HONG KONG EXAMINATIONS AND ASSESSMENT AUTHORITY
HONG KONG DIPLOMA OF SECONDARY EDUCATION EXAMINATION 2021

CHEMISTRY PAPER 2

11:45 am – 12:45 pm (1 hour)
This paper must be answered in English

INSTRUCTIONS

(1) This paper consists of **THREE** sections, Section A, Section B and Section C. Attempt **ALL** questions in any **TWO** sections.

(2) Write your answers in the **DSE(D)** Answer Book provided. Start each question (not part of a question) on a new page.

(3) A Periodic Table is printed on page 8 of this Question Paper. Atomic numbers and relative atomic masses of elements can be obtained from the Periodic Table.

Not to be taken away before the end of the examination session

Section A Industrial Chemistry

Answer **ALL** parts of the question.

1. (a) Answer the following short questions :

(i) At certain conditions, the activation energy for the decomposition of HCOOH(l) to CO(g) and $H_2O(l)$ shown below is +77.7 kJ mol^{-1}.

$$HCOOH(l) \rightleftharpoons CO(g) + H_2O(l) \qquad \Delta H = +28.5 \text{ kJ mol}^{-1}$$

What is the activation energy for the formation of HCOOH(l) from CO(g) and $H_2O(l)$ at the same conditions, in kJ mol^{-1} ?

(1 mark)

(ii) The activation energy for a certain reaction is +65.0 kJ mol^{-1}. The rate constant of the reaction at 27 °C is k_1. Calculate the rate constant of the reaction at 37 °C in terms of k_1.

(Gas constant $R = 8.31$ J K^{-1} mol^{-1}; Arrhenius equation : $\log k = constant - \frac{E_a}{2.3RT}$)

(2 marks)

(iii) The rate equation for the reaction **A**(g) + **B**(g) → **C**(g) at certain conditions is given below, with k_2 being the rate constant :

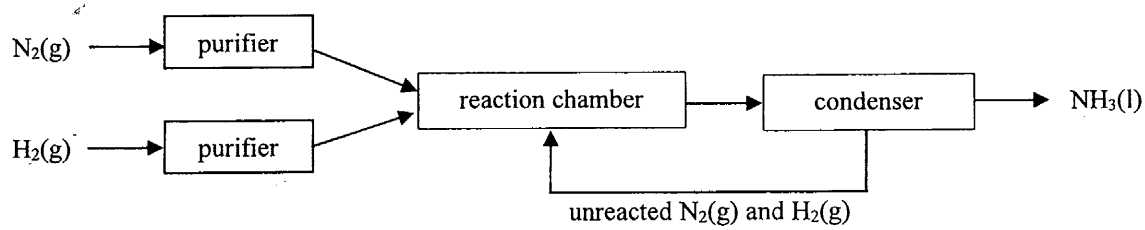
$$\text{Rate} = k_2[\mathbf{A}(g)][\mathbf{B}(g)]^{\frac{3}{2}}$$

(1) What is the order of reaction with respect to **B**(g) ?

(2) The unit of the rate is mol dm^{-3} s^{-1}. State the unit of k_2.

(2 marks)

(b) The diagram below shows how liquid ammonia is produced by the Haber process.



(i) Explain why $N_2(g)$ and $H_2(g)$ need to be purified before going into the reaction chamber.

(1 mark)

(ii) Explain why the unreacted $N_2(g)$ and $H_2(g)$ are passed again to the reaction chamber.

(1 mark)

(iii) Why does ammonia, but not the other gases, become a liquid in the condenser ?

(1 mark)

(iv) Catalyst is used in the reaction of Haber process.

(1) Suggest a catalyst that can be used.

(2) With the aid of a Maxwell-Boltzmann distribution curve, explain why the reaction becomes faster when a catalyst is used.

(5 marks)

1. (c) Methanol is an important chemical in industry and can be produced from methane. The production can be considered as separated into two stages.

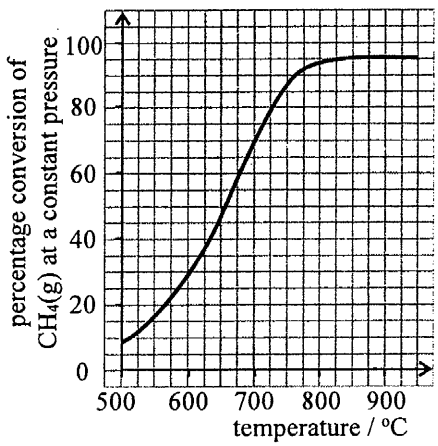
(i) State one potential hazard of methanol.

