Introduction to the Natural Gas Processing Plant

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Natural Gas

- A typical flow scheme for a cryogenic natural gas processing plant is to extract ethane and heavier hydrocarbons from natural gas.
- Methods are shown as an example for rigorous modeling of ethane recovery plant using turbo-expander, refrigeration system, demethanizer and deethanizer columns.

Natural Gas

- Mainly composed of methane (>95%)
- Contain significant amounts of nitrogen and carbon dioxide.
- According to CO_2 content, natural gas system is classified into lean or rich gas.

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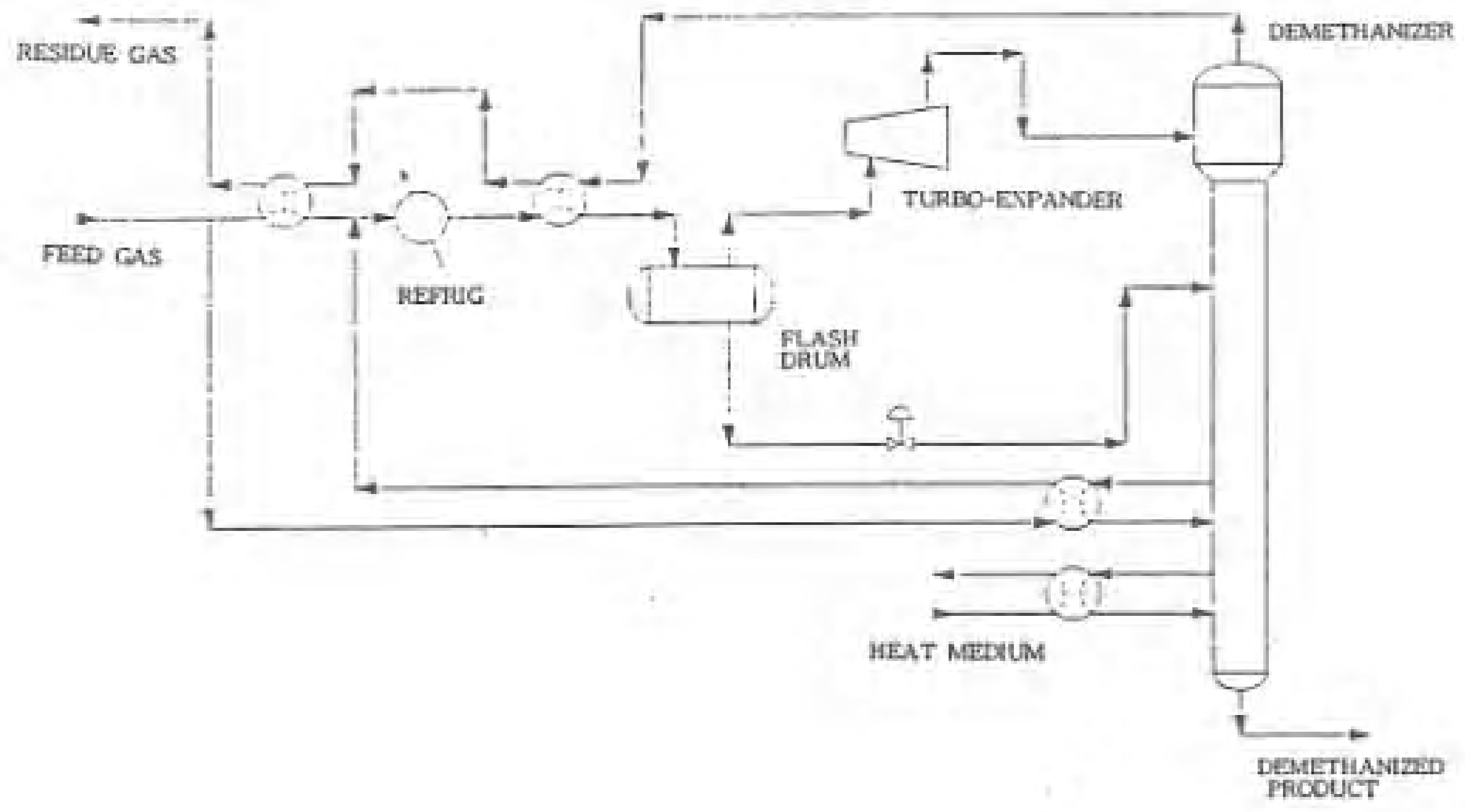
Needs for Studying Gas Plant

- No special licenses for natural gas processing plants
- Not so much difficult since it is only consisted of fractionators (no reactors).

