CHAPTER 17

Reaction Kinetics

Student Learning Outcomes

After studying this chapter, students will be able to::

- Describe collision theory in terms of number of particles per unit volume, frequency of collisions of particles, kinetic energy of particles and activation energy.
- State that catalyst increases the rate of reaction provides alternate pathway with lower activation energy, and remains unchanged at the end of a reaction.
- Describe the physical parameters that may be affected by the rate of reaction including change in mass, temperature, and formation of gas.
- Interpret data, including graphs, for investigating rate of reaction.
- Explain the effect on rate of reaction of changing concentration of a reactant, pressure of gases, surface area of solids, temperature, presence of catalyst (including enzymes) using collision theory.
- Justify the importance of chemical kinetics in the food industry to determine ideal harvesting and transportation times for produce.

Subjective Type Questions

Long Questions prepared in the light of new Examination Techniques
(Knowledge, Understanding, Application, Analytical & Conceptual)

Q.1: Describe the main points of the collision theory of reaction rate.

Ans. A reaction takes place only when the participating particles (atoms, molecules or ions) collide with one another. It has been observed that a very small fraction of collisions lead to the formation of products. In the majority of collisions the reactant particles simply bounce back without any change.

Effective Collisions:

Collisions which lead to reaction are called effective collisions.

The rate of a reaction depends upon the number of effective collisions which, in turn, depends upon the following factors.

(i) The number of particles per unit volume:

The larger the number of particles per unit volume, larger is the possibility of

effective collisions. In other words, higher the concentration of the reactants, more the number of molecules and hence more will be the number of collisions between them.

(ii) The frequency of Collisions:

A greater number of collisions per second will also result in the increase in the number of effective collisions. At higher temperature the velocities of the molecules increase resulting in the increase in the frequency of collisions. This increase in the frequency of collisions will also increase the number of successful collisions.

(iii) The kinetic energy of the particles:

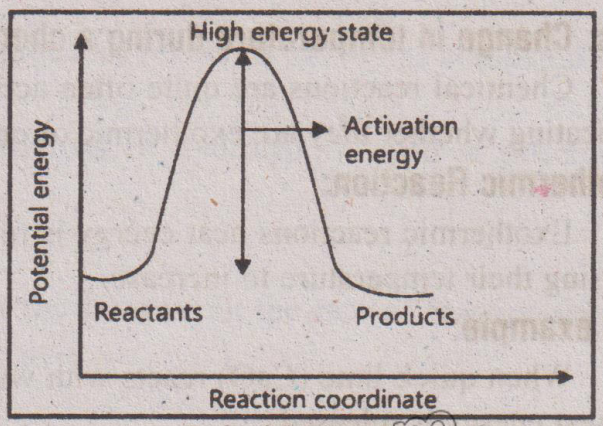
The kinetic theory of particles says that all matter is composed of tiny constant moving particles. Their motion is due to kinetic energy they possess. As the temperature increases, the kinetic energy of the particles also increases. As a result, the particles start moving fast leading to more vigorous motion. The fast moving particles will have more chances to collide with each other.

(iv) Activation energy

According to collision theory, the colliding particles will lead to effective collisions only when they possess sufficient energy to break the bonds present in the reactant molecules. This minimum energy required to start a chemical reaction is called its activation energy.

Generally, at a particular temperature, most of the molecules of the reactant possess average energy. A fraction of total molecules will, however have more than the average energy. Particles will react only when average energy of this small fraction of molecules exceeds the energy needed to activate molecules so that they can undergo a chemical reaction.

When the reactant particles come close to each other at the time of collision, they slow down and the kinetic energy they possess, is converted to increase their potential energy. This process can be understood with the help of a graph drawn between the path of reaction and the potential energy of the system. When the reactant particles possessing activation energy collide they form high energy state with the corresponding increase in the potential energy of the system. After this stage the reactants are converted into the stable products and the potential energy of the system falls down.



Path of the reaction

Q.2: Discuss how change in a mass during a chemical reaction takes place.

Ans. Change in mass during a chemical reaction:

The total mass during a chemical reaction always remains the same. This is the requirement of the law of conservation of mass which is always obeyed. However, some reactions may appear to proceed with a change in mass which can usually be explained

because a reactant or a product is a gas in such reactions.

If a reaction is carried out in an open container where gases can escape or enter, the apparent mass change can occur if a gas is either absorbed or evolved. For example, if a gas is evolved, we shall observe a decrease in mass and if a gas is absorbed, the apparent mass will increase.

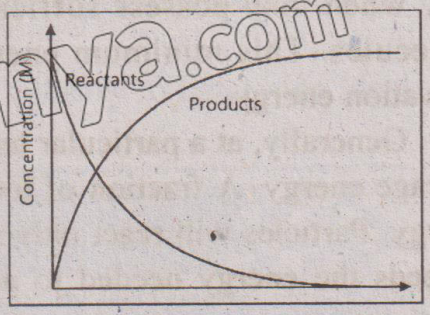
If a ribbon of magnesium is burnt in an open crucible, the mass of the product (MgO) formed will be greater than the reactant (Mg). This increase in mass has occurred due to the reaction of magnesium with oxygen present in air. However, if the two reactants (Mg and O_2) are allowed to react in a closed container, the total mass will remain the same before and after the reaction.

