Lecture 11

Open System and Chemical Potential

Susmita Roy

Equilibrium condition in terms of system properties

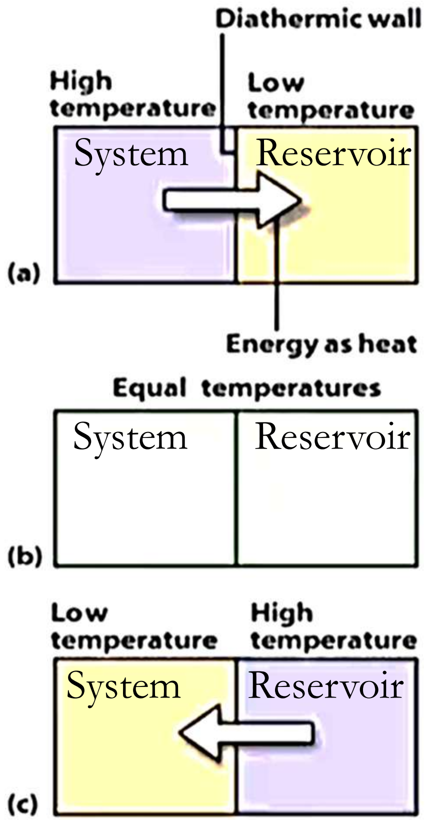
	Thermodynamic state of system	Thermodynamic potential	Condition of equilibrium in terms of	
			Reservoir properties	System properties
Isolated system	S, V, N	$U = U(S, V, N)$	-	Minimization of U
System + Thermostat	T, V, N	$F = U - TS$	$T_{sys} = T_{res}$	Minimization of F
System + Thermostat + Barostat	T, p, N	$G = U - TS + pV$	$T_{sys} = T_{res}$ $p_{sys} = p_{res}$	Minimization of G

Free energy: Amount of energy that is free to do external work

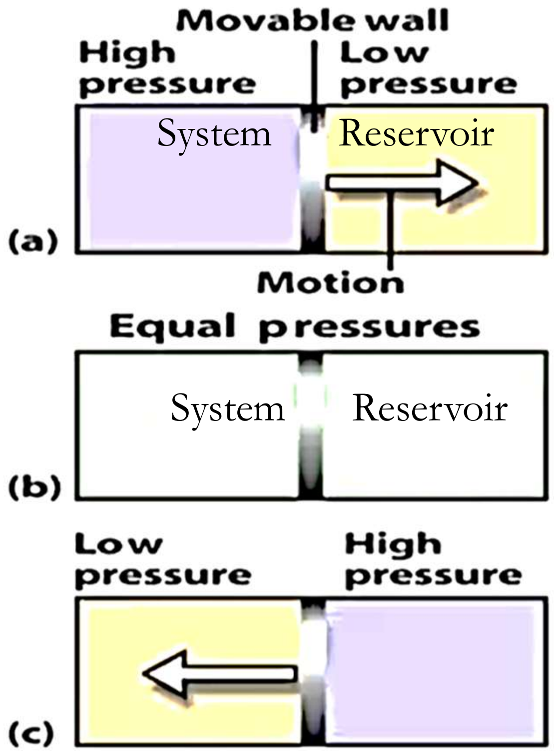
$$A = U - TS \quad \text{and} \quad G = H - TS$$

