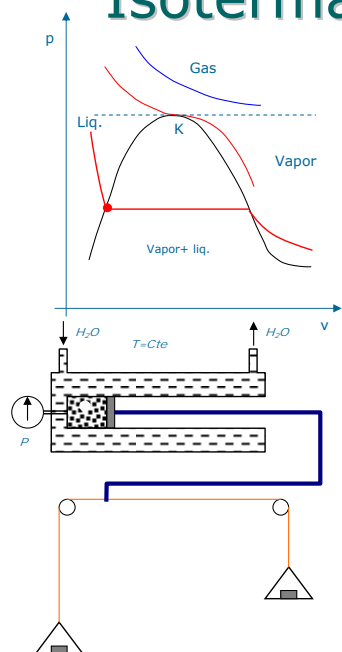


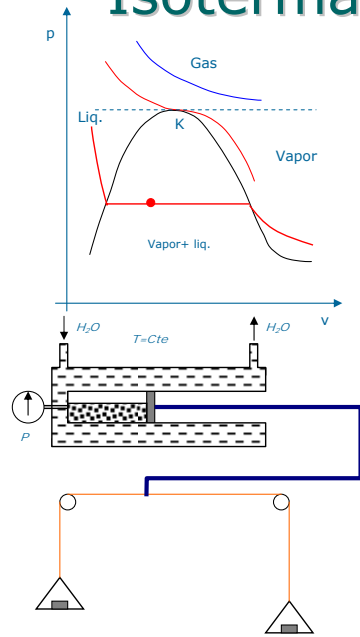
Vapores y gases reales



Isotermas de Andrew



Isotermas de Andrew



Isotermas de Andrew

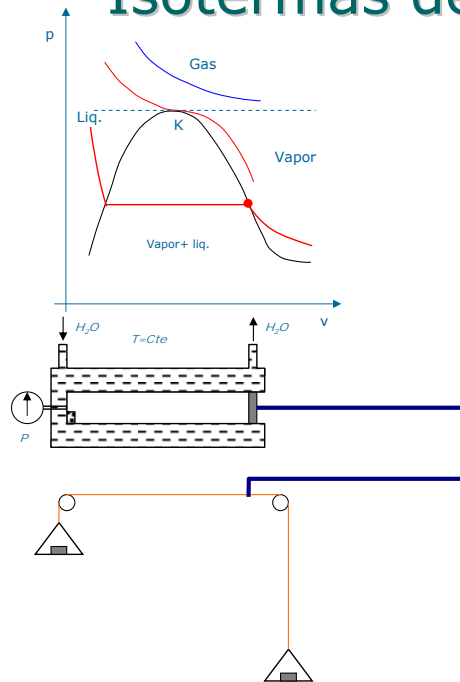
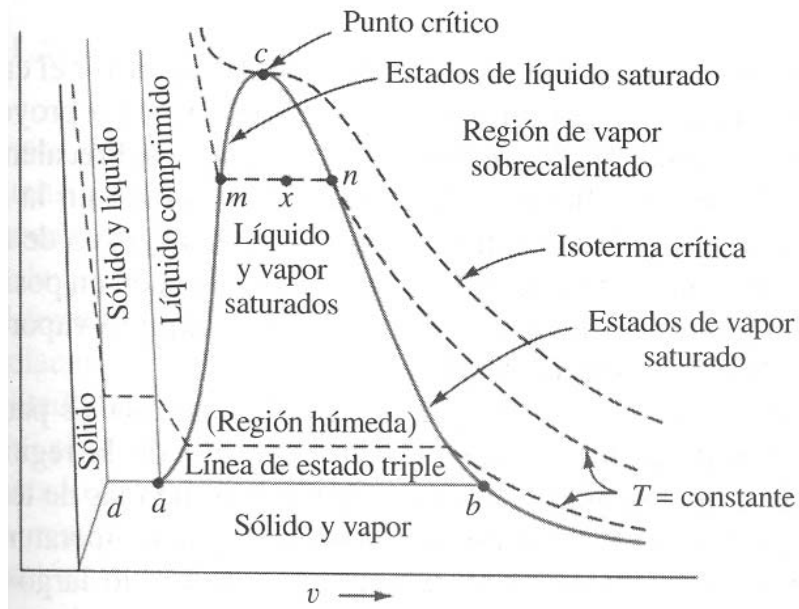
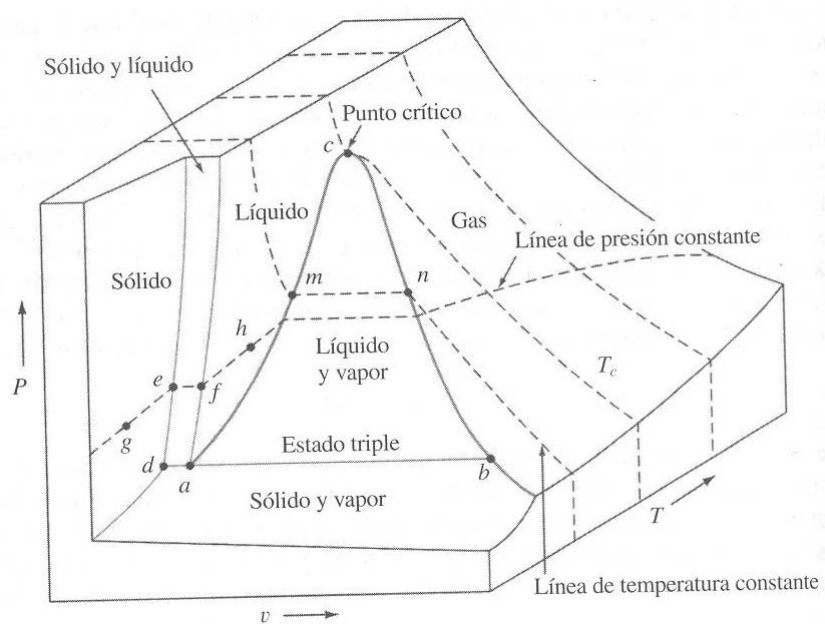


