HONG KONG EXAMINATIONS AND ASSESSMENT AUTHORITY
HONG KONG DIPLOMA OF SECONDARY EDUCATION EXAMINATION 2024

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) (i) Ammonium sulphate is a compound derived from ammonia.

(1) Name the industrial process to produce ammonia. (1 mark)

(2) Explain how ammonium sulphate can alleviate the problem of inadequate food supply in the world. (1 mark)

(ii) Membrane electrolytic cells and flowing mercury cells are used to produce chlorine in the chloroalkali industry.

(1) What is the raw material used in flowing mercury cells ? (1 mark)

(2) Give one advantage of using membrane electrolytic cells over flowing mercury cells in the chloroalkali industry. (1 mark)

(iii) Alcoholic drinks can be produced by fermentation of sugars in the presence of yeast. State the function of yeast in the fermentation of sugars. (1 mark)

(b) Ethanoic acid can be manufactured by the following two methods :

	Method 1	**Method 2**
Reaction in the reaction chamber	$2CH_3(CH_2)_2CH_3 + 5O_2 \longrightarrow 4CH_3COOH + 2H_2O$ The reaction is exothermic.	Three consecutive steps are involved : Step (1): $CH_3OH + HI \longrightarrow CH_3I + H_2O$ Step (2): $CH_3I + CO \longrightarrow CH_3COI$ Step (3): $CH_3COI + H_2O \longrightarrow CH_3COOH + HI$ The overall reaction is exothermic.
Reaction conditions	• 110 – 120 °C and 60 atm • Cobalt(II) ethanoate acts as the catalyst.	• 150 – 200 °C and 30 – 60 atm • Iridium compound acts as the catalyst.

(i) Draw an energy profile for the catalysed reaction involved in Method 1. Label the axes. (2 marks)

(ii) Based on the equation shown, calculate the atom economy of Method 1.
(Relative molecular masses :
$CH_3(CH_2)_2CH_3 = 58.0$, $O_2 = 32.0$, $CH_3COOH = 60.0$, $H_2O = 18.0$) (1 mark)

(iii) Write the chemical equation for the overall reaction involved in Method 2. (1 mark)

(iv) Based on the given information, suggest a reason why HI can also be considered as a catalyst in Method 2. (1 mark)

(v) Based on the given information and the principles of green chemistry, suggest a reason why some people have the view that

(1) Method 1 can be considered as 'greener' than Method 2. (1 mark)

(2) Method 2 can be considered as 'greener' than Method 1. (1 mark)

1. (c) The equation for the decomposition of $N_2O_5(g)$ is given below :

$$2N_2O_5(g) \rightarrow 2N_2O_4(g) + O_2(g)$$

(i) Suggest how the progress of this decomposition can be followed. (1 mark)

(ii) The rate equation for this decomposition is shown below :

$$\text{Rate} = k[N_2O_5(g)]^a$$

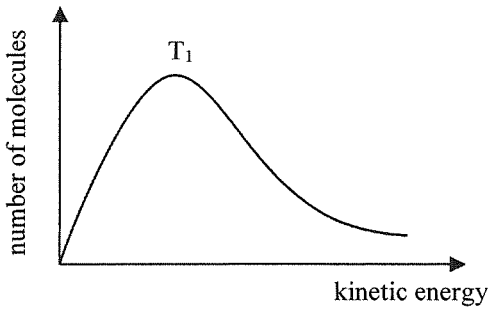
where k is the rate constant and a is the order of reaction with respect to $N_2O_5(g)$.

It is given that the rate constant of this decomposition at 318 K is $4.29 \times 10^{-4}\ s^{-1}$.

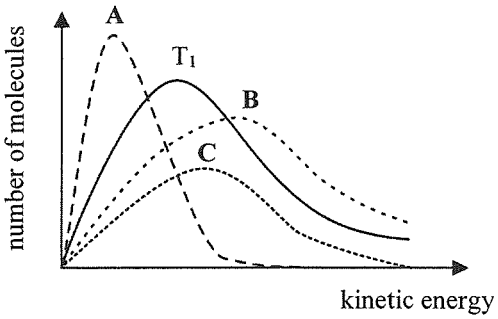
(1) What is the numerical value of a ? (1 mark)

(2) The activation energy of this decomposition is 108.5 kJ mol^{-1}. Calculate the rate constant of this decomposition at 338 K.
(Gas constant $R = 8.31\ J\ K^{-1}\ mol^{-1}$; Arrhenius equation : $\log k = constant - \frac{E_a}{2.3RT}$)
(2 marks)

(iii) The graph below shows the Maxwell-Boltzmann distribution curve for a sample of $N_2O_5(g)$ at temperature T_1.



(1) In the following graph, which of the curves **A**, **B** and **C** can represent the Maxwell-Boltzmann distribution curve of the same sample of $N_2O_5(g)$ at a temperature higher than T_1 ?



