

Chapter 11

Solution Thermodynamics: Theory

- Chapter 6: constant composition fluids.
- Most commonly in chemical engineering application “multi component mixtures” of gases or liquids undergo (composition change). Mixing process, separation, mass transfer process or chemical reactions.
- Objectives:
 1. To develop a fundamental property relation for homogenous solution of variable compositions.
 2. Introduce new properties known as Partial Properties.
 3. Ideal gas mixtures and ideal solution concept.
 4. Fugacity property.

11.1 Fundamental Property Relation

The Chemical Potential of species i in the mixtures,

$$\mu_i \equiv \left[\frac{\partial(nG)}{\partial n_i} \right]_{p,T,n_j} \quad (11.1)$$

The derivative of nG with respect to the number of moles of species i.

Fundamental of Gibbs energy for closed system

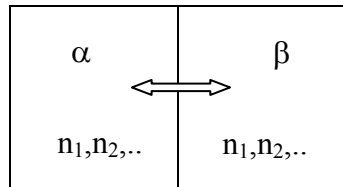
$$d(nG) = (nV) dp - (nS) dT \quad (6.6)$$

For open system it becomes,

$$d(nG) = (nV) dp - (nS) dT + \sum \mu_i dn_i \quad (11.2)$$

11.2 Chemical Potential as a Criterion for Phase Equilibrium

- Write equation 10.2 for each phase in this closed system.



- Total change in the Gibbs free energy of this closed system is given by summation

$$d(nG) = (nV) dp - (nS) dT + \sum \mu_i^\alpha dn_i^\alpha + \sum \mu_i^\beta dn_i^\beta$$

- But for closed system, eq'n 6.6 applies

$$d(nG) = (nV) dp - (nS) dT$$

- Then at equilibrium,

$$\sum \mu_i^\alpha dn_i^\alpha + \sum \mu_i^\beta dn_i^\beta = 0$$

- Since $dn_i^\alpha = -dn_i^\beta$

- Then $\sum (\mu_i^\alpha - \mu_i^\beta) dn_i^\alpha = 0$

$$\mu_i^\alpha = \mu_i^\beta \quad (i=1,2,\dots,N)$$

Criteria of phase equilibrium.

- More than 2 phases,

$$\mu_i^\alpha = \mu_i^\beta = \dots = \mu_i^\pi \quad (i=1,2,\dots,N) \quad (11.6)$$

Thus, multiple phases at the same T and P are in equilibrium when the chemical potential of each species is the same in all phases.

11.2 Partial Properties

$$\bar{M}_i \equiv [\partial(nM) / \partial n_i]_{P,T,n_j} \quad (11.7)$$

Partial molar property of species i in solution

$\bar{U}_i, \bar{H}_i, \bar{S}_i, \bar{G}_i, \dots$ etc.

It is a response function, representing the change of total property nM due to the addition of a differential amount of species i to a finite amount of solution at constant T and P.

Equations relating molar and Partial properties:

$$A- \quad M = \sum x_i \bar{M}_i \quad (11.11)$$

$$nM = \sum n_i \bar{M}_i \quad (11.12)$$

“Summability Relations”

B- Gibbs/Duhem equation

$$(\partial M / \partial P)_{T,x} dP + (\partial M / \partial T)_{P,x} dT - \sum x_i d\bar{M}_i = 0 \quad (11.13)$$

At constant T and P

$$\sum x_i d\bar{M}_i = 0 \quad (11.14)$$

- In summary,

M , Solution Properties.

\bar{M}_i , Partial Properties.

M_i , Pure-species Properties.

