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ST STITHIANS COLLEGE

DEPARTMENT OF PHYSICAL SCIENCES

PRELIMINARY EXAMINATIONS GRADE 12 PAPER 2 – CHEMISTRY

DATE: Monday 18th September 2023

MARKS: 200

TIME: 3 hours

EXAMINERS: Boys' College

MODERATORS: Girls' College

NAME AND SURNAME:

INSTRUCTIONS:

1. Please make sure that your question paper is complete. There are **36** pages, including two blank pages should you need additional space.
2. A Periodic Table and a separate data sheet is included.
3. Read all the questions carefully.
4. It is in your own interest to write legibly and to set your work out neatly.
5. **Show all your working** and round off all **final answers to 2 decimal places** where required.

Q/No	1	2	3	4	5	6	7	8	Total	%
Mark										
Total	20	24	23	24	32	18	22	37	200	

QUESTION 1

Answer these questions on the multiple-choice answer sheet below by making a cross (X) in the box corresponding to the letter that you consider to be correct.

Each question is worth 2 marks.

A	B	☒	D
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Here the option C has been marked as an example.

1.1	A	B	C	D
1.2	A	B	C	D
1.3	A	B	C	D
1.4	A	B	C	D
1.5	A	B	C	D
1.6	A	B	C	D
1.7	A	B	C	D
1.8	A	B	C	D
1.9	A	B	C	D
1.10	A	B	C	D

1.1 In a 20 g sample of molecules, which sample below has the greatest number of moles?

A NH_3

B N_2

C CO_2

D H_2

1.2 The melting point of MgO depends on:

A The strength of the electrostatic forces in the giant ionic solid.

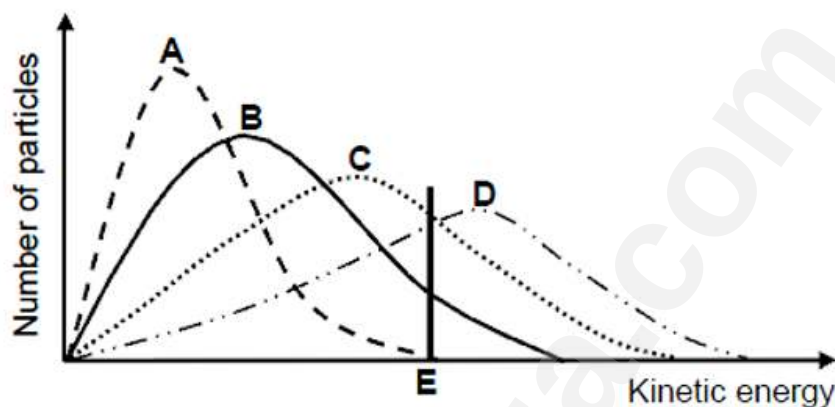
B The strength of the covalent bonds that form the giant ionic solid.

C The bond polarity of the molecule.

D The difference in electronegativity of the elements in MgO .

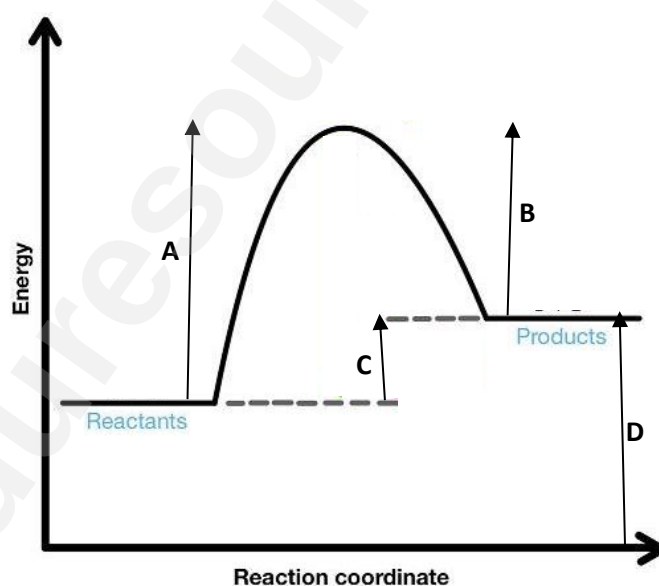
1.3 D

The Maxwell-Boltzmann energy distribution curves below show the number of particles as a function of their kinetic energy for a reaction at four different temperatures. The minimum kinetic energy needed for effective collisions to take place is represented by E.



Which ONE of these curves represents the reaction with the highest rate?

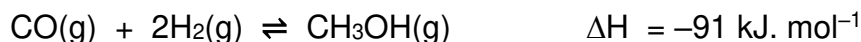
1.4 Consider the reaction profile for a reversible endothermic reaction shown below.



Which arrow represents the activation energy for the reverse reaction?

B

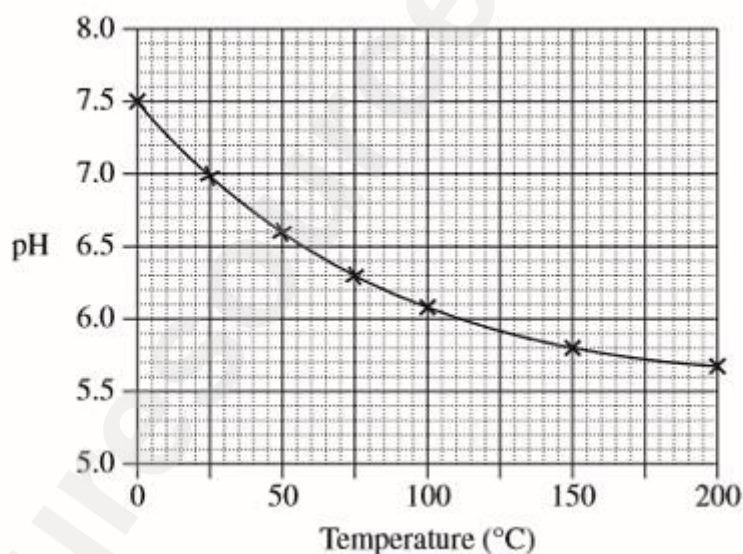
- 1.5 Methanol is synthesised from carbon monoxide and hydrogen according to the equation below.



Which one of the following changes would not affect the value of the equilibrium constant and would not increase the yield of methanol?

- A increase in temperature
- B decrease in temperature
- C increase in pressure
- D decrease in pressure

- 1.6 The graph shows the pH of a solution of a weak acid, HA, as a function of temperature.



What happens as the temperature decreases?