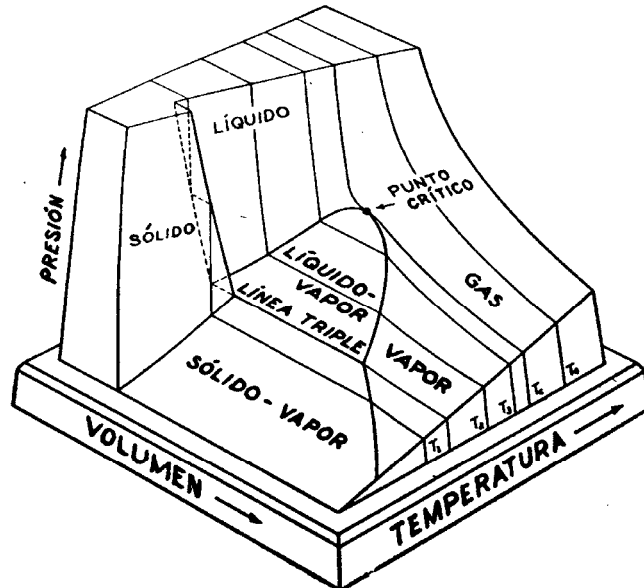
Diagrama p,v de una sustancia pura



Superficie p,v,T de una sustancia pura



Superficie p, v, T de una sustancia pura



Regla de las Fases



Función de Gibbs

$$G = H - T.S$$

$$dG = dH - T.dS - S.dT$$

Si la transformación es reversible

$$dH = T.dS + V.dp$$

$$dG = T.dS + V.dp - T.dS - S.dT$$

$$dG = V.dp - S.dT$$

Si $dp=0$ y $dT=0$

$$dG_{pT} = 0$$

$$G_1 = G_2$$

Regla de las fases

$$T = cte \quad P = cte$$

$$G_1 = m_L \cdot g_L + m_v \cdot g_v$$

$$G_2 = (m_L - dm_v) \cdot g_L + (m_v + dm_v) \cdot g_v$$

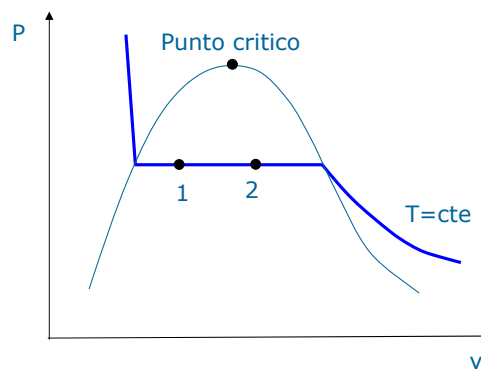
$$G_2 = m_L \cdot g_L + m_v \cdot g_v + dm_v (g_v - g_L)$$

$$G_2 = G_1 + dm_v (g_v - g_L)$$

$$dG_{pT} = 0$$

$$G_1 = G_2$$

$$g_v = g_L$$



Generalizando: p/ F fases

$$g^i = g^{ii} = g^{iii} = \dots = g^F$$

Regla de las fases

Nº de grados de libertad

$$v = a - b$$

a: Nº de variables

b= Nº de ecuaciones

Nº de variables

Nº de variables por fase = (C-1)químicos + 2 físcos

$$a = (C - 1)F + 2F = (C + 1)F$$

C: Nº de componentes

F: Nº de fases

Nº de ecuaciones

$$\begin{array}{l}
 C_1 \left\{ \begin{array}{l} F_1 \rightarrow g_1^i \\ F_2 \rightarrow g_1^{ii} \\ F_3 \rightarrow g_1^{iii} \\ \dots \\ F_F \rightarrow g_1^F \end{array} \right. \\
 \\
 C \left\{ \begin{array}{l} \left. \begin{array}{l} g_1^i = g_1^{ii} = g_1^{iii} = \dots = g_1^F \\ g_2^i = g_2^{ii} = g_2^{iii} = \dots = g_2^F \\ \dots \\ g_c^i = g_c^{ii} = g_c^{iii} = \dots = g_c^F \end{array} \right\} (F-1)C \\
 \left. \begin{array}{l} p^i = p^{ii} = p^{iii} = \dots = p^F \\ T^i = T^{ii} = T^{iii} = \dots = T^F \end{array} \right\} (F-1)2 \end{array} \right. \left. \begin{array}{l} b = (F-1)C + (F-1)2 \\ b = (F-1)(C+2) \end{array} \right.
 \end{array}$$

Regla de las fases

Nº de grados de libertad

$$v = a - b$$

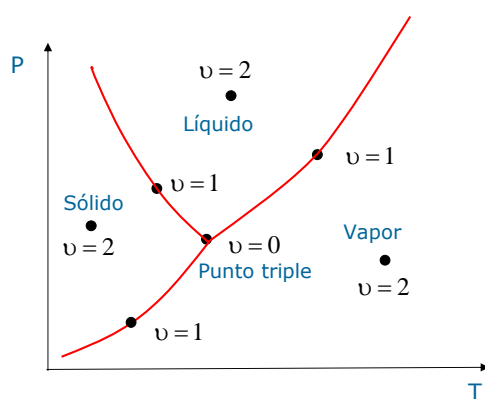
$$a = (C - 1)F + 2F = (C + 1)F$$

$$b = (F - 1)(C + 2)$$

$$v = (\cancel{CF} + \cancel{F}) - (\cancel{CF} - C + \cancel{2F} - 2)$$

$$v = C + 2 - F$$

Regla de las fases: sustancia pura

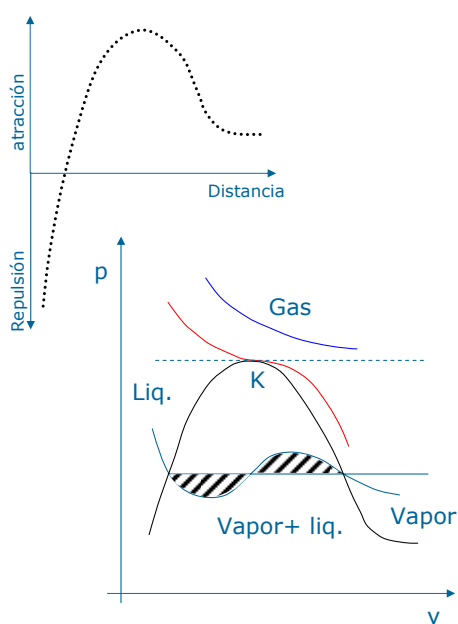


$$v = C + 2 - F$$

$$C = 1 \begin{cases} F = 1 \rightarrow v = 2 \\ F = 2 \rightarrow v = 1 \\ F = 3 \rightarrow v = 0 \end{cases}$$



