

# Physical Sciences

TEST & EXAM PREPARATION

Retha Louw

GRADE

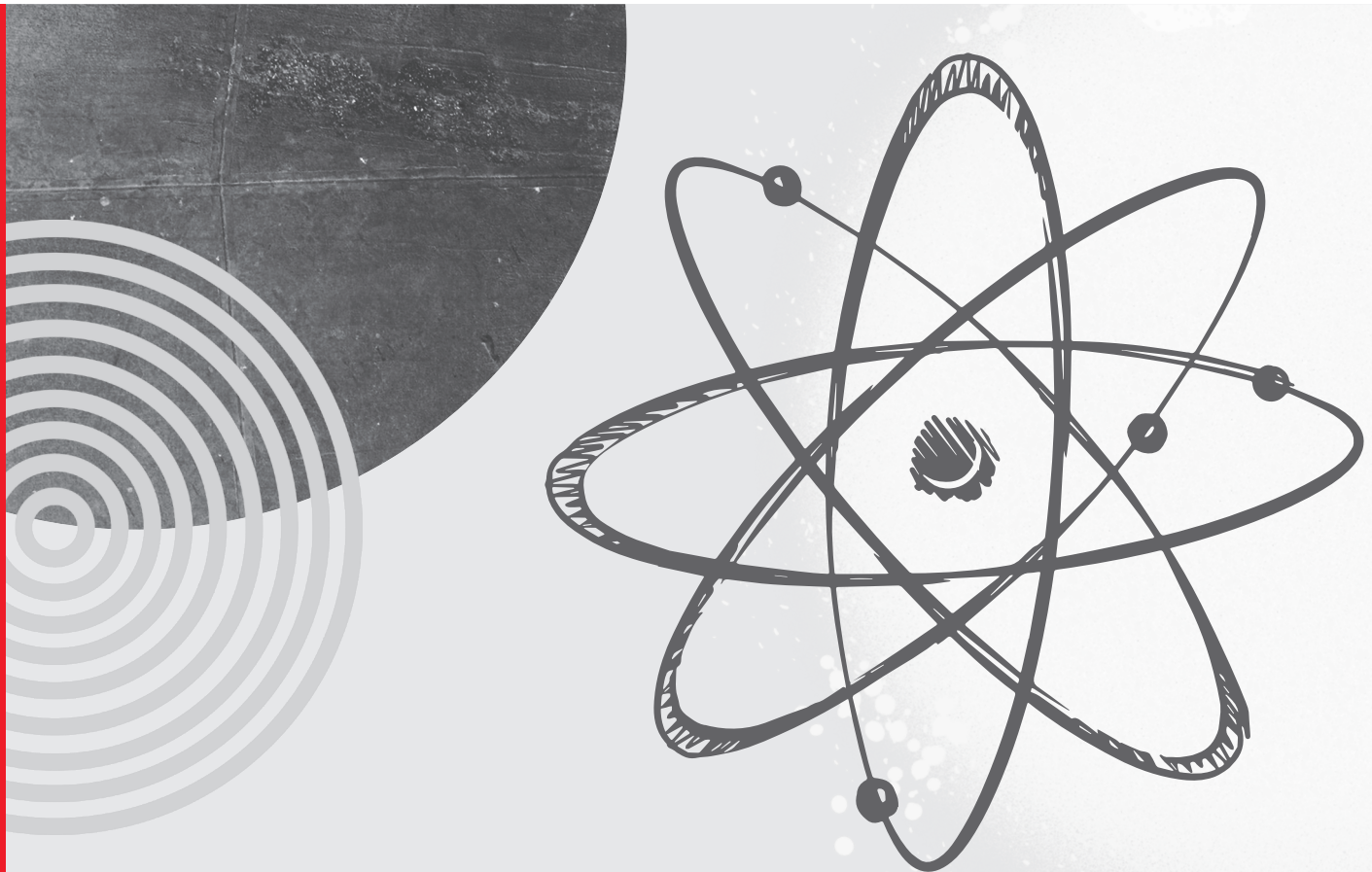
# 12

CAPS

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# Grade 12 **Physical Sciences** 2-in-1 CAPS

## TEST & EXAM PREPARATION

This Grade 12 Physical Sciences 2-in-1 book includes all Grade 12 content relevant to the matric exams. The first section of this study guide focuses on a wide range of questions and answers per topic that are graded according to difficulty. The second section contains recent National and IEB exam papers – CAPS or adapted for CAPS – to prepare learners extensively for their final matric exams.

### **Key features:**

- Carefully selected questions and detailed answers per topic
- 10 exam papers and memos, all with explanations and handy hints

This book is an invaluable tool for consolidation and understanding of the study material as a whole throughout the year, while ensuring optimum, thorough exam preparation.

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# Physical Sciences

Retha Louw

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**GRADE 12  
PHYSICAL SCIENCES  
3-in-1**

**Comprehensive notes,  
questions & answers per topic**



## THIS STUDY GUIDE INCLUDES

### 1 Questions and Answers per Topic

- Mechanics
- Matter and Materials
- Waves, Sound and Light
- Chemical Change
- Electricity and Magnetism
- Chemical Systems

### 2 Exam Papers and Memos

**E-book  
available** 

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# 4: CHEMICAL CHANGE

## Intermolecular and Intramolecular Forces

### Question 1

- 1.1 Distinguish between the terms:
  - 1.1.1 interatomic forces
  - 1.1.2 intermolecular forces
- 1.2 What is meant by:
  - 1.2.1 dipole-dipole forces?
  - 1.2.2 induced dipole forces?
- 1.3 Name the types of forces occurring between the following substances:
  - 1.3.1 CO<sub>2</sub> molecules and H<sub>2</sub>O molecules in a sample of soda water
  - 1.3.2 atoms of liquid neon
  - 1.3.3 HCl molecules
  - 1.3.4 sodium fluoride (NaF) and the H<sub>2</sub>O molecules in which it is dissolved
- 1.4 Name the most important intermolecular forces between molecules of the same type in the following substances:
 

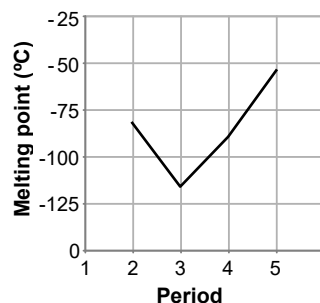
|                      |                                              |
|----------------------|----------------------------------------------|
| 1.4.1 O <sub>2</sub> | 1.4.2 CH <sub>3</sub> Br                     |
| 1.4.3 HF             | 1.4.4 C <sub>2</sub> H <sub>2</sub> (ethyne) |

### Question 2

Consider the following table and graph which displays the melting points of Group VII hydrides:

Melting points (°C)

|     |      |
|-----|------|
| HF  | -83  |
| HCl | -115 |
| HBr | -89  |
| HI  | -51  |



- 2.1 Explain why HF has a higher melting point than that of HCl.
- 2.2 Give a reason for the trend of increasing melting points in the group VII hydrides from HCl to HI.

### Question 3

Consider the following list of substances at room temperature:

- |                     |                   |                     |
|---------------------|-------------------|---------------------|
| A. CCl <sub>4</sub> | B. I <sub>2</sub> | C. H <sub>2</sub> O |
| D. NaCl             | E. HCl            |                     |

In answering the question you may use a substance more than once.

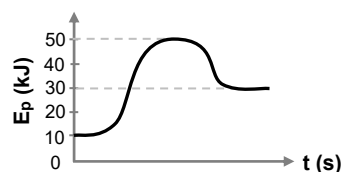
Choose from the list: (Only write down the letters.)

- 3.1 a non-polar solvent
- 3.2 a molecular solid
- 3.3 a molecular substance that will form ions when it dissolves in water
- 3.4 a substance that will dissolve well in the solvent named in Question 3.1
- 3.5 a substance with strong hydrogen bonds between its particles
- 3.6 the substance with the highest boiling point

## Energy and Chemical Change

### Question 4

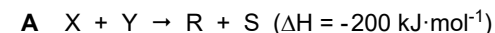
The graph shows the change in E<sub>p</sub> over time for the chemical reaction: NH<sub>4</sub>HS(g) → H<sub>2</sub>S(g) + NH<sub>3</sub>(g)



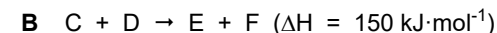
- 4.1 Calculate the heat of this reaction (enthalpy change).
- 4.2 Determine the value of the activation energy in this case.
- 4.3 What effect will the addition of a catalyst have on the value in Question 4.2?
- 4.4 Is energy released or absorbed during this reaction?
- 4.5 How much energy does the activated complex contain?

