ANGLO-CHINESE JUNIOR COLLEGE
DEPARTMENT OF CHEMISTRY
Preliminary Examination

CHEMISTRY **8873/01**
Higher 1

Paper 1 Multiple Choice

16 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, index number and tutorial class 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 booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of **13** printed pages and **1** blank page.

1 Shakudo is a Japanese alloy of copper and gold. The data in the table below was obtained by mass spectrometry of a sample of Shakudo.

mass number	63	65	197
% abundance	65	29	6

Which A_r value for copper is given by these figures?

A 59.8 **B** 63.5 **C** 63.6 **D** 71.6

2 In acid solution, dichromate(VI) ions oxidise hydrogen peroxide, H_2O_2. In alkaline solution, hydrogen peroxide oxidises chromium(III) ions.

Which conditions of oxidation produce oxygen gas?

A both acid and alkaline oxidations

B only the acid oxidation

C neither acid nor alkaline oxidation

D only the alkaline oxidation

3 The mineral tellurite, TeO_2 (M_r = 159.6), is often used in the manufacture of optic fibres. It was found that 1.01 g of TeO_2 required exactly 60 cm^3 of 0.035 mol dm^{-3} acidified $K_2Cr_2O_7$ for complete reaction. In this reaction, $Cr_2O_7^{2-}$ is converted into Cr^{3+}.

What is the oxidation state of Te in the final product?

A +2 **B** +3 **C** +5 **D** +6

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

Calcium can react with nitrogen gas, under suitable conditions, to form the ionic compound calcium nitride, which contains the N^{3-} ion.

What is the percentage by mass of nitrogen in calcium nitride?

A 18.9% **B** 25.9% **C** 34.4% **D** 41.1%

5 Some isotopes are unstable and undergo nuclear (radioactive) reactions. In one type of reaction, an unstable nucleus assimilates an electron from an inner orbital of its electron cloud. The net effect is the conversion of a proton and an electron into a neutron.

$$^{1}_{1}p + ^{0}_{-1}e \rightarrow ^{1}_{0}n$$

Which of the following describes this type of reaction?

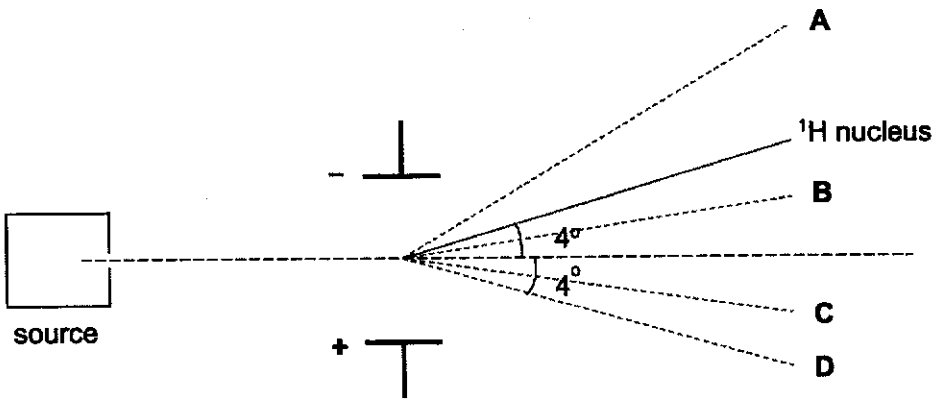
A $^{11}C \rightarrow ^{12}C$

B $^{111}I \rightarrow ^{111}Te$

C $^{76}Br \rightarrow ^{75}Br$

D $^{76}Kr \rightarrow ^{75}Br$

6 When passed through an electric field, the ^{1}H nucleus is deflected as shown below.



Which of the above beams represents the deflection for the ion $^{2}X^{2-}$?

7 The electronegativity values of carbon, selenium and chlorine are all different. Chlorine is more electronegative than both carbon and selenium.

Which molecules are polar?

1 CSe_2

2 $SeCl_2$

3 CCl_4

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

8 The compound lithium aluminium hydride, $LiAlH_4$, was discovered by Finholt, Bond and Schlesinger in 1947.

Which types of bonding are found in the compound?

1 ionic

2 covalent

3 hydrogen bonding

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

9 Ethanoic acid forms a double molecule, or dimer, with the molecular formula $C_4H_8O_4$.

This dimer contains two hydrogen bonds within a ring of eight atoms.

How many C, H and O atoms are present in this ring?

	C	H	O
A	2	2	4
B	2	4	2
C	4	0	4
D	4	2	2

10 Some Period 3 and 4 elements are shown below.

Period 3 elements	Al	Si	P	S
Period 4 elements	Ga	Ge	As	Se

The properties of each Period 4 element resemble those of the Period 3 element directly above it.

Which Period 4 elements form oxides that dissolve in water to give acidic solutions?

A As and Se

B Ga and Ge

C Ga and Se

D Se only

11 Which of the following statements is **Incorrect** about Group 1 and Group 17 elements?

A Group 1 element has smaller atomic radius as compared to Group 17 element in the same Period.

B Group 1 elements are good reducing agents while Group 17 elements are good oxidising agents.

C Reducing power of Group 1 elements increases down the group while oxidising power of Group 17 elements decreases down the group.

D The ionisation energies of Group 1 and Group 17 elements decrease down the groups.

12 Which statement explains why HC*l* has a higher thermal stability than HBr and HI?

A HC*l* has the strongest intermolecular forces of attraction.

B The HC*l* bond has the highest bond energy.

C The ionic bond formed between H^+ and Cl^- is the strongest.

D The HC*l* bond has the longest length.

13 Which reaction has an enthalpy change that is equal to the lattice energy of sodium fluoride?

A $Na(g) + F(g) \rightarrow NaF(s)$

B $Na(s) + \frac{1}{2} F_2(g) \rightarrow NaF(s)$

C $Na^+(g) + F^-(g) \rightarrow NaF(g)$

D $Na^+(g) + F^-(g) \rightarrow NaF(s)$

14 What does ΔH_r of the following equation represent?

$$H_2(g) + \frac{1}{2}O_2(g) \longrightarrow H_2O(g) \qquad \Delta H_r$$

A sum of standard enthalpy change of formation of $H_2(g)$ and the enthalpy change of vaporisation of $H_2O(l)$

B sum of standard enthalpy change of formation of $H_2O(l)$ and the enthalpy change of vaporisation of $H_2O(l)$

C standard enthalpy change of combustion of $H_2(g)$

D standard enthalpy change of formation of $H_2O(l)$

15 In oil refineries, an important process is the recovery of any sulfur from petroleum, as shown by **reaction 1**.

$$2H_2S(g) + O_2(g) \rightarrow 2H_2O(g) + 2S(s) \qquad \textbf{reaction 1}$$

The enthalpy changes of formation of $H_2S(g)$ and $H_2O(g)$ are -20.5 kJ mol^{-1} and -243.0 kJ mol^{-1} respectively.

What is the enthalpy change of **reaction 1** in kJ mol^{-1}?

A -445 **B** $+445$ **C** -222 **D** $+222$

16 Compound **P** reacts to give compounds **Q** and **R** as shown below.

$$\mathbf{P}(g) \longrightarrow \mathbf{Q}(g) + \mathbf{R}(g)$$

The reaction is first order with respect to **P** and the rate constant, k, is 6.93 min^{-1}.

What is the time taken for the concentration of **P** to decrease from 1.80 mol dm^{-3} to 0.225 mol dm^{-3}?

A 0.1 min

B 0.3 min

C 0.4 min

D 0.8 min

17 For a reversible reaction, what is the effect of a catalyst on the

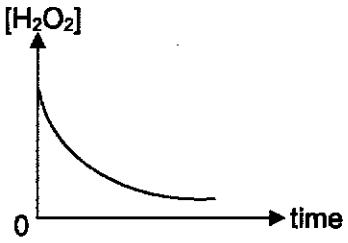
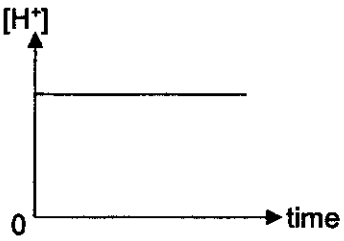
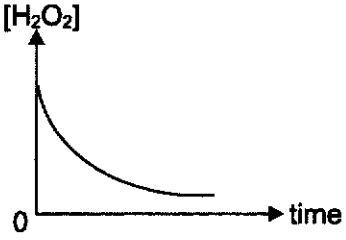
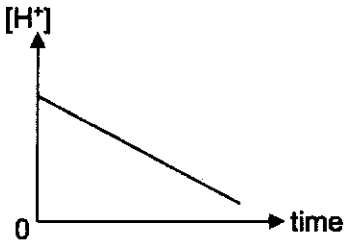
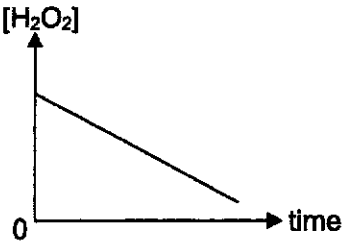
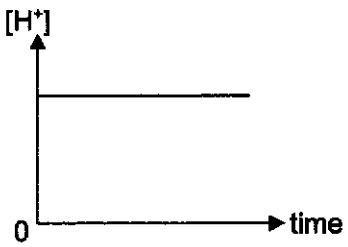
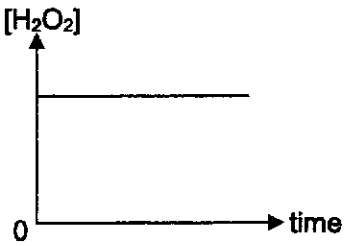
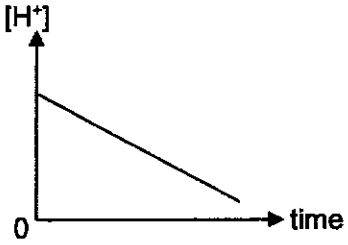
- rate constant for the forward reaction, k_1,
- rate constant for the reverse reaction, k_{-1}, and
- the equilibrium constant, K?

	k_1	k_{-1}	K
A	increases	decreases	no effect
B	increases	increases	increases
C	increases	increases	no effect
D	no effect	no effect	increases

18 The reaction of H_2O_2 with I^- in an acidic solution is first order with respect to H_2O_2, first order with respect to I^-, and zero order with respect to H^+.

$$H_2O_2(aq) + 2H^+(aq) + 2I^-(aq) \rightarrow 2H_2O(l) + I_2(aq)$$

Two experiments were carried out separately. Which pair of diagrams correctly represents the variation of $[H_2O_2]$ and $[H^+]$ with time?

	experiment 1: in the presence of a large excess of I^- and H^+	experiment 2: in the presence of a large excess of I^- and H_2O_2
A		
B		
C		
D		

19 Compound **P** decomposes on heating according to the following equation.

$$2P(g) \rightleftharpoons Q(g) + 2R(g)$$

3 mol of **P** was introduced into a 1 dm^3 container and heated. The equilibrium mixture contained 1.2 mol of **R**.

What is the value of the equilibrium constant, K_c?

