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ASRL CORE RESEARCH PROGRAM ***2019 - 2020***

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[] denotes leveraged research through grant funds.

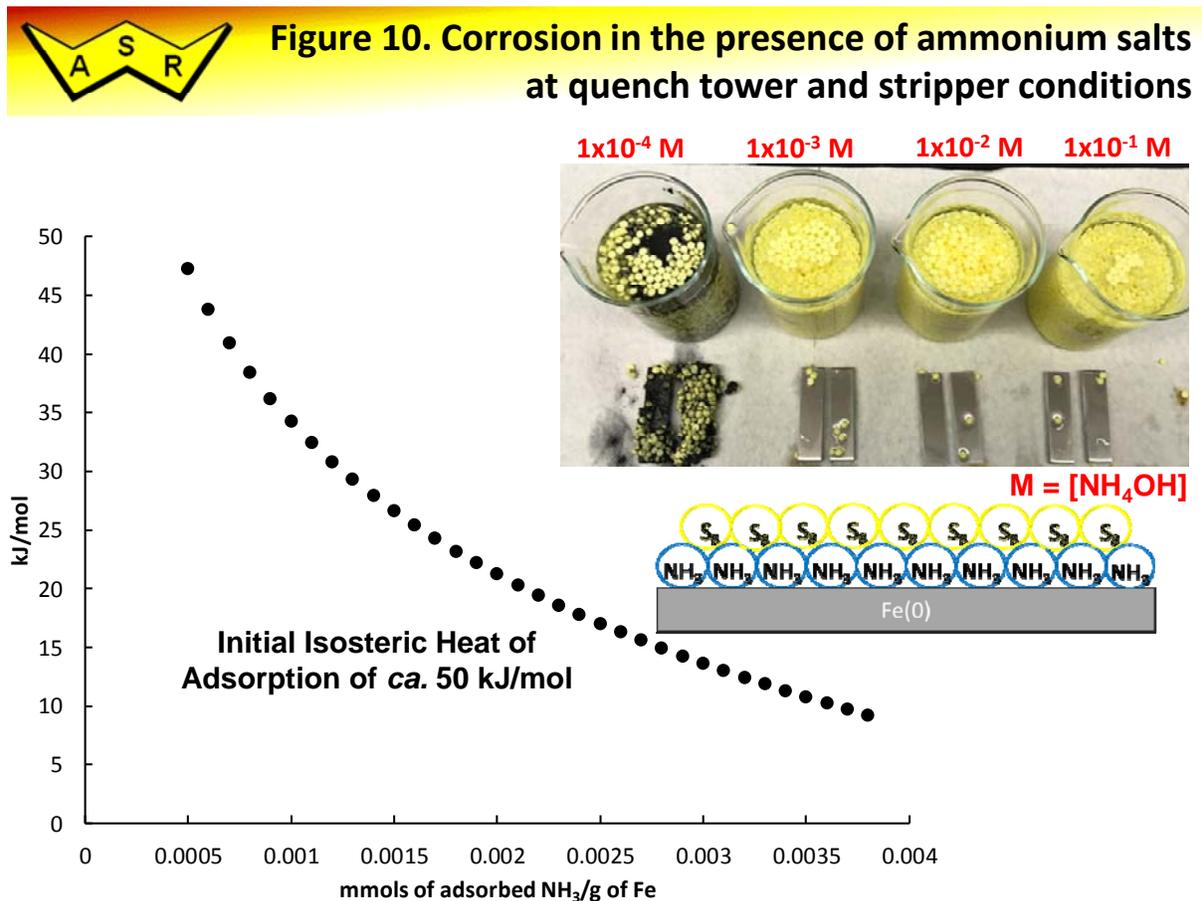
CRP 1. Corrosion and the presence ammonium salts in quench tower and stripper conditions