### Question 5

Study the following two reactions:



The activation energy of reaction A is equal to 350 kJ·mol<sup>-1</sup>.



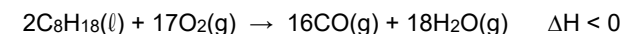
The activation energy of reaction B is equal to 600 kJ·mol<sup>-1</sup>.

Answer the following questions:

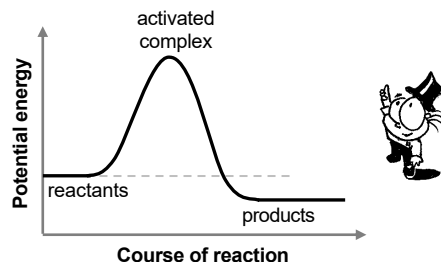
- 5.1 Are the reactions above exothermic or endothermic?
- 5.2 What is meant by the term *activation energy*?
- 5.3 What can we deduce about the rate of the reactions from the information supplied?
- 5.4 Give an equation whereby the ΔH value may be determined.
- 5.5 What can be done to reduce the amount of activation energy involved in a reaction?

### Question 6

In a limited supply of oxygen, such as in a car which is not tuned properly, octane burns incompletely to produce, amongst others, carbon monoxide. The following balanced chemical equation represents the reaction during which carbon monoxide forms:



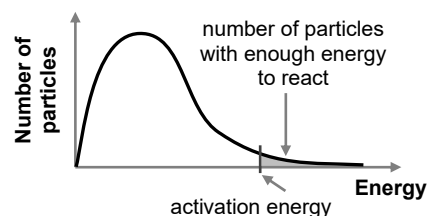
The potential energy versus the course of reaction can be represented by the following graph.



- 6.1 By comparing the activation energies of the forward and reverse reactions, explain whether it will be easier to form products from reactants or reactants from products.
- 6.2 Use the chemical equation above and give a reason why vehicles that are not properly tuned are a health hazard.
- 6.3 Redraw the graph and indicate how a catalyst will accelerate both the forward and reverse reaction.

### Question 7

A catalyst speeds up the rate of a reaction. This behaviour of a catalyst can be explained in terms of activation energy and the collision theory.



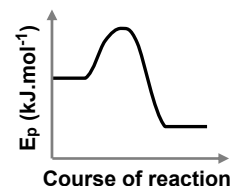
- 7.1 The diagram above shows the Maxwell-Boltzmann distribution curve for a certain reaction.
- 7.1.1 Explain in terms of the collision theory and activation energy, how a catalyst influences the rate of a reaction.
- 7.1.2 Redraw the above distribution curve and show the new activation energy on the diagram when a catalyst is added to the reaction mixture.
- 7.2 When milk is left at room temperature, it spoils rapidly. However, in a refrigerator, it stays fresh for a longer time. Use the collision theory to explain this observation.

## Rate and Extent of Reaction

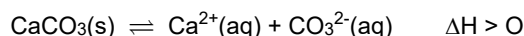
### Multiple choice questions

#### Question 8

- 8.1 Consider the accompanying graph. Which of the following reactions could be represented on the graph?



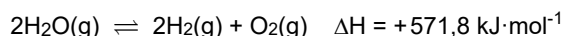
Reaction X:



Reaction Y: The combustion of methane gas.

- A Only X                      B Only Y  
C Both X and Y            D Neither X nor Y

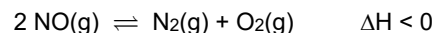
- 8.2 The decomposition of water can be represented by the following chemical equation:



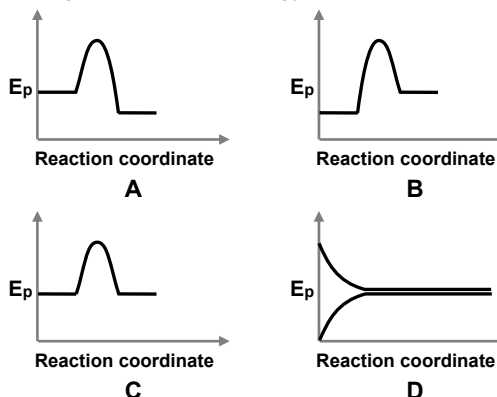
Use the chemical equation to deduce the magnitude and nature of the heat of reaction that produces 2 mol water.

- A  $\Delta H = -571,8 \text{ kJ}$                       C  $\Delta H = -1\,143,6 \text{ kJ}$   
B  $\Delta H = +571,8 \text{ kJ}$                       D  $\Delta H = +1\,143,6 \text{ kJ}$

- 8.3 Consider the following equation of an exothermic reversible reaction:



Which one of the following graphs best represents the changes in potential energy for the forward reaction?



- 8.4 The yield of  $\text{NH}_3(\text{g})$  at equilibrium in the Haber process is 40% at a certain temperature and pressure. If a catalyst is added, at the same temperature and pressure, the yield of  $\text{NH}_3(\text{g})$  would be . . .

- A 40% and obtained more rapidly.  
B 40% and obtained in the same time.  
C higher than 40% and obtained more rapidly.  
D higher than 40% and obtained in the same time.

- 8.5 Two learners, X and Y, prepared hydrogen gas in the laboratory by adding hydrochloric acid to an excess of magnesium. The equation for the reaction is:



Each learner was given the same mass of Mg and the same volume of HCl. Their results were tabulated as follows:

|           | Time (minutes)                            | 1  | 2  | 3  | 4  |
|-----------|-------------------------------------------|----|----|----|----|
| Learner X | Volume of $\text{H}_2$ (cm <sup>3</sup> ) | 20 | 30 | 35 | 35 |
| Learner Y | Volume of $\text{H}_2$ (cm <sup>3</sup> ) | 30 | 35 | 40 | 40 |

The reason for the different volumes that X and Y obtained is: Y had used:

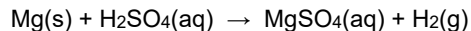
- A a catalyst.  
B a higher concentration of HCl than X.  
C powdered magnesium.  
D a higher temperature than X.

- 8.6 Hydrogen gas is prepared by reacting zinc granules with an excess of a 1 mol·dm<sup>-3</sup> hydrochloric acid (HCl) solution.

Which ONE of the following will NOT increase the rate of the reaction?

- A heating the acid  
B using zinc powder  
C using 1,5 mol·dm<sup>-3</sup> HCl solution  
D doubling the volume of the HCl solution

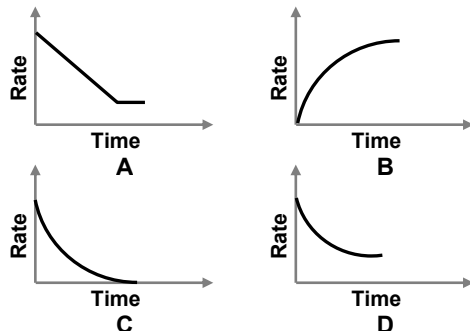
- 8.7 Consider the following reaction between magnesium ribbon and a solution of sulphuric acid:



Which ONE of the following will cause the rate of production of  $\text{H}_2(\text{g})$  to be reduced?

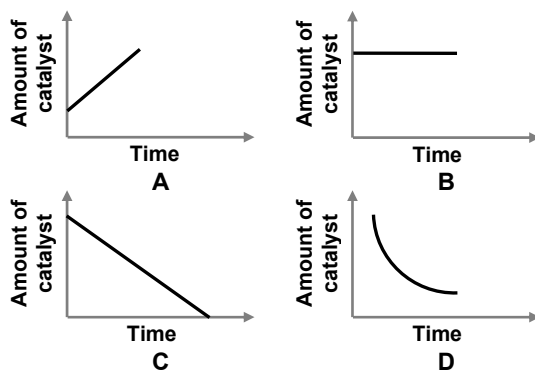
- A adding more magnesium ribbon
- B adding water to the reaction mixture
- C increasing the temperature at which the reaction takes place
- D using magnesium powder instead of magnesium ribbon without changing the mass of magnesium

- 8.8 Which ONE of the following graphs of rate of reaction versus time is typical of a reaction between an excess of hydrochloric acid and a sample of powdered magnesium?

