230117

PVT - Analysis

- Petroleum is a multi-component system.
  * Alkanes (paraffins) - chains of carbon atoms
    CH_4 - methane, C_2H_6 ethane C_3H_8 propane
    C_4H_{10} - butane C_5H_{12} pentane etc.
  * Cycloalkanes: ring-structures consisting of C and H
  * Aromatics: Molecules containing benzene

  * Inorganic gases: CO_2, H_2S, N_2
  * SNO compounds: molecules containing
    S - sulphur
    N - nitrogen
    O - oxygen

PVT - analysis to determine reservoir fluid properties.

PVT - temperature
pressure volume

PVT - relations: how the reservoir fluid is changing with Pressure and Temperature.

- to estimate produced volumes of oil and gas from the reservoir

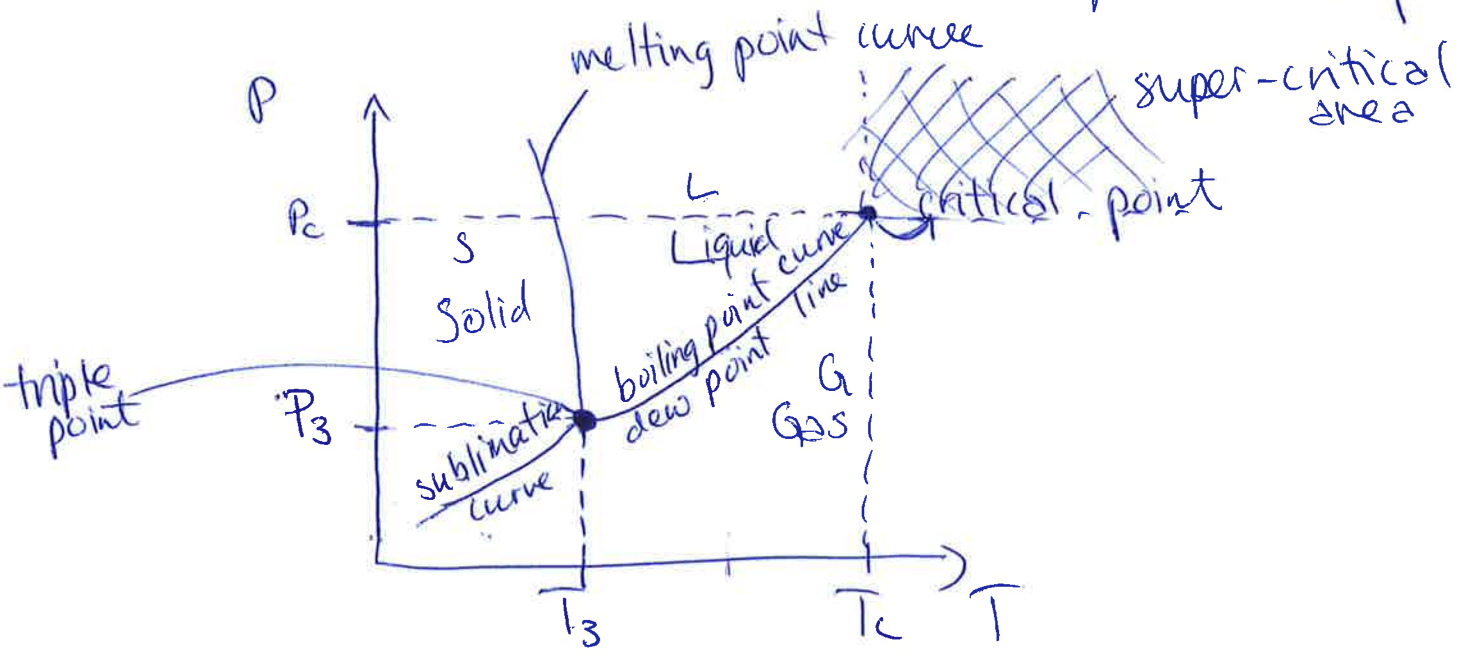
- reservoir fluid has got different properties at reservoir conditions and standard conditions
- what happens to the reservoir fluid during production?
- PVT - relations are also used in simulations

⊗ ONE - COMPONENT SYSTEM

Look at phase behaviour when P and T change. 3 phases: gas (G), liquid (L), solid (S)

Example: H_2O water
- ice / solid
- liquid
- vapour / gas

Phase of the water is depending on P and T.
Phase behaviour illustrated by a PT - diagram (pressure – temperature).



