Thermodynamics

Formula Sheet

1. First law of thermodynamics

$$\Delta Q = \Delta U + \Delta W \quad \text{or} \quad \Delta U = Q - W$$

Where ΔQ = Heat supplied to the system by the surroundings

ΔW = Work done by the system on the surroundings

ΔU = Change in internal energy of the system

* When heat is supplied to the system

$$\Delta U = \Delta Q - P\Delta V \quad [\because \Delta W = -P\Delta V]$$

* For isochoric process (V = Constant) $V \rightarrow$ Volume

$W = 0$ ($W = P\Delta V$ and $\Delta V = 0$), then

$$\Delta U = \Delta Q$$

* For isothermal process (U = Constant as T is constant)

$$\Delta Q = \Delta W \quad [\because \Delta U = 0]$$

2. Heat capacity (S)

$$S = \frac{\Delta Q}{\Delta T}$$

ΔT = change in temperature

3. Specific heat capacity (s)

$$s = \frac{S}{m} = \frac{\Delta Q}{m\Delta T}$$

m = mass of the substance

4. Specific heat capacity for a gas

(Amount of substance is taken in moles μ)

$$C = \frac{S}{\mu} = \frac{\Delta Q}{\mu \Delta T}$$

C = Molar specific heat capacity

* Specific heat capacity is independent of amount of substance.

5. Specific heat capacity at constant volume

$$C_V = \frac{\Delta Q}{\mu \Delta T}$$

6. Specific heat capacity at constant pressure

$$C_P = \frac{\Delta Q}{\mu \Delta T}$$

7. Relation b/w C_P and C_V

$$C_P - C_V = R$$

8. Ideal gas equation for n numbers of moles

$$PV = nRT$$

n = no. of moles of the gas

9. Isothermal Process (T = Constant, $\Delta T = 0 \Rightarrow \Delta U = 0$)

$PV = \text{constant}$ and $Q = W$

10. Work done in isothermal process

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

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

T = Temperature (in Kelvin)

here $\ln(x) = 2.303 \log x$, so

$$W = nRT \; 2.303 \log \frac{V_2}{V_1}$$

[log uses base 10
ln uses base e]

11. Adiabatic process ($\Delta Q = 0$)

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

here $$\gamma = \frac{C_P}{C_V}$$

γ is the ratio of specific heat capacity at constant pressure and at constant volume.

$$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$$

12. Work done in adiabatic process

$$W = \frac{1}{1-\gamma}[P_2V_2 - P_1V_1]$$

$$W = \frac{\mu R[T_1 - T_2]}{\gamma - 1}$$

* If work is done by the gas in adiabatic process $W > 0$ and $T_2 < T_1$
* If work is done on the gas, $T_2 > T_1$ [temp of gas ↑]

13 Isochoric Process ($\Delta V = 0$) Volume remain constant

- No work is done on or by the gas. ($W = 0$)
- All heat absorbed goes to change the internal energy and its temperature. ($Q = \Delta U$)

14. Isobaric Process ($\Delta P = 0$)

Work done by the gas

$$W = P(V_2 - V_1) = nR(T_2 - T_1)$$

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

15 The efficiency of carnot engine (η)

$$\eta = \frac{W}{Q_1} = 1 - \frac{Q_2}{Q_1}$$

W = Total work done

Q_1 = heat absorbed by the gas
Q_2 = heat released by the gas

also, $\eta = 1 - \frac{T_2}{T_1}$

T_1 = Temperature of hot reservoirs
T_2 = Temperature of cold reservoirs

* No engine can have efficiency more than carnot engine.
* The efficiency of carnot engine is independent of the nature of the working substance.

* Units of heat:
Joule and calorie

1 cal = 4.18 joule

* Units of specific heat

- $J\,kg^{-1}\,{}^{\circ}C^{-1}$ SI unit → $J\,kg^{-1}\,K^{-1}$
- $J\,g^{-1}\,{}^{\circ}C^{-1}$
- $cal\,g^{-1}\,{}^{\circ}C^{-1}$

* 1 litre of water = 1 kg = 10^3 g

[$1\,l = (1 \times \rho)$ kg]

* $1\,l = 10^3\,cm^3 = 10^{-3}\,m^3$

* Temperature difference ΔT has same value in °C and K.