a. Water (A)–Glycerol (B) System

$P = 101.3$ kPa

Data of Chen and Thompson, *J. Chem. Eng. Data*, **15,** 471 (1970)

Temperature, °C	y_A	x_A	$\alpha_{A,B}$
100.0	1.0000	1.0000	
104.6	0.9996	0.8846	333
109.8	0.9991	0.7731	332
128.8	0.9980	0.4742	544
148.2	0.9964	0.3077	627
175.2	0.9898	0.1756	456
207.0	0.9804	0.0945	481
244.5	0.9341	0.0491	275
282.5	0.8308	0.0250	191
290.0	0.0000	0.0000	

b. Methanol (A)–Water (B) System

$P = 101.3$ kPa

Data of J.G. Dunlop, M.S. thesis, Brooklyn Polytechnic Institute (1948)

Temperature, °C	y_A	x_A	$\alpha_{A,B}$
64.5	1.000	1.000	
66.0	0.958	0.900	2.53
69.3	0.870	0.700	2.87
73.1	0.779	0.500	3.52
78.0	0.665	0.300	4.63
84.4	0.517	0.150	6.07
89.3	0.365	0.080	6.61
93.5	0.230	0.040	7.17
100.0	0.000	0.000	

c. *Para*-xylene (A)–*Meta*-xylene (B) System

$P = 101.3$ kPa

Data of Kato, Sato, and Hirata, *J. Chem. Eng. Jpn.*, **4,** 305 (1970)

Temperature, °C	y_A	x_A	$\alpha_{A,B}$
138.335	1.0000	1.0000	
138.491	0.8033	0.8000	1.0041
138.644	0.6049	0.6000	1.0082
138.795	0.4049	0.4000	1.0123
138.943	0.2032	0.2000	1.0160
139.088	0.0000	0.0000	

a. Methanol (A)–Water (B) System

$T = 50°C$

Data of McGlashan and Williamson, *J. Chem. Eng. Data*, **21,** 196 (1976)

Pressure, psia	y_A	x_A	$\alpha_{A,B}$
1.789	0.0000	0.0000	
2.373	0.2661	0.0453	7.64
3.369	0.5227	0.1387	6.80
4.641	0.7087	0.3137	5.32
5.771	0.8212	0.5411	3.90
6.811	0.9090	0.7598	3.16
7.800	0.9817	0.9514	2.74
8.072	1.0000	0.0000	

b. Methanol (A)–Water (B) System

$T = 150°C$

Data of Griswold and Wong, *Chem. Eng. Prog. Symp. Ser.*, **48**(3), 18 (1952)

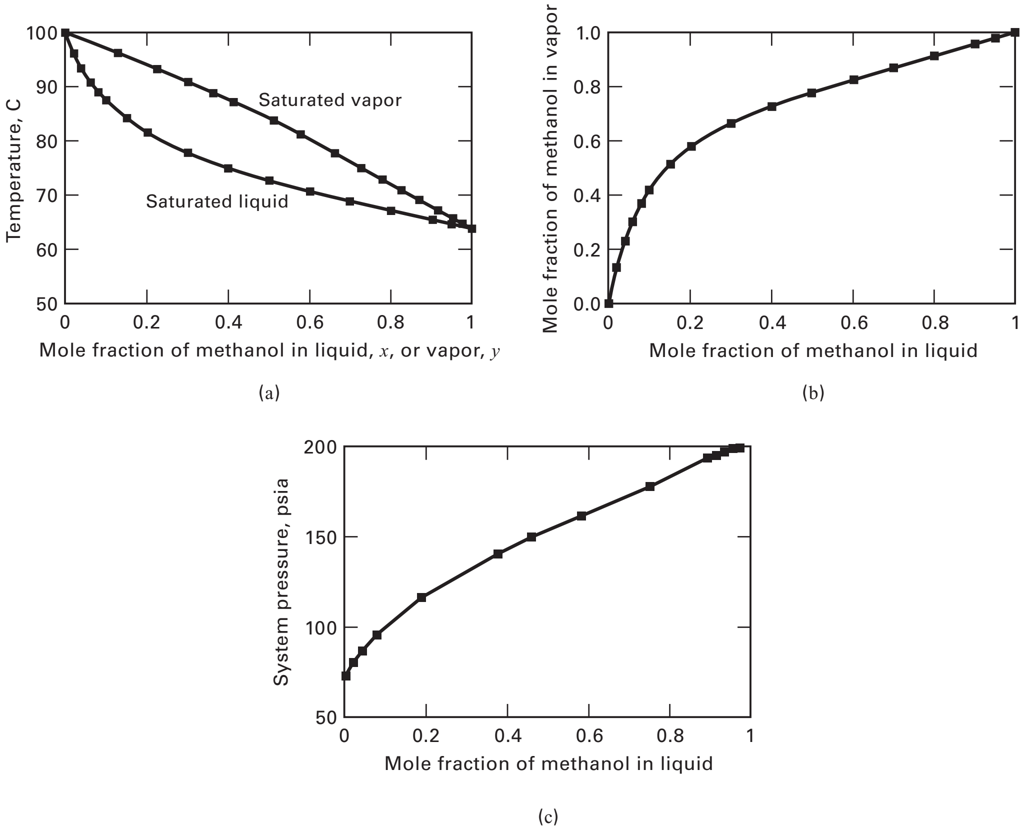
Pressure, psia	y_A	x_A	$\alpha_{A,B}$
73.3	0.060	0.009	7.03
85.7	0.213	0.044	5.88
93.9	0.286	0.079	4.67
139.7	0.610	0.374	2.62
160.4	0.731	0.578	1.98
193.5	0.929	0.893	1.57
196.5	0.960	0.936	1.64
199.2	0.982	0.969	1.75

c. Methanol (A)–Water (B) System

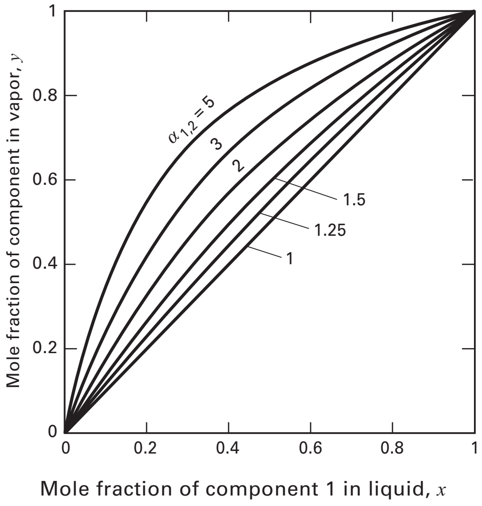
$T = 250°C$

Data of Griswold and Wong, *Chem. Eng. Prog. Symp. Ser.*, **48**(3), 18 (1952)

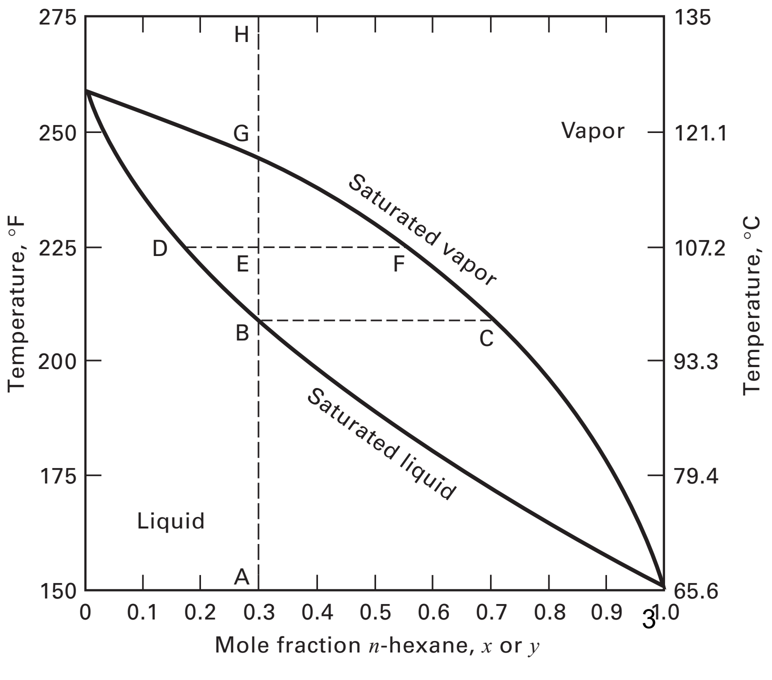
Pressure, psia	y_A	x_A	$\alpha_{A,B}$
681	0.163	0.066	2.76
818	0.344	0.180	2.39
949	0.487	0.331	1.92
1099	0.643	0.553	1.46
1204	0.756	0.732	1.13
1219	0.772	0.772	1.00
1234	0.797	0.797	1.00

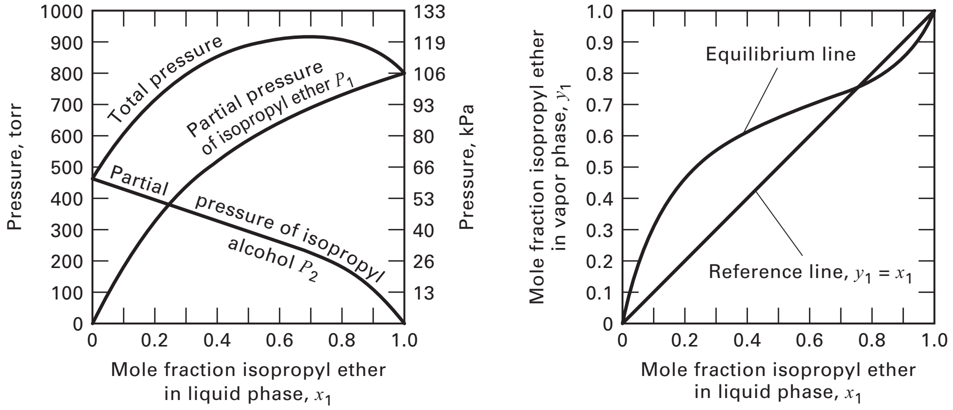


Vapor–liquid equilibrium conditions for the methanol–water system: (a) *T*–*y*–*x* diagram for 1 atm pressure; (b) *y*–*x* diagram for 1 atm pressure; (c) *P*–*x* diagram for 150°C.

