THE SCHOOL FOR EXCELLENCE 2008

UNIT 4 – CHEMISTRY

AREA OF STUDY 1 TEST
INDUSTRIAL CHEMISTRY

Reading Time: 15 minutes
Writing Time: 1 hour 30 minutes

QUESTION AND ANSWER BOOK

Structure of Booklet

Section		*Number of Questions*	*Number of Questions to be Answered*	*Number of Marks*	*Suggested Times (min)*
A	Multiple choice questions	20	20	20	30
B	Short answer questions	6	6	40	60
				Total 60	Total 90

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SECTION A

Specific Instructions For Section A

Section A consists of 20 multiple-choice questions. Section A is worth approximately 33% of the available marks. You should spend approximately 30 minutes on this section.

Choose the response that is **correct** or **best answers the question.**

A correct answer is worth 1 mark, an incorrect answer is worth no marks. No marks will be given if more than one answer is shown for any question. Marks will **not** be deducted for incorrect answers. You should attempt every question.

QUESTION 1
Consider the following reaction:

$2SO_{3(g)} \rightleftharpoons 2SO_{2(g)} + O_{2(g)} \quad \Delta H = 197\ kJ/mol$.

From this equation, it can be concluded that the formation of SO_3 from 2 mole of O_2 is an

A Exothermic process releasing 197 kJ of energy.
B Exothermic process releasing 394 kJ of energy.
C Endothermic process absorbing 197 kJ of energy.
D Endothermic process absorbing 394 kJ of energy.

QUESTION 2
Consider the following reaction: $2NO_{(g)} + O_{2(g)} \rightarrow 2NO_{2(g)} \quad \Delta H = -114kJ/mol$

The amount of energy released during the complete reaction of 1.00 L of nitrogen monoxide at 0^oC and 101.3 kPa is:

A 114 kJ
B -114 kJ
C 2.54 kJ
D -2.54 kJ

QUESTION 3
Which of the following statements **does not** describe a feature of equilibrium?

A The reaction can start either at the reactant end or the product end.
B Temperature and pressure must be kept constant if equilibrium is to be reached.
C The reaction never stops.
D Only the reactants are present in the equilibrium mixture.

QUESTION 4
Equilibrium is said to be dynamic because:

A Equilibrium reactions always occur in a fluid medium (water or gas).
B A high amount of energy is transferred during the reaction.
C Both the forward and reverse reactions continue to occur, but at the same speed.
D None of the above.

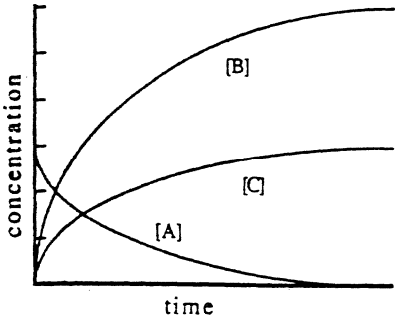
QUESTION 5
Consider the equilibrium system in aqueous solution:

$$Cr_2O_{7(aq)}^{2-} + 3H_2O_{(l)} \rightleftharpoons 2CrO_{4(aq)}^{2-} + 2H_3O_{(aq)}^{+}$$

The correct units for the equilibrium constant is:

A M^{-3}
B M
C M^{3}
D There are no units

QUESTION 6
The following diagram shows the changes in concentration for a reaction that goes to completion.



The equation for the reaction is:

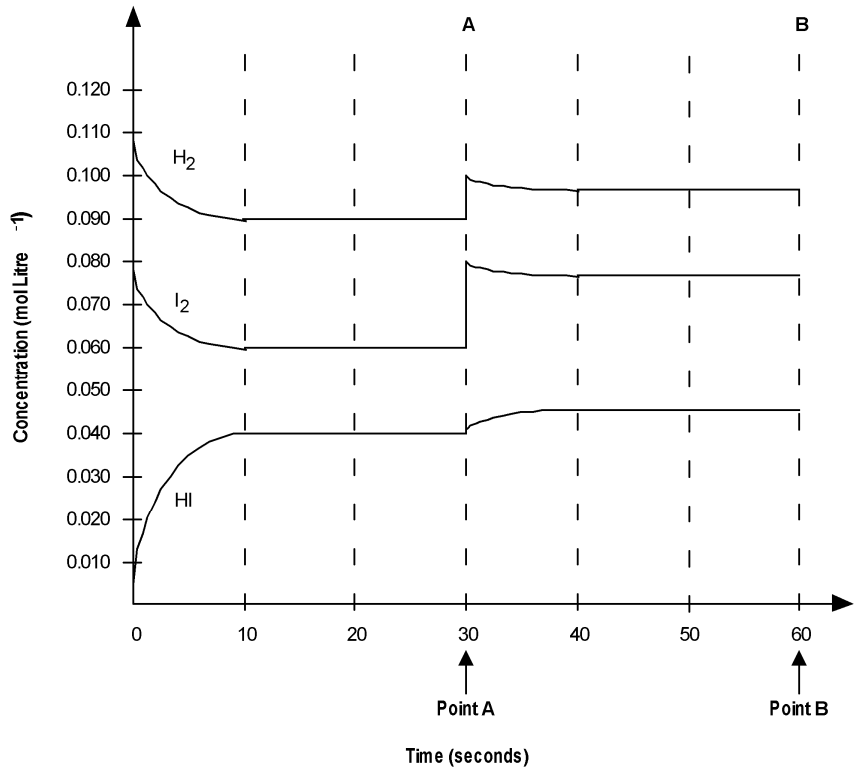
A $A + B \rightarrow C$
B $A + C \rightarrow 2B$
C $A \rightarrow B + 2C$
D $A \rightarrow 2B + C$

The following information relates to Questions 7 and 8:

The reaction between $H_{2(g)}$ and $I_{2(g)}$ in a $1.0\,L$ container was observed to be:

$$H_{2(g)} + I_{2(g)} \rightleftharpoons 2HI_{(g)} \quad \Delta H = -ve$$

During the reaction the temperature was kept at $200^{o}C$. The concentration versus time graph for this reaction was determined and is shown below.



QUESTION 7
The value of K when the system first reaches equilibrium is closest to

A 0.25
B 0.30
C 3.33
D 7.41

QUESTION 8
What change occurred at Point B?

A The volume of the vessel was decreased, changing the value of K.
B The volume of the vessel was decreased, without a change in the value of K.
C $H_{2(g)}$ and $I_{2(g)}$ were added, changing the value of K.
D $H_{2(g)}$ and $I_{2(g)}$ were added, without a change in the value of K.

QUESTION 9

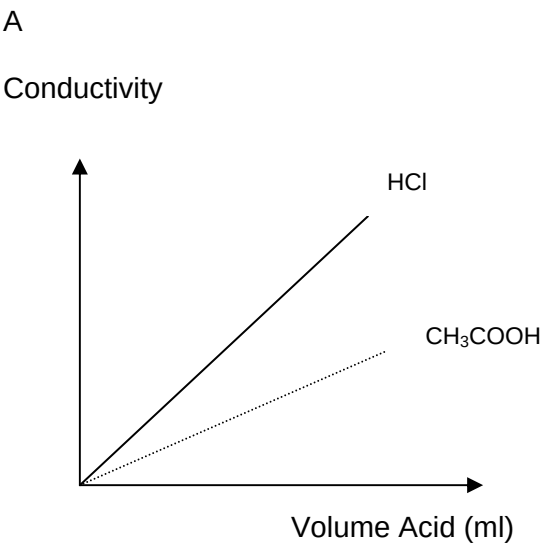
The equilibrium constants for the hydrolysis of $1\,M\ \ HCl$ and $1\,M$ acetic acid are given below.

$1\,M\ \ HCl \qquad K_{eq} = 3 \times 10^{10}$

$1\,M\ \ CH_3COOH \qquad K_{eq} = 2 \times 10^{-2}$

Equal volumes of acid are slowly added to separate beakers containing $100.00\ ml$ of water. Which of the following graphs best describes the changes in electrical conductivity for each hydrolysis reaction?