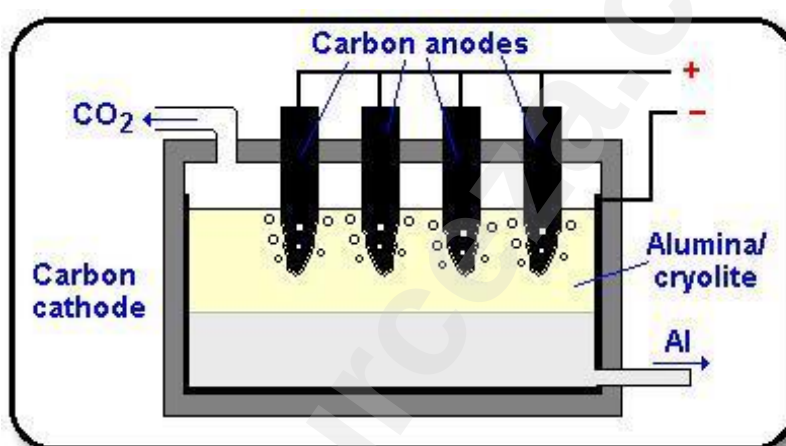
- A HA becomes less ionised and the H^+ concentration increases.
- B HA becomes less ionised and the H^+ concentration decreases.
- C HA becomes more ionised and the H^+ concentration increases.
- D HA becomes more ionised and the H^+ concentration decreases.

1.7 Which of the following will **increase** the emf of a galvanic cell?

- A increasing the concentration of the products
- B using a shorter and wider salt bridge.
- C decreasing the concentration of the products.**
- D increasing the surface area of the electrodes

(2)

1.8 The industrial extraction of aluminium is illustrated in the diagram below:



Consider the following statements about the process above:

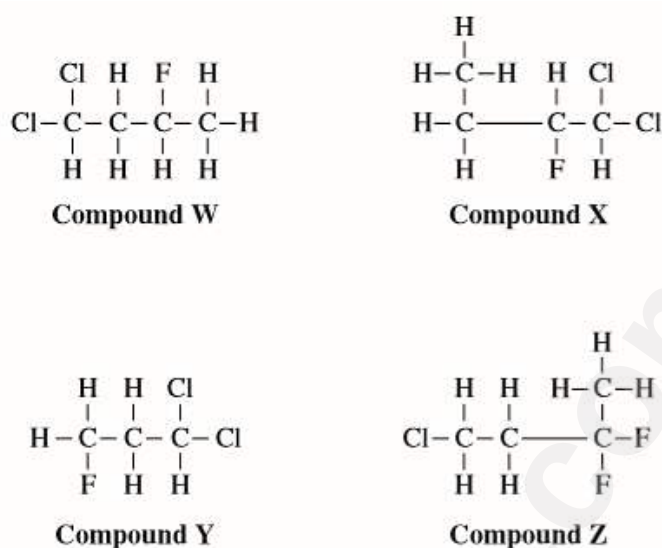
- I the electrolyte is a mixture of cryolite and aluminium oxide.
- II O^{2-} ions are oxidised at the positive electrode as they are stronger reducing agents than F^- ions.
- III Al^{3+} ions are reduced at the negative electrode.
- IV CO_2 is formed at the carbon electrodes.

Which of the above statements are **correct**?

- A I, II and IV only
- B I, II and III only**
- C I, III and IV only
- D I, II, III and IV

(2)

1.9 Four compounds, W, X, Y and Z are represented below:



Which of the following is a pair of isomers?

A W and X

B W and Y

C X and Y

D Y and Z

1.10 Which pair of substances correctly matches the reactant and product of an addition reaction? **C**

	Reactant	Product
A	$\text{CH}_3 - \text{CH}_2 - \text{CH}_2 - \text{CH}_2 - \text{OH}$	$\text{CH}_3 - \text{CH}_2 - \text{CH} = \text{CH}_2$
B	$\text{CH}_3 - \text{CH}_2 - \text{CH}_2 - \underset{\text{OH}}{\text{CH}} - \text{CH}_3$	$\text{CH}_3 - \text{CH}_2 - \text{CH} = \text{CH} - \text{CH}_3$
X	$\text{CH}_3 - \text{CH} = \text{CH} - \text{CH}_2 - \text{CH}_3$	$\text{CH}_3 - \text{CH}_2 - \underset{\text{Cl}}{\text{CH}} - \text{CH}_2 - \text{CH}_3$
D	$\text{CH}_3 - \underset{\text{OH}}{\overset{\text{O}}{\text{C}}}$	$\text{CH}_3 - \underset{\text{O}-\text{CH}_3}{\overset{\text{O}}{\text{C}}}$

QUESTION 2

- 2.1 Study the substances below and select one which meets the criteria of each statement. You can use any of the substances more than once.

K C NaBr BH₃

- 2.1.1 It has polar covalent intramolecular bonds. (1)

BH₃

- 2.1.2 It has a sea of delocalised electrons surrounding positive kernels. (1)

K

- 2.1.3 It has London forces between its molecules. (1)

BH₃

- 2.1.4 It dissociates into ions in water. (1)

NaBr

- 2.1.5 It is a solid which comprises of an atomic lattice of covalently bonded atoms. (1)

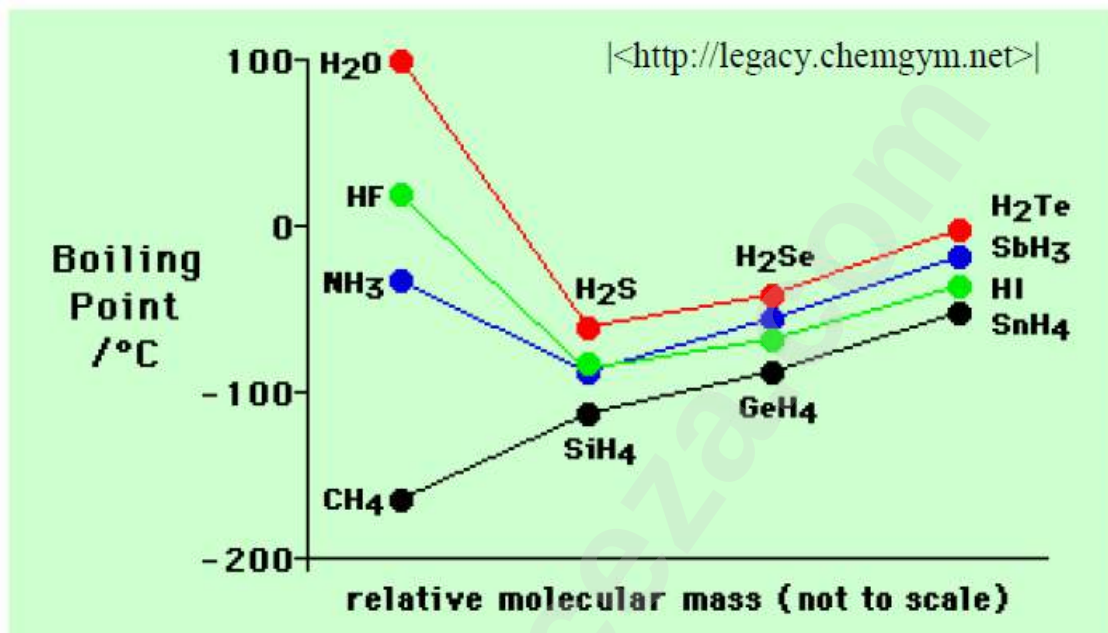
C

- 2.1.6 Name the substance which can conduct electricity when molten but not in its solid state. Explain why this substance is regarded in its molten state but not in its solid state. (3)

Sodium bromide

In the molten state the ions are free to move but in the solid state they are not free to move

- 2.2 The graph below shows the boiling points of the hydrides of the elements in groups 14, 15, 16 and 17. Water (H_2O), hydrogen fluoride (HF) and ammonia (NH_3) do not follow the trend of the other hydrides.



