2024-2025
S.6 CHEM
PAPER 2

Good Hope School
Mock Examination 2024-2025

S.6 CHEMISTRY PAPER 2

1 hour
This paper must be answered in English

Student Name	
Class	
Class Number	
Block Number	

INSTRUCTIONS

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

(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 10 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) Trimethylamine ($(CH_3)_3N$) is a common base used in organic synthesis. It has a rotting fish smell. It can be produced by the following two routes:

Route **(1)**: $3CH_3OH(g) + NH_3(g) \xrightarrow{Al_2O_3/SiO_2} (CH_3)_3N(g) + 3H_2O(l)$

Route **(2)**: $3CO_2(g) + 9H_2(g) + NH_3(g) \xrightarrow{\text{Ruthenium Catalyst}} (CH_3)_3N(g) + 6H_2O(l)$

(i) Trimethylamine can be obtained from rotting fish. Explain why it is still necessary to synthesize it in industry. (1 mark)

It solves the problems of inadequate supply of trimethylamine from natural sources. [1]

Some students thought that the amine obtained from rotting fish is not pure. They did not provide the reason due to large demand can only be met by systhesis.

(ii) Calculate the atom economy of route **(2)** for producing $(CH_3)_3N$. (1 mark)
(Formula masses: H = 1.0, C = 12.0, N = 14.0, O = 16.0)

atom economy = (3 × 12.0 + 9 × 1.0 + 14.0) / (3 × 44.0 + 9 × 2.0 + 17.0) = 35.3% [1]

Satisfactory, calculation of atom economy is quite straight forward.

(iii) Suggest ONE reason why route **(2)** is considered greener than route **(1)**. (1 mark)

Less hazardous chemicals are used in route **(2)** while toxic methanol is used in route **(1)**. [1]

The toxic nature of methanol is well understood by students.

(iv) In route **(1)**, methanol is used as the raw material. It can be produced from syngas.

(1) Write a chemical equation for the production of methanol from syngas. (1 mark)

$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$ [1]

(2) State the catalyst used in this process. (1 mark)

$Cu/ZnO/Al_2O_3$ [1]

Many students do not understand a mixture of three solid is the catalyst used. They just listed either Cu or ZnO or Al_2O_3 as the catalyst used.

(3) Explain the effect of catalyst on a chemical reaction. (1 mark)

A catalyst increases the rate of reaction by providing an alternative pathway with lower activation energy. [1]

Satisfactory.

(v) In both routes, ammonia serves as a raw material. It can be produced from Haber Process.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3(g) \quad \Delta H = -92 \text{ kJ mol}^{-1}$$

(1) Explain why 450°C and 200 atm are chosen to be the operating conditions. (2 marks)

Decreasing the temperature shifts the equilibrium position to the right, and thus increase the yield of ammonia. However, decreasing the temperature will decrease the rate of reaction. [1]

As the number of moles of the product side is less than the reactant side, increasing pressure shifts the equilibrium position to the right. However, increasing pressure will increase the cost of construction / maintenance of the infrastructure required. [1]

Many students were able to discuss both yield and rate are to be considered in choosing an optimal temperature. However, some failed to mention the reason not to choose high pressure is due to the cost of construction / maintenance of the infrastructure.

(2) Explain why nitrogen and hydrogen gas has to be purified before entering the reaction chamber. (1 mark)

To prevent the catalyst from being poisoned. [1]

Well answered.

[9 marks]

(b) An experiment was performed to determine the order of reaction with respect to **W** for the reaction between **W**(aq) and **X**(aq). Four different mixtures of **W**(aq) and **X**(aq) were prepared as shown in the table and all the reactions took place at the same temperature. The initial rates of formation of gas **Z** were recorded.

$$\mathbf{W}(aq) + \mathbf{X}(aq) \rightarrow \mathbf{Y}(aq) + \mathbf{Z}(aq)$$

Mixture	Volume of 0.06 M **W**(aq) / cm^3	Volume of 1.20 M **X**(aq) / cm^3	Volume of distilled water / cm^3	Initial rate of formation of gas **Z** / $cm^3\ s^{-1}$
A	1.0	5.0	4.0	0.0021
B	2.0	5.0	3.0	*x*
C	3.0	5.0	2.0	*y*
D	4.0	5.0	1.0	*z*

(i) Explain why the rate equation is usually determined by the method of initial rates. (1 mark)

The initial concentrations of the reactants are known.
OR
The initial rate can be measured under a controlled conditions, ensuring that temperature / pressure do not change significantly during measurement. [1]

Well answered. Very few student mentioned the alternative answer.

