Tools and methods for PVT calculations

- and what do we really mean by GOR?

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NFOGM, March 19 2009

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Outline

- What is PVT and why do we need it?
- Equations of State – a powerful tool for PVT-predictions
- Example useful output from Equations of State
  - Flash calculations
- What is GOR?

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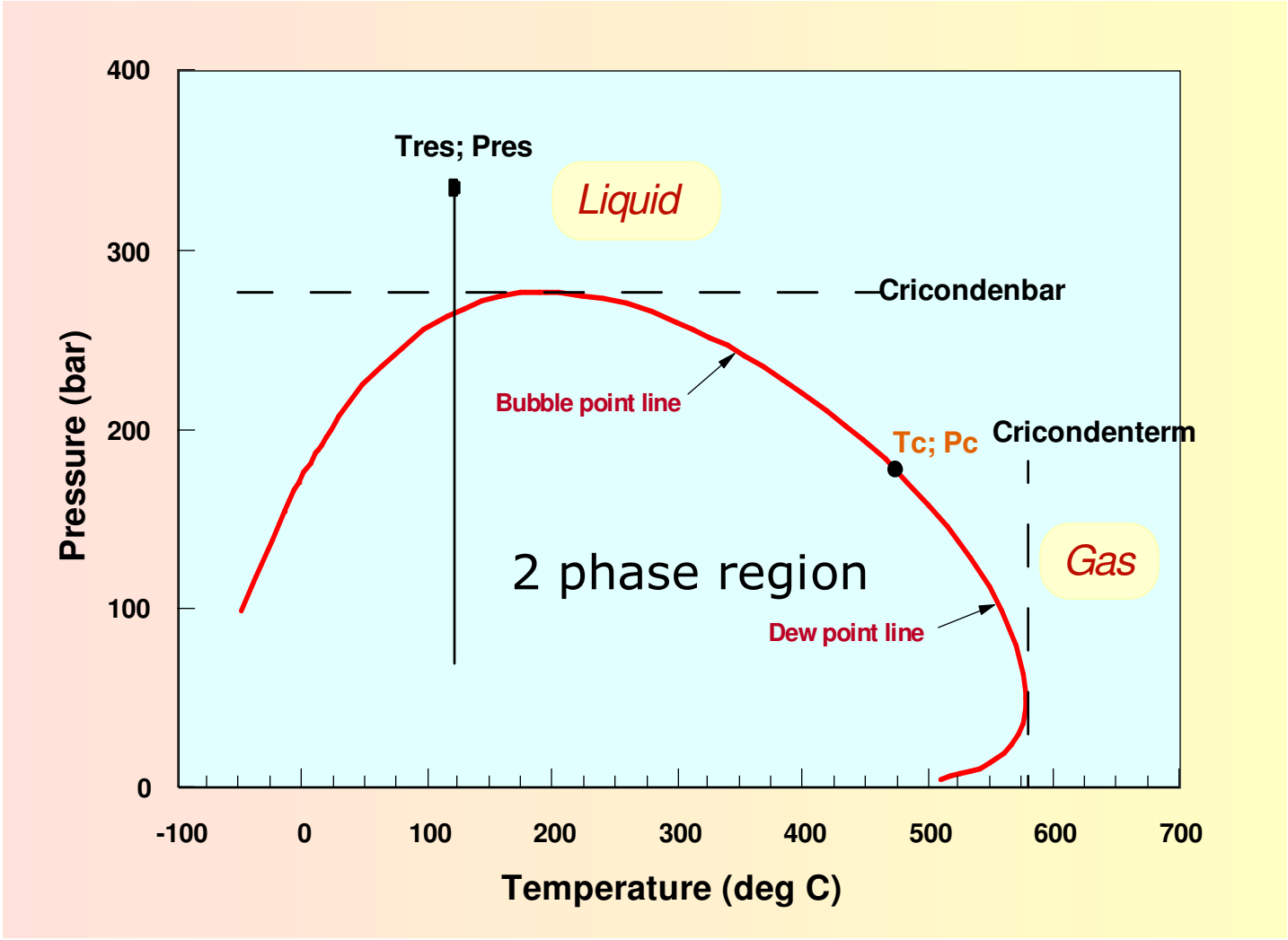
Typical phase envelope of a reservoir oil



