TEMA 9

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$v = (1 - x^v) v^l + x^v v^v$

↳ título vapor

Gas ideal

$pv = RT$

Van der Waals

$\left(p + \frac{a}{v^2}\right)(v - b) = RT$

$a \propto$ f. interm.

$b = N_A \cdot \frac{2\pi}{3} d^3 = 4 N_A V$

$a = \frac{9}{8} RT_c v_c$

$b = \frac{v_c}{3}$

$\Big\} \; R = \frac{8}{3} \frac{p_c v_c}{T_c}$. $X_r = \frac{X}{X_c}$

$\left(p_r + \frac{3}{v_r^2}\right)(3v_r - 1) = 8T_r$ Ley estados correspondientes

Virial

$pv = RT\left(1 + \frac{B}{v} + \frac{C}{v^2} + \dots\right) = RT + B'p + C'p^2 + \dots$

↳ $Z = \frac{pv}{RT}$

Fugacidad

$\left(\frac{\partial G}{\partial n}\right)_{T,p} = \mu$

$d\mu = -s\,dT + v\,dp$, $dT = 0$

Gas ideal $\to \mu = \mu^* + RT \ln p$

No ideal $\to \mu = \mu^* + RT \ln f$ ... nueva variable de estado

$d\mu = RT\, d\ln f = v\,dp$

$d\ln f = \frac{v}{RT} dp$

$\ln f = \ln p + \int_0^{p_1} \left(\frac{v}{RT} - \frac{1}{p}\right) dp$

$\mu_i = \mu^* + RT \ln f^i$

$\mu^* = \mu(T, p^* = 1)$

Sól - Líq

$f_1^s = f_1^v$ o $f_3^v = f_3^l$

$\ln f_2^s - \ln f_1^s = \frac{1}{RT} \int_{p_1}^{p_2} v^s\, dp$

1er orden

$$dQ = L\,dm'' \qquad \Rightarrow \qquad \frac{dp}{dT} = \frac{s''-s'}{v''-v'} = \frac{L}{T(v''-v')}$$

$$L = h''-h'$$

$$L = T(s''-s')$$

$$\mu' = \mu'' \qquad \frac{d\ln p}{dT} = \frac{L}{RT^2}$$

Ecuación de Clapeyron

$$\frac{dL}{dT} = c_p'' - c_p' + \frac{L}{T}\left(1 + T\frac{\alpha' v' - \alpha'' v''}{v''-v'}\right) = T\left(\frac{ds}{dT}\right)_{SAT} \neq (C_{SAT})$$

$$C_{SAT}{}^{v} = c_p{}^{v} - T\alpha v\left(\frac{dp}{dT}\right)_{SAT} \qquad \left(\frac{ds''}{dT}\right)_{SAT} - \left(\frac{ds'}{dT}\right)_{SAT} = \frac{1}{T}\frac{dL}{dT} - \frac{L}{T^2}$$

Vapor: $\frac{dL}{dT} = c_p{}^{v} - c_p{}'$

$L_v\,dm = m\,c^{l}_{SAT}\,dT$ (extr. vapor fusión hielo)

$$\frac{\vec{\nabla}\rho}{\rho} = -\frac{\vec{\nabla} v}{v} = -\alpha\vec{\nabla}T$$

TEMA 11

Molaridad $c = \frac{n_2}{V}$ V/dm^3

Molalidad $m = \frac{n_2}{m_1}$

F. másica $w_2 = \frac{m_2}{m_1+m_2} \cdot 100$

$$c = \frac{\rho x_2}{x_2(M_2-M_1)+M_1}$$

$$m = \frac{(1000)\cdot x_2}{M_1(1-x_2)}$$

$F = \sum n_i f_i$

$$\sum n_i df_i = \left(\frac{\partial F}{\partial T}\right)_{p,n_j} dT + \left(\frac{\partial F}{\partial p}\right)_{T,n_j} dp$$

$$v_2 = \left(\frac{\partial V}{\partial c}\right)\left(\frac{\partial c}{\partial n_2}\right)_{T,p,n_1} \rightarrow v = \frac{n_1 M_1 + n_2 M_2}{\rho} \quad \rho(c)_{T,p}$$

