PROJ 43/45 - DETERMINATION OF FUNDAMENTAL PROPERTIES OF GASEOUS MIXTURES OF INTEREST FOR THE GAS & OIL INDUSTRY IN THE PRESENCE OF COMPLEX FLUIDS (R&D LABORATORY FOR SUPERCRITICAL FLUIDS, OIL & NATURAL GAS)

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Research Centre for Gas Innovation

cleaner energy for a sustainable future

V RCGI WORKSHOP
University of São Paulo, Brazil
21-22 August 2018

Introduction: Project main ideas/goals

- **Determination of basic properties** (phase behavior/PVT*xy*, solubility, viscosity, pH, interfacial/surface tension) of gaseous mixtures of CH4/CO2 and other gases (ethane, H2S, N2, CO, H2, O2) of interest to the Oil & Gas Industry alone or in the presence of complex fluids (H2O/NaCl, crude oil), in a wide range of conditions (P, T and compositions);
- **Creation of a R & D laboratory specialized in supercritical fluids**, oil & natural gas, connected to other important research groups in the area in the world;
- **Capacitation of highly specialized human resources** in this area.

Introduction: Project main ideas/goals

R&D Laboratory will:

- **Generate original knowledge** in the area to further advance it;
- **Generate information necessary or provide technical support** to other projects in the CO2 abatement programme at RCGI (specially Proj 30 – CO2 conversion, Proj 34 – Salt caverns, Proj 39 – Supersonic separator, Proj 40 – Corrosion behavior scCO2) ;
- Prepare human resources in advanced techniques for this kind of study.

Introduction: Importance

CO2 abatement and several technological applications related to it, such as:

CO2 capture and storage (CCS),

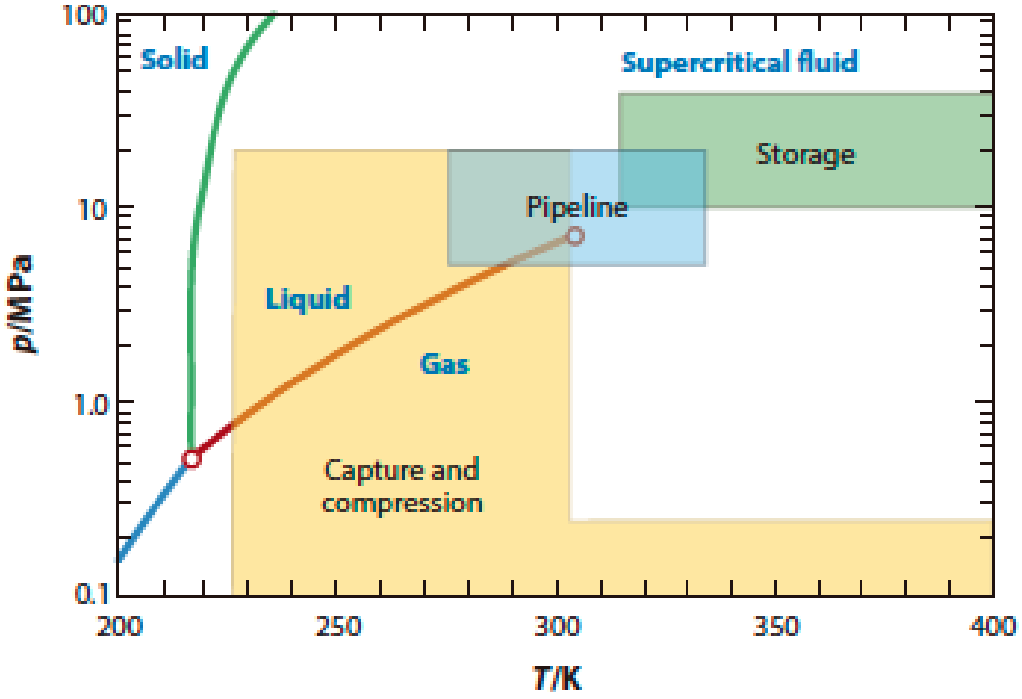
CO2 valuation/conversion,

Enhanced Oil Recovery (EOR) and others rely heavily on the knowledge of phase behavior.

Thermodynamic, transport and similar properties of CO2 and its mixtures with gases such as CH4, CO, N2, O2, H2, H2S, ethane, and other fluids such as water, brine, oil among others.