Commercial Objective: To demonstrate applications that exploit the corrosion inhibition and sulfur solubility properties of NH_3 and weakly concentrated ($< 2 \text{ wt}\%$) $\text{NH}_3/\text{NH}_4^+$ based solvents

Project Description: Recent ASRL research revealed that $\text{NH}_3/\text{NH}_4^+$ based solvents could potentially be quite versatile with respect to the corrosion inhibition and sulfur solubility properties such solvents exhibit. Currently, we suspect NH_3 acts to inhibit corrosion of carbon steel by forming a chemically adsorbed protective monolayer on its surface. Upon these realizations, a number of scenarios related to sulfur recovery came to mind in which these findings could be applied in a beneficial and cost saving way. In this context, several situations we will be investigating are listed below in the specific objectives.

Specific Objectives

- Assess what influence the presence of NH_3 has on high temperature sulfidation
- Simulate SO_2 breakthrough to quench tower with $\text{NH}_3/\text{NH}_4^+$ present/absent and examine effect on corrosion
- Perform sulfur solubility studies at increased pressure and in a sour environment
- Further study the mechanism of inhibition in an aqueous environment



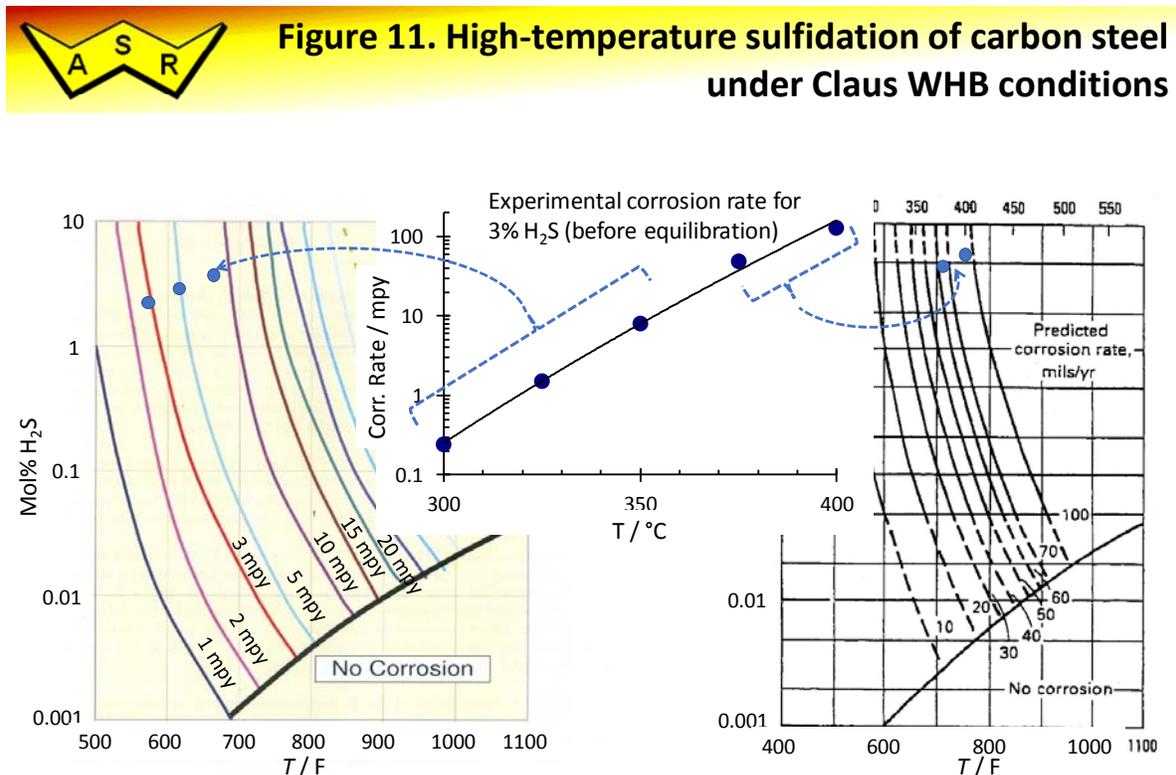
CRP 2. High-temperature sulfidation of carbon steel under Claus waste heat boiler conditions

