

Quiz 10
Chemical Engineering Thermodynamics
March 31, 2016

10.3 The following mixture of hydrocarbons is obtained as one stream in a petroleum refinery on a mole basis: 5% ethane, 10% propane, 40% *n*-butane, 45% isobutane. Assuming the shortcut *K*-ratio model: (a) compute the bubble point of the mixture at 5 bar; (b) compute the dew point of the mixture at 5 bar; (c) find the amounts and compositions of the vapor and liquid phases that would result if this mixture were to be isothermally flash vaporized at 30°C from a high pressure to 5 bar.

-For Part (a) use $T = 290^\circ\text{K}$ and $T = 295^\circ\text{K}$ for two trial temperatures and then extrapolate to the solution. Use the shortcut method. (For 295°K compare the calculated *K* ratios with the values obtained from the DePriester Chart.) INCLUDE THE MARKED CHART WITH YOUR ANSWER SHOWING YOUR WORK.

-For Part (b) use 310°K and 315°K for two trials and then extrapolate to the solution. Use the DePriester Chart rather than the shortcut method to save time. Extrapolate your answer from these two trials. INCLUDE THE MARKED CHART WITH YOUR ANSWER SHOWING YOUR WORK.

-For Part (c) use two trials at $V/F = 0.2$ and at $V/F = 0.05$. Use the DePriester Chart. Extrapolate between these two answers to find the V/F and L/F ratios. Then calculate for the solution the 4 x_i values and the 4 y_i values. (A total of 10 numbers are in the answer.) INCLUDE THE MARKED CHART WITH YOUR ANSWER SHOWING YOUR WORK.

$$K_i = \frac{P_i^{sat}}{P} \quad \text{or} \quad y_i P = x_i P_i^{sat} \quad 10.6$$

$$K_i = \frac{P_i^{sat}}{P} \approx \frac{P_{c,i} 10^{\frac{7}{3}(1+\omega)\left(1-\frac{1}{T_{r,i}}\right)}}{P} \quad \text{Shortcut } K\text{-ratio} \quad 10.7$$

$$x_i = \frac{z_i}{1 + (V/F)(K_i - 1)} \quad 10.15$$

$$y_i = \frac{z_i K_i}{1 + (V/F)(K_i - 1)} \quad 10.16$$

$$\sum_i x_i - \sum_i y_i = \sum_i (x_i - y_i) = \sum_i D_i = 0$$

For a **bubble-temperature** calculation, writing $\sum_i y_i = 1$ as $\sum_i K_i x_i = 1$

For a **dew-temperature** calculation, writing $\sum_i x_i = 1$ as $\sum_i (y_i / K_i) = 1$

$$\sum_i x_i - \sum_i y_i = \sum_i D_i = \sum_i \frac{z_i(1 - K_i)}{1 + (V/F)(K_i - 1)} = 0 \quad 10.23$$

