Chapter 7: Particulate Nature of Matter - Detailed Study Notes

1. Introduction: What is Matter Composed Of?

- **The Break-Down of Matter :** Matter is composed of a very large number of extremely small particles. These constituent particles are so small that they cannot be seen even through an ordinary microscope.
- **Physical vs. Chemical Change:** Grinding a substance, like chalk, into a fine powder is a physical change. The substance does not change into a new substance; only the size of the specks is reduced.
- **Historical Fact (Our Scientific Heritage):** Acharya Kanad, an ancient Indian philosopher, was the first to propose that matter is made up of tiny, indivisible, and eternal particles. He called these particles **"Parmanu"** (atoms) and documented this idea in his work, the *Vaisheshika Sutras*.

2. Important Definitions

- **Constituent Particles:** The basic, extremely tiny units or building blocks that make up a larger piece of a substance or material.
- **Interparticle Spaces:** The empty spaces present between the constituent particles of matter. For example, when sugar dissolves, its particles separate and occupy the available spaces between the water particles.
- **Interparticle Attractions:** The attractive forces that hold the constituent particles of matter together.
- **Melting Point:** The minimum temperature at which a solid melts to become a liquid at atmospheric pressure.
- **Boiling Point:** The temperature at which a liquid boils and turns into vapour (gas) at atmospheric pressure.
- **Evaporation:** The slow process of vapour formation that occurs at all temperatures (even below the boiling point), but only at the surface of the liquid.
- **Fluids:** Substances that can flow and do not retain a fixed shape. Both liquids and gases are classified as fluids.

3. What Decides the Different States of Matter?

The physical state of any substance is ultimately decided by two competing factors:

1. **Interparticle Attractions:** The strength of these forces depends on the nature of the substance and the distance between particles. Even a slight increase in distance drastically decreases the attractive forces.

2. **Thermal (Heat) Energy:** The thermal energy of particles determines how much they move. When thermal energy is low, particles stay close together; when it is high enough, it overcomes the attractive forces, allowing the substance to change state (e.g., solid to liquid, liquid to gas).

4. Detailed Breakdown of the Three States of Matter

A. Solid State

- **Properties:** Solids have a definite shape and a definite volume.
- **Particle Arrangement:** Particles are tightly packed, leaving minimum interparticle space. (Note: The tiny space left between solid particles contains absolutely nothing; it is not filled with air).
- **Forces and Movement:** Interparticle attractions are at their maximum (very strong). Because of this, particles cannot move past each other freely; they can only vibrate or oscillate to and fro about their fixed positions.
- **Effect of Heating (Melting):** When heated, solid particles vibrate more vigorously. Eventually, they leave their fixed positions, interparticle forces weaken, and the solid converts into a liquid.
- **Examples of Melting Points:** Ice $0^{\bullet}$C, Urea $133^{\bullet}$C Iron $1538^{\bullet}$C. Stronger interparticle forces result in higher melting points.

B. Liquid State

- **Properties:** Liquids have a definite volume but no fixed shape. They take the shape of the container they are poured into.
- **Particle Arrangement:** Particles are somewhat farther away from each other compared to solids (though ice is an exception, where particles are farther apart than in liquid water).
- **Forces and Movement:** Interparticle attractions are slightly weaker than in solids but still strong enough to keep particles close together. Particles are free to move, but only within a limited space. This is why you can move your finger through water—you temporarily displace the particles without breaking them.
- **Effect of Heating (Boiling):** Heating causes vigorous movement, pushing particles further apart. At the boiling point, vapour formation is very fast and occurs both at the surface and within the liquid (seen as bubbles).

C. Gaseous State

- **Properties:** Gases have neither a fixed shape nor a fixed volume. They tend to occupy the entire available space of the vessel they are placed in.
- **Particle Arrangement:** Interparticle spacing is at its maximum.
- **Forces and Movement:** Interparticle attractions are negligible (minimum). Particles have enough thermal energy to overcome attractive forces completely, moving freely in all directions.

5. Effect of Heat/Temperature (Thermal Energy)

- **The Role of Thermal Energy:** The state of matter depends highly on the thermal (heat) energy of its particles. In solids, thermal energy is low, so particles remain close.
- **What happens when a solid is heated?** When solids are heated, their particles vibrate more vigorously. At the melting point, the thermal energy overcomes the attractive forces between particles. The particles start leaving their fixed positions, interparticle distance increases slightly, and the solid converts into a liquid.
- **How heat affects particle movement (Experiment):** If you drop potassium permanganate crystals into three glasses of water (hot, room temperature, and ice-cold), it will spread fastest in the hot water. This proves that the movement of particles increases when heat is provided

6. Interparticle Spacing and Compressibility

- **Gases are Highly Compressible:** If you plug a syringe and push the plunger inward, the volume of trapped air decreases. This proves gas particles have a lot of space between them naturally, which can be reduced by applying external pressure.
- **Liquids are Practically Incompressible:** Water in a syringe cannot be easily compressed. However, liquids do have spaces between particles. When sugar dissolves in water, the sugar particles occupy the empty spaces between water particles, which is why the total volume does not increase drastically.
- **Why Sand Doesn't Dissolve:** Sand particles are held together so strongly by interparticle forces that water particles cannot pull them apart. Hence, sand settles at the bottom and increases the total volume of the container.

7. Movement of Particles (Experiments & Observations)

- **Potassium Permanganate in Water:** When a crystal of potassium permanganate is dropped in water, streaks of pink color spread until the entire

liquid is uniformly pink. This happens because water particles are in constant motion; they hit and pull the crystal's particles apart, spreading them throughout the container.

- **The Role of Temperature:** Potassium permanganate spreads the *fastest* in hot water, less quickly in room-temperature water, and the *slowest* in ice-cold water. Therefore, the movement of particles increases when heat is provided.
- **Incense Stick in a Room:** When an incense stick is burnt, the fragrance spreads to fill the room. This proves that invisible air particles are constantly moving; they hit the fragrance/smoke particles and carry them throughout the available space.

8. Real-Life Applications & Advanced Concepts

- **How Soap Cleans Clothes:** The particulate nature of matter helps in cleaning. When washing oil-stained clothes, numerous soap particles surround the oil particles. One end of the soap particle attaches to the oil, and the other end mixes with the water, lifting the oil off the fabric so it can be washed away.
- **Suspended Particulate Matter (SPM):** In the context of pollution, SPM refers to tiny dust particles suspended in the air. These dust particles are *not* constituent particles; they are much larger and are themselves made up of a very large number of atoms and molecules.
- **Atoms vs. Molecules:** The tiny particles making up all matter are atoms and molecules. For example, iron and gold are made of independent iron and gold atoms. However, some elements cannot exist independently; they combine to form a molecule. (e.g., two hydrogen atoms form one stable hydrogen molecule; two hydrogen atoms + one oxygen atom form a water molecule).

9. Summary Table: Differences Between the States of Matter

Feature	**Solid**	**Liquid**	**Gas**
Interparticle Spacing	Minimum spacing.	A little more than in solids.	Maximum spacing.
Packing	Particles are closely packed.	Particles are a little loosely packed than in solids.	Particles are completely free.
Interparticle Attraction	Maximum strength.	Slightly weaker than in solids.	Minimum (negligible).
Movement of Particles	Negligible; restricted to only vibrations.	Restricted to limited space.	Move freely in all the available space.
Shape & Volume	Fixed shape and size/volume.	Definite volume, but no fixed shape.	No fixed shape and no fixed volume.