Termodinámica

Ecuaciones de Estado

Ecuación de Estado Térmica

Clapeyron Mendeleiev: $pV = nRT$

- **Proceso Isotérmico** ($T = cte$)

$$p = \frac{c_1}{V} = p(V),\ c_1 = nRT \tag{1}$$

- **Proceso Isobárico** ($p = cte$)

$$V = c_2 T = V(t),\ c_2 = \frac{nR}{p} \tag{2}$$

- **Proceso Isobárico** ($V = cte$)

$$p = c_3 T = p(T),\ c_3 = \frac{nR}{V} \tag{3}$$

Ecuación de Estado Calórica

$$U = U_0 + C_v(T - T_0) \tag{4}$$

Leyes de la Termodinámica

Primera Ley

$$\delta Q = dU + pdV \tag{5}$$

$$\delta Q = dU + pdV - \sum_{i=1}^{n} \mu_i dN_i \tag{6}$$

Segunda Ley

$$\delta Q = TdS \tag{7}$$

$$\oint \frac{\delta Q}{T} = 0 \tag{8}$$

Tercera Ley

$$\left(\frac{\partial U}{\partial S}\right)_{V,N} = 0 \tag{9}$$

$$\lim_{T \to 0} S(T) = 0 \tag{10}$$

Ecuación Fundamental de la Termodinámica

$$TdS = dU + pdV \tag{11}$$

$$TdS = dU + pdV - \sum_{i=1}^{n} \mu_i dN_i \tag{12}$$

Potenciales Termodinamicos

Energía Interna

$$TdS - pdV = \left(\frac{\partial U}{\partial S}\right)_V dS + \left(\frac{\partial U}{\partial V}\right)_S dV \tag{13}$$

Energía libre de Helmholtz

$$F = U - TS \tag{14}$$

$$-SdT - pdV = \left(\frac{\partial F}{\partial T}\right)_V dT + \left(\frac{\partial F}{\partial V}\right)_T dV \tag{15}$$

Entalpía

$$H = U + pV \tag{16}$$

$$TdS + Vdp = \left(\frac{\partial H}{\partial S}\right)_p dS + \left(\frac{\partial H}{\partial p}\right)_S dp \tag{17}$$

Energía de Gibbs

$$G = U + pV - TS \tag{18}$$

$$Vdp - Sdt = \left(\frac{\partial G}{\partial p}\right)_T dp + \left(\frac{\partial G}{\partial T}\right)_p dT \tag{19}$$

Relaciones Termodinámicas de Maxwell

Energía Interna

$$U = U(V, S) \tag{20}$$

$$\left(\frac{\partial T}{\partial V}\right)_S = \left(-\frac{\partial p}{\partial S}\right)_V \tag{21}$$

Energía libre de Helmholtz

$$F = F(V, T) \tag{22}$$

$$\left(-\frac{\partial S}{\partial V}\right)_T = \left(-\frac{\partial p}{\partial T}\right)_V \tag{23}$$

Entalpía

$$H = H(S, p) \tag{24}$$

$$\left(\frac{\partial T}{\partial p}\right)_S = \left(\frac{\partial V}{\partial S}\right)_p \tag{25}$$

Energia de Gibbs

$$G = G(p, T) \tag{26}$$

$$\left(-\frac{\partial S}{\partial p}\right)_T = \left(\frac{\partial V}{\partial T}\right)_p \tag{27}$$

Condiciones de equilibrio de dos fases

$$\frac{dU_\ell + p_\ell dV_\ell - \mu_\ell dN_\ell}{T_\ell} + \frac{dU_v + p_v dV_v - \mu_v dN_v}{T_v} = 0 \tag{28}$$

Condiciones del sistema

$$U = U_\ell + U_v = cte,\ dU_\ell + dU_v = 0 \tag{29}$$

$$V = V_\ell + V_v = cte,\ dV_\ell + dV_v = 0 \tag{30}$$

$$N = N_\ell + N_v = cte,\ dN_\ell + dN_v = 0 \tag{31}$$

$$\left[\frac{1}{T_\ell} - \frac{1}{T_v}\right] dU_\ell + \left[\frac{p_\ell}{T_\ell} - \frac{p_v}{T_v}\right] dV_\ell - \left[\frac{\mu_\ell}{T_\ell} - \frac{\mu_v}{T_v}\right] dN_\ell = 0 \tag{32}$$

- **Condición de equilibrio térmico**

$$\left[\frac{1}{T_\ell} - \frac{1}{T_v}\right] = 0 \tag{33}$$

- **Condición de equilibrio mecánico**

$$\left[\frac{p_\ell}{T_\ell} - \frac{p_v}{T_v}\right] = 0 \tag{34}$$

- **Condición de equilibrio químico**

$$\left[\frac{\mu_\ell}{T_\ell} - \frac{\mu_v}{T_v}\right] = 0 \tag{35}$$

Coeficientes Térmicos

- **Coeficiente de dilatación térmica Isobárica**

$$\alpha = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_p \tag{36}$$

- **Coeficiente de compresibilidad Isotérmica**

$$\chi_T = -\frac{1}{V}\left(\frac{\partial V}{\partial p}\right)_T \tag{37}$$

- **Coeficiente Piezotérmico**

$$\beta = \frac{1}{p}\left(\frac{\partial p}{\partial T}\right)_V \tag{38}$$

- **Observación**

$$\alpha = p\chi_T\beta \tag{39}$$