P_c = critical pressure
T_c = critical temperature

Critical point : At P and T close to the critical point, the properties of the gas and liquid phases are similar → hard to distinguish the two phases. Similar densities ...

Super-critical area : Super-critical fluid
$T > T_c$, $P > P_c$

boiling point curve
dew point curve
sublimation curve
melting point curve
} represents P and T conditions when 2 phases are in equilibrium.

Triple point : 3 phases existing in equilibrium at exact P and T.
Triple point is characteristic for component.
Found in handbooks
H_2O : T_3 : 273,16 K and P_3 = 611 Pa
0.01 °C and 0,06 atm.

The number of phases that can exist at the same time, at thermodynamic equilibrium, is given by the Gibbs phase rule : (1875)

$$F = C + 2 - P$$

F = Number of degrees of freedom of the system. The number of independent variables, intensive variables. ex. P, T, composition (independent of size/mass)

C = Number of components (type of molecules) in the system.

example : water H_2O C = 1
example : water + ethanol C = 2

P = Number of phases

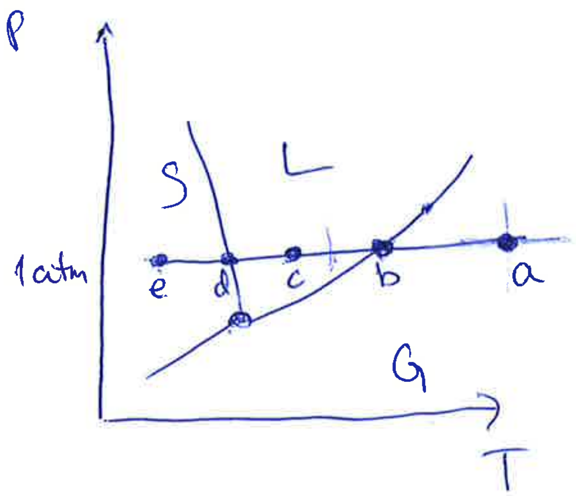
P = 1 : ex. gas phase, ex. solid phase, miscible liquids

P = 2 : "slush" – liquid + solid

The shape of the PT-diagram is explained by Gibbs phase rule:

Ex. One-component system, H_2O.

$C = 1 \Rightarrow F = 3 - P$



a : P = 1 : F = 3 − 1 = 2
can vary 2 variables, P, T
still one phase, gas phase

b : P = 2 : Equilibrium between L and G
F = 3 − 2 = 1. Can only vary one variable, by changing T, Pb will change automatically

c: $P = 1$: Liquid phase $F = 3 - 1 = 2$. Can vary both P and T and still have one liquid phase.

d: $P = 2$. Equilibrium between L and S. $F = 3 - 2 = 1$. Can only vary one parameter and still have two phases present.