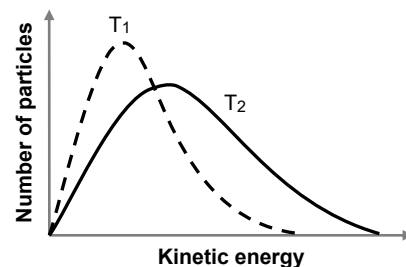


- 8.9 Vanadium pentoxide ( $\text{V}_2\text{O}_5$ ) is a heterogeneous catalyst that is used to accelerate the oxidation of  $\text{SO}_2$  gas.

Which graph best illustrates the change in the amount of  $\text{V}_2\text{O}_5$  during the chemical reaction?



- 8.10 The energy distribution diagrams for particles in a fixed mass of gas at two different temperatures,  $T_1$  and  $T_2$ , are shown below.



Which ONE of the following is the correct interpretation of the diagrams as the temperature of the gas changes from  $T_1$  to  $T_2$ ?

|   | Activation energy ( $E_A$ ) | Number of effective collisions |
|---|-----------------------------|--------------------------------|
| A | remains the same            | increases                      |
| B | decreases                   | decreases                      |
| C | decreases                   | increases                      |
| D | remains the same            | decreases                      |

### Factors that Influence Reaction Rate

#### Question 9

Define:

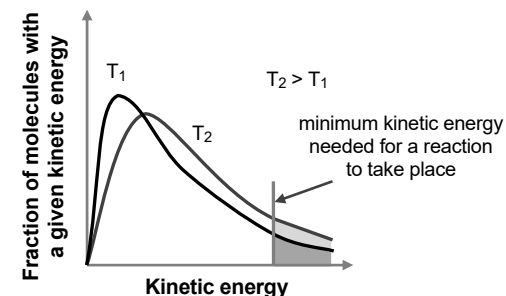
- 9.1 enthalpy                      9.2 reaction heat ( $\Delta H$ )  
 9.3 exothermic reaction      9.4 reaction rate

#### Question 10

Collision theory can be used to explain how different factors affect the rate of a chemical reaction.

- 10.1 Name TWO conditions that determine whether a collision between two molecules, A and B, will lead to a chemical reaction.
- 10.2 In general a teaspoonful of sugar dissolves much quicker in hot water than in the same amount of cold water. Will the rate of a chemical reaction always increase as the temperature increases?

- 10.3 Use the graph below and your knowledge of collision theory to answer this question.



Why does an increase in pressure speed up a reaction involving a gas? Explain your answer.

#### Question 11

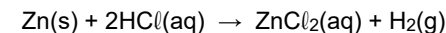
Consider the following three chemical equations in which hydrochloric acid ( $\text{HCl}$ ) of concentration  $1 \text{ mol} \cdot \text{dm}^{-3}$  reacts with zinc ( $\text{Zn}$ ) metal.

- A  $2\text{HCl}(\text{aq}) + \text{Zn}(\text{s}) (\text{chunks}) \xrightarrow{20^\circ\text{C}} \text{ZnCl}_2(\text{aq}) + \text{H}_2(\text{g})$   
 B  $2\text{HCl}(\text{aq}) + \text{Zn}(\text{s}) (\text{powder}) \xrightarrow{20^\circ\text{C}} \text{ZnCl}_2(\text{aq}) + \text{H}_2(\text{g})$   
 C  $2\text{HCl}(\text{aq}) + \text{Zn}(\text{s}) (\text{powder}) \xrightarrow{30^\circ\text{C}} \text{ZnCl}_2(\text{aq}) + \text{H}_2(\text{g})$

- 11.1 In which reaction (A, B or C) is hydrogen gas ( $\text{H}_2$ ) produced at the highest rate?
- 11.2 Give TWO reasons for your answer to Question 11.1.
- 11.3 State TWO ways, other than those mentioned in Question 11.2, of increasing the rate of hydrogen production in Reaction B.

#### Question 12

A learner places a few zinc ( $\text{Zn}$ ) granules in a test tube and covers it with dilute hydrochloric acid ( $\text{HCl}$ ). The following reaction takes place:



How would the rate at which hydrogen ( $\text{H}_2$ ) gas is formed be affected if: (Write down only **increases**, **decreases** or **remains the same**)

- 12.1 a larger volume of  $\text{HCl}$  of the same concentration is used.
- 12.2 a few pieces of copper are added.
- 12.3 the reaction takes place at a lower temperature.
- 12.4 the test tube is shaken.
- 12.5 zinc powder is used.

### Question 13

Learners perform three investigations (**A**, **B** and **C**) to study three factors which affect the rate of chemical reactions. They use the reaction between solid calcium carbonate ( $\text{CaCO}_3$ ) and excess hydrochloric acid ( $\text{HCl}$ ) solution, represented by the balanced equation below, in all three investigations.



**Excess hydrochloric acid** is used and the calcium carbonate is **completely covered** in all the investigations.

#### 13.1 Investigation A:

The learners conduct two experiments using the conditions as shown in the table below.

|        | Mass $\text{CaCO}_3(\text{g})$ | State of $\text{CaCO}_3(\text{g})$ | Conc. of $\text{HCl}$ ( $\text{mol}\cdot\text{dm}^{-3}$ ) | Temp. of $\text{HCl}$ ( $^{\circ}\text{C}$ ) |
|--------|--------------------------------|------------------------------------|-----------------------------------------------------------|----------------------------------------------|
| Exp. 1 | 2                              | powder                             | 0,2                                                       | 25                                           |
| Exp. 2 | 2                              | chunks                             | 0,2                                                       | 25                                           |

- 13.1.1 Which factor influencing reaction rate is investigated?
- 13.1.2 Write down an investigative question for this investigation.
- 13.1.3 The learners now repeat Experiment 1, but use 4 g of calcium carbonate in excess acid, instead of 2 g. They find that the rate of the reaction **increases**.  
Give a reason why the rate increases.



#### 13.2 Investigation B:

The learners conduct two experiments using the conditions as shown in the table below.

|        | Mass $\text{CaCO}_3(\text{g})$ | State of $\text{CaCO}_3(\text{g})$ | Conc. of $\text{HCl}$ ( $\text{mol}\cdot\text{dm}^{-3}$ ) | Temp. of $\text{HCl}$ ( $^{\circ}\text{C}$ ) |
|--------|--------------------------------|------------------------------------|-----------------------------------------------------------|----------------------------------------------|
| Exp. 3 | 2                              | chunks                             | 0,2                                                       | 25                                           |
| Exp. 4 | 2                              | chunks                             | 1,0                                                       | 25                                           |

- 13.2.1 Identify the independent variable in this investigation.
- 13.2.2 Write down a hypothesis for this investigation.
- 13.2.3 Is it fair to compare results obtained in Experiment 3 with that in Experiment 4? Give a reason for the answer.
- 13.2.4 The reactions in Experiments 3 and 4 both run to completion. How will the yield of  $\text{CO}_2(\text{g})$  in Experiment 3 compare to that in Experiment 4? Write down only **larger than**, **smaller than** or **equal to** and give a reason for the answer.

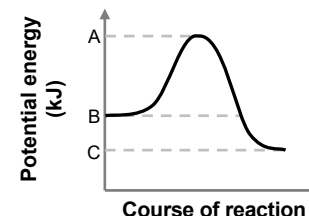
#### 13.3 Investigation C:

The learners conduct two experiments using the conditions as shown in the table below.

|        | Mass $\text{CaCO}_3(\text{g})$ | State of $\text{CaCO}_3(\text{g})$ | Conc. of $\text{HCl}$ ( $\text{mol}\cdot\text{dm}^{-3}$ ) | Temp. of $\text{HCl}$ ( $^{\circ}\text{C}$ ) |
|--------|--------------------------------|------------------------------------|-----------------------------------------------------------|----------------------------------------------|
| Exp. 5 | 4                              | powder                             | 0,2                                                       | 25                                           |
| Exp. 6 | 4                              | powder                             | 0,2                                                       | 35                                           |

- 13.3.1 How does the average kinetic energy of the particles in the reaction in Experiment 5 compare to that in Experiment 6? Write down only **higher than**, **lower than** or **equal to**.
- 13.3.2 On the same set of axes, draw sketch graphs of the number of molecules versus the kinetic energy (Maxwell-Boltzmann distribution curves) for each of Experiment 5 and Experiment 6.  
 > Label the axes.  
 > Clearly label each graph as Experiment 5 or Experiment 6.

