Chapter 17 — Reaction Kinetics

Chemistry — Class X (Solved Exercise)

Exercise A — Multiple Choice Questions

#	Statement	Options	Answer
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	**(c)**
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	**(b)**
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	**(b)**
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.	**(a)**
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.	**(b)**

Exercise B — Short Answer Questions

17.1 What is a successful collision?

Ans: A **successful (effective) collision** is a collision between reactant particles that possess energy equal to or greater than the **activation energy** and occur with the **proper orientation**, so that the collision actually results in the formation of products.

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

Ans: Raising the temperature increases the **kinetic energy** of the reacting particles. This increases both the **frequency of collisions** and, more importantly, the **fraction of molecules possessing energy equal to or greater than the activation energy**. Hence the number of successful collisions increases sharply, and the rate of reaction increases.

17.3 Define activation energy.

Ans: Activation energy is the **minimum extra amount of energy** that colliding reactant particles must possess (over and above their average energy) in order to form the **activated complex** and successfully change into products.

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

Ans: Air contains only about 21% oxygen, the rest being nitrogen and other inert gases, so the **concentration of oxygen** in air is much lower than in pure oxygen. Lower concentration means fewer oxygen molecules per unit volume, so the **collision frequency** between sulphur and oxygen molecules is reduced, making the reaction slower in air compared with pure oxygen.

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

Ans: Powdering the catalyst increases its **surface area**. A larger surface area provides more active sites for the reactant molecules to be adsorbed on, which increases the **effective contact** between catalyst and reactants and therefore speeds up the reaction.

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

Ans: At the start of a reaction, the **concentration of reactants is at its maximum**, so the collision frequency between reactant particles is highest. As the reaction proceeds, reactants are consumed and their concentration falls, so the rate gradually **decreases with time**.

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 is protected by a **thin, tightly adhering layer of magnesium oxide**, and the particles do not have enough energy to overcome the **activation energy barrier**. At high temperature, the particles gain sufficient energy to cross this barrier; the oxide layer breaks down and magnesium combines rapidly and exothermically with oxygen of the air, releasing a large amount of energy as **intense white light**.

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

Ans: On reaching the top of the energy hill (activation energy barrier), the reactants form a short-lived, high-energy, unstable species called the **activated complex (transition state)**. This complex then breaks down and comes down the other side of the hill, forming the **products** of the reaction.

Exercise C — Constructed Response Questions

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

Ans: The number of successful collisions can be increased by:

- Increasing the **concentration** of reactants (more particles per unit volume).
- Increasing the **temperature** (particles gain more kinetic energy and cross the activation energy barrier more easily).
- Increasing the **surface area** of solid reactants, e.g. by powdering them.
- Using a suitable **catalyst**, which provides an alternate pathway of lower activation energy.
- Increasing **pressure** in the case of gaseous reactants (reduces volume, raising concentration).

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

Ans: The **rusting of iron** is such a reaction:

$$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(s)$$

Since iron combines with oxygen from the air to form rust, the mass of the solid increases as the reaction proceeds. (Similarly, the burning of magnesium in air, $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$, also proceeds with a gain in mass.)

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

Ans: Molecules gain the extra energy needed to reach the higher (activated) energy state mainly from **collisions with other molecules** during their continuous random motion — kinetic energy is transferred between colliding particles. Molecules can also absorb **heat energy from the surroundings**, which raises their average kinetic energy and helps them reach the activated state.

17.4 How does the presence of V_2O_5 catalyst lower the activation energy of the following reaction? $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$

Ans: Vanadium pentoxide (V_2O_5) lowers the activation energy by providing an **alternative reaction pathway (mechanism)** that occurs in two low-energy steps instead of one high-energy step:

Step 1: $SO_2 + V_2O_5 \rightarrow SO_3 + V_2O_4$

Step 2: $V_2O_4 + \frac{1}{2}O_2 \rightarrow V_2O_5$ (catalyst regenerated)

Each of these two steps has a much lower activation energy than the direct, uncatalysed reaction between SO_2 and O_2. The catalyst itself is regenerated at the end and is not consumed overall, so a greater fraction of molecules can now cross the (lower) energy barrier, increasing the rate of formation of SO_3.

17.6 Explain the catalytic action of an enzyme.

Ans: Enzymes are **biological (protein) catalysts** that speed up biochemical reactions in living organisms. Each enzyme has a specific three-dimensional pocket called the **active site**. The substrate (reactant) fits into the active site, forming an **enzyme–substrate complex** (the "lock-and-key" or "induced-fit" model). This complex provides an **alternative reaction pathway of lower activation energy**, allowing the reaction to proceed rapidly at body temperature. The complex breaks down to release the products, and the enzyme is left **chemically unchanged**, free to catalyse further reactions.