(ii) The rate equation for this reaction can be written as:

$$\text{rate} = k[\mathbf{W}(aq)]^a[\mathbf{X}(aq)]^b$$

The rate equation can be further simplified to:

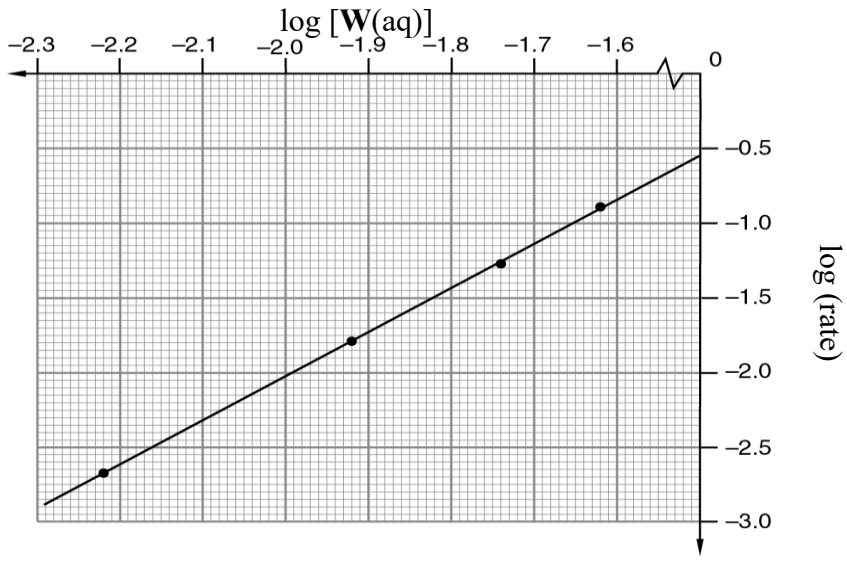
$$\text{rate} = k'[\text{W}(aq)]^a$$

(1) Explain why concentration of **X** in each trial can be considered a constant. (1 mark)

X(aq) is in a large excess. [1]

Some mentioned the volume and concentration remained unchanged in different mixture but failed to compare the concentration of X with the concentration of W.

graph of log(rate) against log[**W**(aq)] is plotted to determine the order of reaction.



(2) Using the graph, deduce the order of reaction with respect to **W**(aq). (2 marks)

Order of reaction = slope [1*]

$$= \frac{-0.85-(-1.80)}{-1.62-(-1.92)} = 3.1666$$

∴ order of reaction = 3 [1]

(3) Determine *y*, the initial rate of formation of gas **Z** for mixture C. (1 mark)

$y = 0.0021 \times 3^3 = 0.0567\ \text{cm}^3\ \text{s}^{-1}$ [1]

The calculations of slope and initial rate are straight forward and well answered.

