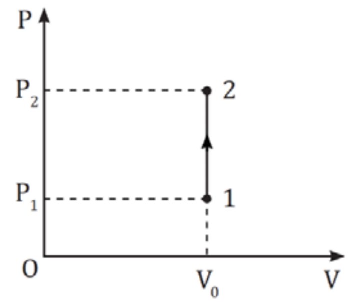
ISOBARIC, ISOTHERMAL AND ADIABATIC PROCESS

Isochoric process and its Characteristics

The graph illustrates an isochoric process. At the beginning, the pressure is P_1, and at the end, it becomes P_2. Throughout this process, the volume of the system remains unchanged.



If the system goes from state 1 to state 2, then the pressure is increasing.

I.e., $P_2 > P_1$

From the ideal gas equation,

$PV = nRT$

$P \propto T$ (Since the volume is constant. For the given system, n, R, and T are constant)

Hence, the temperature will increase with an increase in the pressure, i.e., $T_2 > T_1$ (As $P_2 > P_1$).

Since the internal energy of a thermodynamic system is solely proportional to the change in temperature, as the temperature increases, the internal energy of the system also increases. Thus, $U_2 > U_1$

Now, by applying the first law of thermodynamics in the isochoric process, we get,

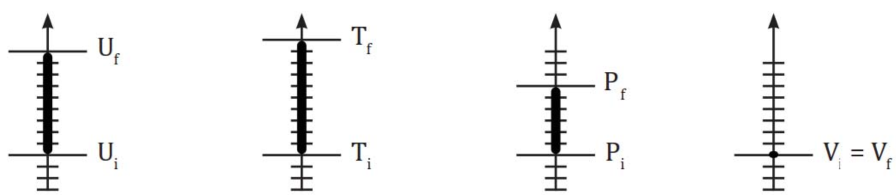
$$\Delta Q = \Delta U + W$$

$\Delta Q = \Delta U$ (Since $\Delta V = 0$ for an isochoric process and $W = P\Delta V$)

Since $U_2 > U_1$, the change in internal energy, i.e., ΔU, is positive. Hence, ΔQ is positive. This indicates that the heat has been supplied to the system.

Because the gas cannot expand, the added heat causes its temperature to increase.

During an isochoric process, if the gas's pressure rises, its temperature and internal energy also increase. This indicates that heat has been added to the gas.



If the gas experiences a drop in pressure while its volume remains constant, both its temperature and internal energy decline as well. This indicates that heat has been extracted from the system.

Isobaric process and its characteristics

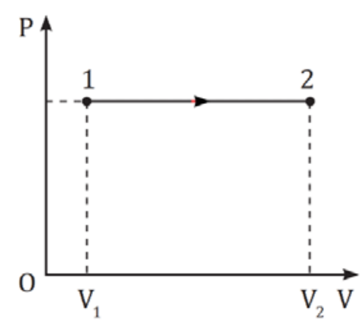
The system is going from state 1 to state 2 at a constant pressure.

$$P_1 = P_2 = P$$

However, the volume of the gas is expanding ($V_2 > V_1$).

Hence, the work done by the gas is positive.

By keeping the pressure constant and applying the ideal gas equation on the system, we get,



$$PV = nRT$$

$$\because P = \text{ Constant}$$

$$V \propto T$$

$$\text{Since } V_2 > V_1$$

$$T_2 > T_1$$

Hence, the internal energy of the system will increase, i.e., ΔU is positive.

Since the gas is expanding, $V_2 > V_1$. Hence, W is positive.

Now, by applying the first law of thermodynamics, we get,

$$\Delta Q = \Delta U + W$$

$$(\Delta U \rightarrow +ve, W \rightarrow +ve)$$

$$\therefore \Delta Q \rightarrow +ve$$

It can be concluded that the gas has absorbed the heat while expanding at a constant pressure. However, if a gas undergoes an isobaric compression ($V_2 < V_1$), then the work done by the gas will be negative,

i.e., $W \rightarrow -ve$[since $W_{\text{isobaric}} = P\Delta V = P(V_2 - V_1)$]

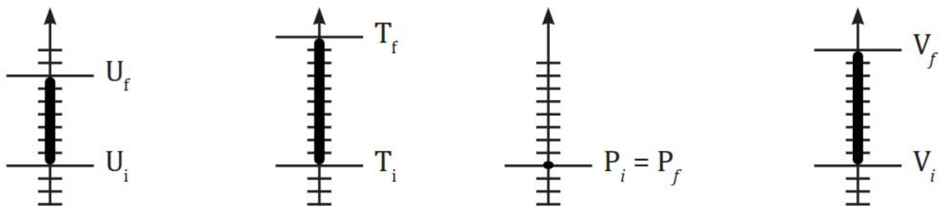
Now, by applying the ideal gas equation on the system, we get,

$$V \propto T$$
$$T_2 < T_1 (\text{ Since } V_2 < V_1)$$
$$\therefore U_2 < U_1 \text{ or } \Delta U \rightarrow -ve$$

According to the first law of thermodynamics, during isobaric compression, the change in heat (ΔQ) is negative. This means that the system releases heat to the surroundings.

