Lesson 3 : The Liquid and the Solid State.

Lesson Objective :

Dear Students ,

At the end of this lesson. you will be :

- Explain the terms: evaporation, boiling,condensation,vapor pressure; Boiling point, molar heat of vaporization and molar heat of condensation.
- Carryout an activity to demonstrate the concept of vapor pressure.
- Carryout an activity to determine the boiling points of water and ethanol, in the terms melting ,fusion,sublimation, melting point,freezing point, molar heat of solidification.
- Explain temperature changes associated with phase changes.
- Determine melting point of ice demonstrate an experiment to show the phase changes from ice to liquid water and then to water.

Brainstorming Question

1. What is the relation altitude and boiling of water?
   2 why same liquids are volatile others ate not?

key terms/ Concepts

- Evaporation
- Heat of vaporization
- Boiling point
- Normal boiling point

Evaporation is the process by which a liquid transforms into a gas or vapor phase at temperatures below its boiling point
2.5 The Liquid and the Solid State

2.5.1 The Liquid State

- As in a gas, particles in a liquid are in constant motion. However, the particles in a liquid are closer together than those in agas.Theattractiveforces between particles in a liquid are stronger than between particles of a gas.
- This attraction between liquid particles is caused by the intermolecular forces of attraction such as dipole- dipole forces, London dispersion forces, and hydrogen bonding.

- Liquids are more ordered than gases because of the stronger intermolecular force and the lower mobility of liquid particles.
- energy Changes In Liquids The process by which a liquid changes to a gass is known as vaporization or evaporation
- .Evaporation is the process by which molecules on the surface of a liquid break away and go into the gas phase.

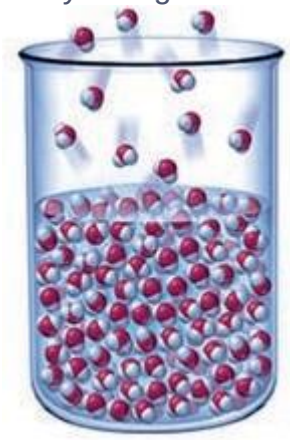
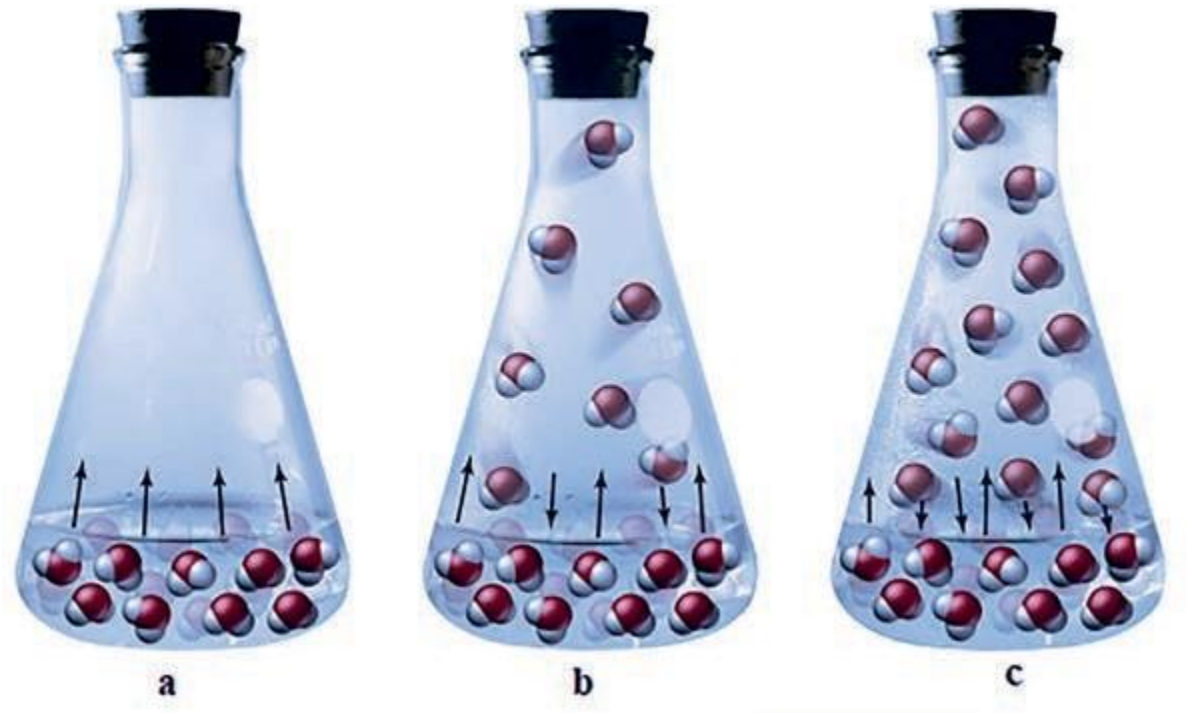