- 13.4 The graph below shows changes in the potential energy for the reaction between calcium carbonate and hydrochloric acid.

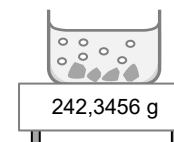


- 13.4.1 Is this reaction endothermic or exothermic? Give a reason for the answer.
- 13.4.2 Use the relevant energy values, A, B and C, to write down an expression for each of the following:  
 (a) the energy of the activated complex  
 (b)  $\Delta H$  for the forward reaction

### Reaction Rate Graphs

#### Question 14

Sharon conducts an experiment to investigate the various factors that influence the rate of chemical reactions.



She places a sample of calcium carbonate in a beaker. The beaker is placed on a sensitive balance and an **excess** of hydrochloric acid ( $\text{HCl}$ ) is added.

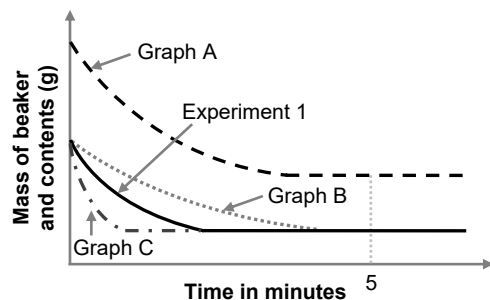
Sharon repeats the experiment a number of times under different conditions, each time with the same volume of  $\text{HCl}$  in excess.

The following table summarises the different experimental conditions of four of her experiments (numbered 1 - 4).

| Exp. no. | Mass $\text{CaCO}_3(\text{g})$ | Conc. $\text{HCl}$ ( $\text{mol}\cdot\text{dm}^{-3}$ ) | Temp. of $\text{HCl}$ ( $^{\circ}\text{C}$ ) | State of $\text{CaCO}_3(\text{s})$ |
|----------|--------------------------------|--------------------------------------------------------|----------------------------------------------|------------------------------------|
| 1        | 10                             | 2                                                      | 25                                           | granules                           |
| 2        | 10                             | 2                                                      | 15                                           | granules                           |
| 3        | 20                             | 2                                                      | 25                                           | granules                           |
| 4        | 10                             | 2                                                      | 25                                           | powder                             |

During each experiment the mass of the beaker and its contents is recorded every minute.

The graphs below indicate the changes in mass of the beaker and its contents during the reaction, as a function of time, for the four experiments:



- 14.1 Give a reason for the decrease in mass as each reaction progresses.
- 14.2 Why are all the graphs straight lines after five minutes?
- 14.3 Which ONE of the graphs A, B or C, represents the results of:
  - 14.3.1 Experiment 2
  - 14.3.2 Experiment 3
  - 14.3.3 Experiment 4

#### Question 15

- 15.1 Collision theory explains why chemical reactions occur and why they take place at different rates. Some of the terms used in collision theory and reaction rate are given below.

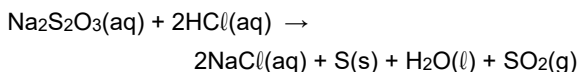
|                |              |                      |                    |
|----------------|--------------|----------------------|--------------------|
| surface area;  | catalyst;    | effective collision; | activated complex; |
| concentration; | temperature; | heat of reaction;    | activation energy  |

Give ONE term, from the list above, for each of the following descriptions. Write down only the term next to the question number (15.1.1 - 15.1.6).

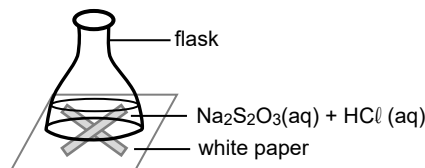
- 15.1.1 A chemical substance that speeds up the rate of a chemical reaction by lowering the net activation energy.
- 15.1.2 A collision in which the reacting particles have sufficient kinetic energy and the correct orientation.

- 15.1.3 The factor responsible for increasing the rate of a reaction when a solid is broken up into smaller pieces.
- 15.1.4 The temporary unstable state that is formed during the course of a chemical reaction.
- 15.1.5 A measure of the average kinetic energy of the particles in a gas.
- 15.1.6 The net amount of energy released or absorbed during a chemical reaction.

- 15.2 Learners use hydrochloric acid and a sodium thiosulphate ( $\text{Na}_2\text{S}_2\text{O}_3$ ) solution to investigate the relationship between rate of reaction and temperature. The reaction that takes place is represented by the following equation:



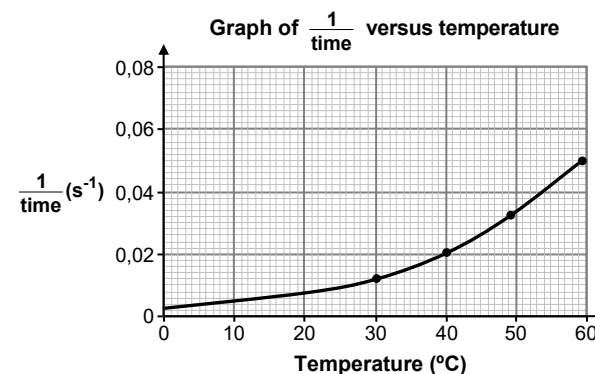
They add 5 cm<sup>3</sup> dilute hydrochloric acid solution to 50 cm<sup>3</sup> sodium thiosulphate solution in a flask. It is placed over a cross drawn on a sheet of white paper, as shown in the diagram below. The temperature of the mixture is 30°C.



They measure the time it takes for the cross to become invisible. The experiment is repeated with the temperature of the mixture at 40°C, 50°C and 60°C respectively.

- 15.2.1 Write down a possible hypothesis for this investigation.
- 15.2.2 Write down the **name** or **formula** of the product that necessitates working in a well-ventilated room.
- 15.2.3 Apart from the volume of the reactants, state ONE other variable that must be kept constant during this investigation.
- 15.2.4 Write down the **name** or **formula** of the product that causes the cross to become invisible.
- 15.2.5 Why is it advisable that the same learner observes the time that it takes for the cross to become invisible?

The graph below is obtained from the results.



- 15.2.6 What is represented by  $\frac{1}{\text{time}}$  on the vertical axis?
- 15.2.7 What conclusion can be drawn from the results obtained?

#### Question 16

Hydrogen peroxide ( $\text{H}_2\text{O}_2$ ) undergoes decomposition to form water and oxygen gas. Usually this is a slow process, but the reaction can be catalysed by using one of a number of substances.

Michael and Thembi are working on a school project to evaluate three different catalysts to see how effectively they work to bring about this decomposition. They have been asked to rank the 3 catalysts in terms of how quickly they bring about the decomposition.

The catalysts that they have been asked to evaluate are  $\text{MnO}_2$  powder,  $\text{PbO}_2$  powder and  $\text{Fe}_2\text{O}_3$  powder.

- 16.1 Formulate an appropriate hypothesis for the investigation.
- 16.2 Suggest a suitable physical quantity that Michael and Thembi will measure in order to carry out the experiment.
- 16.3 Write down a suitable method for Michael and Thembi to follow. (Use point form.)



