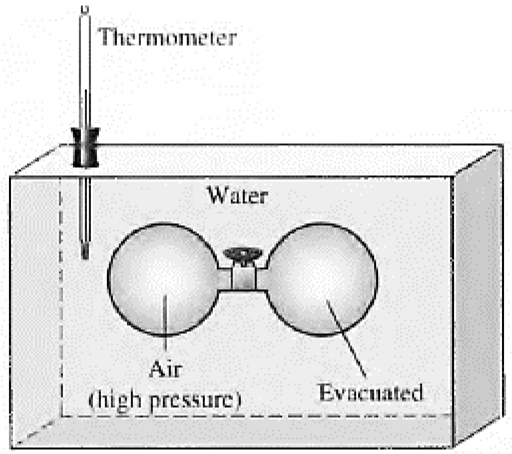
Ninevah University
College of Electronics Engineering
Systems & Control Engineering

Internal Energy and Specific Heats of Ideal Gases

It has been demonstrated experimentally (Joule, 1843) that for an ideal gas the internal energy is a function of the temperature only.



Joule submerged two tanks connected with a pipe and a valve in a water bath. Initially, one tank contained air at a high pressure and the other tank was evacuated. When thermal equilibrium was attained, he opened the valve to let air pass from one tank to the other until the pressures equalized.

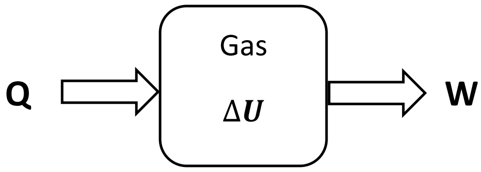
Joule observed no change in the temperature of the water bath (Thermometer) and assumed that no heat was transferred to or from the air. Since there was also no work done, he concluded that the internal energy of the air did not change ($\Delta U = 0$) even though the volume and the pressure changed. Therefore, he concluded that the internal energy is a function of temperature only that is:

$$\Delta U = m\, C_v\, \Delta T$$

1st Law of Thermodynamics Applied to Close System

The change of the internal energy (ΔU) of a system is equal to the heat added to the system (Q) minus the work done by the system (W). i.e.

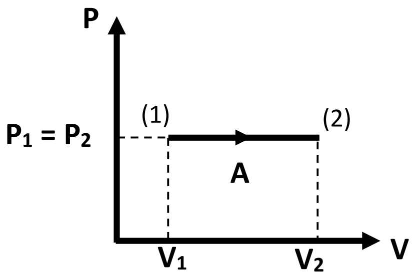
$$\boxed{\Delta U = Q - W}$$



Thermodynamic Process

Change that a system undergoes from one equilibrium state to another.

1. **Isobaric Process**: A process where the pressure is held constant.



$$\Delta U = Q - W$$

$$\Delta U = m\, C_v\, \Delta T$$

$$Q = m\, C_p\, \Delta T$$

$$W = \int_{V_1}^{V_2} P\, dV = P\, \Delta V$$

$$P\, V = m\, R\, T$$

$$\frac{V}{T} = \frac{m\, R}{P} = C \;\rightarrow\; \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

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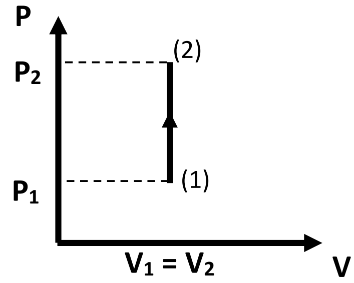
Ex) During an isobaric process, 20 g of air is compressed at a pressure of 1.5 bar from 15 L to 7 L. Calculate the change in the internal energy, the work done on the gas, Heat lost, initial and final temperatures. Take Cv = 0.718 (kJ/(kg. K).

H.W) Prove that Cp = Cv + R.

2. **Isometric Process**: A process where the volume is held constant.



$\Delta U = Q - W$

$\Delta U = m\, C_v\, \Delta T$

$W = \int_{V_1}^{V_2} P\, dV = P\, \Delta V = 0$

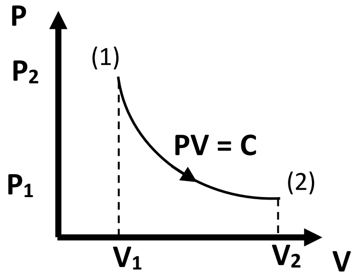
$\Delta U = Q$

$P\, V = m\, R\, T$

$\frac{P}{T} = \frac{m\, R}{PV} = C \;\rightarrow\; \frac{P_1}{T_1} = \frac{P_2}{T_2}$

Ex) A vessel containing 5 mole of air initially at 1.2 bar and 20 ^{o}C. A certain amount of heat is added to the vessel raising the temperature of the air. If the final pressure is 3 bar, calculate the change in the internal energy, heat added to the gas. Take Cv = 5/2 Ru (J/ (mole. K))

3. **Isothermal Process**: A process during which the temperature remains constant.



$\Delta U = Q - W$

$\Delta U = m\, C_v\, \Delta T = 0$

$W = Q$

$$W = \int_{V_1}^{V_2} P \, dV$$

$$W = \int_{V_1}^{V_2} \frac{C}{V} \, dV = W = C \int_{V_1}^{V_2} \frac{1}{V} \, dV$$

$$W = C \, ln \, (V_2 - V_1) = C \, ln \frac{V_2}{V_1}$$

$$P \, V = m \, R \, T = C$$

$$P_1 V_1 = P_2 V_2$$

Ex) A piston-cylinder device initially contains 0.4 m^3 of air at 100 Kpa and 80°C. The air is now compressed to 0.1 m^3 in such a way that the temperature inside the cylinder remains constant. Determine the work done, heat lost during this process and the final pressure.