Commercial Objective: To prepare ASRL curves for estimating corrosion rates from high-temperature sulfidation under Claus waste heat boiler (WHB) conditions

Project Description: The current design criteria for the maximum metal temperature of a WHB tube sheet is based on the published Couper-Gorman curves or modified versions of these curves, which were originally derived for sulfidic corrosion in refinery hydroprocessing operations. Prior to our recent research in this area, there was a lack of experimental data specifically related to high temperature sulfidation of carbon steel within a Claus environment. To that end, our initial findings do indeed support the existing recommendation of a maximum metal skin temperature of 600 °F (343 °C); however, below 350 °C our results match decently with the modified Couper-Gorman curves but at higher temperatures, up to 400 °C, our data is more in line with original Couper-Gorman curves. Currently, we don't have a good explanation for this transition. In moving forward with this research, the aim will be to collect sufficient data to prepare our own predictive curves that can be referenced over the entire temperature range of 300 °C to 400 °C.

Specific Objectives

- Populate our initial curve with more data points, repeat some conditions that were tested, and look at influence that length of experiment has on results
- Perform more experiments in the temperature range of interest with different H_2S/S_x concentrations (6 temperatures with 3 lower H_2S concentrations)
- Perform an experiment with 1% H_2S and 10% CO_2 for molecular sieve regeneration conditions (will these line up with the Claus system?)



CRP 3. BTX destruction in the thermal oxidizer

Commercial Objectives: To understand the conditions required for destruction of BTX in the Claus thermal oxidizer

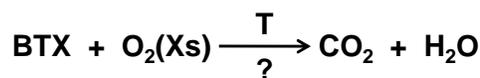
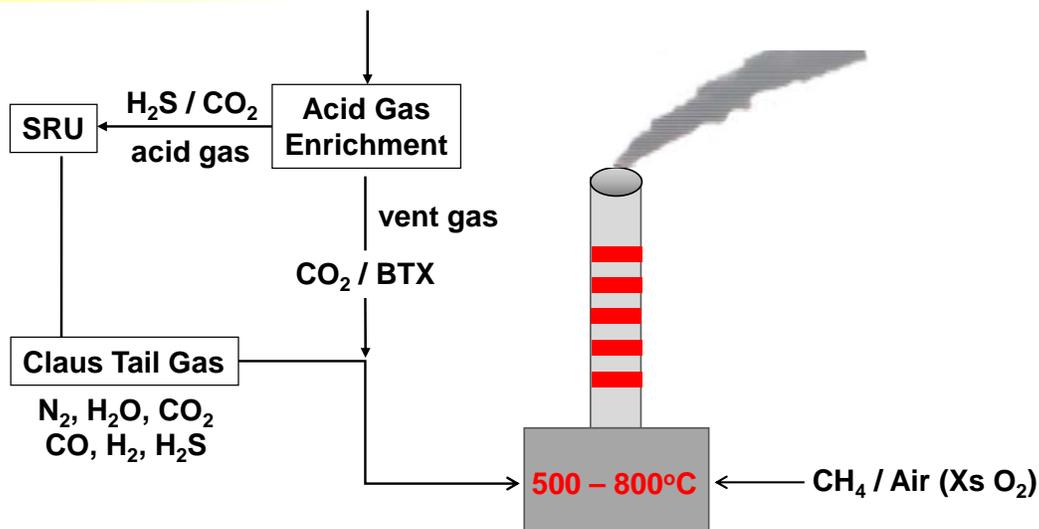
Project Description: While the primary purpose of the Claus thermal oxidizer is to oxidize residual sulfur compounds, such as H₂S, COS, CS₂ and S vapour, certain situations may require the destruction of other components not normally associated with this unit. This includes both NH₃ and BTX which may form part of a stream that is routed to the thermal oxidizer, separate from the tail gas. In the case of BTX this can occur with acid gas enrichment (AGE), where the treated or vent gas is routed to the thermal oxidizer.