Formation of a gas during a chemical reaction:

If a reaction is performed between marble chips and dilute hydrochloric acid in an open container, the mass of products will apparently be less than that of reactants. This apparent decrease in mass is due to evolution of CO2 gas during the reaction which escapes into the atmosphere.

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

When a reaction moves ahead the concentrations of the reactants decrease until all the reactants are used up. At the same time, the concentrations of the products increase and reach the maximum value at the end of the reaction.



Concentration time graph

Q.3: Explain change in temperature during a chemical reaction.

Ans. Change in temperature during a chemical reaction.

Chemical reactions are quite often accompanied by the changes in the temperature indicating whether they are exothermic or endothermic.

Exothermic Reaction:

Exothermic reactions heat energy is released which is absorbed by the surrounding causing their temperature to increase.

For example:

When quick lime (CaO) reacts with water, slaked lime $Ca(OH)_2$ is formed and a lot of heat energy is released.

$$CaO_{(s)} + H_2O_{(l)} \longrightarrow Ca(OH)_{2\,(s)}$$

Endothermic Reactions:

In endothermic reactions heat energy is absorbed causing the surrounding to cool down.

For Example:

When ammonium chloride or ammonium nitrate is dissolved in water, heat energy is absorbed causing the container to cool down.

Effect of Temperature on the Rate of the Reaction:

Increasing the temperature of the reaction, increases its rate. For many reactions, the rate doubles with every 10 °C rise in temperature.

Cooking food uses high temperature to speed up chemical reactions that break down the components of food making it edible.

17.4 Factors Affecting the Rates of Reactions

17.5 Importance of Chemical Kinetics in Food Industry

Q.4: Discuss the effect of concentration of the reactions.

Ans. Effect of Concentrations of the Reactions:

In order for the reaction to occur, the reactants must come in contact with each other. For this reason, the reactions are most often carried out in one phase. For example, in liquid solutions or in gas phase.

When the reactants are present in the same phase, their particles are able to meet on the molecular level and thus are able to collide with each other easily. The higher the number of particles of the reactants per unit volume, higher will be chances of effective collisions and hence higher will be the rate of reaction.

Effect of an Increase or Dreecrease in the Concentrations of the Reactants:

An increase or decrease in concentrations of the reactants will result in increase or decrease in the rate of reaction respectively.

For Example:

- Combustion of coal in air (21% oxygen) proceeds relatively slowly as compared to the reaction in pure oxygen.
- Lime stone reacts with different concentrations of hydrochloric acid at different rates.

Experiment:

An experiment can be performed to show the increase in the rate of reaction with the increase in the concentration of hydrochloric acid.

Procedure: 1

Take a flat- bottomed conical flask fitted with a delivery tube which is connected to a syringe.

The flasks contains:

- Granules of limestone taken in excess.
- A fixed volume of one molar hydrochloric acid.

After the start of reaction carbon dioxide is generated which is collected in the syringe.

The scale present on the syringe directly measure the volume of carbon dioxide gas evolved.

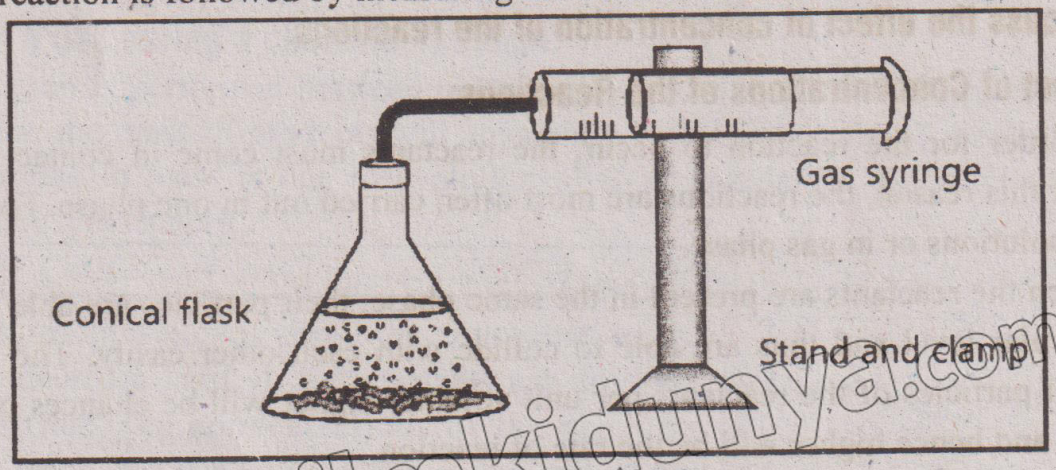
Conditions for the Experiment:

It is essential to keep all the variables constant in this experiment. For example,

- The volume of one molar hydrochloric acid.
- The temperature at which the experiment is being carried out.
- The mass and size of lime stone granules.