- **Binary Solution:** Writing Summability equation for 2 components

$$\bar{M}_1 = M + x_2 \quad dM/dx_1 \quad (11.15)$$

$$\bar{M}_2 = M + x_1 \quad dM/dx_1 \quad (11.16)$$

Ex. 11.2: Describe a graphical interpretation of equations 11.15 and 11.16

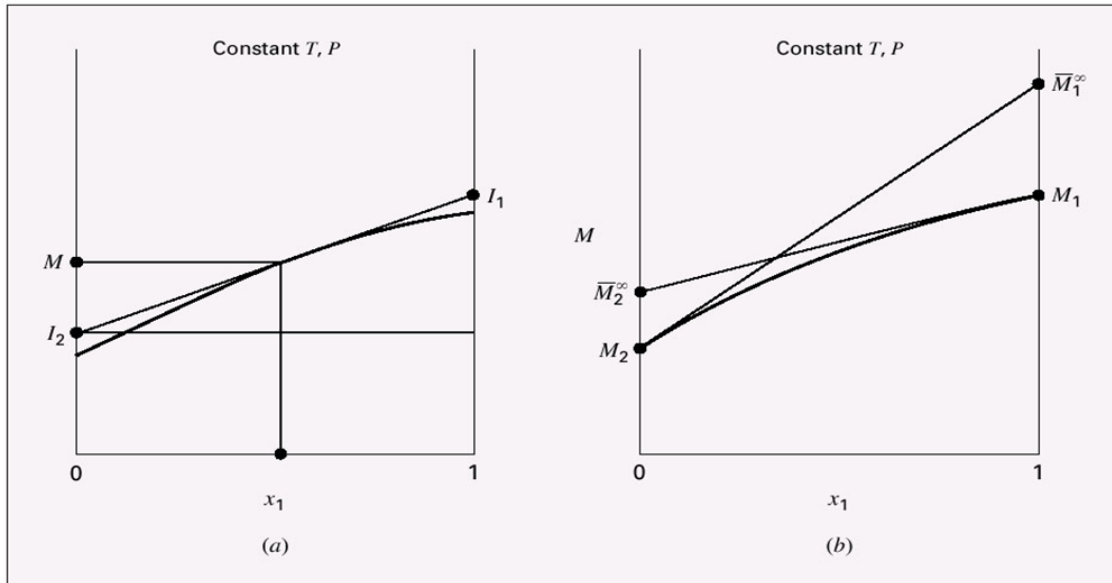


Figure 11.1: (a) Graphical construction of Example 11.2. (b) Infinite-dilution values of partial properties.

- Draw a tangent of the curve M vs x.
- From taking two slopes of this line,
 - (Large triangle): $dM/dx_1 = M - I_2 / x_1 - 0$
 - (Small triangle): $dM/dx_1 = I_1 - I_2 / 1 - 0 = I_1 - I_2$
 Then solve these two equations.
- Values of intercept,

$$I_1 = \bar{M}_1 \quad , \quad I_2 = \bar{M}_2$$
 The tangent intercepts gives directly the partial properties.
- The intercepts shift as point tangency moves along the curve and the limiting value are indicated by fig 11.1 (b).
- At pure species 2 [(x₁=0), (x₂=1)]
 - Subs. in 11.16, $\bar{M}_2 = M_2$
 - The molar property = partial property.
 - The opposite intercept gives $\bar{M}_1 = \bar{M}_1^\infty$ (Partial property of species 1 when it is present at infinite dilution)
- Similar at pure species 1 [(x₁=1), (x₂=0)]
 - Subs. in 11.16, $\bar{M}_1 = M_1$
 - The molar property = partial property.
 - The opposite intercept gives $\bar{M}_2 = \bar{M}_2^\infty$ (Partial property of species 2 when it is present at infinite dilution)

Ex. 11.3

The need arises in a laboratory for 2,000 cm³ of an antifreeze solution consisting of 30-mol-% methanol in water. What volumes of pure methanol and of pure water at 25°C must be mixed to form the 2,000 cm³ of antifreeze, also at 25°C? Partial molar volumes for methanol and water in a 30-mol-% methanol solution and their pure-species molar volumes, both at 25°C, are:

$$\begin{array}{ll} \text{Methanol(1):} & \bar{V}_1 = 38.632 \text{ cm}^3 \text{ mol}^{-1} \quad V_1 = 40.727 \text{ cm}^3 \text{ mol}^{-1} \\ \text{Water(2):} & \bar{V}_2 = 17.765 \text{ cm}^3 \text{ mol}^{-1} \quad V_2 = 18.068 \text{ cm}^3 \text{ mol}^{-1} \end{array}$$