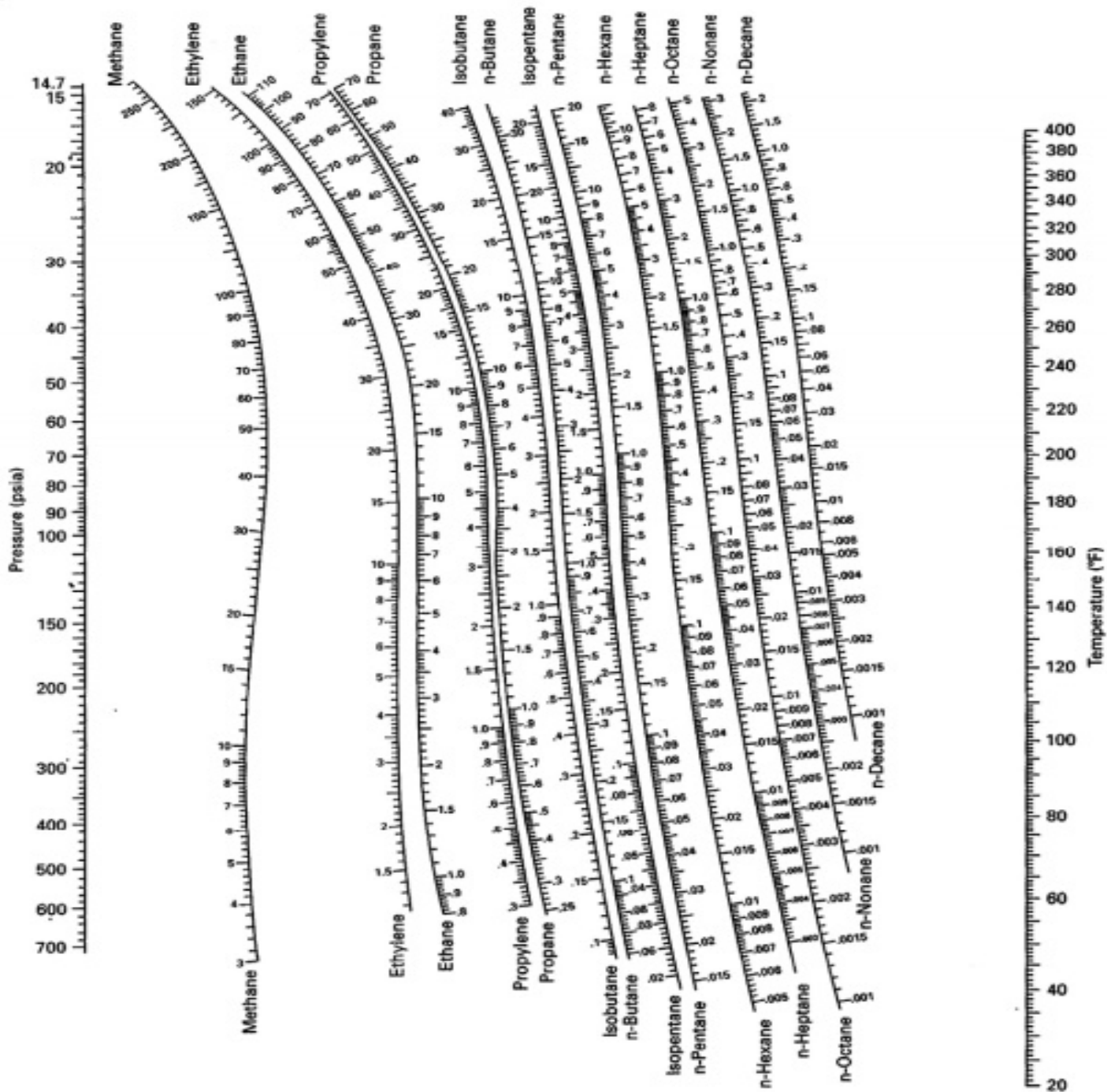
$$^{\circ}\text{C} * 9/5 + 32 = ^{\circ}\text{F}$$