Vol. molar aparente

$$\Phi = \frac{V - n_1 v_1^0}{n_2} = \Phi(n_2)_{T,p,n_1}$$

$$\hookrightarrow v_2 = \Phi + n_2\left(\frac{\partial \Phi}{\partial n_2}\right)_{T,p,n_1}$$

$F^M = F'' - F'$ $= T, p$

$$h_i^M = \left(\frac{\partial H^M}{\partial n_i}\right)_{T,p,n_j} \qquad H^M = Q \qquad h_i^M = h_i - h_i^0$$

$$\mu_i = \left(\frac{\partial G}{\partial n_i}\right)_{T,p,n_j}$$

Mezcl. ideales $\rightarrow \mu_1(T,p,x_2) = \mu_1^0(T,p) + RT\ln x_1$

No ideales $\rightarrow \mu_1(T,p,x_2) = \mu_1^0(T,p) + RT\ln \underbrace{\gamma_1 x_1}_{a_1}$

$$\lim_{x_i \to 1} \gamma_i = 1$$

$\mu_1 = \mu_1(T,p) + RT\ln\gamma_1 x_1$

$\mu_2 = \mu_2(T,p) + RT\ln\gamma_2 x_2$.

$$d\ln\gamma_1 = -\frac{n_2}{n_1} d\ln\gamma_2$$

$$\lim_{x_1 \to 1} \gamma_2^a = 1 \qquad \lim_{x_2 \to 0} \gamma_2^a = 1$$

$$\gamma_2^a x_2^* = 1$$

$$\mu_2(T, p, x_2) = \mu_2(T, p, x_2^*) + RT \ln \gamma_2^a x_2$$

$$(T, p, x_2) = \mu_2^{*x}(T, p) + RT \ln \gamma^{(x)} x_2 \qquad \lim_{\substack{x_2 \\ c \\ m} \to 0} \gamma^{\substack{x \\ c \\ m}} = 1$$

$$(T, p, c) = \mu_2^{*c}(T, p) + RT \ln \gamma^{(c)} \cdot c$$

$$(T, p, m) = \mu_2^{*m}(T, p) + RT \ln \gamma^{(m)} \cdot m$$

Diluidas

$$\mu_2^{*x}(T, p) - \mu_2^{*m}(T, p) = RT \ln \frac{1000}{M_1} \qquad x_2 \approx \frac{m M_1}{1000}$$

$$\frac{\gamma^{(x)}}{\gamma^{(m)}} = \frac{M_1 m}{1000 x_2} = \frac{1}{1 - x_2}$$

$$G^M = G'' - G' = RT \left(\sum n_i \ln \gamma_i x_i \right)$$

$$V = \left(\frac{\partial G}{\partial p} \right)_{T, n_i} \qquad \frac{H}{T^2} = - \left(\frac{\partial G/T}{\partial T} \right)_{p, n_i}$$

$$V^M = RT \sum n_i \left(\frac{\partial \ln \gamma_i x_i}{\partial p} \right)_{T, n_i}$$

$$H^M = -RT^2 \sum n_i \left(\frac{\partial \ln \gamma_i x_i}{\partial T} \right)$$

$$X^E = X^M - X^{M\,id} \ldots \quad \gamma_i = 1$$

m. ideal $\rightarrow V^{M\,id} = 0, \; H^{M\,id} = 0 \quad \rightarrow V^E = V^M, \; H^E = H^M$

$$G^E = RT \sum n_i \ln \gamma_i$$

$$V^E = RT \sum n_i \left(\frac{\partial \ln \gamma_i}{\partial p} \right)_{T, n}$$

$$H^E = -RT^2 \sum n_i \left(\frac{\partial \ln \gamma_i}{\partial T} \right)_{p, n_i}$$

