Interfacial tension – Importance in process design

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Outline

- What is interfacial tension - illustrations
- Importance in oil & gas processing
- Laboratory facilities and experimental results
- Theoretical calculation and prediction with modelling tools
- Impact on daily life – at work!

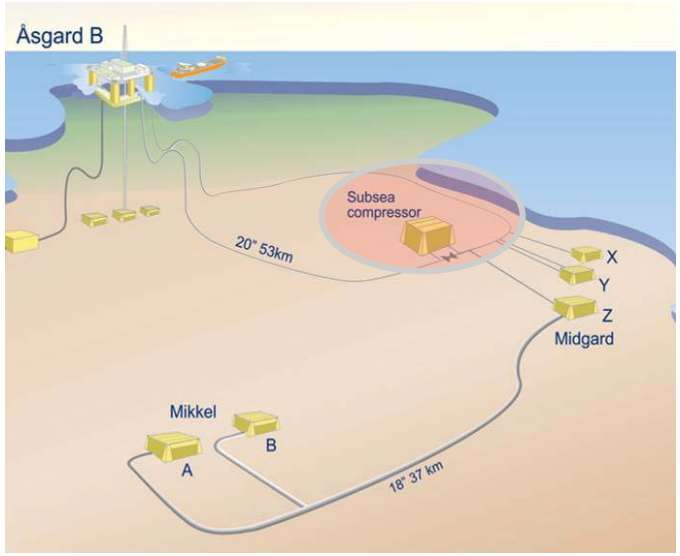
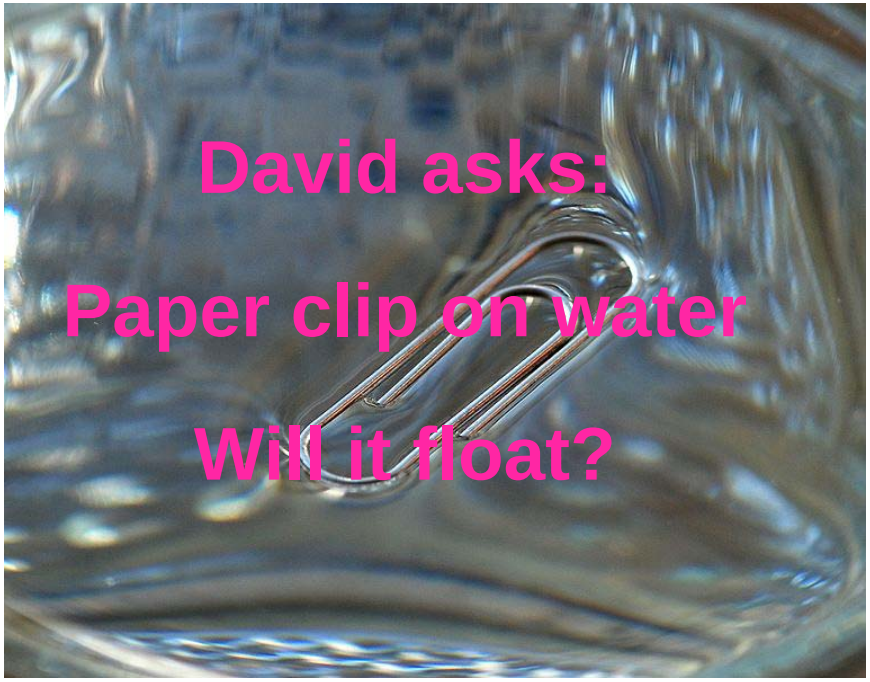


Illustration: Statoil

Statoil



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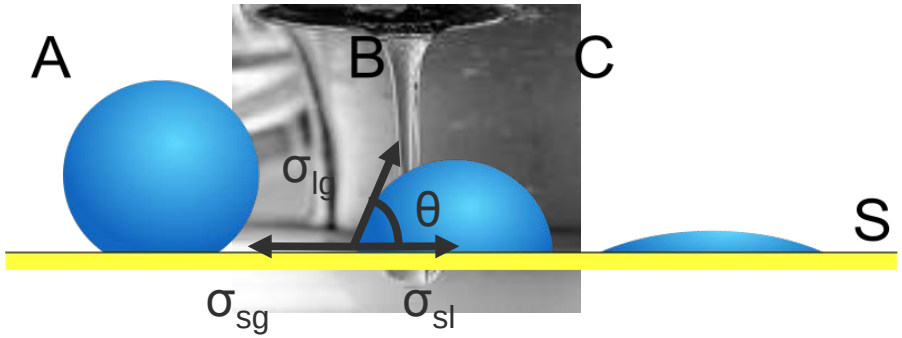
What is interfacial tension?



- Property of a liquid that allows it to resist an external force
- Measured in force per unit length, N/m

- Linked to wetting properties of a liquid on a surface

- Some examples gas/liquid interfacial tension
  - Water 72 mN/m
  - Mercury 487 mN/m
  - Condensate 0-20 mN/m