- 2.2.1 Name the forces present between the molecules of water (H_2O), hydrogen fluoride (HF) and ammonia (NH_3) (1)

Hydrogen bonds

- 2.2.2 What properties of the oxygen, fluorine and nitrogen atom allow these compounds to exhibit these specific intermolecular forces? (3)

They are small atoms

Have high electronegativity

and contain at least one pair of lone electrons

- 2.2.3 Explain why HF has a higher boiling point than the other hydrides of the group 17 elements. (3)

HF has hydrogen bonding and London forces while the other group 17 hydrides have dipole-dipole and London intermolecular forces. Hydrogen bonding is stronger than dipole-dipole and requires more energy to overcome.

- 2.2.4 Name and explain the origin of the intermolecular forces present in the group 14 hydrides. (5)

Group 14 hydrides are non-polar molecules

Adjacent molecules approach each other, their electron clouds will repel and shift

A slight positive and slight negative will form on each side of the electron clouds

Oppositely charged ends/ regions of different/ neighbouring molecules will attract to form London forces

- 2.2.5 With reference to the relevant intermolecular forces and the factors influencing their strength, explain why fluorine (F_2) is a gas at $25^\circ C$ and iodine (I_2) is a solid at the same temperature. (4)

Both F_2 and I_2 have London momentary dipole-induced dipole intermolecular forces

I_2 has a higher electron cloud density than F_2 , leading to a greater induced dipole and hence stronger force of attraction, more energy is required to overcome the London forces.

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QUESTION 3

Marble is composed of calcium carbonate (CaCO_3) which reacts with hydrochloric acid (HCl) as shown in the balanced equation below:



A student investigates the rate of reaction between solid calcium carbonate and dilute hydrochloric acid.

The calcium carbonate remains as a lump until it is completely consumed by the hydrochloric acid.

The student uses a pH meter to monitor the increase in pH of the solution over time. From these pH values, they calculate the concentration of HCl at each reading. The following results were obtained:

Time (s)	pH	$[\text{HCl}] \times 10^{-4} \text{ mol.dm}^{-3}$
0	2,46	51
0,5	2,52	31
1,0	2,67	21
1,5	2,85	13
2,0	3,05	9
2,5	3,22	6
3,0	3,40	4
4,0	3,46	2,0
5,0	3,52	2,0

3.1 Define a *closed system*. (2)

A closed system is a system where mass is conserved inside the system, but energy can leave or enter the system freely.

3.2 Use your answer in question 3.1 to explain why reversible arrows are noted in the equation above. (2)

CO_2 is lost from the open system as a gas, therefore the reverse reaction does not occur.

3.3 Define *reaction rate*. (2)

The change in concentration per unit time of either the reactant or the product.

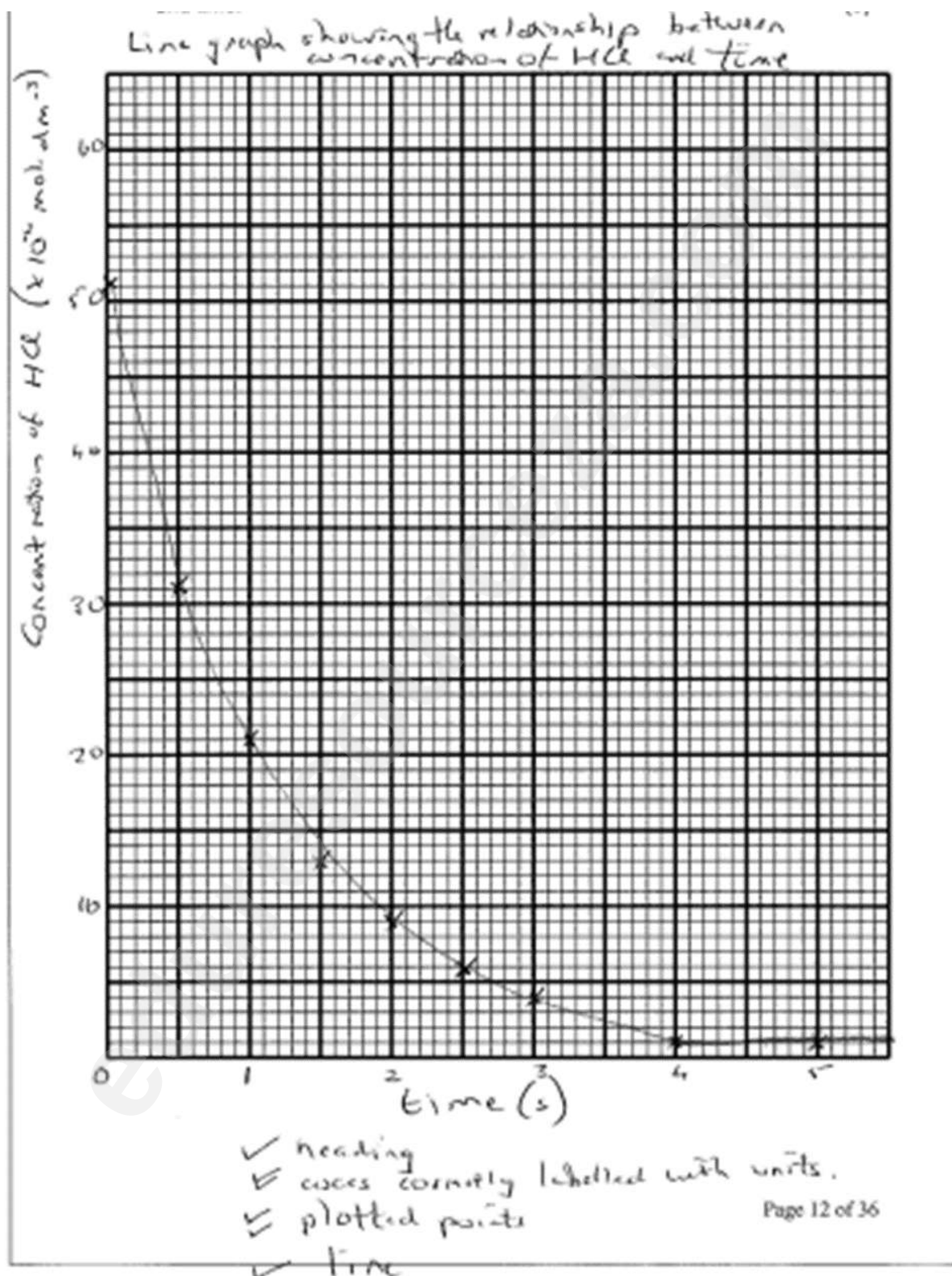
3.4 Use the values in the table to determine the average rate of consumption of hydrochloric acid during the first second of the reaction. (3)