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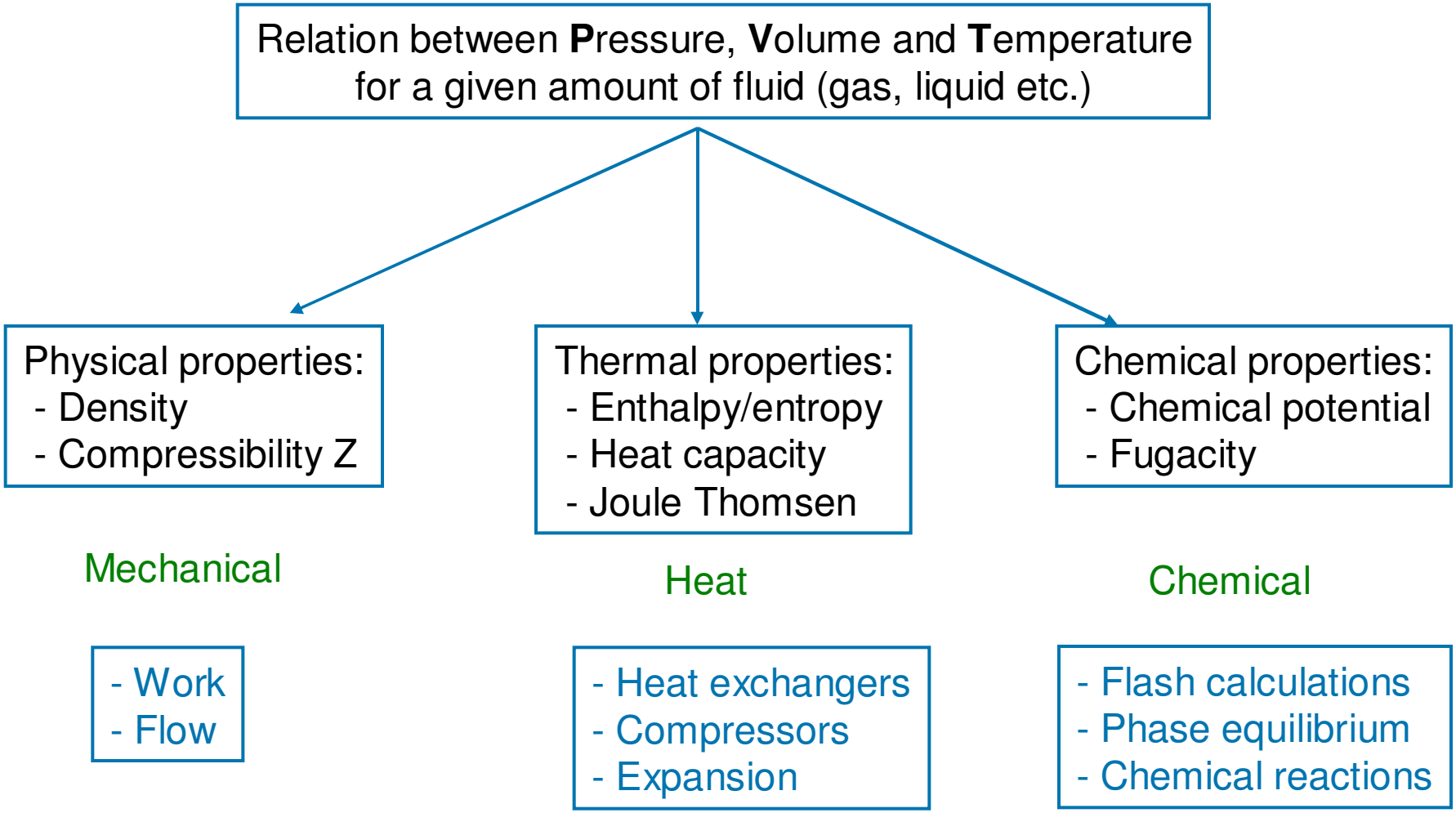
PVT – Pressure Volume Temperature