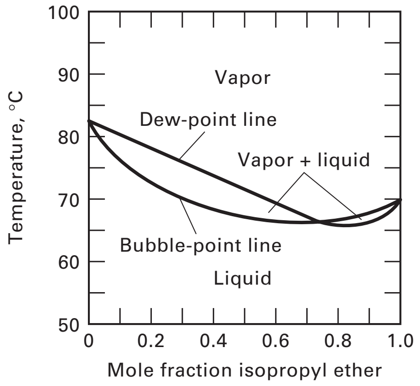


$$y_A = \frac{\alpha_{A,B} x_A}{1 + x_A(\alpha_{A,B} - 1)}$$



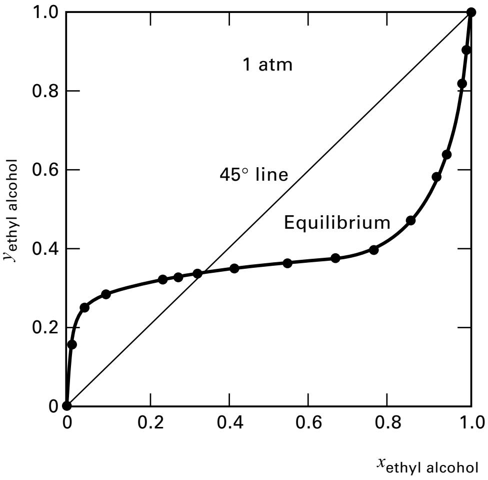


(a) (b)

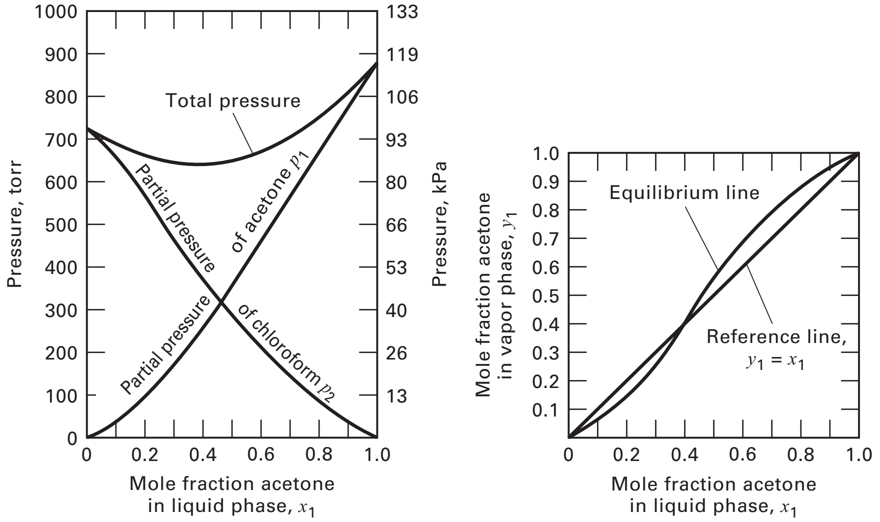


(c)

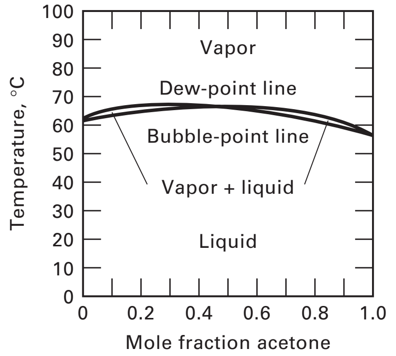
Minimum-boiling-point azeotrope, isopropyl ether–isopropyl alcohol system: (a) partial and total pressures at 70°C; (b) vapor–liquid equilibria at 101 kPa; (c) phase diagram at 101 kPa. [Adapted from O.A. Hougen, K.M. Watson, and R.A. Ragatz, *Chemical Process Principles. Part II*, 2nd ed., John Wiley & Sons, New York (1959).]



Equilibrium curve for *n*-hexane/ethanol.



(a) (b)



(c)

Maximum-boiling-point azeotrope, acetone–chloroform system: (a) partial and total pressures at 60°C; (b) vapor–liquid equilibria at 101 kPa; (c) phase diagram at 101 kPa pressure. [Adapted from O.A. Hougen, K.M. Watson, and R.A. Ragatz, *Chemical Process Principles. Part II*, 2nd ed., John Wiley & Sons, New York (1959).]

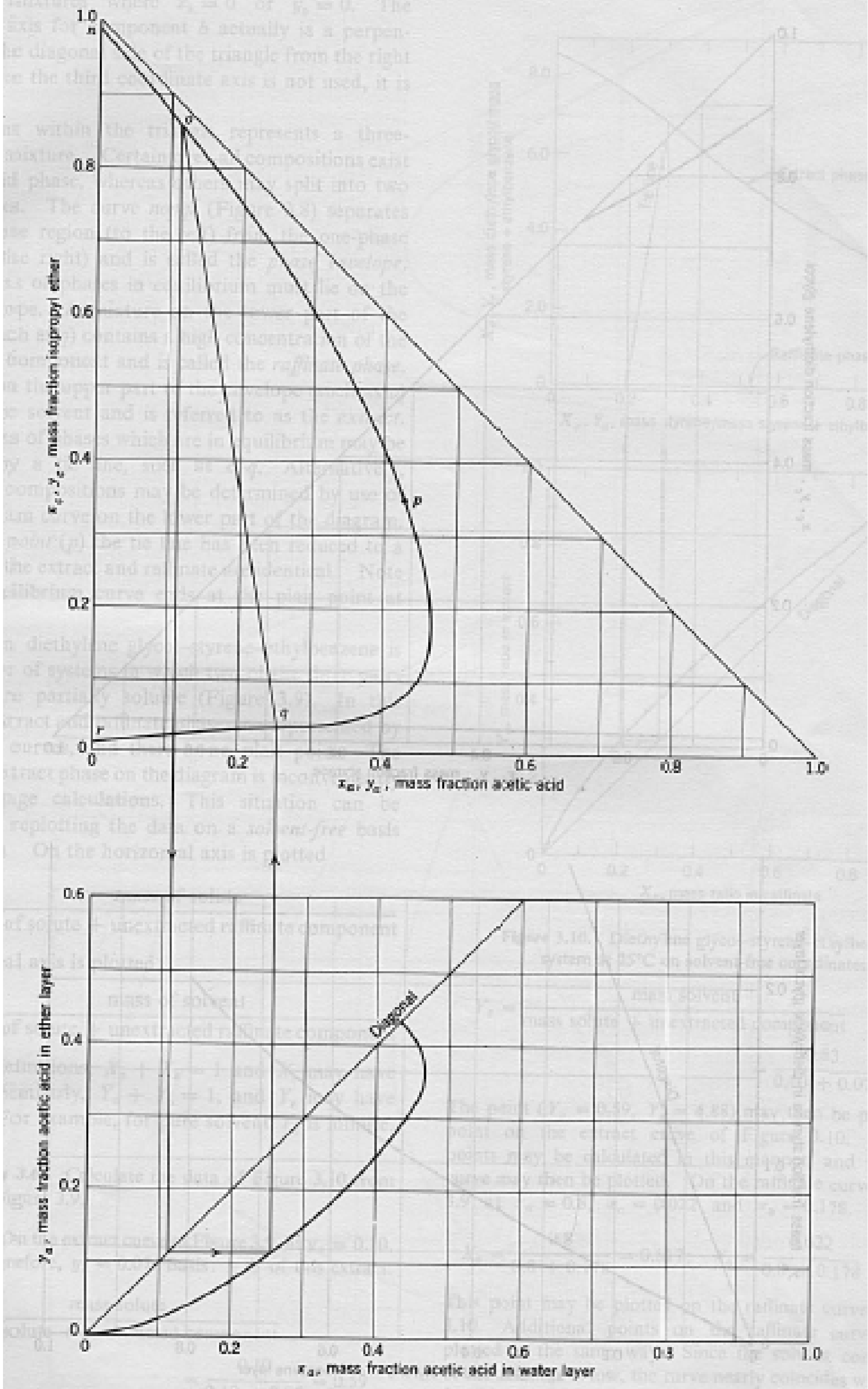
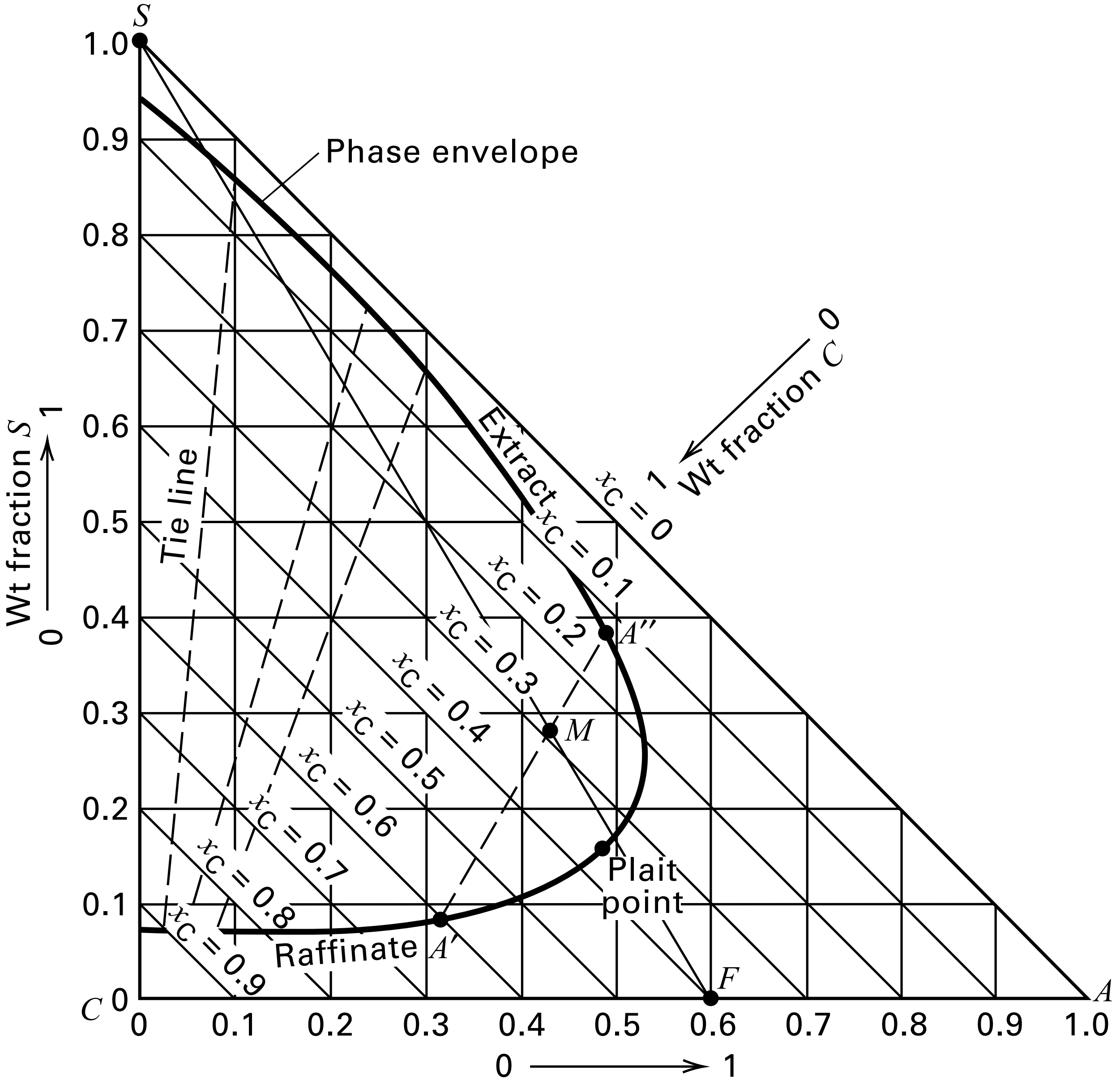
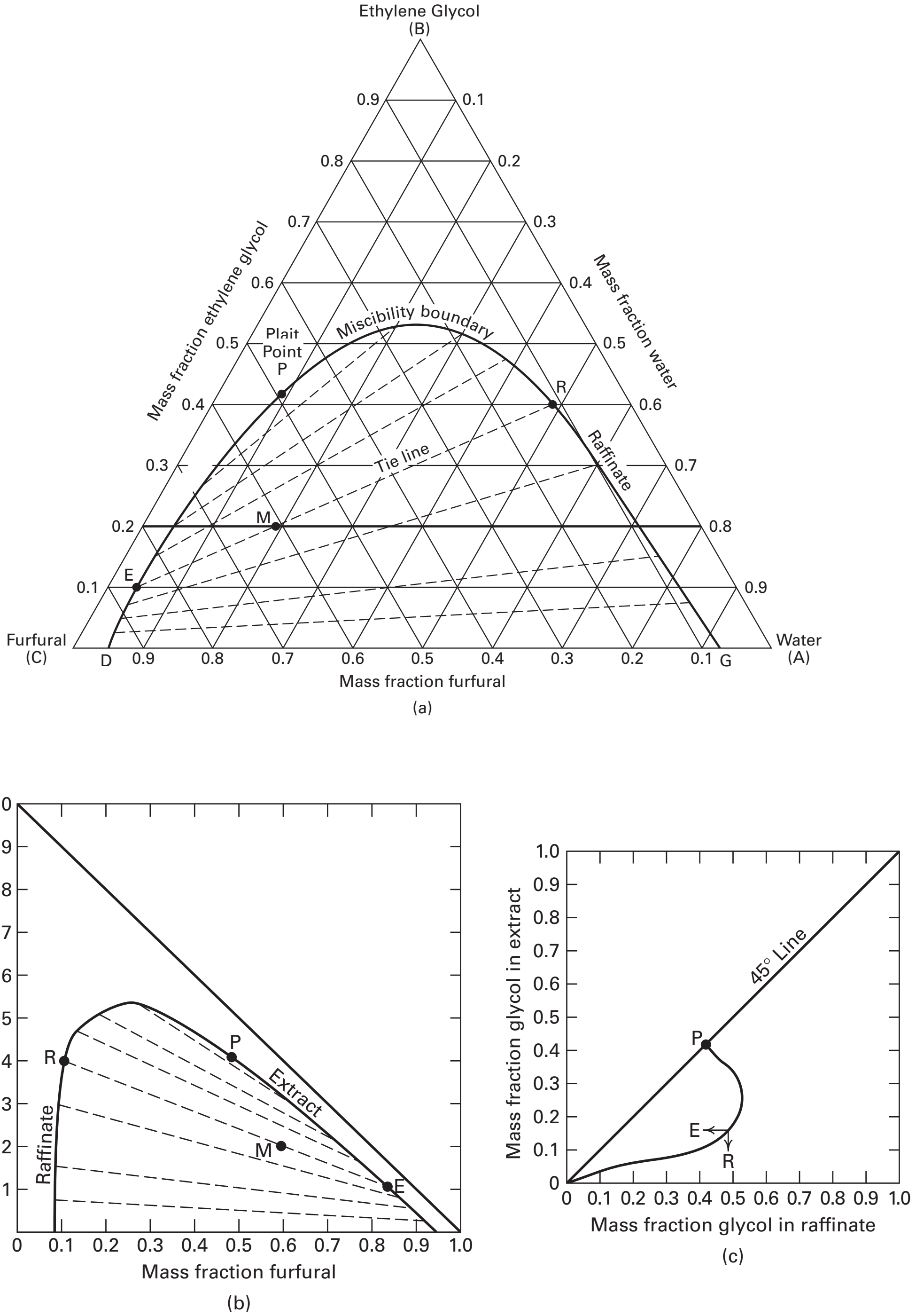