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si T de $\Delta H = 0$

$\Delta G = -T \Delta S$

$S^M = -R \sum n_i \ln \gamma_i x_i$

25 °C sep 1 atm $\rightarrow G'''$

$\rightarrow G'''$ 25 °C 1 atm junt $\rightarrow G''$ 1,7 atm junt

$G^M = G'' - G' = (G'' - G''') - (G' - G''')$

$S^M =$

TEMA 12

$$A_i = \mu_i' - \mu_i'' \qquad \begin{matrix} >0 & I \to II \\ <0 & II \to I \end{matrix}$$

$$= -\Delta\mu_i^o + RT\ln\frac{a_i'}{a_i''}$$

$$d\left(\frac{A_i}{T}\right) = \frac{\Delta h_i^o}{T^2}dT - \frac{\Delta v_i^o}{T}dp + R\,d\ln\frac{a_i'}{a_i''}$$

$$A_i = 0 \to d\ln\frac{a_i''}{a_i'} = \frac{\Delta h_i^o}{RT^2}dT - \frac{\Delta v_i^o}{RT}dp$$

Líquidos $\to$ $dp = 0$, $a_i' = 1$, $a_i'' = a_i$

$$d\ln a_i = \frac{\Delta h_i^o}{RT^2}dT$$

Diluida: $\theta_c \approx \dfrac{R(T_1^o)^2 M_1}{1000\,\Delta h_i}\cdot m = K_c\cdot m \qquad x_2 \approx \dfrac{m M_1}{1000}$

L−V

$$d\ln\frac{x_i^v}{a_i} = \frac{\Delta h_i^o}{RT^2}dT$$

S. no volátil
$a_1 \approx x_1 \to \theta_e = \dfrac{RT_1^{o\,2} M_1}{1000\,\Delta h_1}m$

Δ L−V

$a_i'' = x_i^v$
$a_i' = a_i$ $\longrightarrow$ $x_i^v p = a_i p_i^o = p_i$: presión parcial

$\to$ Diluidas $\quad p_1 = x_1 p_1^o$ Ley de Raoult (soluto)
$\gamma_1 = 1$
$\gamma_2^a = 1 \quad p_2 = x_2 K_2$ " " Henry (disolv.)

$\to$ No diluidas
$p_2 = x_2\gamma_2^a K_2$

Sim: $x_B^v p = \gamma_B^S x_B^L p_B^o$
Asim: $x_B^v p = \gamma_B^A x_B^L K$

Regla de las fases

$$W = 2 + K - \phi - r$$

Ley de Nernst $\to \dfrac{a_3''}{a_3} = K \longrightarrow$ diluidas $K = \dfrac{x_3''}{x_3}$

Presión osmótica $\qquad \mu_1^o(p',T) = \mu_1^o(p'',T) + RT\ln a_1$

$\Pi = p'' - p' \qquad \mu_1(T,p,x_1) = \mu_1^o(T,p) + RT\phi\ln x_1$ disolv.

diluida

$dn_i = \nu_i \, d\xi \quad \rightarrow n_i - n_i^{o} = \nu_i \xi$

$dG = \sum \nu_i \mu_i \, d\xi$

$A = -\sum \nu_i \mu_i \qquad \left(\frac{dG}{d\xi}\right) = -A$

<u>Gas</u>

$\sum \nu_i \mu_i^* = -RT \sum \nu_i \ln \overset{\text{p. parcial}}{p_i} = -RT \ln K$

$K = \prod p_i^{\nu_i} = p^{\sum \nu_i} \prod x_i^{\nu_i} \qquad 1, \dots K$

$Q = \sum \nu_i h_i^{o}$

$\frac{d \ln K}{dT} = \frac{Q}{RT^2} \quad \rightarrow$ Ecux de Van't Off

<u>Disolución</u>

$\sum \nu_i \mu_i^* = -RT \ln a_i$

$K_a = \prod a_i^{\nu_i}$

Sistemas electroquímicos

$A_{\nu+} B_{\nu-} \longrightarrow A^{z+} + B^{z-}$

$\nu_+ z_+ + \nu_- z_- = 0$

$n_2 \rightarrow n_+ = \nu_+ n_2$

$n_- = \nu_- n_2$

$\tilde{\mu}_i = \left(\frac{\partial G}{\partial n_i}\right)_{n_1, n_j} \qquad i \neq j = +, -$

$\hookrightarrow \mu_i'' = \mu_i'$

$\tilde{\mu}_i'' = \tilde{\mu}_i' \quad \rightarrow \mu_2 = \nu_+ \tilde{\mu}_+ + \nu_- \tilde{\mu}_-$

