PETE 310

Lecture # 5

Phase Behavior – Pure Substances

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 (lectures 6 & 7)

The Need to Understand Phase Behavior

- As oil and gas are produced from the reservoir, they are subjected to a series of pressure, temperature, and compositional changes.
- Such changes affect the volumetric and transport behavior of these reservoir fluids and, consequently, the produced oil and gas volumes.

The Need to Understand Phase Behavior

- Except polymer flooding, all of EOR methods rely on the phase behavior of reservoir fluids and fluids injected into the reservoir.
- This behavior is used to classify the recovery method (i.e., thermal, miscible, chemical, etc.), and to design the recovery process.

Major Definitions

- System: A body of matter with finite boundaries (physical or virtual)
- Closed System: Does not exchange matter with surroundings but may exchange energy (heat).
- Open System: Does exchange matter and energy with surroundings.

Major Definitions

- Phase: A portion of the system which has homogeneous intensive properties and it is bounded by a physical surface.
- Interface: Separates two or more phases. These phases are solid, liquid(s), and gas.

Major Definitions

- Intensive Properties: Independent of system mass (i.e density)
- Extensive Properties: Dependent of system mass (i.e volume)

Major Definitions

- Homogeneous System: Intensive properties change continuously and uniformly (smoothly)
- Heterogeneous System: System made up of two or more phases in which the intensive properties change abruptly at phase-contact surfaces

Major Definitions

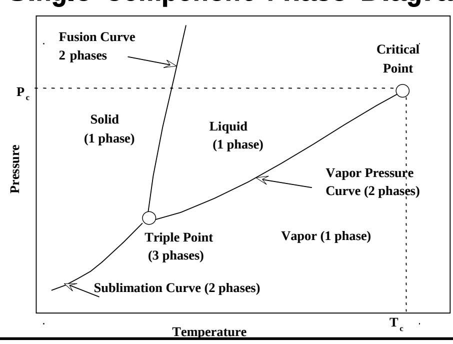
- Properties: Characteristics of a system (phase) that may be evaluated quantitatively. These are,
  - Phase density (liquid, gas, solid)
  - Compressibility
  - Surface tension
  - Viscosity
  - Heat capacity
  - Thermal conductivity

Phase Diagrams

- Types of phase diagrams for a single component (pure substance)
  - (PT)
  - (PV) or (Pρ)
  - (TV) or (Tρ)

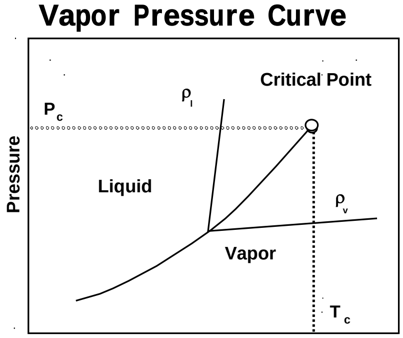
Phase Diagrams

Single Component Phase Diagram

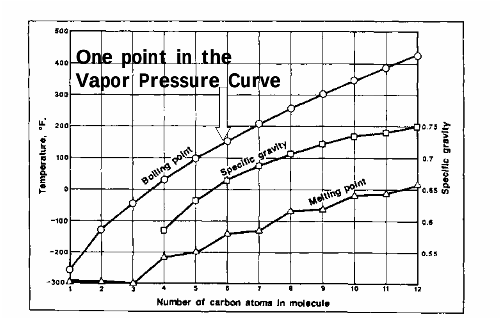


Phase Diagrams

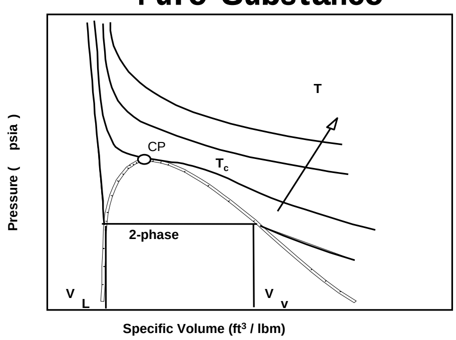
Vapor Pressure Curve



Hydrocarbon Families Physical Properties



Pressure vs Specific Volume Pure Substance



Pure Component Properties

- ❑ Tabulated critical properties (McCain)