Figure 3.8. Isopropyl ether–acetic acid–water system at 20°C. (7)


S
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
C
Wt fraction S
0 → 1
Phase envelope
Tie line
Extract
Raffinate
Plait point
A''
M
A'
F
A
$x_C = 1$
$x_C = 0$
$x_C = 0.1$
$x_C = 0.2$
$x_C = 0.3$
$x_C = 0.4$
$x_C = 0.5$
$x_C = 0.6$
$x_C = 0.7$
$x_C = 0.8$
$x_C = 0.9$
Wt fraction C
0
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
0 → 1

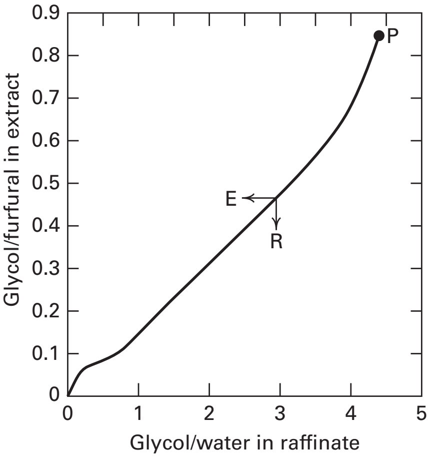


(a)

(b)

(c)

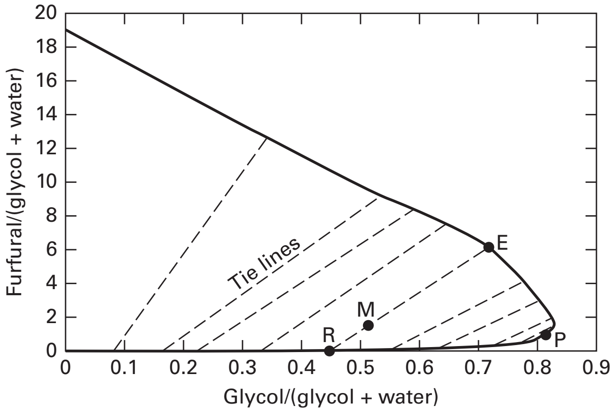
Liquid–liquid equilibrium, ethylene glycol–furfural–water, 25°C, 101 kPa: (a) equilateral-triangular diagram; (b) right-triangular diagram; (c) equilibrium solute diagram in mass fractions; (*continues*)



(d)

Mutual Equilibrium (Tie-Line) Data for the Furfural–Ethylene Glycol–Water System at 25°C and 101 kPa

Glycol in Water Layer, wt%	Glycol in Furfural Layer, wt%
41.5	41.5
50.5	32.5
52.5	27.5
51.5	20.0
47.5	15.0
40.0	10.0
30.0	7.5
20.0	6.2
15.0	5.2
7.3	2.5



(e)

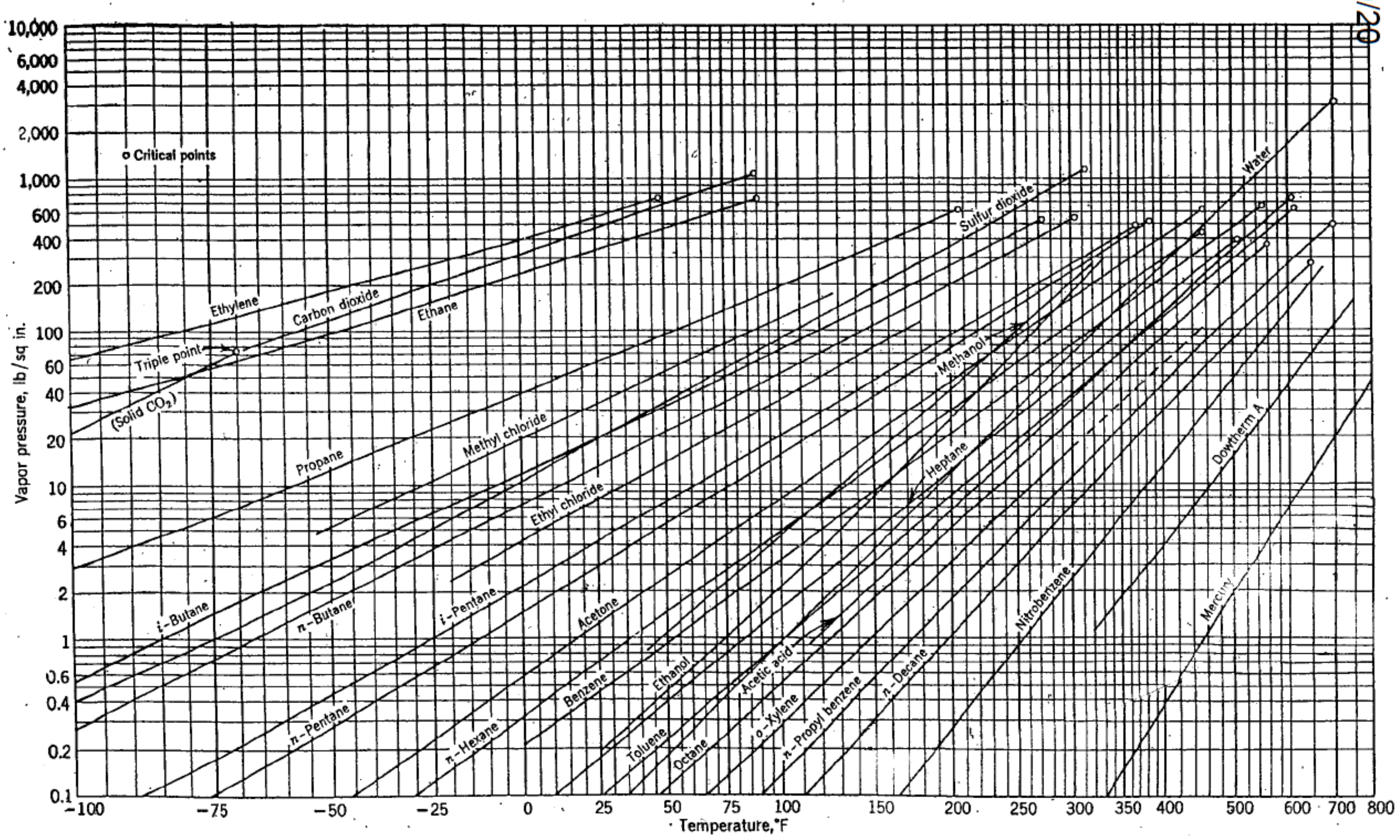
(d) equilibrium solute diagram in mass ratios; (e) Janecke diagram.