Process Description

- Gas is dehydrated usually by molecular sieve.
- Gas is partially chilled by back exchange with residue gas stream.
- Gas is further chilled by refrigeration system.
- Gas is partially separated into gas-liquid two phases.
- Gas is further chilled by demethanizer overhead vapor stream.
- Extremely low temperature stream is obtained by letting down the pressure using turbo-expander.
- Ethane and heaviers are obtained by fractionation.

Schematic Diagram of Natural Gas Plant



Objectives

- Introduction to typical scheme for the natural gas processing plant
- Application of modified cubic equation of state with an appropriate alpha function and new mixing rules to the natural gas system

CO_2-rich System

- Carbon dioxide systems are both of academic and industrial interests because….

Academic Interests

- Even though there is no permanent dipole moment in CO_2, large quadrupole moment, which makes it difficult to predict the molecular interactions between CO_2 and other hydrocarbons. (Induced dipole)

Industrial Interests

- It has been also necessary to use CO_2-rich natural gas according to the increasing demands for usage of natural gas.

Typical Natural Gas Composition (Lean gas)

Component	Mole Percent
Nitrogen	0.106
Carbon dioxide	0.303
Methane	95.600
Ethane	2.361
Propane	0.862
I-Butane	0.195
N-Butane	0.218
Pentane Plus	0.430

Dipole Moment

Component	Dipole Moment
HF	1.910
KBr	9.070
H2O	1.840
NH3	1.470
CO2	0.000
CH4	0.000

Quadrupole Moment

Component	Quadrupole Moment
H_2	0.660
C_2H_2	3.000
C_6H_6	-3.600
H_2O	-3.000
NH_3	-1.000
CO	-2.500
CO_2	-4.300

Why Testing Ternary Systems?

- The ultimate goal of future thermodynamics is to predict multi-component phase behavior with pure component experimental information only, but is is still long way to go.
- The objective of modern thermodynamics is to correlate multi-component VLE or LLE with pure and binary experimental data only.

Testing Ternary Phase Behavior

- $N_2 + CO_2 + C_2H_6$
- $N_2 + CH_4 + C_2H_6$
- $N_2 + CO_2 + CH_4$
- N_2 and CO_2 systems are very important even though natural gas contains only small amounts.

Some significant developments in cubic equations of state

- Functional form:
  - To predict liquid phase density accurately
- The alpha forms:
  - To predict pure component vapor pressure vs. temperature accurately
- The mixing rules:
  - To predict mixture phase behavior more accurately