(1 mark)

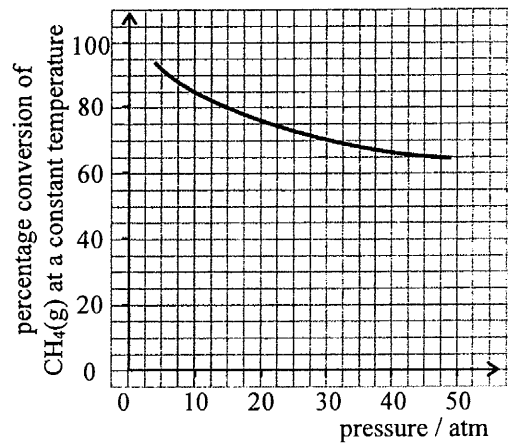
(ii) Other than natural gas, suggest one source of methane.

(1 mark)

(iii) In the first stage, $CH_4(g)$ reacts with $H_2O(g)$ to form $CO(g)$ and $H_2(g)$, and equilibrium would be attained. The graphs below show the percentage conversion of $CH_4(g)$ at equilibrium under different conditions.



Graph 1



Graph 2

(1) With reference to **Graph 1**, explain whether the forward reaction is endothermic or exothermic.

(2) With reference to **Graph 2**, explain, with the aid of a chemical equation, the effect of pressure on the percentage conversion of $CH_4(g)$.

(4 marks)

(iv) In the second stage, $CO(g)$ reacts with $H_2(g)$ to form methanol. Write a chemical equation for the reaction.

(1 mark)

END OF SECTION A

Go on to the next page

Section B Materials Chemistry

Answer **ALL** parts of the question.

2. (a) Answer the following short questions :

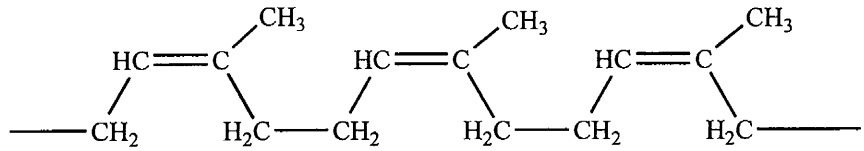
(i) Explain why cellulose can absorb water but chitin cannot.

(2 marks)

(ii) Suggest one use of liquid crystal in daily life.

(1 mark)

(iii) A portion of the structure of natural rubber is shown below :



(1) Draw the repeating unit of natural rubber.

(2) Suggest a physical property of natural rubber that would be improved by 'vulcanisation' in the rubber industry.

(2 marks)

(b) $CH_2=C(CH_3)COOCH_3$ is the monomer of polymethyl methacrylate (PMMA). The following steps show how this monomer can be synthesised :

Step (I) : $CH_3COCH_3 + HCN \rightarrow CH_3C(CN)(OH)CH_3$

Step (II) : $CH_3C(CN)(OH)CH_3 + H_2SO_4 + CH_3OH \rightarrow CH_2=C(CH_3)COOCH_3 + NH_4HSO_4$

(i) The synthesis can be represented by the overall equation shown below :

$CH_3COCH_3 + HCN + H_2SO_4 + CH_3OH \rightarrow CH_2=C(CH_3)COOCH_3 + NH_4HSO_4$

Based on this overall equation, calculate the atom economy of the synthesis.
(Formula masses : HCN = 27.0, CH_3OH = 32.0, CH_3COCH_3 = 58.0, H_2SO_4 = 98.1, $CH_2=C(CH_3)COOCH_3$ = 100.0, NH_4HSO_4 = 115.1)

(1 mark)

(ii) Based on the given information, suggest, with explanation, whether the synthesis can be considered as green.

(1 mark)

(iii) Write a chemical equation for the formation of PMMA from $CH_2=C(CH_3)COOCH_3$.

(1 mark)

(iv) (1) What is meant by the term 'thermosetting plastics' ?

(2) Explain, from molecular level, whether PMMA is a thermosetting plastic.

(2 marks)

(v) State a property of PMMA other than its thermal property. Suggest one use of PMMA based on this property.

(2 marks)

2. (c) Both polylactide (PLA) and stainless steel can be used to make lunch boxes.

