

PETE 310

Lectures # 6 & # 7

Phase Behavior - Pure Substances
(Lecture # 5)

Two Component Mixtures

Three & Multicomponent Mixtures

Learning Objectives

After completing this chapter you will be able to:

- Understand pure component phase behavior as a function of pressure, temperature, and molecular size.
- Understand the behavior of binary and multicomponent mixtures
- Behavior understood through proper interpretation of phase diagrams

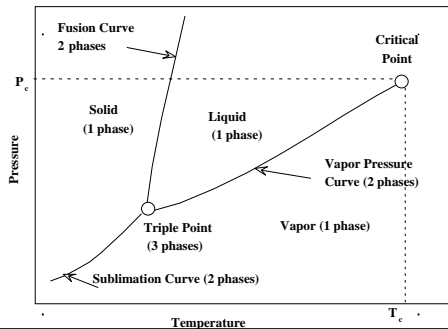
Phase Diagrams

Types of phase diagrams for a single component (pure substance)

- (PT)
- (PV) or (Pp)
- (TV) or (Tp)

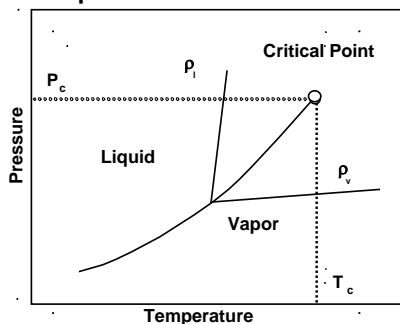
Phase Diagrams

Single Component Phase Diagram

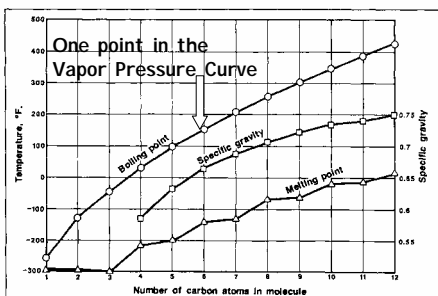


Phase Diagrams

Vapor Pressure Curve



Hydrocarbon Families Physical Properties



Heat Effects Accompanying Phase Changes of Pure Substances

$$L_v = T \Delta V \frac{dP_v}{dT}$$

Approximate relation (Clausius - Clapeyron Equation)

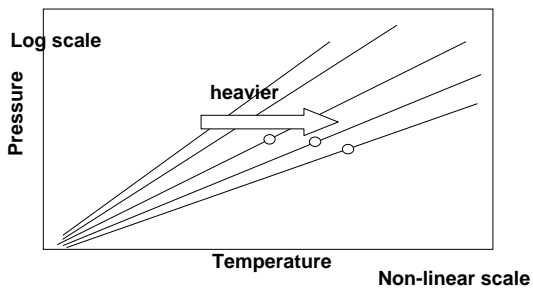
$$\frac{dP_v}{dT} = \frac{L_v}{RT^2} P_v$$

Example of Heat Effects Accompanying Phase Changes

☐ Steam flooding Problem:

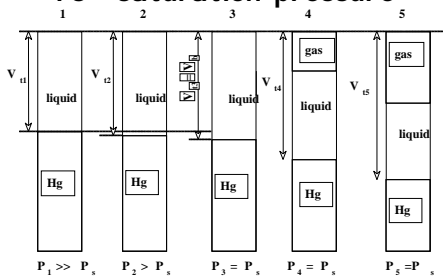
Calculate how many BTU/day (just from the latent heat of steam) are provided to a reservoir by injecting 6000 bbl/day of steam at 80% quality and at a $T=462$ °F

COX - Vapor Pressure Charts (normal paraffins)



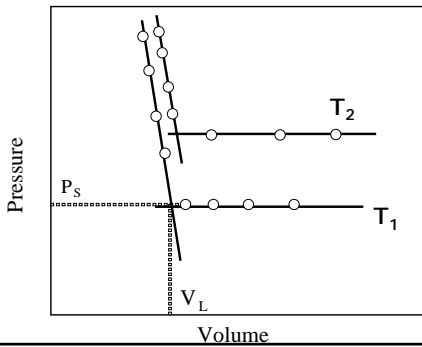
Determination of Fluid Properties

P_s = saturation pressure



Temperature of Test Constant

Vapor Pressure Determination



Binary Mixtures

☐ Relationships to analyze: P , T , molar or specific volume or (molar or mass density) - as for a pure component -

+

☐ COMPOSITION - Molar Composition

Hydrocarbon Composition

□ The hydrocarbon composition may be expressed on a weight basis or on a molar basis (most common)