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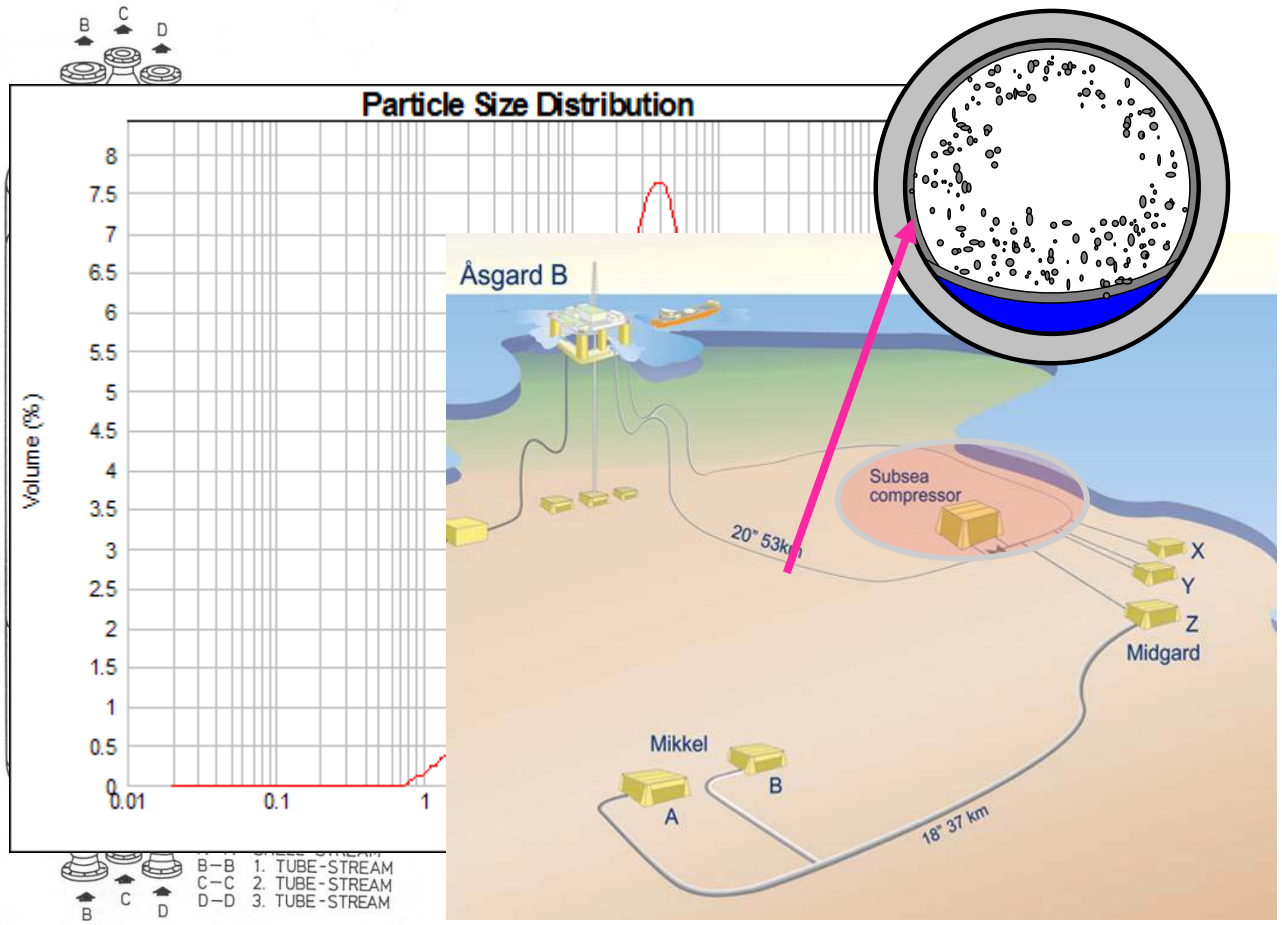
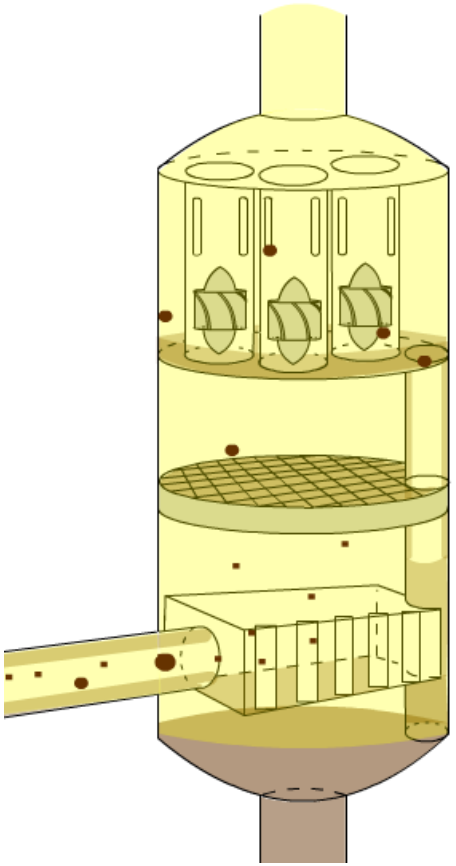
Importance in oil and gas processing

Heat exchanger: Liquid behaviour: Multiphase flow Separation technology





Illustrations: Statoil

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Why is interfacial tension a big issue?