After repeating the experiment, they get the following results:

|                                |                         |         |                                |                         |         |
|--------------------------------|-------------------------|---------|--------------------------------|-------------------------|---------|
| MnO <sub>2</sub>               | 1 <sup>st</sup> reading | 4,8 s;  | PbO <sub>2</sub>               | 1 <sup>st</sup> reading | 7,2 s;  |
| Fe <sub>2</sub> O <sub>3</sub> | 1 <sup>st</sup> reading | 11,3 s; | MnO <sub>2</sub>               | 2 <sup>nd</sup> reading | 5,2 s;  |
| PbO <sub>2</sub>               | 2 <sup>nd</sup> reading | 6,9 s;  | Fe <sub>2</sub> O <sub>3</sub> | 2 <sup>nd</sup> reading | 11,7 s; |
| MnO <sub>2</sub>               | 3 <sup>rd</sup> reading | 5,4 s;  | PbO <sub>2</sub>               | 3 <sup>rd</sup> reading | 7,1 s;  |
| Fe <sub>2</sub> O <sub>3</sub> | 3 <sup>rd</sup> reading | 11,5 s  |                                |                         |         |

- 16.4 Use the data to tabulate the results and calculate the average time taken to complete the reaction for each catalyst.
- 16.5 What observation could Thembi and Michael correctly make about the data in the table?
- 16.6 Draw a rough sketch of volume O<sub>2</sub>(g) formed versus time for each of the catalysts on the same set of axes. Clearly label each graph.
- 16.7 Write a suitable conclusion for this experiment.

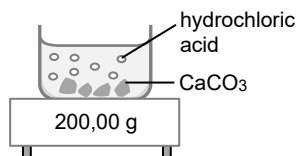
### Question 17

A certain mass of calcium carbonate chunks is added to a hydrochloric acid solution in an open beaker on a scale as shown below. The equation for the reaction is as follows:



CO<sub>2</sub>(g) is allowed to escape from the beaker. The data in the table below was obtained for a time interval of 8 minutes.

| Time (min) | Mass of beaker and contents (g) |
|------------|---------------------------------|
| 0          | 200,00                          |
| 1          | 197,50                          |
| 2          | 195,45                          |
| 3          | 193,55                          |
| 4          | 191,70                          |
| 5          | 189,90                          |
| 6          | 188,15                          |
| 7          | 186,45                          |
| 8          | 184,80                          |



- 17.1 'Rate' in science refers to something that happens in a certain time. Explain the term *reaction rate*.
- 17.2 Calculate the change in mass of the beaker and its contents during the 8 minutes.

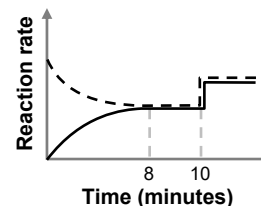
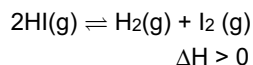
- 17.3 Use your answer to Question 17.2 to show that the average reaction rate during the 8 minutes is 1,9 g·min<sup>-1</sup> of CO<sub>2</sub> produced.
- 17.4 Calculate the mass of calcium carbonate used during the 8 minutes.
- 17.5 Use collision theory to explain how the rate of the above reaction will change when powdered calcium carbonate is used instead of calcium carbonate chunks.

## Chemical Equilibrium

### Multiple choice questions

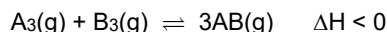
#### Question 18

- 18.1 Pure hydrogen iodide is placed in a sealed container. The hydrogen iodide reacts as follows:



Equilibrium is reached after eight minutes. After a further two minutes, a sudden change in conditions causes the rate of both the forward and reverse reactions to increase by the same amount. The reaction can be expressed by the above graph of reaction rate versus time. The change after ten minutes could have been caused by:

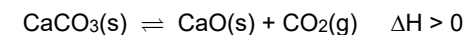
- A an increase in temperature.  
B an increase in the HI concentration.  
C a decrease in temperature.  
D an increase in pressure.
- 18.2 Consider the following hypothetical reaction at equilibrium:



What will be the effect on the number of moles of A<sub>3</sub> (n[A<sub>3</sub>]), and the volume of the system, if the temperature is doubled at constant pressure?

|   | n[A <sub>3</sub> ] | Volume           |
|---|--------------------|------------------|
| A | increases          | decreases        |
| B | decreases          | remains the same |
| C | remains the same   | remains the same |
| D | increases          | increases        |

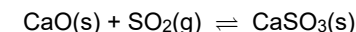
- 18.3 Consider the following chemical equilibrium:



The concentration of the CO<sub>2</sub>(g) can be increased by . . .

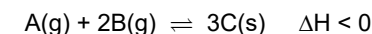
- A adding more CaO(s).  
B adding more CaCO<sub>3</sub>(s).  
C increasing the pressure.  
D increasing the temperature.
- 18.4 In the Haber process for the preparation of ammonia, N<sub>2</sub>(g) + 3H<sub>2</sub>(g) ⇌ 2NH<sub>3</sub>(g) ΔH < 0, a high yield of ammonia is obtained by using . . .
- A a high pressure.  
B a high temperature.  
C platinum as catalyst.  
D vanadium(V) oxide as catalyst.

- 18.5 Consider the equation below:



If the equilibrium concentration of SO<sub>2</sub>(g) at 25°C is equal to x mol·dm<sup>-3</sup>, the value of the equilibrium constant at this temperature will be equal to:

- A x  
B  $\frac{1}{x}$   
C x<sup>2</sup>  
D  $\frac{1}{x^2}$
- 18.6 The following hypothetical reaction is allowed to reach equilibrium in a closed container at 285°C.



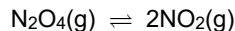
Consider the following statements about changes made to this system:

- I Removal of some C from the container will result in an increase in the K<sub>c</sub> value.  
II An increase in temperature will increase the rate of both the forward and reverse reactions.  
III Cooling the system will increase the yield of C.

Which of the above statements(s) is/are TRUE?

- A only I  
B only I and II  
C only II  
D only II and III

- 18.7 The following reaction reached equilibrium at a temperature of 313 K in a closed gas tube.

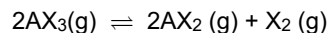


The pressure is then reduced at 313 K by increasing the volume.

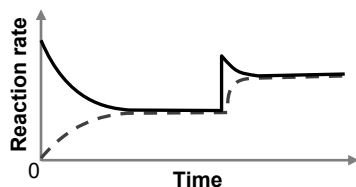
Which ONE of the following is correct?

|   | Amount<br>$\text{N}_2\text{O}_4$ | Amount<br>$\text{NO}_2$ | Change<br>in $K_c$ |
|---|----------------------------------|-------------------------|--------------------|
| A | increases                        | decreases               | remains the same   |
| B | decreases                        | increases               | increases          |
| C | decreases                        | decreases               | decreases          |
| D | decreases                        | increases               | remains the same   |

- 18.8 The decomposition reaction of a hypothetical compound  $\text{AX}_3(\text{g})$ , which is represented by the equation below, reaches equilibrium in a closed container at a temperature  $T_1$ .



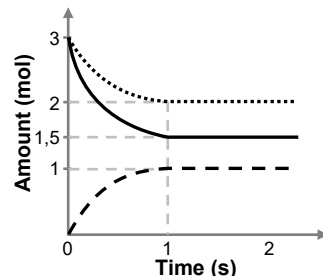
When the temperature is increased the system regains equilibrium at temperature  $T_2$ . The changes in the rate of this reaction are represented in the graph below:



Which ONE of the following statements is correct?

|   | Conclusion                  | Change in $K_c$               |
|---|-----------------------------|-------------------------------|
| A | The reaction is exothermic  | $K_c$ at $T_1 < K_c$ at $T_2$ |
| B | The reaction is exothermic  | $K_c$ at $T_1 > K_c$ at $T_2$ |
| C | The reaction is endothermic | $K_c$ at $T_1 < K_c$ at $T_2$ |
| D | The reaction is endothermic | $K_c$ at $T_1 > K_c$ at $T_2$ |

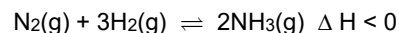
- 18.9 The graph below shows the changes in the amounts of X, Y and Z with time during a reaction.



The equation for the reaction can be represented as follows:

- A  $\text{X} + \text{Y} \rightarrow \text{Z}$       B  $5\text{X} + 3\text{Y} \rightarrow 2\text{Z}$   
C  $3\text{X} + 3\text{Y} \rightarrow \text{Z}$       D  $2\text{X} + 3\text{Y} \rightarrow 2\text{Z}$

- 18.10 Consider the following equilibrium:



Which ONE of the following changes will favour the reverse reaction?