□ Recall

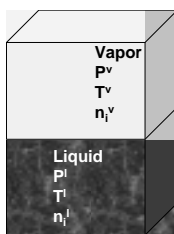
$$n_i = \frac{M_i}{Mw_i} = \frac{\text{mass of "i"}}{\text{molecular weight of "i"}}$$

Hydrocarbon Composition

□ By convention liquid compositions (mole fractions) are indicated with an x and gas compositions with a y .

$$x_1 = \left(\frac{n_1}{n_1 + n_2} \right)_{\text{liquid}}$$
$$y_1 = \left(\frac{n_1}{n_1 + n_2} \right)_{\text{gas}}$$

Our Systems of Concern

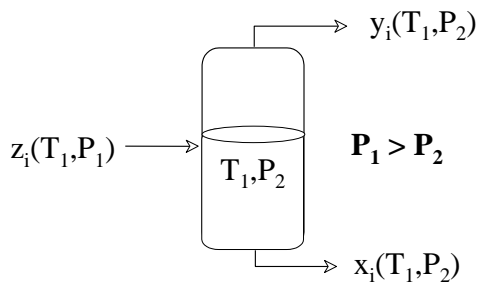


Gas system



Oil system

A separator



Mathematical Relationships

$$z_i = x_i f_l + y_i f_v \quad z_i = x_i(1 - f_v) + y_i f_v$$

with $f_v = \frac{z_i - x_i}{y_i - x_i}$ $f_v = \frac{(n_1 + n_2)_v}{(n_1 + n_2)_v + (n_1 + n_2)_l}$

In general

$$f_v = \frac{z_i - x_i}{y_i - x_i}$$

Key Concepts



- Fraction of vapor (f_v)
- Mole fractions in vapor (or gas) phase $\rightarrow y_i$
- Mole fractions in liquid (or oil) phase $\rightarrow x_i$
- Overall mole fractions (z_i) \rightarrow combining gas & liquid

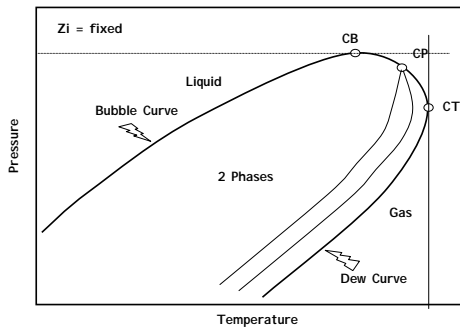
Phase Diagrams for Binary Mixtures

□ Types of phase diagrams for a two- component mixture

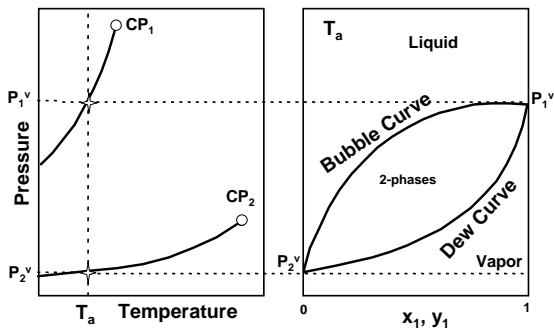
Most common

- $(PT)_{z_i}$ at a fixed composition
- $(Pz_i)_T$ at a fixed T
- $(Tz_i)_P$ at a fixed P
- $(PV)_{z_i}$ or $(Pp)_{z_i}$

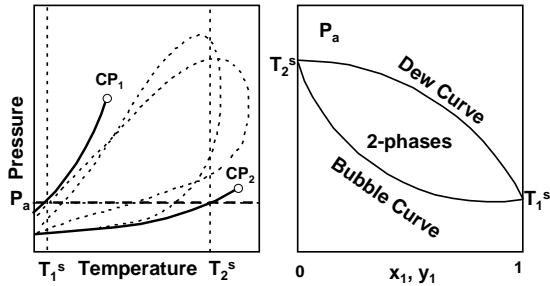
Pressure vs Temperature Diagram $(PT)_{z_i}$



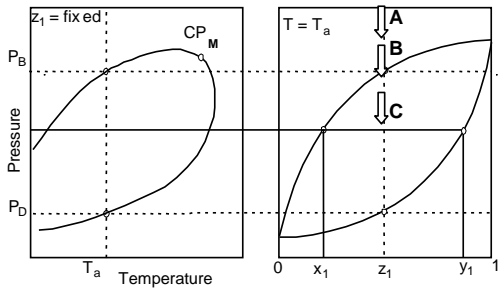
Pressure Composition Diagrams - Binary Systems