A



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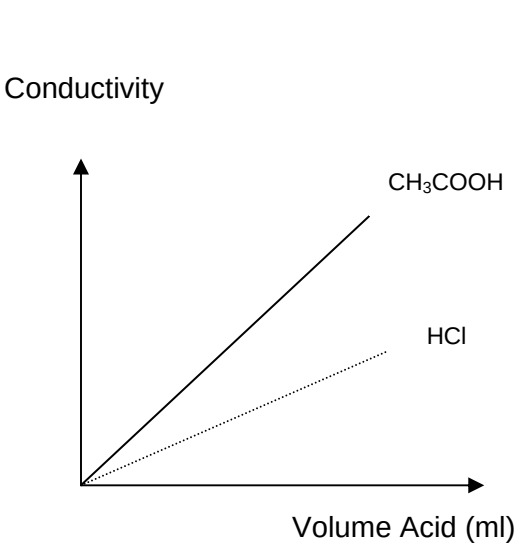

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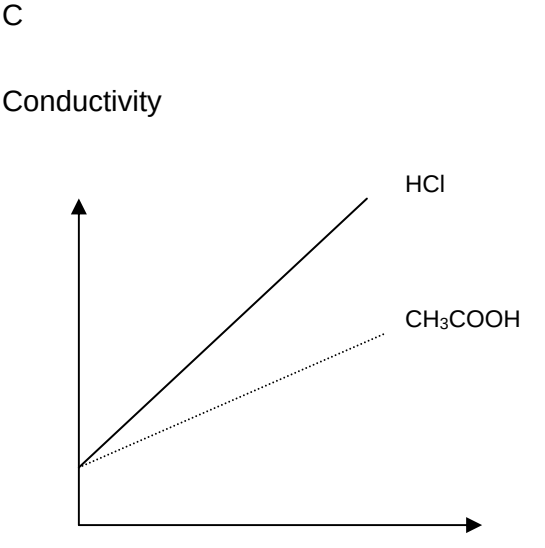
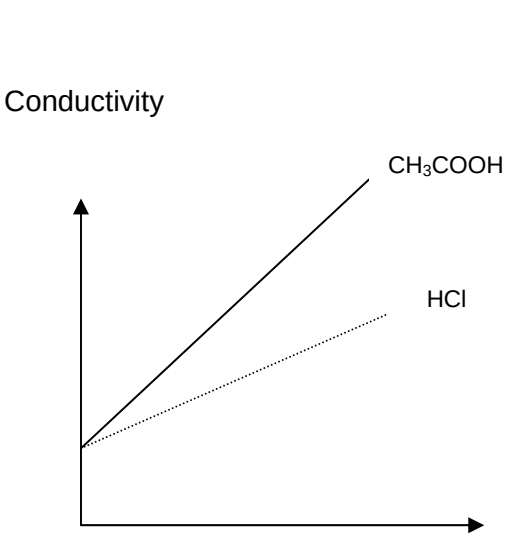
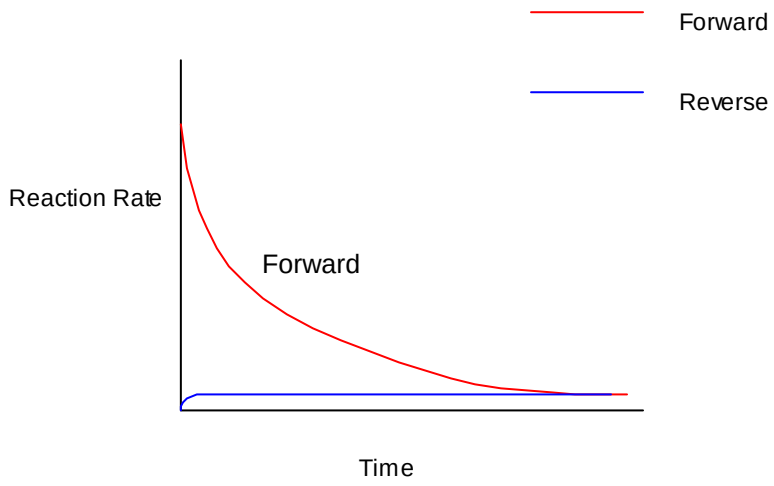


D



QUESTION 10
The following is a rate-time graph for a chemical reaction at constant temperature and volume:



The above reaction:

A Has a high equilibrium constant.
B Has not reached equilibrium.
C Has stopped.
D Will never reach equilibrium.