Figure:Evaporation of Liquid

- Evaporation is explained in terms of the energy that the molecules on the surface of the liquid have. In an open container, evaporation continues until all of the liquid enters the gas (vapor) phase (the above figure).
- Most Of The Molecules That Escape Into the vapor phase do not collide with the surface of the liquid and return to the liquid phase. Instead, they will diffuse through the gas phase away from the container and equilibrium can not be established. Under These Condition's,the liquid will continue to evaporate until it has disappeared, However, liquids in a closed container behave differently. The volume of the liquid decreases for some time, and then, remains unchanged. This is because in closed containers,the vapor can not escape.As more molecules leave the liquid,more gaseous molecules collide with the container walls,with each other,and with the liquid surface and return to the original liquid state.
- The process of when a vapor returns to the liquid state is called condensation.
- Evaporation and condensation are opposing processes. Evaporation is a liquid turning into a gas, and condensation is a gas turning into a liquid.
- For instance,when liquid water is initially put into a closed container,more evaporation happens than condensation because there are so few gaseous water molecules in the space above the water (Figure a). However, as the number of gaseous water molecules increases, the rate of condensation also increases (Figure b). At the point where the rates of condensation and evaporation become equal (Figure c), dynamic equilibrium is reached and the number of gaseous water molecules above the liquid remains constant. The vapor pressure of a liquid is the partial pressure of it's vapor in dynamic equilibrium with its liquid.



- :Evaporation and condensation:
- (a)when water is first put into aclosed container,water molecules begin to evaporate;
- (b)Evaporation continues, but condensation also begins to occur; and
- (c) Dynamic equilibrium: rate of evaporation equals the rate of condensation
  The rate of evaporation of a liquid can be affected by these factors:

- temperature
- intermolecular forces and
- surface area of the liquid
  Temperature

- Some liquids evaporate readily at room temperature.Such liquids are said to bevolatile.
- Volatile Liquid have relatively weak forces of attraction between particles.
- Liquids Such as formaldehyde, ethyl alcohol, mercury, and benzene are volatile liquids.
- Liquids that do not vaporize easily at a given temperature are said to be nonvolatile. Theyhaverelativelystrongerattractiveforcesbetweentheirmolecules.
- Liquids Such as motor oil, edible oil, glycerin, water, and molten ionic compounds are nonvolatile.
- Vapor pressure The partial pressure of the vapor above a liquid is called vapor pressure. The vapor pressure of a liquid depends up on the temperature. At a given temperature, vapor pressure is constant. The vapor pressures of liquids always increase as temperature increases because the rate of evaporation increases with increasing temperature.
  Intermolecular Forces

- Vapor pressure depends also on the intermolecular forces between the molecules of the liquid.
- The Stronger the intermolecular forces,the lower will be the vapor pressure of the liquid because fewer molecules will have enough kinetic energy to overcome the attractive force at a given temperature. For Example,water and ethanol have relatively low vapor pressure because the very strong hydrogen bonding in these liquids account for their unusually low vapor pressures. However, liquids with low intermolecular forces have high vapor pressures at room temperature. For example,diethylether, a non-polar molecule with relatively weak dispersion forces, has a relatively higher vapor pressure.
  Surface area of a liquids ?