- A decreasing the temperature  
B adding a catalyst to the equilibrium mixture  
C removing  $\text{NH}_3$  from the equilibrium mixture  
D decreasing the pressure by increasing the volume of the container

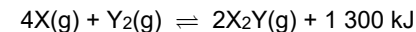
## Le Chatelier's Principle / Equilibrium Constants

### Question 19

- 19.1 Define:  
19.1.1 an open and closed system  
19.1.2 dynamic equilibrium
- 19.2 From what do you deduce that a chemical reaction has reached equilibrium? Give TWO conditions.
- 19.3 Which TWO factors may affect a chemical equilibrium consisting of  
19.3.1 gases and  
19.3.2 solutions.
- 19.4 State *Le Chatelier's principle* in words.

### Question 20

The following reaction is in equilibrium in a closed container:



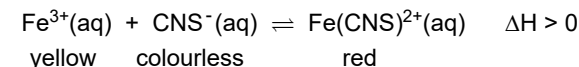
- 20.1 What does the double arrow ( $\rightleftharpoons$ ) indicate?
- 20.2 Write the value of the heat of reaction ( $\Delta H$ ) for the forward reaction.
- 20.3 Is the forward reaction **exothermic** or **endothermic**? Give a reason for your answer.

How will the amount of  $\text{Y}_2$  in the container be influenced if : (Write only **increases**, **decreases** or **stays the same**.)

- 20.4 the temperature is increased.
- 20.5  $\text{X}_2\text{Y}$  is continuously removed from the system.
- 20.6 the pressure of the system is decreased (by increasing the volume).
- 20.7 a suitable catalyst is added.

### Question 21

A few drops of  $\text{Fe}^{3+}$  solution are added to a dilute, colourless solution of potassium thiocyanate (KCNS). The following equilibrium is established:



- 21.1 Is the forward reaction exothermic or endothermic? The solution is now cooled down.
- 21.2 What will the colour of the solution be now?
- 21.3 Will the rate of the reverse reaction **increase**, **decrease** or **stay the same**, as the solution is cooled down?

For Questions 21.4 - 21.6, write only **increases**, **decreases** or **stays the same**.

- 21.4 What effect does adding a suitable catalyst have on the equilibrium concentration of  $\text{Fe}(\text{CNS})^{2+}$ ?
- 21.5 More  $\text{CNS}^-$  is added to the solution. How will this affect the equilibrium concentration of  $\text{Fe}(\text{CNS})^{2+}$ ?
- 21.6 The pressure of the system is now increased without changing the temperature. How will this affect the equilibrium concentration of  $\text{Fe}^{3+}$ ?

# CHEMICAL CHANGE

## Intermolecular and Intramolecular Forces

### Question 1

- 1.1.1 Interatomic forces are the electrostatic forces of attraction between atoms during chemical bonding, e.g. the forces between atoms involved in a covalent bond (electron-pair sharing) or between ions in an ionic bond (electron transfer and ion formation).
- 1.1.2 Intermolecular forces are the electrostatic forces of attraction that hold molecules in the fluid and solid phases together.
- 1.2.1 Dipole-dipole forces are the intermolecular forces between polar molecules. The oppositely charged sides of the dipole align/orient themselves towards each other, attracting each other with an electrostatic force of attraction.
- 1.2.2 Induced dipole forces are the intermolecular forces between non-polar molecules. A temporary dipole can be formed in a non-polar molecule due to the shifting of the electron cloud around it. It can induce a dipole in a neighbouring non-polar molecule and thus electrostatic attraction can be produced between the temporary dipoles
- 1.3.1 dipole-induced dipole forces
- 1.3.2 induced dipole forces (Van der Waals London forces or dispersion forces)
- 1.3.3 dipole-dipole forces      1.3.4 ion-dipole forces
- 1.4.1 induced dipole forces
- 1.4.2 dipole-dipole forces      1.4.3 hydrogen bonding
- 1.4.4 induced dipole forces

### Question 2

- 2.1 Fluorine is the element with the highest electronegativity. Therefore, HF molecules form stronger dipoles than HCl molecules. The smaller size of a fluorine atom enables the hydrogen atom in an adjacent molecule to get very close to it. In this way a much stronger intermolecular force, called hydrogen bonding, is produced between the molecules.

- 2.2 There is an increase in atomic number (Z) from Cl → I. Therefore, HI and HBr molecules contain more electrons than HCl molecules and so a greater separation of charge is possible, resulting in stronger dipoles and dipole-dipole forces. As the molecules increase in size, the London/dispersion forces between them increase and the melting points are higher.

### Question 3

- 3.1 A *CCl<sub>4</sub> molecules are symmetrical and non-polar.*
- 3.2 B *I<sub>2</sub> molecules*
- 3.3 E *HCl + H<sub>2</sub>O → H<sub>3</sub>O<sup>+</sup> + Cl<sup>-</sup>*
- 3.4 B *Molecular solids dissolve in non-polar solvents.*
- 3.5 C *Contains H and O which are relatively small atoms with a difference in electronegativity.*
- 3.6 D *Ionic bonds are very strong. Thus a lot of energy is needed to separate ions, ∴ the melting and boiling points are high.*

## Energy and Chemical Change

### Question 4

- 4.1  $\Delta H = H_{\text{products}} - H_{\text{reactants}} = 30 - 10 = 20 \text{ kJ}$
- 4.2 activation energy =  $50 - 10 = 40 \text{ kJ}$
- 4.3 The catalyst will reduce this value.
- 4.4 absorbed      4.5 50 kJ

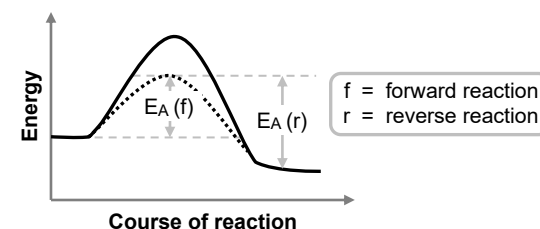
### Question 5

- 5.1 A: exothermic ( $\Delta H$  is negative)  
B: endothermic ( $\Delta H$  is positive)
- 5.2 The minimum amount of energy required to start a reaction.
- 5.3 A: activation energy ( $E_A$ ) =  $350 \text{ kJ} \cdot \text{mol}^{-1}$   
B: activation energy ( $E_A$ ) =  $600 \text{ kJ} \cdot \text{mol}^{-1}$   
Reaction A has a lower activation energy, therefore the reaction rate will be high. (More molecules in the mixture will have sufficient energy ( $E_k \geq E_A$ ) to react.)  
Reaction B has a higher activation energy, therefore the reaction rate will be relatively low. (Fewer molecules in the mixture will have sufficient energy ( $E_k \geq E_A$ ) to be able to react.)

- 5.4  $\Delta H = E_{\text{products}} - E_{\text{reactants}}$
- 5.5 By adding a catalyst, the amount of activation energy required is decreased.

### Question 6

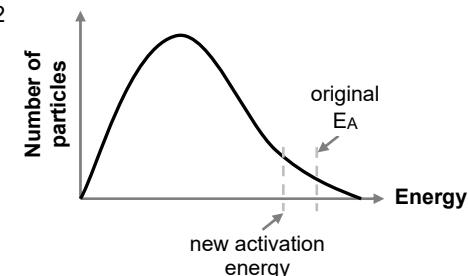
- 6.1 It is easier to form products from reactants because the activation energy for the forward reaction is less than the activation energy required for the reverse reaction, in which reactants are formed from products.
- 6.2 CO (carbon monoxide) is released and is a poisonous gas.
- 6.3



The catalyst provides an alternative route along which the reaction proceeds, decreasing the activation energy for both the forward and reverse reactions.

### Question 7

- 7.1.1 A catalyst accelerates a chemical reaction by decreasing the activation energy required. Therefore, more molecules in the reaction solution will have sufficient energy ( $E_k \geq E_A$ ) to have effective collisions.
- 7.1.2



- 7.2 The higher the temperature of milk,
- ▶ the more kinetic energy the molecules have.
  - ▶ More molecules have  $E_k \geq E_A$ .
  - ▶ ∴ more effective collisions per unit time can take place.
  - ▶ The milk will now go off sooner, because the chemical reactions of the decay-causing bacteria are taking place more rapidly.