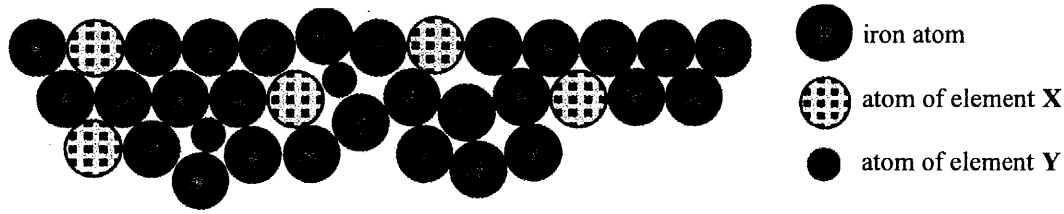
(i) PLA is biodegradable and can be made from the raw material corn starch.

(1) In terms of raw material, suggest one advantage and one disadvantage in using PLA to make disposable lunch boxes.

(2) In terms of molecular structure, explain why PLA is biodegradable.

(4 marks)

(ii) Stainless steel can be used to make reusable lunch boxes. The diagram below shows a portion of a certain layer of atoms in stainless steel.



(1) The presence of **X** in stainless steel makes stainless steel more resistant to corrosion than pure iron. Suggest what **X** would be.

(2) The presence of **Y** in stainless steel makes stainless steel harder than pure iron. Suggest what **Y** would be, and explain how it can increase the hardness.

(3) Iron is the major component of stainless steel and has a cubic close-packed crystal structure under certain conditions. What is the coordination number of an iron atom in this crystal structure ?

(4 marks)

END OF SECTION B

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Section C Analytical Chemistry

Answer **ALL** parts of the question.

3. (a) Answer the following short questions :

(i) Suggest a chemical test to show how $Al_2(SO_4)_3(aq)$ and $ZnSO_4(aq)$ can be distinguished.
(2 marks)

(ii) Suggest a chemical test to show how $(CH_3)_3COH(l)$ and $CH_3COOH(l)$ can be distinguished.
(2 marks)

(iii) State the expected observation of adding 2,4-dinitrophenylhydrazine to propanone.
(1 mark)

(b) In an experiment to prepare cyclohexene from cyclohexanol using concentrated phosphoric acid as a dehydrating agent, a liquid mixture of cyclohexene, phosphoric acid and cyclohexanol was obtained. (Boiling points : cyclohexene = 83 °C, cyclohexanol = 162 °C)

(i) Describe the steps how the phosphoric acid in the mixture can be removed by liquid-liquid extraction, using an aqueous solution.
(3 marks)

(ii) After the removal of the phosphoric acid, a distillate of boiling point of 83 °C was obtained from fractional distillation of the remaining mixture.

(1) Draw a labelled diagram for the set-up of the fractional distillation.

(2) With the help of boiling point and infra-red spectroscopy, suggest how you can support the following statement :

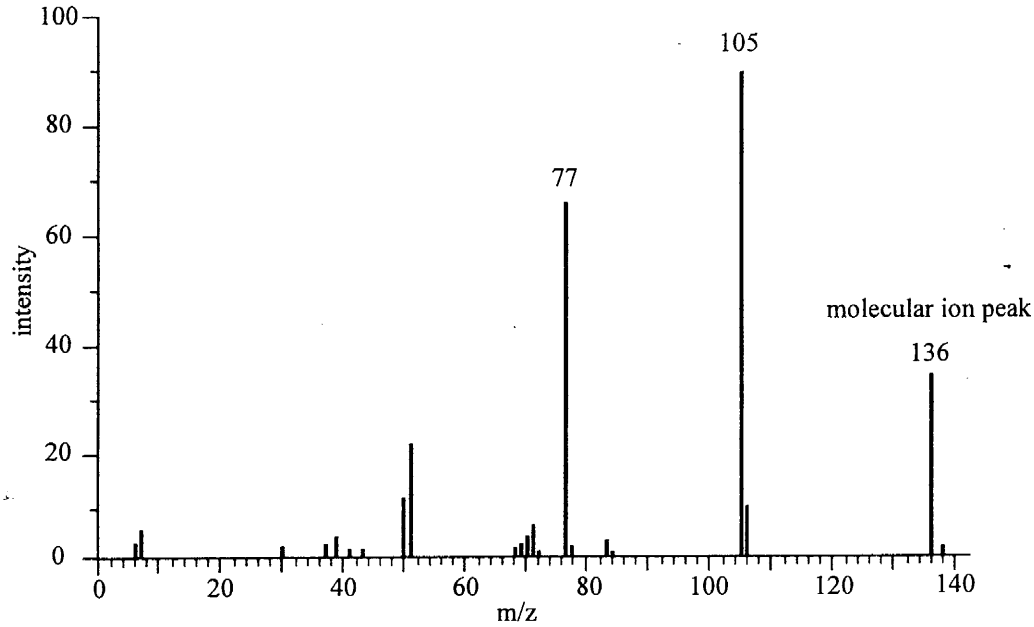
'The distillate is cyclohexene, and without the presence of any cyclohexanol.'