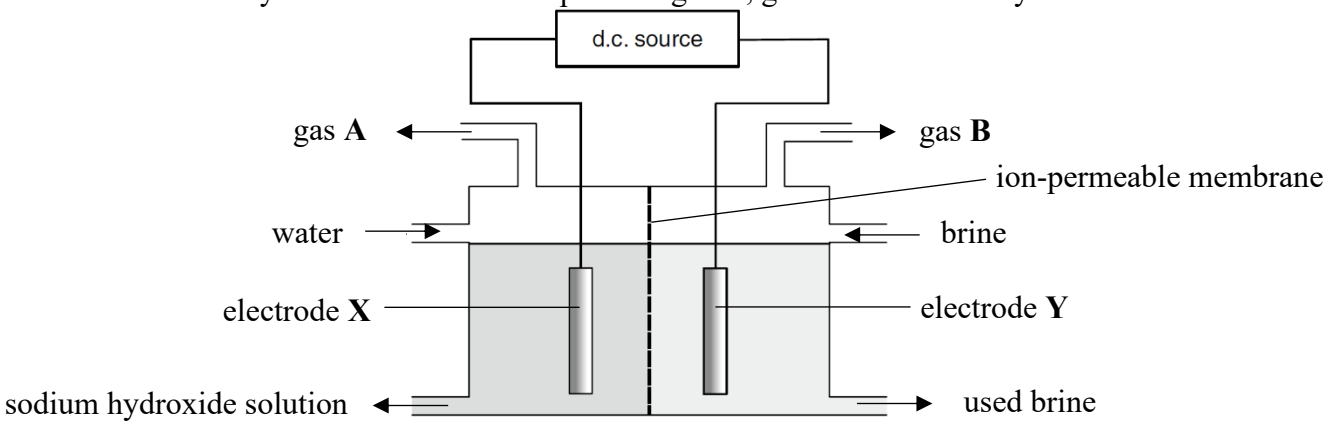
(4) Instead of plotting a graph of log(rate) against log[**W**(aq)], a graph of log(rate) against log(volume of **W**(aq) used) can be plotted to determine the order of reaction. Explain why. (1 mark)

As the total volume of mixture in all mixture are the same, volume of **W**(aq) used is directly proportional to the concentration of **W**(aq). [1]

Well answered.

[6 marks]

(c) The diagram below shows a membrane electrolytic cell used in chloroalkali industry. Brine and water are continuously added into the cell to produce gas **A**, gas **B** and sodium hydroxide solution.



(i) Write the half equations for the reaction occurring at electrode **Y**. (1 mark)

$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$ [1]

(ii) Explain why sodium hydroxide solution is formed and why it does not contain sodium chloride. (2 marks)

$OH^-(aq)$ ions are continuously formed in the cathode part. / $H^+(aq)$ ions are discharged while $OH^-(aq)$ ions are remained in the cathode part. [1]
The ion-permeable membrane only allows $Na^+(aq)$ ions but not $Cl^-(aq)$ ions to pass to the cathode part. [1]

Many students were able to mention the ion-permeable membrane only allows the movement of Na^+ ions. However, many failed to mention the formation of OH^- ions. Some failed to mention the membrane restricts the migration of Cl^- ions in the opposite direction.

(iii) Explain, using a chemical equation, why chlorine bleach should not be mixed with dilute hydrochloric acid. (2 marks)

$2H^+(aq) + Cl^-(aq) + OCl^-(aq) \rightarrow Cl_2(g) + H_2O(l)$ [1]
Toxic Cl_2 gas is produced when chlorine bleach is mixed with dilute hydrochloric acid. [1]

Well answered.

[5 marks]

[20 marks]

Section B Analytical Chemistry

Answer **ALL** parts of the question.

2. (a) (i) Suggest a chemical test to distinguish between $NH_3(aq)$ and $NaOH(aq)$. (2 marks)

Add $CaCl_2(aq)$ to the two solutions. [1]
$NH_3(aq)$: no observable change
$NaOH(aq)$: a white precipitate is formed [1]
OR
Add $NH_3(aq)$ to $CuSO_4(aq)$ drop-wise, a pale blue precipitate is formed which dissolves in excess of $NH_3(aq)$ to form a deep blue solution. [1]
Add $NaOH(aq)$ to $CuSO_4(aq)$ drop-wise, a pale blue precipitate is formed Which is not soluble in excess $NaOH(aq)$. [1]

Very few students used the recommended method of using $CaCl_2(aq)$. Most students used $Pb(NO_3)_2$ solution which is also acceptable. However, some used Pb instead of Pb^{2+} ions; some even used $PbCl_2(aq)$ which is non-existing because PbCl2 is insoluble in water.