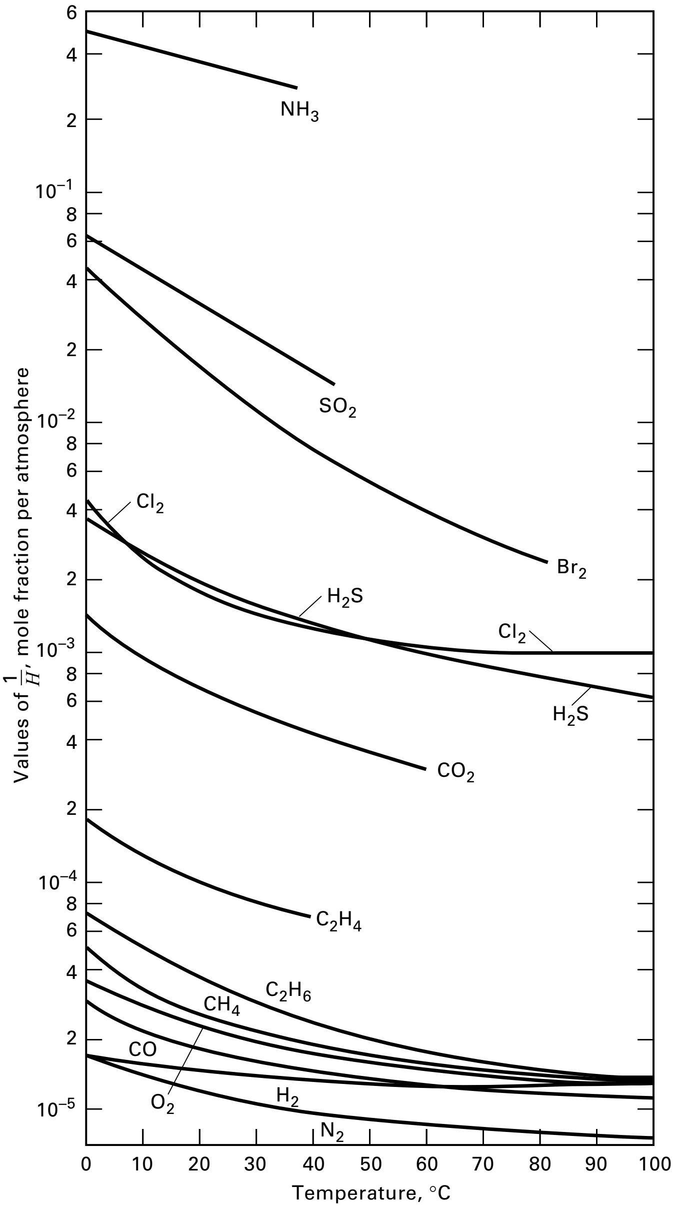
Equilibrium Miscibility Data in Weight Percent for the Furfural–Ethylene Glycol–Water System at 25°C and 101 kPa

Furfural	Ethylene Glycol	Water
95.0	0.0	5.0
90.3	5.2	4.5
86.1	10.0	3.9
75.1	20.0	4.9
66.7	27.5	5.8
49.0	41.5	9.5
34.3	50.5	15.2
27.5	52.5	20.0
13.9	47.5	38.6
11.0	40.0	49.0
9.7	30.0	60.3
8.4	15.0	76.6
7.7	0.0	92.3

20/20

Appendix D-1. VAPOR PRESSURES OF COMMON LIQUIDS (1).





Henry's law constant for solubility of gases in water.

[Adapted from O.A. Hougen, K.M. Watson, and R.A. Ragatz, *Chemical Process Principles. Part I*, 2nd ed., John Wiley & Sons, New York (1954).]

Appendix D-3. HENRY'S LAW CONSTANTS FOR VARIOUS GASES IN WATER (2)

$p_a = H_a x_a$

where p_a = partial pressure of the solute a in the gas phase, atm
x_a = mole fraction of solute a in the liquid phase, mole fraction
H_a = Henry's law constant, atm/mole fraction

	$H_a \times 10^{-4}$, atm/mole fraction									
T, °C	Air	CO_2	CO	C_2H_6	H_2	H_2S	CH_4	NO	N_2	O_2
0	4.32	0.0728	3.52	1.26	5.79	0.0268	2.24	1.69	5.29	2.55
10	5.49	0.104	4.42	1.89	6.36	0.0367	2.97	2.18	6.68	3.27
20	6.64	0.142	5.36	2.63	6.83	0.0483	3.76	2.64	8.04	4.01
30	7.71	0.186	6.20	3.42	7.29	0.0609	4.49	3.10	9.24	4.75
40	8.70	0.233	6.96	4.23	7.51	0.0745	5.20	3.52	10.4	5.35
50	9.46	0.283	7.61	5.00	7.65	0.0884	5.77	3.90	11.3	5.88
60	10.1	0.341	8.21	5.65	7.65	0.103	6.26	4.18	12.0	6.29
70	10.5		8.45	6.23	7.61	0.119	6.66	4.38	12.5	6.63
80	10.7		8.45	6.61	7.55	0.135	6.82	4.48	12.6	6.87
90	10.8		8.46	6.87	7.51	0.144	6.92	4.52	12.6	6.99
100	10.7		8.46	6.92	7.45	0.148	7.01	4.54	12.6	7.01

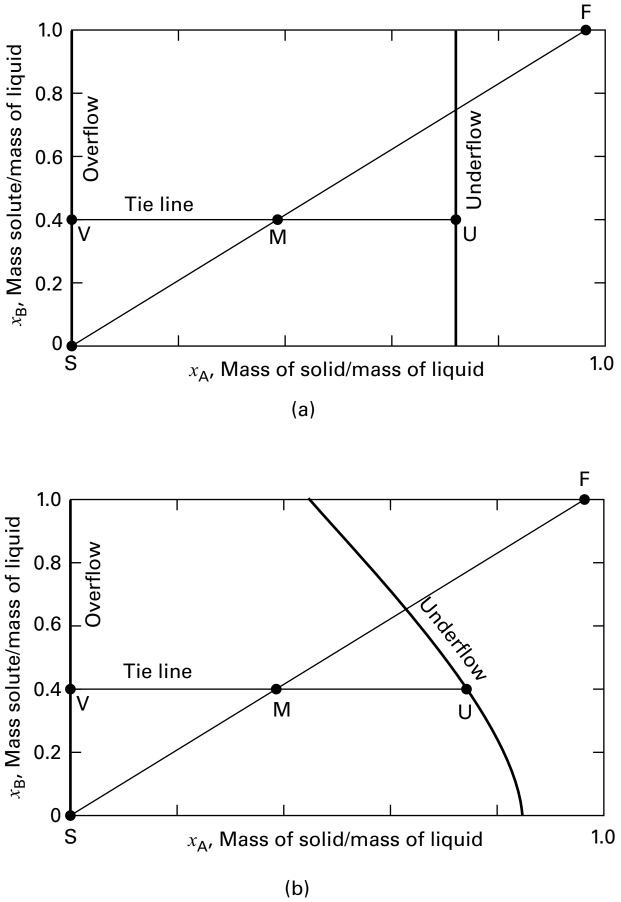
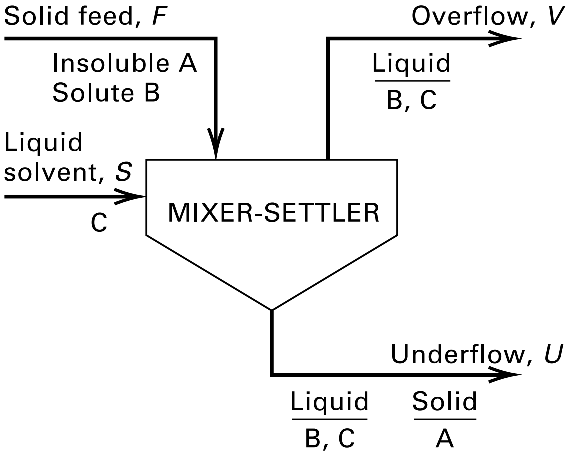
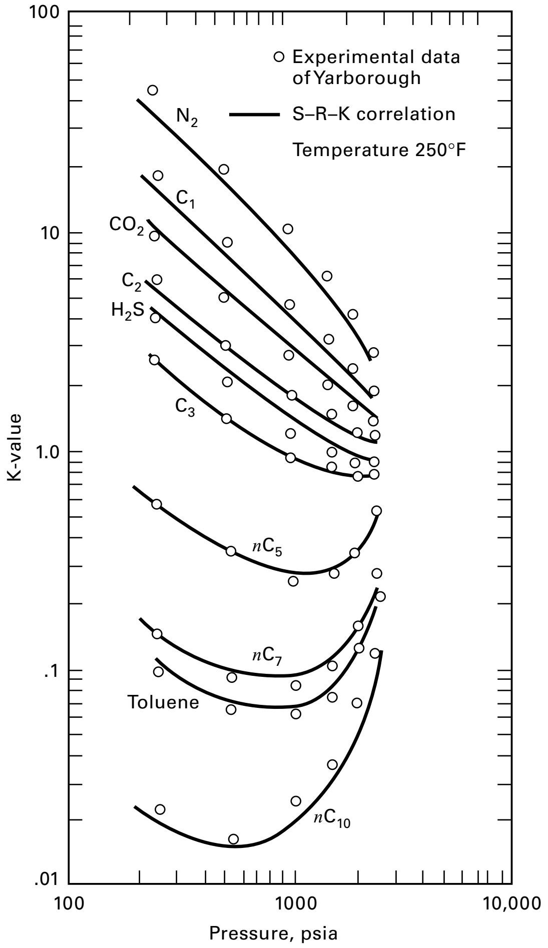
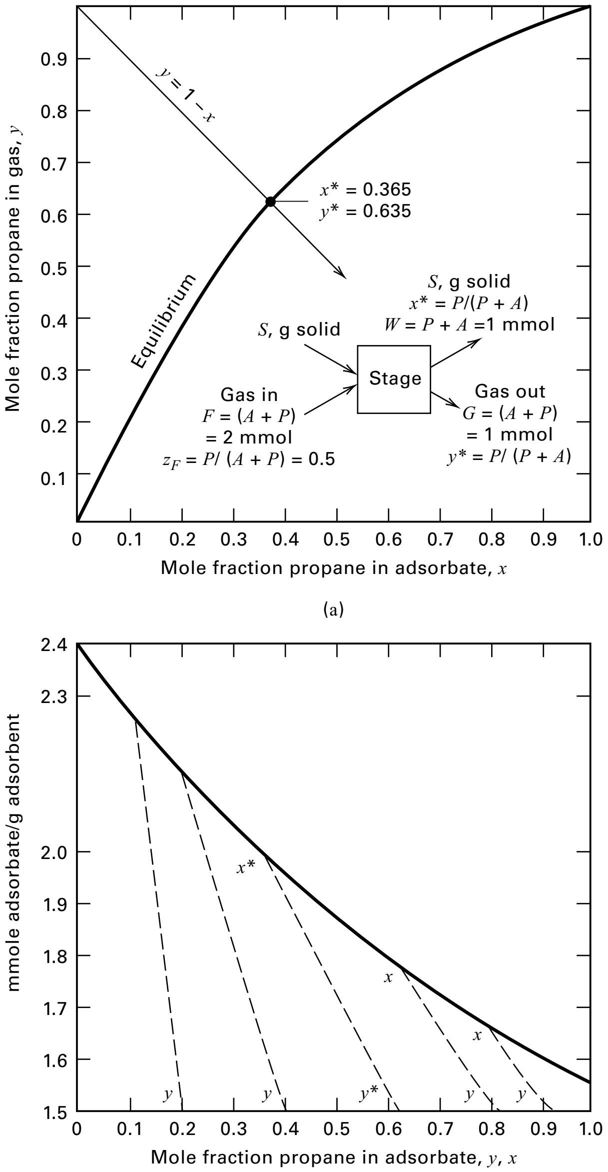


Figure 4.20 Underflow–overflow conditions for ideal leaching: (a) constant-solution underflow; (b) variable-solution underflow.