Characteristic Infra-red Absorption Wavenumber Ranges (Stretching modes)

Bond	Compound type	Wavenumber range / cm^{-1}
C=C	Alkenes	1610 to 1680
C=O	Aldehydes, ketones, carboxylic acids and derivatives	1680 to 1800
C≡C	Alkynes	2070 to 2250
C≡N	Nitriles	2200 to 2280
O–H	Acids (hydrogen-bonded)	2500 to 3300
C–H	Alkanes, alkenes, arenes	2840 to 3095
O–H	Alcohols (hydrogen-bonded)	3230 to 3670
N–H	Amines	3350 to 3500

(4 marks)

3. (c) The mass spectrum of an ester **A** is shown below :



(i) Deduce the molecular formula of **A**.
(Compositions by mass : C = 70.6%, H = 5.9%, O = 23.5%;
Relative atomic masses : H = 1.0, C = 12.0, O = 16.0)

(2 marks)

(ii) Given that the signal at m/z = 77 corresponds to $C_6H_5^+$, deduce the structural formula of ester **A**.
(2 marks)

(iii) 2.75 g of a crude sample of **A** was heated with 50.0 cm^3 of 0.060 M NaOH(aq) until no further reaction. The excess NaOH(aq) in the resulting mixture required 20.40 cm^3 of 0.050 M HCl(aq) for complete neutralisation.

(1) Write a chemical equation for the reaction between **A** and NaOH(aq).

(2) Assuming that only **A** in the sample can react with NaOH(aq), calculate the percentage by mass of **A** in the sample.

(4 marks)

END OF SECTION C
END OF PAPER

PERIODIC TABLE 周期表

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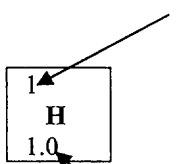

I	II											III	IV	V	VI	VII	0
																	2 **He** 4.0
3 **Li** 6.9	4 **Be** 9.0											5 **B** 10.8	6 **C** 12.0	7 **N** 14.0	8 **O** 16.0	9 **F** 19.0	10 **Ne** 20.2
11 **Na** 23.0	12 **Mg** 24.3											13 **Al** 27.0	14 **Si** 28.1	15 **P** 31.0	16 **S** 32.1	17 **Cl** 35.5	18 **Ar** 40.0
19 **K** 39.1	20 **Ca** 40.1	21 **Sc** 45.0	22 **Ti** 47.9	23 **V** 50.9	24 **Cr** 52.0	25 **Mn** 54.9	26 **Fe** 55.8	27 **Co** 58.9	28 **Ni** 58.7	29 **Cu** 63.5	30 **Zn** 65.4	31 **Ga** 69.7	32 **Ge** 72.6	33 **As** 74.9	34 **Se** 79.0	35 **Br** 79.9	36 **Kr** 83.8
37 **Rb** 85.5	38 **Sr** 87.6	39 **Y** 88.9	40 **Zr** 91.2	41 **Nb** 92.9	42 **Mo** 95.9	43 **Tc** (98)	44 **Ru** 101.1	45 **Rh** 102.9	46 **Pd** 106.4	47 **Ag** 107.9	48 **Cd** 112.4	49 **In** 114.8	50 **Sn** 118.7	51 **Sb** 121.8	52 **Te** 127.6	53 **I** 126.9	54 **Xe** 131.3
55 **Cs** 132.9	56 **Ba** 137.3	57 * **La** 138.9	72 **Hf** 178.5	73 **Ta** 180.9	74 **W** 183.9	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.1	79 **Au** 197.0	80 **Hg** 200.6	81 **Tl** 204.4	82 **Pb** 207.2	83 **Bi** 209.0	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 ** **Ac** (227)	104 **Rf** (261)	105 **Db** (262)													

*	58 **Ce** 140.1	59 **Pr** 140.9	60 **Nd** 144.2	61 **Pm** (145)	62 **Sm** 150.4	63 **Eu** 152.0	64 **Gd** 157.3	65 **Tb** 158.9	66 **Dy** 162.5	67 **Ho** 164.9	68 **Er** 167.3	69 **Tm** 168.9	70 **Yb** 173.0	71 **Lu** 175.0
**	90 **Th** 232.0	91 **Pa** (231)	92 **U** 238.0	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)