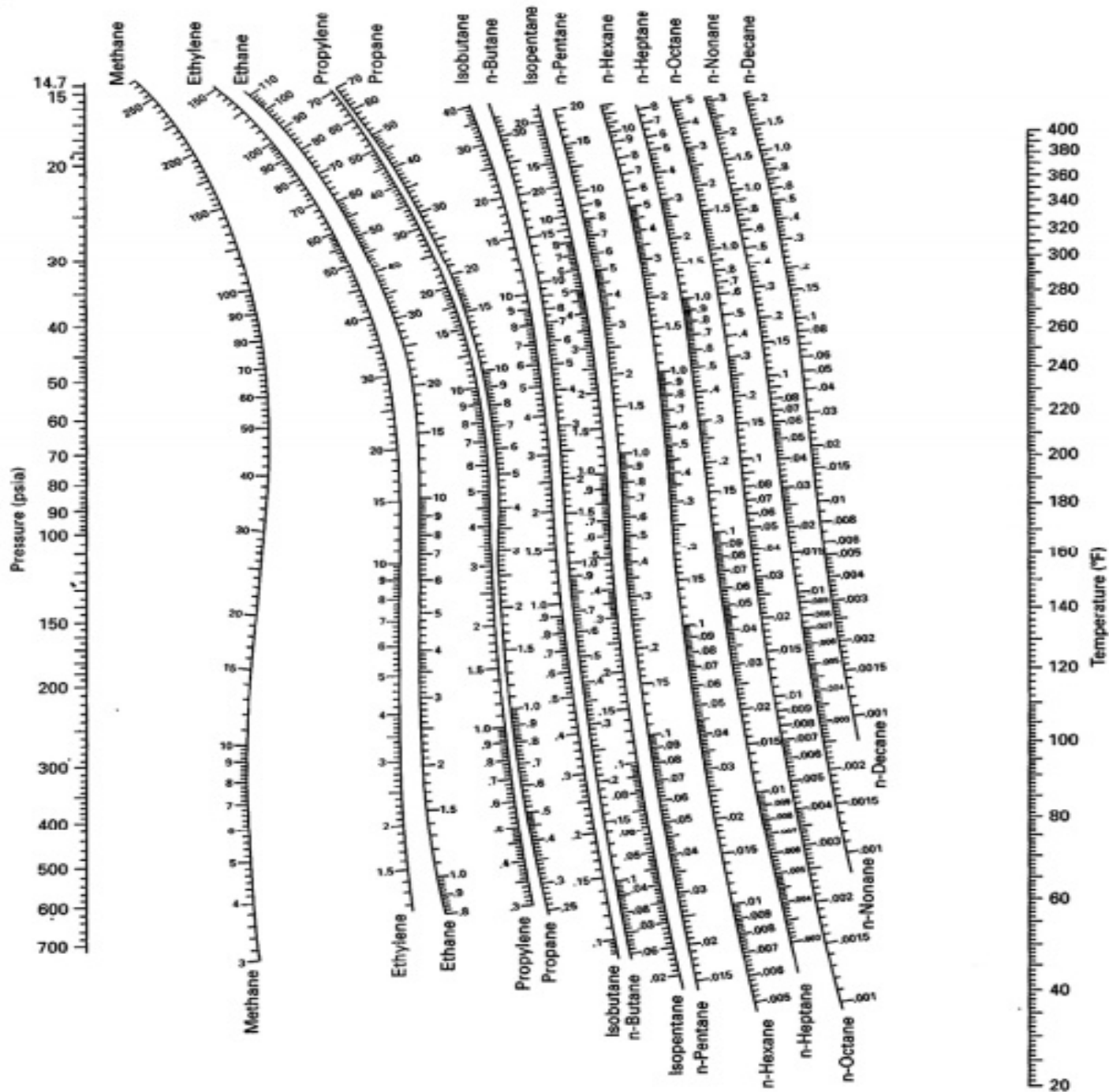
$$145 \text{ psia} = 1 \text{ MPa}$$

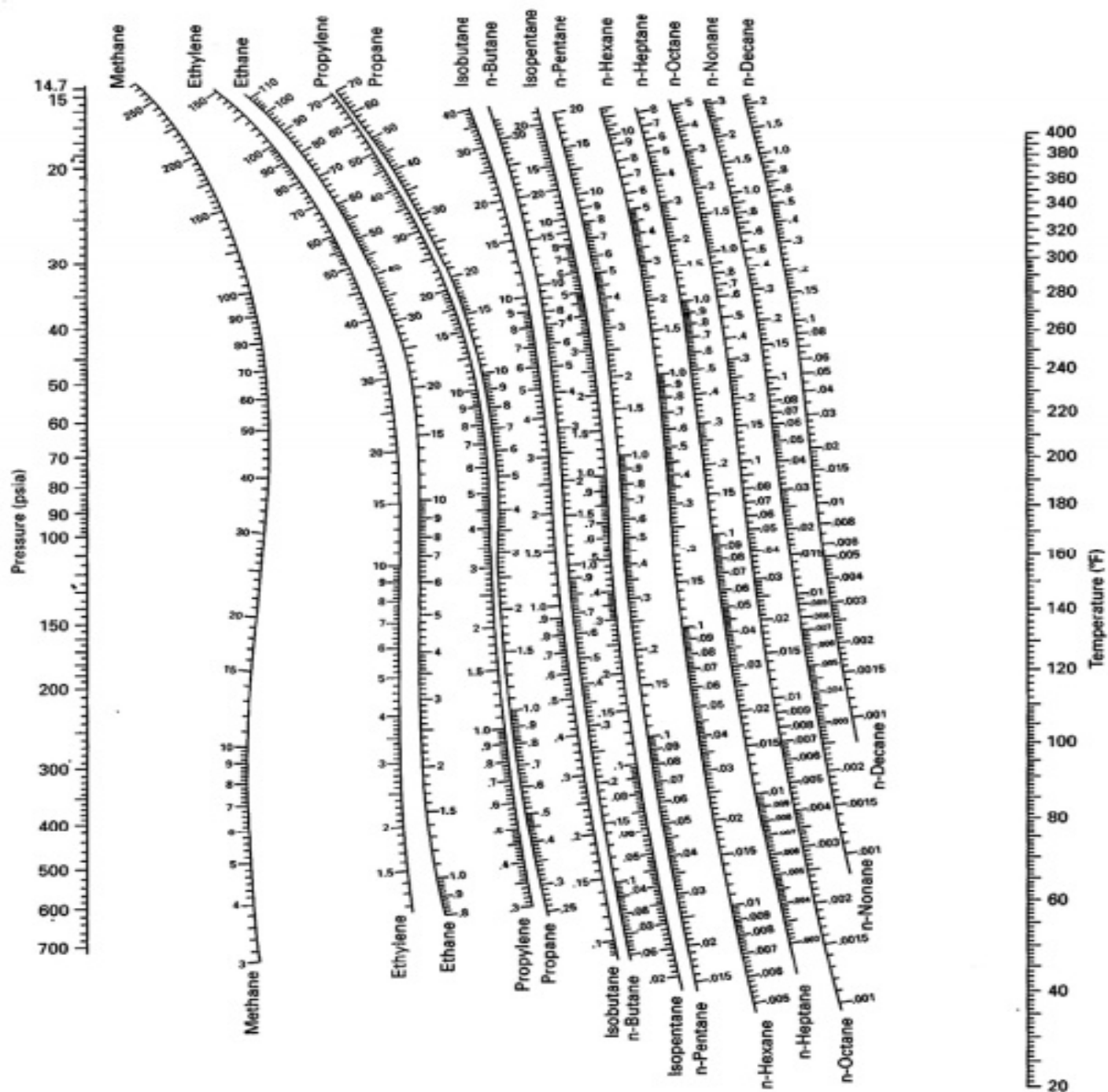
PROPERTIES OF SELECTED COMPOUNDS

Heat capacities are values for *ideal gas at 298 K* and should be used for *order of magnitude calculations only*. See appendices for temperature-dependent formulas and constants.