$\nu = \nu_+ \nu_-$

$\mu_2 = \mu_2^* + \nu RT \ln a_2$

$\hookrightarrow$ iones a partir electrolito

Pilas

$\mu^{B}_{H_2SO_4} = 2\tilde{\mu}^{B}_{H^+} + \tilde{\mu}^{B}_{SO_4^{2-}}$ 　　　 PbO_2 H_2SO_4

$\Delta\tilde{\mu}_e = \tilde{\mu}_e^{\omega} - \tilde{\mu}_e^{\alpha}$

$dW_{NE} = -F\Delta\psi\, dn_e$

$dG = (\mu_e^{\alpha} - \mu_e^{\omega})\, dn_e$

$\Delta\tilde{\mu}_e = -F\Delta\psi \rightarrow \Delta\psi = -\frac{\Delta\tilde{\mu}_e}{F}$

Acumulador

$\Delta\psi = \frac{A}{nF}$ 　　 $n = 2$ plomo

$PbO_2 + 4H^+ + 2e^- \leftrightarrow Pb^{2+} + 2H_2O$

$Pb(s) + PbO_2(s) + 2H_2SO_4(c) \longrightarrow 2PbSO_4(s) + 2H_2O(\ell)$

Pila de Daniell

$\Delta\psi = \frac{A - \Delta\tilde{\mu}_{SO_4^{2-}}}{2F}$ 　　 A: $CuSO_4(c_3) + Zn(s) \rightarrow ZnSO_4(c) + Cu(s)$

$\Delta\mu^{\delta-\gamma}_{SO_4^{2-}}$

Calor de reacción

$Q = \sum \nu_i h_i^0$ 　　　 $s = -\left(\frac{\partial \mu_i}{\partial T}\right)$

$A = -\sum \nu_i \mu_i$ 　　　 $A = nF\Delta\psi$

$Q^* = \sum \nu_i h_i = nF\left[T\left(\frac{\partial \Delta\psi}{\partial T}\right)_{p, x_1, \ldots} - \Delta\psi\right]$

$h_i^M = h_i - h_i^0$

$Q = Q^* - \sum \nu_i h_i^M \approx Q^*$

$$\sigma = \frac{F}{e}$$

$$dW = p\,dV - \sigma\,d\Sigma$$

$$dU = T\,dS - p\,dV + \sigma\,d\Sigma$$

$$dF = -S\,dT + \sigma\,d\Sigma - \mu\,dn$$

<u>Ley de Laplace:</u>

$$p' - p'' = \frac{2\sigma}{r}$$

$$\sigma = \sigma^{\circ}\left(1 - \frac{T}{T_c}\right)^{\nu}$$

Tcrit des. interfase

$\nu = 1{,}27 \pm 0{,}02$

Buff-Lovett

$$p^L - p^V = \frac{2\sigma}{r}$$

$r > 0$

$r < 0$

$$\ln \frac{(p^V)_r}{(p^V)_\infty} = \frac{2\sigma v^L}{RTr}$$

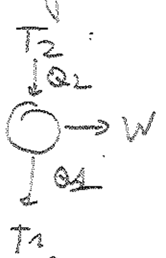
TEMA 15

$\Delta U = Q - W$

Ciclo $\rightarrow W = Q$

Máquinas térmicas

2 focos



$$\eta = \frac{W}{Q_2} < 1$$

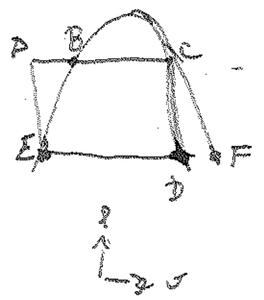
Máquina de vapor - Ciclo de Rankine

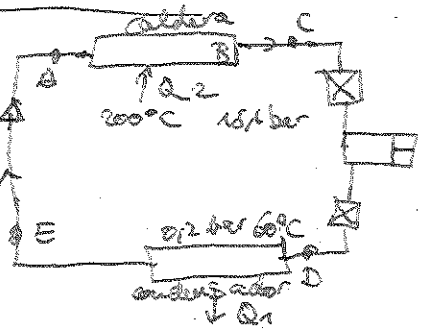
$W = h_C - h_D$

$Q_2 = h_C - h_A$

$$\eta = \frac{h_C - h_D}{h_C - h_A}$$

$$X_D = \frac{S_D - S_E}{S_F - S_E}$$

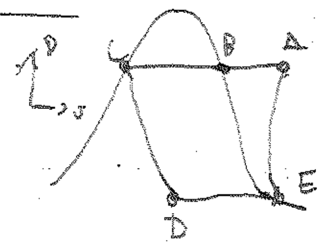




$EA \rightarrow dh = v_E\, dp \rightarrow AB \quad ds = \frac{c_p}{T} dT \Rightarrow T_A$