  Boiling and Boiling Point

- When heat energy is added to a liquid, it increases the kinetic energy of the molecules and the temperature of the liquid increases.
- Heating a liquid always increases its vapor pressure. When a liquid is heated to a sufficiently high temperature under a given applied (usually atmospheric) pressure, bubbles of vapor begin to form below the surface
- ,if the temperature is raised sufficiently,the vapor pressure is high enough that the bubbles can persist and rise to the surface, and burst, releasing the vapor into the air. This process is called boiling. In short, boiling is the change of a liquid to bubbles of vapor that appear throughout the liquids.
- It is the conversion of liquid to vapor within the liquid as well as at its surface. During Evaporation,only molecules at the surface escape into the vaporphase. Itis the formation of vapor bubbles within the liquid itself that characterizes boiling and distinguishes it from evaporation.
- If the temperature of the liquid is increased, the equilibrium vapor pressure also increases. Finally, the boiling point is reached. The boiling point of a liquid is the temperature at which its vapor pressure equals the external atmospheric pressure.
- The normal boiling point is the temperature at which the vapor pressure of a liquid is equal to exactly one atmosphere.
- For Instance, waterboilsat 100°Cat1.0 atmospheric pressure and thus,it's normal boiling point of wateris100°C. Nevertheless,the boiling point of water at 0.83atm is 95°C. Generally,when the pressure exerted on a liquid is varied,the boiling point of a liquid also varies.
- Note that as heat energy is added to vaporize a pure liquid at its boiling point, the temperature remains constant until the liquid is completely changed tovapor.Then, the temperature begins to rise after the liquid is completely changed to vapor
- Boiling of a liquid requires a certain amount of heat energy to break the forces of attraction between the molecules.
- The amount of heat energy necessary to bring about the vaporization of a fixed amount of a liquid at a fixed temperature to the gaseous state is called the heat of vaporization.
- Forexample,the heat of vaporization per mole of water at 298K and 1 atmosphere is 44.0kJ.This Is Called The molar heat of vaporization (ΔHvap)of water.

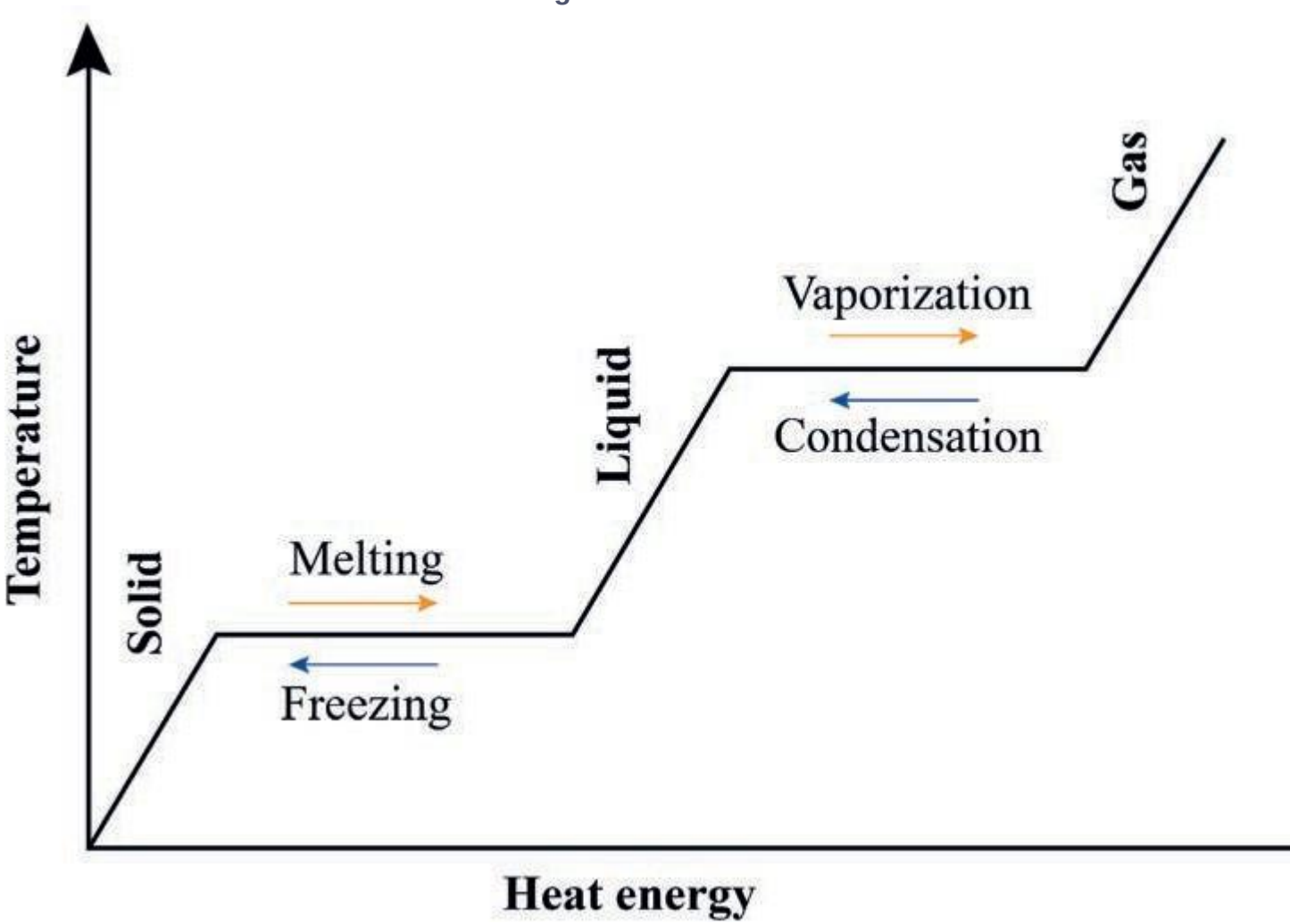
- The Molar heat of Vaporization Is the amount of heart needed to convert 1 mole of a liquid at its boiling point to a gas. It Is equal to the amount of energy that is released when 1 mole of vapour condenses to liquid at the condensing point of vapour
- Condensation is the change of a gas to a liquid at the boiling point of the liquid.
- During condensation heat is released. Thus,the amount of heat realised when 1 mole of gas is converted to a liquid at its condensation point is called the molar heat of condensation (ΔHcond)
- ΔHvap= – ΔHcond
- Note that vaporization is an endothermic process where as condensation is an exothermic process.