Equations of state

Ideal gas law $$P = \frac{nRT}{V}$$

Van der Waals $$P = \frac{RT}{v-b} - \frac{a}{v^2}$$

b – volume of molecules
a – attraction between molecules

SRK $$P = \frac{RT}{v-b} - \frac{a}{v(v+b)}$$

Cubic equations (3rd order)

$$Z^3 - Z^2 + \left(A - B - B^2\right)Z - AB = 0$$

$$A = \frac{aP}{R^2T^2} \qquad B = \frac{bP}{RT} \qquad Z = \frac{RT}{Pv}$$

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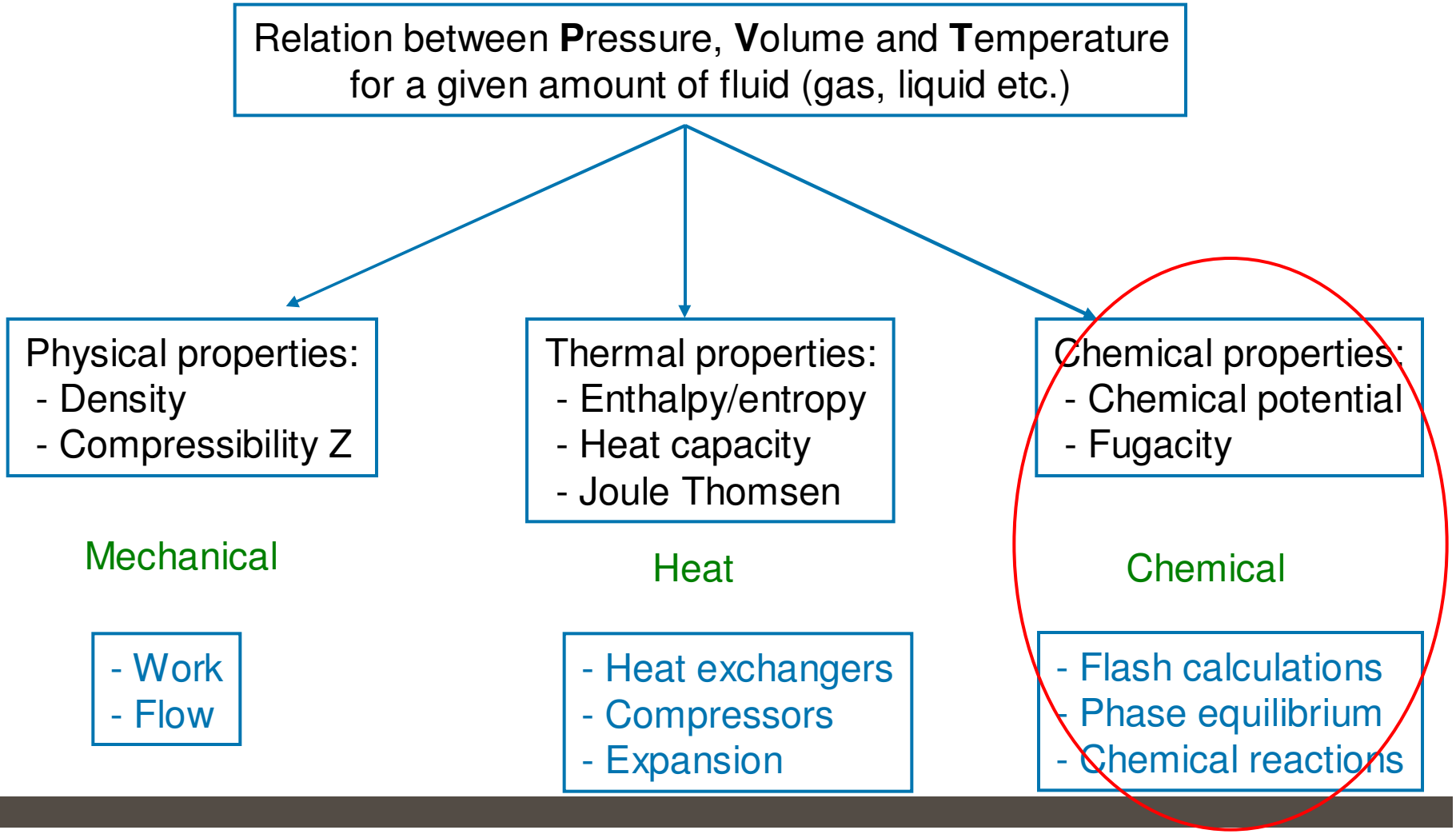
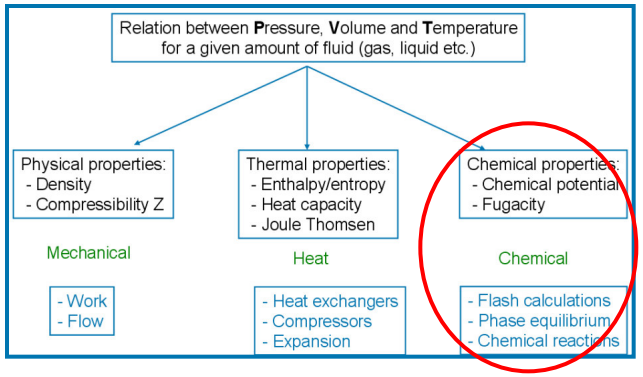
PVT – Pressure Volume Temperature