(1 mark)

(2) With the help of Maxwell-Boltzmann distribution curves, explain why increasing the temperature will increase the rate of a gaseous reaction. (3 marks)

END OF SECTION A

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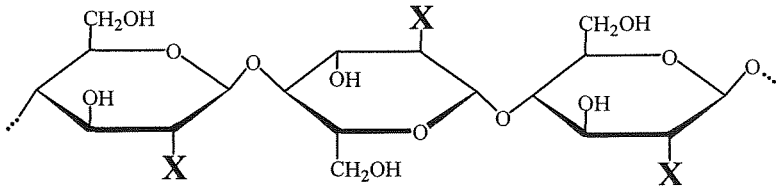
Section B Materials Chemistry

Answer **ALL** parts of the question.

2. (a) (i) Rubber bands are made of vulcanised rubber. When a rubber band is stretched and then released, it can return to its original shape. In terms of molecular structure, explain the elasticity of rubber bands. (2 marks)

(ii) Chitin is a component of the exoskeleton of lobsters. A part of the structure of chitin is shown below :

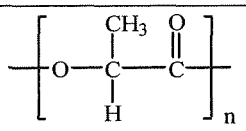


(1) What is **X** ? (1 mark)

(2) In terms of the structure of chitin, explain why chitin is related to the hardness of the exoskeleton of lobsters. (1 mark)

(iii) Name the liquid crystal phase in which the molecules are arranged along the same direction and positionally aligned with each other along a straight line. (1 mark)

(b) Polylactide (PLA) is a synthetic biomaterial. Consider the following information related to PLA :

Structure	
Type of polymer	condensation polymer
Raw material	corn starch
Use	surgical threads for stitching wounds

(i) State the functional group of PLA. (1 mark)

(ii) Draw the structure of the monomer of PLA. (1 mark)

(iii) Suggest why PLA is classified as a condensation polymer. (1 mark)

(iv) According to the principles of green chemistry, explain why it is environmentally friendly to use corn starch as the raw material to produce PLA. (1 mark)

(v) Suggest one property of PLA making it suitable to be used as surgical threads. (1 mark)

(vi) PLA can also be used to make disposable cups. Explain whether PLA disposable cups are suitable to be made by compression moulding. (1 mark)

(vii) Suggest one reason why PLA dissolves in ethyl ethanoate but not in hexane. (1 mark)

2. (c) The crystal structures of iron at atmospheric pressure under different temperatures are shown below :

Temperature	Crystal structure
below 912 °C	body-centred cubic
912 °C – 1 394 °C	cubic close-packed
1 394 °C – 1 538 °C	body-centred cubic

(i) What is the coordination number of an iron atom in the crystal structure at 25 °C ? (1 mark)

(ii) Iron has a cubic close-packed crystal structure at 1 000 °C.

(1) Draw a unit cell of iron crystal at 1 000 °C. (1 mark)

(2) How are the iron atoms arranged in this crystal structure ? (1 mark)

(iii) In view of the same crystal structure of iron at 25 °C and 1 450 °C, a student deduced that the density of iron is the same at these two temperatures. Explain whether this deduction is correct. (1 mark)

(iv) Some information about iron and Kevlar at room temperature is listed below :

	Iron	Kevlar
Relative tensile strength	1	6.7
Density / g cm^{-3}	7.87	1.44
Conduction of heat	good	poor

(1) Which one of the above materials is a better choice for making bullet-proof vests ? Based on the given information, suggest TWO reasons to explain your answer. (2 marks)

(2) Both Kevlar and nylon-6,6 are polyamides. Suggest TWO reasons why Kevlar has a higher rigidity than nylon-6,6. (2 marks)

END OF SECTION B

Go on to the next page

Section C Analytical Chemistry

Answer **ALL** parts of the question.

3. (a) (i) Suggest a chemical test to distinguish between compounds **A** and **B** shown below :

$CH_3CH_2CH_2COCH_3$ **A** $CH_3CH_2CH_2COOH$ **B** (2 marks)

(ii) Paper chromatography can be used to separate the dye components in black ink. Draw a labelled diagram for the set-up required for this paper chromatography experiment. (2 marks)

(iii) Some organic solvents can be used to extract organic compounds from their aqueous solutions. Suggest one property of these solvents rendering them to be used in the liquid-liquid extraction. (1 mark)

(b) A solid sample consists of $PbCO_3$ and a small amount of $CuCO_3$. The following steps were performed to estimate the percentage by mass of $PbCO_3$ in the sample.

Step (1) :	Excess dilute $HNO_3(aq)$ was added to 2.03 g of the sample to give a mixture **X**.
Step (2) :	Excess $NH_3(aq)$ was added to the mixture **X** to form a precipitate.
Step (3) :	The precipitate was collected by filtration. After washing and drying, the precipitate was weighed and its mass was 1.47 g.

(i) Explain why excess dilute $HNO_3(aq)$ was added in Step (1). (1 mark)

(ii) After the addition of excess $NH_3(aq)$ to the mixture **X** in Step (2), apart from the precipitate formed, state another expected observation. (1 mark)

(iii) (1) Why is it necessary to wash and dry the precipitate before weighing in Step (3) ? (2 marks)

(2) What is the precipitate ? (1 mark)

(3) Estimate, by calculation, the percentage by mass of $PbCO_3$ in the solid sample. (Relative atomic masses : H = 1.0, C = 12.0, O = 16.0, Pb = 207.2) (2 marks)

(c) Formaldehyde (systematic name : methanal) is an indoor air pollutant. Instrumental analytical methods are generally used for analysing formaldehyde in indoor air.