Measuring volume of carbon dioxide evolved:

The reaction is followed by measuring the volume of carbon dioxide gas evolved.

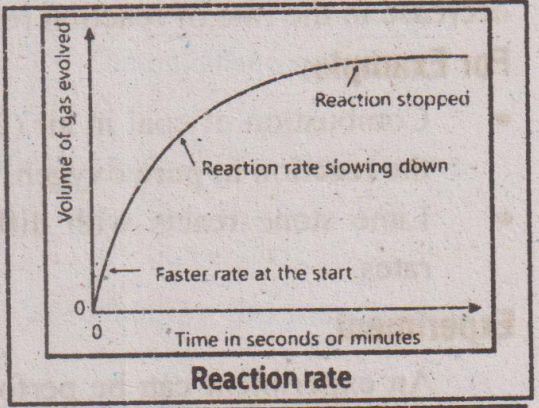


Reaction of hydrochloric acid with limestone

Rate of Reaction shown by a Graph:

The change in the rate of reaction is then seen when a graph is drawn between the time in seconds or minutes against the volume of gas evolved

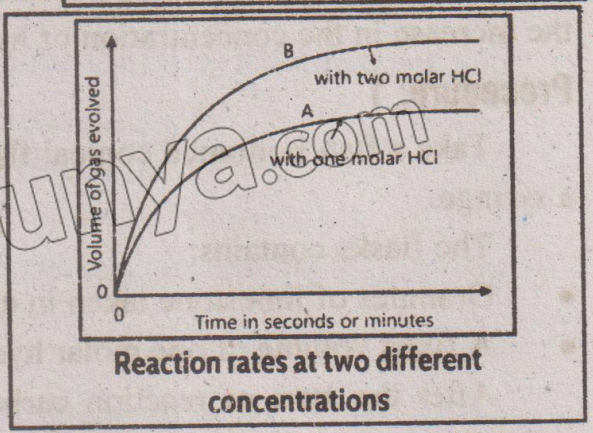
The graph obtained is in the form of a curve. We can measure the rate of reaction during a time interval by drawing a tangent on this curve. The results show that the reaction starts with a very fast rate which then progressively slows down as the concentration of hydrochloric acid decreases. After a while the reaction stops because the whole of hydrochloric acid has been utilized.



Reaction rate

The two curves A and B represent two separate experiments done with one and two molar concentrations of HCl respectively.

The greater the concentration, the steeper is the curve at the start of the experiment which means faster rate of reaction.



Reaction rates at two different concentrations

The more concentrated is the acid, the more are the chances of effective collisions.

Q.5: Discuss the effect of temperature at which a reaction is carried out.

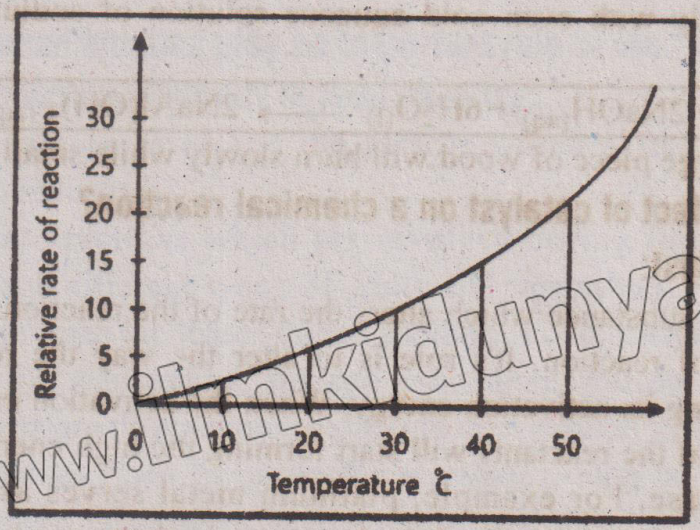
Ans. Everyday Observation:

It is an everyday observation that the rates of chemical reactions increase with increase in temperature.

Examples:

- Food cooks faster at higher temperatures than at lower ones.
- The oxidation of iron is very slow at room temperature but proceeds very fast at high temperature.

In many cases the rate of reaction is nearly doubled when the temperature is increased by 10 °C.



Rise in rate of reaction with temperature

The graph shown in the figure explains this rapid increase in the rate of reaction with the rise in temperaturre.

According to the Collision Theory

According to the collision theory, the rate of reaction depends upon the frequency of successful collisions between reactant molecules.

As the temperature of a reaction is increased, the kinetic energy of the participating reacting particles also increases. This, in turn increases the velocities of their movements. As a result the collisions which lead to the occurrence of reactions also increase, enhancing the rate of reaction.

Q.6: Explain the following factors affecting the rate of reaction:

(a) Reactants present in gas phase.