## Rate and Extent of Reaction

### Question 8

8.1 B *The combustion of methane gas is an exothermic reaction, which corresponds with the graph.*

8.2 C *The forward reaction, during which 2 moles of water decomposes, is endothermic and absorbs  $571,8 \text{ kJ}\cdot\text{mol}^{-1}$  of heat. Therefore, the reverse reaction during which 2 moles of water is formed, is exothermic and releases  $571,8 \text{ kJ}\cdot\text{mol}^{-1}$  of heat. For 2 moles of water to be formed,  $2 \times 571,8 = 1\,143,6 \text{ kJ}$  heat is released.*

8.3 A

8.4 A *A catalyst accelerates a chemical reaction so that equilibrium can be reached more rapidly. It does not affect the equilibrium position, and therefore also not the yield.*

8.5 B

*A higher  $\text{HCl}$  concentration increases the reaction rate (see collision theory). It also has a greater number of moles of  $\text{HCl}$  molecules per unit volume and will form more products if it reacts with an excess of magnesium.*

8.6 D

8.7 B *More water dilutes the acid and fewer acid molecules per unit volume are present.*

8.8 C

*The rate of the reaction gradually decreases as the reactants decrease. The reaction stops once the magnesium is used up and now the rate is zero.*

8.9 B

*A catalyst itself does not take part in a chemical reaction; therefore, its mass remains constant.*

8.10 A

*The activation energy remains the same, but more particles have  $E_k \geq E_A$ , which increases the number of effective collisions.*

### Question 9

9.1 Enthalpy (H) is the sum of the internal energy (U) of a system plus the energy available to do work on the environment (pV). **OR**  
Enthalpy (H) is the internal energy (U) of a system plus the product of pressure and volume:  $H = U + pV$  **OR**  
Enthalpy is the heat content of the system.

- 9.2 Reaction heat ( $\Delta H$ ) is the energy released or absorbed during a chemical reaction at constant pressure.
- 9.3 An exothermic reaction is a reaction during which heat is released to the environment.
- 9.4 Reaction rate is the rate of change in the concentration/mass/volume of one of the reactants or one of the products in a chemical reaction. **OR**  
Reaction rate is a change in the concentration/mass/volume of one of the reactants or one of the products per unit time.

### Question 10

- 10.1 1) The colliding molecules should have sufficient kinetic energy ( $\geq$  the activation energy ( $E_A$ )) to overcome the repulsive forces, break the existing bonds and form new bonds.  
2) The molecules should be correctly oriented for the collision to be effective, thus resulting in a reaction.
- 10.2 Yes, the reaction rate is always higher at a higher temperature.  
If the temperature increases  
 > the velocity and average  $E_k$  of the particles increases  
 > more particles have  $E_k \geq E_A$   
 (the area under curve  $T_2$  representing the number of molecules with  $E_k \geq E_A$ , is greater)  
 > more collisions and also more effective collisions per unit time occur  
 > the rate of the reaction increases
- 10.3 With an increase in pressure  
 > the gas is compressed into a smaller volume  
 > there are more particles per unit volume, increasing the concentration ( $c = \frac{n}{V}$ )  
 > there are more collisions and therefore also more effective collisions per unit time  
 > the reaction rate increases

### Question 11

- 11.1 in C
- 11.2 Of the three reactions, reaction C takes place at the highest temperature; the Zn is in powdered form.
- 11.3 > add  $\text{HCl}$  with a higher concentration  
 > add a catalyst

### Question 12

12.1 remains the same

*The Zn is already covered by the acid; with the addition of more  $\text{HCl}$  of the same concentration, the number of  $\text{HCl}$  molecules per unit volume stays the same.*

12.2 increases

*The copper acts as a catalyst.*

12.3 decreases

*The average  $E_k$  of the molecules decreases, fewer molecules have an  $E_k \geq E_A$ .*

12.4 increases

*If it is shaken, it effectively increases the surface area of the Zn that is in contact with the acid.*

12.5 increases

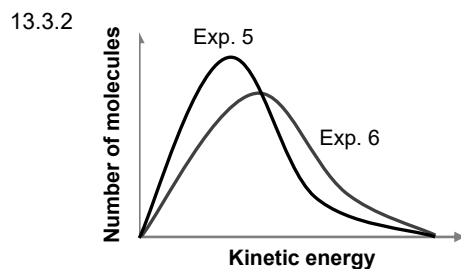
*Zn powder has a greater total contact area.*

### Question 13

- 13.1.1 State of division (of solid)/reaction surface.
- 13.1.2 How will the state of division/reaction surface/surface area of the reactants influence the rate of the reaction? **OR**  
What is the relationship between state of division/reaction surface/surface area of the reactants and reaction rate?
- 13.1.3 More  $\text{CaCO}_3$  produces a greater reaction area, and therefore, more effective collisions per unit time.
- 13.2.1 concentration (of  $\text{HCl}$ )
- 13.2.2 The higher the concentration (of the reactant/acid), the higher the rate of the reaction **OR**  
The higher the concentration, the lower the rate of the reaction. **OR**  
Reaction rate increases with an increase in concentration. **OR**  
Reaction rate decreases with a decrease in concentration.
- 13.2.3 Yes  
All other variables that could influence the reaction rate are kept constant. **OR**  
The acid is in excess, thus the volume of the acid will not affect the rate of the reaction. **OR**  
Concentration is the only independent variable.

- 13.2.4 equal to  
CaCO<sub>3</sub> is the limiting reagent and the same number of moles/mass of CaCO<sub>3</sub> reacts in both experiments.

- 13.3.1 lower than



- 13.4.1 exothermic  
Reactants at higher energy than products /  $\Delta H < 0$

- 13.4.2 (a) A (b) C - B

#### Question 14

- 14.1  $\text{CaCO}_3(\text{s}) + 2\text{HCl}(\text{aq}) \rightarrow \text{CaCl}_2(\text{aq}) + \text{H}_2\text{O}(\text{l}) + \text{CO}_2(\text{g})$   
Because CO<sub>2</sub> is a gas it escapes from the beaker.

Total mass is conserved i.e. if we kept the CO<sub>2</sub> in the same sealed container mass would not decrease.

- 14.2 The reaction is complete. *All the CaCO<sub>3</sub> has reacted.*

- 14.3.1 Graph B

Reaction takes longer to reach completion. Lower temperature decreases reaction rate. The gradient of the curve represents the reaction rate and is less steep.

- 14.3.2 Graph A

Mass is greater to start since more CaCO<sub>3</sub> is present.

- 14.3.3 Graph C

Reaction is faster because powdered CaCO<sub>3</sub> has greater surface area.

#### Question 15

- 15.1.1 catalyst 15.1.2 effective collision  
15.1.3 surface area 15.1.4 activated complex  
15.1.5 temperature 15.1.6 heat of reaction

- 15.2.1 The higher the temperature of the reaction mixture, the less the time it takes for the cross to disappear.  
**OR** If the temperature of the reaction mixture increases then the rate of the reaction increases.



*The hypothesis can also be a false statement, thus the opposites are also valid.*

- 15.2.2 SO<sub>2</sub>/sulphur dioxide/sulphur(IV) oxide

- 15.2.3 The concentrations of the reactants.

- 15.2.4 Sulphur/S

- 15.2.5 It is important that the same learner evaluates the different reactions equally and chooses the same degree of invisibility as the end point. Judgements and reactions times of different people could vary.

- 15.2.6 The rate of the reaction.

- 15.2.7 The higher the temperature of the reaction mixture, the faster the rate of the reaction.

#### Question 16

- 16.1 Fe<sub>2</sub>O<sub>3</sub> catalyses the reaction faster than PbO<sub>2</sub>, while MnO<sub>2</sub> is the weakest catalyst for the reaction. (Catalysts may be listed in any order.)

- 16.2 The volume O<sub>2</sub>(g) formed during a specified time. **OR**  
The time taken for a specific volume O<sub>2</sub>(g) to form.

*You need to consider the reactants given and the products formed in order to decide what Michael and Thembi would observe and be able to measure. H<sub>2</sub>O<sub>2</sub> is a colourless liquid, H<sub>2</sub>O is a colourless liquid, O<sub>2</sub> is a colourless gas. ∴ Because a gas is released, the evolution of that gas will be seen. They can measure the volume of gas collected in a syringe per time unit.*

- 16.3

When writing a method, identify the variables to be measured, independent and dependent. Also, the variable(s) to control to make sure this is a fair test. The independent variable is the variable you change or monitor as changing. If a graph is drawn, this is plotted on the x-axis. The dependent variable changes **because of** the change in the independent variable. This is plotted on the y-axis. Controlled variables are the variables that are identified as affecting the experiment. These must be kept the same (constant) for every experiment to ensure a fair test.