(i) With reference to the information given in the table below, suggest how the presence of the functional group of formaldehyde can be detected in an indoor air sample by using infra-red spectroscopy.

Characteristic Infra-red Absorption Wavenumber Ranges (Stretching modes)

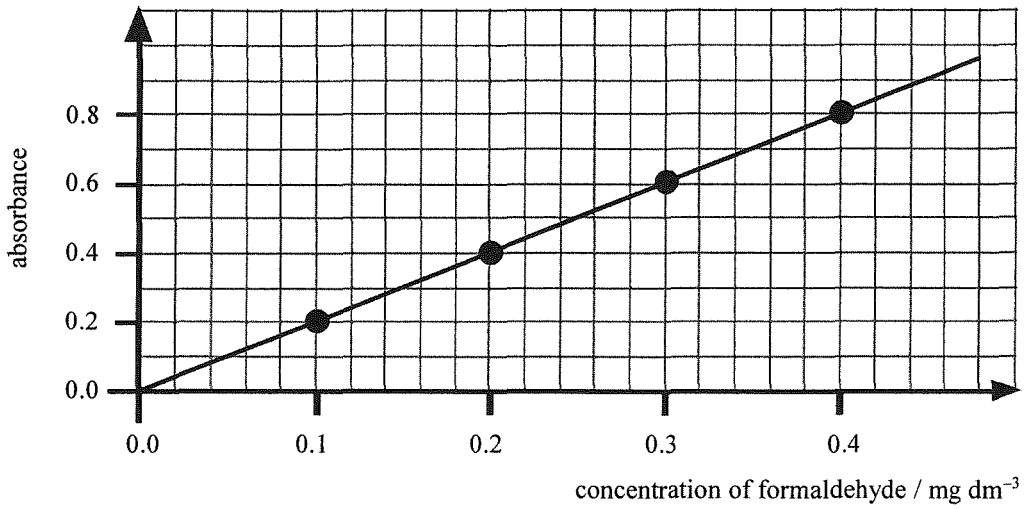
Bond	Compound type	Wavenumber range / cm^{-1}
C=C	Alkenes	1610 to 1680
C=O	Aldehydes, ketones, carboxylic acids and derivatives	1680 to 1800
C≡C	Alkynes	2070 to 2250
C≡N	Nitriles	2200 to 2280
O–H	Acids (hydrogen-bonded)	2500 to 3300
C–H	Alkanes, alkenes, arenes	2840 to 3095
O–H	Alcohols (hydrogen-bonded)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

(1 mark)

3. (c) (ii) The mass spectrum of formaldehyde shows a strong peak at m/z = 29. Suggest one chemical species corresponding to this peak. (1 mark)

(iii) The following steps were carried out to determine the amount of formaldehyde in an indoor air sample.

Step (1) :
Excess reagent **R** reacts with formaldehyde to give a green colour solution. Using the same procedure, standard formaldehyde solutions of various concentrations were separately treated with excess **R** to give green solutions of different colour intensities. The absorbances of these green solutions were measured using an instrument **Y**. The following graph was plotted from the data obtained :



Step (2) :
An indoor air sample with a volume of 0.1 m^3 was collected inside a room. The sample was treated with excess reagent **R** to give 0.03 dm^3 of a green solution **S**. The absorbance of the green solution **S** measured with the instrument **Y** was 0.5.

(1) Name the instrument **Y**. (1 mark)

(2) State the relationship between absorbance and concentration of formaldehyde in the above graph. (1 mark)

(3) By using the above graph, calculate the mass of formaldehyde in solution **S**, in mg. (2 marks)

(4) If the concentration of formaldehyde in indoor air is less than 0.1 mg m^{-3}, the quality of indoor air is considered as good. Based on the given experimental result, explain whether the quality of the air inside the room is good. (1 mark)

(5) Suggest why instrumental analytical methods are generally used for measuring the formaldehyde levels in indoor air. (1 mark)

END OF SECTION C
END OF PAPER

PERIODIC TABLE 周期表

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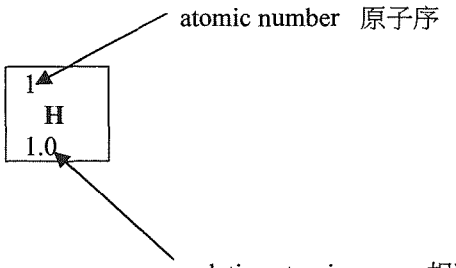

I	II											III	IV	V	VI	VII	0
																	2 **He** 4.0
3 **Li** 6.9	4 **Be** 9.0											5 **B** 10.8	6 **C** 12.0	7 **N** 14.0	8 **O** 16.0	9 **F** 19.0	10 **Ne** 20.2
11 **Na** 23.0	12 **Mg** 24.3											13 **Al** 27.0	14 **Si** 28.1	15 **P** 31.0	16 **S** 32.1	17 **Cl** 35.5	18 **Ar** 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)