○ Experimental data of Yarborough
S–R–K correlation
Temperature 250°F
N_2
C_1
CO_2
C_2
H_2S
C_3
nC$_5$
nC$_7$
Toluene
nC$_{10}$
K-value
100
10
1.0
.1
.01
100
1000
10,000
Pressure, psia

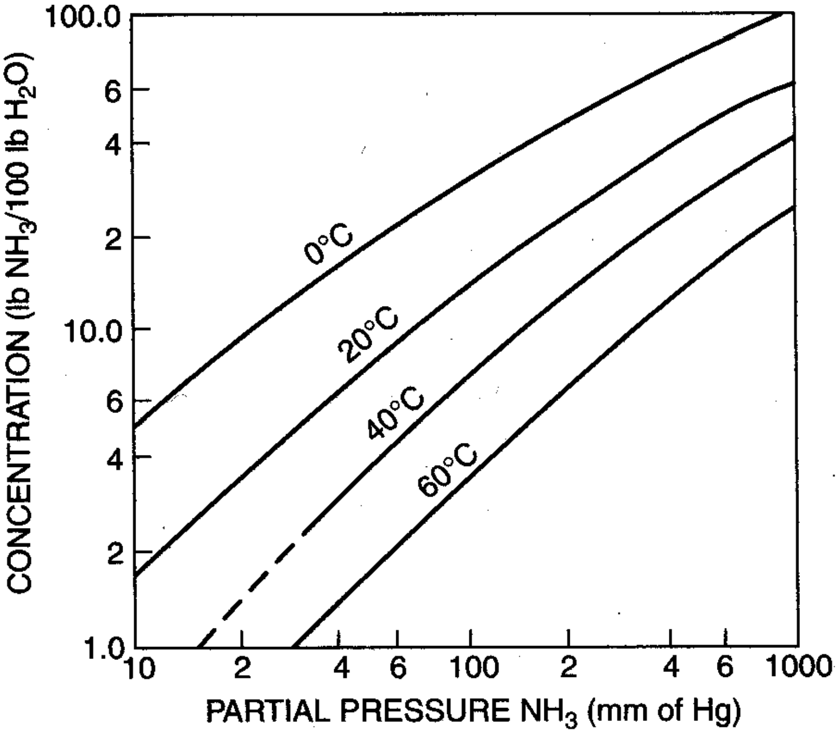


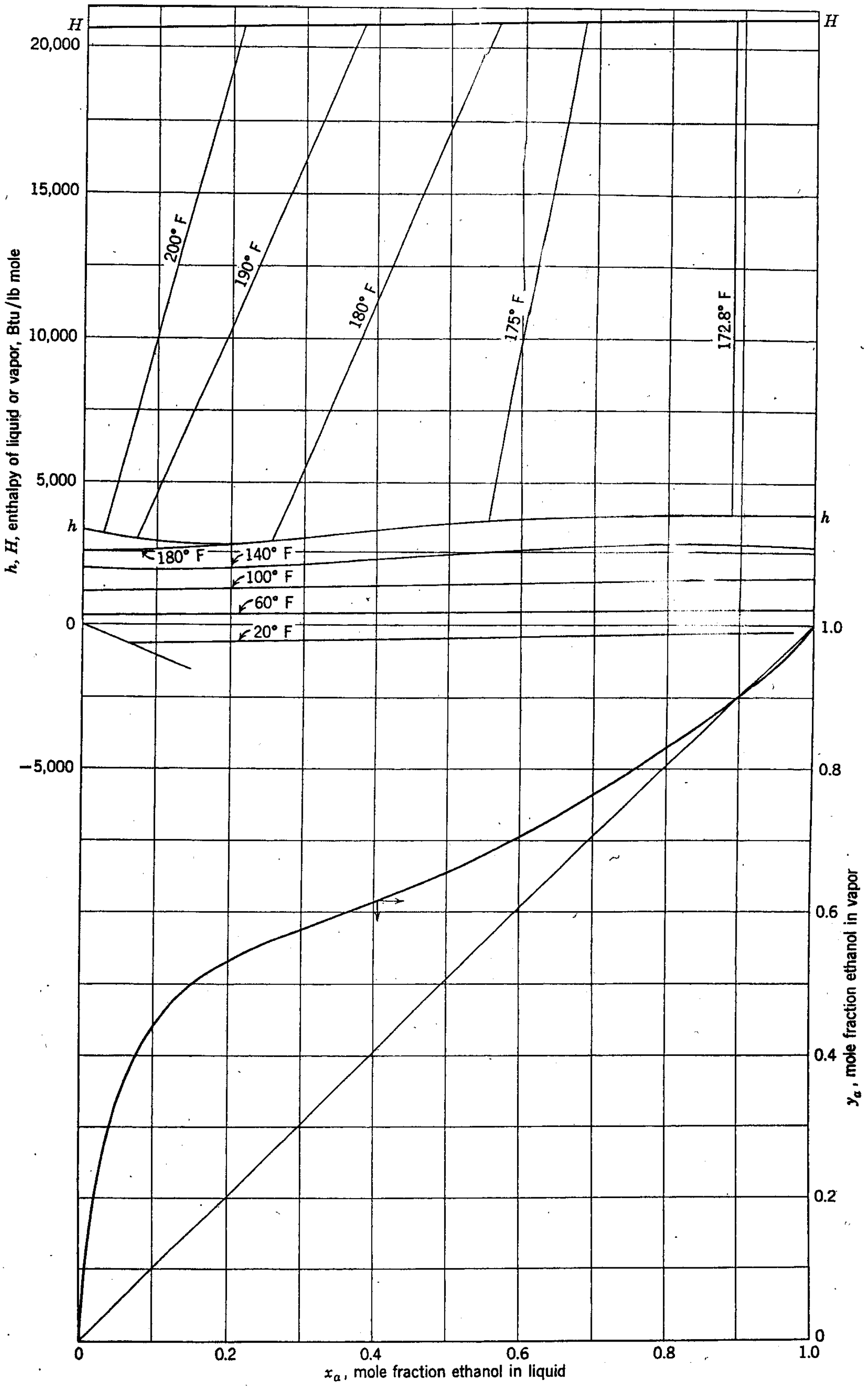
(a)

(b)

Figure 4.29 Adsorption equilibrium at 25°C and 101 kPa of propane and propylene on silica gel.

[Adapted from W.K. Lewis, E.R. Gilliland, B. Chertow, and W. H. Hoffman, *J. Am. Chem. Soc*, **72**, 1153 (1950).]


CONCENTRATION (lb NH3/100 lb H2O)
100.0
6
4
2
10.0
6
4
2
1.0
10
2
4
6
100
2
4
6
1000
PARTIAL PRESSURE NH3 (mm of Hg)
0°C
20°C
40°C
60°C


H
20,000
15,000
10,000
5,000
h
0
−5,000
h, H, enthalpy of liquid or vapor, Btu/lb mole
200° F
190° F
180° F
175° F
172.8° F
180° F
140° F
100° F
60° F
20° F
H
h
1.0
0.8
0.6
0.4
0.2
0
y_a, mole fraction ethanol in vapor
0
0.2
0.4
0.6
0.8
1.0
x_a, mole fraction ethanol in liquid