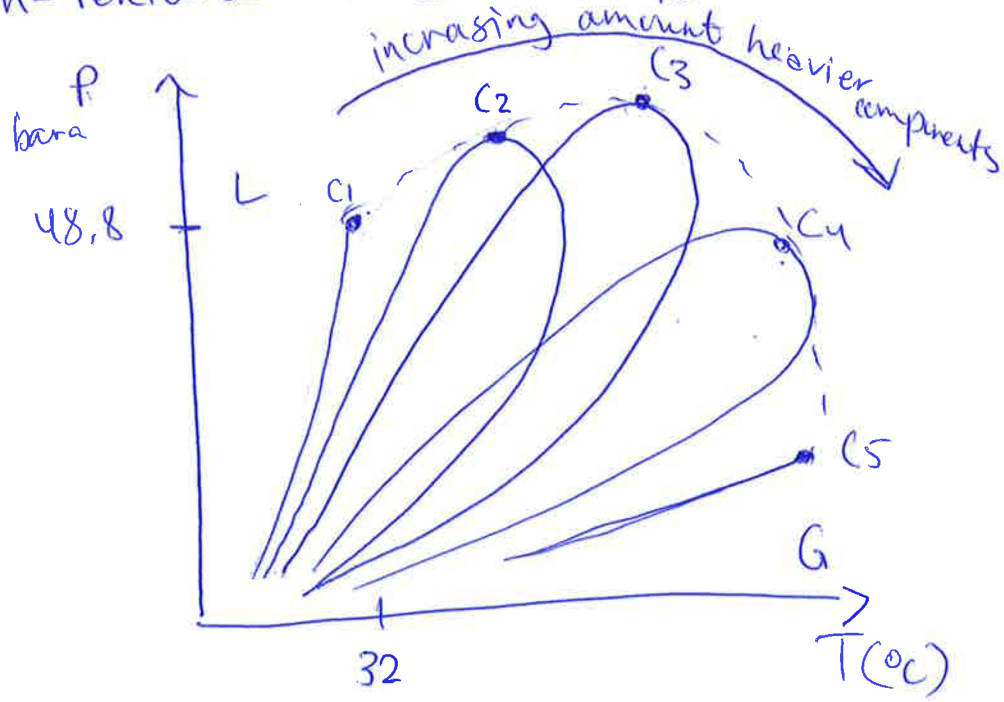
e: $P = 1$: Solid phase : $F = 2$
Can vary both P and T

Triple point : 3 phases in equilibrium
$P = 3 \Rightarrow F = 3 - 3 = 0$
Cannot vary any variables. Triple point exists at exact P and T.

TWO - COMPONENT SYSTEM

Phase diagram for a mixture of ethane and n-pentane, varying mixture ratio

Ethane : C_2 ≈ $T_c \approx 32\,°C$ $P_c \approx 48.8$ bara
n-Pentane : n-C_5 $T_c \approx 96\,°C$ $P_c \approx 33,7$ bara



Critical points :
C_1 : 100 % ethane
C_2 : 90 % ethane
C_3 : 50 % ethane
C_4 : 10 % ethane
C_5 : 0 % ethane

Shape of the PT-digram is dependent on composition, over time

According to the Gibbs phase rule:

$C = 2 \Rightarrow F = 4 - P$

$P = 2$: Equilibrium between two phases

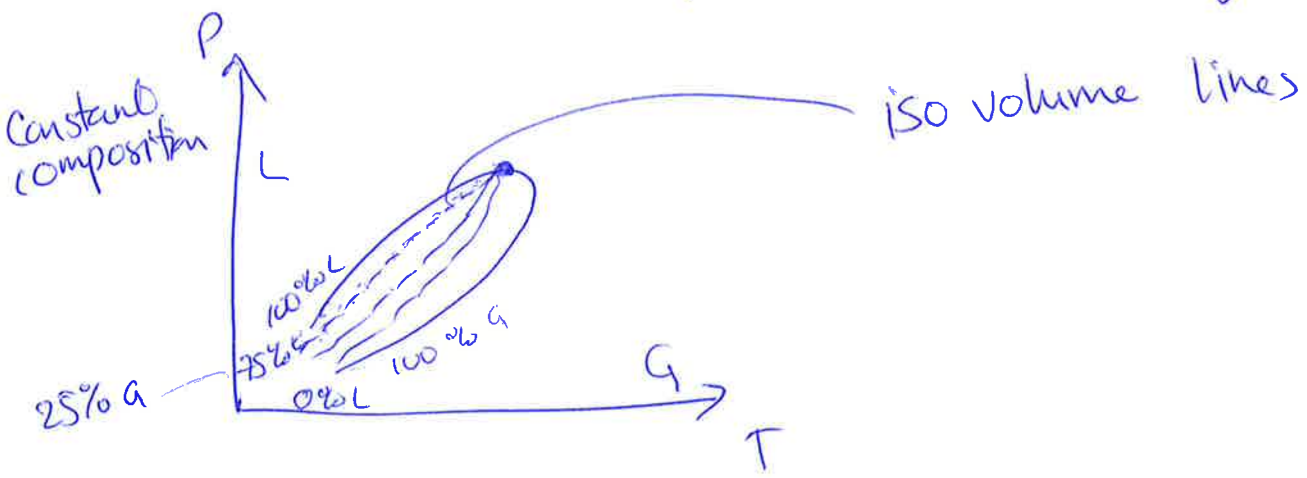
$F = 4 - 2 = 2$

Inside two-phase envelopes we can vary P and T, and still have two phases present. Composition is given.