QUESTION 11
The reaction between copper ions and ammonia is given below.

$$Cu^{2+}_{(aq)} + 4NH_{3(g)} \rightleftharpoons Cu(NH_3)^{2+}_{4(aq)}$$

A sample was tested at various times and the concentration fraction (CF) was determined. The results obtained were as follows:

T = 5 minutes	CF = 0.58
T = 10 minutes	CF = 0.42
T = 15 minutes	CF = 0.33

$K_{eq} = 0.30$

These results indicate that:

A The position of equilibrium lies to the left.
B The position of equilibrium lies to the right.
C The system is in equilibrium at 15 minutes.
D The rates of the forward and reverse reactions are equal.

QUESTION 12
Consider the following reaction:

$$N_{2(g)} + O_{2(g)} \rightleftharpoons 2NO_{(g)} \quad \Delta H = 176 \ kJmol^{-1}$$

An increase in temperature would:

A Shift the equilibrium in favour of the reverse reaction and increase the value of K.
B Shift the equilibrium in favour of the forward reaction and decrease the value of K.
C Shift the equilibrium in favour of the forward reaction and increase the value of K.
D Cause no change to the system.

QUESTION 13
The following is an aqueous equilibrium system:

$$Cu^{2+}_{(aq)} + 4NH_{3(aq)} \rightleftharpoons Cu\left(NH_3\right)_4{}^{2+}_{(aq)}$$

If the solution is diluted by adding more water at constant temperature

A The concentration of Cu^{2+} in the new equilibrium mixture will be higher than in the initial equilibrium mixture.
B The value of K will increase.
C The amount of $Cu(NH_3)_4^{2+}$ in the new equilibrium mixture will be less than in the initial equilibrium mixture.
D The value of K will decrease.

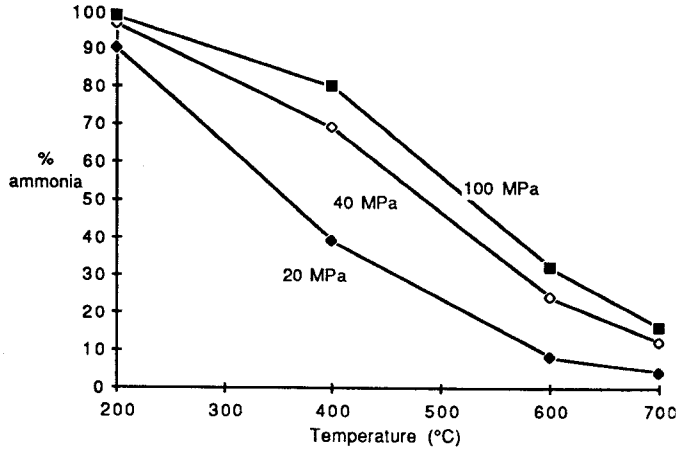
QUESTION 14
Consider the following reaction:

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$$

Addition of a catalyst to this system would:

A Upset the equilibrium permanently as the reactions would be occurring too quickly.
B Increase the yield of product.
C Increase the value of K.
D Allow the system to reach equilibrium more quickly.

QUESTION 15
The percentage of ammonia formed from its elements is plotted against temperature for three different pressures below.



Which of the following conditions would not increase the yield of ammonia?

A High pressures.
B Low temperatures.
C Addition of a catalyst.
D Decreasing the volume of the vessel in which the reaction is occurring.

QUESTION 16
The value of K_w increases with temperature because in the following equilibrium reaction:

$$H_2O_{(l)} + H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$$

A The concentration of reactants decreases because of evaporation.
B Equilibrium is achieved more quickly.
C The forward reaction is endothermic.
D The forward reaction is exothermic.