We have already looked at BTX components individually and found that complete destruction can be obtained at 700 °C with a residence time of 1.4 s. However, the partial combustion products (i.e. CO and H₂) require higher temperatures (800 °C) to be fully oxidized. Future work for this project will involve experiments with all components as part of the feed in addition to quantifying residual BTX levels if a residence time of 0.5 s is unavoidable (i.e., a heat exchanger can be present directly after combustion chamber).

Specific Objectives

- Perform experiments with all three BTX components to see if conditions required for complete combustion are different from experiments with individual components
- Quantify residual BTX levels if a residence time of 0.5 s is unavoidable

 **Figure 1. BTX destruction in the thermal oxidizer**



Temperature / res. time required for complete destruction of BTX

CRP 4. Ammonium salt vapour pressure under Claus conditions

Commercial Objectives: To explore the vapour pressure equilibria for ammonium salts which may deposit in the Claus plant

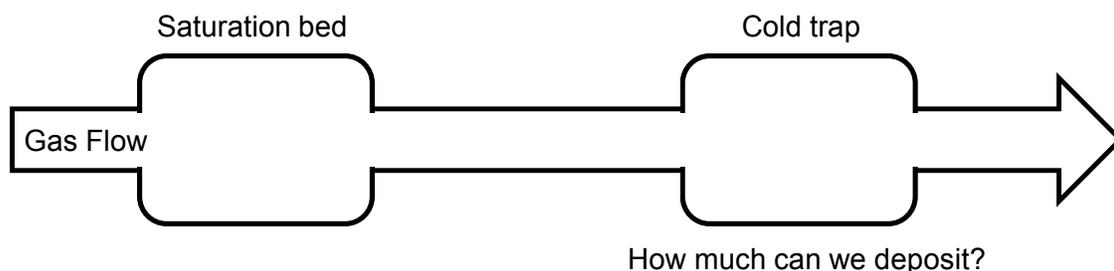
Project Description: Apart from the ammonia destruction and potential ammonia formation, the quantity of ammonia which can be tolerated before deposition occurs still requires some understanding. Assuming that ammonia in a Claus stream is not supersaturated (in the gas phase) solids should not form until the concentrations are above the vapour product equilibrium constant ($K_p = P_{\text{NH}_3} P_X$). These equilibrium conditions are well known for sulfide salts (sour water stripper gas); however, they are less defined for other ammonium salts, e.g., $(\text{NH}_4)_2\text{S}_2\text{O}_3$, $(\text{NH}_4)_2\text{SO}_3$, or $(\text{NH}_4)_2\text{SO}_4$. In this study we will be looking at very low vapour pressures, by moving gaseous species from an ammonium salt bed to a cold trap. This should enable us to pinpoint the conditions for salt deposition with and without other Claus species present. A literature review showed that the sulfate salt has some published data; however, quantitative studies do not agree.

Specific Objectives

- Measure the vapour pressure of three salts from 90 – 130 °C and build equilibrium constants
- Verify the function of the equilibrium constants in a full Claus gas