Solution 11.3

Equation (11.11) is written for the molar volume of the binary antifreeze solution, and known values are substituted for the mole fractions and partial volumes:

$$V = x_1 \bar{V}_1 + x_2 \bar{V}_2 = (0.3)(38.632) + (0.7)(17.765) = 24.025 \text{ cm}^3 \text{ mol}^{-1}$$

Because the required total volume of solution is $V^t = 2,000 \text{ cm}^3$, the total number of moles required is:

$$n = \frac{V^t}{V} = \frac{2,000}{24.025} = 83.246 \text{ mol}$$

Of this, 30% is methanol, and 70% is water:

$$n_1 = (0.3)(83.246) = 24.974 \quad n_2 = (0.7)(83.246) = 58.272 \text{ mol}$$

The volume of each pure species is $V_i^t = n_i V_i$; thus,

$$V_1^t = (24.974)(40.727) = 1,017 \quad V_2^t = (58.272)(18.068) = 1,053 \text{ cm}^3$$

Note that the simple sum of the initial volumes = 2,070 cm³. A volume more than 3% larger than that of solution formed (2000cm³).

Plot values of \bar{V}_1 , \bar{V}_2 and V for the binary solution methanol(1)/water(2) at 25°C as function of x_1 .

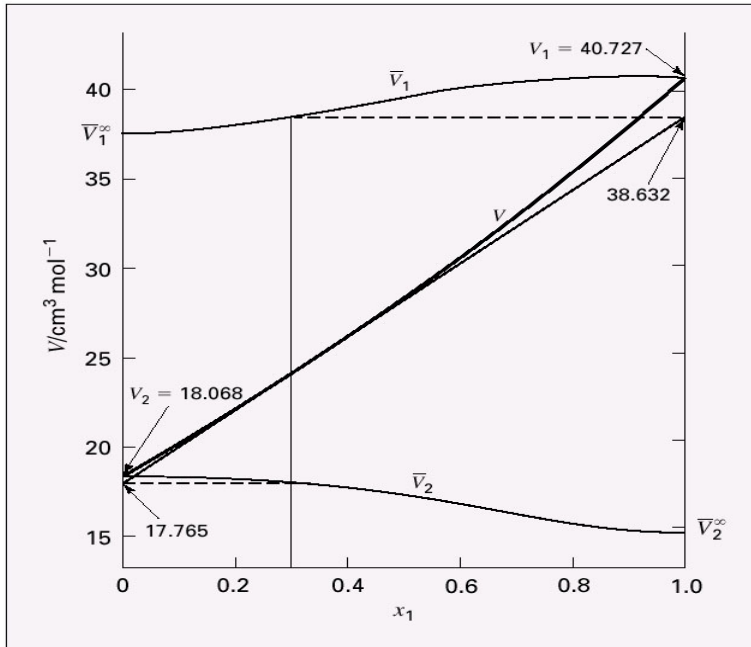


Figure 11.2: Molar volumes for methanol(1)/water(2) at 25°C and 1(atm). Numerical values relate to Ex. 11.3.

- Plot V curve from the known values.
($V_1 = 40.727$, $V_2 = 18.068$, $V @_{x_1=0.3} = 24.025$)
- Draw tangent line to the V curve @ $x_1=0.3$
Obtain values \bar{V}_1 , \bar{V}_2
- Now construct \bar{V}_1 , \bar{V}_2 by the same method. (Or substitute in a given equation as in ex. 11.4)
- From intercept at $x_1 = 0 \rightarrow \bar{V}_1^\infty$
From intercept at $x_1 = 1 \rightarrow \bar{V}_2^\infty$
- Note that \bar{V}_1 curve becomes horizontal (slope = 0) ($d\bar{V}_1 / dx_1 = 0$) at $x_1 = 1$
And \bar{V}_2 curve becomes horizontal (slope = 0) ($d\bar{V}_2 / dx_1 = 0$) at $x_1 = 0$
This is required by Gibbs/Duhem equation
$$\sum x_i d\bar{M}_i = 0 \quad (11.14)$$

