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The Second Stage  
Thermodynamics and Heat  
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## Lecture .8

### Systems, Phases and Components

- 1 Equilibrium represents the state of a process in which the properties like temperature, pressure, concentration of the system do not show any change with passage of time.
- 1 A physical equilibrium is an equilibrium that exists between different phases or physical properties. It represents the existence of the same substance in different physical states.
- 1 This equilibrium does not involve any chemical change. It involves only physical changes like phase changes or solubility.

### System

*A system is that part of the universe, the set of substances and energy associated with them, that is being studied.*

For example if reactions are occurring in a conical flask, everything inside the flask is a system.

# Phase

Picture in picture

- ❑ ***A phase is a homogeneous part of a system which is physically distinct from other parts of the system by a definite boundary.***
- ❑ **Each of the three homogeneous states (*solid, liquid and gas*) in which a substance can exist is called a phase.**
  - For example a mixture of gases is one phase
  - A solution is one phase
  - A saturated solution in the presence of an excess of the solute is a two-phase system

# Component

- ✓ ***A pure substance in a system that defines part of the composition of that system***
- ✓ **A mixture of water and ethanol has two components but one phase**
- ✓ **A mixture of ice and water has two phases but one component**

## Fundamentals of Phase Transitions

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Phase transition is when a substance changes from a solid, liquid, or gas state to a different state. Every element and substance can transition from one phase to another at a specific combination of temperature and pressure.

### Phase Changes

Each substance has three phases it can change into; solid, liquid, or gas . Every substance is in one of these three phases at certain temperatures. The temperature and pressure at which the substance will change is very dependent on the intermolecular forces that are acting on the molecules and atoms of the substance<sup>(2)</sup>. There can be two phases coexisting in a single container at the same time. This typically happens when the substance is transitioning from one phase to another. This is called a two-phase state<sup>(4)</sup>. In the example of ice melting, while the ice is melting, there is both solid water and liquid water in the cup.

There are six ways a substance can change between these three phases; melting, freezing, evaporating, condensing, sublimation, and deposition. These processes are reversible and each transfers between phases differently:

**Melting:** The transition from the solid to the liquid phase

**Freezing:** The transition from the liquid phase to the solid phase

**Evaporating:** The transition from the liquid phase to the gas phase

**Condensing:** The transition from the gas phase to the liquid phase

**Sublimation:** The transition from the solid phase to the gas phase

**Deposition:** The transition from the gas phase to the solid phase

## How Phase Transition works

There are two variables to consider when looking at phase transition, pressure (P) and temperature (T). For the gas state, The relationship between temperature and pressure is defined by the equations below:

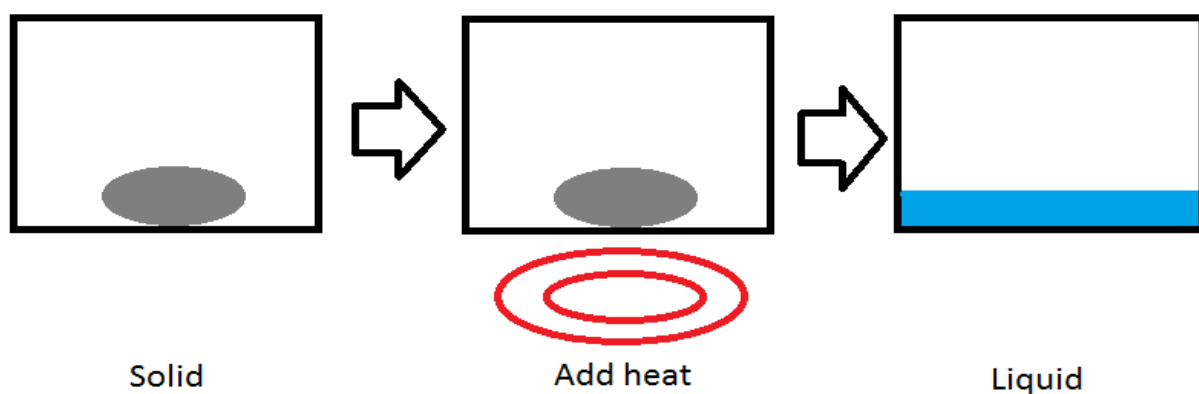
Ideal Gas Law:  $PV=nRT$

Where V is volume, R is the gas constant, and n is the number of moles of gas.

The ideal gas law assumes that no intermolecular forces are affecting the gas in any way, while the van der Waals equation includes two constants, a and b, that account for any intermolecular forces acting on the molecules of the gas.

## Temperature

Temperature can change the phase of a substance. One common example is putting water in a freezer to change it into ice. In the picture above, we have a solid substance in a container. When we put it on a heat source, like a burner, heat is transferred to the substance increasing the kinetic energy of the molecules in the substance. The temperature increases until the substance reaches its melting point . As more and more heat is transferred beyond the melting point, the substance begins to melt and become a liquid<sup>(3)</sup>. This type of phase change is called an isobaric process because the pressure of the system stays at a constant level.