A $\dfrac{(0.6)^2 \times 0.3}{5^2}$

B $\dfrac{(0.6)^2 \times 1.2}{5^2}$

C $\dfrac{0.6 \times (0.3)^2}{1.8^2}$

D $\dfrac{0.6 \times (1.2)^2}{1.8^2}$

20 Which statement is always correct about a system in dynamic equilibrium?

A The addition of a catalyst can affect the position of the equilibrium.

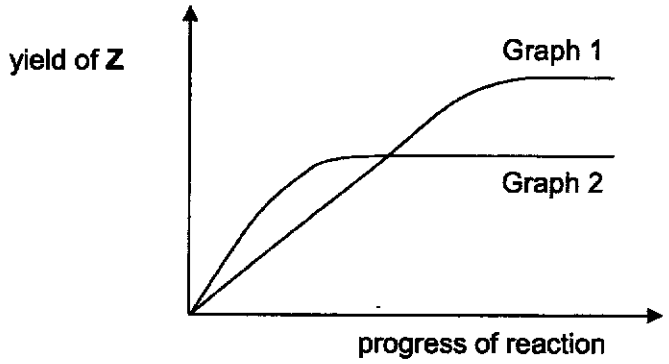
B The rate of forward reaction is the same as the rate of backward reaction.

C The concentration of products is constantly changing.

D The concentration of products is equal to the concentration of reactants.

21 The graph for the reversible reaction involving **X**, **Y** and **Z** is shown below.

$$2\mathbf{X}(g) + 2\mathbf{Y}(s) \rightleftharpoons 3\mathbf{Z}(g) \qquad \Delta H > 0$$



Which of the following changes could account for the change from Graph 1 to Graph 2?

A addition of catalyst

B addition of more **X**

C increase in pressure

D increase in temperature

22 Which of the following acids have pH = 1.0?

1 0.10 mol dm^{-3} nitric acid

2 0.10 mol dm^{-3} sulfuric acid

3 0.10 mol dm^{-3} ethanoic acid

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

23 The dissociation constants, K_w, for the ionisation of water, $2H_2O \rightleftharpoons H_3O^+ + OH^-$, at different temperatures are given below.

temperature / °C	K_w / mol^2 dm^{-6}
0	1.15×10^{-15}
25	1.00×10^{-14}
50	5.50×10^{-14}

Which of the following can be deduced from this information?

A The pH of water at 50 °C is 6.6.

B The forward reaction is exothermic.

C The equilibrium lies more to the left as temperature increases.

D The $[H_3O^+]$ increases while the $[OH^-]$ decreases as temperature increases.

24 Carbonic acid, H_2CO_3, and hydrogen carbonate ion, HCO_3^-, are the agents of the buffer systems in blood. Which of the following will take place when the level of acidity in blood increases?

1 $HCO_3^- \rightarrow H^+ + CO_3^{2-}$

2 $HCO_3^- + H^+ \rightarrow H_2CO_3$

3 $H_2CO_3 \rightarrow CO_2 + H_2O$

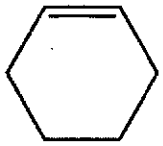
A 1 only **B** 1 and 3 only **C** 2 and 3 **D** 2 only

25 Which type of formula is the same for butanoic acid and ethyl ethanoate?

A displayed **C** skeletal

B structural **D** empirical

26 Which of the following molecules are planar?

1 

2 $H_2C{=}{=}CH_2$

3 

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

27 During the production of ethyl ethanoate, a trace amount of concentrated sulfuric acid is used. Why is concentrated sulfuric acid used?

1 to prevent overheating of the reaction mixture

2 to catalyse the reaction

3 to remove water

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

28 Which reaction will **not** yield an organic product incorporating deuterium, D? [D = $^{2}_{1}H$]

A CH_3COOH heated with CD_3ND_2 in the presence of dicyclohexylcarbodiimide, DCC

B CH_3CHO with $LiAlD_4$ in dry ether at room temperature

C CH_3CH_2Br heated with ethanolic NaOD

D $CH_2{=}CH_2$ with D_2, Pt catalyst at room temperature

29 An ester, **D**, with an odour of bananas has the following formula.

$$CH_3CO_2CH_2CH(CH_3)CH_2CH_3$$

What are the products formed when **D** is heated with aqueous hydrochloric acid?

A CH_3COOH and $CH_3CH_2CH(CH_3)CH_2Cl$

B CH_3CH_2OH and $CH_3CH_2CH(CH_3)COOH$

C CH_3COOH and $CH_3CH_2CH(CH_3)CH_2OH$

D CH_3CH_2Cl and $CH_3CH_2CH(CH_3)COOH$

30 Which statement does **not** correctly describe the polymer poly(vinyl chloride), PVC?

A Combustion of PVC waste produces a highly acidic gas.

B PVC molecules are saturated.

C The empirical formula of PVC is the same as the empirical formula of its monomer.

D The repeat unit of PVC is –(CHCl*l*CHCl*l*)–.

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Index No.	Name	Form Class	Tutorial Class	Subject Tutor

ANGLO-CHINESE JUNIOR COLLEGE
DEPARTMENT OF CHEMISTRY
Preliminary Examination

CHEMISTRY
Higher 1

8873/02

Paper 2 Structured Questions

26 August 2020
2 hours

Candidates answer on the Question Paper

Additional Materials: Data Booklet

READ THESE INSTRUCTIONS FIRST

Write your name, index number, form class, tutorial class and subject tutor's name on all the work you hand in.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, glue or correction fluid.

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

Section A
Answer **all** the questions.

Section B
Answer **one** question.

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

For Examiner's Use	
Question no.	**Marks**
Section A	
B6	
B7	
TOTAL	

This document consists of **22** printed pages.

Section A

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

1 (a) Ionic compounds consist of cations whose total positive charge is balanced by the negative charge of anions. A new class of compounds called *electrides* has been synthesised, with 'trapped' and localised electrons taking on the role of anions.

Electrides have the general formula $\mathbf{M^+(L)}_n e^-$, where:
$\mathbf{M^+}$ is an alkali metal cation,
L is a compound that binds $\mathbf{M^+}$ in a 'cage', and
e^- represents the trapped electrons.

The step where the alkali metal, **M**, forms $\mathbf{M^+}$ determines whether the formation of the electride would be feasible.

The electride $Cs^+(C222)e^-(s)$ is formed from the alkali metal caesium, Cs, and the solid organic compound, C222.

(i) Define the first ionisation energy of caesium, Cs.

.....

.....

.....[1]

(ii) State and explain which alkali metal, sodium or caesium, forms electrides more readily.

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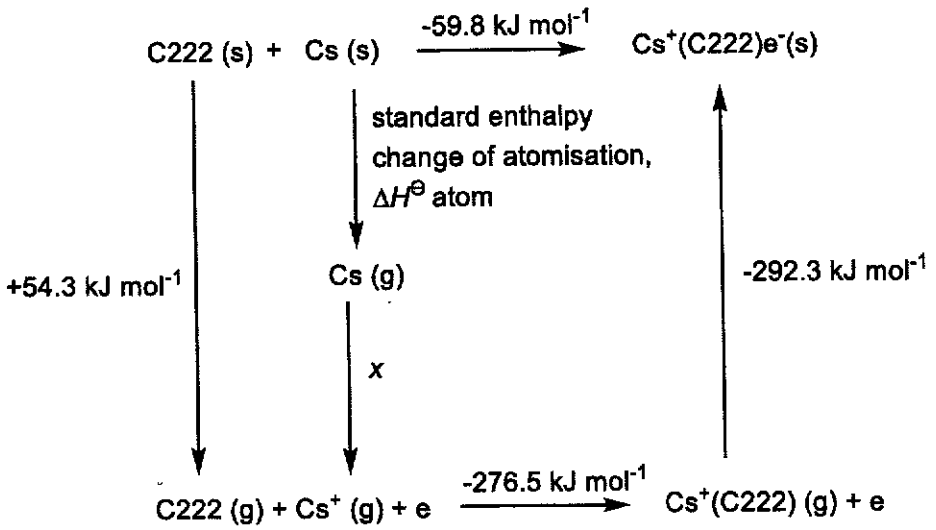
.....[2]

(iii) The energy cycle shows the electride, $Cs^+(C222)e^-$, being formed from Cs and C222.



Use of Data Booklet is relevant to this question.

State the enthapy change value that is given by *x* and hence, calculate the standard enthalpy change of atomisation of caesium, $\Delta H^{\ominus}_{atom}$.

[2]

(iv) Explain why electrides are electrical insulators in the solid state.

.....

.....

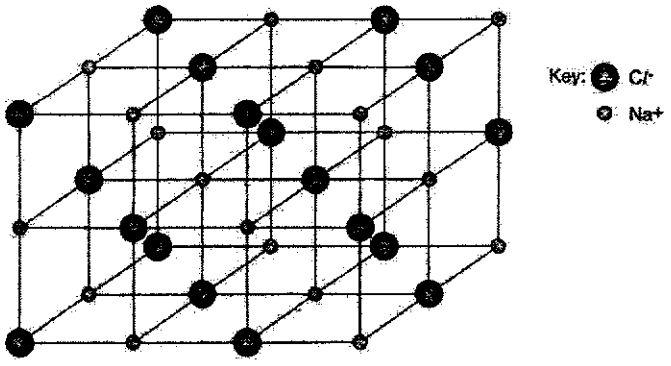
.....[1]

(v) Dimethyl ether, CH_3OCH_3, and trimethylamine, $(CH_3)_3N$, are two solvents that are often used to prepare electrides.

Draw the structures of the molecules and state the shapes about **all** the central atoms.

[4]

(b) The structures of electrides are similar to those of ionic compounds. The sodium chloride lattice is cubic with four sodium ions at four corners and four chloride ions at the other four corners. The *co-ordination number* of each ion is 6. In the crystal lattice of caesium chloride, CsC*l*, the *co-ordination number* has a different value.



Crystal lattice of sodium chloride

(i) Suggest what is meant by the term *co-ordination number*.

.....

.....[1]

(ii) Suggest an explanation for the co-ordination number in CsC*l* lattice being different from that in NaC*l*.

.....

.....

.....[2]

(iii) Unlike Na which forms the electride $[Na^+(NH_3)_6]e^-$, lithium forms the electride $[Li^+(NH_3)_4]e^-$.

By considering the electronic configurations of Na^+ and Li^+ and their relative positions in the Periodic Table, suggest a reason for the difference in the value of n.

.....

.....

.....[1]

[Total: 14]

2 Polylactic acid (PLA) is a thermoplastic polymer produced from renewable resources such as corn starch or sugar cane and has a range of applications such as plastic films and medical devices.

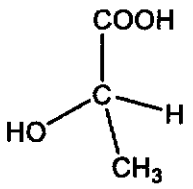
(a) The raw material for the polymer, lactic acid (2-hydroxypropanoic acid), is formed by the fermentation of corn starch using enzymes from bacteria.

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

.....

.....[1]

(ii) The structure of lactic acid is shown below.



State the type of reaction when lactic acid is polymerised to form PLA.

.....[1]

(iii) Draw a repeat unit of PLA.

[1]

(b) One of the reasons that PLA has attracted so much attention is that it is biodegradeable. The simple polymer has a melting point of around 175 °C, but softens between 60-80 °C. Its thermoplastic properties make it suited for use in fibres and food packaging.

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

.....