#### Method:

- Put a given volume of H<sub>2</sub>O<sub>2</sub> in a test tube.
- Add a particular mass of MnO<sub>2</sub>.

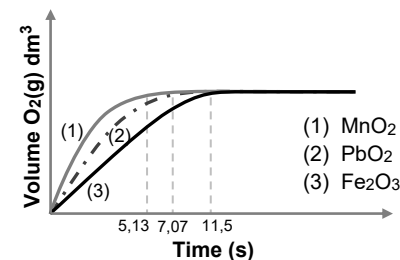
- Start the stop-watch.
- Stop the stop-watch when gas evolution stops.
- Repeat the experiment with the same volume of H<sub>2</sub>O<sub>2</sub>, and the same mass of the other 2 catalysts, at the same temperature. Use the same person to work the stop-watch. (Reaction time might vary)
- Repeat the experiment a number of times.

16.4

| Catalyst used                  | 1 <sup>st</sup> reading time in s | 2 <sup>nd</sup> reading time in s | 3 <sup>rd</sup> reading time in s | Average time in s |
|--------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-------------------|
| MnO <sub>2</sub>               | 4,8                               | 5,2                               | 5,4                               | 5,13              |
| Fe <sub>2</sub> O <sub>3</sub> | 11,3                              | 11,7                              | 11,5                              | 11,5              |
| PbO <sub>2</sub>               | 7,2                               | 6,9                               | 7,1                               | 7,07              |

- 16.5 The time taken to form a specific volume O<sub>2</sub>(g) is the shortest for MnO<sub>2</sub>, longer for PbO<sub>2</sub> and the longest for Fe<sub>2</sub>O<sub>3</sub>.

16.6



- 16.7 MnO<sub>2</sub> is the best catalyst as it catalyses the reaction the fastest, then PbO<sub>2</sub> and then Fe<sub>2</sub>O<sub>3</sub>.

#### Question 17

- 17.1 The change in amount/mass/volume of products formed per unit time. **OR**

The change in amount/mass/volume of reactants used per unit time.

- 17.2 change in mass = 184,8 - 200 = -15,2 g

- 17.3 mass CO<sub>2</sub> produced = -change in mass of the beaker  
= -(-15,2) = 15,2 g

$$\text{reaction rate} = \frac{\text{mass CO}_2 \text{ produced}}{\text{time change}}$$

$$= \frac{15,2}{8} = 1,9 \text{ g} \cdot \text{min}^{-1} \text{ CO}_2 \text{ produced}$$

17.4 mol CO<sub>2</sub> formed:

$$n = \frac{m}{M} = \frac{15,2}{44} = 0,3455 \text{ mol CO}_2$$

mol CaCO<sub>3</sub> used:

$$n(\text{CO}_2 : \text{CaCO}_3)$$

$$= 1 : 1$$

$$= 0,3455 : 0,3455$$

$$\therefore n(\text{CaCO}_3) = 0,3455 \text{ mol}$$

$$m(\text{CaCO}_3) = nM = (0,3455)(100) = 34,55 \text{ g CaCO}_3$$

**OR** From balanced equation:

44 g CO<sub>2</sub> formed from 100 g CaCO<sub>3</sub>

$$\therefore 15,2 \text{ g CO}_2 \text{ formed from } \frac{15,2}{44} \times 100 \text{ g}$$

$$= 34,55 \text{ g CaCO}_3 \text{ formed}$$

17.5 powder

- larger surface area
- more effective collisions per unit time / more molecules colliding with the correct orientation
- increase in reaction rate

## Chemical Equilibrium

### Question 18

18.1 D Both the reactants and the products are made up of 2 moles of gas molecules. Therefore, an increase in pressure will increase the rate of both reactions equally, without favouring one of the reactions.

18.2 D If the kelvin temperature of the gas is doubled at a constant pressure, the volume of the gas will also double. Because the forward reaction is exothermic ( $\Delta H < 0$ ), an increase in temperature favours the reverse reaction, which correlates with an increase in  $n(\text{A}_3)$ , but a decrease in the total moles of gas and thus also in the total gas volume in a ratio of 2:3. Therefore the net change is an increase in volume.

$$pV = nRT \therefore V = \frac{nRT}{p} \therefore V \propto nT \text{ (R and p constant)}$$

$$V_2 \rightarrow \frac{2}{3} n \cdot 2T \rightarrow \frac{4}{3} nT \rightarrow \frac{4}{3} V_1$$

18.3 D The forward reaction is endothermic and is favoured by an increase in temperature. Thereby, the  $[\text{CO}_2]$  and therefore also the  $K_c$  value are increased.

18.4 A The number of moles of products ( $\text{NH}_3$ ) formed during the Haber process is less than the number of moles of reactants ( $\text{N}_2$  and  $\text{H}_2$ ). Therefore, the forward reaction is favoured and a higher yield of ammonia is produced by an increase in pressure.

18.5 B

18.6 D A  $K_c$  value only changes with a change in temperature.

18.7 D A decrease in pressure favours the forward reaction, with more moles of gas on the product side, but the  $K_c$  value remains unchanged.

18.8 C An increase in temperature favours the forward reaction; therefore, the forward reaction is endothermic. Therefore, the new  $K_c$  value is higher.

18.9 D The ratio of the reactants : products  
 $X = 3 - 2$  ;  $Y = 3 - 1,5$  ;  $Z = 0 + 1$   
 $= 1$  ;  $= 1,5$  ;  $= 1$   
 $\therefore X : Y : Z = 1 : 1,5 : 1 = 2 : 3 : 2$

18.10 D A decrease in pressure favoured the reaction with more moles of gas, namely the reverse reaction.

### Question 19

19.1.1 An open system interacts with the environment and some of the reactants can be added to or products can escape from the system.

A closed system is isolated from the environment and the reactants or products cannot be added or escape from the system.

19.1.2 A dynamic equilibrium exists when the rate of the forward reaction is equal to the rate of the reverse reaction during a reversible reaction.

- 19.2
- the rate of the forward reaction should be equal to the rate of the reverse reaction
  - the concentration of all the reactants and products in the reaction mixture should remain constant

19.3.1 a change in temperature or pressure

19.3.2 a change in temperature or concentration

19.4 When the equilibrium in a closed system is disturbed, the system reinstates a new equilibrium by favouring the reaction that counteracts the imposed change.

### Question 20

20.1 It is a reversible reaction.

20.2  $\Delta H = -1\,300 \text{ kJ}$  **OR**  $\Delta H = -650 \text{ kJ} \cdot \text{mol}^{-1}$  of product

20.3 exothermic - heat/energy is released.

20.4 increases

An increase in temperature favours the endothermic/reverse reaction that will absorb the heat/energy that was added (Le Chatelier).

20.5 decreases

If products are removed, the forward reaction is favoured. Reactants react and form products; therefore,  $Y_2$  continually decreases.

20.6 increases A decrease in pressure favours the reaction with more moles of gas, namely the reverse reaction.

20.7 remains the same Catalyst has no effect on the equilibrium.

### Question 21

21.1 endothermic ( $\Delta H > 0$ )

21.2 yellow Temperature decrease favours exothermic/reverse reaction.

21.3 decrease Rate of both the forward and reverse reaction decreases with a decrease in temperature.

21.4 remains the same

21.5 increases Increasing the reactant concentration favours the forward reaction.

21.6 remains the same No gases present; pressure has no effect.

### Question 22

22.1 increases More effective collisions per time unit.

22.2 decreases Increase in temperature favours endothermic/reverse reaction.

22.3 decreases  $K_c = \frac{[\text{products}]}{[\text{reactants}]}$

22.4 increases Increased concentration of reactants.

22.5 increases The forward reaction is favoured and more  $\text{CO}_3^{2-}$  is formed per volume to restore the equilibrium.

22.6 no change  $K_c$  only changes with a change in temperature.

### Question 23

$$23.1 K_c = \frac{[\text{NO}]^2 [\text{O}_2]}{[\text{NO}_2]^2}$$