QUESTION 17
In a dilute solution of bromine in water, some of the brown molecular bromine reacts according to the following equations.

$$Br_{2(aq)} + H_2O_{(l)} \rightleftharpoons HBrO_{(aq)} + Br^-_{(aq)} + H^+_{(aq)}$$
$$HBrO_{(aq)} \rightleftharpoons H^+_{(aq)} + BrO^-_{(aq)}$$

The brown colour of the solution will fade when:

A $NaOH$ is added.
B HCl is added.
C $HBrO$ is added.
D $NaBr$ is added.

QUESTION 18
Under certain conditions, cyclohexane can react to form benzene and hydrogen according to the equation: $C_6H_{12(g)} \rightleftharpoons C_6H_{6(g)} + 3H_{2(g)} \quad \Delta H = +206\ kJ/mol$

Which two changes could be used to increase the rate of reaction?

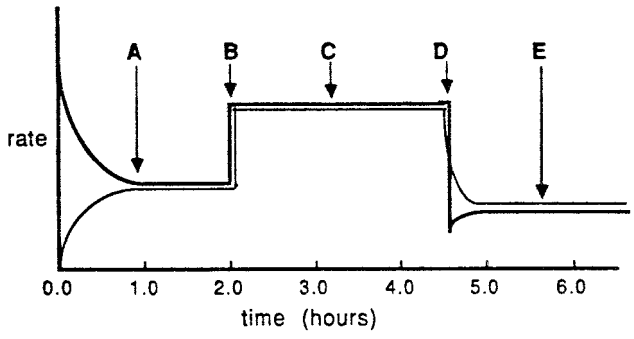
A Add a catalyst and reduce the temperature.
B Add a catalyst and decrease the pressure.
C Increase the temperature and decrease the volume.
D Add a catalyst and decrease the concentration of benzene.

QUESTION 19
The graph below shows the variation in the reaction rates for the following reactions:

$H_{2(g)} + I_{2(g)} \rightarrow 2HI_{(g)}$ (Heavy Line)
$2HI_{(g)} \rightarrow H_{2(g)} + I_{2(g)}$ (Light Line)

Which of the following changes was introduced at the 4.5 hour mark?

A A catalyst was added.
B The temperature was increased.
C The temperature was decreased.
D HI was removed.



QUESTION 20

$300\,ml$ of a $0.35\,M\ Ca(OH)_2$ solution was reacted with $300\,ml$ of $0.40\,M\ HCl$.
The pH of the resultant solution is closest to:

A 0.82
B 1.12
C 12.88
D 13.18

SECTION B – SHORT ANSWER QUESTIONS

Specific Instructions For Section B

Section B consists of six short-answer questions numbered 1 to 6; you must answer all of these questions. This section is worth 40 marks which is approximately 67 per cent of the total available marks. You should spend approximately 60 minutes on this section.

The marks allotted to each question are shown at the end of each question.

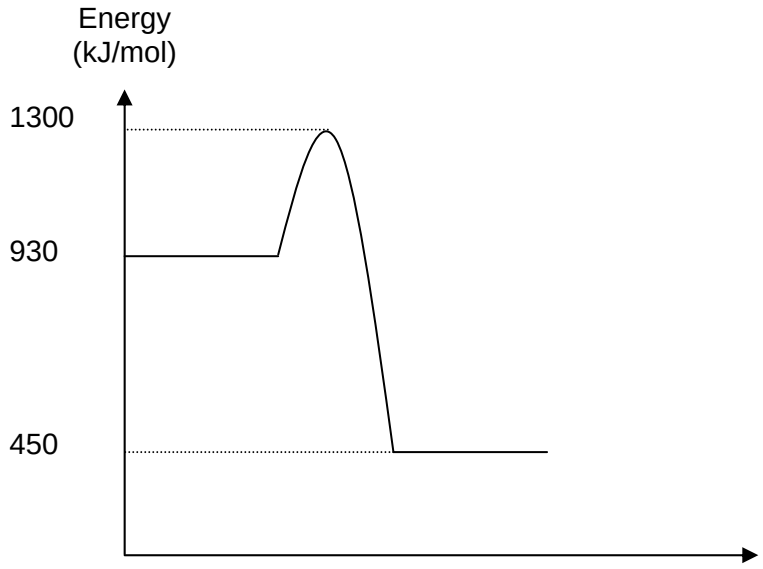
Questions must be answered in the spaces provided in this book.