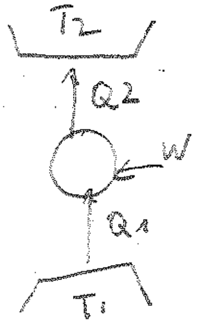
Máquina frigorífica

$$\eta = \frac{Q_1}{|W|} \gtrless 1$$



DC isoh.

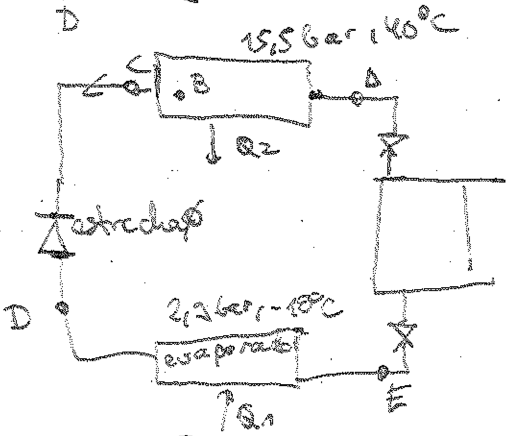
EA adiab.



$T_1 < T_2$

Bomba calor

$$\eta = \frac{Q_2}{W} > 1$$



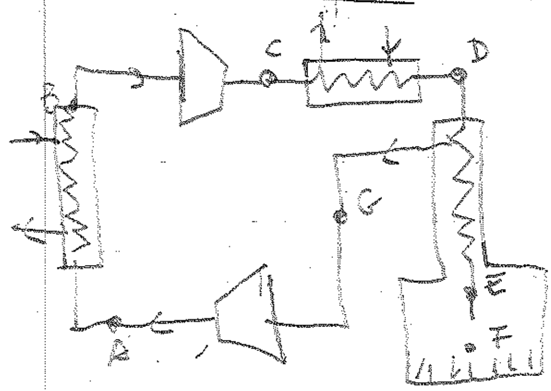
$h_D = h_C$

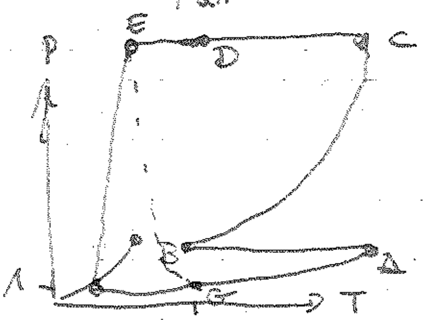
$S_A = S_E$

$T_A = 115°C$

$X_D = 0,18$

Licuación de gases





$\vec{j_z} \quad z = 1, 2, \ldots K, U = f(\vec{\nabla} T, \vec{\nabla} p, \vec{\nabla} \mu_i, \vec{j}, \Delta_i)$

$d^2 z = \vec{j_z}\, d\vec{\Delta}\, dt$

$\vec{j_z} = \lambda_{zT} \vec{\nabla} T + \lambda_{zp} \vec{\nabla} p + \lambda_{zc} \vec{\nabla} C_z + \lambda_{zj} \vec{j}$ $\qquad \Delta = 0$

$\lambda_{zi} (T, p, C_z)$ $\qquad \Delta \neq 0$

$j_z \to$ fl. termod.

$\vec{\nabla} \to$ fuer "

$\lambda_{zi} \to$ coef. fenom. o de tr.

