

Particulate Nature of Matter: Case Studies

Case Study 1: The Curious Case of the Dissolving Sugar

Meera was helping her mother prepare lemonade. She filled a glass with 200 mL of cold water, added two tablespoons of fine sugar crystals, and stirred continuously. She noticed that after a few minutes, the solid sugar disappeared completely, leaving behind a clear liquid. Out of curiosity, Meera checked the water level in the glass and observed that it had not changed at all compared to before the sugar was added. She then wondered if using warm water instead of cold water would have changed how quickly the sugar dissolved.

Q1.1 Explain why the water level remained unchanged even after two tablespoons of sugar dissolved completely in the beaker.

Q1.2 What would happen to the speed at which sugar dissolves if Meera used warm water instead of cold water? Explain using the kinetic theory of matter.

Q1.3 Identify the physical process that takes place when sugar particles spread evenly throughout the water.

Q1.4 If Meera keeps adding sugar continuously to the glass without changing the water volume or temperature, will it keep dissolving indefinitely? Name the type of solution formed when no more sugar can dissolve.

Case Study 2: Kitchen Aromas and Thermal Expansion

Aarav walked into his house after school and immediately announced that his favorite dish, *pav bhaji*, was being cooked in the kitchen. He was standing in the living room, several meters away from the stove. Later, while sitting at the dining table, Aarav picked up an airtight plastic container containing leftover cold soup. He tightened the cap completely and placed it inside a vessel filled with boiling hot water to warm it up. Within a few minutes, the sides of the sealed plastic container began to bulge outward.

Q2.1 How was Aarav able to identify what was being cooked in the kitchen from the living room? Name the phenomenon responsible for this observation.

Q2.2 Why do hot food aromas travel much faster across a room than the smell of cold food?

Q2.3 Explain the molecular cause behind the bulging of the sealed plastic container when placed in boiling hot water.

Q2.4 Compare the kinetic energy of air particles inside the container when it is at room temperature versus when it is heated.

Case Study 3: The States of Matter in a Laboratory Experiment

During a science practical class, students were given three unlabeled test tubes containing different substances:

- **Tube A:** Iron filings (Solid)
- **Tube B:** Water (Liquid)
- **Tube C:** Carbon dioxide gas (Gas)

The teacher asked the students to test the compressibility, shape, and volume of the contents in each tube using syringes and plunger mechanisms. The students observed that Tube C's content compressed significantly under pressure, whereas Tube A's content resisted any shape change or compression. Tube B took the shape of whatever container it was poured into, but its volume remained fixed.

Q3.1 Why are gases like the one in Tube C easily compressible compared to solids and liquids?

Q3.2 Explain why the iron filings in Tube A maintain a fixed shape and volume, while water in Tube B has a fixed volume but no fixed shape.

Q3.3 Arrange the three substances (iron, water, carbon dioxide) in **increasing order** of:

- (a) Interparticle forces of attraction
- (b) Interparticle spaces between their molecules

Q3.4 What will happen to the motion of particles in Tube B if it is placed in a freezer at 0°C? Describe the change in state.

Case Study 4: Ancient Philosophy and Modern Atomic Theory

In a history of science class, Sanya learned that thousands of years before modern chemistry developed, thinkers pondered what would happen if you kept dividing matter into smaller and smaller pieces. Indian philosopher **Acharya Kanad** proposed that if we break down matter (*Padartha*), we eventually reach ultimate, indivisible particles called *Parmanu*. Centuries later, Greek philosopher Democritus came up with a similar concept, calling these indivisible units *atomos*. Modern science later confirmed that all matter—whether solids, liquids, or gases—is composed of tiny particles that are in continuous motion and interact with each other.

Q4.1 What term did Acharya Kanad use for the smallest indivisible particle of matter, and what is its modern scientific equivalent?

Q4.2 State three fundamental properties of particles of matter as established by modern science.

Q4.3 A drop of blue ink added to water spreads on its own without stirring. Does this observation support the ancient concept of static particles or the modern concept of dynamic particles? Explain.

Q4.4 Why can a diver easily cut through water in a swimming pool, but cannot push through a solid concrete wall? Explain in terms of interparticle forces and spaces.

Answer Key & Detailed Explanations

Answers for Case Study 1

Ans 1.1: Sugar breaks down into tiny constituent particles that fit neatly into the existing **interparticle spaces** between water molecules. As a result, they do not take up additional overall space.

Ans 1.2: Sugar would dissolve **faster**. Heating increases the kinetic energy of water particles, causing them to move faster and collide more frequently and vigorously with sugar crystals.

Ans 1.3: Diffusion (and dissolution).

Ans 1.4: No, it will not dissolve indefinitely. When no more sugar can dissolve at that temperature, it forms a **saturated solution**.

Answers for Case Study 2

Ans 2.1: Through **diffusion**, where vaporized aromatic food particles mix with air particles and move continuously across the room.

Ans 2.2: Hot food particles have higher kinetic energy due to high temperature, making them move and diffuse much faster than cold food particles.

Ans 2.3: Heating increases the kinetic energy of trapped air particles inside the container. They move faster, collide with greater force against the inner walls, and cause the container to bulge outward.

Ans 2.4: Kinetic energy is **significantly higher** when heated compared to room temperature.

Answers for Case Study 3

Ans 3.1: Gases have large **interparticle spaces** and very weak forces of attraction, allowing particles to be easily squeezed closer under pressure.

Ans 3.2: Iron (solid) has very strong interparticle forces holding particles in fixed, rigid positions. Water (liquid) has moderate forces allowing particles to slide past each other while remaining within a definite volume.

Ans 3.3:

(a) **Forces of attraction:** Carbon dioxide < Water < Iron

(b) **Interparticle spaces:** Iron < Water < Carbon dioxide

Ans 3.4: Particles lose kinetic energy, slow down, and lock into fixed positions. Liquid water undergoes **freezing** (solidification) to become solid ice.

Answers for Case Study 4

Ans 4.1: Acharya Kanad used the term **Parmanu**. Its modern scientific equivalent is the **Atom** (or constituent particle).

Ans 4.2: (1) Particles of matter have spaces between them; (2) Particles of matter are in continuous motion; (3) Particles of matter attract each other.

Ans 4.3: It supports the **modern concept of dynamic particles**, proving that water and ink particles are in continuous random motion and mix on their own via diffusion.

Ans 4.4: Water (liquid) has weaker interparticle forces and larger interparticle spaces, allowing a diver to easily break through. Concrete (solid) has extremely strong interparticle forces and tightly packed particles that resist penetration.