(b) Effect of surface area of solids.

Ans. (a) Reactants present in gas phase:

If reactants in a reaction are present in gas phase, their concentration can be changed by changing their pressure. For example, the rate of reaction between hydrogen

and chlorine can be doubled if the pressure of chlorine gas is double provided the other component hydrogen is present in excess.

(b) Effect of surface area of solids:

Reactions involving solids take place on their surfaces and the rates of their reactions depend to a great extent on the area of the surface contact between them. The larger the surface area of the solids, the more is possibility of their particles to come in contact with each other and the higher is the rate of reaction. Finely divided solids, because of the greater surface area available, react more rapidlly than do large pieces of the same substances.

For examples: Aluminum foil reacts with warm sodium hydroxide but in finely divided state it reacts rapidly with even cold aqueous solution of sodium hydroxide evolving hydrogen gas.

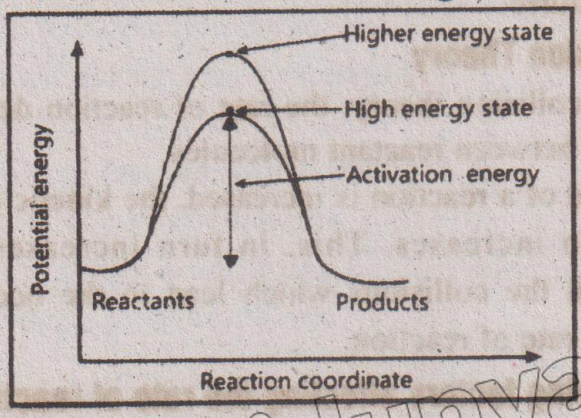
$$2Al_{(s)} + 2NaOH_{(aq)} + 6H_2O_{(l)} \longrightarrow 2NaAl(OH)_{4\,(aq)} + 3H_{2\,(g)}$$

Similarly, a large piece of wood will burn slowly while small pieces burn rapidly.

Q.7: Explain the effect of catalyst on a chemical reaction?

Ans. Effect of catalyst:

A catalyst is a substance which alters the rate of the reaction but it is not consumed during the course of reaction. It's role is to alter the way the reaction takes place by substantially lowering its activation energy. When the activation energy is lowered, more and more particles of the reactants will start forming the high energy state and the rate of reaction will increase. For example, platinum metal serves as a catalyst during the addition of hydrogen in ethene. Both hydrogen and ethene are known to adsorb on the surface of platinum metal and the bonds, present in them, get weakened. Thus, the surface of metal helps the reactant molecule to react together.



Path of reaction with or witought the presence of catalyst

In the presence of a catalyst, the activation energy is sufficiently lowered allowing more and more molecules to react together.

Q.8: Write briefly about the role enzymes play in our body as biological catalysts.

Ans. Enzymes:

Enzymes are biological catalyst.

Role of enzymes:

These are basically protiens which help to speed up specific chemical reactions taking place in our body.

Explanation:

Enzymes react with the reactant molecules using the active sites present in them. Once bound with the reactant molecule the particular bonds in the reactant molecule are sufficiently weakened for the reaction to take place. The product formed then dissociates itself from enzyme which is then free to bind another reactant molecule. The active sites present in enzymes are very specific such that a particular enzyme can catalyze a specific reaction only.

Q.9: How does chemical kinetics play an important role in the food industry?

Ans. Importance of chemical kinetics in food industry:

The study of reaction rates and the factors which affect these rates play an important role in food industry.

The rates of chemical reactions which are involved during food ripening and food spoilage are studied for different types of fruits and vegetables. The information thus obtained is used to minimize the losses due to spoilage. Food scientists can determine the optimum conditions for harvesting, storage and transportation of food products by studying the rates of enzymatic reactions, oxidation or microbial growth.

Fruits and vegetables ripen owing to the reactions which involve enzymes. These reactions convert starches into sugars, soften tissues and develop characteristics flavour and colours. With the help of rates of these enzymatic reactions, farmers can predict when the product will reach at its peak quality and ready for harvesting. For example, the rate of production of ethene during ripening can be monitored to determine the best time to harvest the fruits.

Some enzymes which are naturally present in foods can spoil the foods which then undergo changes in texture, flavour and nutritional value. Again understanding the rates of these enzymatic reactions will allow us to plan how to stop this spoilage.

For example, if a fruit is known to degrade rapidly during transportation or storage owing to high temperature, refrigeration can be employed to prevent rapid spoilage.

17.1 Quick Check!

1. How will you increase the frequency of collisions?

Ans. The frequency of collisions can be increased by:

- Increasing temperature
- Increasing concentration
- Increasing pressure (for gases)

2. What happens to the reactant particles after collision?

Ans. After collisions, one of two things happens:

- A very small fraction of collisions lead to the formation of products.
- The reactant particles simply bounce back without any change.