Average rate = $\frac{\text{change in concentration}}{\text{time interval}}$

$$\text{Ave rate} = 21 \times 10^{-4} - 51 \times 10^{-4} / 1$$

$$\text{Ave rate} = -30 \times 10^{-4} \text{ mol.dm}^{-3}.\text{s}^{-1}$$

- 3.5 Draw a graph showing the relationship between the concentration of HCl and time. (6)



- 3.6 How does the average rate of consumption of HCl in the fourth second compare with that in the first second.

State only INCREASE; DECREASE or STAYS THE SAME (1)

Decrease

- 3.7 Use collision theory to provide an explanation for your answer in question 3.6. (3)

As the reaction progresses the HCl get used up, reducing the concentration.

There are less particles per unit volume to react.

There are less collisions per unit time, and therefore less successful collisions per unit time.

The reaction rate is therefore decreasing.

3.8 Two other students repeat the experiment.

They collect the gas in a gas syringe whilst doing three new experiments. They change various conditions in each experiment, as shown in the table below.

Experiment	Temperature (°C)	[HCl] mol.dm ⁻³
1	10	0,1
2	10	0,2
3	5	0,1

For each experiment:

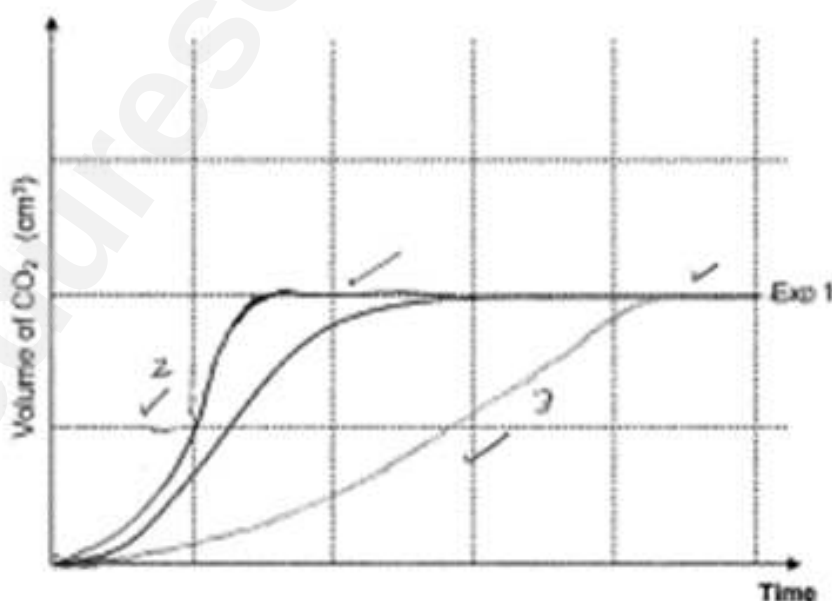
- the same volume of HCl is used
- a single lump of calcium carbonate is used
- the acid is in excess

A graph of experiment 1 is plotted to show the volume of CO₂ collected over time and is shown on the graph below.

It is labelled Exp 1.

On the same set of axes, draw the corresponding graphs to show the volume of CO₂ collected over time for Experiments 2 and 3. Please label each graph.

(4)



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QUESTION 4

The first stage in the Ostwald process used in the manufacture of nitric acid involves the catalytic oxidation of ammonia. The balanced chemical equation for this reaction is given below:



- 4.1 State *Le Chatelier's Principle*. (2)

When an external stress is applied to a system in dynamic equilibrium the equilibrium point will change in such a way to counteract the stress.

- 4.2 What volume change must be made to the reaction container so that a high yield of products is obtained? Explain by referring to Le Chatelier's principle. (4)

Increasing the volume decreases the pressure of the system.

According to LCP the system will react to increase the pressure by favouring the reaction that forms the greatest number of mols.

The forward reaction is favoured and a high yield of products will be obtained.

Ammonia and oxygen were added to a reaction vessel which was then sealed. The gases reacted and dynamic chemical equilibrium was reached. The temperature was changed at 35 s, after which the system was allowed to reach equilibrium for the second time. The graph below represents the changes in the number of moles of the reactants and products for this reaction with time.

- 4.3 At what time did the above reaction reach equilibrium for the first time? (1)

15 s

- 4.4 What temperature change (INCREASE or DECREASE) was made to the system at 35 s? (1)

DECREASE

- 4.5 Explain why the temperature change made at 35 s would be both an advantage and a disadvantage in industry. (4)

Advantage: A decrease in temperature favours the forward reaction to produce the desired yield.

Disadvantage: Decreasing the temperature slows the rate of the reaction, therefore the yield is obtained slower.

- 4.6 More moles of oxygen are then added to the system at 70 s.



State how each of the following would be affected:

Choose from INCREASES, DECREASES or NO CHANGE.

- 4.6.1 The rate of the reverse reaction. (1)

Increase (increasing the amount of gas in the system causes more collisions to take place per unit time.)

- 4.6.2 The yield of NO. (1)

Increase

- 4.6.3 The equilibrium constant, K_c . (1)

No change (only temp affects the value of K_c)

- 4.7 The ammonia used in the Ostwald process is prepared by the reaction of hydrogen and nitrogen as shown in the following balanced chemical equation:



2,8 mol of $\text{N}_2(\text{g})$ and 8,7 mol $\text{H}_2(\text{g})$ were injected into a $0,5 \text{ dm}^3$ reaction vessel which was then sealed and allowed to reach equilibrium at 470°C . When equilibrium was reached it was found that the concentration of $\text{NH}_3(\text{g})$ was $1,2 \text{ mol}\cdot\text{dm}^{-3}$.