	See Note No. →		1.	2.		3.			
							Critical contents		
No.	Compound	Formule	Molecular weight	Boiling point, °F 14.696 psia	Vapor pressure, psia 100 °F	Freezing point, °F 14.696 psia	Pressure, psia	Temperature, °F	Volume, ft³/lb
1	Methane	CH_4	16.043	−258.74(28)	(5000.)	−296.45[d]	667.8	−116.68	0.0988
2	Ethane	C_2H_6	30.070	−127.44	(800.)	−297.04[d]	707.8	90.10	0.0788
3	Propane	C_3H_8	44.097	−43.73	188.0	−305.82[d]	616.3	206.01	0.0737
4	n-Butane	C_4H_{10}	58.124	31.12	51.54	−217.05	550.7	306.62	0.0703
5	Isobutane	C_4H_{10}	58.124	10.74	72.39	−255.28	529.1	274.96	0.0724
6	n-Pentane	C_5H_{12}	72.151	96.91	15.575	−201.51	488.6	385.6	0.0674
7	Isopentane	C_5H_{12}	72.151	82.11	20.444	−255.82	490.4	369.03	0.0679
8	Neopentane	C_5H_{12}	72.151	49.10	36.66	2.21	464.0	321.08	0.0673
9	n-Hexane	C_6H_{14}	86.178	155.73	4.960	−139.58	436.9	453.6	0.0687
10	2-Methylpentane	C_6H_{14}	86.178	140.47	6.769	−244.59	436.6	435.74	0.0682
11	3-Methylpentane	C_6H_{14}	86.178	145.89	6.103	—	453.1	448.2	0.0682
12	Neohexane	C_6H_{14}	86.178	121.51	9.859	−147.77	446.9	420.04	0.0668
13	2,3-Dimethylbutane	C_6H_{14}	86.178	136.36	7.406	−199.37	453.5	440.20	0.0665

Heat Effects Accompanying Phase Changes of Pure Substances

Clapeyron equation

$$Lv = T\Delta V \frac{dP^v}{dT} \quad \text{Btu/lb-mol}$$

With

$$\Delta V = V_{Mg} - V_{Ml}$$

Heat Effects Accompanying Phase Changes of Pure Substances

$$Lv = T\Delta V \frac{dP^v}{dT}$$

Approximate relation (Clausius - Clapeyron Equation)

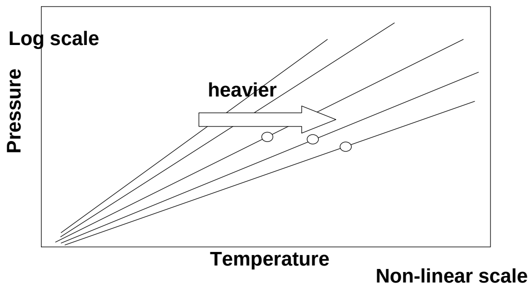
$$\frac{dP^v}{dT} = \frac{Lv}{RT^2} P^v$$

Example of Heat Effects Accompanying Phase Changes

- **Steam flooding Problem:**

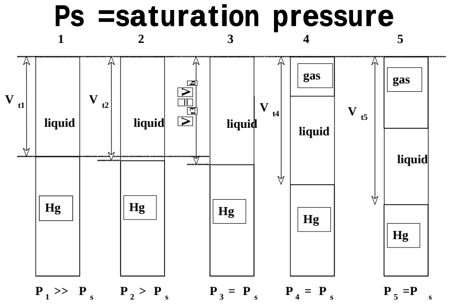
  Calculate how many BTU/day (just from the latent heat of steam) are provided to a reservoir by injecting 6000 bbl/day of steam at 80% quality and at a T=462 °F

COX - Vapor Pressure Charts (normal paraffins)



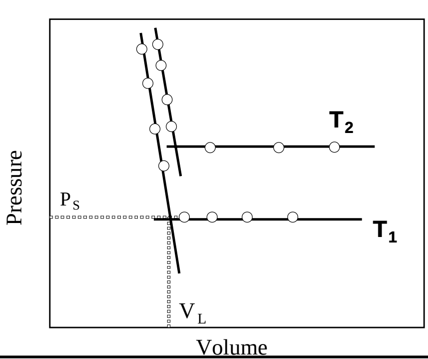
Determination of Fluid Properties

Ps =saturation pressure



Temperature of Test Constant

Vapor Pressure Determination



Homework

- See Syllabus for HW Problems due