(ii) Chlorate(I) ion, ClO^-, is the active ingredient in many household bleaches.
10.0 cm^3 of bleach was made up to 250.0 cm^3. 25.0 cm^3 of this solution reacted with 10.0 cm^3 of 1.0 mol dm^{-3} acidified potassium iodide according to the following equation.

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

5 cm^3 of starch solution was added to the resulting solution which was titrated against 0.10 mol dm^{-3} sodium thiosulphate solution. The titration was repeated several times and the average titre was 12.60 cm^3.

$$2S_2O_3^{2-} (aq) + I_2 (aq) \rightarrow 2I^- (aq) + S_4O_6^{2-} (aq)$$

(1) State the colour change at the end point. (1 mark)

Blue to colourless [1]

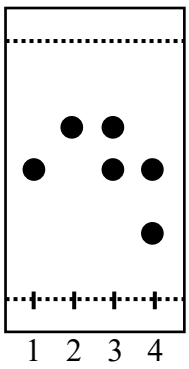
Many students answered with colourless to blue which reflects they do not fully understand the titration procedure.

(2) Calculate the concentration of chlorate(I) ions in the bleach. (3 marks)

One mole of $ClO^- (aq)$ produces one mole of $I_2 (aq)$ which reacts with two moles of $S_2O_3^{2-} (aq)$. Therefore, 1 : 2 ratio of $ClO^- (aq) : S_2O_3^{2-} (aq)$
Number of moles of $S_2O_3^{2-}(aq) = 12.6/1000 \times 0.1 = 1.26 \times 10^{-3}$ moles [1]
Number of moles of $ClO^-(aq)$ in 25.0 $cm^3 = 6.30 \times 10^{-4}$ moles
Number of moles of $ClO^- (aq)$ in 250.0 $cm^3 = 6.30 \times 10^{-4} \times 10$
$= 6.30 \times 10^{-3}$ moles [1]
10.0 cm^3 bleach contains 6.30×10^{-3} moles of ClO^- ions
Therefore, the concentration of ClO^- ions in the bleach is 0.630 mol dm^{-3} [1]

Those who understood the titration calculated correctly.

(b) Salicylic acid can be used to make aspirin. An aspirin sample **X** was analyzed by thin-layer chromatography (TLC). The diagram below shows the chromatogram obtained.



1. aspirin
2. salicylic acid
3. salicylic acid + aspirin
4. sample **X**

(i) Describe the composition of sample **X** as far as possible based on the chromatogram. (1 mark)

The sample contains aspirin and one impurity and it does not contain salicylic acid.

Many failed to mention the existence of the unknown compound in sample X.

(ii) All the substances analyzed are colourless, suggest how you would make the spots visible. (1 mark)

Put the chromatogram under UV light / put the plate in a jar containing a few crystals of iodine / saturated with iodine vapour. [1]

Well answered. A few mentioned the use of ninhydrin spray to visualize the spots. They did not realize ninhydrin spray is only for amino acids visualization on TLC.

(iii) Explain why salicylic acid moves further up the TLC plate than aspirin. (1 mark)

Salicylic acid is more soluble in the solvent / mobile phase than aspirin. [1]

OR

Salicylic acid has lower absorptivity on the stationary phase than aspirin.

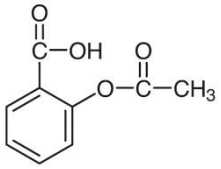
Well answered.

(iv) Apart from using chromatography, suggest one other method to show that sample **X** contains impurities. (1 mark)

By melting point determination. Sample X contains impurities and therefore does not give a sharp melting point. [1]

Many students failed to suggest the use of melting point determination. Answers like GCMS, Infra spectroscopy showed their poor understanding.