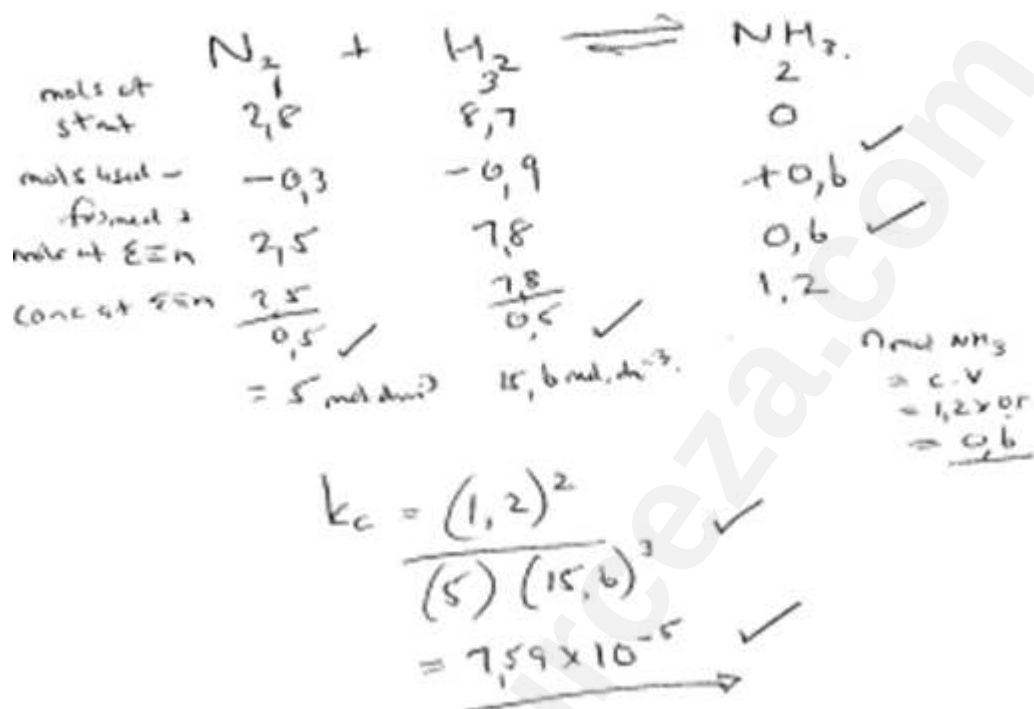
- 4.7.1 Write down the expression for the equilibrium constant, K_c , for this reaction. (2)

See next page

$$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3} \quad \checkmark \checkmark$$

4.7.2 Calculate the equilibrium constant (K_c) at 470 °C.

(6)



4.7.3 What information does your answer for **question 4.7.2** give regarding the expected yield of products (HIGH or LOW) in this reaction?

(1)

LOW

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QUESTION 5

The following questions have to do with acids and bases.

- 5.1 Give the definition of a **Brønsted-Lowry acid**. (2)

A proton donor.

- 5.2 Define a *strong acid*. (2)

An acid that ionises completely in an aqueous solution.

- 5.3 Explain the difference between a weak acid and a dilute acid. (2)

A weak acid only ionises partially in an aqueous solution whereas a dilute acid contains a small number of moles of acid per unit volume of water.

- 5.4 Magriet finds an old bottle of ethanoic acid in the storeroom. The label is no longer completely visible, and the concentration is unknown. She decides to titrate this with sodium hydroxide as a base, and proceeds to make up a $0,1 \text{ mol.dm}^{-3}$ sodium hydroxide solution in a 250 ml volumetric flask. Gabriel tells her that she cannot use her calculated concentration of the sodium hydroxide to determine the concentration of the ethanoic acid as is it not a suitable standard solution since sodium hydroxide is known to absorb immeasurable amounts of water from the atmosphere during storage.

- 5.4.1 What is a *standard solution*? (2)

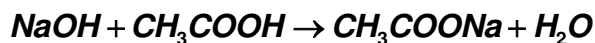
A solution of known concentration.

- 5.4.2 Explain why Gabriel is correct in stating that it would be impossible to establish the actual concentration of Magriet's prepared solution? (3)

Magriet does not know the actual concentration of the sodium hydroxide because it has absorbed water from the atmosphere. Therefore, it is not a standard solution.

- 5.5 Ultimately it is found that the real concentration of the sodium hydroxide solution is $0,09 \text{ mol.dm}^{-3}$. A titration is then performed by placing 40 ml of the unknown diluted ethanoic acid into a conical flask and adding 10 ml of the sodium hydroxide solution.

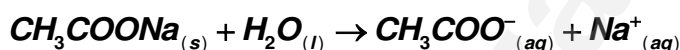
5.5.1 Write the balanced equation for this reaction. (2)



5.5.2 Will the pH of this solution after the titration be higher or lower than 7? Explain your answer in terms of the hydrolysis of the produced salt and support your argument with the use of suitable equations. (5)

The pH of the solution will be > 7 .

The CH_3COONa is a salt from a weak acid and a strong base and it dissociates in water:

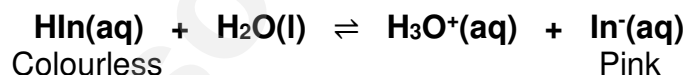


The $\text{CH}_3\text{COO}^{-}$ ion will undergo hydrolysis in water:



The hydrolysis reaction produces hydroxide ions which will increase the pH of the solution.

5.5.3 Indicators behave like weak acids in solution as shown by the equation below:



Use Le Chatelier's principle to explain why an ethanoic acid solution containing a few drops of phenolphthalein changes from colourless to pink on the addition of sodium hydroxide? (5)

When NaOH is added to the solution, we are adding OH^{-} ions. These will react with the H_3O^{+} ions to form water and this will decrease the concentration of H_3O^{+} ions. According to LCP, the equilibrium will shift to increase the number of H_3O^{+} . Thus, the equilibrium will shift to the right, the forward reaction will be favoured, and the solution will change from colourless to pink.

5.5.4 Determine the concentration of the diluted ethanoic acid. (3)

For NaOH :

$$c_b = 0,09 \text{ mol.dm}^{-3}$$

$$V_b = 10 \text{ ml} = 0,01 \text{ dm}^3$$

$$n_b = c_b \cdot V_b$$

$$n_b = 0,09 \times 0,01$$

$$n_b = 9 \times 10^{-4} \text{ mol}$$

NaOH : CH₃COOH

1 : 1

$$\therefore n_a = 9 \times 10^{-4} \text{ mol}$$

$$c_a = \frac{n_a}{V_a}$$

$$c_a = \frac{9 \times 10^{-4}}{0,04}$$

$$c_a = 0,0225 \text{ mol.dm}^{-3}$$

For CH₃COOH :

$$c_a = ?$$

$$V_a = 40 \text{ ml} = 0,04 \text{ dm}^3$$

5.5.5 Determine the concentration of the original bottle of ethanoic acid if 5 ml was measured off into a 250 ml volumetric flask and filled up to the mark with water. (3)

$$c_1 \times V_1 = c_2 \times V_2$$

$$c_1 \times 0,005 = 0,0225 \times 0,25$$

$$c_1 = 1,125 \text{ mol.dm}^{-3}$$

5.5.6 Calculate the concentration of hydroxide ions in the original bottle of ethanoic acid. (3)

$$K_w = [H_3O^+][OH^-] = 1 \times 10^{-14}$$

$$1,125[OH^-] = 1 \times 10^{-14}$$

$$[OH^-] = \frac{1 \times 10^{-14}}{1,125}$$

$$[OH^-] = 8,89 \times 10^{-15} \text{ mol.dm}^{-3}$$

(Ethanoic acid is a monoprotic acid. The concentration of H₃O⁺ ions produced is thus the same as the concentration of the acid)