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

Ans: The reaction can be effectively stopped (or its rate reduced almost to zero) by **rapidly cooling the reaction mixture** to a much lower temperature (e.g. by placing it in an ice bath), since lowering the temperature sharply reduces the kinetic energy of particles and the fraction able to cross the activation energy barrier. Removing the catalyst (if any), diluting the reactants, or adding an inhibitor can also be used to slow down or stop the reaction.

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

Ans: A catalyst lowers the activation energy by providing an **alternative reaction pathway (mechanism)** for the reaction, one whose energy barrier is lower than that of the uncatalysed reaction. Because more reactant molecules now possess enough energy to cross this lower barrier, a greater fraction of collisions become successful, and the reaction proceeds faster. The catalyst itself takes part in the mechanism but is regenerated unchanged at the end.

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

Ans: Two important features are:

1. **High specificity** — each enzyme acts only on a particular substrate (or a closely related group of substrates) due to the specific shape of its active site.

2. **Sensitivity to temperature and pH** — every enzyme works best at a specific optimum temperature and pH; its activity decreases, and the enzyme may be permanently denatured, outside this range.

Exercise D — Descriptive Questions

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

Ans: For a reaction involving a solid reactant, only the particles present at the **surface** are exposed and available to collide with the other reactant. Breaking a solid into smaller pieces or grinding it into a powder greatly increases its **total surface area** without changing its mass. A larger surface area exposes more particles to collisions, increasing the **collision frequency** and hence the rate of reaction. For example, powdered marble reacts with dilute hydrochloric acid much faster than a single lump of marble of the same mass, and coal dust burns explosively fast compared with a solid lump of coal.

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

Ans: The collision theory can be summarised in the following main points:

1. **Reactant particles must collide** with one another before a reaction can occur.

2. **Not all collisions lead to a reaction**; only a small fraction of collisions, called **successful (effective) collisions**, result in product formation.

3. **A collision is successful only if** the colliding particles possess energy equal to or greater than the **activation energy** of the reaction.

4. **Correct orientation** of the colliding particles at the moment of impact is also necessary for a collision to be effective.

5. **The rate of reaction depends on the frequency of successful collisions** — anything that increases the collision frequency or the fraction of energetic particles (concentration, temperature, surface area, catalyst, pressure) increases the rate of reaction.

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

(a) Effect of concentration of the reactants — Increasing the concentration of reactants means there are more particles packed into the same unit volume. This raises the **collision frequency** between reactant particles, so more successful collisions occur per unit time and the rate of reaction increases. Conversely, decreasing concentration lowers the rate.

(b) Effect of temperature — Raising the temperature increases the average **kinetic energy** of the reacting particles. This has two effects: it increases the frequency of collisions, and — more significantly — it increases the **fraction of particles possessing energy equal to or greater than the activation energy**. As a result, the number of successful collisions rises sharply, and the rate of reaction increases considerably (as a rule of thumb, the rate roughly doubles for every 10°C rise in temperature).

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

Ans: Chemical kinetics helps in understanding and controlling the rates of reactions involved in **food spoilage, preservation, and processing**. Knowledge of how temperature, concentration, and enzymes affect reaction rates allows the food industry to: slow down spoilage reactions (oxidation, microbial and enzymatic decay) by **refrigeration or freezing**, which lowers reaction rates and increases shelf life; control the rate of fermentation reactions used in making bread, yogurt, cheese and vinegar; determine the correct time and temperature for **pasteurisation and canning** so that harmful microbial reactions are stopped without destroying nutrients; and choose suitable preservatives/antioxidants that slow down the rate of spoilage reactions. In short, kinetics allows food scientists to predict and control shelf life, safety and quality of food products.

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

Ans: Enzymes are **biological catalysts** (mostly proteins) that speed up the biochemical reactions occurring inside the body without being consumed themselves. They lower the **activation energy** of reactions so that these can proceed rapidly at normal body temperature. For example, **amylase** breaks down starch into sugars, **protease (pepsin/trypsin)** breaks down proteins into amino acids, and **lipase** breaks down fats into fatty acids and glycerol during digestion. Other enzymes control respiration, DNA replication, and countless metabolic reactions. Each enzyme is highly **specific** to its substrate and works best within a narrow range of temperature and pH, making enzymes essential for regulating and coordinating the chemistry of life.