as that made from nylon-6,6.

With the aid of a diagram, showing relevant interactions, explain why nylon-6,6 is stronger than polyester.

.....

.....

..... [3]

For Examiner's Use

(iii) Rust on window grilles can be removed by spraying the grilles with the rust remover shown in Fig 6.1 before scrubbing with a brush.

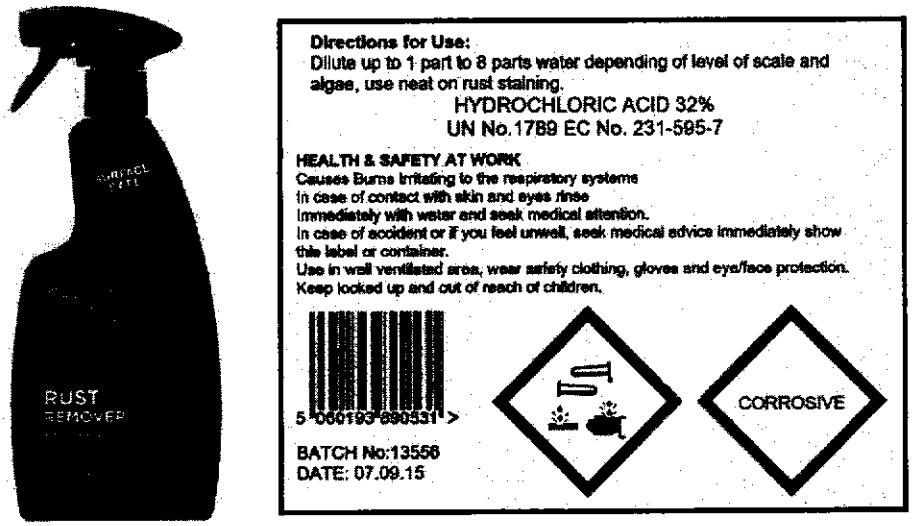


Fig 6.1

Explain whether a brush with nylon bristles or high density poly(ethene) bristles should be used for the scrubbing.

.....

.....

..... [2]

(iv) State whether nylon-6,6 is classified as a thermoplastic or thermoset. Hence, explain whether it can be recycled.

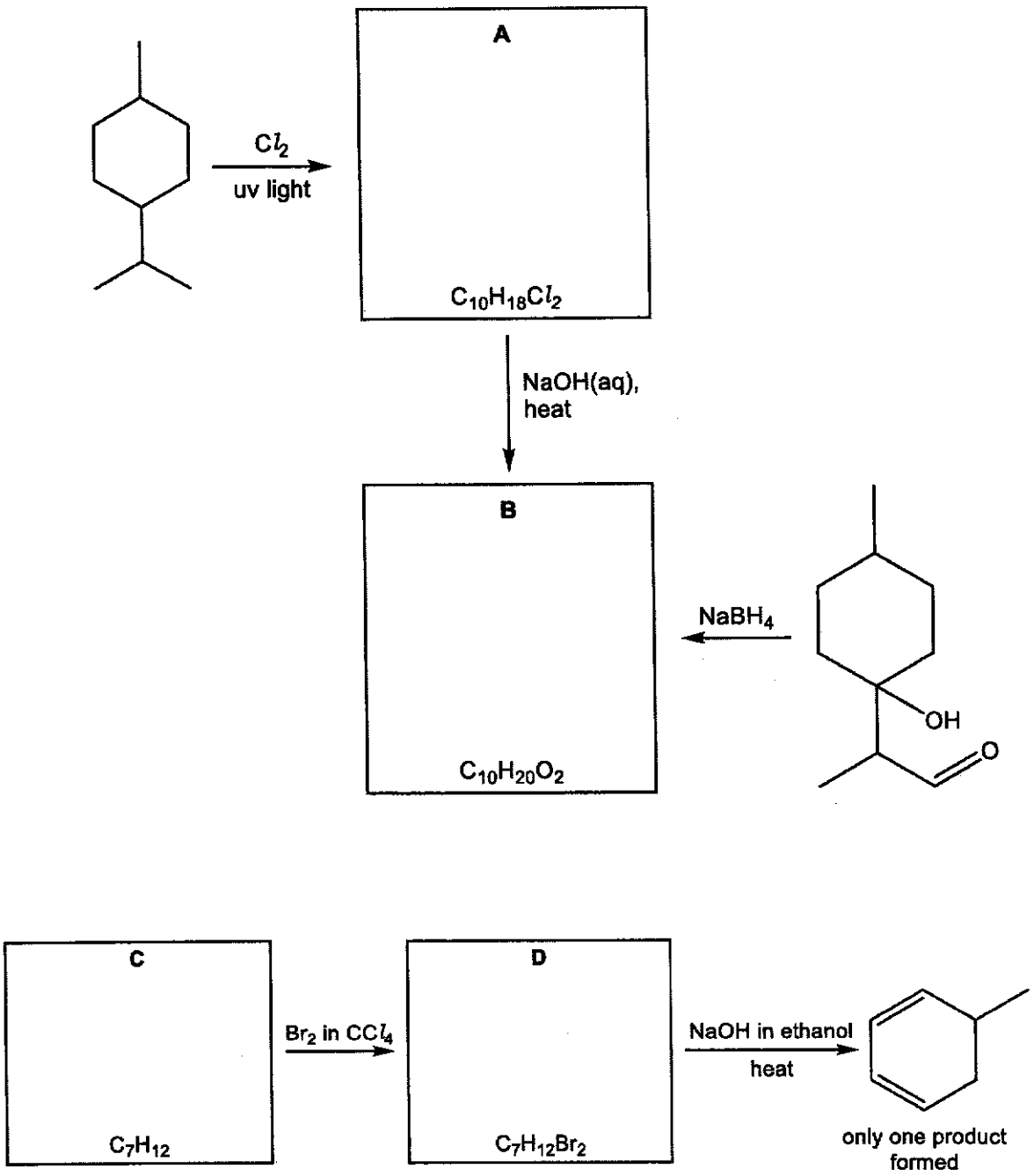
.....

.....

..... [2]

(b) Suggest a structural formula for each of the compounds **A** to **D** in the following schemes.

For Examiner's Use



[4]

[Total: 12]

Section B

For Examiner's Use

Answer **one** question in this section in the space provided.

7 (a) Oleic acid is a monosaturated omega 9 fatty acid found in olive oil. It is said to potentially reduce the risk of coronary heart disease if taken daily.

Oleic acid has the structure shown:

$$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$$

(i) Describe the pi bonding in terms of orbital overlap. You may draw a diagram to illustrate your answer.

.....

..... [2]

(ii) Oleic acid exists as a pair of isomers.

Draw and label the structural formulae of the two isomers.

[2]

(iii) Describe a chemical test that would distinguish oleic acid from ethanoic acid.

.....

.....

..... [2]

For Examiner's Use

(b) Fig. 7.1 shows a bomb calorimeter, inside a controlled temperature water jacket, which is used to find an accurate value of the standard enthalpy change of combustion of oleic acid.

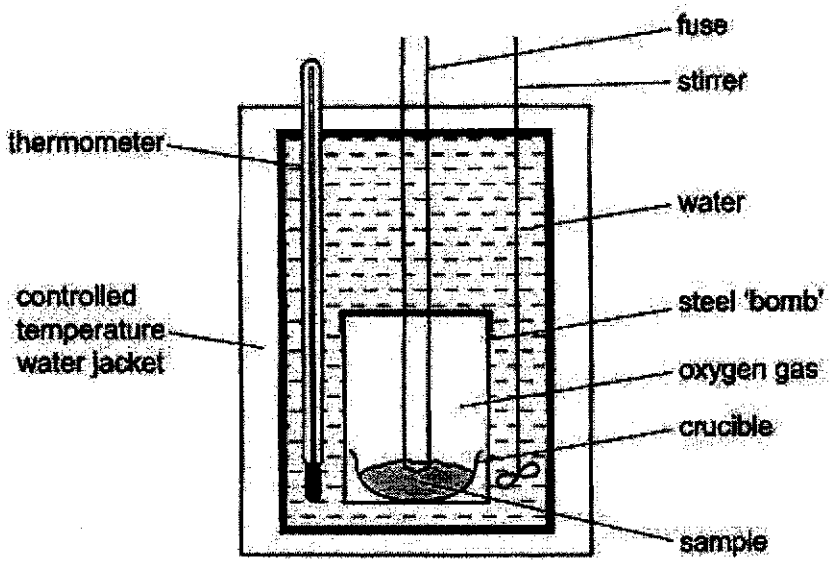


Fig. 7.1

(i) Explain why the steel 'bomb' is flushed with a high pressure of oxygen at the start of the experiment.

.....

..... [1]

(ii) There is minimal heat lost from the calorimeter because of the controlled temperature water jacket. Suggest how the controlled temperature water jacket achieves this.

.....