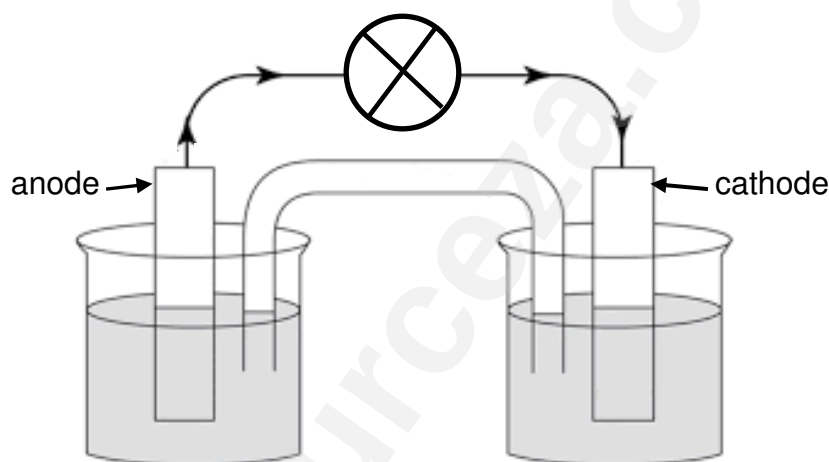
QUESTION 6

A galvanic cell is set up by a student under standard conditions. He placed a lead electrode in a lead (II) nitrate solution and an aluminium electrode in an aluminium sulphate solution. Each electrode was connected to a 1,5 V light bulb by a conducting wire. A salt bridge also joined each beaker.

6.1 Fully label the diagram below to show how the above galvanic cell should be set up in order to deliver current. Include the following:

- the symbols of the elements for both electrodes; Al left and Pb right
- the symbols of the ions present in the anode and cathode solutions; Al^{3+} and Pb^{2+}
- the chemical formula of a suitable solution for the salt bridge

(5)



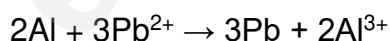
6.2 Define a *redox reaction*. (2)

A reaction involving the transfer of electrons

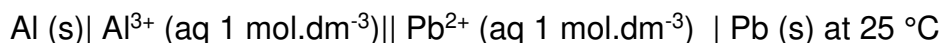
6.3 What would you observe at the anode? (1)

It will get smaller/corrode

6.4 Write the net ionic equation for the cell. (3)



6.5 Write the cell notation for the above cell. (Include state symbols and standard conditions) (3)



- 6.6 Use a calculation to determine if the light bulb will glow at the recommended brightness. (4)

$$E_{\text{cell}} = E_{\text{cathode}} - E_{\text{anode}}$$

$$= -0.13 - (-1.66)$$

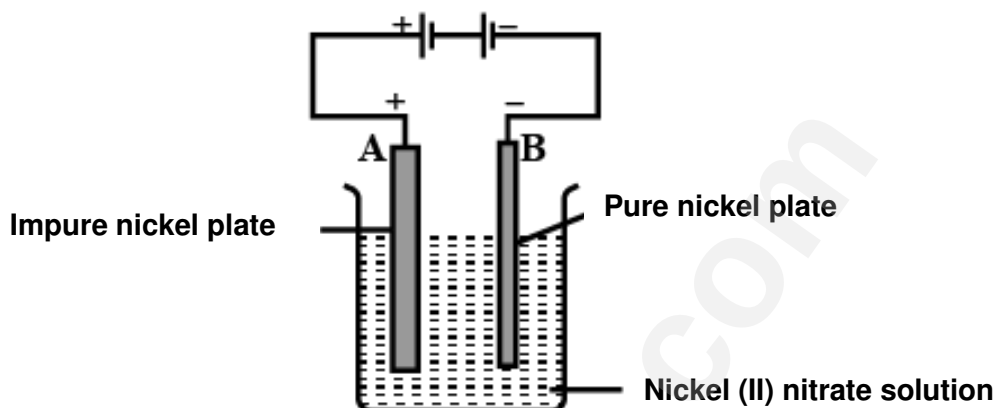
$$= 1.53 \text{ V which is higher than the } 1.5 \text{ V required}$$

yes bulb will glow

[18]

QUESTION 7

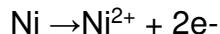
- 7.1 A electrolytic cell was set up as in the diagram below. The impure nickel plate also contains very small amounts of magnesium, silver and copper.



- 7.1.1 Define the term *electrolyte*. (2)

electrolyte as a substance that can conduct electricity by forming free ions when molten or dissolved in solution

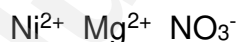
- 7.1.2 Write the half reactions that take place at the anode. (2)



- 7.1.3 Which of the metals in the impure nickel plate do not react and fall to the bottom of the beaker as anode mud? (2)

silver and copper

- 7.1.4 Which ions are present in the solution? (2)



- 7.1.5 Explain why only Ni^{2+} ions will be reduced at the cathode? (2)

Ni^{2+} ions are the stronger oxidising agent than BOTH magnesium ions and water

- 7.1.6 Calculate the mass of nickel deposited at the cathode if a current of 0,5 A in the external circuit runs for 6 minutes. (5)

$$q = It = (0.5)(360) = 180 \text{ C}$$

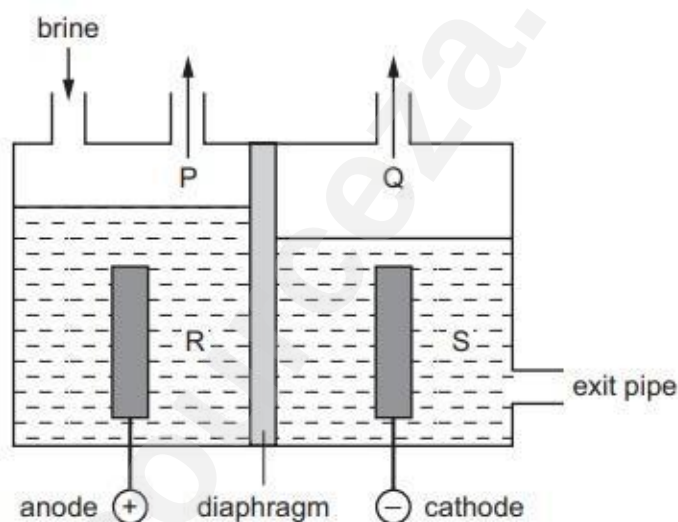
$$n = q/F = 180 / 96500 = 1.87 \times 10^{-3} \text{ mol}$$



2:1 therefore $9.32 \times 10^{-4} \text{ mol of Ni}$

$$m = nM = (9.32 \times 10^{-4}) 59 = 0.055 \text{ g}$$

- 7.2 The diaphragm cell is one of the cells used in the Chlor-Alkali industry to electrolyse a concentrated sodium chloride solution. The diagram below shows a simplified diagram of the diaphragm cell.