To obtain full marks for your responses you should

- Give simplified answers with an appropriate number of significant figures for all numerical questions; unsimplified answers will not be given full marks.
- Show all working in your answers to numerical questions. No credit will be given for an incorrect answer unless it is accompanied by details of the working.
- Make sure that all chemical equations are balanced and that the formulas for individual substances include an indication of state (for example, $H_{2(g)}$; $NaCl_{(s)}$).

QUESTION 1

Below is the energy profile for the reaction: $2A_{(g)} + B_{(g)} \rightarrow C_{(g)}$.



a. (i) Give the value and sign of the ΔH of the forward reaction.

_____

_____

(ii) What is the Activation Energy for the forward reaction?

_____

_____

(iii) How would the addition of a catalyst affect the rate of the back reaction?

_____

_____

1 + 1 + 1 = 3 marks

b. (i) What is the Activation Energy for the reverse reaction?

_____

_____

(ii) Consider the forward reaction. Would you expect the bonds in the reactants to be stronger or weaker than the bonds within the products? Give a reason for your answer.

_____

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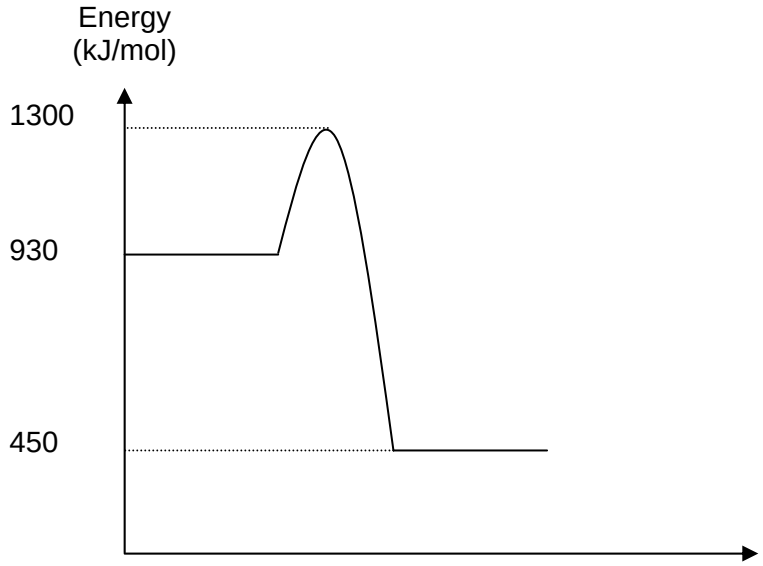
1 + 2 = 3 marks

c. On the axes below, sketch the energy changes that would occur for the reaction involving 1.00 mole of A.

$2A_{(g)} + B_{(g)} \rightarrow C_{(g)}$.



3 marks

Total Marks = 9

QUESTION 2

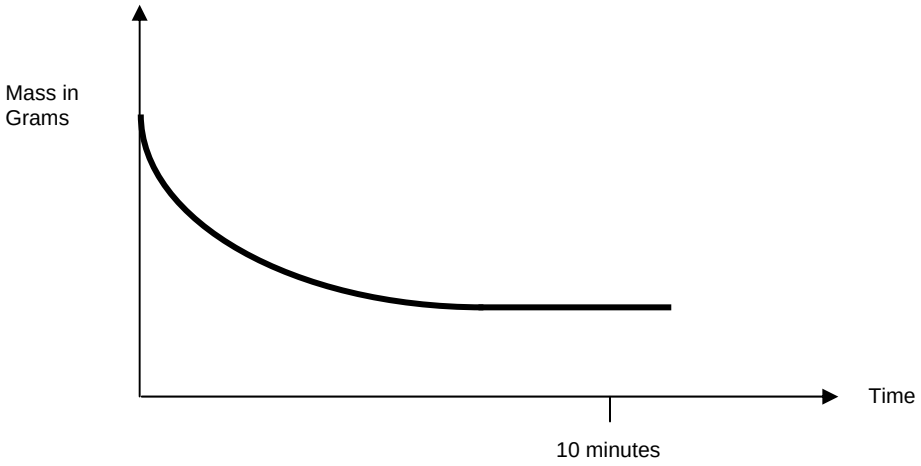
Some carbon dioxide is to be generated by reacting $50\ g$ of calcium carbonate with $200\ ml$ of $0.50\ M$ hydrochloric acid at $25^{o}C$ in an open vessel. The reaction that occurs is:

$$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$$

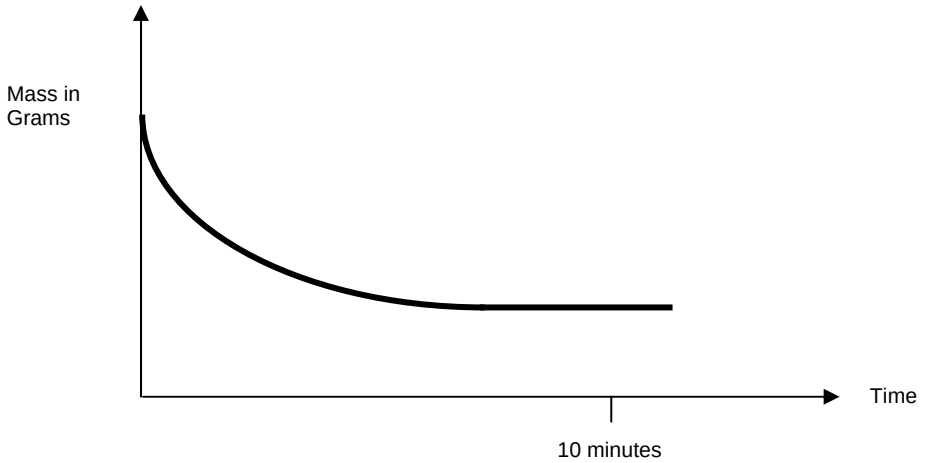
The change in mass of the vessel and its contents is recorded at 20 second intervals for the first 10 minutes of the reaction, as illustrated in the graphs below.

On the same set of axes, sketch the graph you could expect to observe if the following changes were introduced:

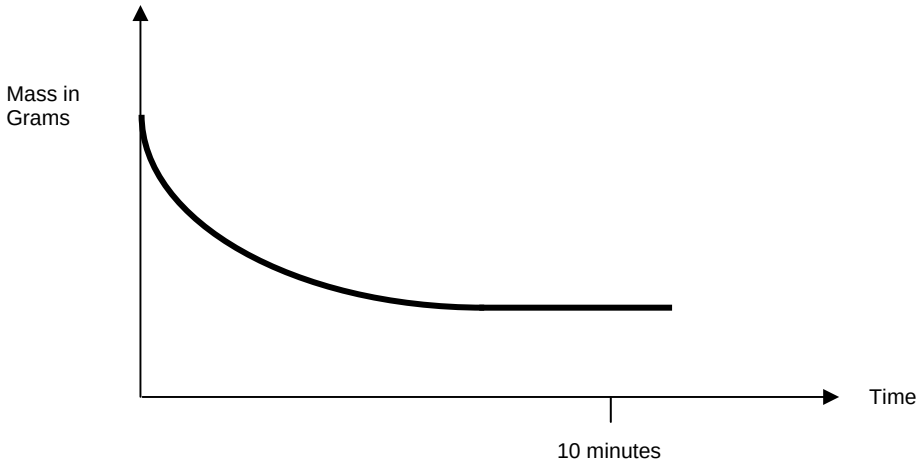
a. The calcium carbonate is ground into a finer powder.



b. The concentration of hydrochloric acid is increased to $1.0\ M$ keeping volume and temperature constant.



c. $400\ ml$ of $0.50\ M$ hydrochloric acid is used instead of $200\ ml$ at constant temperature.