Introduction: Importance

Example: CCS



Mixtures components

- Carbon dioxide
- Diluents: N_2, O_2, CO, Ar, H_2
- Acid gases: H_2S, COS, SO_2
- Aqueous species: H_2O, amines, salts
- Hydrocarbons: gas, condensates, oils
- Others: NO_x, trace elements

Trusler, J.P.M., Annual Review of Chemical and Biomolecular Engineering, 2017. ***8****(1): p. 381-402*

Academic revision: phase behavior / PVT*xy* overview

- **Phase behavior properties** (PVT*xy* properties, critical points, densities and compositions of both liquid and gas phases) are very well known for pure CO2, CH4, and most of the gases of interest for CO2 abatement projects, at a wide range of P and T;
- **Equations of state** that model and simulate this phase behavior are also well developed for these pure compounds.

Academic revision: phase behavior / PVT*xy* overview

- **Data on binary mixtures of CO2** is also available for the most important ones (CO2/CH4, CO2/H2O and CO2/N2, and others), at a wide range of P, T and compositions;
- **There are a few gaps at high pressures and temperatures**, or for specific pressure/temperature combinations in some cases;
- **The development of equations of state** to model and simulate this behavior still has room to improve, especially in terms of the precision of the results.

Academic revision: phase behavior / PVT*xy* overview

- **Data on multicomponent mixtures of CO2**, on the other hand, are more scarce.

  Mixtures such as CO2/CH4/H2O, CO2/CH4/brine, CO2/CH4/N2 and others have been studied, but in a narrow range of pressures, temperatures and compositions.

- The **development of equations of state** precise enough for most applications can become challenging in these situations.

Academic revision: other properties overview

- **Data on mixtures of CO2 with oil and other complex fluids are very scarce** and restricted to swelling, minimum mixing pressures and other simpler to measure properties, at a narrow range of P, T and compositions;
- **Composition determination** are rare or non-existent, even for the gas phase;
- **Data on multicomponent mixtures of CO2** on these conditions are very scarce;
- *Model and simulation* of phase behavior in these conditions is very challenging

Academic revision: other properties overview

- **Other important properties such as solubility behavior** (gas solubilities, liquid solubilities for a component of interest), **transport properties** (viscosity, diffusion coefficients), **surface/interface properties** (interfacial and superficial tensions), **heat transfer properties** (heat capacities), **pH**, and several other follow the same pattern, with data available for the pure substances or binary mixtures of CO2, however the data available is not as widespread as it is for phase behavior, and in more limited conditions of P and T;
- **Data for multicomponent mixtures** is more scarce or unavailable.

Conclusions and way forward

i) **Establish a specialized laboratory** (equipment/trained personnel) to measure phase behavior and other properties of complex multicomponent mixtures of CO2 and other gases and complex fluids

- Fulfill knowledge gaps in the literature;

- Provide information for the other projects in the CO2 abatement program at RCGI on a continuous basis;

Conclusions and way forward

ii) **Interact with the other groups in the CO2 abatement program at RCGI** to identify their needs in the knowledge of experimental properties of CO2 and its mixtures at P, T and compositions not directly available in the literature, even when the systems are well known;

This can include properties for mixtures that or not in equilibrium (kinetics of dissolutions or phase transitions for especial cases, for example, salt dissolution in high pressure fluid mixtures with CO2);

Conclusions and way forward

iii) **Measure phase behavior** (PVTxy properties), densities, viscosities and pH (when possible) of multicomponent mixtures of CO2 and other gases of interest.

Fulfill knowledge gaps in the literature;

Provide information for the other projects in the CO2 abatement program at RCGI.

Conclusions and way forward

iv) Measure interfacial properties of mixtures of CO2 and other gases and fluids at high pressures.

Fulfill knowledge gaps in the literature;

Provide information for the other projects in the CO2 abatement program at RCGI.

v) Measure interfacial properties of mixtures of CO2 and other gases and fluids at high pressures.

Fulfill knowledge gaps in the literature;

Provide information for the other projects in the CO2 abatement program at RCGI.

Conclusions and way forward

Vi) Evaluate the possibility of modelling and simulating the properties measured for those complex systems.

Fulfill knowledge gaps in the literature;

Provide information for the other projects in the CO2 abatement program at RCGI;

vii) Build database of properties.

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