Chemical properties and phase equilibrium

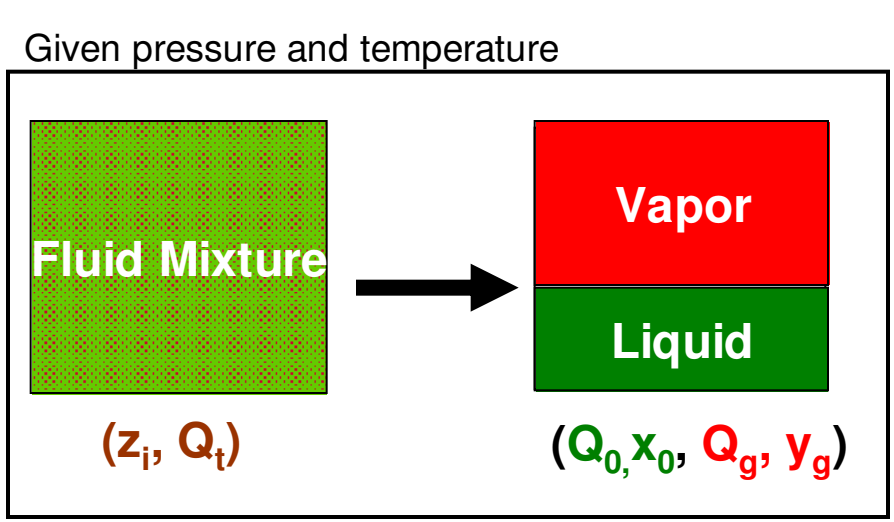
- Nature will always try to minimize energy
- Chemical potential is the “Chemical energy” that can be “used” in a reaction:

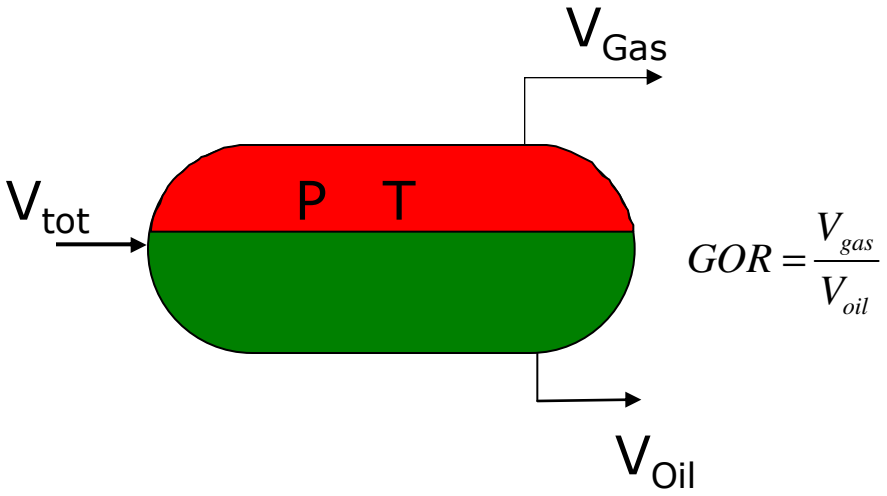
$$\mu_i\left(T,P\right)=\mu_i^{IG}\left(T,P^\circ\right)+RT\ln\left(\frac{f_i}{P^\circ}\right)$$



- Phase equilibrium: **All components must have same chemical potential in all phases**
  - If CH_4 has higher chemical potential in the gas phase than in the oil phase, CH_4 will move from the gas (high E) to the liquid phase (low E)
- Thermodynamic equilibrium occurs when the chemical potential of each components (methane, ethane etc.) are equal both in the liquid and in the gas phase.
- This vapor-liquid equilibrium of a fluid system is determined by its thermodynamic properties, **which can be derived analytically from any cubic EOS by flash calculations**.

Phase equilibrium and flash calculations





Given:	Total rate and an overall fluid composition at given pressure and temperature.
Determine:	Which phases are present (Oil, gas or both?)
	Rates of the different phases (and GOR)
	Composition of the phases
	Other properties
Solution:	**Flash calculation by using equation of state ("PVT-package")**

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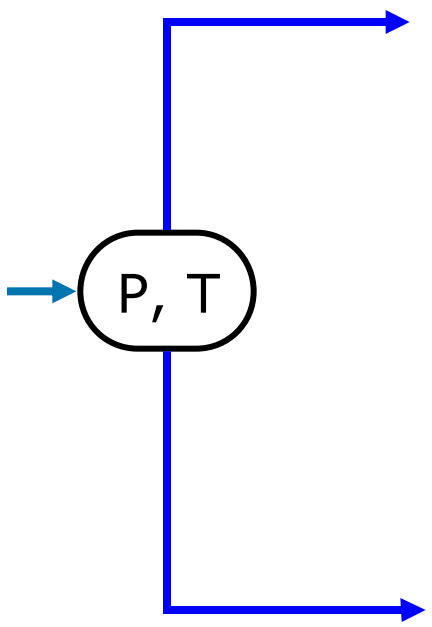
Single stage flash