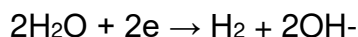
- 7.2.1 Name the gas produced at **P**. (1)

Chlorine

- 7.2.2 What is the reason for the level of the solution in the anode compartment being higher than the solution level in the cathode compartment? (2)

Solution forced to flow in one direction to reduce mixing of wrong ions at the wrong electrodes

- 7.2.3 Write the half-reaction that occurs at the cathode. (2)

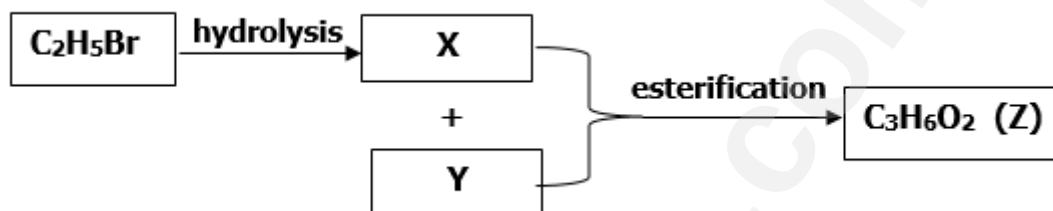


- 7.2.4 Name the advantage of using the diaphragm cell. (2)

Large quantities of sodium hydroxide and chlorine can be produced at reasonable cost

QUESTION 8

The incomplete flow diagram below gives the molecular formulae of some organic compounds.



- 8.1 Study the diagram and give the IUPAC names for the organic compounds labelled X, Y and Z. (4)

X: ethanol

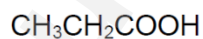
Y: methanoic acid

Z: ethyl methanoate

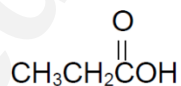
- 8.2 Describe a *functional isomer*. (2)

Compounds with the same molecular formula, but with different functional groups

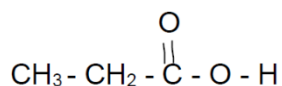
- 8.3 Write the condensed structural formula of a functional isomer of compound Z. (2)



or



or



- 8.4 Which of either compound Z or the isomer drawn in question 8.3 would have the higher boiling point? Explain your answer. (5)

Compound Z has predominantly London forces whereas the isomer has predominantly hydrogen bonding intermolecular forces.

Hydrogen bonds are stronger than London forces

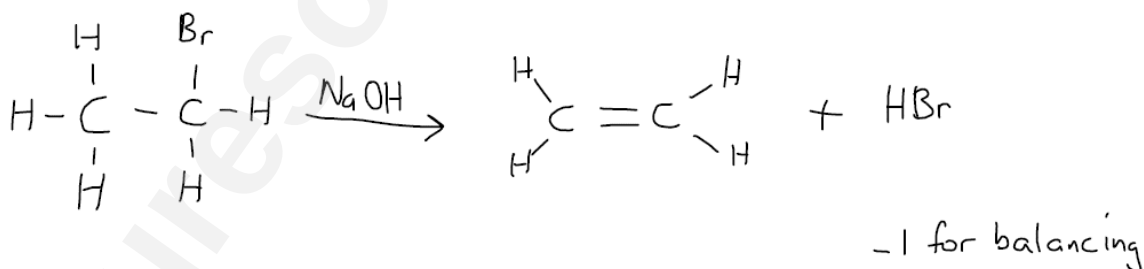
Therefore, more energy is required to overcome the hydrogen bond forces

Therefore, the isomer would have the higher boiling point

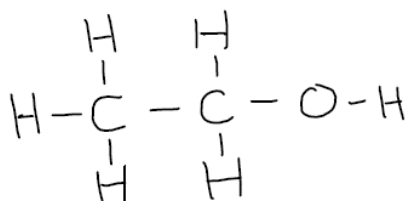
- 8.5 What additional reagent is needed for the hydrolysis of C_2H_5Br ? (2)

Dilute NaOH

- 8.6 C_2H_5Br can also be reacted with hot, concentrated sodium hydroxide in ethanol. Using structural formulae show the fully balanced equation for the reaction. (3)



- 8.7 Draw the Couper structure of ethanol. (2)

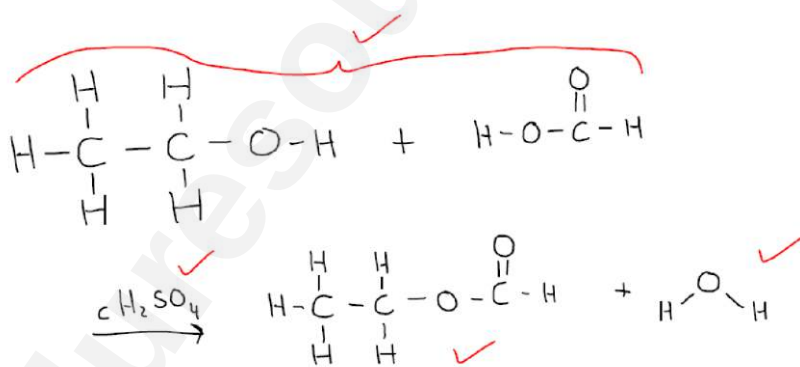


- 8.8 When compound X and compound Y are heated with concentrated sulfuric acid, they react to form compound Z.

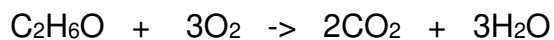
The concentrated sulfuric acid serves two functions in the reaction. Identify each of the functions and explain how it influences the reaction. (4)

Sulphuric acid is a catalyst to speed up the reaction
and as a dehydrating agent to remove water

- 8.9 Write a balanced equation using structural formulae for the esterification reaction in the above diagram. (4)



- 8.10 Compound X is burnt in excess oxygen. Using molecular formulae, write a balanced chemical equation for this reaction. (3)



