Good Hope School
Mock Examination 2020-2021
S.6 CHEMISTRY PAPER 2

12:00–13:00 (1 hour)

This paper must be answered in English

Student name	
Class	
Class Number	
Block Number	

INSTRUCTIONS

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

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

(3) A Periodic Table is printed on page 6 of this Question Paper. Atomic numbers and relative atomic masses of elements can be obtained from the Periodic Table.

Section A Industrial Chemistry

Answer **ALL** parts of the question.

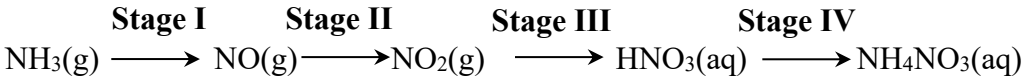
1. (a) Answer the following short questions:

(i) Consider the manufacture of ammonia by the Haber process in a chemical plant.

(1) Why does the Haber process use air and natural gas as the raw materials?

(2) Without changing the optimal reaction conditions, suggest one design to make the manufacture of ammonia more economical.

(3) Nitrogenous fertilizers are important for crop production. One of the nitrogenous fertilizers is ammonium nitrate which can be synthesized from ammonia industrially as follows:



Write the chemical equation for the reaction involved in **Stage III**.

(3 marks)

1. (a) (i) (1) They are convenient / cheap [1] to obtain.

(2) Install a heat exchanger which helps heat up the reactants mixture by the hot products mixture / install a recycling pump to recycle/reuse the unreacted nitrogen and hydrogen [1].

(3) $4NO_2 + O_2 + 2H_2O \rightarrow 4HNO_3$ [1]

(ii) Methanol can be manufactured directly from syngas through catalytic process.

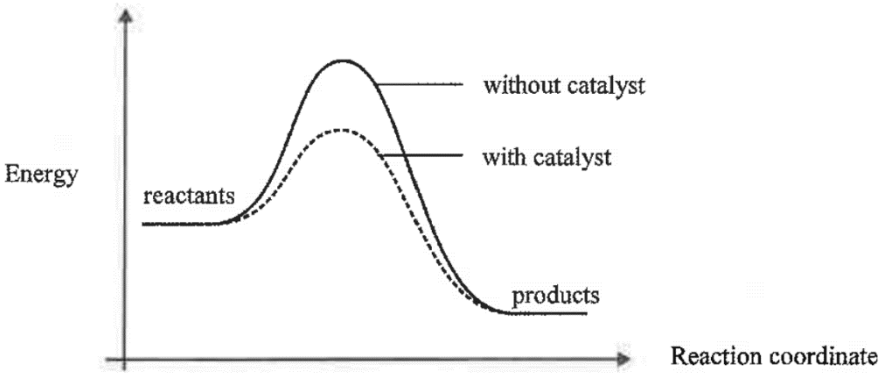
(1) State the catalyst used in this process.

(2) Explain, with the aid of a labelled energy profile, why the total amount of methanol produced per unit time would decrease in the absence of a catalyst.

(4 marks)

(a) (ii) (1) Cu / ZnO / Al_2O_3 [any one, 1]

(2) [1 mark for correct labels of axes.]
[1 mark for correct energy profiles.]



In the absence of a catalyst, less reactant molecules have sufficient energy to overcome the high activation energy. Thus, there are fewer effective collisions per unit time / chance of effective collisions is lower [1]. As a result, the rate of production of product decreases.

(iii) What does the area under a Maxwell-Boltzmann distribution curve represent? (1 mark)

(a) (iii) Total number of molecules / particles [1].