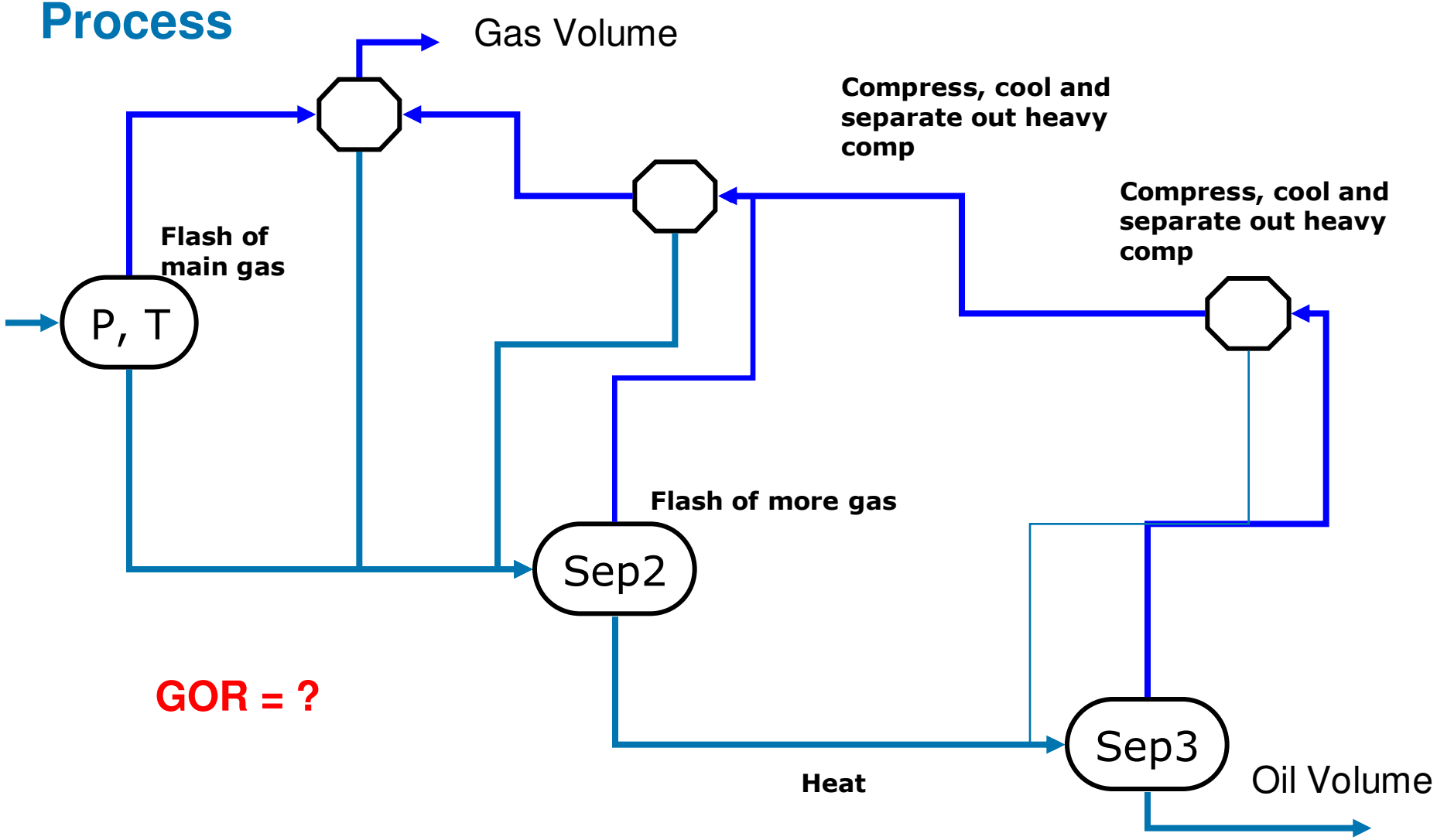


Gas Volume

Oil Volume

$$GOR[m^3/m^3] = \frac{GasVolume}{OilVolume}$$

Process


Gas Volume
Compress, cool and separate out heavy comp
Compress, cool and separate out heavy comp
Flash of main gas
P, T
Flash of more gas
Sep2
GOR = ?
Heat
Sep3
Oil Volume