3.5. 2 The solid State

- The temperature at which pure liquid changes to crystalline sollids called the freezing point; it is identical to the meltingpoint.The melting or freezing occurs at the temperature where the liquid and solid are in dynamic equilibrium.
- When a solid is continuously heated the ordered crystalline structure of solids will bedisturbed. As a result,particles gradually get freedom of motion and melting(or fusion) take place. Melting is the process of converting solid into the liquid. The temperature at which a crystalline solid changes to a liquid or melts is called the melting point.
- On the other hand,when a liquid is cooled,its molecules come closer toone another and thus, the intermolecular forces of attraction between them get stronger. As aresult, its particles arrange themselves into a regular pattern and then converted to a solid. This process is called freezing or solid ification.Forinstance,ice melts at0°C and water freezes at 0 °C. Ice and water coexist in equilibrium at 0 °C as follow
- Un like boiling points, melting points are affected only by large pressure changes.
- Note that both the melting point and the boiling point are characteristics of physical properties of a substance and can be used to help identify it.
- The amount of heat needed to convert one gram of solid to liquid at the melting point is called heat of fusion.
- The molar heat of fusion or molar enthalpy of fusion (ΔHfus) is the quantity of heat needed to convert one mole of a solid at its melting point to the liquid state.
- For example,the molar heat of fusion of ice is 6.01kJat0°C. This is the amount of energy needed to break the attractive forces in the solid, ice, at its melting point.
- Melting requires the supply of energy; therefore, it is an endothermic process.
- During the process of solidification,the amount of heat liberated is exactly equal to the heat of fusion. The heat liberated is called the heat of solidification or heat of crystallization.
- The molar heat of crystallization (ΔHcryst) is the quantity of energy that is removed from one mole of a liquid to convert it to the solid state at its freezing point.
- ΔHcryst= -ΔHfus
- Some solids have significant vapor pressure and thus, evaporate directly from the solid to the vapor state with out passing through the liquid state. This process is called sublimation. i.e., the change of solid to vapor. The opposite of sublimation is deposition that is the change of vapor to solid. The process can be expressed as follows