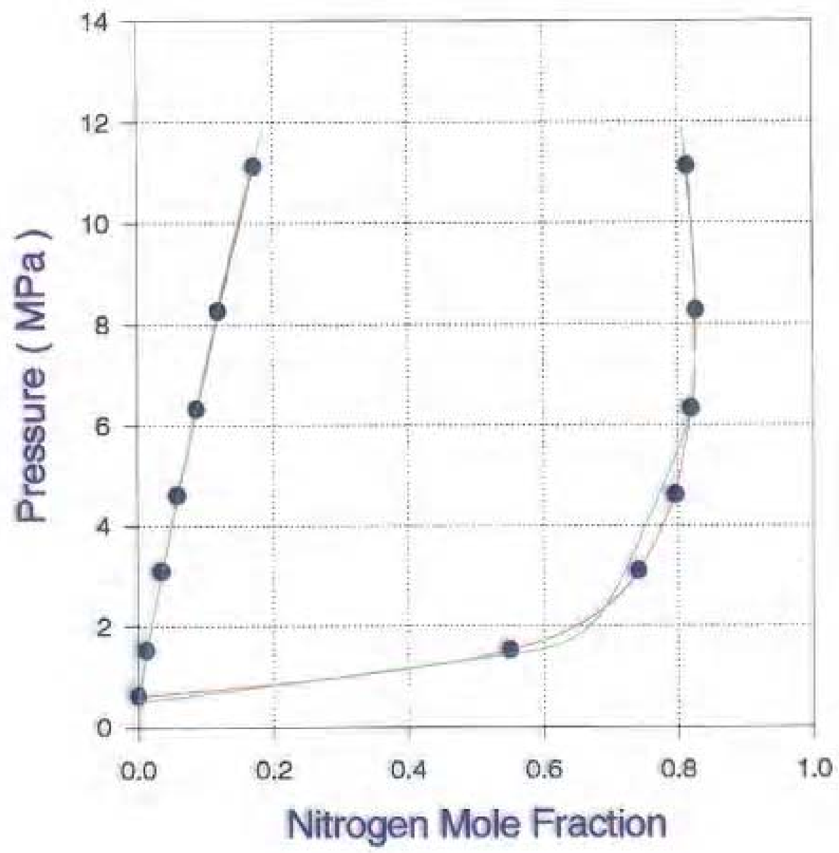
The equations of state formulations

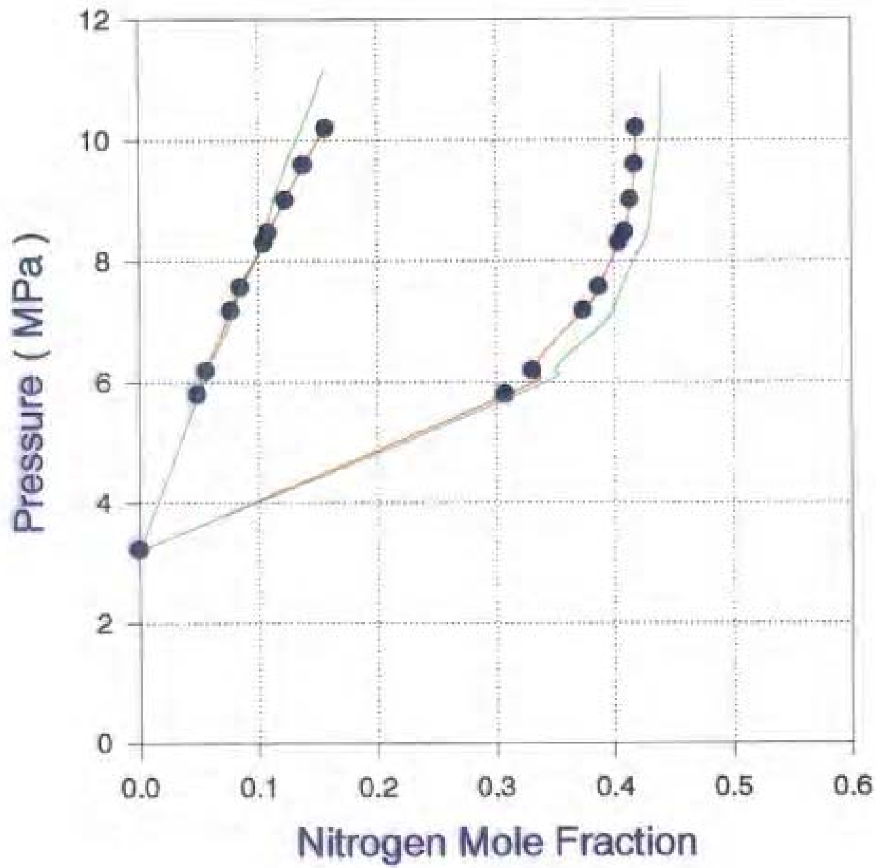
- Functional form is important for the liquid phase density calculations.
- The van der Waals (1873)
- Redlich-Kwong (1949)
- Soave-Redlich-Kong (1972)
- Peng-Robinson (1976)

Two-parameter Cubic Equation of State

- Any two parameter cubic equation of state is notorious for not being able to correlate the liquid density well since the critical compressibility factor is constant for all pure components.
- Z_c in vdw EOS is 0.3750.
- Z_c in RK EOS is 0.3333.
- Z_c in PR EOS is 0.3074.
- Experimental values for critical compressibility factor are 0.2880 for methane, 0.2840 for ethane and 0.2800 for propane.