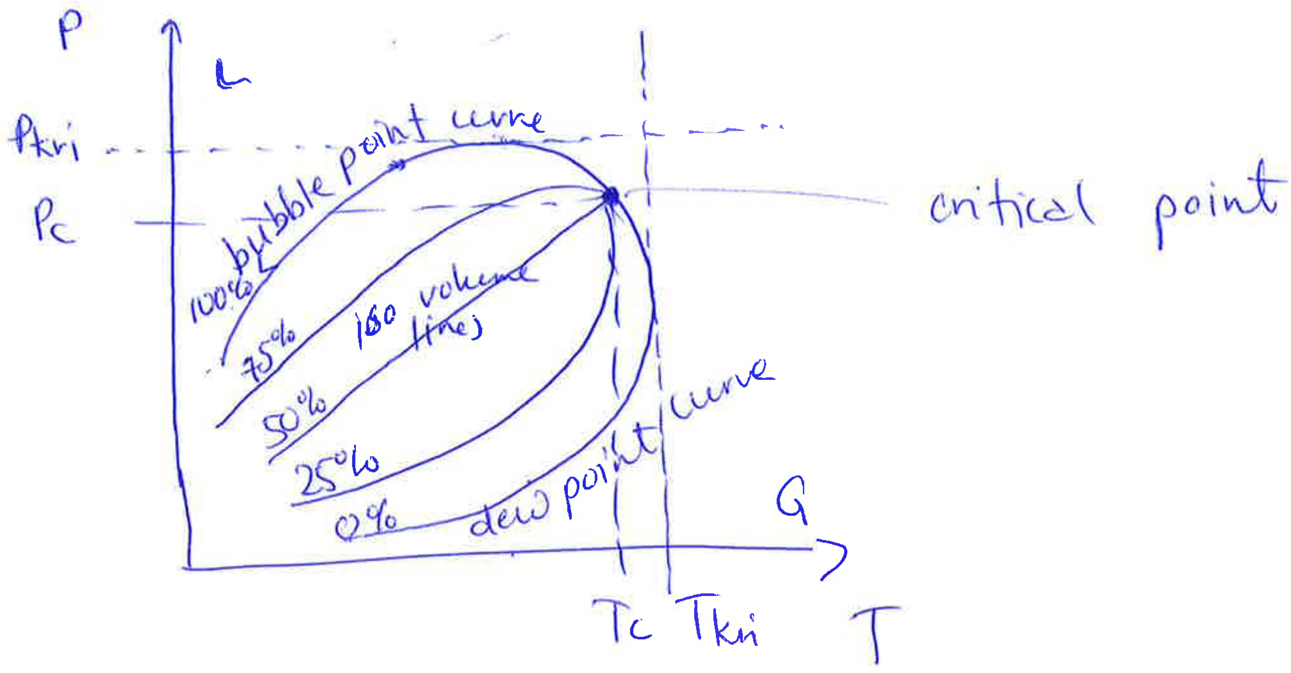
$P = 1$: $F = 4 - 1 = 3$, can vary P, T, composition

Inside the two-phase envelopes:

- 2 phases present
- ratio between phases can vary.



MULTI COMPONENT SYSTEM



Two phase envelope: given by bubble point curve and dew point curve. Inside: two phases present in different ratios depending on P and T.

Critical point (T_c, P_c): at P and T close to this point, both phases have similar properties. Difficult to distinguish phases.

Iso volume lines: Lines within the two-phase envelope, having constant volume % liquid and gas.

P_{kri} = Cricondenbar : max. P where two phases can exist simultaneously.

T_{kri} = Cricondentherm: max T where two phases can exist simultaneously.

Phase diagram, PT-diagram for a reservoir fluid can be determined in the lab.

Two-phase envelope will give the ratio between gas and liquid/oil in the reservor.

=> How phases change in the reservoir by pressure depletion.