(b) Three trials of an experiment were performed under the same experimental conditions to study the kinetics of the following reaction:

$$\mathbf{A}(aq) + \mathbf{B}(aq) \rightarrow \mathbf{C}(aq) + \mathbf{D}(g)$$

The table below shows the data obtained:

Trial	Initial concentration of **A**(aq) / mol dm^{-3}	Initial concentration of **B**(aq) / mol dm^{-3}	Initial rate of formation of **D**(g) / mol dm^{-3} s^{-1}
1	0.06	0.20	4.50×10^{-4}
2	0.06	0.40	6.37×10^{-4}
3	0.02	0.40	2.12×10^{-4}

(i) Describe how the initial rate of formation of **D**(g) of each trial can be found experimentally. (3 marks)

(ii) Deduce the order of reaction with respect to **B**(aq).
(Note: The order of a reaction may NOT be an integer.) (2 marks)

(iii) The activation energy of this reaction is 120 kJ mol^{-1}. Calculate the ratio of rate constant at 700 ºC to the rate constant at 500 ºC for the reaction.
(Gas constant R = 8.31 J K^{-1} mol^{-1}) (2 marks)

(b) (i) Monitor the gas pressure of the system with time by connecting the reaction flask to a data-logger with a pressure sensor / measure the volume of gas evolved with time by connecting the reaction flask to a gas syringe [1].

Plot a graph of gas pressure/volume of gas evolved against time [1]. Draw a tangent line to the curve obtained at time = 0. Initial rate equals to the slope of the tangent line [1].
Or: Measure the time taken (t) for the gas pressure / volume to reach a certain value [1].
Initial rate is inversely proportional to the time taken [1].

(ii) $2^x = \dfrac{\mathbf{6.37 \times 10^{-4}}}{\mathbf{4.50 \times 10^{-4}}}$ [1*]

x = 0.5 [1]

(iii) $\log \dfrac{k2}{k1} = \dfrac{-120(1000)}{2.3(8.31)} \left(\dfrac{1}{700+273} - \dfrac{1}{500+273}\right)$ [1*]

$\dfrac{k2}{k1} = 46.8$ [1]

[No mark for k1/k2]

1. (c) Chlorine is one of the products manufactured in the chloroalkali industry.

(i) Write the overall equation for the reaction involved in the chloroalkali industry. (1 mark)

(ii) State the use of membrane in the membrane electrolytic cell. (1 mark)

(iii) Other than the hazardous effect of mercury, state another disadvantage of a flowing mercury cell over a membrane electrolytic cell. (1 mark)

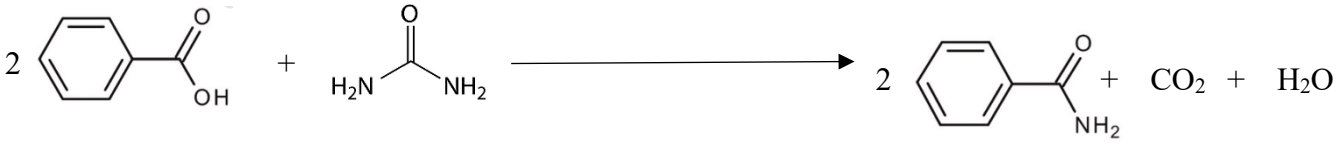
(c) (i) $2NaCl(aq) + 2H_2O(l) \rightarrow Cl_2(g) + H_2(g) + 2NaOH(aq)$ [1]

(ii) The membrane is permeable to cations but not anions [1].

(iii) More energy / more maintenance is needed [1].

(d) The two methods below can produce benzamide:

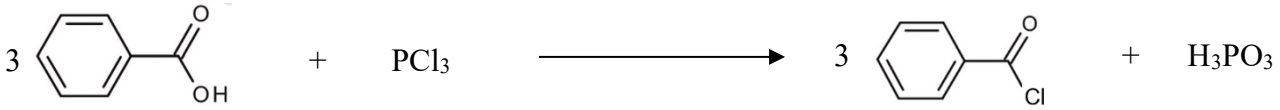
Method (I):



benzoic acid urea benzamide

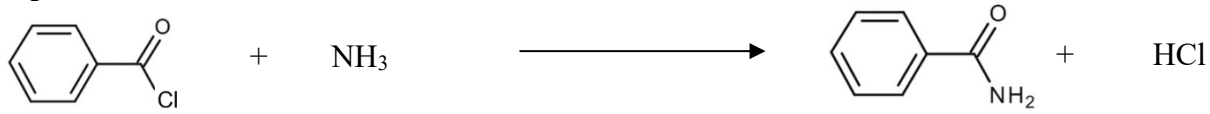
Method (II):