Gases Reales



$$p \cdot (v - b) = R \cdot T \quad \text{Ec. de Clausius}$$

b: covolumen

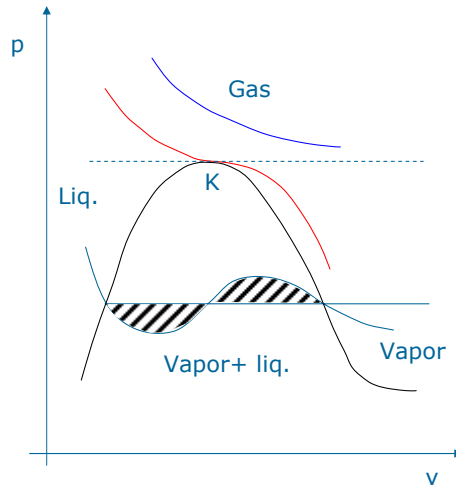
$$(p + p') \cdot (v - b) = R \cdot T$$

$$p' = a \cdot \rho \cdot \rho = \frac{a}{v^2}$$

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

$$p = \frac{R \cdot T}{(v - b)} - \frac{a}{v^2}$$

Gases Reales, Van Der Waals



$$p_c = \frac{R.T_c}{v_c - b} - \frac{a}{v_c^2}$$

$$\left(\frac{\delta p}{\delta v}\right)_T = -\frac{R.T_c}{(v_c - b)^2} + \frac{2.a}{v_c^3} = 0$$

$$\frac{R.T_c}{(v_c - b)^2} = \frac{2.a}{v_c^3}$$

Eliminando R.T_c

$$\frac{p_c + \frac{a}{v_c^2}}{v_c - b} = \frac{2.a}{v_c^3}$$

$$\frac{p_c + \frac{a}{v_c^2}}{(v_c - b).2.a} = \frac{1}{v_c^3} \quad \text{Ec. A}$$

Van Der Waals

$$\left(\frac{\delta^2 p}{\delta v^2}\right)_T = \frac{2.R.T_c}{(v_c - b)^3} - \frac{6.a}{v_c^4} = 0$$

$$\frac{2.R.T_c}{(v_c - b)^3} = \frac{6.a}{v_c^4}$$

$$\frac{R.T_c}{v_c - b} = p_c + \frac{a}{v_c^2}$$

Mult. x 2 y dividiendo por (vc-b)²

$$\frac{2.R.T_c}{(v_c - b)^3} = \frac{2.\left(p_c + \frac{a}{v_c^2}\right)}{(v_c - b)^2}$$

$$\frac{6.a}{v_c^4} = \frac{2.\left(p_c + \frac{a}{v_c^2}\right)}{(v_c - b)^2}$$

$$\frac{3(v_c - b)}{2.v_c^4} = \frac{p_c + \frac{a}{v_c^2}}{2.a.(v_c - b)}$$

$$\frac{p_c + \frac{a}{v_c^2}}{(v_c - b).2.a} = \frac{1}{v_c^3} \quad \text{Ec. A}$$

$$\frac{3(v_c - b)}{2.v_c^4} = \frac{1}{v_c^3}$$

Van Der Waals

$$\frac{3(v_c - b)}{2 \cdot v_c^4} = \frac{1}{v_c^3}$$

$$3(v_c - b) = 2 \cdot v_c$$

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

$$\frac{p_c + \frac{a}{v_c^2}}{(v_c - b) \cdot 2 \cdot a} = \frac{1}{v_c^3}$$

Ec. A

$$\frac{p_c + \frac{a}{v_c^2}}{(v_c - \frac{v_c}{3}) \cdot 2 \cdot a} = \frac{1}{v_c^3}$$

$$p_c + \frac{a}{v_c^2} = \frac{4 \cdot a}{3 \cdot v_c^2}$$

$$p_c = \frac{a}{3 \cdot v_c^2}$$

$$a = 3 \cdot p_c \cdot v_c^2$$

$$p_c = \frac{R \cdot T_c}{v_c - b} - \frac{a}{v_c^2}$$

$$p_c = \frac{R \cdot T_c}{\frac{2 \cdot v_c}{3}} - \frac{3 \cdot p_c \cdot v_c^2}{v_c^2}$$

$$R = \frac{8}{3} \cdot \frac{p_c \cdot v_c}{T_c}$$

Estados correspondientes

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

$$a = 3 \cdot p_c \cdot v_c^2$$

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

Reemplazando a y b

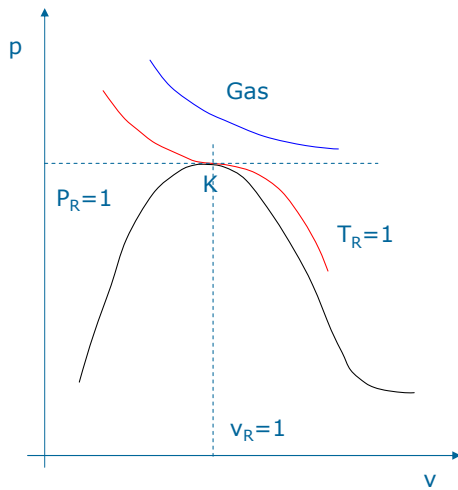
$$\left(p + \frac{3 \cdot p_c \cdot v_c^2}{v^2} \right) \cdot \left(v - \frac{v_c}{3} \right) = \frac{8}{3} \frac{p_c \cdot v_c}{T_c} \cdot T$$

$$\left(\frac{p}{p_c} + \frac{3}{\left(\frac{v}{v_c} \right)^2} \right) \cdot \left(\frac{v}{v_c} - \frac{1}{3} \right) = \frac{8}{3} \frac{T}{T_c}$$

$$\frac{T}{T_c} = T_R \quad \frac{p}{p_c} = p_R \quad \frac{v}{v_c} = v_R$$

$$\left(p_R + \frac{3}{v_R^2} \right) \cdot \left(v_R - \frac{1}{3} \right) = \frac{8}{3} T_R$$

Estados correspondientes



$$\left(p_R + \frac{3}{v_R^2}\right) \left(v_R - \frac{1}{3}\right) = \frac{8}{3} T_R$$

$$\frac{T}{T_c} = T_R \quad \frac{p}{p_c} = p_R \quad \frac{v}{v_c} = v_R$$

Gases diferentes en estados correspondientes se comportan de la misma manera.