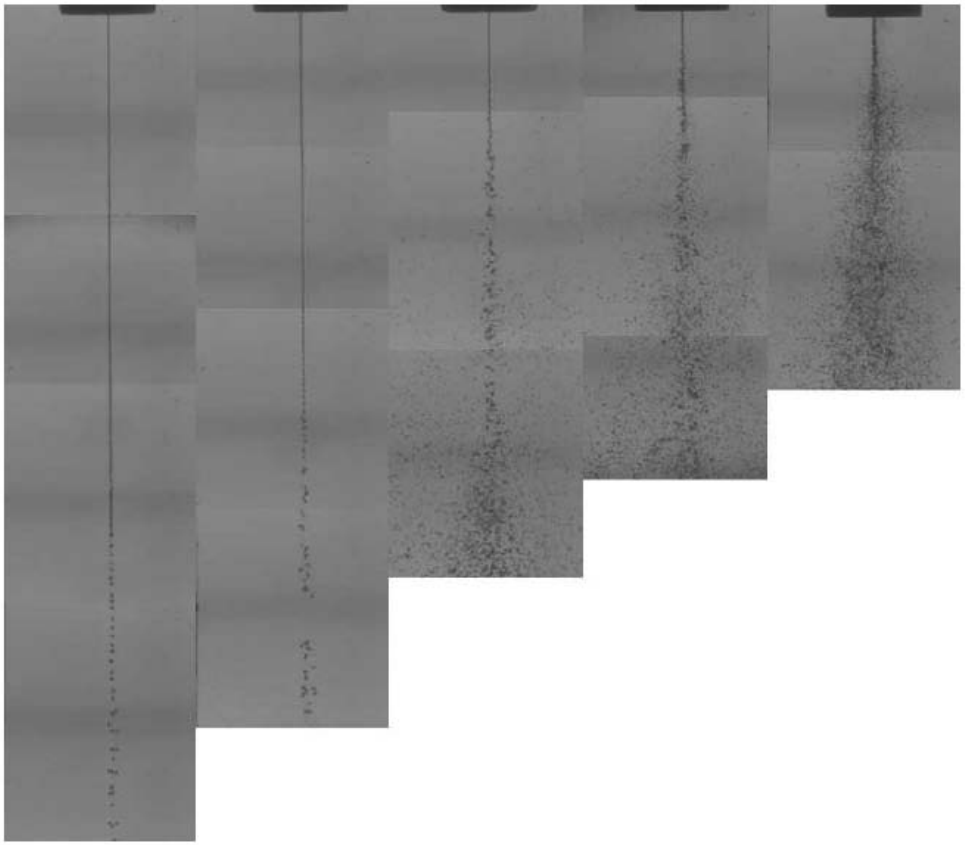

Figure 6.14: n-decane/CO_2 system (from left) at 6, 11, 21, 31 and 41 bar and Δp of 500 mbar.

Determines liquid behaviour!

12 mN/m < σ < 22 mN/m

Figure is taken from: **Johnsen, C. G.** 'Experimental and Numerical Investigation of Droplet Phenomena', Ph.D thesis, 2007:248**, NTNU**

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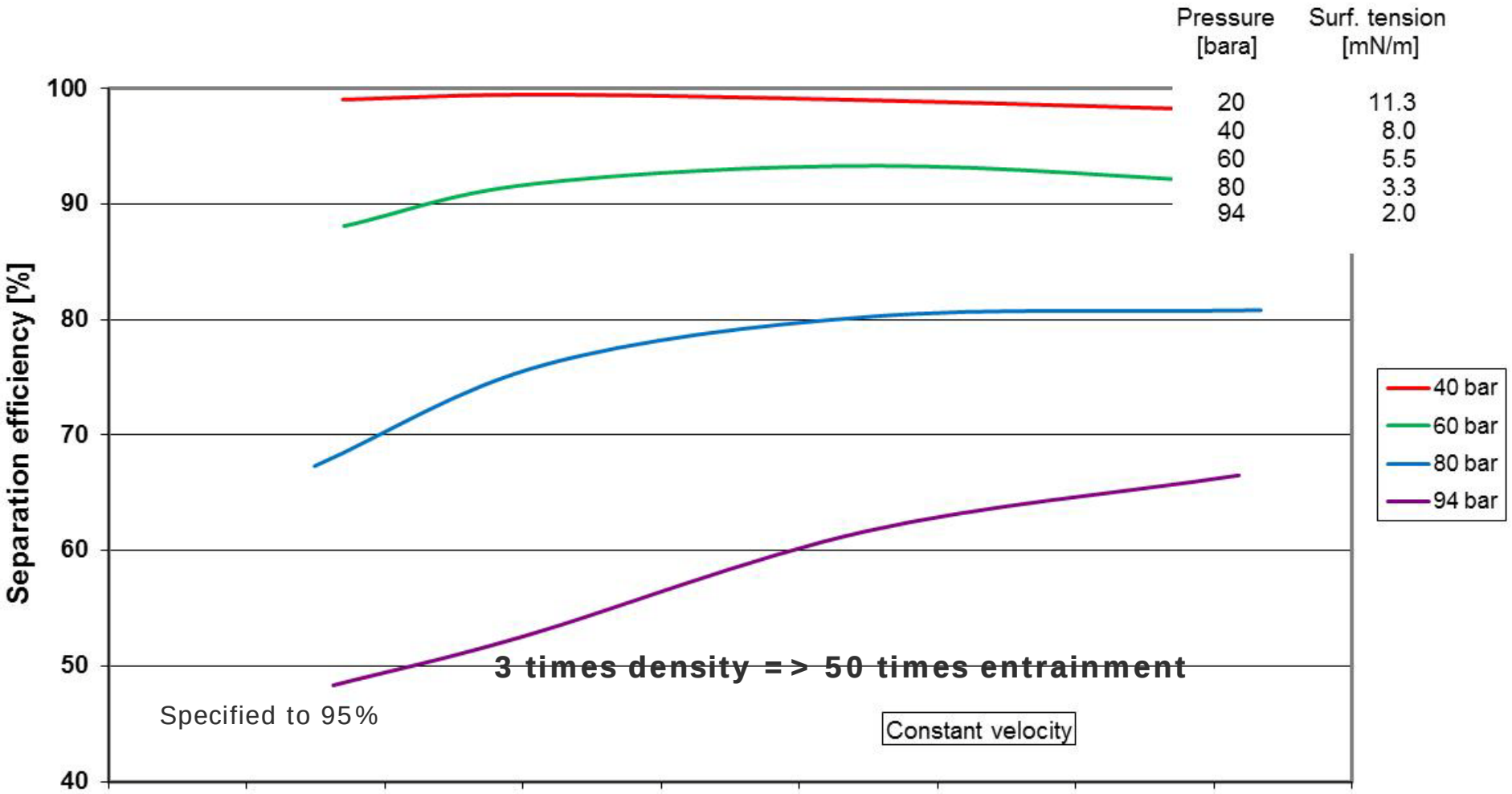
Separation efficiency, impact of reduced IFT