It becomes $x_1 d\bar{V}_1 + x_2 d\bar{V}_2 = 0$
Divide by dx_1 and arrange,
 $d\bar{V}_1 / dx_1 = -x_2 / x_1 d\bar{V}_2 / dx_1$

- The results show: $d\bar{V}_1 / dx_1$ and $d\bar{V}_2 / dx_1$ must be of opposite signs.
- **Read Ex.11.4**

11.4 Ideal Gas Mixtures

* A Partial molar Property (other than volume) of a constituent species in an ideal gas mixture is equal to the corresponding molar property of the species as a pure ideal gas @ the mixture temp. but @ Pressure equal to its partial pressure in the mixture.

$$\Rightarrow \bar{m}_i^{i2}(T, P) = m_i^{i2}(T, P_i) \quad (11.21)$$

But $\bar{m}_i^{i2} \neq v_i^{i2}$

* For Properties indep. of Pressure, such as (H & U)

$$\bar{H}^{i2} = H_i^{i2} \quad (11.22)$$

$$\bar{H}^{i2} = \sum y_i H_i^{i2} \quad (11.23)$$

$$\therefore \underbrace{\bar{H}^{i2} - \sum y_i H_i^{i2}}_{\text{Enthalpy change of mixing}} = 0$$

* For Property dep. on Pressure "Entropy"

$$\bar{S}_i^{i2}(T, P) = S_i^{i2}(T, P) - R \ln y_i$$

or

$$\bar{S}_i^{i2} = S_i^{i2} - R \ln y_i \quad (11.24)$$

By the summability eq'n $m = \sum y_i \bar{m}_i$ or $S^{i2} = \sum y_i \bar{S}_i^{i2}$

$$S^{i2} = \sum y_i S_i^{i2} - R \sum y_i \ln y_i \quad (11.25)$$

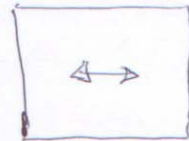
rearrange, $S^{i2} - \sum y_i S_i^{i2} = R \sum y_i \ln y_i$ Entropy change for mixing for ideal gas.

Problem 11.2

11.2

N_2	Ar
4 moles	2.5 moles
$75^\circ C$	$130^\circ C$
30 bar	20 bar

fix
volume



mix adiabatic

$$\Delta S = ?$$

N_2 & Ar ideal gases

$$C_{V,N_2} = \frac{5}{2} R$$

$$C_{V,Ar} = \frac{3}{2} R$$

For closed system, adiabatic, fixed volume system

$$\Delta U = 0$$

for ideal gas $\Delta U = C_V \Delta T$

* Find T & P after mixing

for T

$$\Delta U = 0 \quad \therefore \Delta U = C_V \Delta T$$

$$\therefore n_{N_2} C_{V,N_2} (T - T_{N_2}) + n_{Ar} C_{V,Ar} (T - T_{Ar}) = 0$$

Solve for T \Rightarrow $T = 90^\circ C$

for P

$$V^k = V_{N_2} + V_{Ar}$$

for ideal gas ($PV = nRT$)

$$\therefore \frac{n^k RT}{P} = \frac{n_{N_2} RT_{N_2}}{P_{N_2}} + \frac{n_{Ar} RT_{Ar}}{P_{Ar}}$$

Solve for P \Rightarrow $P = 24.83 \text{ bar}$

Now Calculate Entropy by two step Path:

① Bring individual gas to mixture T & P

② mix gases @ mix. T & P.

$$\therefore \Delta S = \Delta S_{N_2} + \Delta S_{Ar} + \Delta S_{mix}$$

$$\Delta S_{N_2} = n_{N_2} \left[C_{p_{N_2}} \ln \left(\frac{T}{T_{N_2}} \right) - R \ln \left(\frac{P}{P_{N_2}} \right) \right] \quad \text{ch.s}$$

$$\Delta S_{Ar} = n_{Ar} \left[C_{p_{Ar}} \ln \left(\frac{T}{T_{Ar}} \right) - R \ln \left(\frac{P}{P_{Ar}} \right) \right] \quad \text{ch.s}$$