.....[1]

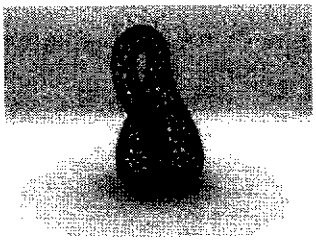
(ii) PLA containers are not used to contain hot drinks. Suggest a reason for this.

.....

.....[1]

(iii) Three-dimensional (3D) printing or additive manufacturing is the process of making 3D solid objects from a digital file. The 3D objects are usually fused layer by layer together in the liquid state, then solidified.

An example of a 3D printed object:



Suggest why PLA would be suitable as a polymer for 3D printing.

.....

.....[1]

(iv) Compare three different properties between thermoplastics and thermosets.

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.....[3]

(v) Suggest two reasons why the continued production of non-biodegradable polymers is a cause for environmental concern.

.....

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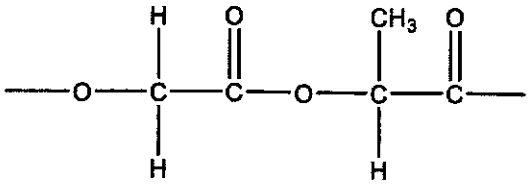
.....[2]

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

A repeat unit of the co-polymer is shown below:



(i) Draw the displayed formula of glycolic acid.

[1]

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

.....

.....

.....[1]

[Total: 13]

3 (a) Catalysts can be described as homogeneous or heterogeneous.

(i) What is meant by the term *heterogeneous catalyst*?

.....

.....[1]

(ii) Give an example of a heterogeneous catalyst and write an equation for the reaction that it catalyses.

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.....[2]

(iii) Outline the mode of action of how the catalyst that you have chosen in **(a)(ii)** works to decrease the activation energy of the reaction.

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.....[2]

(b) An ammonium iron alum has the formula $(NH_4)_aFe(SO_4)_b.xH_2O$.

A 1.00 g sample of the salt was dissolved in 100 cm^3 of water and the solution was divided into two equal portions.

To one portion, an excess of NaOH(aq) was added and the mixture was boiled. The ammonia that was evolved exactly neutralised 10.40 cm^3 of 0.100 mol dm^{-3} HC*l*(aq).

$$NH_4^+ + OH^- \rightarrow NH_3 + H_2O$$

To the other portion, an excess of zinc was added which reduced the Fe^{3+}(aq) to Fe^{2+}(aq). The mixture was filtered and the filtrate required 20.8 cm^3 of 0.0100 mol dm^{-3} $KMnO_4$(aq) to oxidise the Fe^{2+}(aq) back to Fe^{3+}(aq).

$$Zn + 2Fe^{3+} \rightarrow Zn^{2+} + 2Fe^{2+}$$

(i) Construct an ionic equation to show the reaction of Fe^{2+} and MnO_4^-(aq) in acidic solution.

.....

.....

.....[1]

(ii) Calculate the value of ***a***.

[3]

(iii) Find the value of ***b***.

[1]

(iv) Calculate the M_r of the ammonium iron alum and the value of x.

[2]

(c) A student went to a chemical store and realised that **five** chemical bottles have missing labels. The labels are "Aluminium Oxide", "Magnesium Oxide", "Silicon Dioxide", "Phosphorous(V) Oxide" and "Phosphorous Pentachloride". He decided to perform some tests to deduce the identities of the chemicals in the unlabelled bottles, so that they can be re-labelled correctly.

The student named the five bottles **A** to **E**. The following tests were conducted and the observations were recorded:

- Samples from bottles **A, B** and **C** were insoluble in water. However, sample **A** dissolved readily in hydrochloric acid, while sample **B** dissolved in aqueous sodium hydroxide. Compound **C** dissolved in both hydrochloric acid and aqueous sodium hydroxide.
- The sample from bottle **D** was soluble in aqueous sodium hydroxide.
- Samples from bottles **D** and **E** melted at relatively low temperatures compared to **A, B** and **C**. Both of them reacted vigorously with water to form acidic solutions. Furthermore, sample **E** gave off thick white fumes when it reacted with water.

Suggest identities of **A** to **E**, writing balanced equations to support your answers where necessary.

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.....[6]

[Total: 18]

4 In organic chemistry, hydrocarbons are organic compounds consisting entirely of hydrogen and carbon. Examples of these include propene and butane.

(a) Propene, $CH_2=CHCH_3$, is a gaseous alkene.

Describe, in terms of orbital overlap, the bonding between the two carbon atoms of the C=C bond in propene. A labelled diagram may be drawn to clarify your answer.

.....

.....

.....

.....[2]

(b) Under suitable conditions, butane forms two monobrominated products, compounds **A** and **B**. Compounds **A** and **B** react with hot aqueous NaOH to produce compounds **C** and **D** respectively.

Heating compound **D** with acidified aqueous potassium dichromate(VI) produces compound **F**. A solution of **F** turns blue litmus paper red.

Reduction of compound **E** using $NaBH_4$ produces compound **C**.

Identify the structures of compounds **A**, **B**, **C**, **D**, **E** and **F** and explain the reactions described.

[8]

[Total: 10]

5 *Use of the Data Booklet will be relevant to this question.*

Iron ore from different mines contain different percentages by mass of iron. The percentage of iron in a sample of ore can be estimated by converting all of the iron present into $Fe^{2+}(aq)$ ions and then using a redox titration.

A sample of iron ore weighing 11.05 g was converted to $Fe^{2+}(aq)$ ions using the method described above. The resultant solution was then made up to a volume of 250 cm^3 in a volumetric flask.

25.0 cm^3 portions of this solution were then titated with 0.100 mol dm^{-3} of aqueous potassium dichromate(VI), $K_2Cr_2O_7(aq)$ using a suitable indicator. The results are shown below.

titration number	1	2	3
initial burette reading / cm^3	0.00	19.95	2.10
final burette reading / cm^3	21.10	39.95	22.10
titre / cm^3	21.10		

(a) Complete the table above and use the results to determine the number of moles of potassium dichromate(VI) required to react with the Fe^{2+} ions in 25.0 cm^3 of the solution.

[2]

(b) Given the following reaction of $Fe^{2+}(aq)$ with acidified $Cr_2O_7^{2-}(aq)$, calculate the percentage by mass of iron in the iron ore.

$$6Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) + 14H^+(aq) \longrightarrow 6Fe^{3+}(aq) + 2Cr^{3+}(aq) + 7H_2O(l)$$

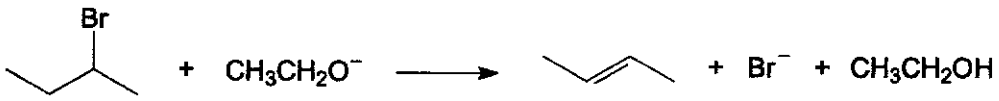
[3]

[Total: 5]

Section B

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

6 (a) 2–bromobutane reacts with $CH_3CH_2O^-Na^+$ in the solvent ethanol according to the following equation.



(i) Name the type of reaction that occurred.

.....[1]

(ii) The product, but-2-ene, exists as a pair of cis-trans isomers.

- State the two criteria that give rise to cis-trans isomerism.
- Draw and label the isomers.

Isomers:

.....

.....

.....

.....[3]

(iii) Other than but-2-ene, another alkene can also be formed from the above reaction.

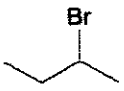
Draw the skeletal formula of this alkene.

[1]

(iv) Another organic compound, which does not contain a halogen, can also be converted to but-2-ene. State the functional group it contains and draw its displayed formula.

functional group: .....

[2]

(v) Compare the boiling points of 

and  in terms of their structures and bonding.

.....

.....

.....

.....[3]

(vi) But-2-ene undergoes complete combustion according to the following equation.

$$CH_3CH{=}CHCH_3 + 6O_2 \rightarrow 4CO_2 + 4H_2O$$

With reference to relevant information in the *Data Booklet*, calculate the enthalpy change of the above reaction.

[2]

(b) The kinetics of the reaction between 2–bromobutane and $CH_3CH_2O^-Na^+$ was studied and results are shown in Table 6.1.

Table 6.1

experiment	[2–bromobutane] / mol dm^{-3}	[$CH_3CH_2O^-Na^+$] / mol dm^{-3}	relative initial rate
1	0.060	0.060	1.00
2	0.050	0.060	0.833
3	0.040	0.050	0.667

(i) Use the data given above to deduce the rate equation.

[3]

(ii) Explain how the rate of reaction will be affected when 2–chlorobutane is used instead of 2–bromobutane.

.....

.....

.....[2]

(iii) With the aid of a Boltzmann Distribution curve, explain how increasing temperature affects the rate of the reaction.

.....

.....

.....

.....[3]

[Total: 20]

7 (a) NO_2 can exist in equilibrium with dinitrogen tetroxide, N_2O_4:

$$\underset{\text{colourless}}{N_2O_4(g)} \rightleftharpoons \underset{\text{brown}}{2NO_2(g)}$$

An experiment was conducted at 25 °C by varying initial concentrations of N_2O_4 and NO_2 contained in a closed reaction vessel. The initial and equilibrium concentrations of the two gases are shown in Table 7.1.

Table 7.1

expt number	initial concentration / mol dm^{-3}		equilibrium concentration / mol dm^{-3}	
	$[N_2O_4]$	$[NO_2]$	$[N_2O_4]$	$[NO_2]$
1	0.000	0.200	0.0898	0.0204
2	0.600	0.040	0.594	0.0523
3	0.500	0.030	0.491	0.0475
4	0.446	0.050	0.448	0.0457
5	0.670	0.000	0.643	0.0547

(i) State *Le Chatelier's Principle*.

.....

.....

.....[1]

(ii) State and explain what will be observed when the pressure in the reaction vessel is decreased.

.....

.....

.....

.....[2]

(iii) Identify the experiment that gives the initial concentrations of N_2O_4 : NO_2 in the ratio 15 : 1.

.....[1]

(iv) Use the experiment identified in (a)(iii) to calculate the equilibrium constant, K_c, of the reaction, stating its units.

[2]

(b) Nitric acid, HNO_3, is formed by the reaction of NO_2 with water. This is an example of an inorganic *strong acid*. Ethanoic acid, CH_3COOH, an example of an organic acid, is considered a *weak acid*.

(i) Explain and write equations to illustrate what is meant by the terms in italics.

.....

.....

.....

.....

.....[3]

(ii) Given that the K_a value of ethanoic acid is 1.75×10^{-5}, calculate the pH of a 0.2 mol dm^{-3} of ethanoic acid solution.

[2]

(iii) Ethanoic acid is titrated with aqueous sodium hydroxide. Suggest a suitable indicator and explain your choice.

.....

.....

.....[2]

(iv) A solution **Z** was prepared by mixing excess ethanoic acid solution with sodium hydroxide.

When a small amount of strong acid is added to solution **Z**, its pH remained relatively constant. With the aid of an equation, explain why this is so.

.....

.....

.....[2]

(c) In an experiment, 20 cm^3 of 1.00 mol dm^{-3} sodium hydroxide is added to 30 cm^3 of 1.00 mol dm^{-3} aqueous nitric acid. The temperature of the mixture rises by 5.4 °C.

(i) Deduce, with appropriate working, which reagent is limiting.