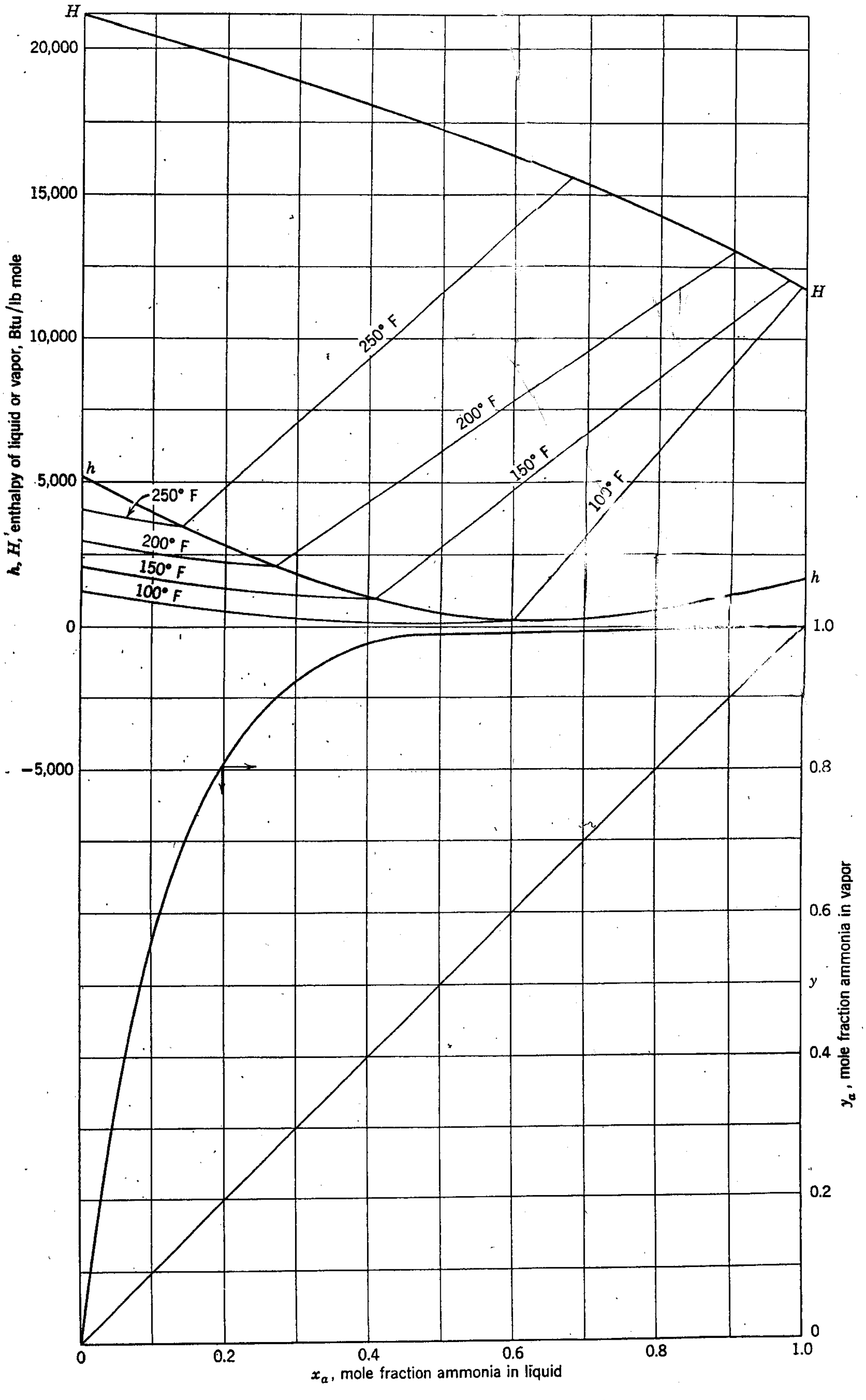


Figure 3.5. Enthalpy-composition diagram for ammonia–water at 100 psia (2). Reference state: liquid water at 32°F, liquid ammonia at −40°F.

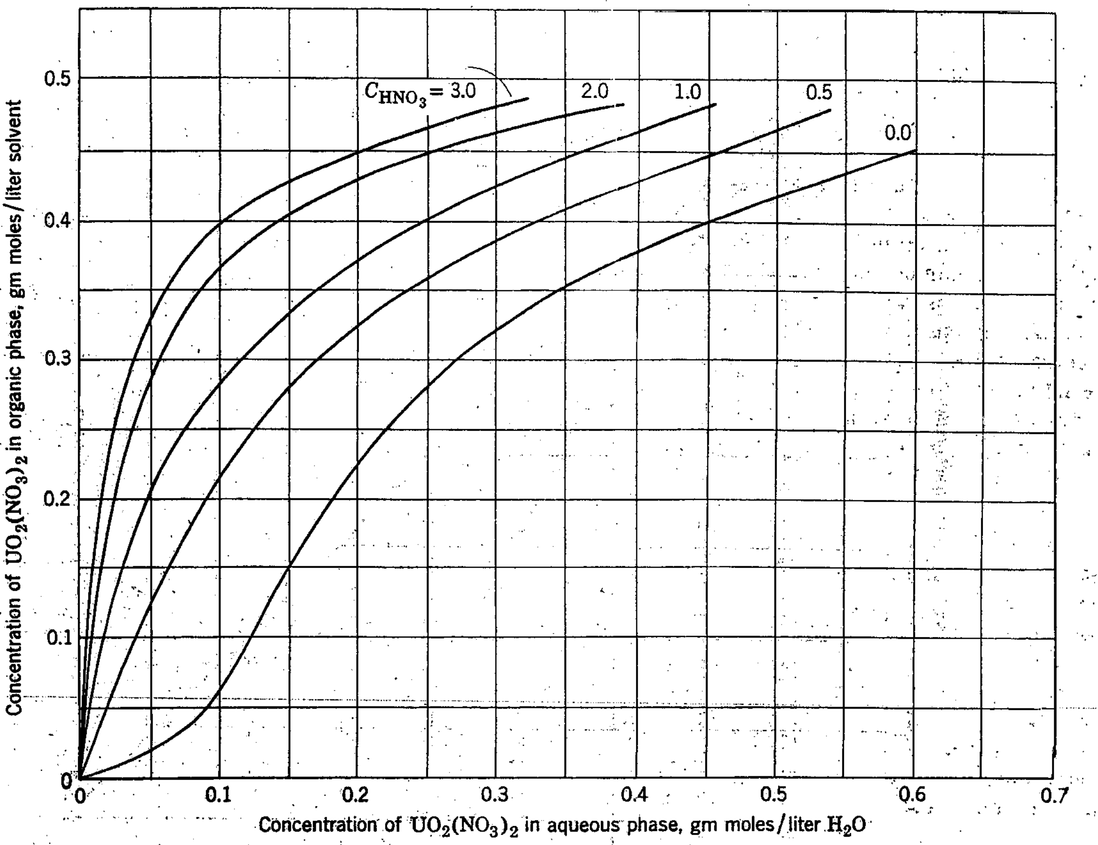


Figure 3.7. Distribution of uranyl nitrate between aqueous nitric acid solutions and an organic solvent at 25°C (3). Organic solvent: 30 volume percent tributyl phosphate in kerosene c_{HNO_3} = gm moles nitric acid per liter of water.

Appendix D-3. HENRY'S LAW CONSTANTS FOR VARIOUS GASES IN WATER (2)

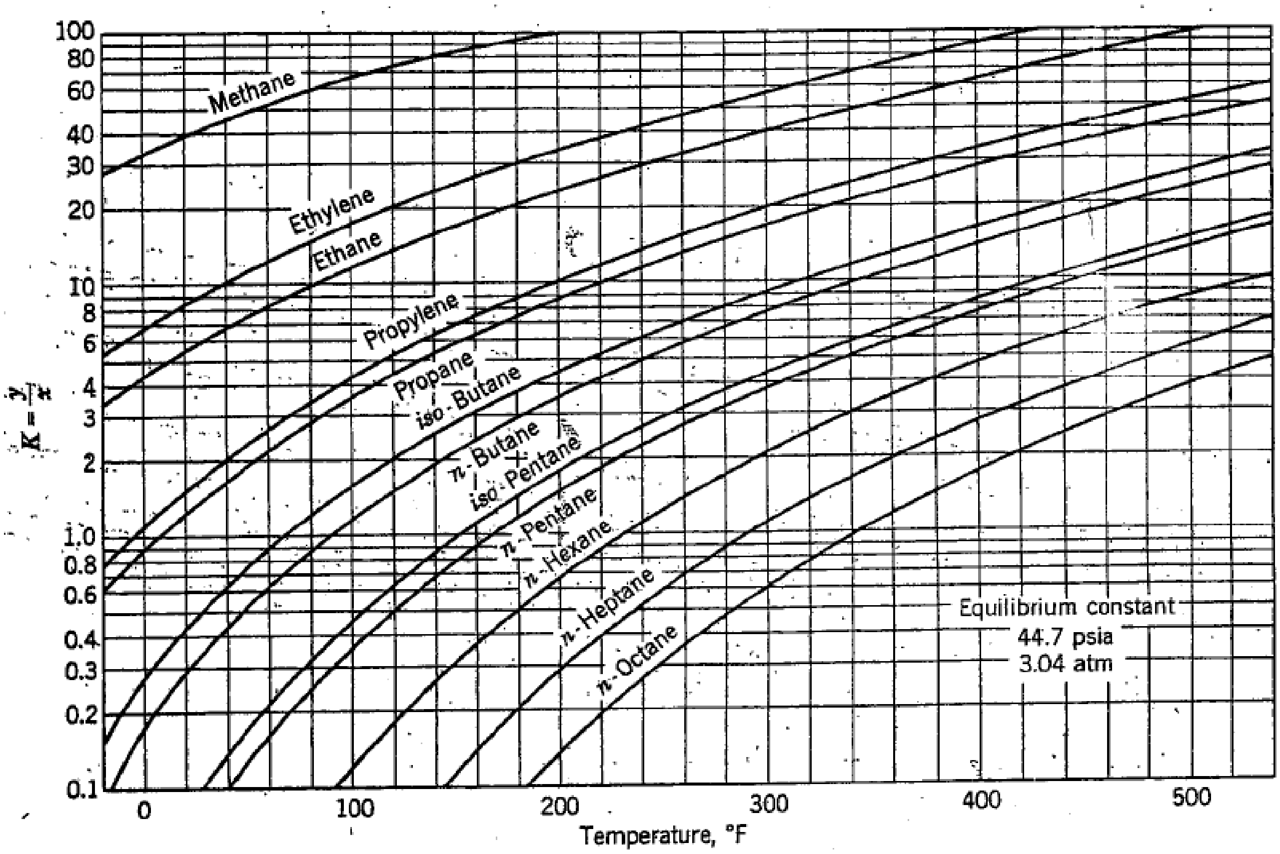
$p_a = H_a x_a$

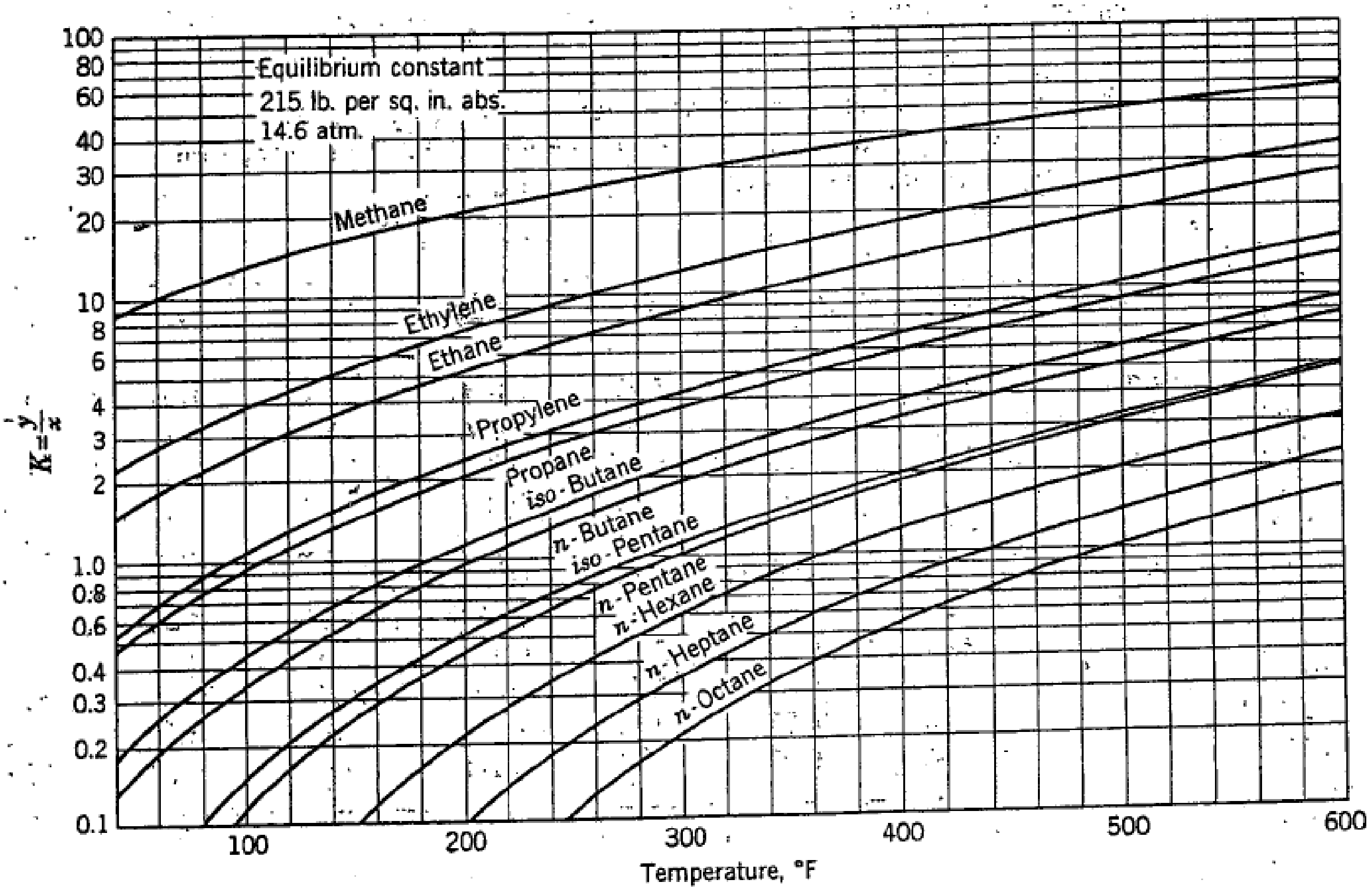
where p_a = partial pressure of the solute a in the gas phase, atm