Single flash GOR vs process GOR

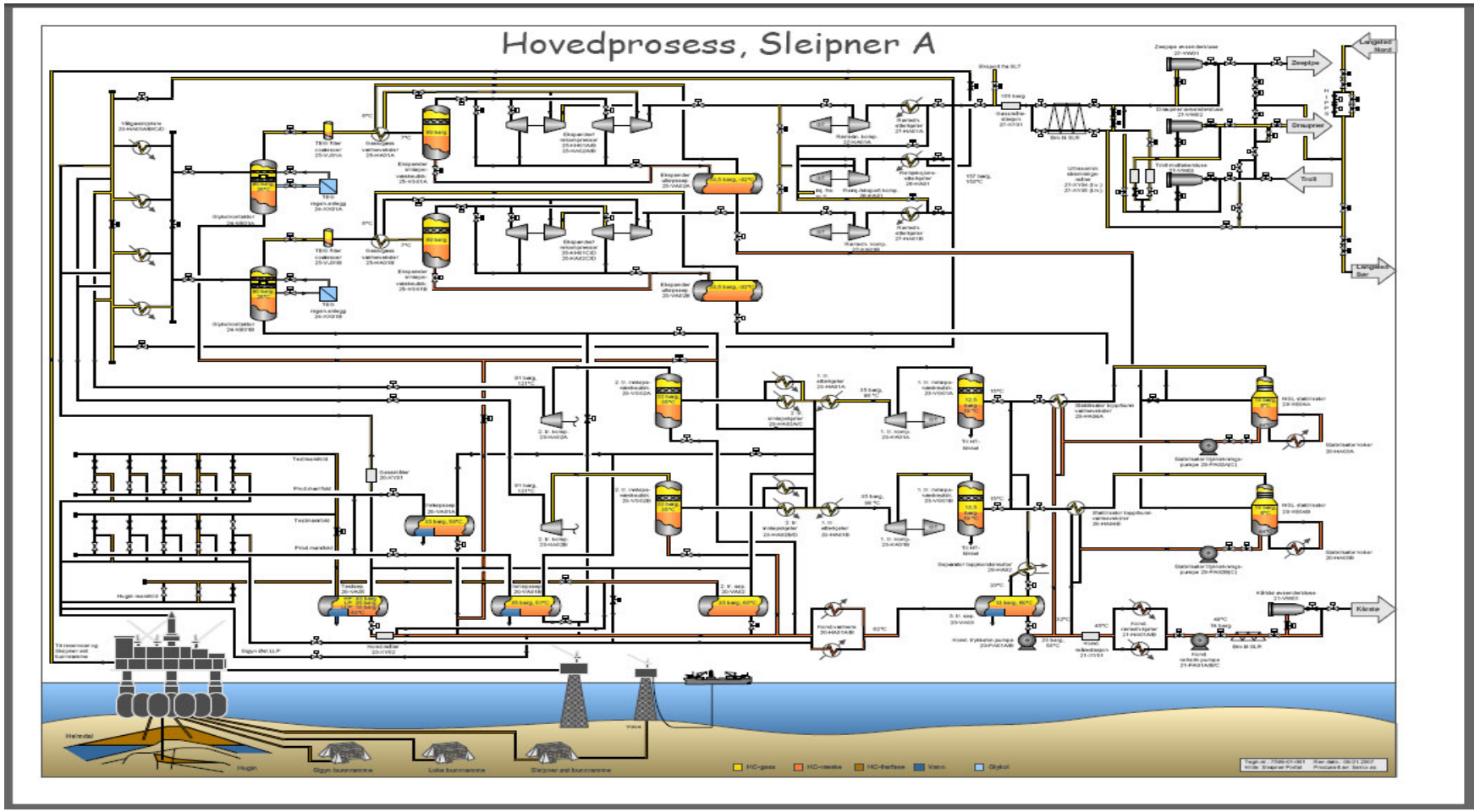
- **GOR is process dependent!**
- Single stage flash to for example standard conditions (1 atm, 15°C)
  - A single stage flash is fluid specific – it tells something about the composition
- However, a platform process will normally try to
  - Increase amount of liquid
  - Remove heavy components from gas

➢ Process GOR is not the same as single flash GOR! NOT fluid specific!