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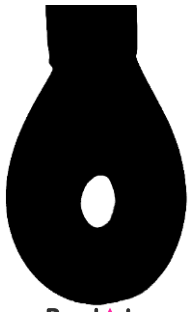
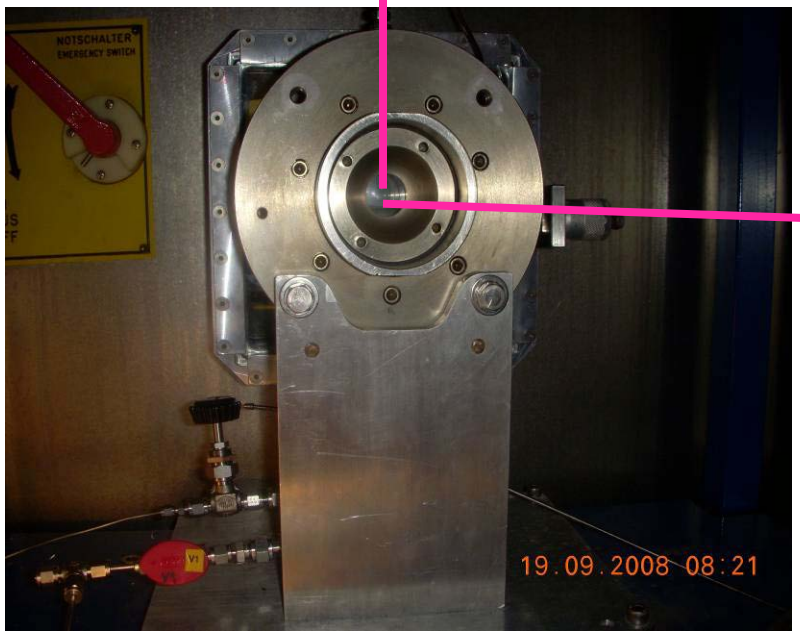
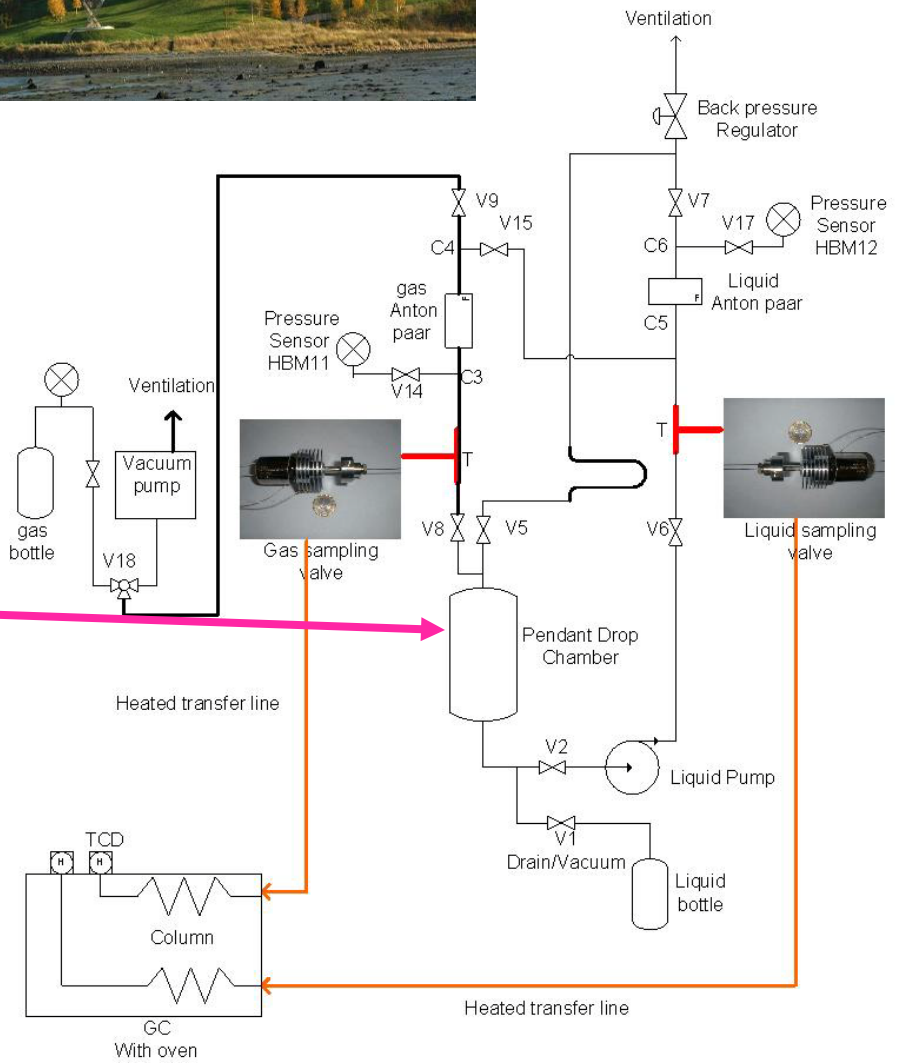
Laboratory facilities