Coeficiente de compresibilidad

$$p \cdot v = Z \cdot R \cdot T$$

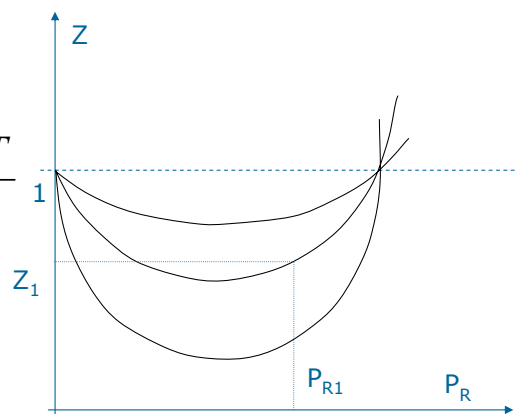
$$Z = f(p, T)$$

$$v_{real} = \frac{Z \cdot R \cdot T}{p} \quad v_{ideal} = \frac{R \cdot T}{p}$$

$$v_{real} - v_{ideal} = \frac{R \cdot T}{p} \cdot (Z - 1)$$

$$\frac{T}{T_c} = T_R \quad \frac{p}{p_c} = p_R$$

$$Z = f_2(p_R, T_R)$$



Coeficiente de compresibilidad

Analizando 2 gases diferentes en estados correspondientes.

$$T_{R1} = T_{R2} \quad P_{R1} = P_{R2}$$

$$z_1 = z_2 \quad v_{R1} \neq v_{R2}$$

$$Z = \frac{p \cdot v}{R \cdot T} \quad \frac{p_1 \cdot v_1}{R_1 \cdot T_1} = \frac{p_2 \cdot v_2}{R_2 \cdot T_2}$$

$$p_1 = P_{R1} \cdot p_{c1} \quad T_1 = T_{R1} \cdot T_{c1}$$

$$p_2 = P_{R2} \cdot p_{c2} \quad T_2 = T_{R2} \cdot T_{c2}$$

$$\frac{p_{c1} \cdot P_{R1} \cdot v_1}{R_1 \cdot T_{c1} \cdot T_{R1}} = \frac{p_{c2} \cdot P_{R2} \cdot v_2}{R_2 \cdot T_{c2} \cdot T_{R2}}$$

$$\frac{v_1}{R_1 \cdot T_{c1}} = \frac{v_2}{R_2 \cdot T_{c2}}$$

$\frac{p_{c1}}{p_{c2}}$
Vol. Critico ideal o pseudocritico

$$v_{ci1} = \frac{R_1 \cdot T_{c1}}{p_{c1}} \quad v_{ci2} = \frac{R_2 \cdot T_{c2}}{p_{c2}}$$

Vol. reducido ideal o pseudoreducido

$$v_{Ri1} = \frac{v_1}{v_{ci1}} \quad v_{Ri2} = \frac{v_2}{v_{ci2}}$$

Gases diferentes en estados correspondientes tienen volúmenes pseudoreducidos iguales.

$$v_{Ri1} = v_{Ri2}$$

Ec. De Beattie-Bridgman

$$p = \frac{R \cdot T \cdot \left(1 - \frac{c}{v \cdot T^3}\right)}{v^2} \cdot \left(v + B_0 \left(1 - \frac{b}{v}\right)\right) - \frac{A_0}{v^2} \cdot \left(1 - \frac{a}{v}\right)$$

- 1928
- 5 ctes tabuladas para diferentes sustancias.
- válida para densidades de hasta el 80% de la critica.

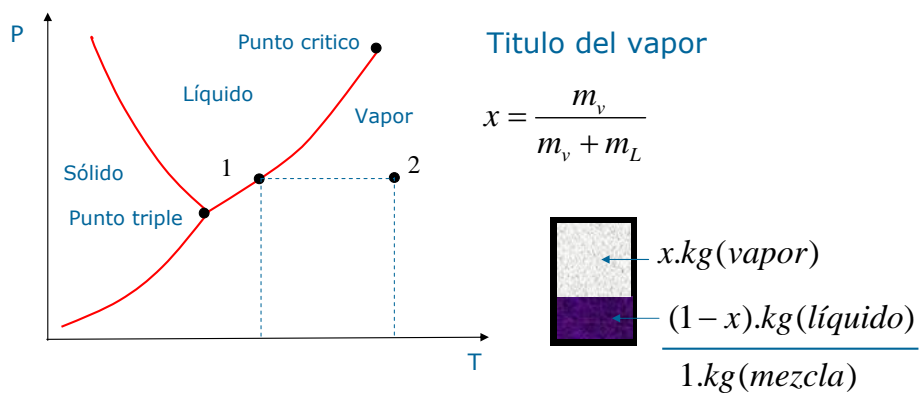


Vapores: definiciones

Vapor saturado: vapor en equilibrio con su líquido.

Líquido saturado: líquido en equilibrio con su vapor.

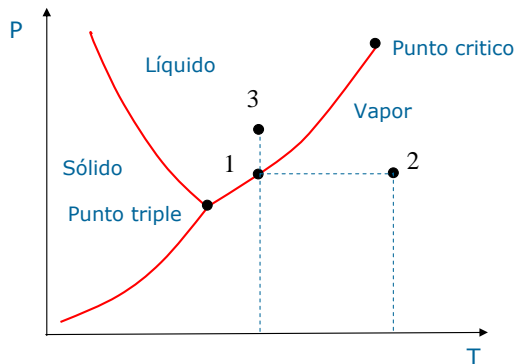
Vapor húmedo: mezcla de vapor saturado y líquido saturado.



Vapores: definiciones

Vapor sobrecalentado: vapor a una temperatura superior a la del equilibrio con su líquido (2).