..... [1]

For Examiner's Use

(iii) A 2.98 g sample of oleic acid ($C_{18}H_{34}O_2$) is burned in a bomb calorimeter with a heat capacity of 1.98 kJ K^{-1}. The temperature of the calorimeter increases by 59.3 °C. The process is known to be 95 % efficient.

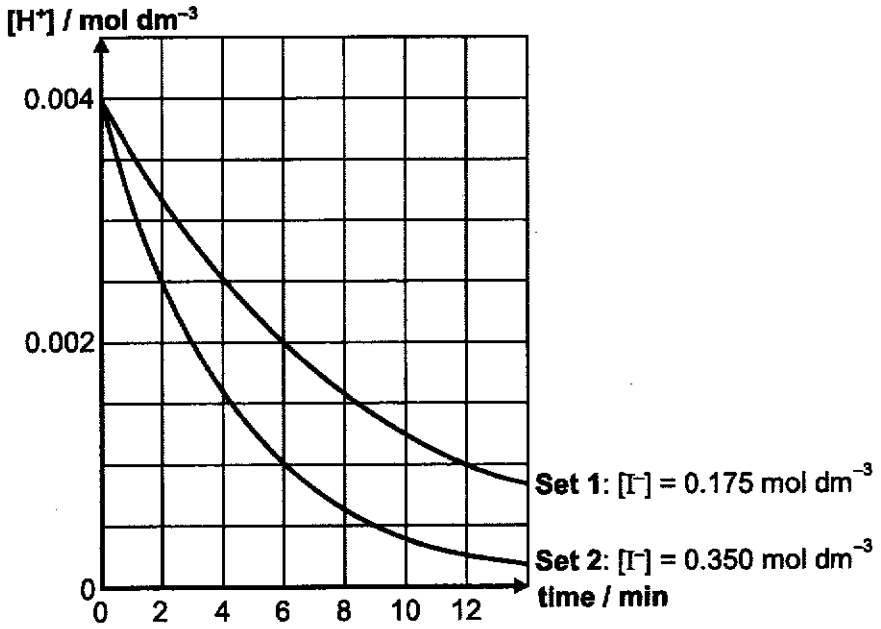
Calculate the standard enthalpy change of combustion of oleic acid.

[3]

(c) The Harcourt and Esson reaction is a reaction involving hydrogen peroxide and acidified potassium iodide.

$$H_2O_2 + 2I^- + 2H^+ \longrightarrow 2H_2O + I_2$$

To determine the order of reaction of each reactant, two sets of reaction mixtures containing varying concentrations of I^- were prepared. The concentration of hydrogen peroxide used for both experiments is 0.200 mol dm^{-3}. The results are as follows.



For Examiner's Use

(i) Given that the initial reaction rate for Set 2 is 1.00×10^{-3} mol dm^{-3} min^{-1}, calculate the initial rate of reaction for **Set 1**. Show your working clearly.

[1]

(ii) Use the information given above to determine the order of reaction with respect to I^- and H^+. Show your reasoning clearly.

[2]

(iii) The actual order of reaction with respect to H_2O_2 is one.

The rate of the reaction was measured as 4.4×10^{-5} mol dm^{-3} s^{-1} when $[H_2O_2] = 0.002$ mol dm^{-3}, $[H^+] = 0.2$ mol dm^{-3} and $[I^-] = 0.2$ mol dm^{-3}

Determine the rate constant for this reaction and state its units

[2]

For Examiner's Use

(d) Hydrogen iodide can be formed by the reaction between H_2 and I_2 under strongly heated platinised asbestos. It exists as a homogeneous equilibrium system.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \quad \cdots\cdots (1)$$

(i) Give the expression of the equilibrium constant, K_c of reaction (1).

[1]

(ii) Calculate the value of K_c at 445 °C, if the equilibrium concentrations in mol dm^{-3} of $H_2(g)$, $I_2(g)$ and HI (g) are 2.06, 13.40 and 36.98 respectively.

[1]

(ii) The value for the equilibrium constant, K_c for reaction (1) at 1000 °C is 13. By comparing the values of K_c at 445 °C and 1000 °C, deduce whether the reaction between hydrogen and iodine is endothermic or exothermic.

.....

.....

.....

.....

..... [2]

[Total: 20]

For Examiner's Use

8 (a) When 1 g of ethanol was burned under a container of water, it was found that 100 g of water was heated from 20 °C to 60 °C. The process was known to be only 65 % efficient.

Use these data and values from the *Data Booklet* to calculate the enthalpy change of combustion of ethanol.

[3]

(b) Fig 8.1 shows an energy cycle involving ethanol.

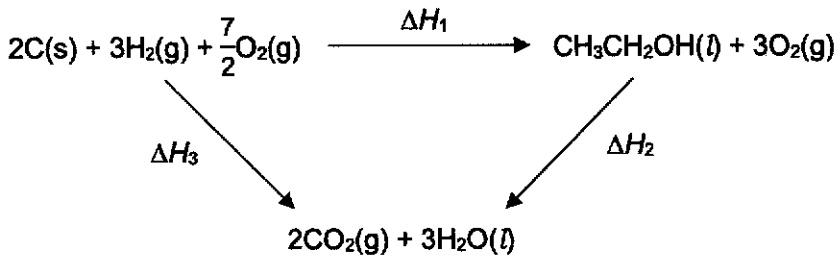


Fig 8.1

(i) Name the enthalpy change represented by ΔH_1.

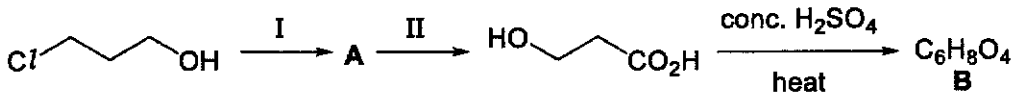
..... [1]

(ii) Given that the enthalpy change of combustion of carbon and hydrogen are -393.5 kJ mol^{-1} and -285.8 kJ mol^{-1} respectively, use the energy cycle given above and your answer to **(a)** to calculate ΔH_1.

[3]

For Examiner's Use

(c) A series of reactions starting from 3-chloropropan-1-ol is shown.



(i) State the reagents and conditions required for reactions **I** and **II**.

Step **I**: ..... [1]

Step **II**: ..... [1]

(ii) Draw the structural formulae of **A** and **B**.

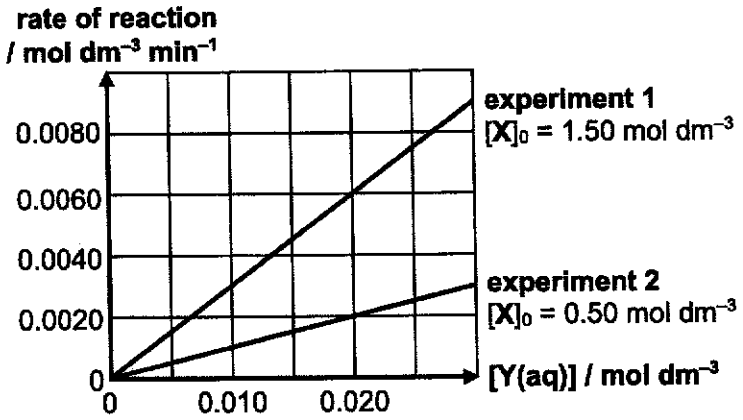
[2]

For Examiner's Use

(d) The reaction between **X** and **Y** can be represented by the following equation:

$$X(aq) + 2Y(aq) \longrightarrow Z_1(aq) + Z_2(g)$$

To study the kinetics of the above reaction, two experiments were carried out in the presence of excess **X**. The experimental results obtained are graphically represented below.



Note: $[X]_0$ = initial concentration of **X**(aq)

(i) With the aid of the graph, determine the order of reaction with respect to each of the two reactants, **X** and **Y**.

[2]

(ii) Hence, write the rate equation for the reaction and state the units for the rate constant k.

[2]

(e) 8.00 g of solid potassium chromate(VI), K_2CrO_4, is dissolved in acid to make a 100 cm^3 solution. A dynamic equilibrium occurs in the mixture according to the equation below:

For Examiner's Use

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$$

(i) Write the K_c expression for the above equilibrium mixture.

[1]

(ii) At pH 5.75, the system reaches equilibrium and **one-fifth** of the original amount of chromate(VI) ions remain. Calculate the concentration of chromate(VI) ions at this pH.

[1]

(iii) Hence, calculate the value of K_c.

[3]

[Total: 20]

BLANK PAGE

2020 JC2 Prelim Exam
H1 Chemistry 8873
Paper 1 Worked Solution

1 **A** is incorrect as both $^{36}S^{2-}$ and $^{37}Cl^-$ have 20 neutrons but 18 electrons so that they have **fewer** (not more) electrons than neutrons.

B is incorrect as $^{38}S^{2-}$ has 36 nucleons but $^{37}Cl^-$ has 37 nucleons.