17.2 Quick Check!

1. Why a catalyst is mostly used in finely divided from?

Ans. A catalyst is used as a fine powder (finely divided) to increase its surface area. a larger surface area provides more "active sites" where reactant molecules can absorb and react which significantly speeds up the reaction compared to using a single large piece of catalyst.

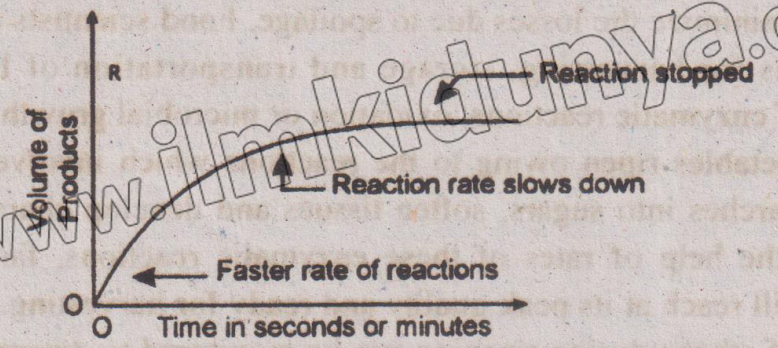
2. How do you increase the number of succesful collisions?

Ans. Succeful (effective) collisions are increased by:

- **Adding a catalyst:**
  This lowers the activation energy, allowing greater fraction of particles to have enough energy to react.
- **Increasing Temperature :**
  This provides more particles with the minimum required activation energy.

3. How does the concenctrations of the products change during reaction? Explain with the help of a graph.

Ans. At the start of a reaction, the concentration of reactants is high, while the concentration of proeducts is zero. The reaction starts with a very fast rate. As the reaction proceeds, the concentration of products increases rapidly. Over time, as reactants are consumed, the rate of product formation slows down because the whole of the reactants have been utilized.



17.3 Quick Check!

1. How would you determine the best time of fruit harvestrng?

Ans. The best time of fruit harvesting is determined by monitoring the rate of production of ethane during ripening. By understanding the kinetics of the enzymatic reactions that convert starches to sugars and change fruit texture, farmers can harvest when the fruit is at its peak quality for transport or consumption.

2. Why some fruits and vegetables get destroyed early during summer than during winter.

Ans. Chemical and enzymatic reactions follow the rule that reaction rates increase with temperature.
In summer, the high ambient temperature speeds up the rates of oxidation and microbial growth, leading to rapid spoilage.
In winter, the lower temperatures act like natural refrigeration, slowing these kinetic processes down.

THINGS TO KNOW

- Understanding kinetics helps us to control the reaction conditions in order to speed up or slow down reactions as needed.

INTERESTING INFORMATION

- Understanding the kinetics of oxidation reactions of fats helps to prevent spoilage of butter.

INTERESTING INFORMATION

- Enzyme based biosensors are used to detect glucose in blood.

INTERESTING INFORMATION

- Kinetics helps us to increase the yield of a reaction and minimize the waste.

Objective Type Questions

Additional MCQ's

Multiple Choice Questions prepared in the light of new Examination Techniques
(Knowledge, Understanding, Application, Analytical & Conceptual)

17.1	Collision Theory of Reaction Rate
17.2	Change in Mass during a Chemical Reaction
17.3	Change in Temperature During a Chemical Reaction

1. According to collision theory, what are collisons that result in the formation of products called?

(a) Random Collsions (b) Effective Collisions
(c) Elastic Collisions (d) Frequent Collsions

2. The minimum energy required to start a chemcial reaction known as?

(a) Thermal energy (b) Kinetic energy
(c) Activation energy (d) Potential energy

3. What typically happens to the rate of many reactions for every 10 °C rise in temeprature?

(a) It doubles (b) It halves (c) It stays the same (d) It triples

4. Which types of reaction releases heat energy into the surroundings?

(a) Neutralization (b) Exothermic (c) Endothermic (d) Decomposition

5. What happens to the concentration of products as a reaction moves toward completion?

(a) It stays constant (b) It decreases
(c) It increases (d) It becomes zero

6. **Dissolving ammonium chloride in water makes the container feel cold. This is example of a/an:**
   (a) Fast reaction (b) Activation reaction
   (c) Endothermic reaction (d) Exothermic reaction
7. **When CaO (quick lime) reacts with water, what happens to the temperature?**
   (a) It remains at 0 °C (b) It increases
   (c) It decreases (d) It fluctuates randomly
8. **How does increasing the concentration of reactants (particles per unit volume) affect the reaction rate?**
   (a) It increases the rate (b) It increases activation energy
   (c) It has no effect on the rate (d) It decrease the rate.