Temperature vs. Composition Diagrams - Binary Systems

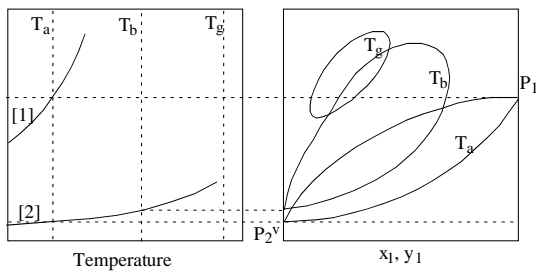


Gas-Liquid Relations

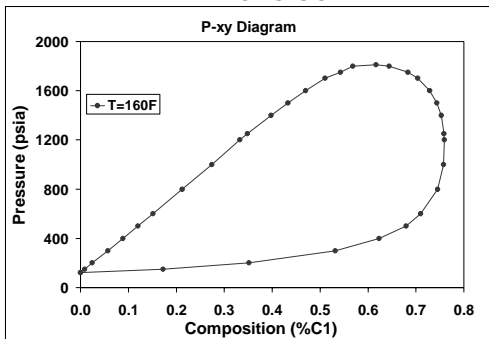


z_1 =overall mole fraction of [1], y_1 =vapor mole fraction of [1], x_1 =liquid mole fraction of [1]

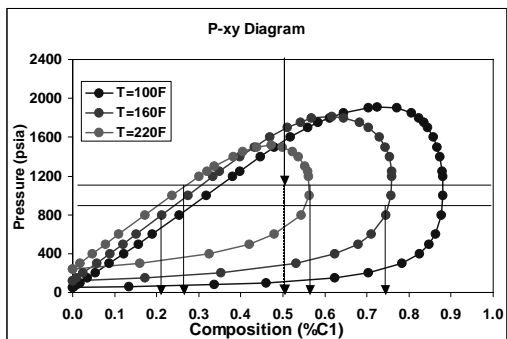
Supercritical Conditions Binary Mixture



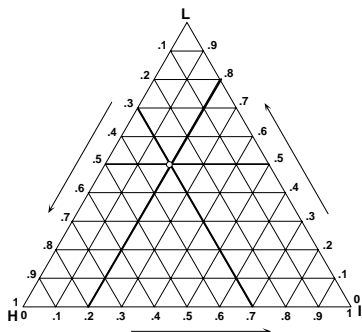
Quantitative Phase Equilibrium Exercise



Quantitative Phase Equilibrium Exercise

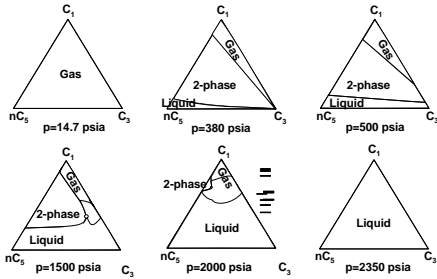


Ternary Diagrams: Review



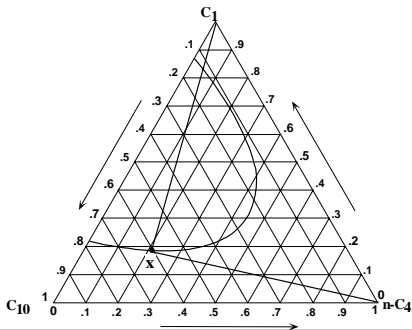
Ternary Diagrams: Review

Pressure Effect



Ternary Diagrams: Review

Dilution Lines



Ternary Diagrams: Review

Quantitative Representation of Phase Equilibria - Tie (or equilibrium) lines

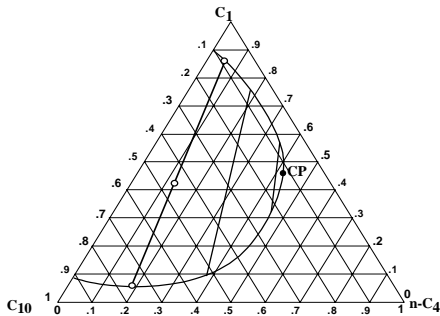
- Tie lines join equilibrium conditions of the gas and liquid at a given pressure and temperature.
 - Dew point curve gives the gas composition.
 - Bubble point curve gives the liquid composition.

Ternary Diagrams: Review

Quantitative Representation of Phase Equilibria - Tie (or equilibrium) lines

- All mixtures whose overall composition (z_i) is along a tie line have the SAME equilibrium gas (y_i) and liquid composition (x_i), but the relative amounts on a molar basis of gas and liquid (f_v and f_l) change linearly (0 - vapor at B.P., 1 - liquid at B.P.).