2. (c) An aspirin sample **Y** contains caffeine as the only impurity. The structure of aspirin is shown below:



Aspirin is an organic acid while caffeine is an organic base. Both aspirin and caffeine are insoluble in water but soluble in ether. Outline an experimental procedure, based on liquid-liquid extraction, to obtain aspirin from sample **Y**. (4 marks)

Dissolve sample X in ether, transfer the mixture to a separating funnel [1]
Shake the mixture with $NaHCO_3(aq)/Na_2CO_3(aq)/NaOH(aq)$. [1]

Collect the bottom/lower/aqueous layer and add dilute HCl(aq) and ether. [1]
Collect the organic layer. Distill off ether to obtain aspirin. [1]
OR
Collect the bottom/lower/aqueous layer and added dilute HCl(aq). [1]
Collect aspirin by filtration. [1]

Alternatively
Dissolve sample X in ether, transfer the mixture to a separating funnel. [1]
Shake the mixture with $HCl(aq)/H_2SO_4(aq)$. [1]
Collect the upper/organic layer, [1]
and distill off ether to obtain aspirin. [1]

Some students added $NaHCO_3$ before dissolving the solid into ether first. Otherwise, this question is well answered.

(d) **A** is an alcohol with a molecular formula of $C_5H_{12}O$. Oxidation of **A** gives a compound **B** with a molecular formula of $C_5H_{10}O$.
Two chemical tests are performed on **B** and the results are as follows :

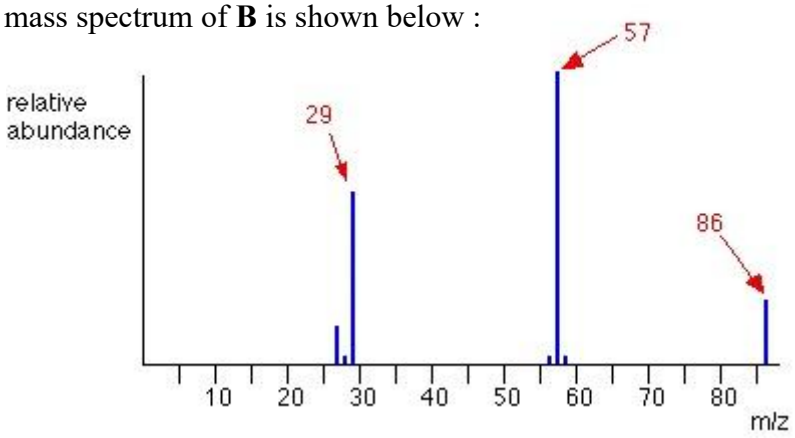
Test (1) : **B** gives an orange precipitate when tested with 2,4-dinitrophenylhydrazine.

Test (2) : **B** gives a negative result when treated with acidified potassium dichromate.

(i) With reference to the results of both Test (1) and Test (2), suggest one functional group that may be present in **B**. (1 mark

ketone group

(ii) The mass spectrum of **B** is shown below :

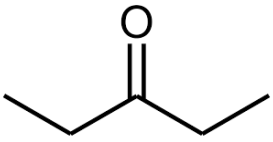


Suggest one chemical species corresponding to each of the signals at m/z = 57 and 29.(2 marks)

m/z = 57 suggested the presence of $CH_3CH_2CO^+$ ion. [1]
m/z = 29 suggested the presence of $CH_3CH_2^+$ ion. [1]

Well answered. Some thought that the m/z=57 was due to the presence of $CH_3COCH_2^+$ which led to the structure of B to be pentan-2-one instead of the correct answer pentan-3-one.

(iii) Draw one possible structure of **B**. (1 mark)



(iv) 'Infra-red spectroscopy is a quick and convenient way for a chemist to check to see if a reaction has proceeded as planned.'

With reference to the information given in the table below, comment on this statement by referring to the oxidation of **A** to **B**. (2 marks)

The reactant **A** has a broad absorption of –OH group around 3230 to 3670 cm^{-1}.
The product **B** contains a ketone group which has a characteristic absorption at 1680 to 1800 cm^{-1}. [1]

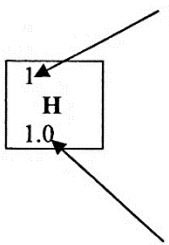
The disappearance of the O-H absorption at 3230 to 3670 cm^{-1} and the appearance of C=O absorption at 1680 to 1800 cm^{-1} may indicate that the oxidation has been successful. [1]

Well answered.

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)