C is incorrect as $^{36}S^{2-}$ and $^{37}Cl^-$ have outer electronic configuration of $3s^23p^6$.

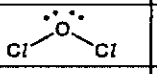
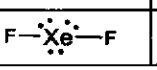
D is correct as both $^{36}S^{2-}$ and $^{37}Cl^-$ contain 20 neutrons.
⇒ **D**

2

	Species	Before losing an electron	After losing an electron
A	C^-	$1s^22s^22p^3$	$1s^22s^22p^2$
B	N	$1s^22s^22p^3$	$1s^22s^22p^2$
C	N^-	$1s^22s^22p^4$	$1s^22s^22p^3$
D	O^+	$1s^22s^22p^3$	$1s^22s^22p^2$

⇒ **C**

3

	Structure	No. of bp & lp; shape
A		2bp, 2lp Bent
B	H—C≡N	2 bp, 0lp linear
C	H—Be—H	2 bp, 0lp linear
D		2 bp, 3lp linear

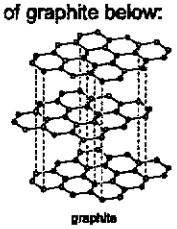
⇒ **A**

4 **1** is correct as there is a lone pair on the O atom on propanone which can form attractions to the H atom with a partial positive charge on water.

2 is wrong as the lower density of ice is due to its open structure with large amount of spaces in between that arises due to hydrogen bonding. The strength of hydrogen bonds is not affected.

3 is wrong as the lower boiling point is due to the much larger number of electrons in pentanol, which leads to significantly stronger instantaneous dipole-induced dipole interactions.
⇒ **D**

5 **A** and **B** are true as can seen from the structure of graphite below:



C is true as the delocalised electrons can act as mobile charge carriers to conduct electricity within each layer.

D is false as graphite has high thermal stability due to the strong covalent bonds between the carbon atoms.
⇒ **D**

6

		Amt of molecules	Amount of atoms
	16 g of O_2	0.5 mol	2×0.5 **= 1 mol**
A	**2 g of H_2**	**1 mol**	**2 mol**
B	2 g of He	0.5 mol	0.5 mol
C	16 g of N_2	$\frac{16}{28.0}$ mol	$2 \times \frac{16}{28.0}$ mol
D	16 g of CH_4	1 mol	5 × 1 = 5 mol

⇒ **A**

7 Let the empirical formula of the salt be $MgSO_4 \cdot xH_2O$

$$\frac{18.0x}{24.3 + 32.1 + 4 \times 16.0 + 18.0x} \times 100\% = 51.1$$

$$x = 7$$

⇒ **D**

8 **A** and **B** are false as this is a disproportionation reaction, and $S_2O_4^{2-}$ is both the oxidising and reducing agent.
C is true cos of the following.

Oxid no of S in $S_2O_4^{2-} = \frac{-2-4(-2)}{2} = +3$;

oxid no of S in $S_2O_3^{2-} = \frac{-2-3(-2)}{2} = +2$.

D is false as the oxidation number of hydrogen is +1 in both H_2O and HSO_3^-.
⇒ **C**

9 Amt of zinc metal reacted $= \frac{1.926}{65.4}$
$= 0.02945$ mol

$$Zn \longrightarrow Zn^{2+} + 2e^-$$

Amt of electrons lost by zinc metal
= 2 × 0.02945 mol
= amt of electrons gained by VO_3^-

Amt of VO_3^- reacted
$= \frac{20}{1000} \times 1.5 = 0.03$ mol
Hence, 1 mol of VO_3^- gained $\frac{2 \times 0.02945}{0.03} \approx 2$ mol of electrons
⇒ oxid no. of VO_3^- decreased by 2.

Oxid no. of V in VO_3^- = -1 - 3(-2) = +5
Oxid no of V in product = +5 - 2 = +3
⇒ **B**

10 **A** is incorrect as there is a big jump between the first and second ionisation energies, indicating that the element is in group 1 and not group 2.

B is correct as group 1 metals can conduct electricity due to presence of sea of mobile valence electrons in its metallic lattice structure.

C is incorrect as group 1 oxides are basic.

D is incorrect as group 1 chlorides do not hydrolyse in water and produces a neutral solution.
⇒ **B**

11 **1** The element that has the highest melting point is silicon, not aluminium.
2 The element with the highest electrical conductivity is aluminium due to largest amt of delocalised valence electrons in its metallic lattice structure.
3 The element with the smallest anion is chlorine due it having the largest nuclear charge amongst the anions that are all isoelectronic.
⇒ **A**

12 ΔH = BE(reactants)- BE(products)
= 2(+944) - 6(+160) = +928 kJ mol^{-1}
⇒ **B**

13 ΔH of reaction = $\Sigma\Delta H_f^\theta$ of products - $\Sigma\Delta H_f^\theta$ of reactants. Since Ca(s) and H_2(g) are elements in their standard states, $\Delta H_f^\theta(Ca) = \Delta H_f^\theta(H_2) = 0$ the other data required would be the $\Delta H_f^\theta(H_2O)$ which is equal to $\Delta H_c^\theta(H_2)$.
Since both are represented by
$H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(l)$.
⇒ **C**

14 Given $t_{1/2}$ = 2.0 hour

After 1st $t_{1/2}$, mass of **X** = ½(320) = 160 mg

After 2nd $t_{1/2}$, mass of **X** = ½(160) = 80 mg

After 3rd $t_{1/2}$, mass of **X** = ½(80) = 40 mg

Hence, drug **X** will still be effective after 3 half-lives (3 x 2.0 = 6.0 hour).
⇒ **C**

15 The order of reaction with respect to D is 2, hence tripling its concentration will lead to a $(3)^2 = 9$ times increased in reaction rate. Acid is the catalyst in the reaction, thus it introduces alternative reaction pathway with lower activation energy.
Based on Arrhenius equation ($k = Ae^{-\frac{E_a}{RT}}$), an increase in temperature causes rate constant increase as it leads to increase in reaction rate.
⇒ **C**

16 **A:** H_2O is behaving as a base as it gains a proton from NH_4^+.

B: NaOH is behaving as a base as the OH^- gains a proton from C_6H_5OH.

C: Na is not behaving as a base as it does not gain a proton. This reaction is a redox reaction, not an acid-base reaction.

D: $CH_3CH_2NH_2$ is behaving as a base as it gains a proton from H_3O^+.
⇒ **D**

17 **A** is false as CH_3COOH is a weak acid, so the pH should be higher than –lg(0.001).

B is false as the equivalence volume shld be $\left(\frac{25.0}{1000} \times 0.001\right) \div 0.002 \times 1000 = 12.50$ cm^3.

C is false as a basic salt, $CH_3COO^-Na^+$ is formed.

D is true as a mixture of CH_3COO^- and CH_3COOH will be obtained upon addition of 6.00 cm^3 of NaOH.
⇒ **D**

18 When the enthalpy change of reaction is zero, it is neither endothermic nor exothermic. Hence, changes in temperature will not affect its equilibrium position, thus its equilibrium constant will not be changed as a result.
⇒ **A**

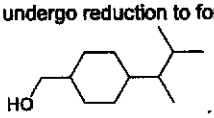
19 Let % of MbO_2 be y% & $[MbO_2]_{eqm}$ be $\frac{xy}{100}$
Let x be the initial concentration of Mb(aq).

Let % of Mb be (100–y)% & $[Mb]_{eqm}$ be $\frac{(100-y)}{100}x$

$$K_C = \frac{[MbO_2]}{[O_2][Mb]} = \frac{\frac{xy}{100}}{[6.5\times10^{-6}](\frac{100-y}{100})x} = 1\times10^{6}\ mol^{-1}dm^3$$

% of MbO_2 in the Mb-MbO_2 mixture,
y = 86.7%
⇒ **C**

20 Both alkenes and carbonyl group will undergo reduction to form



⇒ **D**

21 An unsaturated 5–carbon alcohol would have molecular formula, $C_5H_{12}O$, e.g. $CH_3CH_2CH_2CH_2CH_2OH$.

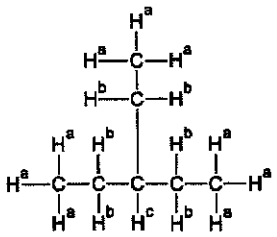
E has 4 less H atoms which implies that there is presence of 2 multiple bonds which could be C=C or C=O bond.

Hence, the possible isomers are CH_2=CHCH=$CHCH_2OH$, CH_2=$CHCH_2COCH_3$ and CH_2=$CHCH_2CH_2CHO$.