17.4 Factors Affecting the Rates of Reactions

17.5 Importance of Chemical Kinetics in Food Industry

9. **Which form of a solid reactant will react the fastest with a liquid?**
   (a) Finely divided powdered (b) A few medium-sized lumps
   (c) One large crystal (d) A flast sheet of the solid
10. **What happens to a catalyst at the end of a reaction?**
   (a) It is completely used up (b) It remains chemically unchanged
   (c) It is turned into a product (d) It evaporates
11. **Enzymes are best described as:**
   (a) Products of spoilage (b) Biological Catalyst
   (c) Inorganic reactants (d) Temperature inhibitors
12. **What process do enzymes catalyze to ripen fruits?**
   (a) Freezing the fruit tissue (b) Conversion of starches into sugars
   (c) Conversion of sogars into starches (d) Increasing the oxygen content
13. **Enzymes are best described as:**
   (a) Products of spoilage (b) Biological catalysts
   (c) Inorganic reactants (d) Temperature inhibitors
14. **Which gas production rate can be monitored to deteremine the best time for fruit harvasting?**
   (a) Ethene (b) Nitrogen (c) Hydrogen (d) Carbon monoxide
15. **In many cases the rate of reaction is double when the temperature is increased by:**
   (a) 10 °C (b) 20 °C (c) 30 °C (d) 40 °C

Answers

1.	(b)	2.	(c)	3.	(a)	4.	(b)	5.	(c)	6.	(c)	7.	(b)
8.	(a)	9.	(a)	10.	(b)	11.	(b)	12.	(b)	13.	(b)	14.	(a)
15.	(a)												

Additional Short Questions

Short Answer Questions prepared in the light of new Examination Techniques
(Knowledge, Understanding, Application, Analytical & Conceptual)

17.1	Collision Theory of Reaction Rate
17.2	Change in Mass during a Chemical Reaction
17.3	Change in Temperature During a Chemical Reaction

1. Define rate of reaction.

Ans. Rate of reaction:

Rate of reaction is the speed at which the reaction takes place.

2. What is the basic requirement of collision theory for a reaction to occurs.

Ans. According to the theory, a reaction takes palce only when the participating particles (atoms, molecules or ions) collide with one anotehr.

3. What are "effective collisions"?

Ans. Collisions which lead to reaction are called effective collisions.

4. How does the number of particles per unit volume affect the reaction state?

Ans. The larger the number of particles per unit volume, larger is the possibility of effective collisons and a faster reaction rate.

5. What is the effect of temperature on the frequency of collisons?

Ans. At higher temperature the velocities of the molecules increase resulting in the increase in the frequency of collisions.

6. How does kinetic energy relate to the reaction rate?

Ans. As temperature increases, the kinetic energy of the particles also increases. As a result, the particles start moving fast leading to more vigorous motion. The fast moving particles will have more chances to collide with each other.

7. Does the total mass of substances change during a chemical reaction?

Ans. No. According to the law of conservation of mass, the total mass remains the same throughout the reaction.

8. Why does the mass of marble chips seem to decrease when reacted with dilute HCl in an open container?

Ans. The apparent decrease in mass is due to evolution of CO_2 gas during the reaction which escapes into the atmosphere.

9. What happens to the concentration of reactants and products as a reaction moves ahead?

Ans. When a reaction moves ahead the concentration of the reactants decrease untill all the reactants are used up. At the same time, the concentrations of the products increase and reach the maximum value at the end of the reaction.

10. Differentiate between exothermic and endothermic reactions.

Ans. Exothermic Reactions:

In exothermic reaction heat energy is relased which is absorbed by the surrounding causing their temperature to increase.

For example: When quick lime (CaO) reacts with water, slaked lime $Ca(OH)_2$ is formed and a lot of energy is realsed.

$$CaO_{(s)} + H_2O_{(l)} \longrightarrow Ca(OH)_{2\,(s)}$$

Endothermic Reaction: In endothermic reaction heat energy is absorbed causing the surrounding to cool down.

For example: When ammonium chloride or ammonium nitrate is dissolved in water, heat energy is absorbed causing the container cool down.

11. How much does the reaction rate typically increase with temperature?

Ans. Increasing the temperature of the reactions, increases its rate. For many reactions, the rate doubles with energy 10 °C rise in temperature.

17.4 Factors Affecting the Rates of Reactions

17.5 Importance of Chemical Kinetics in Food Industry

12. How does the concentration of reactants affect the rate of reaction?

Ans. An increase are decrease in concentrations of the reactants will result in increase or decreases in the rate of reaction respectively.

For Example:

Combustion of coal in air (21 % oxygen) proceeds relatively slowly as compared to the reaction in pure oxygen.

13. How does pressure affect the rate for gases?

Ans. If reactants in a reaction are present in gas phase, their concentrations can be changed by changing their pressure.

For Example: The rate of reaction between hydrogen and chlorine can be doubled if the prssure of chlorine gas is doubled provided the other component hydrogen is present in excess.

14. What is the effect of surface area on the reaction rate of solids?

Ans. Finely divided solids, because of the greater surface area available, react more rapidly than do large pieces of the same substances.