ID	Compound	T_c (K)	P_c (MPa)	ω	ρ g/cm ³	MW	C_p^{ig}/R	δ (J/cm ³) ^{1/2}	α (J/cm ³) ^{1/2}	β (J/cm ³) ^{1/2}
Aliphatics										
1	METHANE	190.6	4.604	0.011	0.29	16	4.30	11.7	0	0
2	ETHANE	305.4	4.880	0.099	0.43	30	6.31	13.5	0	0
3	PROPANE	369.8	4.249	0.152	0.58	44	8.85	13.1	0	0
4	<i>n</i> -BUTANE	425.2	3.797	0.193	0.60	58	11.89	13.5	0	0
5	ISOBUTANE	408.1	3.648	0.177	0.55	58	11.70	12.5	0	0
7	<i>n</i> -PENTANE	469.7	3.369	0.249	0.62	72	14.45	14.3	0	0
8	ISOPENTANE	460.4	3.381	0.228	0.62	72	14.28	13.9	0	0
9	NEOPENTANE	433.8	3.199	0.196	0.60	72	14.62	13.1	0	0
11	<i>n</i> -HEXANE	507.4	3.012	0.305	0.66	86	17.21	14.9	0	0
17	<i>n</i> -HEPTANE	540.3	2.736	0.349	0.68	100	19.95	15.3	0	0
27	<i>n</i> -OCTANE	568.8	2.486	0.396	0.70	114	22.70	15.5	0	0
27	ISOCTANE	544.0	2.570	0.303	0.70	114	22.50	14.1	0	0
46	<i>n</i> -NONANE	595.7	2.306	0.437	0.71	128	25.45	15.6	0	0
56	<i>n</i> -DECANE	618.5	2.123	0.484	0.73	142	28.22	15.7	0	0
64	<i>n</i> -DODECANE	658.2	1.824	0.575	0.75	170	33.71	15.9	0	0
66	<i>n</i> -TETRADECANE	696.9	1.438	0.570	0.76	198	39.22	16.1	0	0
68	<i>n</i> -HEXADECANE	720.6	1.419	0.747	0.77	226	44.54	16.2	0	0







ANSWERS: Quiz 10
Chemical Engineering Thermodynamics
March 31, 2016

Problem 10.3a

10.3 (a) BP $p = 0.5 \text{ MPa}$

Take $z_i = x_i$

	x_i	w	T_c °K	P_c MPa	γ_i eqn.
ethane	0.05	0.099	305	4.88	$0.48 \cdot 10^8 \left[2.78 \left(1 - \frac{305}{T} \right) \right]$
propane	0.10	0.152	370	4.25	$0.85 \cdot 10^8 \left[2.39 \left(1 - \frac{370}{T} \right) \right]$
n-butane	0.40	0.193	425	3.80	$30.4 \cdot 10^8 \left[2.78 \left(1 - \frac{425}{T} \right) \right]$
isobutane	0.45	0.177	408	3.65	$3.29 \cdot 10^8 \left[2.78 \left(1 - \frac{408}{T} \right) \right]$

$y_i = k_i x_i$

$k_i = \frac{P_{sat}}{P}$ $\frac{P_{sat}}{P} = \left(\frac{P_c}{P} \right)^{10^{\left[\frac{7}{3} (1+w) \left(1 - \frac{T}{T_c} \right) \right]}}$

$P_{sat} @ w, P_c, T_c$ $T_{BP} \left(\sum y_i = 1 \right)$
 largest

$T = 290^\circ \text{K}$	$T = 295^\circ \text{K}$
y_i	y_i
0.359	
0.187	
0.154	
0.250	
$\sum y_i = 0.91$	1.04

$295^\circ \text{K} = 0.09 \left(\frac{5^\circ \text{K}}{0.13} \right) = 293^\circ \text{K}$
 T_{BP}

Problem 10.3b

10.3 (b) DP $P = 0.5 \text{ MPa}$

Take $z_i = x_i$

	y_i	w	T_c (K)	P_c (MPa)	$\left(\frac{P}{P_c}\right)^{1/w} x_i$ eqn.
ethane	0.05	0.099	305	4.86	$(5.12e-3)^{1/0.099} [2.78(1 - \frac{305}{T})]$
propane	0.10	0.152	370	4.25	$(1.18e-2)^{1/0.152} [2.39(1 - \frac{370}{T})]$
n-butane	0.40	0.193	425	3.80	$(5.26e-3)^{1/0.193} [2.78(1 - \frac{425}{T})]$
isobutane	0.45	0.177	408	3.65	$(6.16e-3)^{1/0.177} [2.78(1 - \frac{408}{T})]$