Types of Equilibrium

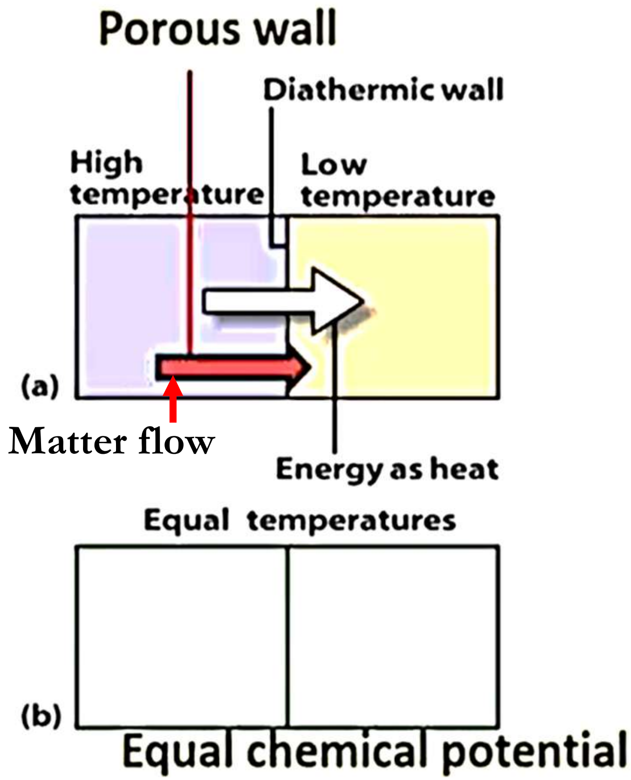
Thermal Equilibrium



Mechanical Equilibrium



Material Equilibrium



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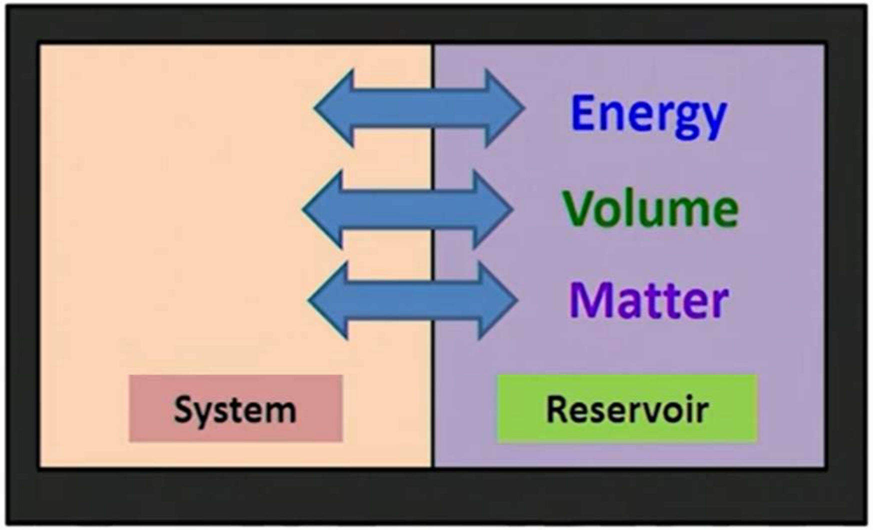
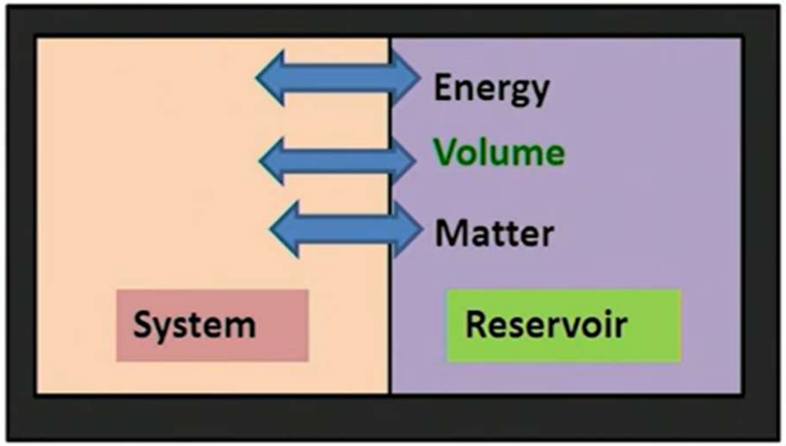
Equilibrium State of an Open System



System	Wall			Equilibrium state
Open	Diathermal	Flexible	Permeable	T, p, μ

Equilibrium State of an Open System



System	Wall			Equilibrium state
Open	Diathermal	Rigid	Permeable	$\mathrm{T}, \mathrm{V}, \mu$
		Flexible		$\mathrm{T}, \mathrm{p}, \mu$
Closed	Diathermal	Rigid	Impermeable	T, V, N
	Diathermal	Flexible	Impermeable	T, p, N
Isolated	Adiabatic	Rigid	Impermeable	U, V, N Or S, V, N

General Definition of Chemical Potential

- Chemical potential, μ_i is the rate of change of the thermodynamic potential with respect to change in number of particles, n_i of type *i* (*i=1,M*)

$$dU = T\,dS - pdV + \sum_{i=1}^{M} \mu_i\, dn_i \quad \Rightarrow \mu_i = \left(\frac{\partial U}{\partial n_i}\right)_{S,V,n_{j\neq i}}$$

$$dH = T\,dS + Vdp + \sum_{i=1}^{M} \mu_i\, dn_i \quad \Rightarrow \mu_i = \left(\frac{\partial H}{\partial n_i}\right)_{S,p,n_{j\neq i}}$$

$$dF = -S\,dT - pdV + \sum_{i=1}^{M} \mu_i\, dn_i \quad \Rightarrow \mu_i = \left(\frac{\partial F}{\partial n_i}\right)_{T,V,n_{j\neq i}}$$

$$dG = -S\,dT + Vdp + \sum_{i=1}^{M} \mu_i\, dn_i \quad \Rightarrow \mu_i = \left(\frac{\partial G}{\partial n_i}\right)_{T,p,n_{j\neq i}}$$

Most common formulae of Chemical Potential

Commonly used definition of chemical potential

$$\mu_i = \left(\frac{\partial G}{\partial n_i}\right)_{T,p,n_{j\neq i}}$$

$$dG = -S\,dT + V dp + \sum_{i=1}^{M} \mu_i\, dn_i$$

$$G = G(T, p, n_1, n_{2,}.., n_M)$$

- Thank you all !