Figure 15. Ammonium salt vapour pressure under Claus conditions

Ammonium salts observed in lines leading to the incinerator



CRP 5. Investigating ammonia formation in amine units

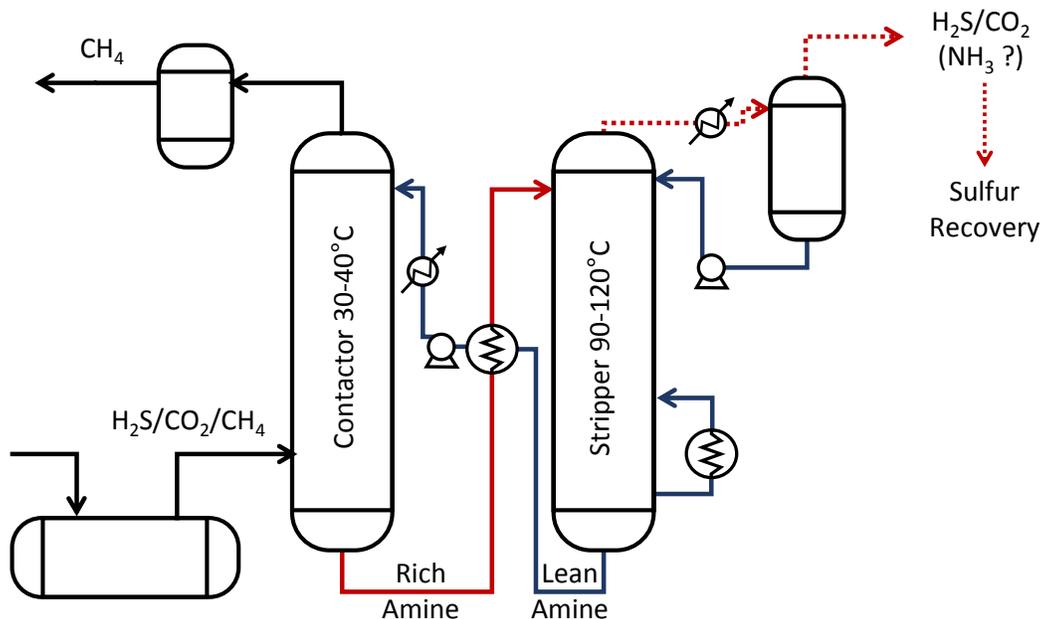
Commercial Objective: To determine ammonia formation during amine degradation in sour service

Project Description: Over the past 7 years ASRL has investigated amine degradation mechanisms under sour gas sweetening conditions. While other groups have investigated the formation of NH_3 during amine degradation with CO_2 and/or oxygen, the evolution of ammonia during the regeneration of alkanolamines under sour service has not been thoroughly explored. As ammonia will follow the acid gas and find its way into the Claus process, we will be exploring ammonia formation rates for primary, secondary and tertiary amines in the presence of sour gas. This may provide a plausible explanation for the accumulation of ammonia in gas plants. An extension of this study will include the presence of small amounts of elemental sulfur and/or other impurities (e.g., bicine and $\text{Fe}^{2+}/\text{Fe}^{3+}$ from corrosion products).

Specific Objectives

- Reproduce ammonia formation results at for MEA in the presence of CO_2 (contactor conditions) to verify agreement with literature
- Investigate ammonia formation under regenerator/reboiler conditions for MEA, DEA, DGA and MDEA with and without degradation products

 **Figure 6. Investigating ammonia formation in amine units**



Amines for testing include: MEA, DEA, DGA and MDEA.