## Melting point ( $T_f$ )

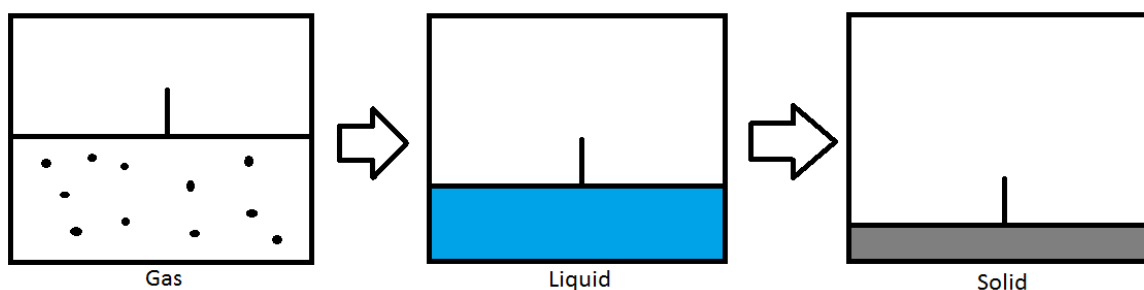
Each substance has a melting point. The melting point is the temperature that a solid will become a liquid. At different pressures, different temperatures are required to melt a substance. Each pure element on the periodic table has a normal melting point, the temperature that the element will become liquid when the pressure is 1 atmosphere<sup>(2)</sup>.

## Boiling Point ( $T_b$ )

Each substance also has a boiling point. The boiling point is the temperature that a liquid will evaporate into a gas. The boiling point will change based on the temperature and pressure. Just like the melting point, each pure element has a normal boiling point at 1 atmosphere.

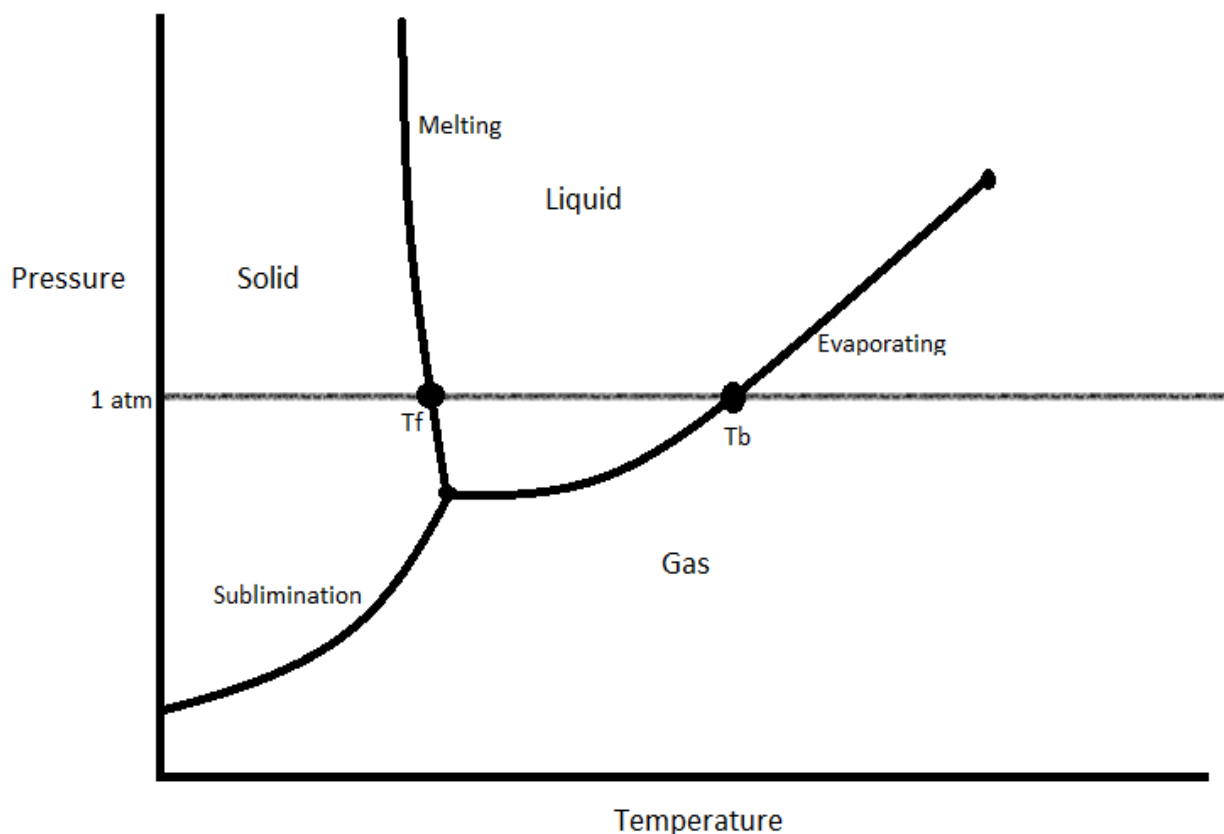
## Pressure

Pressure can also be used to change the phase of the substance. In the picture above, we have a container fitted with a piston that seals in a gas. As the piston compresses the gas, the pressure increases. Once the boiling point has been reached, the gas will condense into a liquid. As the piston continues to compress the liquid, the pressure will increase until the melting point has been reached. The liquid will then freeze into a solid. This example is for an isothermal process where the temperature is constant and only the pressure is changing.



## A Brief Explanation of a Phase Diagram

Phase transition can be represented with a phase diagram. A phase diagram is a visual representation of how a substance changes phases.



This is an example of a phase diagram. Often, when you are asked about a phase transition, you will need to refer to a phase diagram to answer it. These diagrams usually have the normal boiling point and normal melting point marked on them, and have the pressures on the y-axis and temperatures on the x-axis. The bottom curve marks the temperature and pressure combinations in which the substance will sublimate. The left left marks the temperature and pressure combinations in which the substance will melt. Finally, the right line marks the conditions under which the substance will evaporate.