Photos and figure: Statoil

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How to model IFT

Parachor method, Weinaug-Katz procedures

$$\sigma^{\frac{1}{4}} = \sum_{i=1}^{N} \left(\overline{\rho}_{Liq} [P]_i x_i - \overline{\rho}_{Vap} [P]_i y_i \right)$$

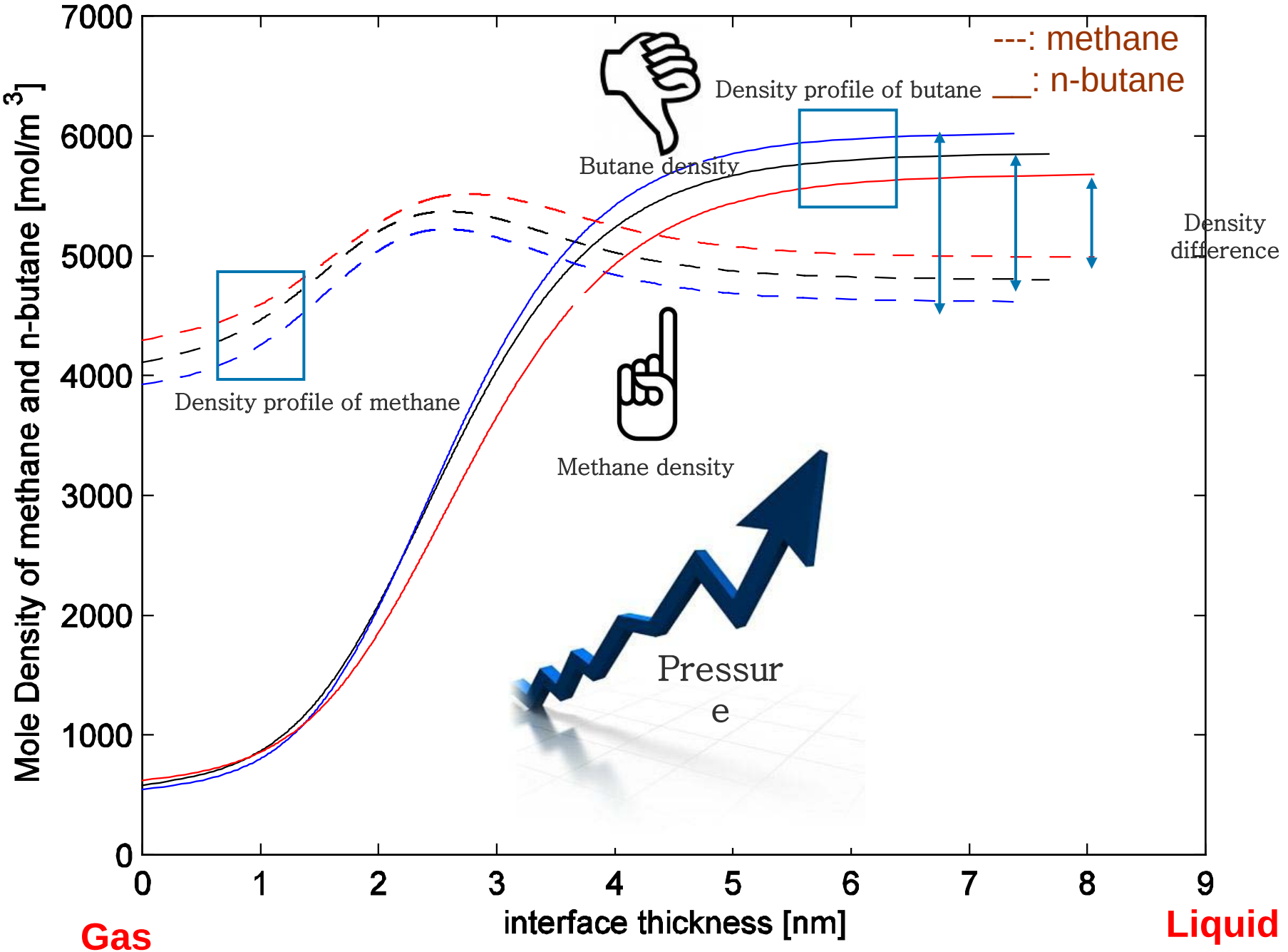
PVTsim **Proll – select method**

Brock Bird

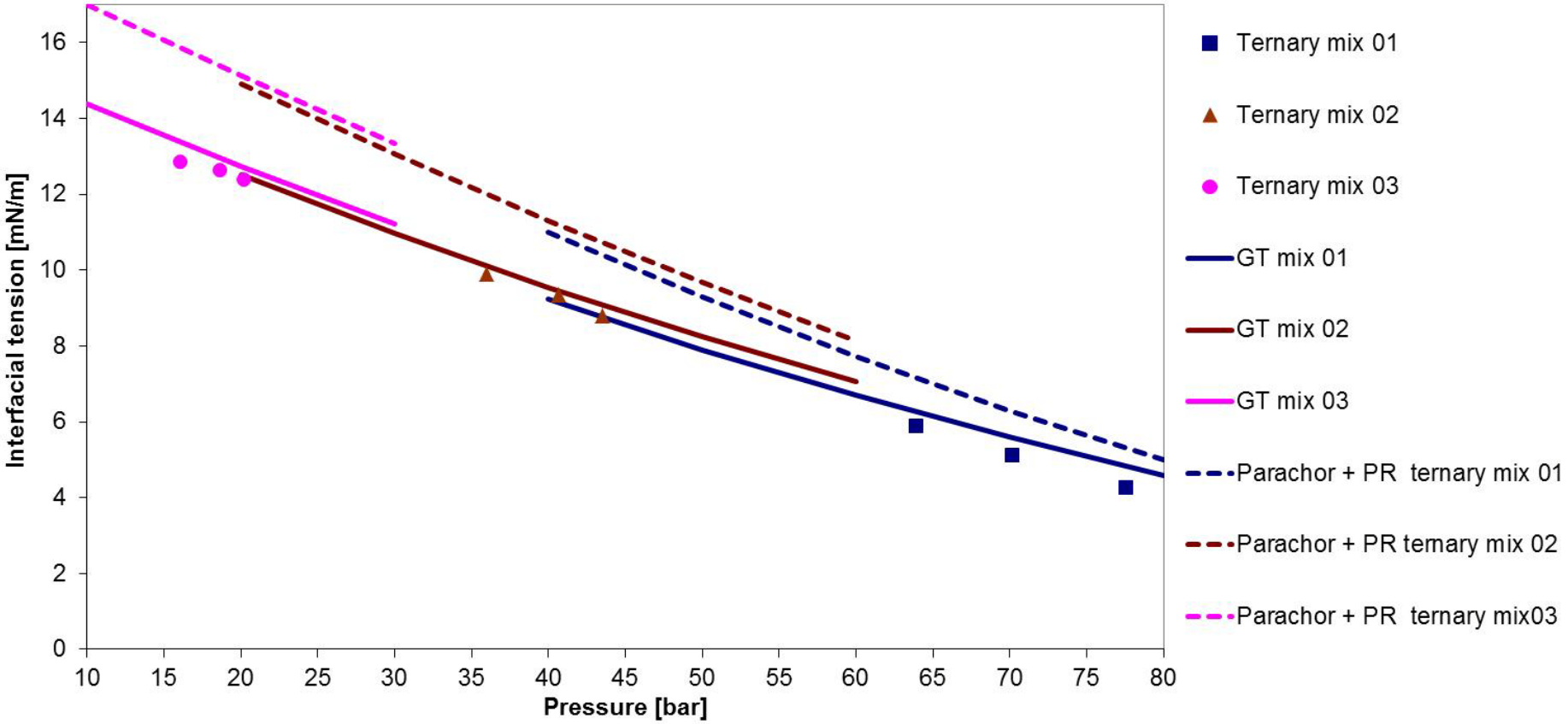
Hysys

Gradient theory

$$\sigma = \int_{n_{ref}^{Vap}}^{n_{ref}^{Liq}} \sqrt{2\Delta\Omega(n_1,\ldots n_N) \sum_i \sum_j c_{ij} \frac{dn_i}{dn_{ref}} \frac{dn_j}{dn_{ref}}} dn_{ref}$$


Red: P=106.9 Bar; Black: P=96.5 Bar; Blue: P=89.6 Bar
---: methane