[1]

(ii) Calculate the enthalpy change of the reaction.

[2]

(iii) A student repeated the experiment using 20 cm^3 of 1.00 mol dm^{-3} sodium hydroxide and 30 cm^3 of 1.00 mol dm^{-3} aqueous ethanoic acid. All other conditions were kept constant.

Suggest whether the temperature increase will be more or less than 5.4 °C and give an explanation for your answer.

.....

.....

.....[2]

[Total: 20]

ANGLO-CHINESE JUNIOR COLLEGE
DEPARTMENT OF CHEMISTRY
Preliminary Examination

CHEMISTRY **8873/01**
Higher 1

Paper 1 Multiple Choice

16 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, index number and tutorial class 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 booklet.
The use of an approved scientific calculator is expected, where appropriate.

This document consists of [redacted] pages.

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

1 Shakudo is a Japanese alloy of copper and gold. The data in the table below was obtained by mass spectrometry of a sample of Shakudo.

mass number	63	65	197
% abundance	65	29	6

Which A_r value for copper is given by these figures?

A 59.8 **B** 63.5 **C** 63.6 **D** 71.6

Answer: C
Copper – Mass number 63 and 65
Gold – Mass number 197
A_r = (63 x 65) + (65 x 29) / 94 = 63.6

2 In acid solution, dichromate(VI) ions oxidise hydrogen peroxide, H_2O_2. In alkaline solution, hydrogen peroxide oxidises chromium(III) ions.

Which conditions of oxidation produce oxygen gas?

A both acid and alkaline oxidations
B only the acid oxidation
C neither acid nor alkaline oxidation
D only the alkaline oxidation

Answer: B
In order to produce oxygen gas, H_2O_2 must undergo oxidation and this occurs only in acid solution.

[R] $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$
[O] $H_2O_2 \rightarrow O_2 + 2H^+ + 2e^-$
$Cr_2O_7^{2-}$ undergo reduction and H_2O_2 undergo oxidation (oxidation number of oxygen atom increases from -1 to 0).
In alkaline solution, H_2O_2 will be reduced to water as it oxidises Cr^{3+} ions.
This is because if Cr^{3+} is oxidised, H_2O_2 has to be reduced to form H_2O (oxidation number of oxygen atom decreases from -1 to -2).

3 The mineral tellurite, TeO_2 (M_r = 159.6), is often used in the manufacture of optic fibres. It was found that 1.01 g of TeO_2 required exactly 60 cm^3 of 0.035 mol dm^{-3} acidified $K_2Cr_2O_7$ for complete reaction. In this reaction, $Cr_2O_7^{2-}$ is converted into Cr^{3+}.

What is the oxidation state of Te in the final product?

A +2 **B** +3 **C** +5 **D** +6

Answer: D
[R]: $Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$

Hence n(e^-) gained by $Cr_2O_7^{2-}$ = 6 x n($Cr_2O_7^{2-}$) = 6 x (60/1000)(0.035) = 0.0126 mol

n(TeO_2) = 1.01/159.6 = 0.006328 mol

Since n(e^-) gained by $Cr_2O_7^{2-}$ = n(e^-) lost by 0.006328 mol of TeO_2 = 0.0126 mol

Hence 0.0126 mol of e^- is lost by 0.006328 mol of TeO_2
Hence 2 mol of e^- is lost by 1 mol of TeO_2

Let Te^x represent the Te containing product

Hence: 1 $TeO_2 \rightarrow 2e^- + Te^x$

Equating oxidation number of Te on both sides of equation

Hence 1(+4) = 2(-1) + 1(x)
Hence x = +6

Hence answer is +6 → D

(Note the Te containing product can be TeO_4^{2-}, TeO_3, TeO_2^{2+} with oxidation number = +6)

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

Calcium can react with nitrogen gas, under suitable conditions, to form the ionic compound calcium nitride, which contains the N^{3-} ion.

What is the percentage by mass of nitrogen in in calcium nitride?

A 18.9% **B** 25.9% **C** 34.4% **D** 41.1%

Answer: A

Formula of Calcium Nitride is Ca_3N_2
Percentage by Mass of N= (14x2)/(40.1x3+14x2)
=18.9%

5 Some isotopes are unstable and undergo nuclear (radioactive) reactions. In one type of reaction, an unstable nucleus assimilates an electron from an inner orbital of its electron cloud. The net effect is the conversion of a proton and an electron into a neutron.

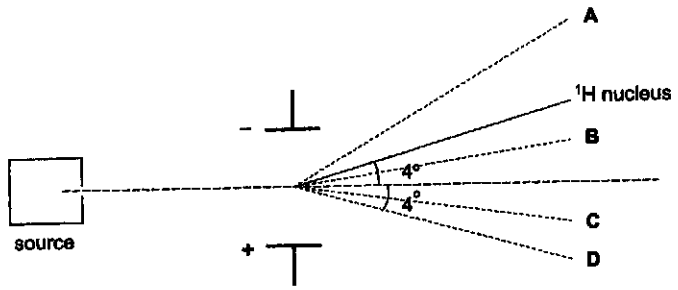
$$^{1}_{1}p + ^{0}_{-1}e \rightarrow ^{1}_{0}n$$

Which of the following describes this type of reaction?

	A	$^{11}C \rightarrow ^{12}C$
	B	$^{111}I \rightarrow ^{111}Te$
	C	$^{76}Br \rightarrow ^{75}Br$
	D	$^{76}Kr \rightarrow ^{75}Br$

Answer: B
The conversion results in the loss of a proton. So proton no decrease by 1.
Since the proton is converted into a neutron, mass no (nucleon no do not change)
$^{111}_{53}I \rightarrow ^{111}_{52}Te$

6 When passed through an electric field, the ^{1}H nucleus is deflected as shown below.



Which of the above beams represents the deflection for the ion $^{2}X^{2-}$?

Answer: D

angle of deflection $\alpha \frac{charge}{mass}$

for $^{1}H^{+}$, $\frac{z}{m} = +\frac{1}{1}$

for $^{2}X^{2-}$, $\frac{z}{m} = -\frac{2}{2}$

Hence, angle of deflection for $^{2}X^{2-} = \underline{-4^{o}}$

7 The electronegativity values of carbon, selenium and chlorine are all different. Chlorine is more electronegative than both carbon and selenium.

Which molecules are polar?

	1	CSe_2
	2	$SeCl_2$
	3	CCl_4

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

Answer: D

Explanation:
CSe_2 is linear (2 bond pairs) and non-polar
$SeCl_2$ is bent (2 lone pairs & 2 bond pairs) and polar
CCl_4 is tetrahedral (4 bond pairs) and non-polar

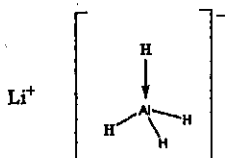
8 The compound lithium aluminium hydride, $LiAlH_4$, was discovered by Finholt, Bond and Schlesinger in 1947.

Which types of bonding are found in the compound?

	1	ionic
	2	covalent
	3	hydrogen bonding

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

Answer: C
$LiAlH_4$ has both ionic and covalent bonding and not hydrogen bonding.



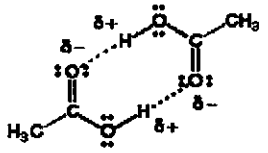
9 Ethanoic acid forms a double molecule, or dimer, with the molecular formula $C_4H_8O_4$.

This dimer contains two hydrogen bonds within a ring of eight atoms.

How many C, H and O atoms are present in this ring?

	C	H	O
A	2	2	4
B	2	4	2
C	4	0	4
D	4	2	2

Answer: A



Ethanoic acid form dimers via hydrogen bonds.

10 Some Period 3 and 4 elements are shown below.

Period 3 elements	Al	Si	P	S
Period 4 elements	Ga	Ge	As	Se

The properties of each Period 4 element resemble those of the Period 3 element directly above it.

Which Period 4 elements form oxides that dissolve in water to give acidic solutions?

A	As and Se
B	Ga and Ge
C	Ga and Se
D	Se only

Answer: A

Based on knowledge of P and S, we know that these elements form acidic solutions in water.

$P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$

$SO_3(l) + H_2O(l) \rightarrow H_2SO_4(aq)$

Hence, we can deduce that As and Se also follow a similar pattern, forming acidic solutions in water

11 Which of the following statements is **incorrect** about Group 1 and Group 17 elements?

A	Group 1 element has smaller atomic radius as compared to Group 17 element in the same Period.
B	Group 1 elements are good reducing agents while Group 17 elements are good oxidising agents.
C	Reducing power of Group 1 elements increases down the group while oxidising power of Group 17 elements decreases down the group.
D	The ionisation energies of Group 1 and Group 17 elements decrease down the groups.

Answer: A

Across the period, atomic radius decreases thus Group 1 element should have larger atomic radius than Group 17 element in the same Period.

12 Which statement explains why HC*l* has a higher thermal stability than HBr and HI?

A	HC*l* has the strongest intermolecular forces of attraction.
B	The HC*l* bond has the highest bond energy.
C	The ionic bond formed between H^+ and Cl^- is the strongest.
D	The HC*l* bond has the longest length.

Answer: B

The greater the bond energy, the harder for the bond to be broken and thus require higher temperature to be broken. Therefore, HCl has a higher thermal stability.

13 Which reaction has an enthalpy change that is equal to the lattice energy of sodium fluoride?

A	$Na(g) + F(g) \rightarrow NaF(s)$
B	$Na(s) + \frac{1}{2} F_2(g) \rightarrow NaF(s)$
C	$Na^+(g) + F^-(g) \rightarrow NaF(g)$
D	$Na^+(g) + F^-(g) \rightarrow NaF(s)$

Answer: D

Lattice energy is the **energy evolved** when **one mole of an ionic solid is formed** from its constituent **gaseous ions** (at infinite distance apart).

14 What does ΔH_f of the following equation represent?

$$H_2(g) + \frac{1}{2}O_2(g) \longrightarrow H_2O(g) \qquad \Delta H_f$$

A	sum of standard enthalpy change of formation of $H_2(g)$ and the enthalpy change of vaporisation of $H_2O(l)$
B	sum of standard enthalpy change of formation of $H_2O(l)$ and the enthalpy change of vaporisation of $H_2O(l)$
C	standard enthalpy change of combustion of $H_2(g)$
D	standard enthalpy change of formation of $H_2O(l)$

Answer: B
standard enthalpy change of formation of $H_2O(l)$ is when 1 mole of H_2O (l) is formed from $H_2(g)$ and $O_2(g)$

$$H_2(g) + \frac{1}{2}O_2(g) \longrightarrow H_2O(l)$$

Enthalpy change of vaporisation of $H_2O(l)$ is when $H_2O(l) \rightarrow H_2O(g)$
Hence it is the sum of both enthalpy changes of formation $H_2O(l)$ and the vaporisation of $H_2O(l)$

15 In oil refineries, an important process is the recovery of any sulfur from petroleum, as shown by **reaction 1**.

$$2H_2S(g) + O_2(g) \rightarrow 2H_2O(g) + 2S(s) \qquad \textbf{reaction 1}$$

The enthalpy changes of formation of $H_2S(g)$ and $H_2O(g)$ are -20.5 kJ mol^{-1} and -243.0 kJ mol^{-1} respectively.