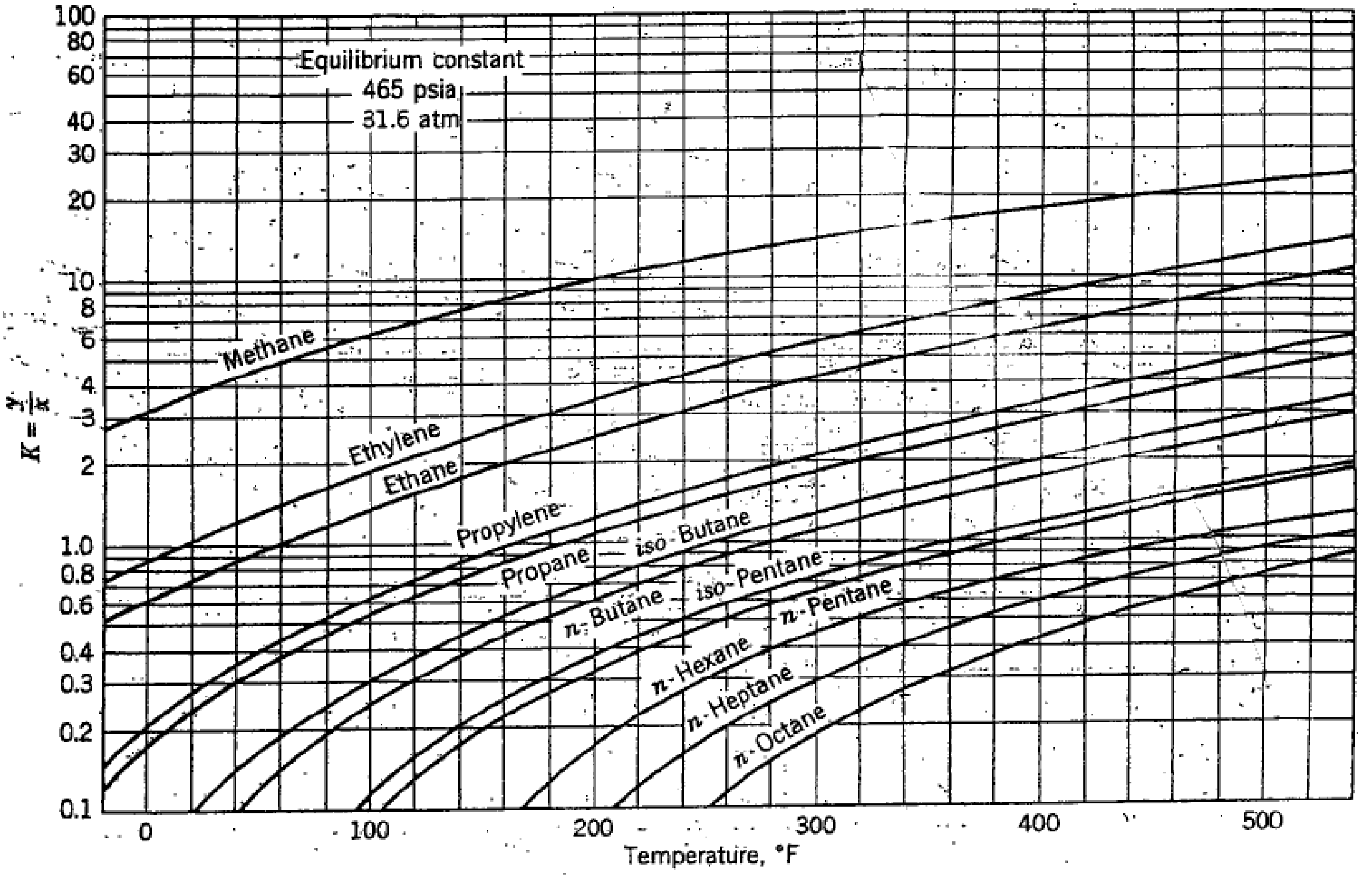
x_a = mole fraction of solute a in the liquid phase, mole fraction

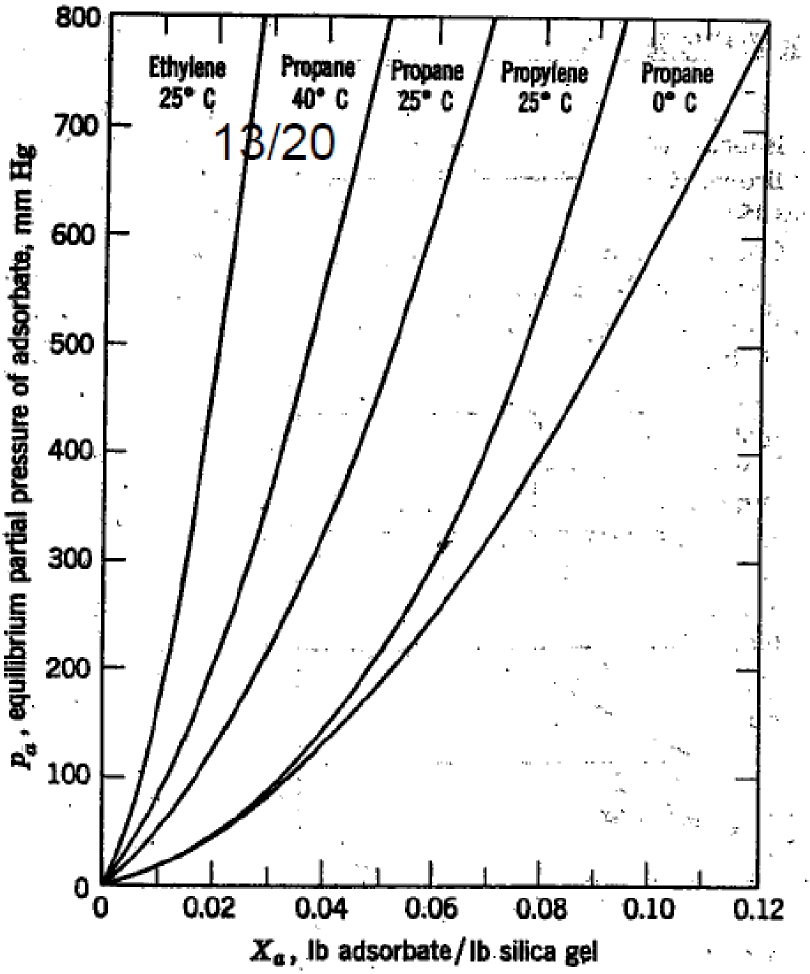
H_a = Henry's law constant, atm/mole fraction

	$H_a \times 10^{-4}$, atm/mole fraction									
T, °C	Air	CO_2	CO	C_2H_6	H_2	H_2S	CH_4	NO	N_2	O_2
0	4.32	0.0728	3.52	1.26	5.79	0.0268	2.24	1.69	5.29	2.55
10	5.49	0.104	4.42	1.89	6.36	0.0367	2.97	2.18	6.68	3.27
20	6.64	0.142	5.36	2.63	6.83	0.0483	3.76	2.64	8.04	4.01
30	7.71	0.186	6.20	3.42	7.29	0.0609	4.49	3.10	9.24	4.75
40	8.70	0.233	6.96	4.23	7.51	0.0745	5.20	3.52	10.4	5.35
50	9.46	0.283	7.61	5.00	7.65	0.0884	5.77	3.90	11.3	5.88
60	10.1	0.341	8.21	5.65	7.65	0.103	6.26	4.18	12.0	6.29
70	10.5		8.45	6.23	7.61	0.119	6.66	4.38	12.5	6.63
80	10.7		8.45	6.61	7.55	0.135	6.82	4.48	12.6	6.87
90	10.8		8.46	6.87	7.51	0.144	6.92	4.52	12.6	6.99
100	10.7		8.46	6.92	7.45	0.148	7.01	4.54	12.6	7.01