2 + 2 + 2 = 6 marks

Total Marks = 6

QUESTION 3

One of the steps in the production of sulfuric acid is the oxidation of sulfur dioxide (SO_2):

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$$

2.000 mole of SO_2 and 2.000 mole of O_2 were placed in a $10.00\,L$ flask and allowed to react at a constant temperature. When equilibrium had been reached, 0.150 mol of SO_2 remained.

a. Write the equilibrium law expression for the above reaction.

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1 mark

b. Calculate the numerical value of the equilibrium constant for the forward reaction.

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3 marks

c. Calculate the numerical value of the equilibrium constant for the reverse reaction reaction at the given temperature.

1 mark

d. Briefly describe how you could experimentally determine whether the forward reaction is exothermic or endothermic.

2 marks

Total Marks = 7

QUESTION 4

There are many ways in which the pressure within a gaseous system can be changed, each resulting in different changes on the position of equilibrium. As an example, the pressure within a gaseous system can be changed by adding or removing a gaseous reactant or product, by adding an inert gas and by changing the volume of the container.

Consider the production of ethene from the cracking of ethane, which is described by the equation below.

$$C_2H_{6(g)} \rightleftharpoons C_2H_{4(g)} + H_{2(g)}$$

a. The total pressure of the system is changed by decreasing the volume of the container, keeping temperature constant.

(i) How would the position of equilibrium shift as the result of this change?

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(ii) What effect would this change have on the final equilibrium concentration of ethene? Give a reason for your answer.

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(iii) What effect would this change have on the final reaction rates? Give a reason for your answer.

_____

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1 + 2 + 2 = 5 marks

b. The total pressure of the system is changed by adding helium gas, keeping temperature and volume constant.

What change would be observed in the position of equilibrium as the result of this change? Give a reason for your answer.

_____

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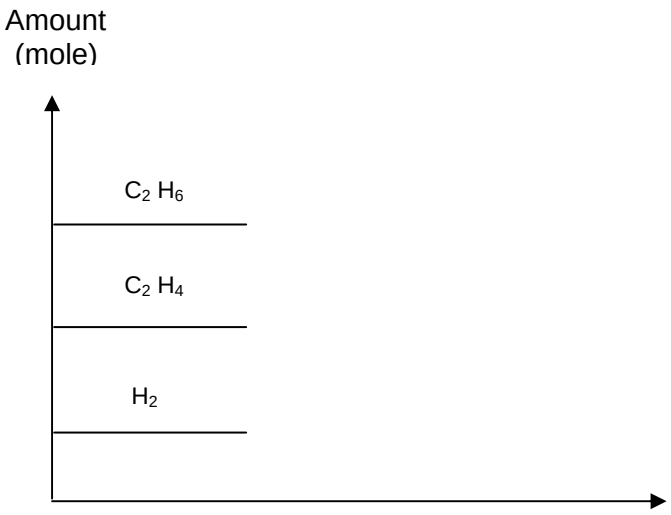
2 marks

c. The total pressure of the system is increased by adding ethane, keeping volume and temperature constant.

On the axes below, sketch the changes that would be observed to the amounts of each species as the system re-established equilibrium.



3 marks

Total Marks = 10

QUESTION 5

At 20^oC, the value of K_w is 0.680×10^{-14}.

a. Calculate the pH of pure water at 20^oC.

3 marks

b. (i) Calculate the pH of $0.00400\ M\ \ NaOH$ at 25^oC**.**

(ii) Calculate the pH of $0.00400\ M\ \ NaOH$ at 20^oC.

(iii) Hence determine whether the dissociation of $NaOH$ is an exothermic or endothermic process. Give a reason for your answer.

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2 + 2 + 2 = 6 marks

Total Marks = 9

QUESTION 6

Boric acid, H_3BO_3 was used in the old days as eyewash to treat infections. The K_a value for boric acid at 37^oC is 7.30×10^{-10}.

a. Comment on the K_a value of boric acid in terms of its strength and why it was safe to use as eyewash.

2 marks

b. (i) Calculate the pH of a $0.50\ M$ solution of boric acid.

(ii) In the calculations above, an approximation was used. Explain why it was appropriate to use this approximation in this case.

(iii) What percentage of the boric acid hydrolyses at 37^oC?

3 + 1 + 2 = 6 marks

Total Marks = 8

END OF TEST