- 8.11 If 28,75 kg of water is collected, determine what mass of ethanol was burnt if the original sample had a 70% purity. (6)

$$n = m/M = 28750/18 = 1597.22 \text{ mol}$$



$$1 : 3$$

$$532.41 : 1597.22$$

$$m = nM = 532.41 (12 \times 2 + 6(1) + 16)$$

$$= 24\,490.74 \text{ g}$$

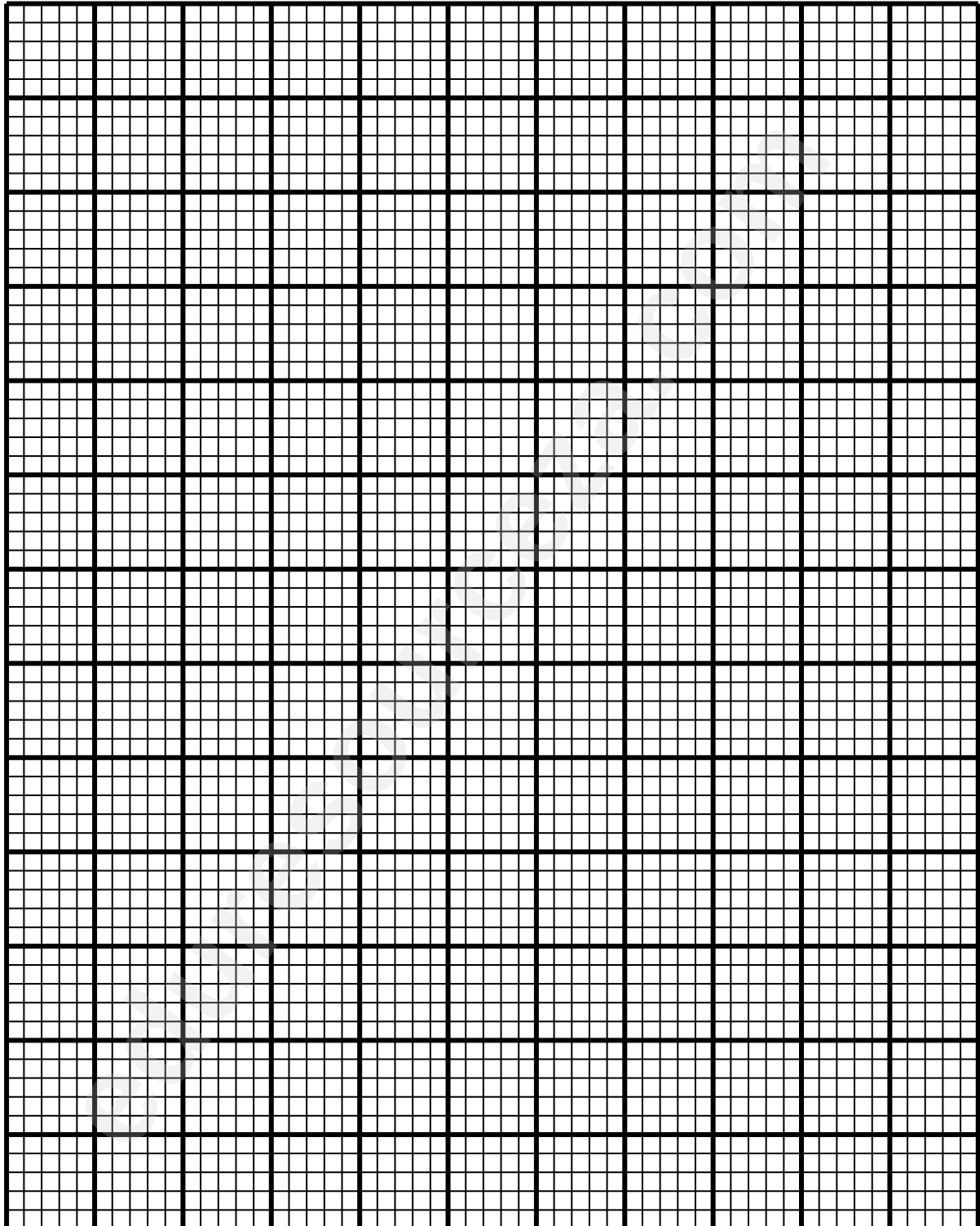
$$70\% \text{ purity} \quad 70/100 = 24\,490/x$$

$$x = 34\,986.77 \text{ g}$$

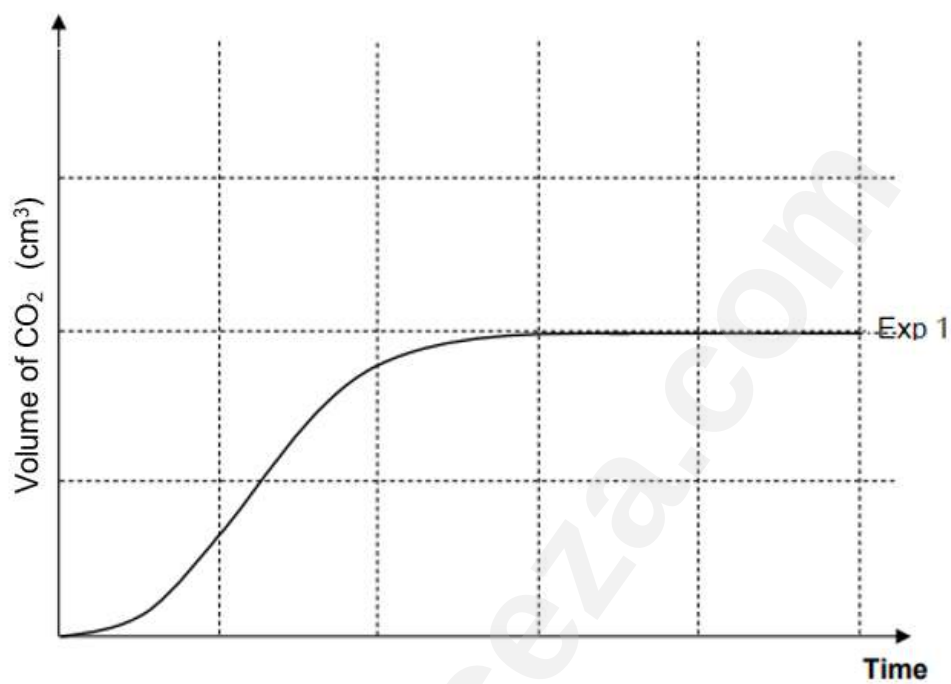
[37]

TOTAL: 200

ADDITIONAL GRAPH SHEET FOR QUESTION 3.5



ADDITIONAL GRAPH FOR QUESTION 3.8



ADDITIONAL SPACE (ALL questions)

**REMEMBER TO CLEARLY INDICATE AT THE QUESTION THAT YOU USED
THE ADDITIONAL SPACE TO ENSURE THAT ALL ANSWERS ARE MARKED.**

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ADDITIONAL SPACE (ALL questions)

**REMEMBER TO CLEARLY INDICATE AT THE QUESTION THAT YOU USED
THE ADDITIONAL SPACE TO ENSURE THAT ALL ANSWERS ARE MARKED.**

HONOUR CODE:

*On my honour as a St Stithians Pupil, I have neither given, nor received any
help on this paper; nor am I aware of any breach of the Honour Code.*

SIGNED: _____ DATE: _____