___: n-butane
Density profile of butane
Butane density
Density profile of methane
Methane density
Density difference
Pressure
Mole Density of methane and n-butane [mol/m^3]
interface thickness [nm]
Gas
Liquid
0
1000
2000
3000
4000
5000
6000
7000
0
1
2
3
4
5
6
7
8
9

Gradient theory modelling, ternary systems



Article: **Nilssen, H. N. et.al. '**Equilibrium phase densities, vapor phase compositions and interfacial tension for the methane + ethane + n-pentane system at 294.15 K, Journal of chemical & engineering data, September 2011

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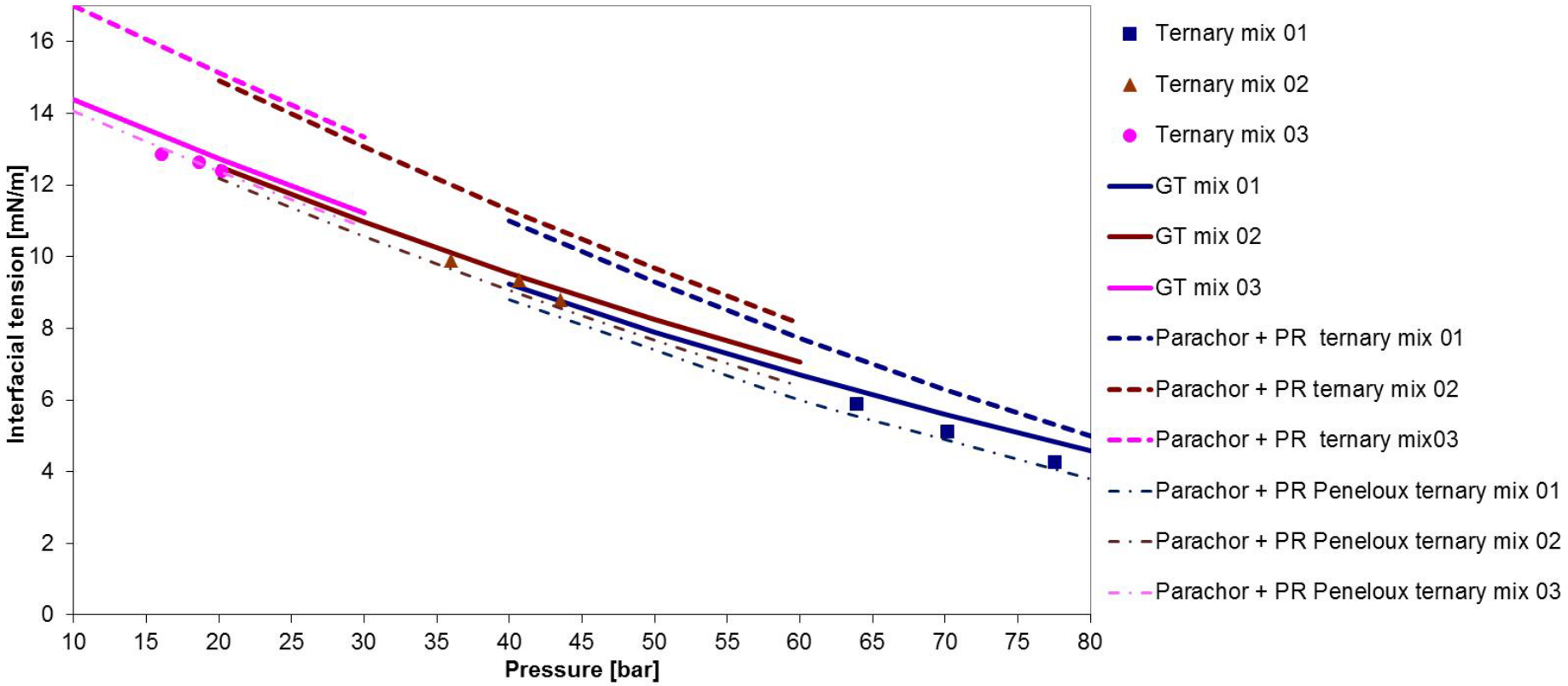
Gradient theory modelling, ternary systems