  - Process contains several separators, coolers and compressors
  - Resulting gas and liquid are NOT in equilibrium
- Example: Midgard fluid on Åsgard B:
  - Single flash GOR: >10 000 Sm^3/m^3
  - Process GOR on Åsg B 4-6 000 Sm^3/m^3

Example: Sleipner A process plant

not a single stage flash…



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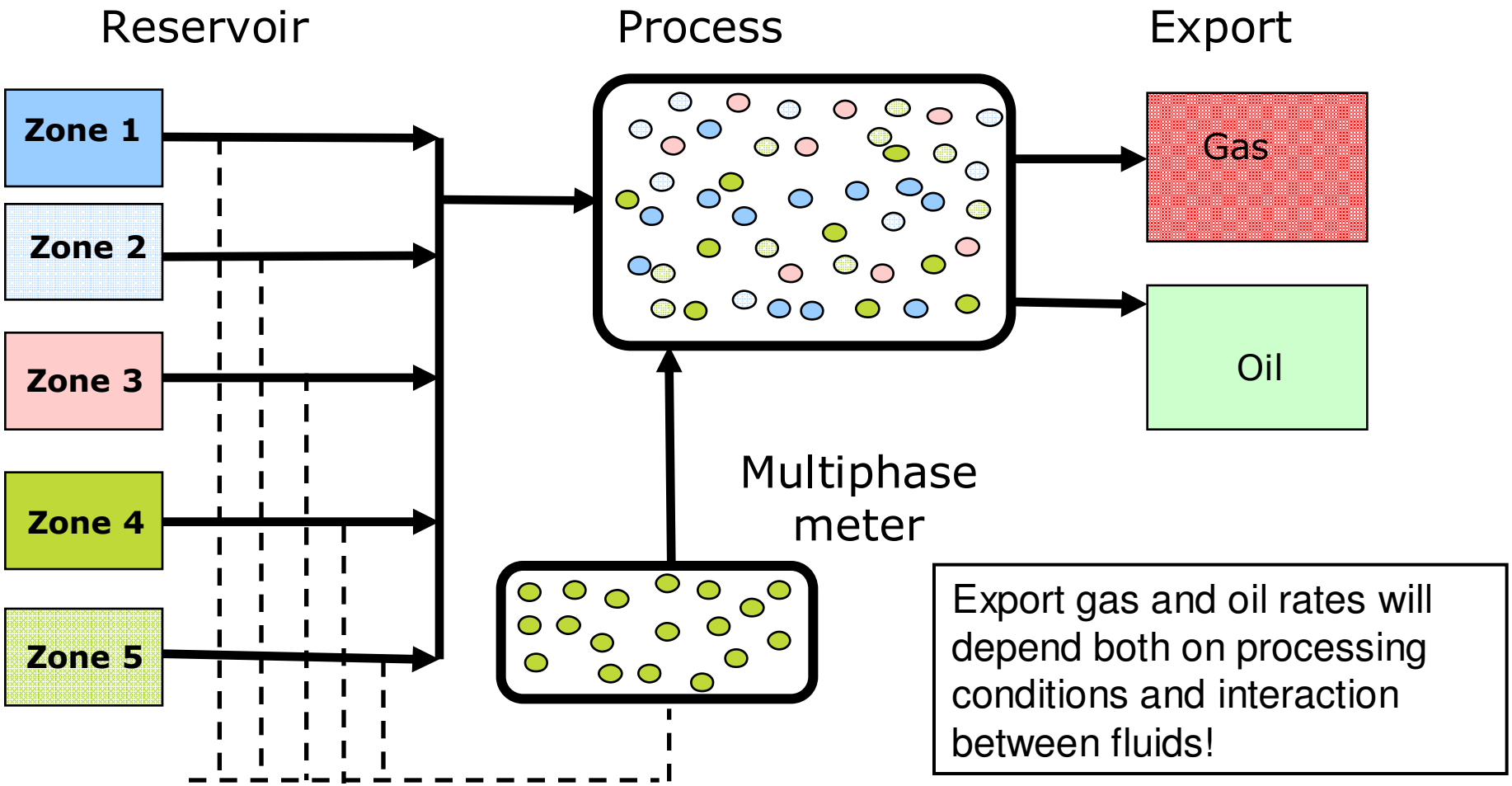
Export gas and oil rates – processing effects



Export gas and oil rates will depend both on processing conditions and interaction between fluids!

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Thank you!