1st Law of Thermodynamics

Chapter 5

- **Law of conservation of energy**
- **E is the energy of the system**

$$E = U + KE + PE$$

E – energy of the system

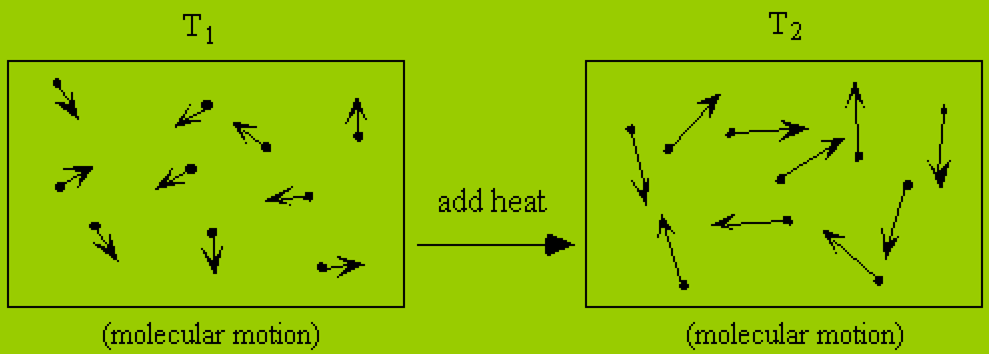
U – Internal energy

KE – Kinetic energy

PE – Potential energy

Internal energy, U

- **Let's focus on the internal energy, *u*. It is associated with the random or disorganized motion of the particles.**



u is a function of the state of the system

The change in energy of a system is equal to the difference between the heat *added to* the system and the work *done by* the system.

$\Delta E = Q - W$ (units are Joules)

$$dE = dU + d(KE) + d(PE)$$

- **It represents all the energy of the system at the given state (E)**
    - **Kinetic energy of the system (KE)**
    - **Potential energy of the system (PE)**
    - **Internal energy (U) such as kinetic energy of the molecules**

$$Q - W = dU + d(KE) + d(PE)$$

KE and PE

- KE = $\frac{1}{2} m V^2$ or Δ KE = $\frac{1}{2} m (V_2^2 - V_1^2)$
- PE = mgZ or $\Delta PE = mg(Z_2 - Z_1)$

Substitute into equation

Q – W = dU + d(KE) + d(PE)

$$\Delta \mathrm{KE} = \frac{1}{2} m(V_2^2 - V_1^2)$$

$$\Delta PE = mg(Z_2 - Z_1)$$

$$ {}_1Q_2 = U_2 - U_1 + \frac{m(V_2^2 - V_1^2)}{2} + mg(Z_2 - Z_1) + {}_1W_2 $$

In many situations the potential energy and the kinetic energy of the system are constant.

- Then $\Delta e = \Delta u$,
- $\Delta u = q - w$ or $\Delta U = Q - W$
- Can also write the first law in differential form:

  $dU = \delta Q - \delta W$ or $du = \delta q - \delta w$

Enthalpy

- $H = U + PV$
- $h = u + Pv$

- For saturation condition ;

$$h = h_f + x\, h_{fg}$$

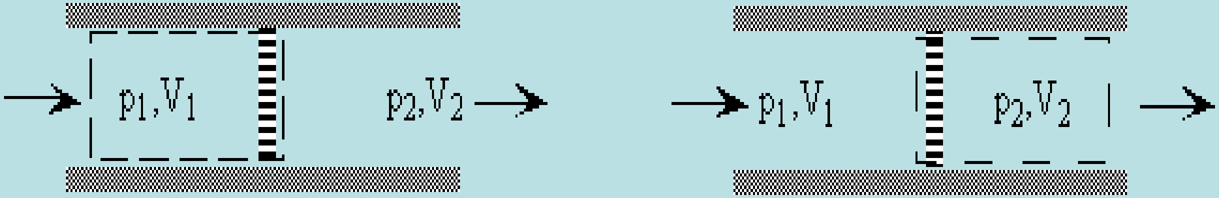
$$\begin{aligned} Q &= (U_2 - U_1) + W \\ &= (U_2 - U_1) + p(V_2 - V_1) \end{aligned}$$

since $p_1 = p_2 = p$ (constant P)

$$\begin{aligned} Q &= (U_2 + pV_2) - (U_1 + pV_1) \\ &= H_2 - H_1 \end{aligned}$$

Example

– **Consider adiabatic throttling of a gas (gas passes through a flow resistance). What is the relation between conditions before and after the resistance?**



$Q = 0$ therefore $\Delta U = - \Delta W$

or $U_2 - U_1 = -(p_2V_2 - p_1V_1)$

so $U_2 + p_2V_2 = U_1 + p_1V_1$

$H_2 = H_1$

First Law in terms of enthalpy

$dU = \delta Q - \delta W$ (for any process, $\Delta KE = \Delta PE = 0$)

$dU = \delta Q - pdV$

Known $H = U + pV$

Therefore

$dH = dU + pdV + Vdp$

$dH = \delta Q - \delta W + pdV + Vdp$ (any process)

OR

$dH = \delta Q + Vdp$

Lets do some exercises

Quiz 1

Quiz 2

Specific Heats and Heat Capacity

- **$Q = C\Delta T$**

  where C is a heat capacity constant that depends on the substance.

- **Specific heat :**

  The amount of heat required per unit mass to raise the temperature by one degree.

$$C = \frac{1}{m}\frac{\partial Q}{\partial T}$$

- **For a constant pressure process:**

$$C_p = \left(\frac{\delta Q}{\partial T}\right)_p \qquad c_p = \left(\frac{\delta q}{\partial T}\right)_p$$

- **For a constant volume process:**

$$C_v = \left(\frac{\delta Q}{\partial T}\right)_v \qquad c_v = \left(\frac{\delta q}{\partial T}\right)_v$$

use c_p and c_v to relate u and h to the temperature for an ideal gas

- First Law for a quasi-static process

$$du = \delta q - pdv$$

- If the process is *constant volume*:

$$du = \delta q$$

$$C_v = \frac{1}{m}\left(\frac{dU}{dT}\right)$$

- Substitute into Equation (5.14)

$dU = mC_v dT$ (For constant volume only)

$$U_2 - U_1 = mC_v(T_2 - T_1)$$

$$Q = U_2 - U_1 = mC_v(T_2 - T_1)$$

- If the process is *constant pressure,*

$$dh = \delta q$$

- Note: $dh = du + dpv = du + pdv + vdp$

$$C_p = \frac{1}{m}\left(\frac{dH}{dT}\right)$$

$dH = mC_p dT$ (for constant pressure)

$$H_2 - H_1 = mC_p(T_2 - T_1)$$

$$Q = H_2 - H_1 = mC_p(T_2 - T_1)$$

exercise

QUIZ 11

More exercise

Quiz 4

Quiz 5

Quiz 6

Quiz 7

Quiz 8

Quiz 9