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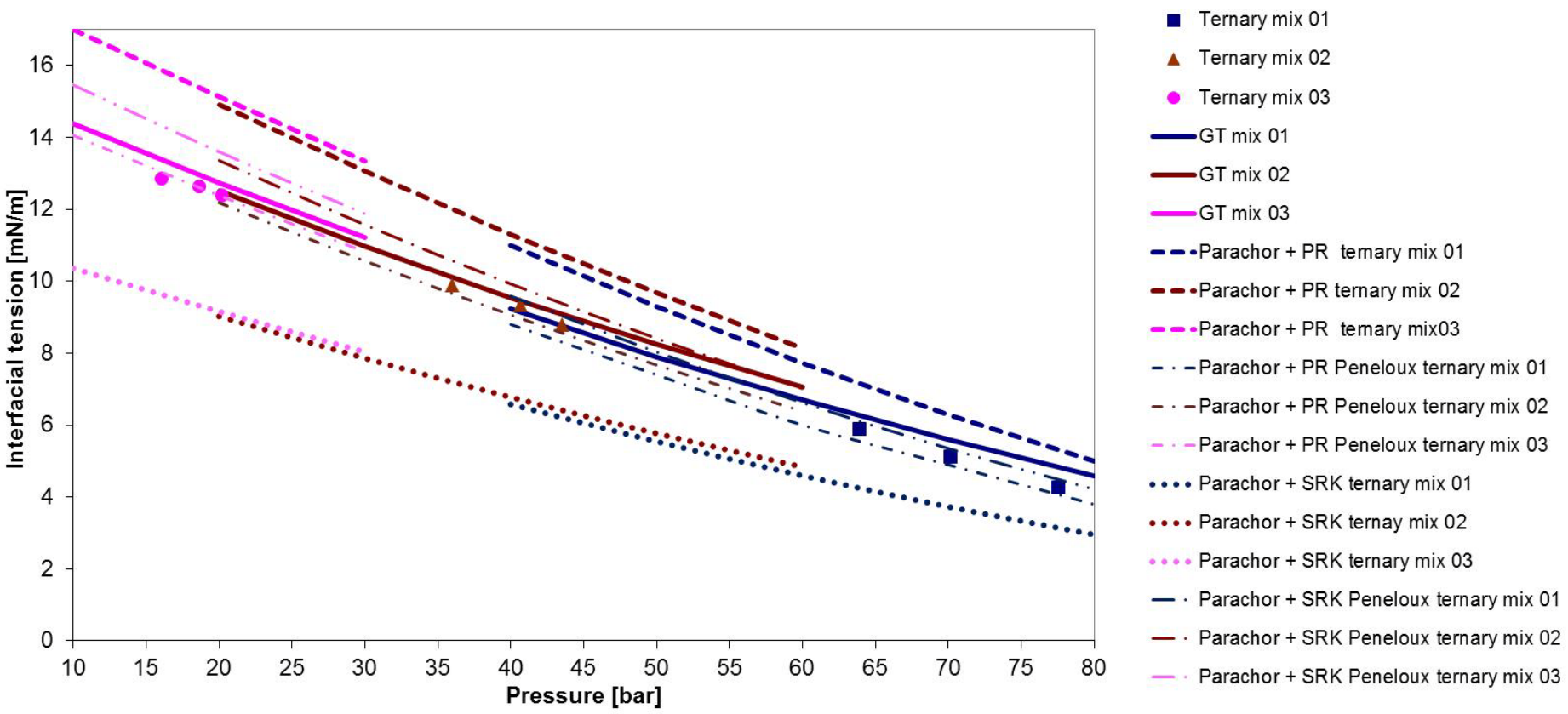
Gradient theory modelling, ternary systems