$y_i = K_i x_i$ $x_i = \frac{y_i}{K_i}$

$K_i = \frac{P_{sat}}{P}$ $\frac{P_{sat}}{P} = \left(\frac{P_c}{P}\right)^{1/w} \left[\frac{2.7}{3} (1+w) \left(1 - \frac{T_c}{T}\right) \right]^A$

$P_{sat} @ w, P_c, T_c$ T_{BR} $\sum y_i \approx 1$

Target

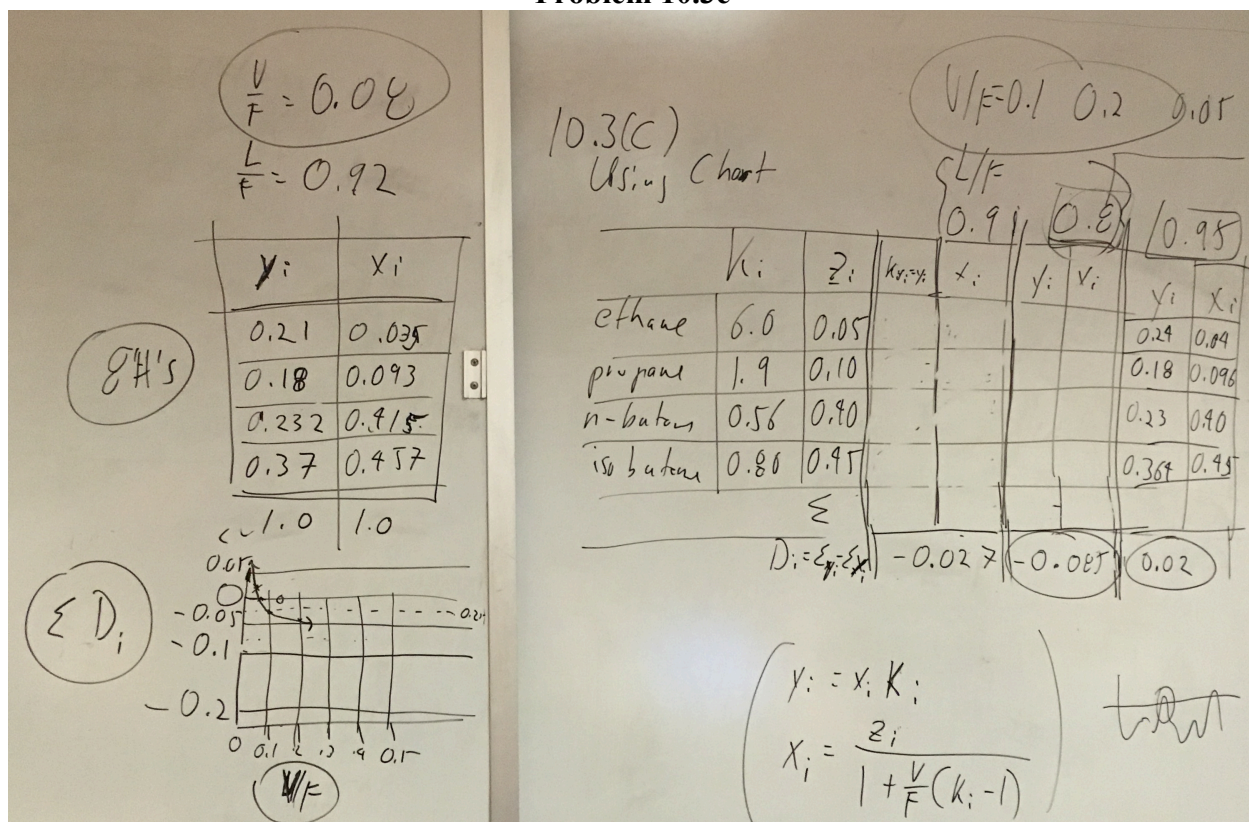
~ 312

$T = 310^\circ \text{K}$ $T = 315^\circ \text{K}$ 310

x_i	x_i	K_i	$x_i = \frac{y_i}{K_i}$
0.005	0.004	0	
0.034	0.031	0	
0.565	0.492	0	
0.455	0.399	0	
$\sum x_i = 1.06$	0.926		