Hence, there can be alkene, alcohol, ketone and aldehyde present in the isomers of C_5H_8O. (1 and 2 only)

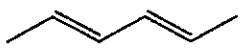
An ester is not possible as there is only 1 oxygen atom present in **E**.
⇒ **B**

22



The chlorine atom can substitute once with H^a, H^b or H^c. (i.e. there are 3 types of hydrogen atoms - H^a, H^b and H^c, with different chemical environments) Hence, there can only be 3 possible structural isomers of monochloro-compounds.
⇒ **B**

23



There are 2 double bonds that can exhibit cis-trans. So there are 3 cis trans isomers. cis-cis, trans-trans and cis-trans(take note trans-cis is the same as cis-trans since the molecule is symmetrical)
⇒ **C**

24 Both halogenoalkane groups undergoes elimination with ethanolic NaOH, the molecule loses 2 molecules of HBr to form 2 double bonds.
⇒ **D**

25 For option D, the product $OHCH_2C(CH_3)CHCH_3$ or $HOCHC(CH_3)CH_2CH_3$ will be formed.
⇒ **D**

26 Primary alcohol **L** is oxidized by acidified potassium dichromate to form a carboxylic acid which reacts with sodium carbonate to form carbon dioxide gas. Secondary alcohol **M** is oxidised by acidified potassium dichromate to form a ketone. Tertiary alcohol **N** does not undergo oxidation.
⇒ **A**

27 Since the 2 aldehydes combine to form a single aldol, reaction 1 is an addition reaction. For reaction 2, water is removed from the original molecule thus it is an elimination reaction.
⇒ **D**

28

	Rxn with $K_2Cr_2O_7$?	Rxn with $NaBH_4$?
CH_3CH_2OH	Yes	No
CH_3CHO	Yes	Yes
CH_3COCH_3	No	Yes
$CH_3CH(OH)CH_3$	Yes	No

⇒ **B**

29 **A**: There are 15 C atoms, 22 H atoms and 2 O atoms. So 15 mol of CO2 will be formed upon complete combustion of 1 mol of this cpd.

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 is a carboxylic acid functional group that can undergo condensation reaction with ethanol upon heating in acidic conditions.

D:Carboxylic acid can undergo condensation with amine group in the presence of DCC to form an amide
⇒ **B**

30 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.
⇒ **B**

Answer Key

Qn	Ans	Qn	Ans	Qn	Ans
1	D	11	A	21	B
2	C	12	B	22	B
3	A	13	C	23	C
4	D	14	C	24	D
5	D	15	C	25	D
6	A	16	D	26	A
7	D	17	D	27	D
8	C	18	A	28	B
9	B	19	C	29	B
10	B	20	D	30	A

EUNOIA JUNIOR COLLEGE
JC2 Preliminary Examination 2020
General Certificate of Education Advanced Level
Higher 1

CANDIDATE NAME							
CIVICS GROUP	1	9	–			INDEX NUMBER	

CHEMISTRY

8873/02

Paper 2 Structured Questions

02 September 2020
2 hours

Candidates answer on the Question Paper

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, civics group, index number on all the work you hand in.
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.

The use of an approved scientific calculator is expected, where appropriate.
A Data Booklet is provided.

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

For Examiner's Use	
Section A	
1	/ 8
2	/ 10
3	/ 10
4	/ 12
5	/ 8
6	/ 12
Section B	
7 / 8	/ 20
Total	/ 80

This document consists of **23** printed pages and **1** blank page.

[Turn Over

Section A

For Examiner's Use

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

1 (a) Beams of particles travelling at the same speed are subjected to an electric field. Fig 1.1 shows the experimental set-up in which protons are found to be deflected through an angle of $+x°$.

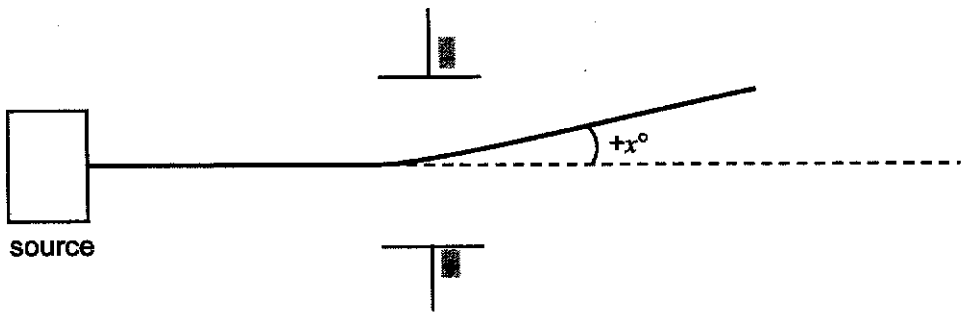


Fig 1.1

(i) Indicate in Fig 1.1, the polarity of the plates and explain your answer.

The plate on top is negatively charged as the **positively charged proton is attracted to it.**

..... [2]

(ii) Assuming an identical set of experimental conditions, state and explain the **angle** and **direction** of deflection in terms of $x°$ for the following particles.

I: ^{4}He nuclei

$\frac{q}{m} = \frac{2}{4} = \frac{1}{2}$ Hence, angle of deflection is 1/2 that of the proton's, **+x/2°** **(towards negative plate)**

..... [2]

II: ^{2}H atom

0°. The atom has **no net charge** and hence remains **undeflected**.

..... [1]

(b) With reference to the electronic configurations, explain why the first ionisation energy of fluorine is smaller compared to that of neon.

For Examiner's Use

Electronic configuration of fluorine: $1s^2\ 2s^2\ 2p^5$

Electronic configuration of neon: $1s^2\ 2s^2\ 2p^6$

Ne has a greater nuclear charge compared to F, while the shielding effect experienced by both species is approximately the same as they both have same number of inner core electrons. The 2p electron in Ne experiences a greater effective nuclear charge than F as it is more strongly attracted to the nucleus. Hence, more energy is required to remove 2p electron from Ne atoms.

..... [3]

[Total: 8]

For Examiner's Use

2 Ascorbic acid ($C_6H_6O_8$), or more commonly known as Vitamin C, is an important component of our diet. Vitamin C pills are widely available in the market as dietary supplements, with about 1000 mg or 500 mg of Vitamin C in each pill.

To determine the amount of Vitamin C in a pill, a titration involving the following steps can be carried out.

Step 1: IO_3^- is reacted with I^- to produce a known amount of I_2:

$$IO_3^- + 6H^+ + 5I^- \longrightarrow 3I_2 + 3H_2O$$

Step 2: A Vitamin C pill is dissolved in deionised water.

Step 3: The I_2 produced in Step 1 is reacted with the Vitamin C solution from Step 2:

$$C_6H_8O_6 + I_2 \longrightarrow C_6H_6O_6 + 2I^- + 2H^+$$

Step 4: The **unreacted** I_2 from Step 3 will be titrated against $S_2O_3^{2-}$:

$$I_2 + 2S_2O_3^{2-} \longrightarrow 2I^- + S_4O_6^{2-}$$

(a) (i) Write half-equations to show the oxidation and reduction processes that occur in Step 1.

oxidation $2I^- \longrightarrow I_2 + 2e^-$

reduction $2IO_3^- + 12H^+ + 10e^- \longrightarrow I_2 + 6H_2O$ [2]

In Step 1, 5.00 g of KIO_3 (M_r = 214.0) was first dissolved in 10 cm^3 of deionised water. The solution was then acidified and made up to 250 cm^3. 25.0 cm^3 of the resulting solution was pipetted out. 2.50 g of KI was added and stirred to ensure complete reaction.

(ii) Calculate the amount of KIO_3 in 25.0 cm^3 of solution.

$$\text{Total amount of } KIO_3 \text{ dissolved} = \frac{5.00}{214.0} = 0.02336 \text{ mol}$$

$$\text{Amount of } KIO_3 \text{ in 25 cm}^3 \text{ of solution} = \frac{5.00}{214.0} \times \frac{25.0}{250} = \mathbf{0.00234\ mol}$$

[1]

For Examiner's Use

(iii) Hence, calculate the amount of iodine formed in Step 1.

$$\text{Amount of KI reacted} = \frac{2.50}{166.0} = \mathbf{0.0151\,mol}$$

Since $KIO_3 \equiv 5KI$,
0.01506 mol of KI will need 0.003012 mol of KIO_3 for complete reaction.
Hence, **KIO_3 is the limiting reagent.**

Amount if I_2 formed = 3 × amount of KIO_3 = **0.00701 mol**

[3]

(b) Is Vitamin C, $C_6H_6O_8$, acting as a reducing agent or an oxidising agent in Step 3? Explain your answer in terms of the change in oxidation numbers.

Reducing agent. It reduces iodine as can be seen from the **decrease** in oxidation number from **0 in iodine** to **−1 in iodide**. [1]

(c) In Step 3, the solution of I_2 obtained in **(a)(ii)** was mixed with a solution of Vitamin C. The unreacted I_2 from Step 3 required 20.85 cm^3 of 0.400 mol dm^{-3} $S_2O_3^{2-}$ for complete reaction in Step 4.