Procesos termoeléctricos

$I, \frac{dT}{dx}$ Obs: $I, T, \Delta\psi$ Rel $\to J_u, \frac{d\tilde{\mu}_e}{dx}$ $\qquad \Delta J_u = J_u^{II} - J_u^{I}$

J_Q

S: coef. Seebeck = ~~pot~~. termoel. $\qquad$ Estac $\to \Delta J_u = J_Q$

$\Delta\psi = \psi^{II} - \psi^{I}$

σ: conductividad eléctrica

π: coef. Peltier $\qquad \tilde{\mu}_e = \left(\frac{\partial G}{\partial N_i}\right)_{T, p, n_j}$ $\quad N = n \cdot N_A$, $N_A = 6.022 \cdot 10^{23}\ \frac{1}{\text{mol}}$

$$J_u = K\Delta \frac{dT}{dx} + \left(\pi - \frac{\tilde{\mu}_e}{e}\right) I$$

$$\frac{d\frac{\tilde{\mu}_e}{e}}{dx} = S \frac{dT}{dx} - \frac{I}{\sigma\Delta}$$

① L. Fourier $I = 0$, $\quad J_u = K\Delta \frac{dT}{dx}$

② Ef. Joule $I \neq 0$, $\quad J_u = -\frac{\tilde{\mu}_e}{e} I = I\Delta\psi = W_{el} = J_Q$

③ Ef. Peltier $I \neq 0$, $\frac{dT}{dx} \neq 0$ $\quad (\pi_y - \pi_x)\frac{I}{\Delta} = K_x \left(\frac{dT}{dx}\right)_x - K_y \left(\frac{dT}{dx}\right)_y$

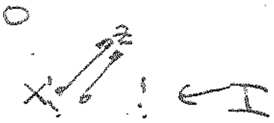
$J_Q > 0$ $x \, \overset{z}{\underset{<}{/}} \, y \, \overset{z}{\underset{>}{/}} \, x_<$ $\leftarrow I, J_u$ $\quad (J_u)_x > (J_u)_y$

④ Ley Ohm

$\frac{dT}{dx} = 0$, $I \neq 0 \to \Delta\psi = \underbrace{\frac{\Delta x}{\sigma A}}_{R} I$

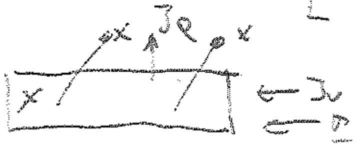
⑤ Efecto Seebeck $\Delta\psi \neq 0$, $I = 0$, $\frac{dT}{dx} \neq 0$

$$\Delta\psi = \int_{T_I}^{T_{II}} (S_z - S_x)\, dT + IR$$



⑥ Coeficiente de Thomson J_Q, $I = $ cte

$$\Delta\left[K\Delta \frac{dT}{dx}\right] + I \int_{T^i}^{T^f} \tau\, dT + I\Delta\psi = J_Q$$



$\tau(\Delta T) = \left(\frac{d\pi}{dT} - S\right)$

Formulación M.E.

Fuerza $T\theta = \psi = J_s \frac{dT}{dx} + I\left(-\frac{d(\tilde{\mu}_e/e)}{dx}\right)$ $\quad$ $\theta \equiv$ prod. entropía

flujos $\quad$ fuerzas $\quad$ Δ, rever. $\theta = 0$

$T J_s = J_U + I\left(\frac{\tilde{\mu}_e}{e}\right)$ $\quad$ irrev. $\theta > 0$

$Q = \Delta U + W$

$$\begin{pmatrix} J_s \\ I \end{pmatrix} = L \begin{pmatrix} dT/dx \\ -\frac{d\tilde{\mu}_e/e}{dx} \end{pmatrix} \qquad L_{12} = L_{21}$$

RRO $\quad \Pi = TS \longrightarrow (\Pi_x - \Pi_y) = T(S_x - S_y)$

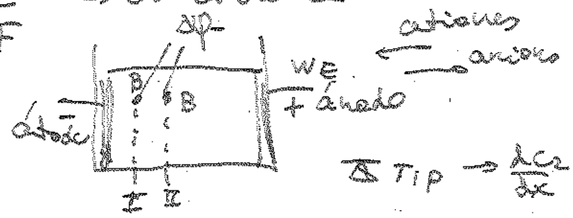
$$K = \frac{I}{A}\left(L_{11} - \frac{L_{21}L_{12}}{L_{22}}\right)$$

$$\Pi = T\frac{L_{12}}{L_{22}} \qquad S = \frac{L_{21}}{L_{22}} \qquad \sigma = \frac{L_{22}}{A}$$