Líquido comprimido: líquido sometido a una presión mayor que la presión de equilibrio correspondiente a su temperatura (3).



Parámetros extensivos

Volumen específico

$$v = x.v^{ii} + (1-x).v^i$$

$$v = x.v^{ii} + v^i - x.v^i$$

$$v = x(v^{ii} - v^i) + v^i$$

$$x = \frac{v - v^i}{v^{ii} - v^i}$$

Entalpía específica

$$h = x.h^{ii} + (1-x).h^i$$

$$x = \frac{h - h^i}{h^{ii} - h^i}$$

Entropía específica

$$s = x.s^{ii} + (1-x).s^i$$

$$x = \frac{s - s^i}{s^{ii} - s^i}$$

Entalpía de vaporización

Diferencia de entalpías entre el vapor saturado y el líquido saturado.

$$r = h^{ii} - h^i$$

$$r = u^{ii} - u^i + p.(v^{ii} - v^i)$$

$$g^{ii} = g^i$$

$$g^{ii} + dg^{ii} = g^i + dg^i$$

$$dg^{ii} = dg^i$$

$$dg = v.dp - s.dT$$

$$v^i.dp - s^i.dT = v^{ii}.dp - s^{ii}.dT$$

$$(s^{ii} - s^i).dT = (v^{ii} - v^i).dp$$

$$(s^{ii} - s^i) = \frac{r}{T}$$

$$\frac{r}{T}.dT = (v^{ii} - v^i).dp$$

$$r = T.(v^{ii} - v^i). \frac{dp}{dT}$$

Ecuación de Clapeyron-Clausius.

Ecuación aproximada para calcular presiones de vapor

Hipótesis simplificativas:

- $v^i \ll v^{ii} \rightarrow v^i \approx 0$
- El vapor saturado es un gas perfecto
- $r = r_0 = \text{cte}$ en un entorno

$$r = T.(v^{ii} - v^i). \frac{dp}{dT}$$

$$v^{ii} = \frac{R.T}{p}$$

$$r_0 = \frac{R.T^2}{p}. \frac{dp}{dT}$$

$$\frac{r_0.dT}{R.T^2} = \frac{dp}{p}$$

$$\ln \frac{p}{p_0} = \frac{r_0}{R} \left(\frac{1}{T_0} - \frac{1}{T} \right)$$

Valida para bajas presiones.

Diagrama entrópicos para vapores

$s = f(T, p)$ $ds = \left(\frac{\partial s}{\partial T}\right)_p dT + \left(\frac{\partial s}{\partial p}\right)_T dp$ $ds = \frac{\delta Q_R}{T}$ $\delta Q_R = dh - v \cdot dp$ $ds = \frac{1}{T} dh - \frac{v}{T} dp$	$h = f(T, p)$ $dh = \left(\frac{\partial h}{\partial T}\right)_p dT + \left(\frac{\partial h}{\partial p}\right)_T dp$ $ds = \frac{1}{T} \cdot \left(\frac{\partial h}{\partial T}\right)_p dT + \frac{1}{T} \left[\left(\frac{\partial h}{\partial p}\right)_T - v \right] dp$ $\left(\frac{\partial s}{\partial T}\right)_p = \frac{1}{T} \cdot \left(\frac{\partial h}{\partial T}\right)_p$ $\left(\frac{\partial h}{\partial T}\right)_p = c_p$ $\left(\frac{\partial s}{\partial T}\right)_p = \frac{c_p}{T}$
--	--

Diagrama entrópicos para vapores

$$ds = \left(\frac{\partial s}{\partial T}\right)_p dT + \left(\frac{\partial s}{\partial p}\right)_T dp \quad ds = \frac{1}{T} \cdot \left(\frac{\partial h}{\partial T}\right)_p dT + \frac{1}{T} \left[\left(\frac{\partial h}{\partial p}\right)_T - v \right] dp$$

$$\left(\frac{\partial s}{\partial T}\right)_p = \frac{1}{T} \cdot \left(\frac{\partial h}{\partial T}\right)_p \quad \boxed{\left(\frac{\partial s}{\partial p}\right)_T = \frac{1}{T} \left[\left(\frac{\partial h}{\partial p}\right)_T - v \right]}$$

$$\left(\frac{\partial^2 s}{\partial T \cdot \partial p}\right) = \left(\frac{\partial^2 s}{\partial p \cdot \partial T}\right)$$

$$\frac{1}{T} \cdot \left(\frac{\partial^2 h}{\partial T \partial p}\right) = \frac{-1}{T^2} \cdot \left[\left(\frac{\partial h}{\partial p}\right)_T - v \right] + \frac{1}{T} \cdot \left[\left(\frac{\partial^2 h}{\partial p \partial T}\right) - \left(\frac{\partial v}{\partial T}\right)_p \right] =$$

$$= \frac{-1}{T^2} \cdot \left(\frac{\partial h}{\partial p}\right)_T - \frac{-1}{T^2} \cdot v + \frac{1}{T} \cdot \left(\frac{\partial^2 h}{\partial p \partial T}\right) - \frac{1}{T} \cdot \left(\frac{\partial v}{\partial T}\right)_p$$

Diagrama entrápicos para vapores

$$\frac{1}{T} \cdot \left(\frac{\partial^2 h}{\partial T \partial p} \right) = \frac{-1}{T^2} \cdot \left(\frac{\partial h}{\partial p} \right)_T - \frac{-1}{T^2} \cdot v + \frac{1}{T} \cdot \left(\frac{\partial^2 h}{\partial p \partial T} \right) - \frac{1}{T} \cdot \left(\frac{\partial v}{\partial T} \right)_p \quad \left(\frac{\partial^2 h}{\partial T \partial p} \right) = \left(\frac{\partial^2 h}{\partial p \partial T} \right)$$

$$\left(\frac{\partial h}{\partial p} \right)_T = v - T \left(\frac{\partial v}{\partial T} \right)_p \quad \left(\frac{\partial s}{\partial p} \right)_T = \frac{1}{T} \left[\left(\frac{\partial h}{\partial p} \right)_T - v \right]$$

$$\left(\frac{\partial s}{\partial p} \right)_T = - \left(\frac{\partial v}{\partial T} \right)_p$$

$$ds = \left(\frac{\partial s}{\partial T} \right)_p dT + \left(\frac{\partial s}{\partial p} \right)_T dp$$

$$ds = c_p \cdot \frac{dT}{T} - \left(\frac{\partial v}{\partial T} \right)_p dp$$