(i) Calculate the amount of I_2 that has reacted with $S_2O_3^{2-}$ in Step 4.

$$\text{Amount of } I_2 \text{ reacted with } S_2O_3^{2-} = \frac{20.85}{1000} \times 0.400 \times \frac{1}{2}$$
$$= \mathbf{0.00417\,mol}$$

[1]

(ii) Using your answer in **(a)(ii)**, calculate the amount of I_2 reacted with Vitamin C in Step 3.

$$\text{Amount of } I_2 \text{ reacted with Vitamin C} = 0.007009 - 0.004170$$
$$= \mathbf{0.00284\,mol}$$

[1]

(iii) Hence, calculate the mass of Vitamin C in the pill.

$$\text{Amount Vitamin C reacted} = \text{Amount of } I_2 \text{ reacted} = 0.002839\,\text{mol}$$
$$\text{Mass of Vitamin C in pill} = 0.002839 \times 176.0$$
$$= \mathbf{0.500\,g}$$

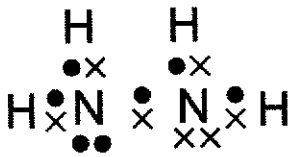
[1]

[Total: 10]

For Examiner's Use

3 Nitrogen can form a few hydrides such as NH_3 and N_2H_4.

(a) (i) Draw a 'dot-and-cross' diagram to show the bonding in N_2H_4. State the shape of the molecule about each nitrogen atom.



Shape **Trigonal pyramidal** .....

[2]

(b) The boiling points of three compounds are given in the table below.

compound	boiling point/ °C
NH_3	-33
N_2H_4	114
C_2H_4	-103

Explain the difference between the boiling points of:

(i) N_2H_4 and C_2H_4

The **intermolecular hydrogen bonds between N_2H_4** are **stronger** than the **instantaneous dipole-induced dipole interactions between C_2H_4**. Hence, more energy is required to overcome the intermolecular forces of attraction between N_2H_4 than C_2H_4

..... [2]

(ii) NH_3 and N_2H_4

N_2H_4 can form an average of two hydrogen bonds per molecule as compare to NH_3 which can only form one. More energy is required to break the **more extensive hydrogen bonds between N_2H_4**, hence it has a higher boiling point.

..... [1]

For Examiner's Use

(c) When NH_3 is reacted with HC*l*, a white solid of NH_4Cl with a melting point of 338 °C can be obtained upon heating to dryness. The melting point of the NaC*l* solid obtained after a similar reaction between NaOH and HC*l* is found to be much higher at 801 °C.

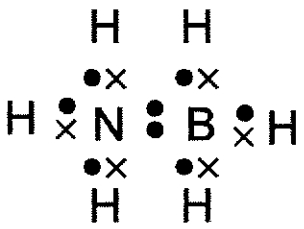
Explain why this is so.

NH_4Cl and NaC*l* both have **giant ionic structures**, with **strong electrostatic forces of attractions between oppositely charged ions**. The strength of ionic bonds is measured by the magnitude of lattice energy.

The charges of the ions in both solids are the same, but **NH_4^+ has a larger ionic radius than Na^+**. Since $|\Delta H_{latt}| \propto \left|\frac{q_+ \times q_-}{r_+ + r_-}\right|$, the **magnitude of lattice energy of NH_4Cl is smaller**, and **ionic bonds are weaker**. Hence, NH_4Cl has a lower melting point than NaC*l*. [3]

(d) (i) NH_3 reacts with BH_3 to form ammonia borane, NH_3BH_3.

Draw a 'dot-and-cross' diagram to show the bonding in NH_3BH_3.



[1]

(ii) Is ammonia borane a polar molecule? Explain your answer clearly.

Yes. There is a net dipole moment as the **dipole moments** due to the **polar** N–H and N–B **bonds do not cancel out**. [1]

[Total: 10]

For Examiner's Use

4 (a) An experiment was carried out to determine the relative oxidising power of three unknown halogens X_2, Y_2 and Z_2. Table 4.1 shows the results of experiments in which the halogens X_2, Y_2 and Z_2 were added to separate aqueous solutions containing X^-, Y^- and Z^- ions.

	X^- (aq)	Y^- (aq)	Z^- (aq)
X_2		no reaction	no reaction
Y_2	brown solution formed		orange solution formed
Z_2	brown solution formed	no reaction	

Table 4.1

(i) Using the results given in Table 4.1, suggest the identity of X_2, Y_2 and Z_2.

X_2: **I_2 or iodine**

Y_2: **Cl_2 or chlorine (accept F_2 or fluorine)**

Z_2: **Br_2 or bromine**

[2]

(ii) Hence, state the most powerful oxidising agent among the halogens.

Chlorine, Cl_2 (accept Y_2) [1]

(iii) Explain, in terms of ease of gaining of electrons, why the element you have identified in **(a)(ii)** is the most powerful oxidising agent.

Chlorine has the **smallest atomic radius,** hence the **tendency to accept electrons is highest**

[2]

(b) Describe what happens when separate samples of magnesium oxide and aluminium oxide are added to water. Give equations for any reactions that occur.

For Examiner's Use

What is the effect of adding universal indicator to each resulting solution?

Aluminium oxide **does not dissolve in or react with water**. Universal indicator is **green** colour.

MgO is sparingly soluble in water to give a **weakly alkaline** solution. Universal indicator is **blue** in colour. **$MgO(s) + H_2O(l) \rightleftharpoons Mg(OH)_2(aq)$**

[3]

(c) Describe the reactions of the chlorides of magnesium and phosphorus with water. Include the approximate pH value of any resulting solutions and write equations for any reactions that occur.

When $MgCl_2$ dissolves in water, the Mg^{2+} gets hydrated.

The hydrated Mg^{2+} undergoes **slight hydrolysis** to give H_3O^+. The resultant solution has a **pH ≈ 6.5**.

$MgCl_2 + 6H_2O \rightarrow [Mg(H_2O)_6]^{2+} + 2Cl^-$

$[Mg(H_2O)_6]^{2+} + H_2O \rightleftharpoons [Mg(OH)(H_2O)_5]^+ + H_3O^+$

PCl_5 **hydrolyses** in water to give H_3O^+ as shown.

The resultant solution has a **pH ≈ 2** .

$PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$

[4]

[Total: 12]

For Examiner's Use

5 Ammonia, NH_3 is commonly used as a household cleaner to remove greasy dirt in ovens. It is also used to clean windows as it evaporates quickly and does not leave stains on glass.

25.0 cm^3 of 0.500 mol dm^{-3} NH_3 was titrated against 0.500 mol dm^{-3} HC*l*. Fig. 5.1 shows the pH changes during the titration.

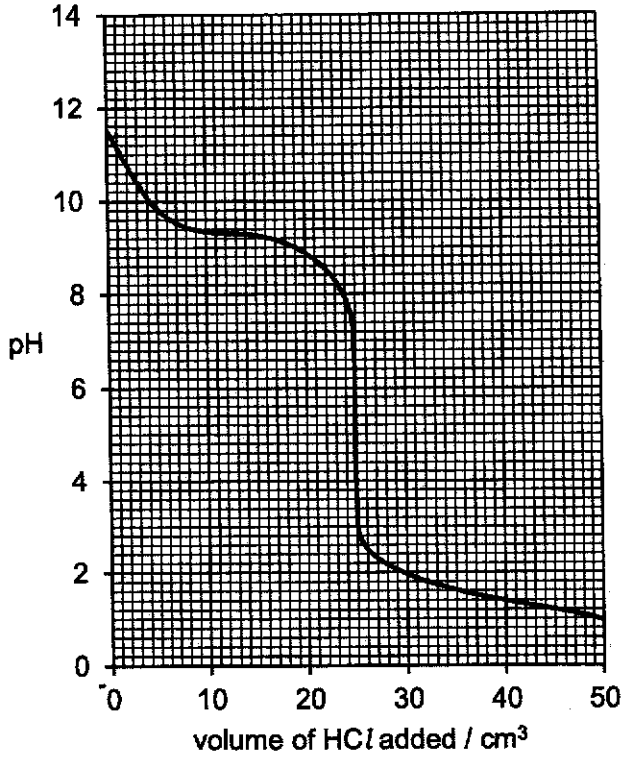


Fig. 5.1

(a) (i) Using the pH from the graph, calculate the concentration of hydroxide ions, in mol dm^{-3}, in the 25.0 cm^3 of 0.500 mol dm^{-3} solution of NH_3.

$$pOH = 14 - 11.5$$
$$= 2.5$$
$$[OH^-] = 10^{-2.5} = 0.00316 \text{ mol dm}^{-3}$$

[2]

(ii) Explain how your answer in **(a)(i)** indicates that NH_3 is a weak base.

The concentration of OH^- produced from the dissociation of NH_3 is **lower than the initial concentration of NH_3**, hence only **partial dissociation** has occured.