For Example:

Aluminium foil reacts slowy with warm sodium hydroxide but in finely divided state it reacts rapidly with even cold aqueous solution of sodium hydroxide evolving hydrogen gas.

$$2Al_{(s)} + 2NaOH_{(aq)} + 6H_2O_{(l)} \longrightarrow 2NaAl(OH)_{4\,(aq)} + 3H_{2\,(g)}$$

15. Give an everyday example of the surface area affect.

Ans. Small pieces of wood burn much more rapidly than a large piece of wood because of the increased surface area available for the fire.

16. Why do chemical reactions proceed faster at higher temperatures?

Ans. As the temperature of reaction is increased, the kinetic energy of the participating reacting particles also increases. This, in turn increases the velocities of their movements, as a result the collisions which lead to the occurence of reactions also increase, enhancing the rate of reaction.

17. Define a catalyst.

Ans. Catalyst: A catalyst is a substance which alters the rate of the reaction but it is not consumed during the course of reaction.

18. How does a catalyst speed up a reaction?

Ans. The role of a catalyst is to after the way reaction takes place by substantially lowering its activation energy. When the activation energy is lowered, more and more particles of the reactants will start forming the high energy state and the rate of reactions will increase.

19. What are enzymes?

Ans. Enzymes: Enzymes are biological catalysts. They are basically protiens which helps to speed up specific chemical reactions taking place in our body.

20. Why is the study of reaction rates important in the food industry?

Ans. It helps scientists to determine the optimum conditions for harvesting, storage and transportation of food products by studying the rates of enzymatic reactions, oxidation or microbial growth.

21. How do enzymes affect the ripening of fruits?

Ans. Fruits and vegetables owing to the reactions which involve enzymes. These reactions convert starches into sugars, soften tissues and develop characteristics flavour and clours.

22. How can farmers use kinetics to predict harvesting time?

Ans. With the help of rates of there enzymatic reactions, farmers can predict when the product will reach at its peak quality and ready for harvesting.

For Example: The rate of production of ethene during ripening can be monitored to determine the best time to harvest the fruits.

23. Why does food spoil faster in summer than in winters?

Ans. Hy temperatures in summer increase the rate of enzymatic reactions and microbial growth, leading to rapid degradation of texture, flavour and nutritional value compared to the cooler winter months.

24. How is refrigeration used to prevent food spoilage?

Ans. Refrigeration lowers the temperature, which significantly slows down the rates of oxidation reactions and enzymatic processes that cause food do decay.

25. What kind of biosensors are used to detect glucose in blood?

Ans. Enzyme based bisosensors are used to detect glucose in blood.

Exercise Questions (Solved)

A. Multiple Choice Questions

☆ **Choose and tick the correct answer from the given choices.**

1. The number of collisions per unit volume of the reaction mixture is called:

(a) Collision energy (b) Activation energy
(c) Collision frequency (d) Collision force

2. If the reactants possess an energy higher than the activation energy, then the reaction will be:

(a) Slow (b) Fast (c) Not affected (d) Instantaneous

3. Which of the following explains the increase in rate of reaction in the presence of a catalyst?

(a) Catalyst provides extra energy to the reactant molecules
(b) Catalyst provides an alternative pathway which lowers the activation energy.
(c) Catalyst increases the collision frequency
(d) Catalyst decreases the collision frequency

4. Which of the following statements is correct?

(a) Collisions with energy equal to or greater than the activation energy lead to reaction.
(b) Collision frequency is not related to the reaction rate
(c) All collisions lead to a reaction.
(d) Collisions with energy less than the activation energy lead to the reaction.

5. When a reaction proceeds ahead, how the concentrations of reactants and products change?

(a) Concentration of reactants increases and that of the products decreases.
(b) Concentration of reactants decreases and that of the products increases.
(c) Concentration of both reactants and products decreases.
(d) Concentration of both reactants and products increases.

Answers

1. (c) 2. (b) 3. (b) 4. (a) 5. (b)

B. Short Answer Questions

17.1 What is a successful collision?

Ans. A successful collision is one that results in the formation of products. For a collisions to be successful, the colliding particles must have the correct orientation and energy equal to or greater than the activation energy.

17.2 How does increase in the temperature increase the rate of a reaction?

Ans. As the temperature of a reaction is increased, the kinetic energy of the participating reacting particles also increases. This, in turn increases the velocities of their

movements. As a result the collisions which lead to the occurrence of reactions also increase, enhanced the rate of reaction.

17.3 Define activation energy.

Ans. Activation Energy:

The minimum energy required to start a chemical reaction is called its activation energy.

17.4 Why does the burning of sulphur proceed slower in air than in pure oxygen?

Ans. The burning of sulphur proceeds slower in air than in pure oxygen. It is because air contains only about 21 % oxygen, while pure oxygen has a much higher concentration, leading to a higher collision frequency between sulphur and oxygen molecules.

17.5 Why a catalyst used in a reaction is preferably taken in the powdered form?

Ans. A catalyst used in a reaction is preferably taken in the powdered form because powdered form increases the surface area, providing more active sites for the reactant molecules to absorb and react, this increasing the reaction rate.