Illustration of Phase Envelope and Tie Lines



Uses of Ternary Diagrams

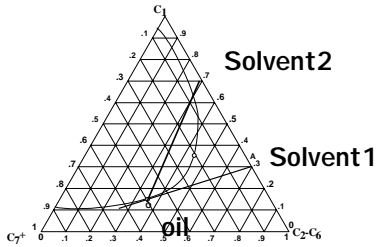
Representation of Multi-Component Phase Behavior with a Pseudoternary Diagram

- Ternary diagrams may approximate phase behavior of multi-component mixtures by grouping them into 3 *pseudocomponents*

- heavy (C_7^+)
- intermediate (C_2-C_6)
- light ($C_1, CO_2, N_2-C_1, CO_2-C_2, \dots$)

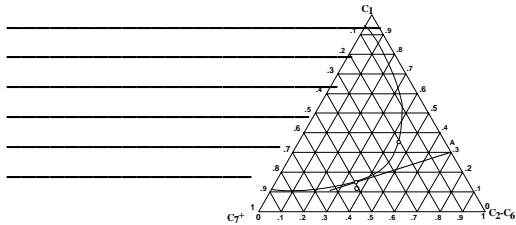
Uses of Ternary Diagrams

Miscible Recovery Processes

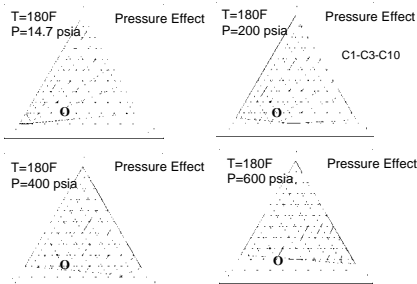


Exercise

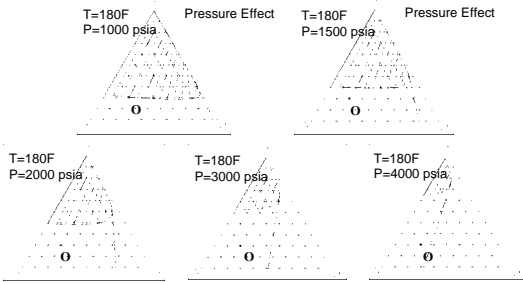
Find overall composition of mixture made with 100 moles oil "O" + 10 moles of mixture "A".



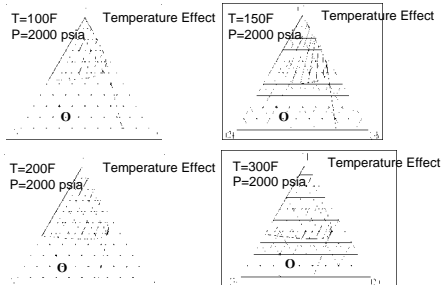
Practice Ternary Diagrams Pressure Effect



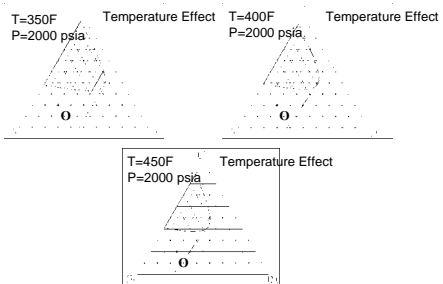
Practice Ternary Diagrams Pressure Effect



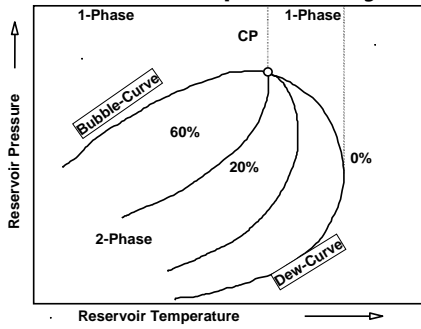
Practice Ternary Diagrams Temperature Effect



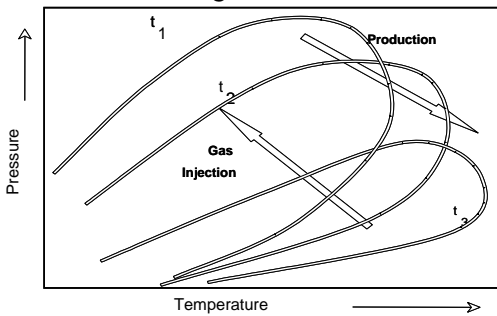
Practice Ternary Diagrams Temperature Effect



Pressure-Temperature Diagram for Multicomponent Systems



Changes During Production and Injection



Homework



☐ See Syllabus please