Note

When a gas expands in an isobaric process, the work done by the gas is positive. Some of the heat taken in by the gas is used to perform this work and increase its internal energy.

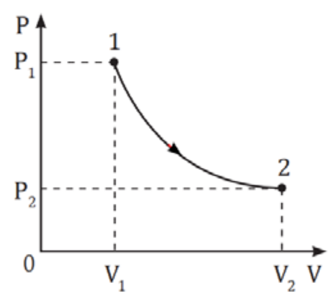


Isothermal process and its Characteristics

The temperature stays the same when a gas or a system undergoes a change of state.

When we maintain the temperature unchanged (meaning T = Constant, leading to $\Delta U = 0$), and use the ideal gas equation, we obtain:

$$P \propto \frac{1}{V}$$



Hence, the higher the pressure, the lower is the volume of the gas.

From the first law of thermodynamics, we get,

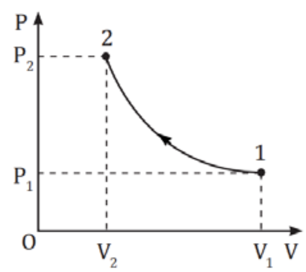
$$\Delta Q = W(\text{ Since } \Delta U = 0)$$

Therefore, it can be concluded that the heat supplied will be equal to the work done by the system.

In the case of an isothermal expansion (i.e., $T_2 = T_1$ and $V_2 > V_1$), the work is done by the system. Hence, the heat is supplied to the system.

Therefore,

$$\Delta T = 0, \Delta Q \rightarrow +ve, \text{ and } P_2 < P_1$$



Since $\Delta T = 0$, the change in internal energy is, $\Delta U = 0$. Therefore, by applying the first law of thermodynamics, it can be concluded that W is positive.

In the case of an isothermal compression (i.e., $T_2 = T_1$ and $V_2 < V_1$), the work is done by the surroundings on the system. Hence, the heat has been released by the system.

Therefore,

$$\Delta T = 0, \Delta Q \rightarrow -ve, \text{ and } P_Y > P_1$$

Since $\Delta T = 0$, the change in internal energy is $\Delta U = 0$. Therefore, by applying the first law of thermodynamics, it can be concluded that W is negative.

Sign convention

1. If the work is done by the system on the surroundings, W is positive.
2. If the work is done on the system by the surroundings, W is negative

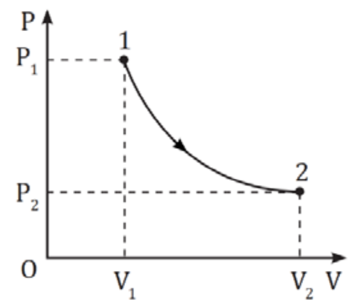
Adiabatic process and its Characteristics

There is no exchange of heat (i.e., $\Delta Q = 0$) between the system and the surroundings during the adiabatic process.

For an adiabatic process,

$$PV^{\gamma} = \text{Constant}$$

$$P \propto \frac{1}{V^{\gamma}}\left(\text{Where, } \gamma = \frac{C_P}{C_V}\right)$$



Hence, the higher the pressure, the lower is the volume of the gas.

In an adiabatic expansion ($\Delta Q = 0$ and $V_2 > V_1$), the work is done by the gas. Thus,

$$W_{gas} \rightarrow +ve$$
$$\Rightarrow W = -\Delta U$$
$$\therefore \Delta U \rightarrow -ve$$

Therefore, we can infer that the gas will perform work, which reduces its internal energy. As a result of this decrease in internal energy, the gas's temperature will also decrease ($T_2 < T_1$).

In an adiabatic compression ($\Delta Q = 0$ and $V_2 < V_1$), the work is done on the gas by the surroundings. Thus,

$$W_{gas} \rightarrow -ve$$
$$\text{Since } \Delta U = -W$$
$$\Delta U \rightarrow +ve$$

Thus, when work is done on the gas, its internal energy rises, leading to an increase in temperature.

Note

1. For any ideal gas—whether monoatomic, diatomic, or polyatomic—the value of γ is always greater than 1.
2. Because γ is greater than 1, in this case, the decrease in pressure will be more significant compared to what occurs in an isothermal process. Therefore, the steepness of the adiabatic process on a given PV curve is higher than that of the isothermal process.
3. Since there is no heat exchange ($\Delta Q = 0$), applying the first law of thermodynamics yields the equation: Work (W) equals negative change in internal energy (ΔU).