17.6 Why is the rate of a reaction often very fast at the beginning of the reaction?

Ans. The rate of reaction is often very fast of the beginning of the reaction because at the start, the concentration of reactants is greater which means faster rate of reaction and more chance of effective collisions.

17.7 Magnesium does not react with air at room temperature but it reacts very fast at high temperature giving intense white light. Explain.

Ans. At room temperature, magnesium atoms do not have enough energy to break their bonds and start a reaction with the oxygen in the air. When magnesium is heated at high temperature.

Activation Energy:

The heat provides the "starting energy" (activation energy) needed for the reaction to begin.

Chemical reaction:

The magnesium starts to burn rapidly, reacting with oxygen to form magnesium oxide.

Energy Release:

This reaction is very strong and releases a lot energy all at once, giving intense white light.

17.8 What happens to the reactants after they climb the energy hill during a reaction?

Ans. In a chemical reaction, the "energy hill" is the amount of energy reactants must gain to actually change into something new.

Once the reactants reach the top of that hill:

- They reach a very unstable state where their original bonds are broken.
- They immediately "slide down" the other side of the hill. As they do this atoms

rearrange themselves and form new bonds, and turned into products.

17.9 How does a catalyst lower the activation energy of a reaction?

Ans. A catalyst lowers activation energy by providing an alternative reaction pathway with a lower energy barrier, allowing the reaction to occur faster.

17.10 Give any two features of the catalytic action of an enzyme.

Ans. **(i) High specificity:** An enzyme acts only on a particular substrate.
(ii) Reusability: The enzyme cannot consumed and can be used repeatedly.

C. Constructed Response Questions

17.1 In what different ways you can increase the successful collisions between the particles of the reactants?

Ans. To increase the rate of reaction, you must increase the number of effective collisions. This can be achieved by:

- **Increasing Concentration:**
  Adding more reactant particles into the same volume increases the probability of them hitting each other.
- **Increasing Temperature:**
  This gives particles more kinetic energy. They move faster (increasing collision frequency) and more importantly, a larger percentage of particles will have energy equal to or greater than the activation energy.
- **Increasing Surface Area:**
  For solid reactants, crushing them into a powder exposes more "inner" atoms to the other reactants, allowing more collisions to occur simultaneously.
- **Adding a catalyst:**
  This provides an alternative pathway with a lower activation energy, making it "easier" for collisions to be successful.

17.2 Give an example of a reaction which proceeds with the gain in mass.

Ans. A classic example is the combustion of Magnesium ribbon.

$$2\,Mg_{(s)} + O_{2\,(g)} \longrightarrow 2\,MgO_{(s)}$$

If a ribbon of magnesium is burnt in an open crucible, the mass of the product (MgO) formed will be greater than the reactant (Mg). This increase in mass has occurred due to the reaction of magnesium with oxygen present in air.

17.3 From where do molecules get energy to attain higher energy state?

Ans. Molecules primarily gain energy through molecular collisions. In any sample, particles are moving at different speeds. When they collide, kinetic energy is transferred. If a molecule undergoes several high-energy collisions, it may accumulate enough energy to reach the activated complex state (the top of the energy hill).

Endothermic Reaction:

In an endothermic reaction, this energy is absorbed from the surroundings (heat).

Reaction Mixture:

In a reaction mixture, increasing the external temperature provides the thermal energy that increases the internal energy of the molecules.

17.4 How does the presence of V_2O_5 catalyst lowers the activation energy of the following reaction?

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

Ans. The vanadium (V) oxide (V_2O_5) acts as a heterogeneous catalysts in the contact process. It does not simply "push" the molecules; it provides a new chemical pathway consisting of two smaller steps:

- First, SO_2 reacts with V_2O_5 to form SO_3 and a reduced catalyst (V_2O_4).
- Then the V_2O_4 reacts with O_2 to regenerate the original V_2O_5.

Because each of these individual steps has a lower activation energy than the direct collisions of SO_2 and O_2, the overall reaction proceeds much faster.

17.5 Explain the catalytic action of an enzyme.

Ans. For answer See Q7 (Long Subjective Questions)

17.6 If you desire to stop a reaction going on at 60°C, what action you will take?

Ans. By lowering the temperature, system will cool rapidly. So the reaction rate decreases or stops.

D. Descriptive Questions

17.1 Explain the effect of surface area on the rate of a raection.

Ans. For answer See Q6 (b)

17.2 Describe the main points of the collision theory of reaction rate.

Ans. For answer See Q1

17.3 Discuss the following factors affecting the rate of a reaction:

(a) Effect of concentrations of the reactants.

(b) Effect of temperature at which a reaction is carried out.

Ans. (a) For answer See Q4

(b) For answer See Q5

17.4 How does chemical kinetics play an important role in the food industry?

Ans. For answer See Q9

17.5 Write briefly about the role enzymes play in our body as biological catalysts.

Ans. For answer See Q8