Thermodynamics

Processes

Isometric (Isochoric) Process

$$\Delta V = 0 \Rightarrow W = 0$$

$$\Delta U = Q = nC_{v,m}\Delta T$$

$$\frac{P_1}{P_2} = \frac{T_1}{T_2}$$

Isobaric Process

$$\Delta P = 0 \Rightarrow W = -P(V_2 - V_1) = -nR\Delta T$$

$$\Delta U = Q + W \Rightarrow nC_{v,m}\Delta T = nC_{p,m}\Delta T + (-P\Delta V)$$

$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$

Isothermal Process

$$\Delta T = 0 \Rightarrow \Delta U = 0 \Rightarrow Q = -W$$

$$P_1V_1 = P_2V_2$$

$$W = \int_{V_1}^{V_2} -PdV = -\int_{V_1}^{V_2} \frac{nRT}{V}dV = -nRT\ln\frac{V_2}{V_1} = -PV\ln\frac{V_2}{V_1}$$

Adiabatic Process

$$\Delta Q = 0 \Rightarrow \Delta U = W$$

$$TV^{\gamma-1} = constant \Rightarrow PV^{\gamma} = constant$$

$$W = \int_{V_1}^{V_2} -PdV = -PV^{\gamma}\int_{V_1}^{V_2} V^{-\gamma}dV = -\frac{P_2V_2 - P_1V_1}{1-\gamma}$$

Isothermal vs Adiabatic

Isothermal

$$\frac{dP}{dV} = -\frac{P}{V}$$

Adiabatic

$$\frac{dP}{dV} = -\gamma\frac{P}{V}$$

$$\left|\frac{dP}{dV}\right|_{adia} > \left|\frac{dP}{dV}\right|_{iso}$$

Second Law of Thermodynamics

Kelvin-Plank Statement

It is impossible for any device that operates in a cycle to receive heat from a single reservoir and produce a net amount of work

Third Law of Thermodynamics

Definition

The entropy of a system approaches a constant value as its temperature approaches absolute zero.

First Law of Thermodynamics

Definition

In a closed system, the total amount of energy of all kinds is constant.

$$\Delta U = Q + W \quad (\Delta U = \text{change in internal energy},\ Q = \text{heat supplied to system},\ W = \text{work done on gas})$$

Work Done By Gas

$$W = \int_{V_1}^{V_2} -PdV$$

Molar Heat Capacity of Gas

Constant Volume

$C_{v,m}$: Molar heat capacity at constant volume, i.e. heat required to warm 1 mol of gas through 1K at constant volume

$$\Delta U = Q_v = nC_{v,m}\Delta T$$

Constant Pressure

$C_{p,m}$: Molar heat capacity at constant pressure, i.e. heat required to warm 1 mol of gas through 1K at constant pressure

$$\Delta U = Q_p + W = nC_{p,m}\Delta T$$

$$Q_p > Q_v$$

$$C_p - C_v = R$$

$$\gamma = \frac{C_p}{C_v} = 1 + \frac{2}{f}$$