$$\text{where } C_p = C_v + R$$

Then

$$\Delta S_{mix} = n^t (-R \sum y_i \ln y_i)$$

$$\text{where } y_1 = \frac{n_{N_2}}{n^t} \quad \checkmark \quad y_2 = \frac{n_{Ar}}{n^t}$$

finally

$$\Delta S = \Delta S_{N_2} + \Delta S_{Ar} + \Delta S_{mix}$$

$$= 38.27 \frac{J}{K}$$

$$\underline{\underline{\quad \quad \quad}}$$

11.5 Fugacity and Fugacity Coefficient: Pure Species

* Application of equili. criteria is facilitated by the use of
or Fugacity

* The. origine of fugacity concept comes from eq'n 11.27

$$G_i^{ig} = \Gamma_i(T) + RT \ln P$$

Valid only for pure species i in the ideal-gas state.

* For Real fluid, write an analoge eq'n:

$$G_i = \Gamma_i(T) + RT \ln f_i \quad (11.30)$$

* Fugacity (F): is a thermodynamic function used in place of Partial Pressure in rxns involving real gases & mixtures.

* subtract 11.27 from 11.30

$$\underbrace{G_i - G_i^{ig}}_{R G_i} = RT \ln \underbrace{\frac{f_i}{P}}_{\phi_i}$$

$$\therefore \boxed{G_i^R = RT \ln \phi_i} \quad (11.31)$$

$$\boxed{\frac{f_i}{P} = \phi_i} \quad (11.32)$$

$\phi_i \equiv$ fugacity coeff.
(dimensionless)

* Fugacity:

Fugative \equiv الهروب

\Rightarrow Real

$$f^i = P \quad (11.32)$$

Fugacity Determination:

(A) PVT Data

$$\ln \phi_i = \int_0^P (Z_i - 1) \frac{dP}{P} \quad (\text{Correct}) \quad (11.35)$$

(B) Cubic eqns

$$\ln \phi_i = Z_i - 1 - \ln(Z_i - \beta_i) - q_i I_i \quad (11.37)$$

(C) 11.7 Gen. Corr. for the fugacity coeff. (Zores)

1- Lee-Kesler Gen eqn

$$\phi = \phi^0 (\phi^1)^w \quad (11.67)$$

Tables E15 & E16 as function of T_r & P_r .

Ex. 11.8

2- Gen. Corr. for the second virial coeff.

$$\ln \phi = \frac{P_r}{T_r} = \frac{P_r}{T_r} (B^0 + w B^1)$$

$$\phi = \exp \left[\frac{P_r}{T_r} (B^0 + w B^1) \right] \quad (11.68)$$

3.61 3.62

EX.

11-XI Calc. ϕ and f bar by the RK eqn of state of Compress with values taken from a suitable gen. corr.

(a) Acetylene @ 325 K & 15 bar

from App. B, for acetylene

$$T_c = 308.3 \text{ K} \quad P_c = 61.39 \text{ bar} \quad w = 0.187$$

$$T_r = \frac{T}{T_c} = 1.054 \quad P_r = \frac{P}{P_c} = 0.244$$

$$\beta = \Omega \frac{P_r}{T_r} \quad (3.50) \Rightarrow \boxed{\beta = 0.02}$$

$$q = \frac{\psi(T_r)}{\Omega T_r} \quad (3.51) \quad \text{from table 3.1}$$

$$q = \frac{\psi(T_r^{1/2})}{\Omega T_r^{1.5}} = \frac{\psi}{\Omega T_r^{1.5}} \Rightarrow \boxed{q = 4.559}$$

Iteration:-

(1)* Guess $Z = 1$ in (3.49)

(2)* Find from (3.49) new value for Z (left hand side)

$$Z = 1 + \beta - q\beta \frac{Z - \beta}{(Z + \epsilon\beta)(Z + \sigma\beta)} \quad (3.49)$$

for RK from table 3.1

$$\Rightarrow Z = 1 + 0.02 - \frac{0.0218}{(1 + 0)(1 + 0)} \frac{1 - 0.02}{1(1 + 0.02)} = 0.93$$