Electrodifusión

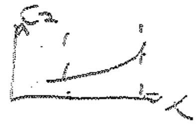
B/B^{z-} $\quad$ $B \leftrightarrow B^{z-} + z_- e$ $\quad$ 1: dis, 2: sol. $A_{\nu+} B_{\nu-} \longrightarrow A^{z+}, B^{z-}$

$J_1, J_+, J_-, \Delta\varphi_- = \frac{\Delta\mu_-}{z_- F}$ $\longrightarrow$ observables



$z_- \Delta\tilde{\mu}_e = -\Delta\tilde{\mu}_-$

$\Delta\psi = -\frac{\Delta\tilde{\mu}_e}{F} = \frac{\Delta\mu_-}{z_- F}$ $\quad$ Δ TIP $\rightarrow \frac{dc_2}{dx}, I$ v. ind



Ec. fen:

$$\begin{pmatrix} J_1 \\ \frac{J_+}{\nu_+} \end{pmatrix} = \begin{pmatrix} D_1 A & \frac{Z_1}{F} \\ D_2 A & \frac{t_+}{\nu_+ z_+ F} \end{pmatrix} \begin{pmatrix} \frac{dc_2}{dx} \\ I \end{pmatrix}$$

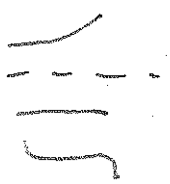
D_c: C difusión

Z_1: nº transfer.

t_+: nº transp.

$I = 0 \longrightarrow$ Dif. simple $\rightarrow \frac{J_+}{\nu_+} = \frac{J_-}{\nu_-} = J_2$

$\frac{dc_2}{dx} = 0 \longrightarrow$ Proc. " cond. eléctrica no definido J_2



Cond. eléctrica simple

$\frac{dc_2}{dx} = 0$

$J_+ = \frac{t_+}{z_+ F} I$ $\quad$ $t_+ = \frac{z_+ F J_+}{I}$ $\quad$ $t_- = \frac{z_- F J_-}{I}$ $\quad$ $t_+ + t_- = 1$

$\nu_1 J_1 + \nu_2 \frac{J_+}{\nu_+} + \frac{\nu_B}{z_- F} I = 0$ $\quad$ $D_1 = -\frac{\nu_-}{\nu_1} D_2$

$$Z_1 = \frac{\nu - \nu_B - \nu_2 t_+}{\nu_+ z_+ \nu_1}$$

$$\frac{J_+'}{\nu_+} = \frac{J_+}{\nu_+} - \left(\frac{c_2}{c_1}\right) J_1$$

$$\begin{pmatrix} J'_+ \\ I \end{pmatrix} = L \begin{pmatrix} d\mu_2/dx \\ d\psi_-/dx \end{pmatrix} \qquad L_{12} = L_{21} \qquad \frac{L_{12}}{L_{22}} = \frac{t_+}{\nu_+ z_+ F} \qquad t_+' = -\nu_+ z_+ F \left(\frac{d\psi}{d\mu_2}\right)_{I=0}$$

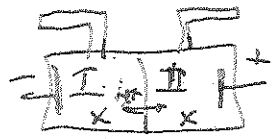
$$\frac{d\psi_-}{dx} = \alpha_- \frac{dc_2}{dx} + \frac{I}{\sigma}$$

$$\alpha_- = \frac{t_+'}{\nu_+ z_+ F} \frac{d\mu_2}{dc_2}$$

Electrodifusión en membranas

T, p cte

$\Delta c_2, I, \frac{dc_2}{dx}$ $\qquad t_+ + t_- = 1$



$$J_1 = p_1 A \Delta c_2 + \frac{z_1}{F} I \qquad \Delta\psi_- = \frac{\Delta\mu_-}{z_- F} = \delta \Delta c_2 + RI$$

$$\frac{J_+}{\nu_+} = p_2 A \Delta c_2 + \frac{t_+}{z_+ \nu_+ F} I \qquad \Delta\tilde{\mu}_- = z_- F \Delta\psi_-$$