Step 1



benzoic acid phosphorus trichloride benzoyl chloride

Step 2



benzoyl chloride ammonia benzamide

(i) The atom economy of **Method (I)** is 79.6 %. Calculate the atom economy of **Method (II)**.
(Formula masses: benzoic acid = 122.0; phosphorus trichloride = 137.5;
benzoyl chloride = 140.5; ammonia = 17.0; benzamide = 121.0)
(1 mark)

(ii) Apart from waste production and low atom economy, suggest a reason why **Method (II)** is NOT a green synthetic route. (1 mark)

(d) (i) Atom economy of Method (II) $= \frac{3(121)}{3(122)+137.5+3(17)} = 65.5\ \%$ [1]

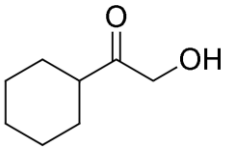
(ii) Hazardous reagents are used / produced in synthesis, e.g. toxic PCl_3 / NH_3 is used; corrosive benzoyl chloride / H_3PO_3 / HCl is produced. [1]

END OF SECTION A

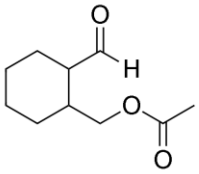
Section B Analytical Chemistry

Answer **ALL** parts of the question:

2. (a) (i) Suggest a chemical test to distinguish the following compounds: (2 marks)



Compound P



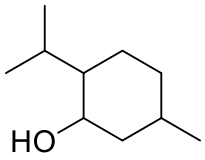
Compound Q

(ii) Describe how you would show the presence of zinc ions in a sample of $ZnCO_3$ (s). (3 marks)

2. (a) (i) Warm each compound with Tollen's reagent in a boiling tube [1].
Only Q gives a silvery deposit / silver mirror [1].

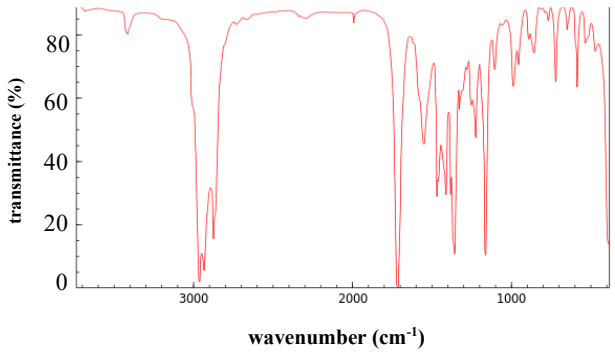
(ii) Addition of excess HCl (aq)/ H_2SO_4 (aq)/ HNO_3 (aq) [1] to $ZnCO_3$(s), then add NH_3 (aq) until in excess. [1].
White precipitate formed would redissolve. [1]

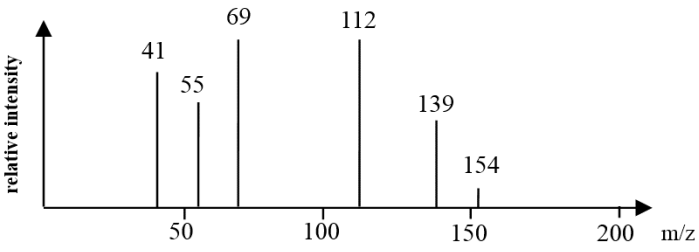
(b) Menthol (molecular mass = 156) is one of the major constituents of peppermint oil. The structure of menthol is shown below:



Menthol
(molecular mass = 156)

Another major component, compound **X**, can be separated as a colourless liquid from peppermint oil. Its IR spectrum and mass spectrum are shown below. Compound **X** can be made from menthol in a simple one-step process.





Characteristic Infra-red Absorption Wavenumber Ranges (Stretching modes)

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

2. (b) (i) Use the above information, suggest a structure for compound **X**. Explain your answer.

(4 marks)

(ii) The table shows some information about menthol and compound **X**:

	Menthol	**Compound X**
Melting point / °C	42.5	-6.6
Boiling point / °C	215	207
% by mass in peppermint oil	42% -64%	29%-42%

Traditionally, menthol can be crystallized by cooling peppermint oil at around 0°C.