Diagrama entrápicos para vapores

$$ds = c_p \cdot \frac{dT}{T} - \left(\frac{\partial v}{\partial T} \right)_p dp$$

$$\alpha = \frac{1}{v_0} \cdot \left(\frac{\partial v}{\partial T} \right)_p$$

$$\left(\frac{\partial v}{\partial T} \right)_p = v_0 \cdot \alpha$$

$$ds = c_p \cdot \frac{dT}{T} - \alpha \cdot v_0 \cdot dp$$

$$s_2 - s_1 = c_p \cdot \ln \frac{T_2}{T_1} - v_0 \cdot \int_{p_1}^{p_2} \alpha \cdot dp$$

Para estados alejados del Pc

$$c_p \cdot \ln \frac{T_2}{T_1} \gg v_0 \cdot \int_{p_1}^{p_2} \alpha \cdot dp$$

$$s_2 - s_1 = c_p \cdot \ln \frac{T_2}{T_1}$$

Adopt. $S_0=0$ p/líquido a $T_0=273K$

$$s = c_p \cdot \ln \frac{T}{T_0}$$

$$T = T_0 \cdot e^{\frac{s}{c_p}}$$

Variación del Cp con T

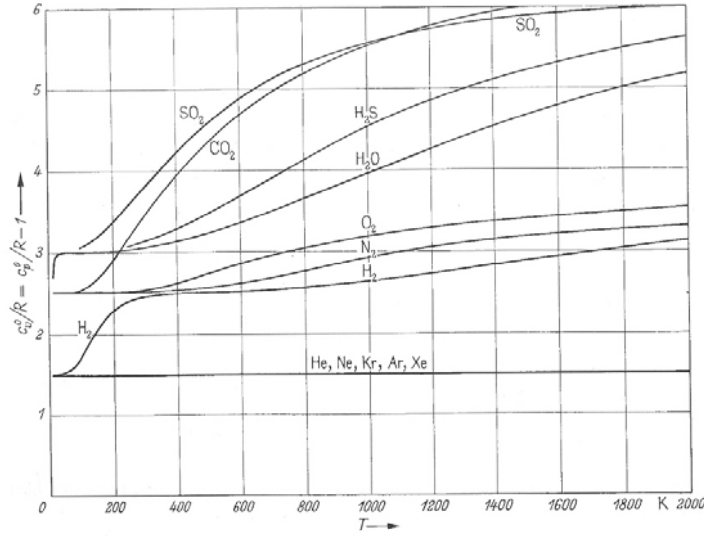


Diagrama entrópico para vapores

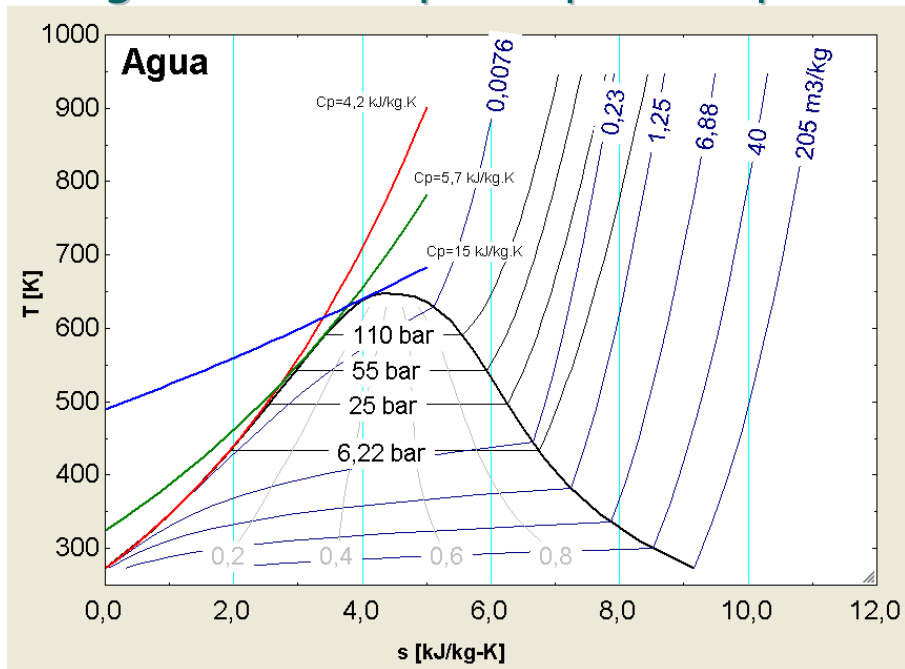
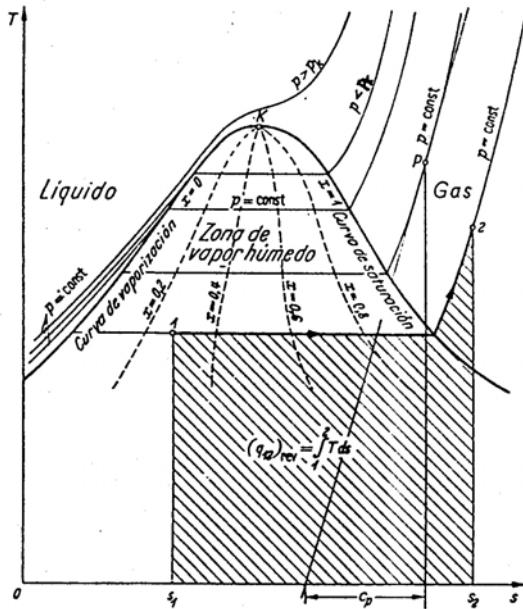


