THERMODYNAMIC PROCESS

Graphical Analysis and comparison of general processes in Thermodynamics

A thermodynamic process illustrates the journey a system has traveled from one condition to another. These conditions are determined by factors such as pressure, volume, and temperature. Additionally, the internal energy remains constant at a given state since it's contingent upon the system's temperature. The various thermodynamic processes are as follows:

Isochoric process ($\Delta V = 0$; Constant volume)

In this process, the system is constrained to have a constant volume.

Isobaric process ($\Delta P = 0$; Constant pressure)

In this process, the system is constrained to have a constant pressure.

Isothermal process ($\Delta T = 0$; Constant temperature)

In this scenario, the system has an infinite heat capacity. The heat absorbed by the system matches the heat released to the surroundings, ensuring the system maintains a steady temperature. A container with diathermic walls, which conduct heat, permits the system to exchange heat with its surroundings.

Adiabatic process ($\Delta Q = 0$; Insulated system)

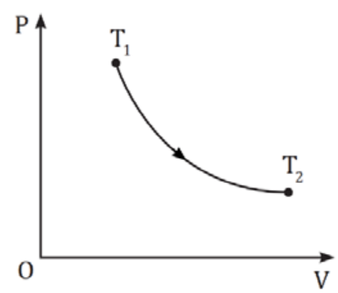
This process involves no transfer of heat between the system and its surroundings. Adiabatic processes happen rapidly, giving the system little time for heat exchange with its surroundings. A container with insulating walls, known as adiabatic walls, prevents heat exchange between the system and its surroundings.

Reversible and Irreversible Processes

Reversible process

A reversible process is an ideal situation where both the system and its surroundings stay in balance thermodynamically at every stage.

In a reversible process, a key aspect is that both the system and its surroundings reach a state of balance at every stage. This happens only when the system transitions between states very slowly.



The starting and ending points of the system are linked by a solid line because the system reaches equilibrium at each point. So, it has specific parameters like pressure, volume, or temperature.

When the system moves from one state to another, it does so through many small steps, like dividing the line joining the points into many segments.

If a reversible process (from A to B) is reversed, the system will pass through the same states but in reverse order.

In a reversible process, the work done by the system is balanced by the work done on the system. So, the work done by the system in the reverse process will be equal and opposite to the work done in the direct process.

We can write it as:

$$W_{A\to B} = -W_{B\to A}$$
$$\Delta U_{A\to B} = -\Delta U_{B\to A}$$
$$\Delta Q_{A\to B} = -\Delta Q_{B\to A}$$

For a process to be considered reversible, the system must change very slowly and remain in thermodynamic balance. Additionally, any dissipative forces such as friction or drag must be nonexistent.

Irreversible process

An irreversible process happens when the system and its surroundings can't go back to how they were at the start of the process.

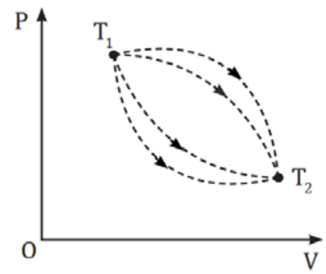
All real-life thermodynamic processes are irreversible.

These processes happen fast.

During this process, the system and its surroundings never balance out thermodynamically.

An irreversible process finishes in a set number of steps.

In irreversible processes, we can't define specific state parameters (like pressure, volume, temperature) at any point. Therefore, we can only represent them with a dashed line connecting two system states.



Heating water in a closed container from 30°C to 60°C and then cooling it back to 30°C isn't reversible. This is because the system and surroundings aren't in balance at each step, and the surroundings don't go back to how they were initially.

Limitations of First Law of Thermodynamics

It only discusses how energy remains constant in a thermodynamic system.

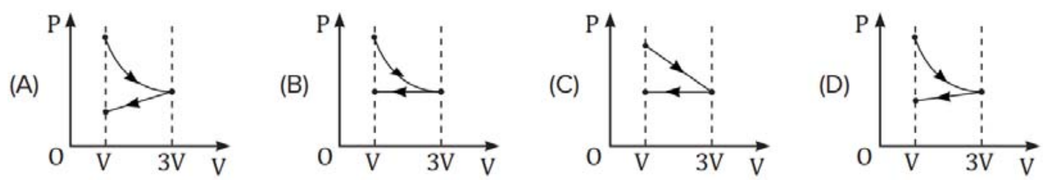
It doesn't tell us which way energy naturally flows in a process, like whether a process happens on its own. Basically, it doesn't show us the path from the starting point to the ending point.

Example:

Heat always moves from something hot to something cooler, similar to how water flows downhill from higher ground to lower ground.

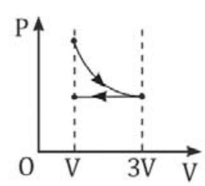
Numerical from Graphical Analysis

Ex. One mole of an ideal gas first undergoes an isothermal expansion from volume V to 3V. Later, its volume is reduced from 3V to V at a constant pressure. Which of the following is the correct PV diagram representing the two processes?



Sol. The first process is an isothermal expansion which is correctly shown in options (B) and (D) because the PV graph is in the form of a hyperbola and the volume is increasing.

The second process is an isobaric compression which is correctly shown in options (C) and (B) because the PV graph is a straight line parallel to the V-axis.



Ex. A sample of gas expands from volume V1 to V2. If the amount of the work done by the gas is the greatest, then what will be the expansion?

Sol. The work done by a gas is given by the area under the PV graph.

The figure shows the various thermodynamic processes for the expansion of a gas from volume V_1 to V_2.

The adiabatic process will have a steep curvature as compared to that of the isothermal process.

From the figure, we get the order of area as follows:

$$\text{Area}_{\text{Isobaric}} > \text{Area}_{\text{Isothermal}} > \text{Area}_{\text{Adiabatic}}$$

$$W_{\text{Isobaric}} > W_{\text{Isothermal}} > W_{\text{Adiabatic}}$$

Hence, the isobaric process will give the maximum work done by the gas.