(1) Describe how you would check the purity of the menthol crystals formed.

(2) Suggest a reason why the yield of menthol by the traditional method is low.

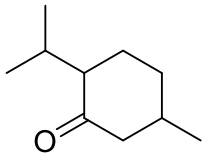
(3) Suggest an alternative method to extract menthol from peppermint oil. Justify your choice.

(3 marks)

(iii) A sample of solid organic acid **Y** is contaminated with small amount of menthol. Both **Y** and menthol are insoluble in water but soluble in cyclohexane.
Outline the procedure for purifying the sample using HCl (aq), NaOH (aq) and cyclohexane.

(4 marks)

(b) (i) From the molecular ion peak, the molecular mass of compound X is 154, which shows that X has 2 H atoms less than menthol. [1]
The absence of broad absorption band at 3230 – 3670 cm^{-1} shows the absence of O-H [1].
The strong absorption peak at 1680-1800 cm^{-1} suggests the presence of C=O [1].
X is likely to be:



[1]

(ii) (1) By melting point determination. Sharp melting point is obtained if the crystals are pure. [1]

(2) Menthol dissolves very well in compound X/ other constituent in peppermint oil (even at lower temperature) [1]

(3) Fractional distillation because the difference in boiling points of menthol and X is small. [1]

(iii) Dissolve the sample in cyclohexane and shake with NaOH (aq) in a separating funnel [1].
Allow the mixture to settle and discard the organic layer. [1]
Add HCl (aq) into the aqueous layer (until no more precipitate is formed). [1]
Remove solid acid Y from liquid by filtration [1].

(c) Vanadium is a transition metal, its chemical symbol is V. The formulae of four aqueous vanadium-containing ions are shown below:

Formula	VO_2^+ (aq)	VO^{2+} (aq)	V^{3+} (aq)	V^{2+} (aq)

In an experiment, air was drawn through 10.0 cm^3 of an aqueous solution of vanadium(II) sulphate of 0.100 mol dm^{-3}. The colour of the solution slowly changed as oxidation took place. The air-oxidized solution was acidified with excess H_2SO_4 (aq) and then titrated with 0.0200 mol dm^{-3} $KMnO_4$ (aq). The average volume of $KMnO_4$ (aq) required to reach the end point was 20.0 cm^3.

(i) Calculate the mole ratio of MnO_4^- (aq) ions to the vanadium-containing ions for complete reaction in the titration. (1 mark)

(ii) Given that VO_2^+ (aq) ions were formed in the titration, deduce the oxidation number of V in the vanadium-containing ions in the air-oxidized solution. (2 marks)

(iii) Sodium oxalate ($Na_2C_2O_4$) is commonly used to standardize potassium permanganate solution. Write the chemical equation for the reaction involved. (1 mark)

(c) (i)

	MnO_4^- (aq)	Vanadium-containing ion
No. of moles	20 (0.02) / 1000 = 0.0004	10 (0.1) / 1000 = 0.001
Mole ratio	2	5

Mole ratio of MnO_4^- (aq): vanadium ion = 2 : 5 [1]

(ii) Oxidation number of Mn changes from +7 to +2, oxidation number of Mn decreases by 5 units
Since the mole ratio of MnO_4^- (aq): vanadium ion is 2 : 5
Oxidation number of V should increase by 2 units [1]
[Also accept explanation in terms of no. of electrons transferred]
The oxidation number of vanadium in the air-oxidized solution is (+5) - 2 = +3. [1]

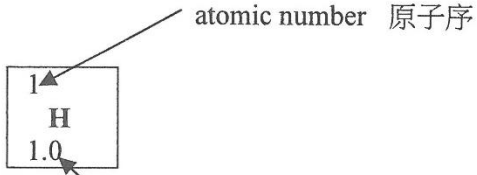
(iii) $2\ MnO_4^-\ (aq) + 5\ C_2O_4^{2-}\ (aq) + 16H^+\ (aq) \rightarrow 10CO_2\ (g) + 2\ Mn^{2+}\ (aq) + 8H_2O\ (l)$ [1]

END OF SECTION B

END OF PAPER

PERIODIC TABLE 周期表

GROUP 族



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)