Diagrama entrópico para vapores



$$s^{ii} - s^i = \frac{r}{T}$$

$$s = x \cdot s^{ii} + (1 - x) \cdot s^i$$

$$x = \frac{s - s^i}{s^{ii} - s^i}$$

$$ds = \int_{T_B}^T c_p \cdot \frac{dT}{T}$$

Diagrama entrópico para agua

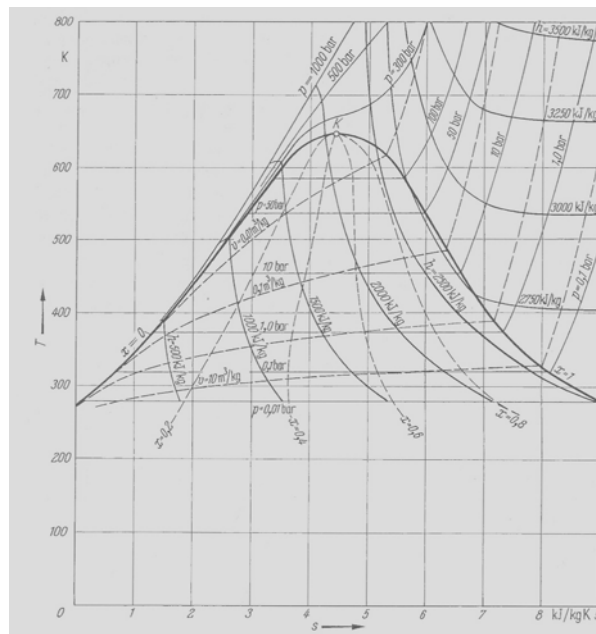
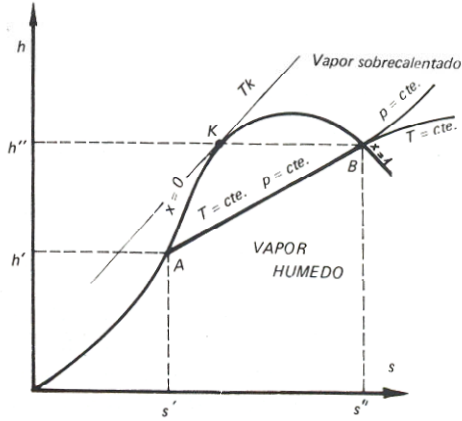


Diagrama de Mollier



$$dh = c_p \cdot dT + \left[v - T \cdot \left(\frac{\partial v}{\partial T} \right)_p \right] dp$$

Para agua líquida

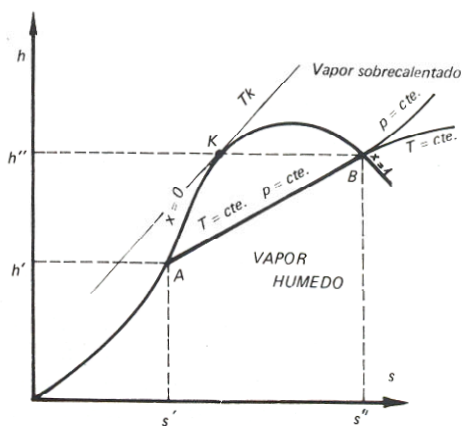
$$dh = c_p \cdot dT$$

$$h_2 - h_1 = c_p \cdot (T_2 - T_1)$$

Adopt. $h_0=0$ $p/T_0=273K$

$$h' = c_p \cdot (T - T_0) = c_p \cdot t$$

Diagrama de Mollier



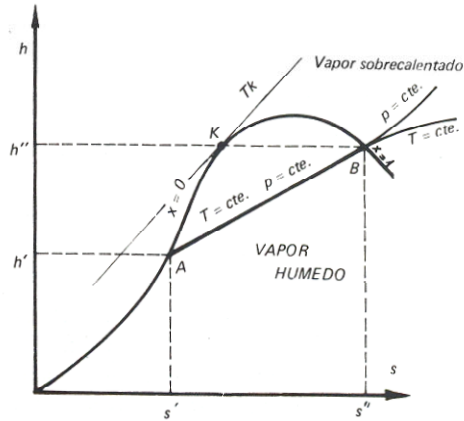
Curva limite superior

$$h'' = h' + r$$

$$s'' = s' + \frac{r}{T}$$

$$\frac{h'' - h'}{s'' - s'} = \frac{r}{\frac{r}{T}} = T$$

Diagrama de Mollier



Pendiente de las isobáricas

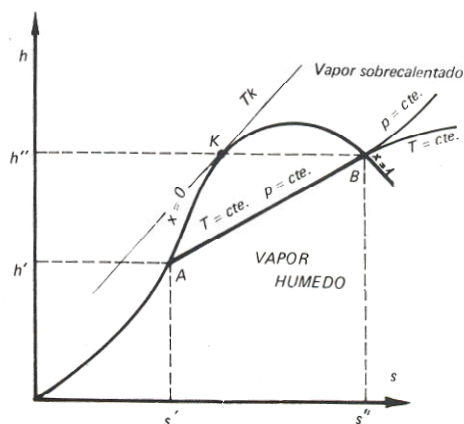
$$\left(\frac{\partial h}{\partial s}\right)_p = \frac{\left(\frac{\partial h}{\partial T}\right)_p}{\left(\frac{\partial s}{\partial T}\right)_p} = \frac{c_p}{\frac{c_p}{T}} = T$$

Pendiente de una isotérmica

$$\left(\frac{\partial h}{\partial s}\right)_T = \frac{\left(\frac{\partial h}{\partial p}\right)_T}{\left(\frac{\partial s}{\partial p}\right)_T} = \frac{v - T \left(\frac{\partial v}{\partial T}\right)_p}{-\left(\frac{\partial v}{\partial T}\right)_p}$$

$$\left(\frac{\partial h}{\partial s}\right)_T = T - v \left(\frac{\partial T}{\partial v}\right)_p$$

Diagrama de Mollier



Zona heterogénea

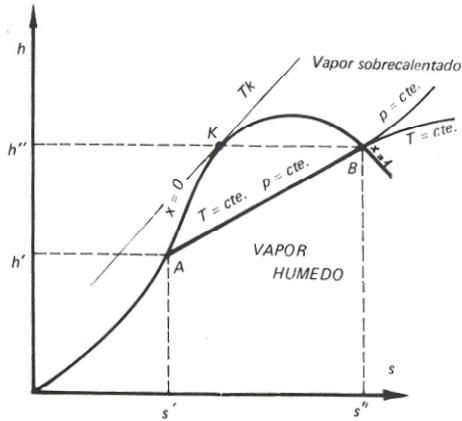
$$\left(\frac{\partial T}{\partial v}\right)_p = 0$$

$$\left(\frac{\partial h}{\partial s}\right)_T = T = \left(\frac{\partial h}{\partial s}\right)_p$$