What is the enthalpy change of **reaction 1** in kJ mol^{-1}?

A	−445	**B**	+445	**C**	−222	**D**	+222

Answer: A
Enthalpy change of reaction, $\Delta H_r = \sum m\Delta H_f^{\ominus}$ (Products) $- \sum n\Delta H_f^{\ominus}$ (Reactants)
$\Delta H_r = 2(-243) - (2)(-20.5) = -486 + 41 = -445$ kJ mol^{-1}

16 Compound **P** reacts to give compounds **Q** and **R** as shown below.

$$P(g) \longrightarrow Q(g) + R(g)$$

The reaction is first order with respect to **P** and the rate constant, k, is 6.93 min^{-1}.

What is the time taken for the concentration of **P** to decrease from 1.80 mol dm^{-3} to 0.225 mol dm^{-3}?

A	0.1 min
B	0.3 min
C	0.4 min
D	0.8 min

Answer: B

$$t_{1/2} = \frac{\ln 2}{k} = \frac{\ln 2}{6.93} = 0.100 \text{ min}$$

To decrease the concentration from 1.80 mol dm^{-3} to 0.225 mol dm^{-3} requires 3 half-lives
(1.8 → 0.9 → 0.45 → 0.225)
Total time taken = 3 x 0.1 = 0.3 min

17 For a reversible reaction, what is the effect of a catalyst on the
- rate constant for the forward reaction, k_1,
- rate constant for the reverse reaction, k_{-1}, and
- the equilibrium constant, K?

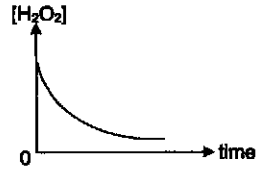
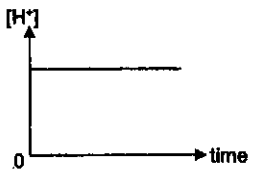
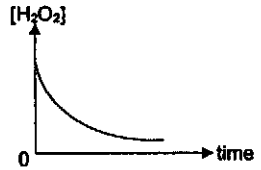
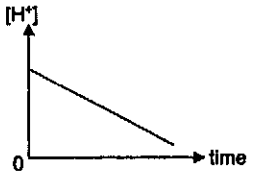
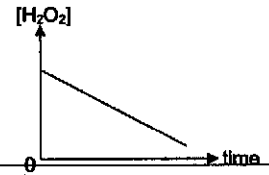
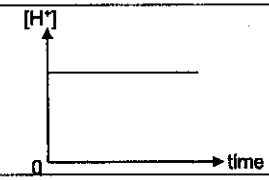
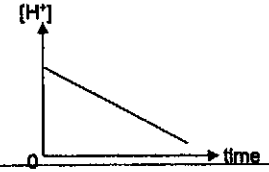
	k_1	k_{-1}	K
A	increases	decreases	no effect
B	increases	increases	increases
C	increases	increases	no effect
D	no effect	no effect	increases

Answer: C
Eqm constant K is only affected by temp.
When catalyst is added, both rate constant for forward (k_1) and backward (k_{-1}) will increase.

18 The reaction of H_2O_2 with I^- in an acidic solution is first order with respect to H_2O_2, first order with respect to I^-, and zero order with respect to H^+.

$$H_2O_2(aq) + 2H^+(aq) + 2I^-(aq) \rightarrow 2H_2O(l) + I_2(aq)$$

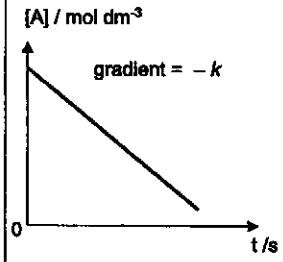
Two experiments were carried out separately. Which pair of diagrams correctly represents the variation of $[H_2O_2]$ and $[H^+]$ with time?

	experiment 1: in the presence of a large excess of I^- and H^+	experiment 2: in the presence of a large excess of I^- and H_2O_2
A		
B		
C		
D		

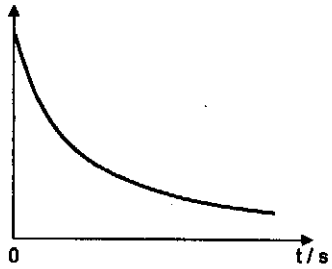
Answer: B

It is first order with respect to hydrogen peroxide and zero order with respect to hydrogen ions.

For zero order with respect to reactant, A,



For first order with respect to reactant A,



19 Compound P decomposes on heating according to the following equation.

$$2P(g) \rightleftharpoons Q(g) + 2R(g)$$

3 mol of P was introduced into a 1 dm^3 container and heated. The equilibrium mixture contained 1.2 mol of R.

What is the value of the equilibrium constant, K_c?

	A	$\frac{(0.6)^2 \times 0.3}{5^2}$	**B**	$\frac{(0.6)^2 \times 1.2}{5^2}$
	C	$\frac{0.6 \times (0.3)^2}{1.8^2}$	**D**	$\frac{0.6 \times (1.2)^2}{1.8^2}$

Answer: D

	2P(g)	⇌	Q(g) +	2R(g)
I / moldm^{-3}	3		0	0
C / moldm^{-3}	-1.2		+0.6	+1.2
E / moldm^{-3}	1.8		0.6	1.2

$$K_c = \frac{[Q][R]^2}{[P]^2} = \frac{0.6 \times 1.2^2}{1.8^2}$$

20 Which statement is always correct about a system in dynamic equilibrium?

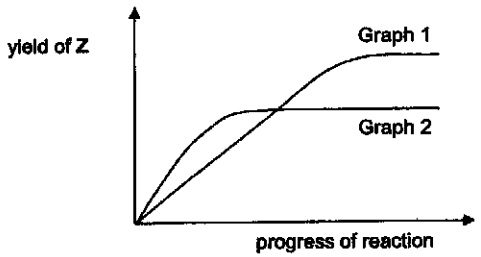
	A	The addition of a catalyst can affect the position of the equilibrium.
	B	The rate of forward reaction is the same as the rate of backward reaction.
	C	The concentration of products is constantly changing.
	D	The concentration of products is equal to the concentration of reactants.

Answer: B

Dynamic equilibrium refers to a reversible process at equilibrium in which the rate of the forward reaction equals to the rate of backward reaction.

21 The graph for the reversible reaction involving X, Y and Z is shown below.

$$2X(g) + 2Y(s) \rightleftharpoons 3Z(g) \quad \Delta H > 0$$



Which of the following changes could account for the change from Graph 1 to Graph 2?

	A	addition of catalyst
	B	addition of more X
	C	increase in pressure
	D	increase in temperature

Answer: C

From graph 1 to graph 2, two changes occurred:
1. Rate of reaction increased as the gradient is getting larger.
2. Equilibrium position has shifted to the left as less product, Z is formed.

Option **A**: catalyst would increase the rate of reaction but has no effect on equilibrium position

Option **B**: Addition of **X** would increase the rate of reaction but it will cause the equilibrium position to shift to the right due to greater concentration of **X** upon addition of **X**.

Option **C**: Increase the pressure will lead to a higher rate of reaction. It also favours the reactant as it has less number of moles of gaseous particles (2 moles) as compared to the number of moles of gaseous particles in the product (3 moles). Hence, the equilibrium position will shift to the left.

Option **D**: Increase the temperature will lead to a higher rate of reaction. A higher temperature also favours endothermic reaction to remove excess heat. Since the forward reaction is endothermic, the equilibrium position will shift to the right.

22 Which of the following acids have pH = 1.0?

1	0.10 mol dm^{-3} nitric acid
2	0.10 mol dm^{-3} sulfuric acid
3	0.10 mol dm^{-3} ethanoic acid

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

Answer: A

$HNO_3 \rightarrow H^+ + NO_3^-$
$H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$

$[HNO_3] = [H^+] = 0.1$ mol dm^{-3}
$pH = -lg\,[H^+] = 1$

$[H^+]$ in 0.1 mol dm^{-3} $H_2SO_4 = 2 \times [H_2SO_4] = 0.2$ mol dm^{-3}

Ethanoic acid is a weak acid and thus $[H^+] << [CH_3COOH]$

23 The dissociation constants, K_w, for the ionisation of water, $2H_2O \rightleftharpoons H_3O^+ + OH^-$, at different temperatures are given below.

temperature / °C	K_w / $mol^2\ dm^{-6}$
0	1.15×10^{-15}
25	1.00×10^{-14}
50	5.50×10^{-14}

Which of the following can be deduced from this information?

A	The pH of water at 50 °C is 6.6.
B	The forward reaction is exothermic.
C	The equilibrium lies more to the left as temperature increases.
D	The $[H_3O^+]$ increases while the $[OH^-]$ decreases as temperature increases.

Answer: A
A: $[H^+] = \sqrt{5.50 \times 10^{-14}} = 2.345 \times 10^{-7}$ mol dm^{-3}
$pH = -lg(2.345 \times 10^{-7}) = 6.63$
B & C: $K_w = [H_3O^+][OH^-]$ K_w increases as temperature increases. Hence, as temperature increases, the forward reaction is favoured as $[H_3O^+]$ and $[OH^-]$ increases. Equilibrium shifts to the right. Increase in temperature will favour the

endothermic reaction. Since the equilibrium shifts to the right when temperature increases, the forward reaction is endothermic.
D: Both $[H_3O^+]$ and $[OH^-]$ increases to the same extent as temperature increases.

24 Carbonic acid, H_2CO_3, and hydrogen carbonate ion, HCO_3^-, are the agents of the buffer systems in blood. Which of the following will take place when the level of acidity in blood increases?

1	$HCO_3^- \rightarrow H^+ + CO_3^{2-}$
2	$HCO_3^- + H^+ \rightarrow H_2CO_3$
3	$H_2CO_3 \rightarrow CO_2 + H_2O$

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

Answer: C

When level of acidity in blood increases, the HCO_3^- present removes the additional H^+ to form H_2CO_3 and the pH remains almost constant.

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

Excess carbonic acid will dissociate to form carbon dioxide and water. CO_2 is expelled out of the body as you breathe out.

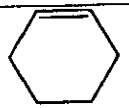
$$H_2CO_3(aq) \rightarrow CO_2(g) + H_2O(l)$$

25 Which type of formula is the same for butanoic acid and ethyl ethanoate?

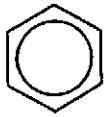
A	displayed	**C**	skeletal
B	structural	**D**	empirical

Answer: D
The structural formula for butanoic acid, $CH_3CH_2CH_2COOH$ and ethyl ethanoate is $CH_3COOCH_2CH_3$. Both have the same empirical formula C_2H_4O.

26 Which of the following molecules are planar?

1 

2 $H_2C{=}{=}CH_2$

3 

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

Answer: A

Benzene and ethene are planar with sp^2 hybridised carbon atom but cyclohexene is non planar as it contains sp^3 hybridised carbon atoms.

27 During the production of ethyl ethanoate, a trace amount of concentrated sulfuric acid is used. Why is concentrated sulfuric acid used?