..... [1]

For Examiner's Use

(b) During the addition of the first 15.0 cm^3 of HCl, the mixture is behaving as a buffer.

(i) State what is meant by the term *buffer solution*.

A buffer solution is one which is able to **resist changes in pH** upon **addition of a small amount of acid or base**. [1]

(ii) Explain how the mixture is behaving as a buffer at this stage of the titration. Include an equation in your answer.

$NH_3 + H^+ \rightarrow NH_4^+$ Nearly all the **H^+ ions added are removed by the large reservoir of NH_3 present**. Hence, the **concentration of H^+ does not increase significantly**, and the pH is kept approximately constant. [2]

(c) A student proposes using phenolphthalein as the indicator to determine the end-point of this titration. Using information from Fig. 5.1 and Table 5.1, explain why the student's proposal is not valid, and suggest a more suitable indicator.

indicator	colour in acid	colour in alkali	pH range over which the colour change occurs
alizarin	yellow	orange	10.1–13.0
bromocresol green	yellow	blue	3.8–5.4
gentian violet	yellow	violet	0.0–1.6
phenolphthalein	colourless	pink	8.2–10.0

Table 5.1

The **region of rapid pH change** of this titration occurs **below pH 8**, hence is **not within the working range of phenolphthalein**.

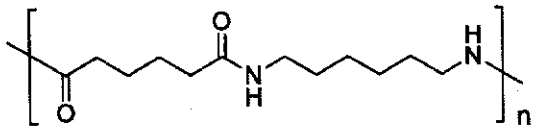
A more suitable indicator will be **bromocresol green**. [2]

[Total: 8]

For Examiner's Use

6 (a) The two most common types of nylon used in textile and plastic industries are nylon-6 and nylon-6,6.

The structure of nylon-6,6 is shown below.



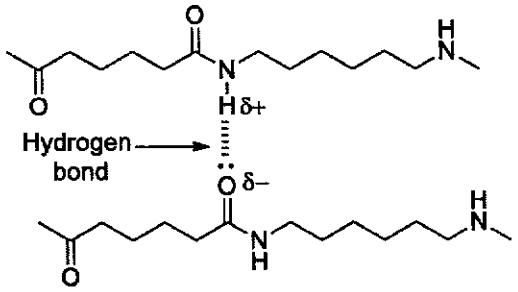
nylon-6,6

(i) Define the term *polymer*.

A polymer is a **macromolecule** made from monomers with **average molecular mass of at least 1000 or at least 100 repeat units.** [1]

(ii) Ropes made of nylon-6,6 are chosen for its high tensile strength. Ropes made from polyesters such as poly(ethylene terephthalate) (PET) are about 90% as strong as that made from nylon-6,6.

With the aid of a diagram, showing relevant interactions, explain why nylon-6,6 is stronger than polyester.



There are **stronger hydrogen bonds** in between nylon polymer chains as compared to **permanent dipole–permanent dipole interactions** in polyester chain. [3]

For Examiner's Use

(iii) Rust on window grilles can be removed by spraying the grilles with the rust remover shown in Fig 6.1 before scrubbing with a brush.

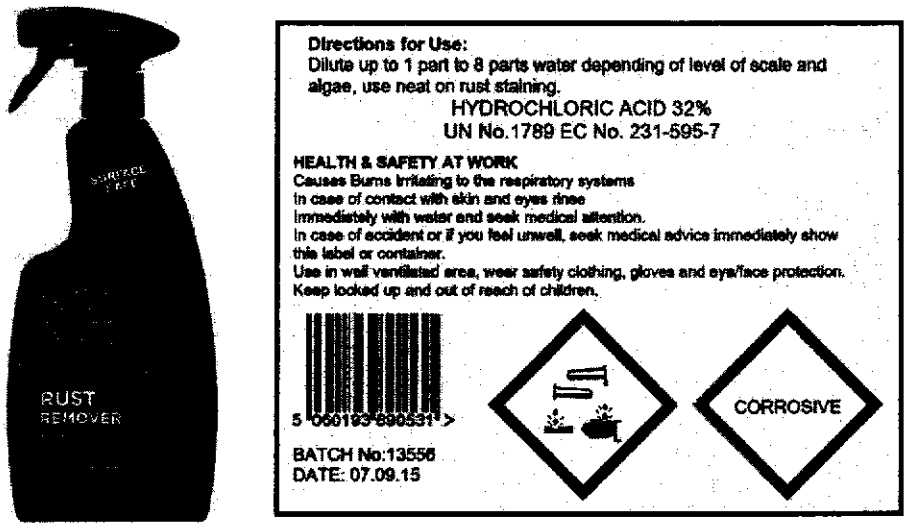


Fig 6.1

Explain whether a brush with nylon bristles or high density poly(ethene) bristles should be used for the scrubbing.

A brush with **high density poly(ethene)** bristles should be used.

The **acid** in the rust remover would cause **hydrolysis of the amide linkage in nylon bristles** while **poly(ethene) bristles are unaffected**. [2]

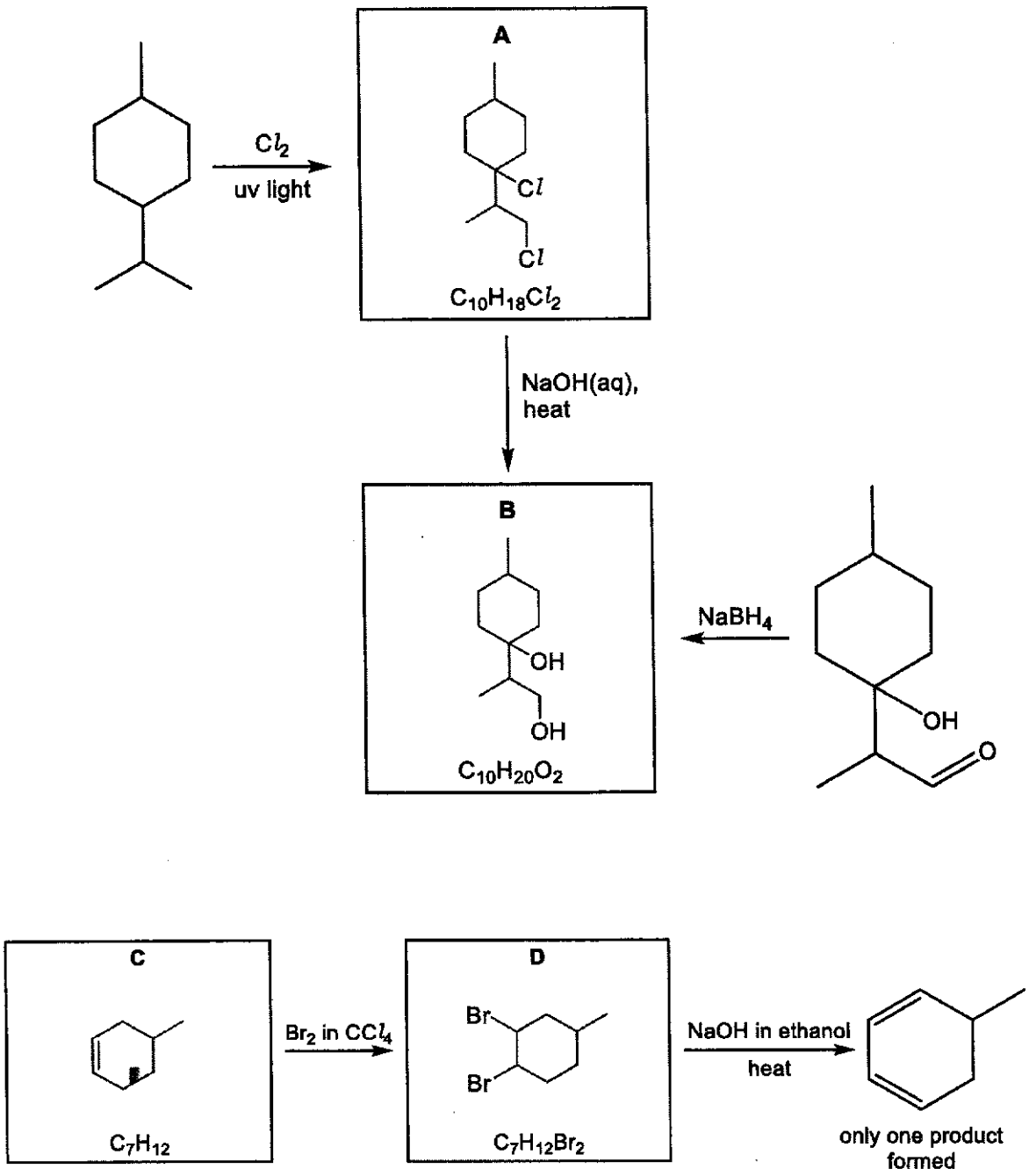
(iv) State whether nylon-6,6 is classified as a thermoplastic or thermoset. Hence, explain whether it can be recycled.