Comparison of Mixing Rule 1 & 2 for N_2+CO_2 System at 220K & 270K





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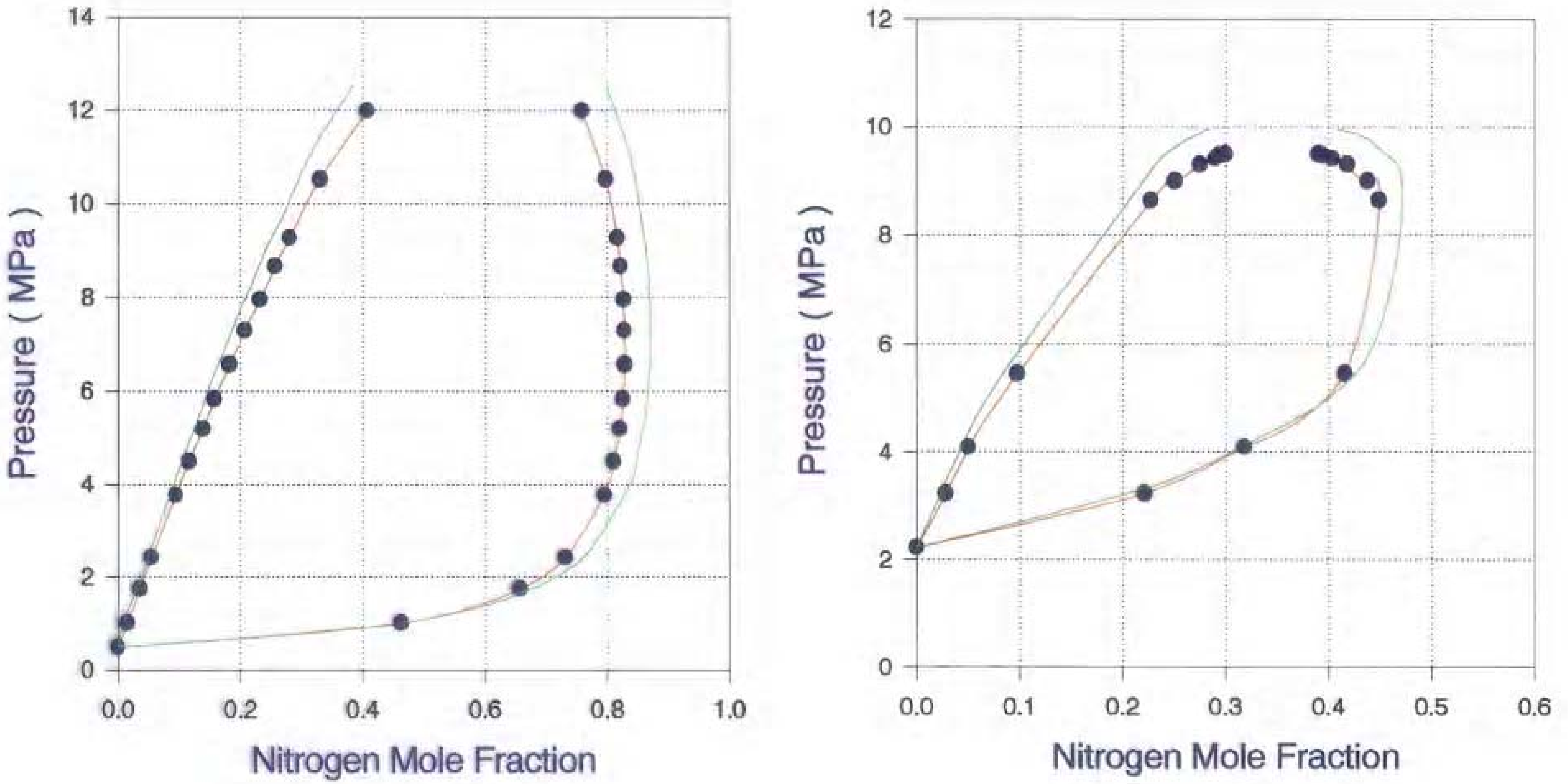
Comparison of Mixing Rule 1 & 2 for N2+C2 System at 220K & 270K