Important: Gradient Theory not sensitive to EoS

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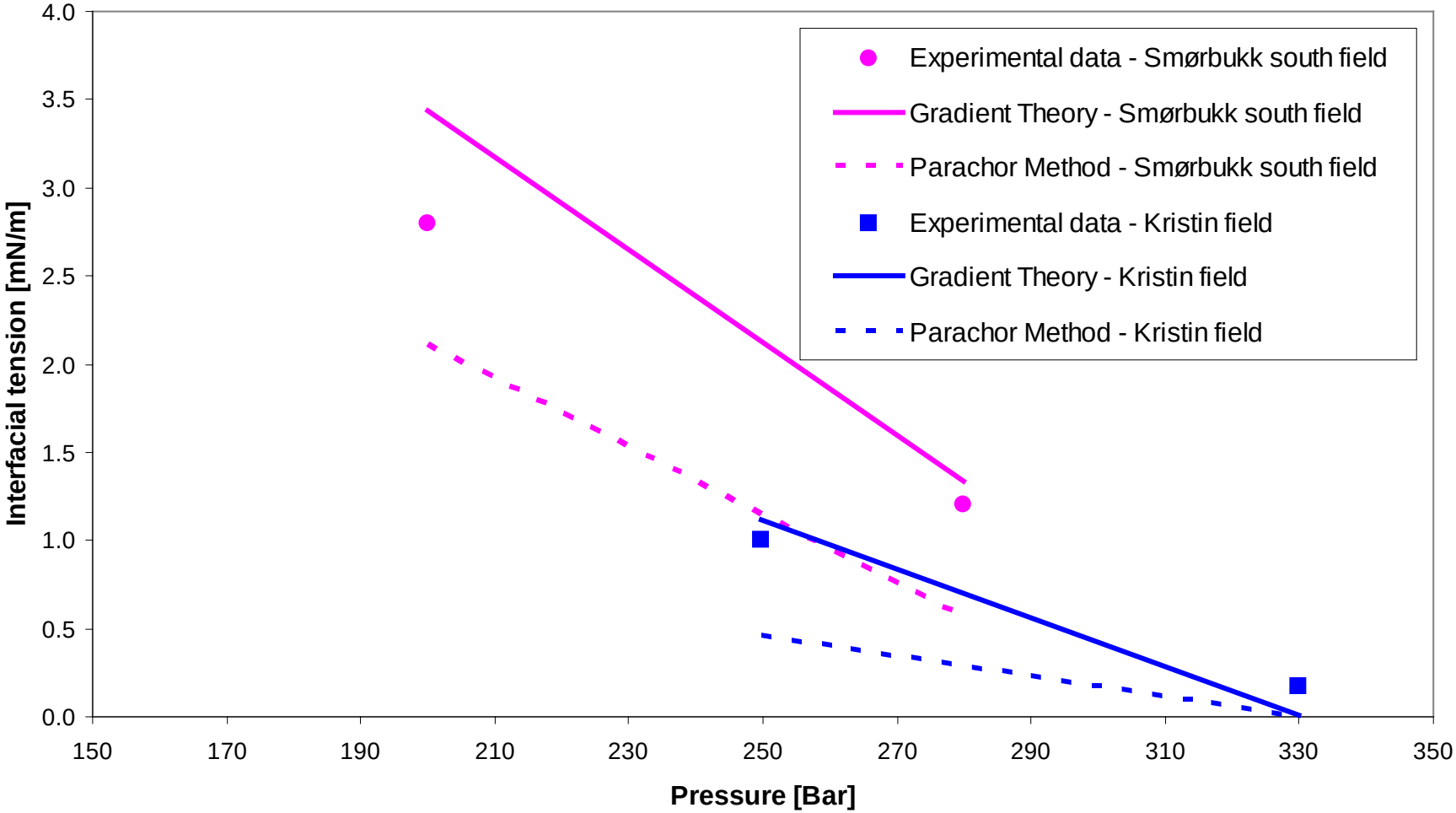
Gradient theory modelling, real systems



Important: Gradient Theory not sensitive to fluid characterization

Article: **Nilssen, H. N. et.al.** 'Theoretical prediction of interfacial tensions for hydrocarbon mixtures with gradient theory in combination with Peng-Robinson equation of state' OTC-20453-PP

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IFT calculations, input to process design

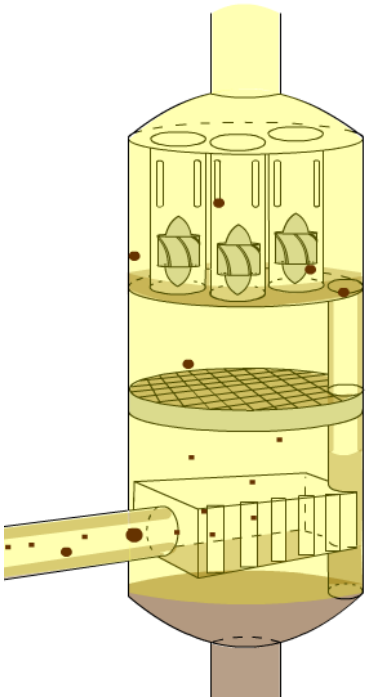

Illustration: Statoil

- Interfacial tension scrubber
  - Hysys: 5.6 mN/m
  - PVTsim: 0.9 mN/m (Hysys characterization)
  - Gradient theory: 1.3 mN/m
- Choice of separation technology very important

HIPGLS High Pressure Gas Liquid Separation

New experimental data for binary and ternary systems:

Nilssen, H. N. et.al. 'Equilibrium phase densities, interfacial tension for the ethane + n-pentane system at 294.15 K, Journal of chemical & engineering data, March 2011

Nilssen, H. N. et.al. 'Equilibrium phase densities, vapor phase compositions and interfacial tension for the methane + ethane + n-pentane system at 294.15 K, Journal of chemical & engineering data, September 2011

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Take home message

- Different software gives large variations in calculated interfacial tension
- Gradient theory not sensitive to EoS or fluid characterization
- Interfacial tension is an important physical property in gas processing and must be given attention