Nylon-6,6 is a **thermoplastic**. It is **recyclable** as it **melts upon heating** as the **hydrogen bonds between the chains can be broken**.

[2]

(b) Suggest a structural formula for each of the compounds **A** to **D** in the following schemes.

For Examiner's Use



[4]

[Total: 12]

For Examiner's Use

Section B

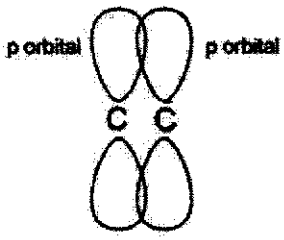
Answer **one** question in this section in the space provided.

7 (a) Oleic acid is a monosaturated omega 9 fatty acid found in olive oil. It is said to potentially reduce the risk of coronary heart disease if taken daily.

Oleic acid has the structure shown:

$$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$$

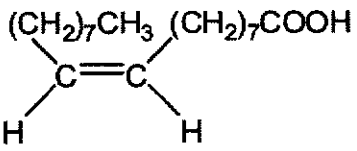
(i) Describe the pi bonding in terms of orbital overlap. You may draw a diagram to illustrate your answer.



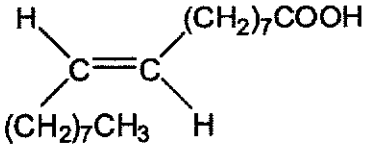
The C–C π bond is formed by the **sideway overlap** between the **2*p* orbital of the carbon atom and 2*p* orbital of another carbon**. [2]

(ii) Oleic acid exists as a pair of isomers.

Draw and label the structural formulae of the two isomers.



cis isomer



trans isomer

[2]

(iii) Describe a chemical test that would distinguish oleic acid from ethanoic acid.

Add **Br_2 in CCl_4** to each compound in the **dark** at **r.t.p.**

Oleic acid: Orange-red bromine solution is **decolourised**.

Ethanoic acid: Orange-red bromine solution is **not decolourised**. [2]

For Examiner's Use

(b) Fig. 7.1 shows a bomb calorimeter, inside a controlled temperature water jacket, which is used to find an accurate value of the standard enthalpy change of combustion of oleic acid.

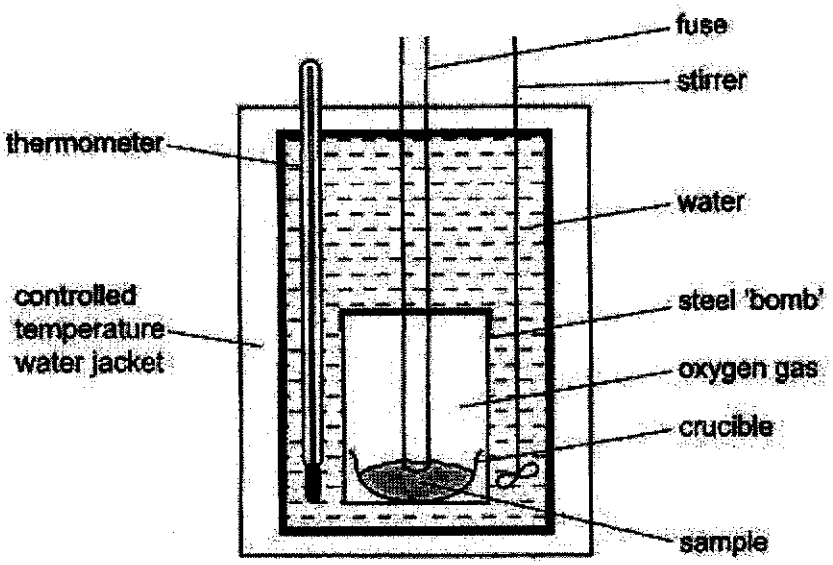


Fig. 7.1

(i) Explain why the steel 'bomb' is flushed with a high pressure of oxygen at the start of the experiment.

It is to ensure that there is **sufficient O_2** present in the steel bomb for **complete combustion**. [1]

(ii) There is minimal heat lost from the calorimeter because of the controlled temperature water jacket. Suggest how the controlled temperature water jacket achieves this.

The **temperature of water in the jacket is raised** with an electric heater so that it just **matches the average temperature** of the calorimeter. [1]

For Examiner's Use

(iii) A 2.98 g sample of oleic acid ($C_{18}H_{34}O_2$) is burned in a bomb calorimeter with a heat capacity of 1.98 kJ K^{-1}. The temperature of the calorimeter increases by 59.3 °C. The process is known to be 95 % efficient.

Calculate the standard enthalpy change of combustion of oleic acid.

Heat absorbed by calorimeter = 1.98 × 59.3 = 117 kJ

Amount of oleic acid used = $\frac{2.98}{282.0}$ = 0.0106 mol

$$\Delta H_c^{\circ}(\text{oleic acid}) = -\frac{117 \times (\frac{100}{95})}{0.0106}$$

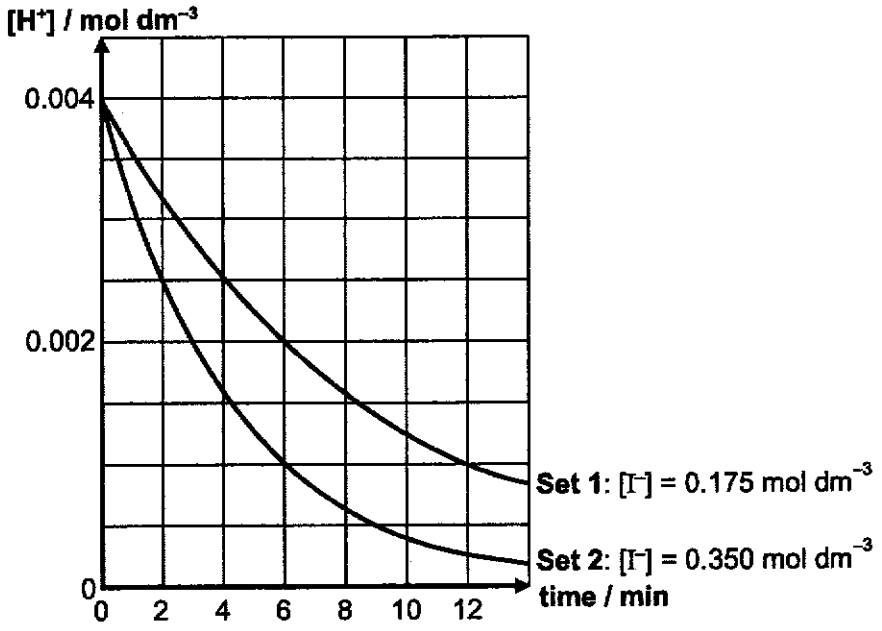
$$= -11700 \text{ kJ mol}^{-1}$$

[3]

(c) The Harcourt and Esson reaction is a reaction involving hydrogen peroxide and acidified potassium iodide.

$$H_2O_2 + 2I^- + 2H^+ \longrightarrow 2H_2O + I_2$$

To determine the order of reaction of each reactant, two sets of reaction mixtures containing varying concentrations of I^- were prepared. The concentration of hydrogen peroxide used for both experiments is 0.200 mol dm^{-3}. The results are as follows.



(i) Given that the initial reaction rate for Set 2 is 1.00×10^{-3} mol dm^{-3} min^{-1}, calculate the initial rate of reaction for **Set 1**. Show your working clearly.

For Examiner's Use

Taking gradient of tangent at t = 0,

set 1 = 0.004 ÷ 8
= **5×10^{-4} mol dm^{-3} min^{-1}**

[1]

(ii) Use the information given above to determine the order of reaction with respect to I^- and H^+. Show your reasoning clearly.

When $[H^+]$ decreases from 0.004 mol dm^{-3} to 0.002 mol dm^{-3}, time taken is 3 min
When $[H^+]$ decreases from 0.002 mol dm^{-3} to 0.001 mol dm^{-3}, time taken is 3 min
Since $t_{½}$ is constant at 3 min, order of reaction wrt H^+ is 1.

	$[H_2O_2]$ / mol dm^{-3}	$[I^-]$ / mol dm^{-3}	$[H^+]$ / mol dm^{-3}	initial rate / mol dm^{-3} min^{-1}
Set 1	0.200	0.175	0.004	0.0005
Set 2	0.200	0.350	0.004	0.001

Comparing Set 1 and Set 2, when concentration of $[I^-]$ is doubled, the rate is also doubled. Since rate is directly proportional to $[I^-]$, order of reaction wrt $[I^-]$ is 1.

OR Deduce constant half life to deduce order of reaction to I^-

[2]

(iii) The actual order of reaction with respect to H_2O_2 is one.