- Like vaporization, the process of sublimation requires an input of energy to overcome intermolecular attractions. The enthalpy of sublimation,ΔHsub, is the energy required to convert one mole of a substance from the solid to the gaseous state. Sublimation is an endothermic process. The reverse of sublimation is called deposition, a process in which gaseous substances directly change into the solid state, bypassing the liquid state. Whereas, during deposition heat energy (ΔHdep) is released. The enthalpy change during deposition is equal in magnitude but opposite in sign to sublimation. The enthalpy of deposition, ΔHdep, is the energy released when one mole of a substance from the gaseous state change to solid. The heat (enthalpy) of sublimation is related to the enthalpies of fusion and vaporization by:
  ΔHsub= ΔHfus+ ΔHvap
  ΔHsub= ΔHdep

Heating curve



- A heating curve is a plot of the temperature versus the amount of heat added .It is commonly used to show the relationship between phase changes and enthalpy for a given substance.

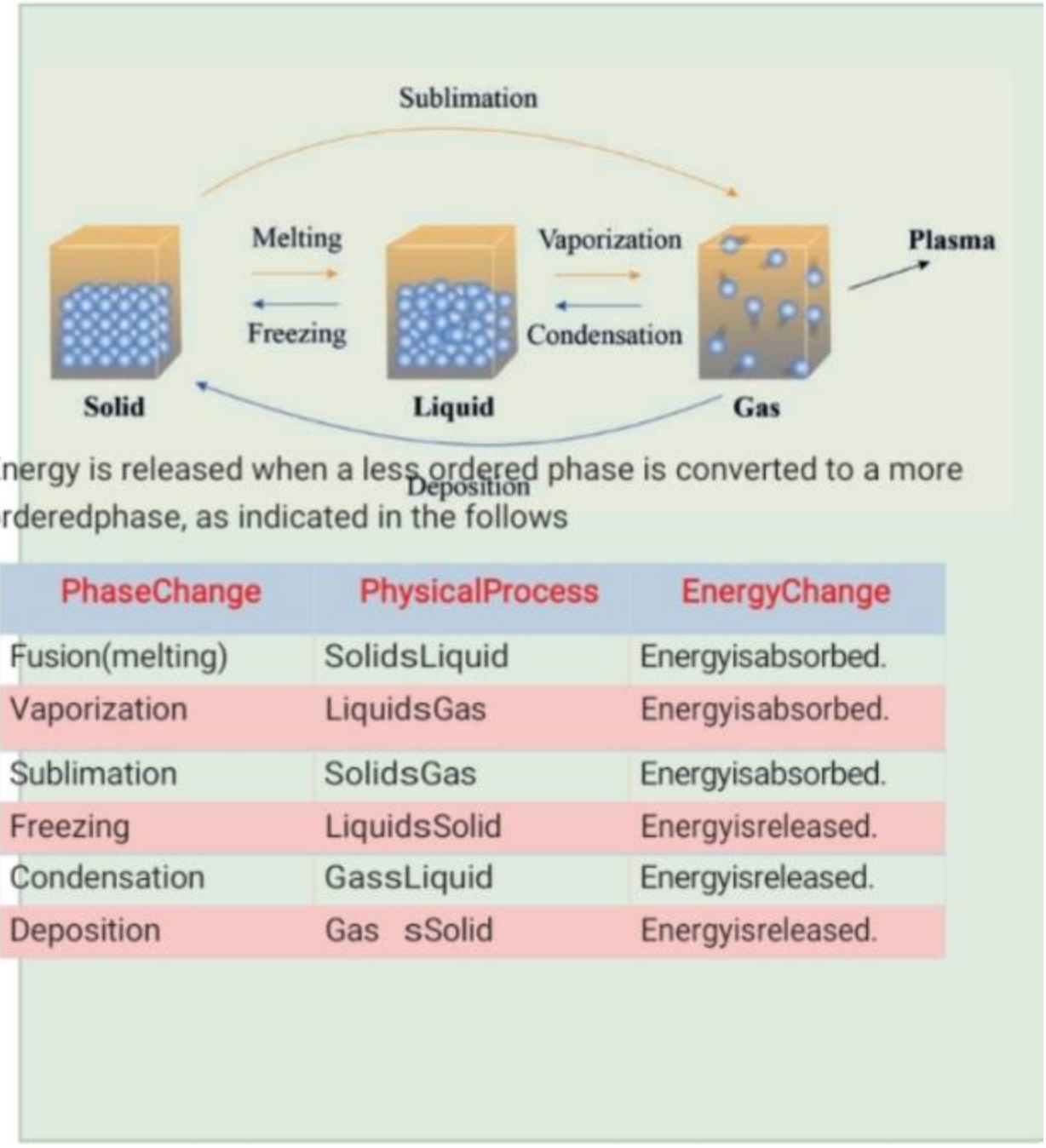
Lesson 3 : Summary

Evaporation is the process by which a liquid transforms into a gas or vapor phase at temperatures below its boiling point. Here are the key points about evaporation:

1. **Process**: Evaporation occurs at the surface of a liquid when molecules with enough kinetic energy break free from the liquid phase and enter the gas phase. This process continues until equilibrium is reached between the rate of evaporation and the rate of condensation.
2. **Temperature**: Unlike boiling, which occurs throughout the liquid at its boiling point, evaporation can occur at any temperature below the boiling point of the liquid. Higher temperatures generally increase the rate of evaporation because more molecules have sufficient kinetic energy to escape.
3. **Factors Influencing Evaporation**:

- **Temperature**: Higher temperatures increase the kinetic energy of molecules, leading to more rapid evaporation.
- **Surface Area**: Larger surface areas expose more liquid molecules to the air, increasing the rate of evaporation.
- **Humidity**: Lower humidity (dry air) promotes faster evaporation because the air can hold more vapor.
- **Air Movement**: Wind or air currents help carry away vapor molecules from the liquid surface, enhancing evaporation.

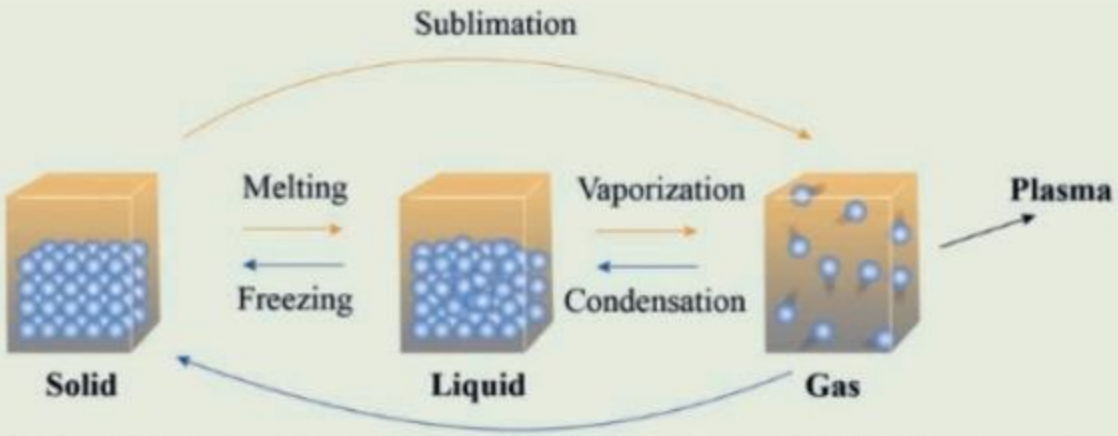
1. **Examples**: Examples of evaporation include the drying of wet clothes, the formation of water vapor over lakes and oceans, and the cooling effect of sweating in humans and other animals.
2. **Applications**: Evaporation is widely used in processes such as drying food products, concentrating solutions in industries (like the production of salt from seawater), and cooling systems (such as evaporative cooling towers).
3. **Importance**: Understanding evaporation is essential in fields such as meteorology, where it plays a role in the water cycle and weather patterns, and in engineering, where it affects the efficiency of cooling systems and the design of drying processes.



Energy is released when a less ordered phase is converted to a more orderedphase, as indicated in the follows

PhaseChange	PhysicalProcess	EnergyChange
Fusion(melting)	SolidsLiquid	Energyisabsorbed.
Vaporization	LiquidsGas	Energyisabsorbed.
Sublimation	SolidsGas	Energyisabsorbed.
Freezing	LiquidsSolid	Energyisreleased.
Condensation	GassLiquid	Energyisreleased.
Deposition	Gas sSolid	Energyisreleased.

- There are two main observations that we can learn from the heating curve: regions where the temperature increases as heat is added and plateaus where the temperature stays constant. It is at plateaus that a phase change occurs.
  Phase change and the Process



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