1 to prevent overheating of the reaction mixture

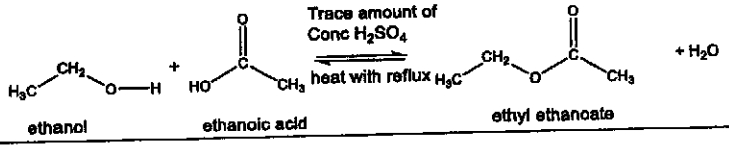
2 to catalyse the reaction

3 to remove water

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

Answer: C

Role of concentrated sulfuric acid: **acid catalyst and dehydrating agent**. It **removes the water** formed by shifting the equilibrium to the right.



ethanol ethanoic acid ethyl ethanoate

28 Which reaction will **not** yield an organic product incorporating deuterium, D? [D = ^2_1H]

A	CH_3COOH heated with CD_3ND_2 in the presence of dicyclohexylcarbodiimide, DCC.
B	CH_3CHO with $LiAlD_4$ in dry ether at room temperature
C	CH_3CH_2Br heated with ethanolic NaOD
D	$CH_2{=}CH_2$ with D_2, Pt catalyst at room temperature

Answer: C

A: Condensation occurs and $CH_3CONDCD_3$ will be formed
B: Reduction occurs and $CH_3CHD(OD)$ is formed
C: Elimination of HBr occurs and $CH_2{=}CH_2$ is formed, no deuterium incorporated
D: Reduction occurs and CH_2DCH_2D is formed

29 An ester, **D**, with an odour of bananas has the following formula.

$CH_3CO_2CH_2CH(CH_3)CH_2CH_3$

What are the products formed when **D** is heated with aqueous hydrochloric acid?

A	CH_3COOH and $CH_3CH_2CH(CH_3)CH_2Cl$
B	CH_3CH_2OH and $CH_3CH_2CH(CH_3)COOH$
C	CH_3COOH and $CH_3CH_2CH(CH_3)CH_2OH$
D	CH_3CH_2Cl and $CH_3CH_2CH(CH_3)COOH$

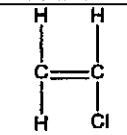
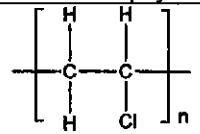
Answer: C

$$CH_3CO_2CH_2CH(CH_3)CH_2CH_3 \xrightarrow[\text{heat}]{\text{dilute } H_2SO_4} CH_3COOH + HOCH_2CH(CH_3)CH_2CH_3$$

30	Which statement does **not** correctly describe the polymer poly(vinyl chloride), PVC?	
	A	Combustion of PVC waste produces a highly acidic gas.
	B	PVC molecules are saturated.
	C	The empirical formula of PVC is the same as the empirical formula of its monomer.
	D	The repeat unit of PVC is –(CHCl/CHCl)–.

Answer: D

Combustion of PVC waste produces a highly acidic gas, HCl so Statement A is true.
Statement B is true as the PVC molecule is saturated (no C=C).
Statement C is true as the empirical formula of PVC and its monomer is C_2H_3Cl.
Statement D is false as the repeat unit of PVC is $-(CH_2CHCl)-$.

Monomer	Formula of polymer
 vinyl chloride	 polyvinyl chloride (PVC)

ACJC H1 Chem Prelim 2020 Paper 2 Answers

Section A (60 marks)

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

1 (a) Ionic compounds consist of cations whose total positive charge is balanced by the negative charge of anions. A new class of compounds called *electrides* has been synthesised, with 'trapped' and localised electrons taking on the role of anions.

Electrides have the general formula $M^+(L)_ne^-$, where:
M^+ is an alkali metal cation,
L is a compound that binds M^+ in a 'cage', and
e^- represents the trapped electrons.

The step where the alkali metal, **M**, forms M^+ determines whether the formation of the electride would be feasible.

The electride $Cs^+(C222)e^-(s)$ is formed from the alkali metal caesium, Cs, and the solid organic compound, C222.

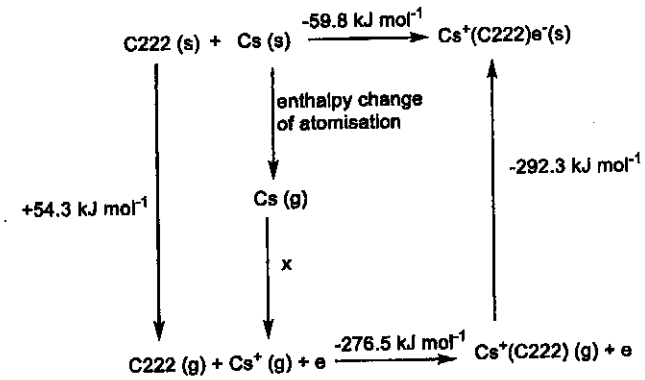
(i) Define the first ionisation energy of caesium, Cs. [1]

The first ionisation energy of caesium, Cs is defined as the energy absorbed to **remove one mole of electrons from one mole of gaseous Cs atoms** to form **one mole of singly charged positive Cs gaseous ions**, Cs^+.

(ii) State and explain which alkali metal, sodium or caesium, forms electrides more readily. [2]

Caesium is predicted to form electrides more readily. Cs has a lower first ionisation energy than Na. Its **valence electron is further away from the nucleus** hence the **electrostatic forces of attraction** between valence electron and the nucleus is the **weaker**.

(iii) The energy cycle shows the electride, $Cs^+(C222)e^-$, being formed from Cs and C222.



State the enthapy change value that is given by *x* and hence, calculate the standard enthalpy change of atomisation of caesium, $\Delta H_{atom}^{\ominus}$. [2]

First ionisation energy of Cs = **+ 376 kJ mol^{-1}**

$-59.8 = +54.3 + \Delta H_{atom}^{\ominus} + 376 - 276.5 - 292.3$

$\Delta H_{atom}^{\ominus}$ = **+ 78.7 kJ mol^{-1}**

Standard enthalpy change of atomisation of alkali metal, Cs = + 78.7 kJ mol^{-1}

(iv) Explain why electrides are electrical insulators in the solid state. [1]

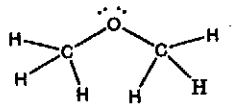
There is an absence of charge carriers (delocalised electrons and free mobile ions). OR the ions are held in fixed positions.

(v) Dimethyl ether (CH_3OCH_3) and trimethylamine ($CH_3)_3N$ are two solvents that are often used to prepare electrides.

Draw the structures of the molecules and state the shapes about **all** the central atoms. [4]

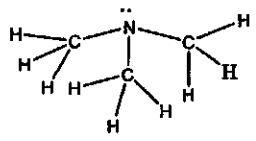
Answers:

Structure of dimethyl ether:



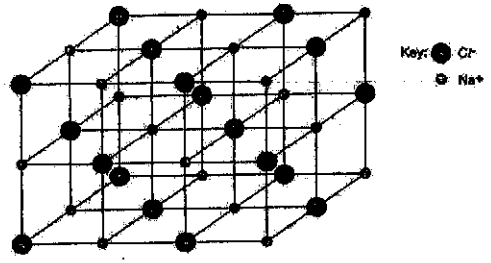
Shape: **tetrahedral** about **C atom** and **bent** about **O atom**

Structure of trimethylamine:



Shape: **tetrahedral** about **C atom** and **trigonal pyramidal** about **N atom**

(b) The structures of electrides are similar to those of ionic compounds. The sodium chloride lattice is cubic with four sodium ions at four corners and four chloride ions at the other four corners. The *co-ordination number* of each ion is 6. In the crystal lattice of caesium chloride, CsC*l*, the *co-ordination number* has a different value.



Crystal lattice of sodium chloride

(i) Suggest what is meant by the term *co-ordination number*. [1]

Co-ordination number is the **total number of ions surrounding another ion of opposite charge.**

(ii) Suggest an explanation for the co-ordination number in CsC*l* lattice being different from that in NaC*l*. [2]

Co-ordination number depends on relative size & relative charge of the cations & anions.

Cs^+ has a **larger size** than Na^+.
Thus, **more Cl^- could be packed around this larger Cs^+ ion.**

Hence, the **co-ordination number will be larger for Cs^+ ion** compared to Na^+.

(iii) Unlike Na which forms the electride $[Na^+(NH_3)_6]e^-$, lithium forms the electride $[Li^+(NH_3)_4]e^-$.

By considering the electronic configurations of Na^+ and Li^+ and their relative positions in the Periodic Table, suggest a reason for the difference in the value of n. [1]

Unlike Na, lithium is a period 2 element and has no energetically accessible vacant 3d orbitals to accommodate more than eight electrons, hence can only accommodate a maximum of 8 electrons.

[Total: 14]

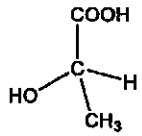
2 Polylactic acid (PLA) is a thermoplastic polymer produced from renewable resources such as corn starch or sugar cane and has a range of applications such as plastic films and medical devices.

(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 does high acidity reduce the effectiveness of the enzymes? [1]

High acidity could affect the **active site of enzymes** as enzymes are high specific and each enzyme has an active site into which only one type of substrate (reactant) can fit.
OR
High acidity could **denature the enzyme** OR
alter the 3D structure/tertiary structure/shape of active site of enzyme

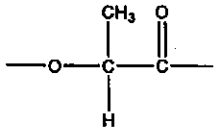
(ii) The structure of lactic acid is shown below.



State the type of reaction when lactic acid is polymerised to form PLA.

Condensation

(iii) Draw a repeat unit of PLA.



(b) One of the reasons that PLA has attracted so much attention is that it is biodegradeable. The simple polymer has a melting point of around 175 °C, but softens between 60-80 °C. Its thermoplastic properties make it suited for use in fibres and food packaging.

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

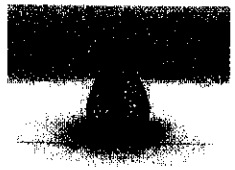
The acid present in vinegar would hydrolyse the ester linkage.

(ii) PLA containers are not used to contain hot drinks. Suggest a reason for this.

Hot water would soften the PLA container as it softens between 60-80 °C.

(iii) Three-dimensional (3D) printing or additive manufacturing is the process of making 3D solid objects from a digital file. The 3D objects are usually fused layer by layer together in the liquid state, then solidified

An example of a 3D printed object:



Suggest why PLA would be suitable as a polymer for 3D printing. [1]

PLA can be easily melted (softened when heated) and molded into different shapes.
OR
PLA can be used as it is a thermoplastic and it softened on heating and solidify (harden) when cooled.

(iv) Compare three different properties between thermoplastics and thermosets. [3]

	Thermoplastics (linear polymers)	**Thermosets/ Thermosetting plastic (cross-linked polymers)**
Softening behaviour	Will be softened upon heating due to breaking of weak intermolecular forces between chains. Can be reshaped and reused	Will degrade upon heating to strong cross–links. Cannot be reshaped
Capacity to be recycled	Yes	No
Rigidity	Flexible and soft Weak intermolecular forces between chains can be broken easily allowing molecular movements.	Very rigid, harder and stiffer Strong cross links between chains restrict movement of chains.

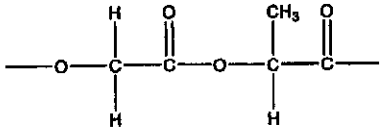
Tensile Strength	Low	High

(v) Suggest two reasons why the continued production of non-biodegradable polymers is a cause for environmental concern. [2]

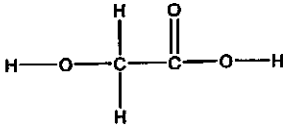
Burning polymers releases greenhouses gases such as carbon dioxide contribute to global warming.
OR
Burning PVC can also release toxic gases like hydrogen chloride (polluting the environment).
OR
There could be a possibility of leeching of toxic chemicals into our environment.
OR
Plastic waste can end up as litter and reduce the amount of available oxygen for aquatic life.