$$\Delta\tilde{\mu}_+ = \frac{\Delta\mu_2}{\nu_+} + z_+ F \Delta\psi_-$$

$$\varphi = J_1 \Delta\mu_1 + \frac{J_+}{\nu_+} \Delta\mu_2 + I \Delta\psi = \frac{J_+'}{\nu_+} \Delta\mu_2 + I \Delta\psi_-$$

$$\frac{J_+'}{\nu_+} = \frac{J_+}{\nu_+} - \frac{c_2}{c_1} J_1$$

$$\begin{pmatrix} J_+'/\nu_+ \\ I \end{pmatrix} = \rho \begin{pmatrix} \Delta\mu_2 \\ \Delta\psi_- \end{pmatrix} \qquad \rho_{12} = \rho_{21} \qquad \frac{\rho_{12}}{\rho_{22}} = \frac{t_+'}{\nu_+ z_+ F}$$

$$t_+' = -\frac{\nu_+ z_+ F \Delta\psi_-}{\Delta\mu_2}$$

Electrodiálisis

membrana $\begin{cases} K & t_+^K \approx 1 \\ A & t_-^A \approx 1 \end{cases}$

$$J_1 = J_1^K - J_1^A \qquad \Delta c_2 = c_2'' - c_2'$$

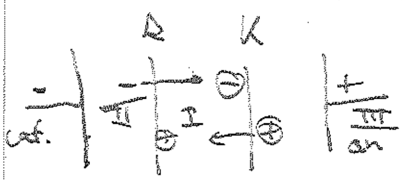
$$J_2 = (J_+^K - J_+^A)/\nu_+ \qquad p_1 = p_1^K + p_1^A$$

$$p_2 = p_2^K + p_2^A$$

$$J_1 = p_1 A \Delta c_2 + \frac{\Delta z_1}{F} I \qquad \Delta z_1 = z_1^K - z_1^A$$

$$\Delta t_+ = t_+^K - t_+^A$$

$$J_2 = p_2 A \Delta c_2 + \frac{\Delta t_+}{\nu_+ z_+ F} I$$



1 atm = 1,01325 × 10^5 Pa

1 mmHg = 133,322 Pa

1 bar = 10^5 Pa

1 psi = 6,89476 × 10^3 Pa

1 cal = 4,1868 J

R = 8,31441 J/molK

= 1,9862 cal/molK

= 0,08209 $\frac{\text{atm dm}^3}{\text{molK}}$

$N_A = 6{,}023 \cdot 10^{23}$ /mol

$$dU = n c_V dT + \left[T\left(\frac{\partial p}{\partial T}\right)_V - p\right] dV$$

$$dH = n c_p dT + \left[V - T\left(\frac{\partial V}{\partial T}\right)_p\right] dp$$

$$dS = \frac{n c_V}{T} dT + \left(\frac{\partial p}{\partial T}\right)_V dV$$

$$= \frac{n c_p}{T} dT - \left(\frac{\partial V}{\partial T}\right)_p dp = \frac{n c_p}{T}\left(\frac{\partial T}{\partial V}\right)_p dV + \frac{n c_V}{T}\left(\frac{\partial T}{\partial p}\right)_V dp$$

$$dU = n c_V dT + \left[T\frac{\alpha}{K} - p\right] dV$$

$K = X$

$$dH = n c_p dT + V(1 - \alpha T) dp$$

$$dS = \frac{n c_V dT}{T} + \frac{\alpha}{K} dV$$

$$dS = \frac{n c_p}{T} dT - \alpha V dp = \frac{n}{\alpha T}\left[c_p \frac{dV}{V} + K c_V dp\right]$$

$$c_p - c_V = \frac{T v \alpha^2}{K}$$

$$dU = TdS - pdV + \mu dn$$

$$dF = -SdT - pdV + \mu dn$$

$$dH = +TdS + Vdp + \mu dn$$

$$dG = -SdT + Vdp + \mu dn$$

$U = TS - pV + \mu n$

$F = U - TS = -pV + \mu n$

$G = \mu n = F + pV$

$$d\mu = -s dT + v dp$$

paro y votas

pato y votap

vapo patos

vota patov