074

Problem 10.3c



$\Delta D = 1.302$
 $\Delta \frac{V}{F} = 0.1$

① $0.95 - (0.02) \frac{0.15}{0.105} = 0.92 = \frac{L}{F}$

② $\frac{V}{F} = 0.08$

Answer $\frac{L}{F} = 0.92$ $\frac{V}{F} = 0.08$

x_i 's 8#s
 y_i 's

$\frac{L}{F} + \frac{V}{F} = 1$
 10#s in Answer

(10.03) The following mixture of hydrocarbons ...

a) By short-cut vapor pressure eqn.

$$\frac{y_i}{x_i} = K_i \equiv \frac{10^{\left[\frac{7}{3}(1 + \omega_i) \left(1 - \frac{1}{T_{b,i}} \right) \right]}}{P_{r,i}}$$

$$y_i = x_i K_i$$

$$\text{Find } T \text{ when } \sum_i y_i \equiv \sum_i x_i K_i = 1$$

For given liquid composition, at $P = 0.5 \text{ MPa}$

$$\text{Bubble point temperature} = \boxed{293.376 \text{ K}}$$

OR

By Antoine Vapor Pressure Equation,

$$y_i = x_i \frac{P_i^{\text{sat}}}{P}; \quad P_i^{\text{sat}} = 10^{\left[A_i - \frac{B_i}{T + C_i} \right]}$$

$$\text{Find } T \text{ when } \sum_i y_i = 1$$

A_i, B_i, C_i from tabulated in appendix or ACTCOEFF.xls

$$\text{bubble point temperature} = \boxed{294.68 \text{ K}}$$

b) Dew Point

$$\text{Short-cut method: } x_i = \frac{y_i}{K_i}$$

$$\text{Find } T \text{ when } \sum_i x_i = 1$$

$$T_{\text{dew.pt}} = \boxed{312.479 \text{ K}}$$

$$\text{Dew pt. By Antoine Eqn, } x_i = y_i \frac{P}{P_i^{\text{sat}}}$$

$$\text{Find } T \text{ when } \sum_i x_i = 1$$

$$T_{\text{dew.pt}} = \boxed{313.116 \text{ K}}$$

c) Isothermal Flash

Shortcut

$$L/F = 0.827$$

L/F

Antoine

$$L/F = 0.852$$

$$x = 0.02047$$

ethane

$$x = 0.02336$$

$$y = 0.19122$$

$$y = 0.20341$$

$$x = 0.08305$$

propane

$$x = 0.085735$$

$$y = 0.18100$$

$$y = 0.182122$$

$$x = 0.43173$$

n-butane

$$x = 0.42751$$

$$y = 0.24829$$

$$y = 0.24166$$

$$x = 0.46475$$

iso-butane

$$x = 0.46340$$

$$y = 0.37949$$

$$y = 0.37281$$

N.B: Choose the initial guess for L/F as between zero and unity.

Summary of shortcut calculations:

Problem 10.3

				Part (a)		Part (b)		Part c	
				BUBT 293.376 =T		DEWT 312.479 =T		FLASH 303.15 =T	
								L/F= 0.826613	
	T _c	P _c	w	K	y	K	x	K	
0.05	305.4	48.8	0.099	7.662148	0.383107	11.15689	0.004482	9.341512	-0.17049
0.1	369.8	42.49	0.152	1.694715	0.169471	2.730432	0.036624	2.179405	-0.09792
0.4	425.2	37.97	0.193	0.426258	0.170503	0.752168	0.531796	0.575108	0.183473
0.45	408.1	36.48	0.177	0.615371	0.276917	1.053624	0.427097	0.817164	0.08497
				0.999999		1		3.47E-05	

Comparing with the PREOS, PREOS⇒: a)298K (b) 312K (c) L/F=.874,

K={6.1,1.9,.61,.83}