(3)* Subs. back into 3.49

Continue iteration till $Z = 0.925$

(4)* I from (6.62b) $I = \ln \left(\frac{Z + \sigma\beta}{Z + \epsilon\beta} \right)$

$$I = \ln \left(\frac{0.925 + 0.02}{0.925 + 0} \right) = 0.0214$$

(5)* $\ln \phi_i = z_i - 1 - \ln(z_i - \beta_i) - q_i I_i$ (11.37)

$$\phi_i = \exp \left[\dots \right]$$

$$= \exp \left[0.925 - 1 - \ln(0.925 - 0.02) - (4.559) \left(\frac{0.0214}{0.0214} \right) \right]$$

$$= 0.93$$

(6) $f_i = \phi_i P_i = (0.93)(15) = 13.95$

Generalized Correlation

Part (a) 15 bar \Rightarrow ~~use~~ By gen. corr. use ^{second} Virial eq

from APP.B for Acetylene

$$T_c = 308.3 \text{ K} \quad P_c = 61.39 \text{ bar} \quad \omega = 0.187$$

$$T_r = \frac{T}{T_c} = 1.054$$

$$P_r = \frac{P}{P_c} = 0.244$$

$$B^0 = 0.083 - \frac{0.422}{T_r^{1.6}}$$

$$(3.61)$$

$$= 0.083 - \frac{0.422}{(1.054)^{1.6}}$$

$$= -0.3049$$

$$B^1 = 0.139 - \frac{0.172}{T_r^{4.2}}$$

$$(3.62)$$

$$= 0.001$$

$$\phi = \exp \left[\frac{P_r}{T_r} (B^0 + \omega B^1) \right] \quad \text{Eq. (11.65)}$$

$$= \exp \left[\frac{0.244}{1.054} (-0.3049 + (0.187)(0.001)) \right] = 0.932$$

$$P_i = \phi_i P_i = (0.932)(15) = 13.98$$

vapor-liquid Equilibrium for Pure species :

$$G_i^v = \Gamma_i(T) + RT \ln f_i^v \quad (11.38 a)$$

$$G_i^L = \Gamma_i(T) + RT \ln f_i^L \quad (11.38 b)$$

By difference

$$G_i^v - G_i^L = RT \ln \frac{f_i^v}{f_i^L}$$

$$\Rightarrow G_i^v - G_i^L = 0 \quad (6.66)$$

$$\Rightarrow f_i^v = f_i^L = f_i^{sat} \quad (11.39) \quad \phi_i^{sat} = \frac{f_i^{sat}}{p_i^{sat}} \quad (11.40)$$

ϕ_i^{sat} value of sat'd liq. or sat'd vapor.

\Rightarrow For a pure species coexisting liquid & vapor phases are in equilibrium when they have the same T & P and fugacity.

Fugacity of Pure liquid:

① fugacity coeff. of sat'd vapor $\phi_i^{sat} = \phi_i^v$

- Integral of (11.34) $\ln \phi_i = \int_0^p (Z_i - 1) \frac{dp}{p}$

- (11.40) find $f_i^{sat} = \phi_i^{sat} p_i^{sat}$

② As $p^{sat} \rightarrow P$, state sat'd liq. \rightarrow compressed liq. from

fugacity change resulting from state change $\rightarrow \ln \frac{f_i}{f_i^{sat}} = -\frac{V_i^L (P - p_i^{sat})}{RT}$

$G_i - G_i^{sat} \Rightarrow f_i^{sat} = \phi_i^{sat} p_i^{sat} \underbrace{\exp \left(\frac{V_i^L (P - p_i^{sat})}{RT} \right)}_{\text{Poynting factor}}$

$$\Rightarrow f_i = \phi_i^{sat} p_i^{sat} \exp \left(\frac{V_i^L (P - p_i^{sat})}{RT} \right) \quad (11.44) \quad (\text{Ex 11.5})$$

EX. 11.5

H₂O @ T = 300°C

P up to 10,000 kPa (100 bar)

Calc. values of f_i and φ_i from data in steam tables & plot vs P.