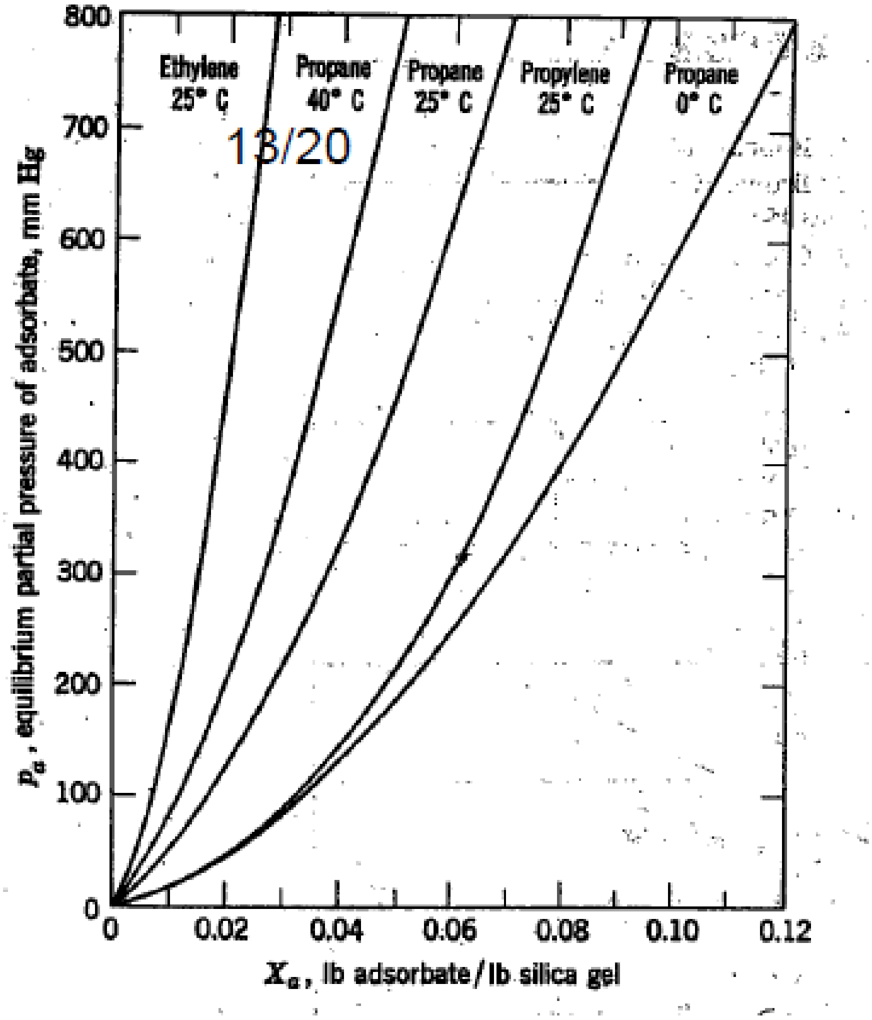

Equilibrium constant
215 lb. per sq. in. abs.
14.6 atm.
$K=\frac{y}{x}$
100
80
60
40
30
20
10
8
6
4
3
2
1.0
0.8
0.6
0.4
0.3
0.2
0.1
Methane
Ethylene
Ethane
Propylene
Propane
iso-Butane
n-Butane
iso-Pentane
n-Pentane
n-Hexane
n-Heptane
n-Octane
100
200
300
400
500
600
Temperature, °F

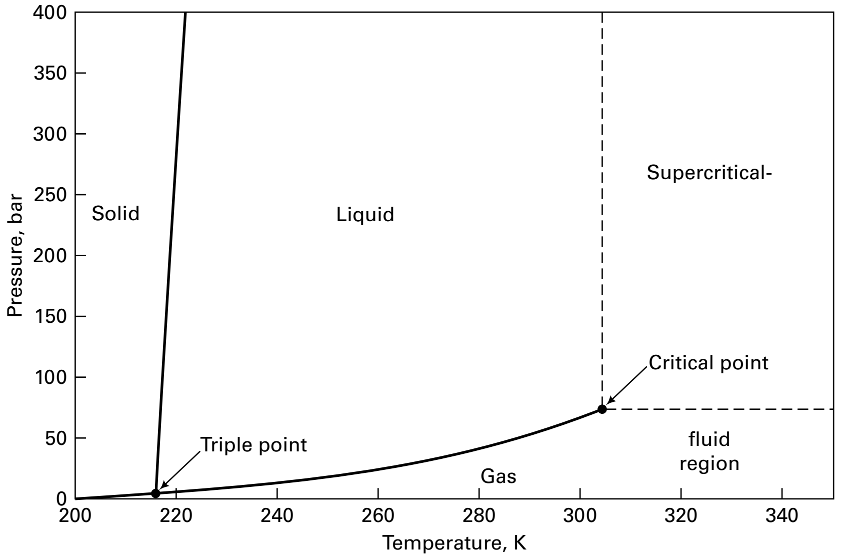

Equilibrium constant
465 psia
31.6 atm
$K=\frac{y}{x}$
100
80
60
40
30
20
10
8
6
4
3
2
1.0
0.8
0.6
0.4
0.3
0.2
0.1
Methane
Ethylene
Ethane
Propylene
Propane
iso-Butane
n-Butane
iso-Pentane
n-Pentane
n-Hexane
n-Heptane
n-Octane
0
100
200
300
400
500
Temperature, °F

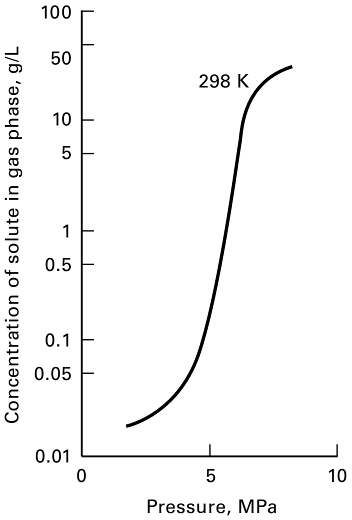


(*b*) Sulfur Dioxide

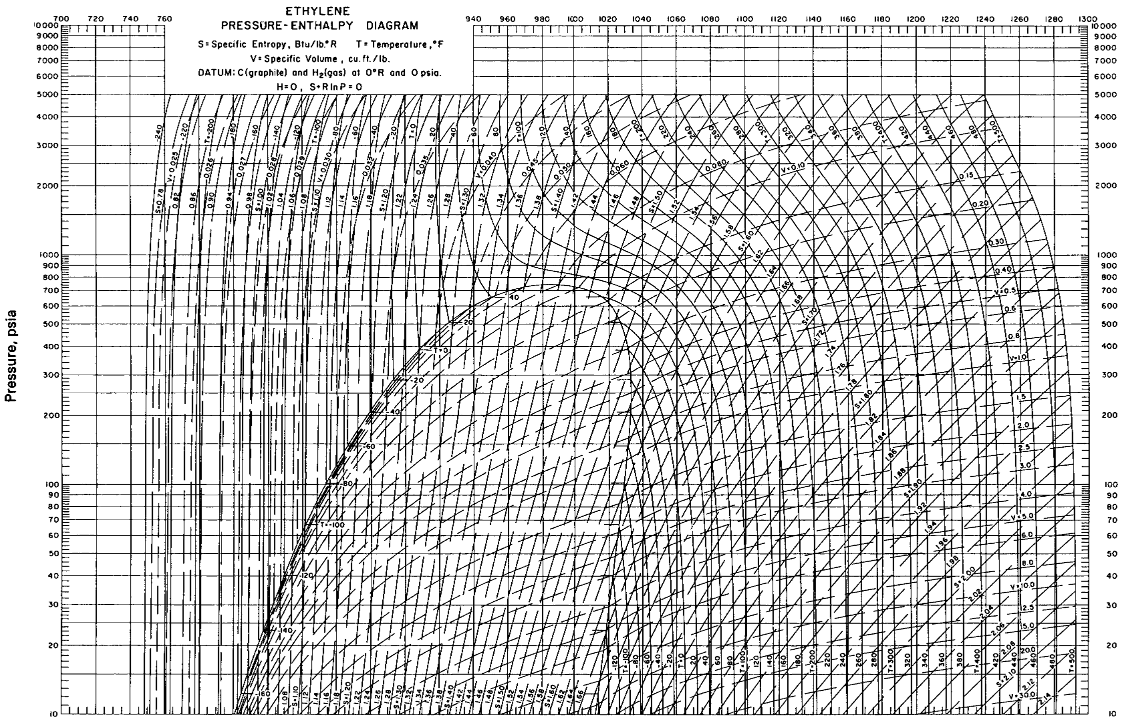
Mass SO_2 per 100 Masses H_2O	Partial pressure of SO_2, mm Hg							
	0°C	7°C	10°C	15°C	20°C	30°C	40°C	50°C
20	646	657						
15	474	637	726					
10	308	417	474	567	698			
7.5	228	307	349	419	517	688		
5.0	148	198	226	270	336	452	665	
2.5	69	92	105	127	161	216	322	458
1.5	38	51	59	71	92	125	186	266
1.0	23.3	31	37	44	59	79	121	172
0.7	15.2	20.6	23.6	28.0	39.0	52	87	116
0.5	9.9	13.5	15.6	19.3	26.0	36	57	82
0.3	5.1	6.9	7.9	10.0	14.1	19.7		
0.1	1.2	1.5	1.75	2.2	3.2	4.7	7.5	12.0
0.05	0.6	0.7	0.75	0.8	1.2	1.7	2.8	4.7
0.02	0.25	0.3	0.3	0.3	0.5	0.6	0.8	1.3


Ethylene 25° C
Propane 40° C
Propane 25° C
Propylene 25° C
Propane 0° C
13/20
p_a, equilibrium partial pressure of adsorbate, mm Hg
0
100
200
300
400
500
600
700
800
0
0.02
0.04
0.06
0.08
0.10
0.12
X_a, lb adsorbate / lb silica gel





Effect of pressure on solubility of pICB in supercritical ethylene.



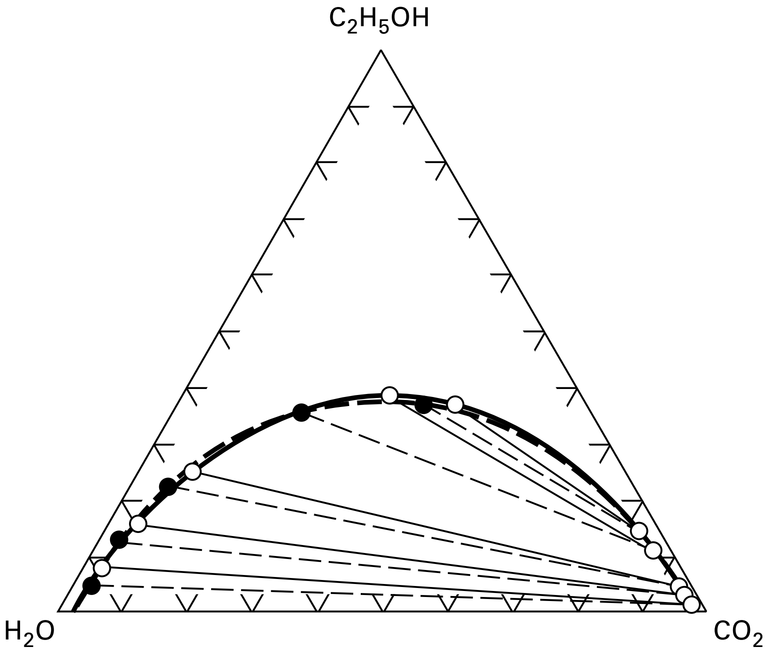


Figure 11.43 Liquid–fluid equilibria for CO_2–C_2H_5OH–H_2O at 308–313.2 K and 10.1–10.34 MPa.

Solvent	Critical Temperature, K	Critical Pressure, MPa	Critical Density, kg/m^3
Methane	192	4.60	162
Ethylene	283	5.03	218
Carbon dioxide	304	7.38	468
Ethane	305	4.88	203
Propylene	365	4.62	233
Propane	370	4.24	217
Ammonia	406	11.3	235
Water	647	22.0	322