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

A repeat unit of the co-polymer is shown below:



(I) Draw the displayed formula of glycolic acid.



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

Instantaneous dipole-induced dipole interactions due to the **methyl** group and
Permanent dipole-permanent dipole interactions due to the **ester** group

[Total: 13]

3 (a) Catalysts can be described as homogeneous or heterogeneous.

(i) What is meant by the term *heterogeneous catalyst*?

A **heterogeneous** catalyst is a catalyst which is in **different phase** as the **reactants**.

(II) Give an example of a heterogeneous catalyst and write an equation for the reaction that it catalyses. [2]

Haber process
$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$
Solid Fe or Fe_2O_3

OR

Use of catalytic converters to remove oxides of nitrogen in the exhaust gases from car engine
$2NO(g) \rightarrow N_2(g) + O_2(g)$
$2NO_2(g) \rightarrow N_2(g) + 2O_2(g)$
Catalyst: Rh (s) & Pt (s)

OR

Contact process
$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$
Catalyst: V_2O_5

(III) Outline the mode of action of how the catalyst that you have chosen in **(a)(II)** works to decrease the activation energy of the reaction. [2]

Diffusion, adsorption, reaction, desorption and diffusion

Reactants become adsorbed on active sites on catalyst surface by means of **instantaneous dipole-induced dipole forces**. This **weakens the intramolecular bonds** between atoms in reactant molecules. Adjacent reactants on the catalyst surface react to form products at a lower E_a than uncatalysed reaction. The **products** eventually **desorb from the catalyst surface**. The **products diffuse away from the surface**. The vacant active sites are now available for adsorption of other reactant molecules for the whole process to repeat itself.

(b) An ammonium iron alum has the formula $(NH_4)_aFe(SO_4)_b.xH_2O$.

A 1.00 g sample of the salt was dissolved in 100 cm^3 of water and the solution was divided into two equal portions.

To one portion, an excess of NaOH(aq) was added and the mixture was boiled. The ammonia that was evolved exactly neutralised 10.40 cm^3 of 0.100 mol dm^{-3} HCl(aq).

$$NH_4^+ + OH^- \rightarrow NH_3 + H_2O$$

To the other portion, an excess of zinc was added which reduced the $Fe^{3+}(aq)$ to $Fe^{2+}(aq)$. The mixture was filtered and the filtrate required 20.8 cm^3 of 0.0100 mol dm^{-3} $KMnO_4(aq)$ to oxidise the $Fe^{2+}(aq)$ back to $Fe^{3+}(aq)$.

$$Zn + 2Fe^{3+} \rightarrow Zn^{2+} + 2Fe^{2+}$$

(I) Construct an ionic equation to show the reaction of the Fe^{2+} and $MnO_4^-(aq)$ in acidic solution. [1]
[O]: $Fe^{2+} \rightarrow Fe^{3+} + e$
[R]: $5e^- + 8H^+ + MnO_4^- \rightarrow Mn^{2+} + 4H_2O$

Overall: $MnO_4^- + 5Fe^{2+} + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$

(ii) Calculate the value of ***a***. [3]

Amt of NH_4^+ = amt of NH_3 = amt of HCl

$= 0.100 \times \frac{10.4}{1000} = 1.04 \times 10^{-3}$ mol

Amt of $MnO_4^- = 0.0100 \times \frac{20.8}{1000} = 2.08 \times 10^{-4}$ mol

Amt of Fe^{3+} = Amt of $Fe^{2+} = 5 \times 2.08 \times 10^{-4} = 1.04 \times 10^{-3}$ mol

Hence mole ratio of $Fe^{3+} : NH_4^+ = 1 : 1$

Since formula of alum is $(NH_4)_aFe(SO_4)_b.xH_2O$, → <u>a = 1</u>

(iii) Find the value of ***b***. [1]

$(NH_4)Fe(SO_4)_b.xH_2O \rightarrow NH_4^+ + Fe^{3+} + bSO_4^{2-} + x\,H_2O$

LHS overall charge = 0
RHS:
+1 +3 -2(b) = 0
To balance the charges, <u>b = 2</u>

(iv) Calculate the M_r of the ammonium iron alum and the value of x. [2]

Mass of salt used in each titration = $\frac{1.00}{2}$ g = 0.500 g

Thus mass of 1.04×10^{-3} mol of salt = 0.500 g

mass of 1 mol of salt = $\frac{0.500}{1.04 \times 10^{-3}} = 480.8$ g

Hence Mr of salt = <u>480.8</u>

Formula $(NH_4)Fe(SO_4)_2.xH_2O$

$14 + 4(1) + 55.8 + 2(32.1 + 64) + x(18) = 480.8$
x = <u>12</u>

(c) A student went to a chemical store and realised that **five** chemical bottles have missing labels. The labels are "Aluminium Oxide", "Magnesium Oxide", "Silicon Dioxide", "Phosphorous(V) Oxide" and "Phosphorous Pentachloride". He decided to perform some tests to deduce the identities of the chemicals in the unlabelled bottles, so that they can be re-labelled correctly.

The student named the five bottles **A** to **E**. The following tests were conducted and the observations were as follow:

- Samples from bottles **A, B** and **C** were insoluble in water. However, sample **A** dissolved readily in hydrochloric acid, while sample **B** dissolved in sodium

hydroxide. Compound **C** dissolved in both hydrochloric acid and aqueous sodium hydroxide.

- The sample from bottle **D** was soluble in aqueous sodium hydroxide.
- Samples from bottles **D** and **E** melted at relatively low temperatures as compared to **A, B** and **C**. Both of them reacted vigorously with water to form acidic solutions. Furthermore, sample **E** gave off thick white fumes when it reacted with water.

Suggest identities of **A** to **E**, writing the relevant balanced equations to support your answers where necessary. [6]

A = MgO

B = SiO_2

C = Al_2O_3

D = P_4O_{10}

E = PCl_5

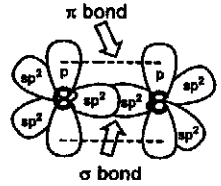
- $MgO + 2HCl \rightarrow MgCl_2 + H_2O$
- $SiO_2 + 2NaOH \rightarrow Na_2SiO_3 + H_2O$
- $Al_2O_3\,(s) + 6HCl\,(aq) \rightarrow 2AlCl_3\,(aq) + 3H_2O\,(l)$
- $Al_2O_3\,(s) + 2\,NaOH\,(aq) + 3H_2O\,(l) \rightarrow 2NaAl(OH)_4\,(aq)$
- $P_4O_{10} + 12NaOH \rightarrow 4Na_3PO_4\,(aq) + 6H_2O\,(l)$
- $P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$
- $PCl_5 + 4H_2O \rightarrow H_3PO_4 + 5HCl$

[Total: 18]

4 In organic chemistry, hydrocarbons are organic compounds consisting entirely of hydrogen and carbon. Examples of these include propene and butane.

(a) Propene, $CH_2{=}CHCH_3$ is a gaseous alkene.

Describe, in terms of orbital overlap, the bonding between the two carbon atoms of the C=C bond in propene. A labelled diagram may be drawn to clarify your answer.



The two carbon atoms are sp^2 hybridised. One sp^2 orbital from each carbon atom <u>**overlaps head-on**</u> to give a **C-C** <u>**sigma**</u> (σ) bond.

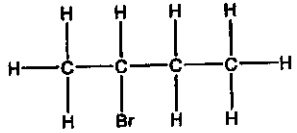
The **unhybridised p orbital** of the adjacent carbon atoms **overlap sideways** to form a C-C **π bond**.

(b) Under suitable conditions, butane forms two monobrominated products, compounds **A** and **B**. Compounds **A** and **B** react with hot aqueous NaOH to produce compounds **C** and **D** respectively.

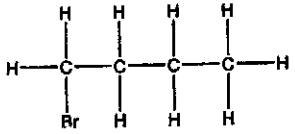
Heating compound **D** with acidified aqueous potassium dichromate produces compound **F**. A solution of **F** turns blue litmus paper red.

Reduction of compound **E** using $NaBH_4$ produces compound **C**.

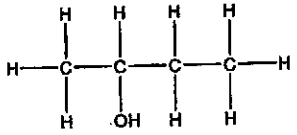
Identify the structures of compounds **A, B, C, D, E** and **F** and explain the reactions described. [8]



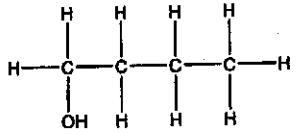
A



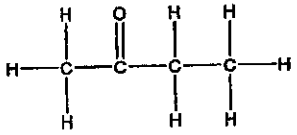
B



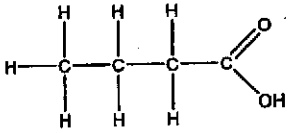
C



D



E



F

Butane undergoes substitution reaction with bromine to form **A** and **B**.
A and **B** undergoes substitution reaction with hot aqueous NaOH to form **C** and **D**.

D undergoes **oxidation** when heated with acidified potassium dichromate to form **F**. Solution **F** turns blue litmus paper red implies solution **F** is **acidic.**

[Total: 10]

5 *Use of the Data Booklet will be relevant to this question.*

Iron ore from different mines contain different percentages by mass of iron. The percentage of iron in a sample of ore can be estimated by converting all of the iron present into $Fe^{2+}(aq)$ ions and then using a redox titration.

A sample of iron ore weighing 11.05 g was converted to $Fe^{2+}(aq)$ ions using the method described above. The resultant solution was then made up to a volume of 250 cm^3 in a volumetric flask.

25.0 cm^3 portions of this solution were then titated with 0.100 mol dm^{-3} of aqueous potassium dichromate(VI) , $K_2Cr_2O_7$ (aq) using a suitable indicator. The results are shown below.

titration number	1	2	3
initial burette reading / cm^3	0.00	19.95	2.10
final burette reading / cm^3	21.10	39.95	22.10
titre / cm^3	21.10		

(a) Complete the table above and use the results to determine the number of moles of potassium dichromate(VI) required to react with the Fe^{2+} ions in 25.0 cm^3 of the solution. [2]

titration number	1	2	3
initial burette reading / cm^3	0.00	19.95	2.10
final burette reading / cm^3	21.10	39.05	22.10
titre / cm^3	21.10	20.00	20.00

average volume of $K_2Cr_2O_7$ used $= \frac{1}{2}(20.00 + 20.00)$

$= \underline{20.00\ cm^3}$

$n(K_2Cr_2O_7)$ required $= \frac{20.00}{1000} \times 0.100$

$= \underline{0.00200\ mol}$

(b) Given the following reaction of $Fe^{2+}(aq)$ with acidified $Cr_2O_7^{2-}(aq)$, calculate the percentage by mass of iron in the iron ore. [3]

$6Fe^{2+}(aq) + Cr_2O_7^{2-}(aq) + 14H^+(aq) \longrightarrow 6Fe^{3+}(aq) + 2Cr^{3+}(aq) + 7H_2O(l)$

No. of moles of Fe^{2+} in 25.0 cm^3 that reacts with $Cr_2O_7^{2-}$ = 0.00200 x 6
= 0.0120 mol

No. of moles of Fe^{2+} in 250 cm^3 volumetric flask = 0.012 x 10
= 0.12 mol
= no. of moles of Fe (in the iron ore)

$Fe \rightarrow Fe^{2+} + +2e^-$

Mass of Fe that is converted to Fe^{2+} = 0.12 x 55.8 = 6.696g

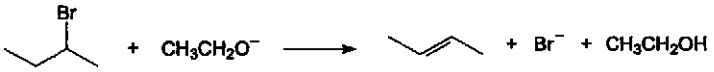
Percentage by mass of iron in iron ore = $\frac{6.696}{11.05}$ x 100% = <u>60.6%</u>

[Total: 5]

Section B

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

6 (a) 2–bromobutane reacts with $CH_3CH_2O^-Na^+$ in the solvent ethanol according to the following equation.