Sol'n: التفرقة السؤال ⇒ Show how f_i & φ_i vary with Pressure (Vapor then liquid)

* write eq'n 11.34 twice,

For a state at Pressure P $G_i = f_i(T) + RT \ln f_i$

& for a low Pressure ref. state $G_i^* = f_i(T) + RT \ln f_i^*$

* The difference $\ln \frac{f_i}{f_i^*} = \frac{1}{RT} (G_i - G_i^*)$

* ∴ by definition $G_i = H_i - T S_i$

∴ $\ln \frac{f_i}{f_i^*} = \frac{1}{RT} \left[\frac{H - H_i^*}{T} - (S_i - S_i^*) \right]$ (A)

* From steam tables @ 300°C, low pressure, 1 kPa (F-2)

∴ for practical reasons can be assumed IDEAL GAS where $f_i^* = P^* = 1 \text{ kPa}$ (As we said for ideal gas $f_i^* = P$)

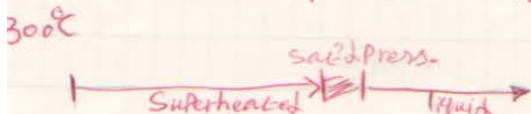
and $H_i^* = 3,076.8 \frac{\text{J}}{\text{g}}$ $S_i^* = 10.345 \frac{\text{J}}{\text{g K}}$

* For the state of superheated steam @ 300°C for various Pressures from 1 kPa to the sat'n Pressure of 8,592.7 kPa apply eq'n (A).

بالنسبة لـ F.1 عند T=300°C (أول القيمة) P.711
 في ظل F.2 آخر قيم السوبر هيتد عند P=8,400
 - بعد الساتر و يصبح عند (liq.)

For example, @ P = 4000 kPa & 300°C (F.2) P.711

$H_i = 2,962 \frac{\text{J}}{\text{g}}$ $S_i = 6.3642 \frac{\text{J}}{\text{g K}}$



To substitute in eqn (A) (Correct for units $R = 8.314 \frac{J}{mol \cdot K}$)
 multiply by $\frac{H_{fs}}{M_w}$ (18.015)

$$\ln \frac{f_i}{f_i^*} = \frac{18.015}{8.314} \left[\frac{29962.0 - 31076.8}{573.15} - (6.3642 - 10.345) \right] = 8.1917$$

$$\frac{f_i}{f_i^*} = 3,611.0$$

$$f_i = (3,611) (f_i^*) = (3,611) (1 \text{ kPa}) = 3,611 \text{ kPa}$$

and fugacity Coeff. @ 4000 kPa:

$$\phi_i = \frac{f_i}{P} = \frac{3,611}{4000} = 0.9028$$

* Similar Calc. @ other pressures, lead to the values plotted in (Fig 11.3) at Press. up to the sat'n Press. of 8,952.7 kPa, where

$$f_i = f_i^{sat} = 6,738.9 \text{ kPa} \quad \text{and} \quad \phi_i = \phi_i^{sat} = 0.7843$$

* Now, after sat'n is reached, we have liquid water @ higher Press. values of f_i & ϕ_i are found from eqn (11.44), with V_i^L equal to the molar volume of sat'd liq. water @ 300°C

$$V_i^L = (1.403) (18.015) = 25.28 \text{ cm}^3 \text{ mol}^{-1}$$

(F1) cm³/2 3/mol

At 10,000 kPa,

$$f_i = \phi_i^{sat} P_i^{sat} \exp \frac{V_i^L (P - P_i^{sat})}{RT} \quad (11.44)$$

$$f_i = 6,738.9 \exp \frac{(25.28) (10,000 - 8,952.7)}{(8.314) (573.15)} = 6,789.4 \text{ kPa}$$