The rate of the reaction was measured as 4.4×10^{-5} mol dm^{-3} s^{-1} when $[H_2O_2]$ = 0.002 mol dm^{-3}, $[H^+]$ = 0.2 mol dm^{-3} and $[I^-]$ = 0.2 mol dm^{-3}

Determine the rate constant for this reaction and state its units

rate = $k[H_2O_2][I^-][H^+]$
$4.4 \times 10^{-5} = k(0.002)(0.2)(0.2)$
k = 0.550 mol^{-2} dm^6 s^{-1}

[2]

For Examiner's Use

(d) Hydrogen iodide can be formed by the reaction between H_2 and I_2 under strongly heated platinised asbestos. It exists as a homogeneous equilibrium system.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \quad \cdots\cdots (1)$$

(i) Give the expression of the equilibrium constant, K_c of reaction (1).

$$K_c = \frac{[HI]^2}{[H_2][I_2]}$$

[1]

(ii) Calculate the value of K_c at 445 °C, if the equilibrium concentrations in mol dm^{-3} of $H_2(g)$, $I_2(g)$ and HI (g) are 2.06, 13.40 and 36.98 respectively.

$$K_c = \frac{36.98^2}{2.06 \times 13.40} = \mathbf{49.5}$$

[1]

(ii) The value for the equilibrium constant, K_c for reaction (1) at 1000 °C is 13. By comparing the values of K_c at 445 °C and 1000 °C, deduce whether the reaction between hydrogen and iodine is endothermic or exothermic.

K_c at 1000 °C is less than K_c at 445 °C.

At a **higher temperature**, there is a **smaller proportion** of HI at equilibrium.

This implies that **backward reaction** is **favoured to absorb the heat**.

Hence, the forward reaction is **exothermic.**

..... [2]

[Total: 20]

For Examiner's Use

8 (a) When 1 g of ethanol was burned under a container of water, it was found that 100 g of water was heated from 20 °C to 60 °C. The process was known to be only 65 % efficient.

Use these data and values from the *Data Booklet* to calculate the enthalpy change of combustion of ethanol.

$(CH_3CH_2OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O)$

Heat absorbed by water (65% efficient) = $mc\Delta T$
= (100)(4.18)(60 – 20)
= 16720 J

Heat evolved by combustion of ethanol (100%) = $\frac{16720}{0.65}$
= 25.72 kJ

Enthalpy change of combustion of ethanol = $-\frac{25.72}{\frac{1}{46}}$ = –1180 kJ mol^{-1}

[3]

(b) Fig 8.1 shows an energy cycle involving ethanol.

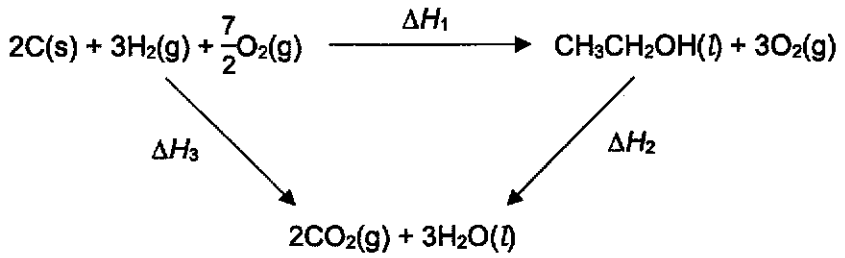


Fig 8.1

(i) Name the enthalpy change represented by ΔH_1.

(standard) enthalpy change of formation of ethanol ..... [1]

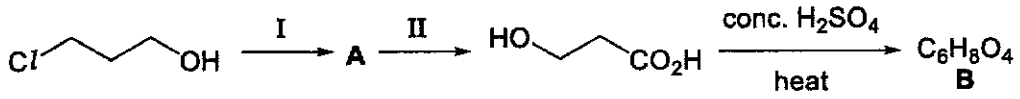
(ii) Given that the enthalpy change of combustion of carbon and hydrogen are –393.5 kJ mol^{-1} and –285.8 kJ mol^{-1} respectively, use the energy cycle given above and your answer to **(a)** to calculate ΔH_1.

$\Delta H_1 = \Delta H_3 - \Delta H_2$
= [2(–393.5) + 3(–285.8)] – (–1180)
= –1644.4 + 1330
= –464 kJ mol^{-1}

[3]

For Examiner's Use

(c) A series of reactions starting from 3-chloropropan-1-ol is shown.



(i) State the reagents and conditions required for reactions **I** and **II**.

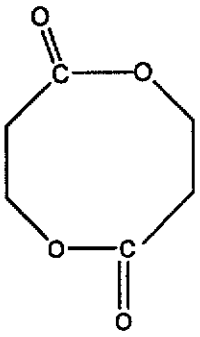
Step **I**: $KMnO_4(aq)$ or $K_2Cr_2O_7(aq)$, $H_2SO_4(aq)$ heat under reflux ..... [1]

Step **II**: NaOH(aq), heat under reflux, followed by addition of H_2SO_4 (aq) (any acid) ..... [1]

(ii) Draw the structural formulae of **A** and **B**.

A

B



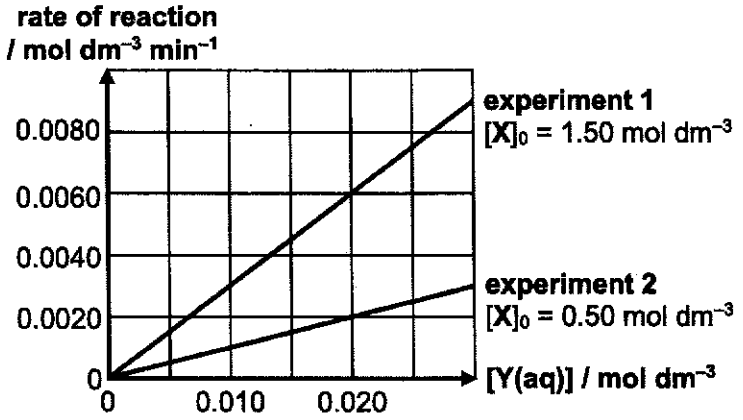
[2]

For Examiner's Use

(d) The reaction between **X** and **Y** can be represented by the following equation:

$$X(aq) + 2Y(aq) \longrightarrow Z_1(aq) + Z_2(g)$$

To study the kinetics of the above reaction, two experiments were carried out in the presence of excess **X**. The experimental results obtained are graphically represented below.



Note: $[X]_0$ = initial concentration of **X**(aq)

(i) With the aid of the graph, determine the order of reaction with respect to each of the two reactants, **X** and **Y**.

Consider either experiment 1 or experiment 2.
The graph obtained is a straight line having a positive gradient and passing through the origin. This implies that the rate is directly proportional to [Y].
Hence order of reaction with respect to Y is 1.

Consider the two rates of reaction when [Y] = 0.020 mol dm^{-3}.
For expt. 1 where $[X]_0$ = 1.50 mol dm^{-3}, rate = 0.0060 mol dm^{-3} min^{-1}.

For expt. 2 where $[X]_0$ = 0.50 mol dm^{-3}, rate = 0.0020 mol dm^{-3} min^{-1}.

Hence when [X] is tripled, rate is corresponding tripled.
This implies that rate is directly proportional to [X]. Therefore order of reaction with respect to X is 1.

[2]

(ii) Hence write down the rate equation for the reaction and state the units for the rate constant k.

rate = k [X][Y]

units for rate constant, k: mol^{-1} dm^3 min^{-1}

[2]

For Examiner's Use

(e) 8.00 g of solid potassium chromate(VI), K_2CrO_4, is dissolved in acid to make a 100 cm^3 solution. A dynamic equilibrium occurs in the mixture according to the equation below:

$$2CrO_4^{2-}(aq) + 2H^+(aq) \rightleftharpoons Cr_2O_7^{2-}(aq) + H_2O(l)$$

(i) Write the K_c expression for the above equilibrium mixture.

$$K_c = \frac{[Cr_2O_7^{2-}]}{[CrO_4^{2-}]^2[H^+]^2}$$

[1]

(ii) At pH 5.75, the system reaches equilibrium and **one-fifth** of the original amount of chromate(VI) ions remain. Calculate the concentration of chromate(VI) ions at this pH.

Initial $[CrO_4^{2-}] = \frac{8}{194.2} \div \frac{100}{1000} = 0.4119$ mol dm^{-3}

$[CrO_4^{2-}]$ at eqm = $\frac{1}{5}(0.4119)$ = **0.0824 mol dm^{-3}**

[1]

(iii) Hence, calculate the value of K_c.

$[Cr_2O_7^{2-}]$ at eqm = $\frac{4}{5}(0.4119) \div 2 = 0.1648$ mol dm^{-3}

$[H^+] = 10^{-5.75} = 1.778 \times 10^{-6}$ mol dm^{-3}

Substituting into K_c,

$$K_c = \frac{[0.1648]}{[0.08239]^2[1.778 \times 10^{-6}]^2} = 7.67 \times 10^{12} mol^{-3} dm^9$$

[3]

[Total: 20]

BLANK PAGE

For Examiner's Use