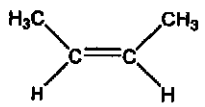
(i) Name the type of reaction that occurred.
Elimination [1]
Comments: Student must recognise the change in functional group from halogenoalkane to alkene.

(ii) The product, but-2-ene, exists as a pair of cis-trans isomers.

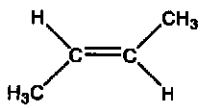
- State the two criteria that give rise to cis-trans isomerism.
- Draw and label the isomers.

(a) Two criterions are as follow:

1. <u>**Restricted rotation about C=C double bond**</u> (due to presence of of π bond).
2. The <u>**2 groups bonded to each carbon in the C=C bond**</u> must <u>**not be identical**</u>.



cis isomer



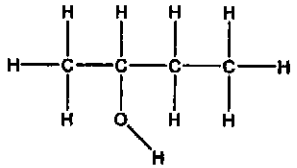
trans isomer

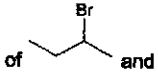
(iii) Other than but-2-ene, another alkene can also be formed from the above reaction.

Draw the skeletal formula of this alkene.

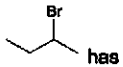
(iv) Another organic compound, which does not contain a halogen, can also be converted to but-2-ene. State the functional group it contains and draw its displayed formula.

secondary alcohol



(v) Compare the boiling points of  and  in terms of their structures and bonding. [3]

 is a polar molecule with <u>**simple molecular structure**</u>. 
is a non-polar molecule with <u>**simple molecular structure**</u>. <u>**More energy**</u> is required to overcome the <u>**stronger permanent dipole-permanent dipole (pd-pd) interactions between molecules**</u> than the <u>**weaker instantaneous dipole-induced dipole (id-id) interactions**</u> between molecules.

Thus,  has a <u>**higher boiling point**</u> than  .

(vi) But-2-ene undergoes complete combustion according to the following equation.

$$CH_3CH{=}CHCH_3 + 6O_2 \rightarrow 4CO_2 + 4H_2O$$

With reference to relevant information in the Data Booklet, calculate the enthalpy change of the above reaction. [2]

Bonds Broken
C=C (610 kJ mol^{-1})
2x C – C (2x350 = 700 kJ mol^{-1})
8x C – H (8x410 = 3280 kJ mol^{-1})
6x O =O (6x496 = 2976 kJ mol^{-1})

Bonds formed
8x O – H (8x460 = 3680 kJ mol^{-1})
8 C=O (8x805 = 6440 kJ mol^{-1})

Bonds broken + Bonds formed quoted correctly [1]

ΔH = 610 + 700 + 3280 + 2976 – 3680 – 6440 = -2550 kJ mol^{-1} (to 3 s.f.) [1]

(b) The kinetics of the reaction between 2–bromobutane and $CH_3CH_2O^-Na^+$ was studied and results are shown in Table 6.1.

Table 6.1

experiment	[[2–bromobutane] / mol dm^{-3}	[$CH_3CH_2O^-Na^+$]] / mol dm^{-3}	relative initial rate
1	0.060	0.060	1.00
2	0.050	0.060	0.833
3	0.040	0.050	0.667

(i) Use the data given above to deduce the rate equation [3]

Let the order of reaction with respect to  be x.

Comparing experiments 1 & 2 in which [$CH_3CH_2O^-$] is kept constant,

$$\frac{(0.060)^x}{(0.050)^y} = \frac{1.00}{0.833}$$

$$\left(\frac{6}{5}\right)^x = \frac{6}{5} \qquad x = 1$$

OR

when [] increases 1.2 times, the relative initial rate also decreases 1.00/0.833 ≈ 1.2 times.

Rate of reaction is directly proportional to [].

Hence, order of reaction with respect to  is 1.

Let the order of reaction with respect to $CH_3CH_2O^-$ be y.

Comparing experiments 2 & 3,

$$\frac{(0.060)^x(0.050)}{(0.050)^x(0.040)} = \frac{0.833}{0.667}$$

$$\left(\frac{6}{5}\right)^x = 0.999 \approx 1$$

$$x = 0$$

$$\frac{(0.060)^y(0.050)}{(0.050)^y(0.040)} = \frac{0.833}{0.667}$$

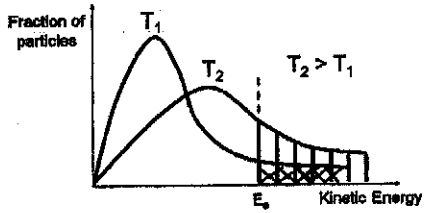
$$\left(\frac{6}{5}\right)^y = 0.999 \approx 1 \qquad y = 0$$

Hence, rate = k []

(ii) Explain how the rate of reaction will be affected when 2–chlorobutane is used instead of 2–bromobutane. [2]

The rate of reaction will be slower when 2–chlorobutane is used instead of 2–bromobutane.
This is because C–Cl bond is stronger than C–Br bond. More energy required to break the C–Cl bond (higher E_a) and reaction is slower.

(iii) With the aid of a Boltzmann Distribution curve, explain how increasing temperature affects the rate of the reaction. [3]



When temperature increases, there are **more particles with kinetic energy ≥ E_a**. This leads to an **increase in the frequency of effective collisions** between reactant particles. Hence, the **rate of reaction increases** with increasing temperature.

[Total: 20]

7 (a) NO_2 can exist in equilibrium with dinitrogen tetroxide (N_2O_4):

$$\underset{\text{colourless}}{N_2O_4(g)} \rightleftharpoons \underset{\text{brown}}{2NO_2(g)}$$

An experiment was conducted at 25 °C by varying initial concentrations of N_2O_4 and NO_2 contained in a closed reaction vessel. The initial and equilibrium concentrations of the two gases are shown in Table 7.1.

expt number	Initial concentration /mol dm^{-3}		Equilibrium concentration /mol dm^{-3}	
	$[N_2O_4]$	$[NO_2]$	$[N_2O_4]$	$[NO_2]$
1	0.000	0.200	0.0898	0.0204
2	0.600	0.040	0.594	0.0523
3	0.500	0.030	0.491	0.0475
4	0.446	0.050	0.448	0.0457
5	0.670	0.000	0.643	0.0547

Table 7.1

(i) State *Le Chatelier's Principle*. [1]

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

(ii) State and explain what will be observed when the pressure in the reaction vessel is decreased. [2]

When pressure in the reaction vessel is decreased, the system will respond by shifting the position of equilibrium to the **right**, **increasing the number of gaseous particles**. The colour of the gas **darkens** or turns a darker brown due to more NO_2 gas formed.

(iii) Identify the experiment that gives the initial concentrations of N_2O_4 : NO_2 in the ratio 15:1. [1]

Experiment 2

(iv) Use the experiment identified in (a)(iii) to calculate the equilibrium constant, K_c, of the reaction, stating its units

$$K_c = \frac{[NO_2]^2}{[N_2O_4]}$$
$$= \frac{(0.0523)^2}{(0.594)}$$
$$= 4.60 \times 10^{-3} \text{ mol dm}^{-3}$$

(b) Nitric acid, HNO_3, is formed by the reaction of NO_2 with water. This is an example of an inorganic *strong acid*. Ethanoic acid, CH_3COOH, an example of an organic acid, is considered a *weak acid*.

(i) Explain and write equations to illustrate what is meant by the terms in italics. [3]

A strong acid dissociates completely into its ions when dissolved in water whereas a weak acid dissociates partially when dissolved in water.

$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$
$HNO_3 \rightarrow H^+ + NO_3^-$

(ii) Given that K_a value of ethanoic acid is 1.75 x10^{-5}, calculate the pH of a 0.2 mol dm^{-3} of ethanoic acid solution. [2]

$$K_a = \frac{[H^+]^2}{[CH_3COOH]}$$

$$\frac{[H^+]^2}{0.2} = 1.75 \times 10^{-5}$$

$[H^+] = 1.87 \times 10^{-3}$ mol dm^{-3}

pH = -lg (1.87×10^{-3}) = 2.73

(iii) Ethanoic acid is titrated with aqueous sodium hydroxide. Suggest a suitable indicator and explain your choice. [2]

Phenolphthalein/thymol blue

The pH at equivalence point coincides with the working range of the indicator.

Phenolphathalein pH = 8 – 10

Thymol blue pH = 8 to 9.5

(iv) A solution **Z** was prepared by mixing excess ethanoic acid solution with sodium hydroxide. [2]

When a small amount of strong acid is added to solution **Z**, its pH remained relatively constant. With the aid of an equation, explain why this is so.

$CH_3COO^-(aq) + H^+(aq) \longrightarrow CH_3COOH(aq)$

The additional little hydrogen ions, H^+ (aq) from the strong acid react with the large reservoir of ethanoate ion to form ethanoic acid. Thus the increase in the hydrogen ion concentration is not significant.

(c) In an experiment, 20 cm^3 of 1.00 mol dm^{-3} sodium hydroxide is added to 30 cm^3 of 1.00 mol dm^{-3} aqueous nitric acid. The temperature of the mixture rises by 5.4 °C.

(i) Deduce, with appropriate working, which is limiting. [1]

HNO_3 + NaOH → $NaNO_3$ + H_2O
no. of moles of HNO_3 = 0.030 mol
no. of moles of NaOH = 0.020 mol
since NaOH : HNO_3 = 1 : 1, NaOH is the limiting reagent.

(ii) Calculate the enthalpy change of the reaction. [2]

$q = mc\Delta T$
$q = (50)(4.18)(5.4) = 1128.6$ J
$\Delta H = -1128.6/0.02 = -56430$ $Jmol^{-1}$ = <u>-56.4 kJ mol^{-1}</u>

(iii) A student repeated the experiment using 20 cm^3 of 1.00 mol dm^{-3} sodium hydroxide and 30 cm^3 of 1.00 mol dm^{-3} aqueous ethanoic acid. All other conditions were kept constant.

Suggest whether the temperature increase will be more or less than 5.4 °C and give an explanation for your answer. [2]

Temperature rise will be below 5.4°C.
Ethanoic acid is a weak acid that partially ionises in water. **<u>Additional amount of energy is required to completely ionises the acid into its ions</u>** and thus overall enthalpy change of reaction between ethanoic acid and sodium hydroxide will be less exothermic.

[Total: 20]