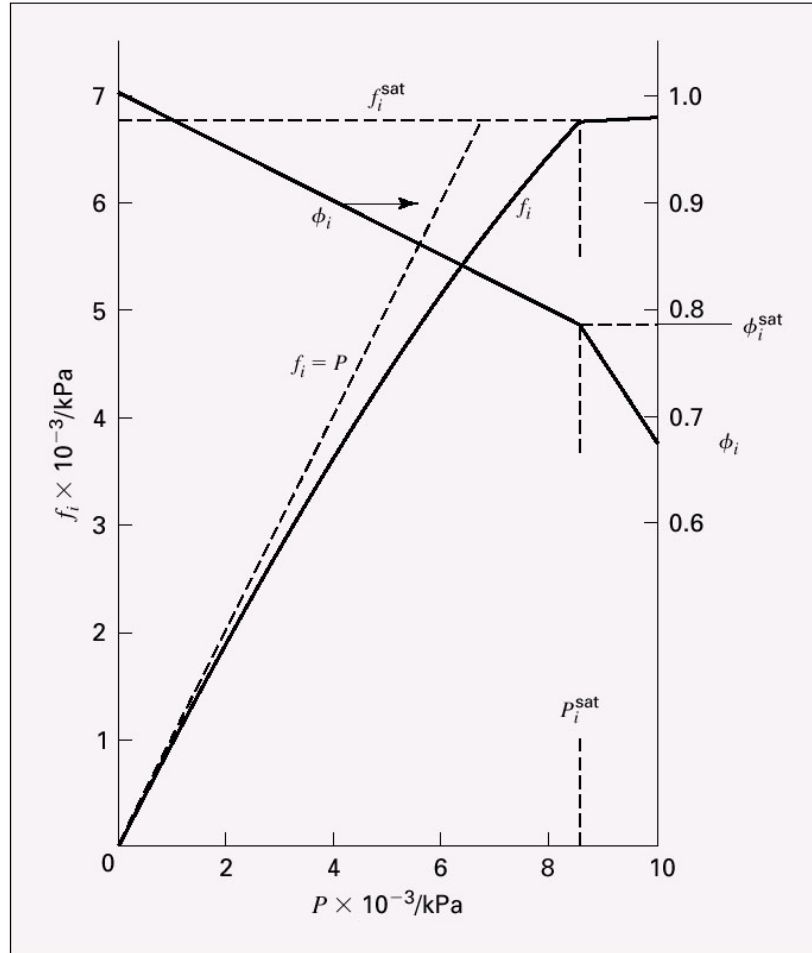
(0.7843)(8,952.7)

The fugacity Coeff. of liq. water at these conditions

$$\phi_i = \frac{f_i}{P} = \frac{6,789.4}{10,000} = 0.6789$$

This will complete calc. of Fig 11.3, and show how f_i & ϕ_i vary with pressure.

Figure 11.3: Fugacity and fugacity coefficient of steam at 300°C.



Comments on fig. 11.3:

- f_i starts at the origin.
- Deviation from ideality (dashed line) increases as pressure increase.
- At P_i^{sat} there is discontinuity in f_i curve slope.
- Fugacity of liquid water at 300°C is weak function of pressure. (Characteristics of liquids at temp. well below T_c).
- ϕ_i decreases from unity steadily from its zero pressure value as the pressure raises.
- Then decrease rapidly in the liquid region as a result of fugacity behavior.

11.6 Fugacity and Fugacity Coefficient: Species in Solution

~~at eq~~ { Multiple phases at the same T and P are in equilibrium
 when the fugacity of each constituent species is the same in all phases.

$$f_i^{\alpha} = f_i^{\beta} = \dots = f_i^{\pi} \quad (11.47)$$

for sol'n (similar to pure species, but more comp. calc.)

$$\bar{G}_i^R = RT \ln \hat{\phi}_i \quad (11.51)$$

Fugacity of species in sol'n

$$\hat{\phi}_i = \frac{f_i}{y_i P} \quad (11.52)$$

and, From the compressibility-factor data (ex 11.6)

$$\ln \hat{\phi}_i = \int_0^P (\bar{Z}_i - 1) \frac{dP}{P} \quad (11.60)$$

analogous to eq'n 11.34, allows calc. of $\hat{\phi}_i$ for species in sol'n from PVT data.

11.8 The Ideal Solution

* Similar to ideal gas mixtures.
(change i^r by i^d) sec. (11.8)

* Replace Residual Properties r^r by
EXCESS PROPERTIES (E) (sec. 11.9)