Zona vapor sobrecalentado

$$\left(\frac{\partial h}{\partial s}\right)_T \rightarrow 0$$

Diagrama de Mollier



Si el gas se comporta como gas perfecto $h=f(T)$ y si $T=cte$ y $h=cte$

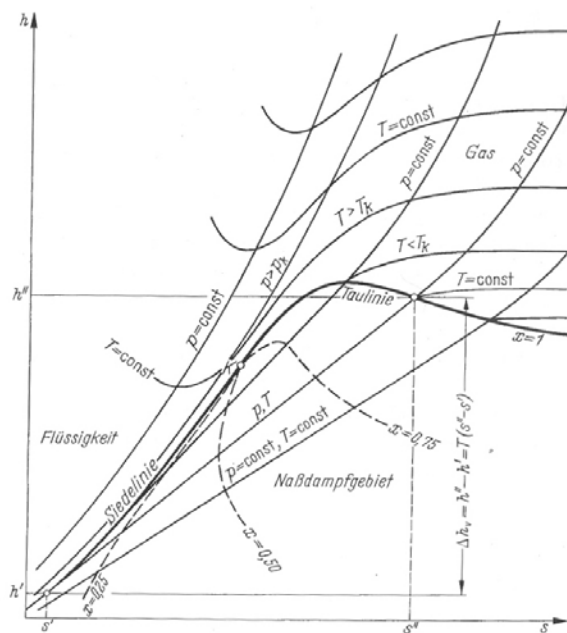
$$T = \frac{p \cdot v}{R}$$

$$\left(\frac{\partial T}{\partial v}\right)_p = \frac{p}{R}$$

$$\left(\frac{\partial h}{\partial s}\right)_T = T - v \cdot \left(\frac{\partial T}{\partial v}\right)_p$$

$$\left(\frac{\partial h}{\partial s}\right)_T = T - v \cdot \frac{p}{R} = T - T = 0$$

Diagrama de Mollier



Mezcla de Gases Perfectos



Mezclas de gases perfectos

Características de la composición

$$m = \sum m_j$$

$$g_i = \frac{m_i}{m} \quad \text{Fracción en masa}$$

$$\sum g_i = 1$$

Fracción molar

$$x_i = \frac{n_i}{n}$$

$$n_A = \frac{m_A}{M_A}$$

$$n = \sum n_j \quad n = \frac{m_A}{M_A} + \frac{m_B}{M_B} + \dots$$

Masa molar de la mezcla

$$M_m = \frac{m}{n} \quad M_m = \sum x_i \cdot M_i$$

Conversión entre másica y molar

$$x_A = \frac{n_A}{n} = \frac{m_A}{M_A} \cdot \frac{M_m}{m} = g_A \cdot \frac{M_m}{M_A}$$

$$g_A = x_A \cdot \frac{M_A}{M_m}$$

$$n = n_A + n_B + \dots$$

$$\frac{m}{M_m} = \frac{m_A}{M_A} + \frac{m_B}{M_B} + \dots$$

$$\frac{1}{M_m} = \frac{g_A}{M_A} + \frac{g_B}{M_B} + \dots$$

Mezclas de gases perfectos

Presión parcial

$$p_i = x_i \cdot p$$

$$\sum_{i=1}^n p_i = \sum_{i=1}^n x_i \cdot p = p$$

Ley de Dalton

$$p = n \cdot \frac{R \cdot T}{V} = \left(\sum_{i=1}^n n_i \right) \cdot \frac{R \cdot T}{V}$$

$$p = n_A \cdot \frac{R \cdot T}{V} + n_B \cdot \frac{R \cdot T}{V} + n_C \cdot \frac{R \cdot T}{V} + \dots$$

$$n_A \cdot \frac{R \cdot T}{V} = n_A \cdot \frac{p}{n} = x_A \cdot p = p_A$$

$$p = p_A + p_B + p_C + \dots$$

La presión total es igual a la suma de las presiones que ejercería cada uno de los gases ocupando el volumen total a la misma temperatura.

Ecuación de estado

En magnitudes molares

$$p_A \cdot V = n_A \cdot R \cdot T$$

$$p_B \cdot V = n_B \cdot R \cdot T$$

$$\dots = \dots$$

$$p \cdot V = n \cdot R \cdot T$$

En magnitudes específicas

$$p_A \cdot V = m_A \cdot R p_A \cdot T$$

$$p_B \cdot V = m_B \cdot R p_B \cdot T$$

$$\dots = \dots$$

$$p \cdot V = (m_A \cdot R p_A + m_B \cdot R p_B + \dots) \cdot T = m \cdot R p_m \cdot T$$

$$R p_m = \sum g_i \cdot R p_i$$

$$n \cdot R = m \cdot R p_m$$

$$R p_m = \frac{n}{m} \cdot R$$

$$R p_m = \frac{R}{M_m}$$

Energía interna

En magnitudes molares

$$U = U_A + \dots$$

$$U = n \cdot \bar{u}_m = n_A \cdot \bar{u}_A + n_B \cdot \bar{u}_B$$

$$\bar{u}_m = \sum x_j \cdot \bar{u}_j$$

$$\bar{u}_m = \frac{m}{n} \cdot u_m = M_m \cdot u_m$$

En magnitudes específicas

$$U = U_A + U_B + \dots$$

$$U = m \cdot u_m = m_A \cdot u_A + m_B \cdot u_B + \dots$$

$$u_m = \sum g_i \cdot u_i$$

Calores molares o específicos

En magnitudes molares

$$\bar{c}_{v,m} = \frac{d\bar{u}_m}{dt}$$

$$\bar{c}_{v,m} = \sum x_i \cdot \bar{c}_{v,i}$$

En magnitudes específicas

$$c_{v,m} = \sum g_i \cdot c_{v,i}$$

Exponente adiabático

$$\gamma_m = \frac{x_A \cdot c_{p,A} + x_B \cdot c_{p,B}}{x_A \cdot c_{v,A} + \dots}$$

$$\gamma_m \neq \sum x_i \cdot \gamma_i$$