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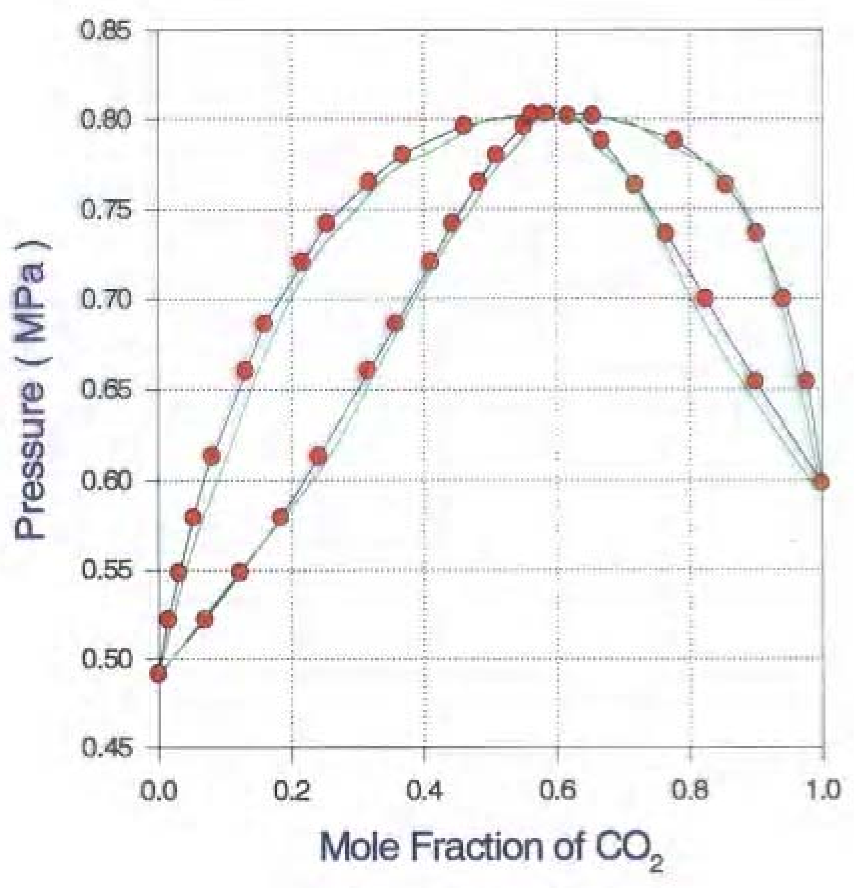
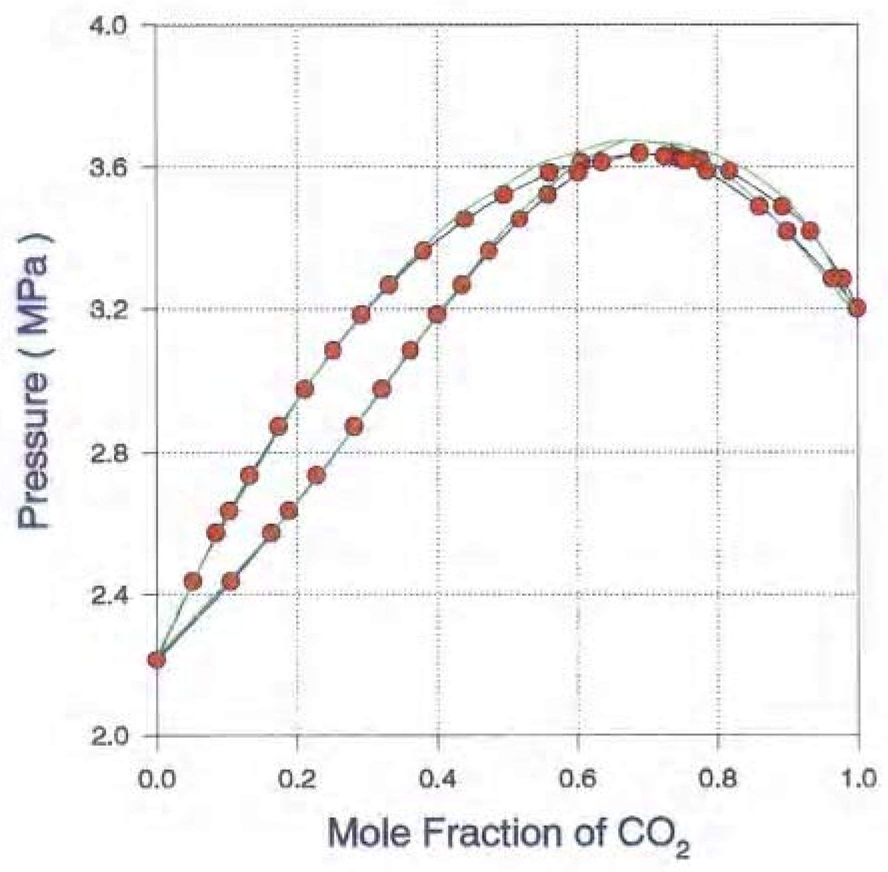
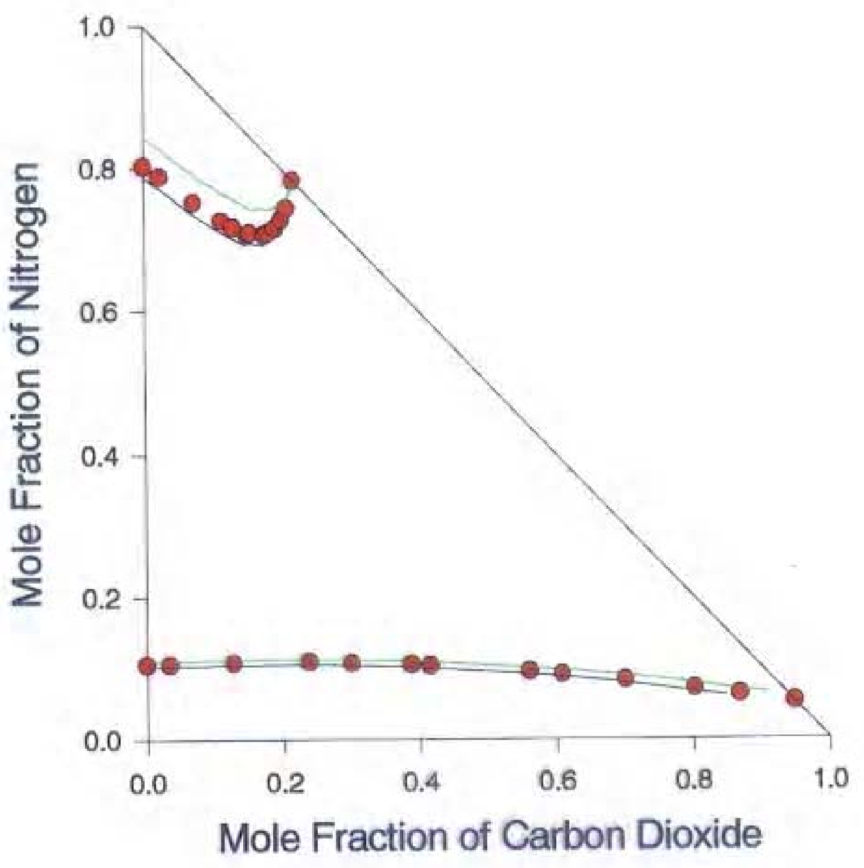
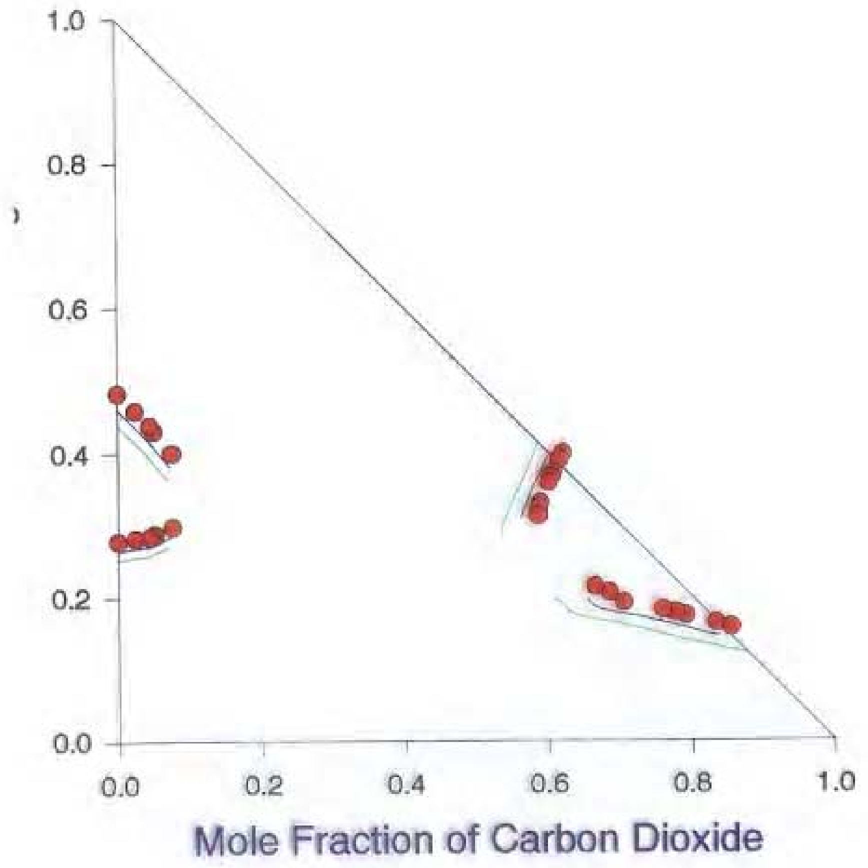
Comparison of Mixing Rule 1 & 2 for CO_2+C2 System at 220K & 270K





Comparison of Mixing Rule 1 & 2 for $CO_2+N_2+C_2$ System at 220K & 270K





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