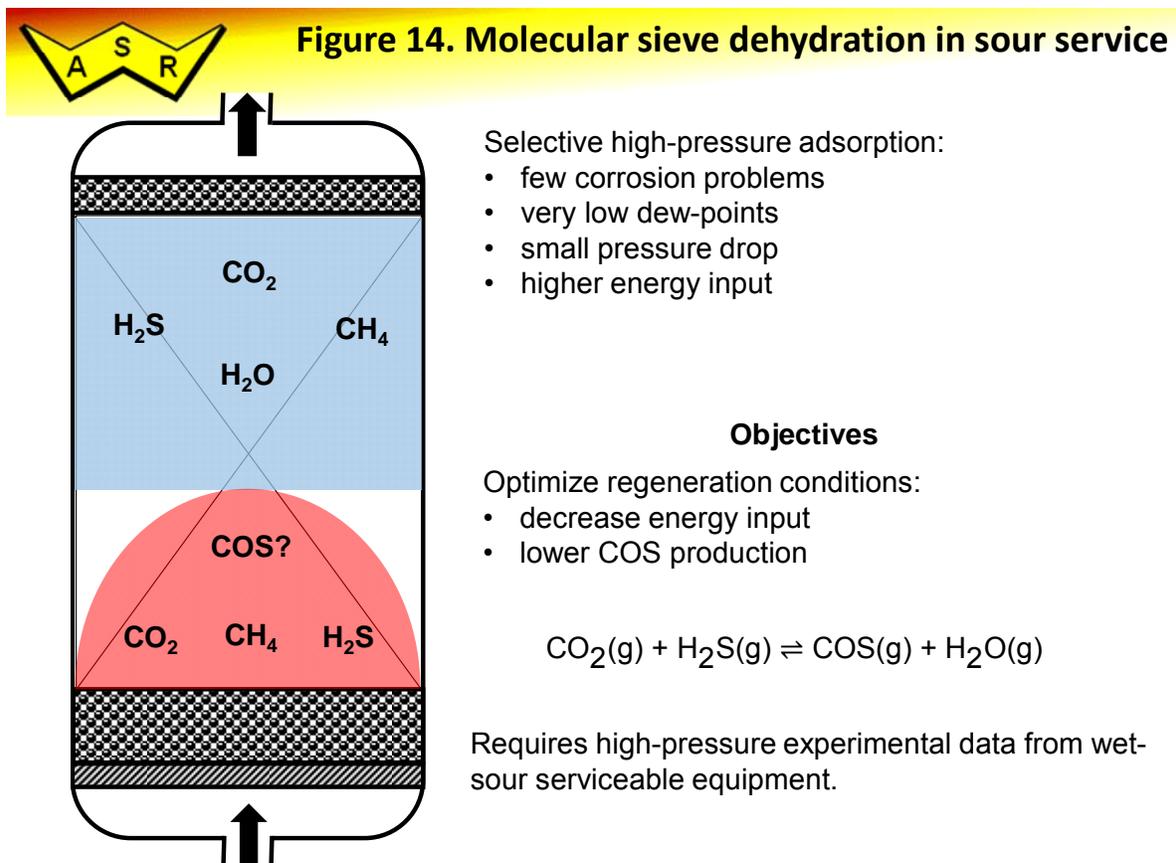
CRP 6. Molecular sieve dehydration in sour service [NSERC ASRL IRC Funding]

Commercial Objectives: To provide reference quality information for simulation/design of molecular sieve dehydration

Project Description: Molecular sieves are used for dehydration of sour gas which is produced in remote locations, where gathering and transport lines are protected from corrosion and hydrate issues. In addition, the liquefaction of natural gas requires deep dehydration which is also achieved with molecular sieves. Robust multicomponent adsorption models are required to optimize the thermal regeneration of these processes for several reasons, *e.g.*, COS formation can occur upon over-stripping an adsorbent and adsorbent degradation can occur when stripping is aggressive. In the past 7 years, this laboratory has built multiple high-pressure adsorption instruments which can handle H₂S, COS, CO₂ and other natural gas contaminants. High-pressure adsorption isotherms for pure and mixed fluids have been measured for calibration of reference quality models. These models are now being used to simulate bed cycling and optimization under sour gas conditions. This research is funded through NSERC-ASRL IRC grant program.

Specific Objectives

- Report measurements/models for pure fluid isotherms on silica gel [addition to Zeolite 13X and 4A]
- Report reference multicomponent modelling efforts with multicomponent bed measurements
- Report bed simulation results with dew-point versus regeneration temperature for various molecular sieve materials
- Perform extended cycling tests for adsorbent degradation on zeolite 13X, 4A and silica gel
- Investigate in the influence of pore size on silica gel absorption modelling



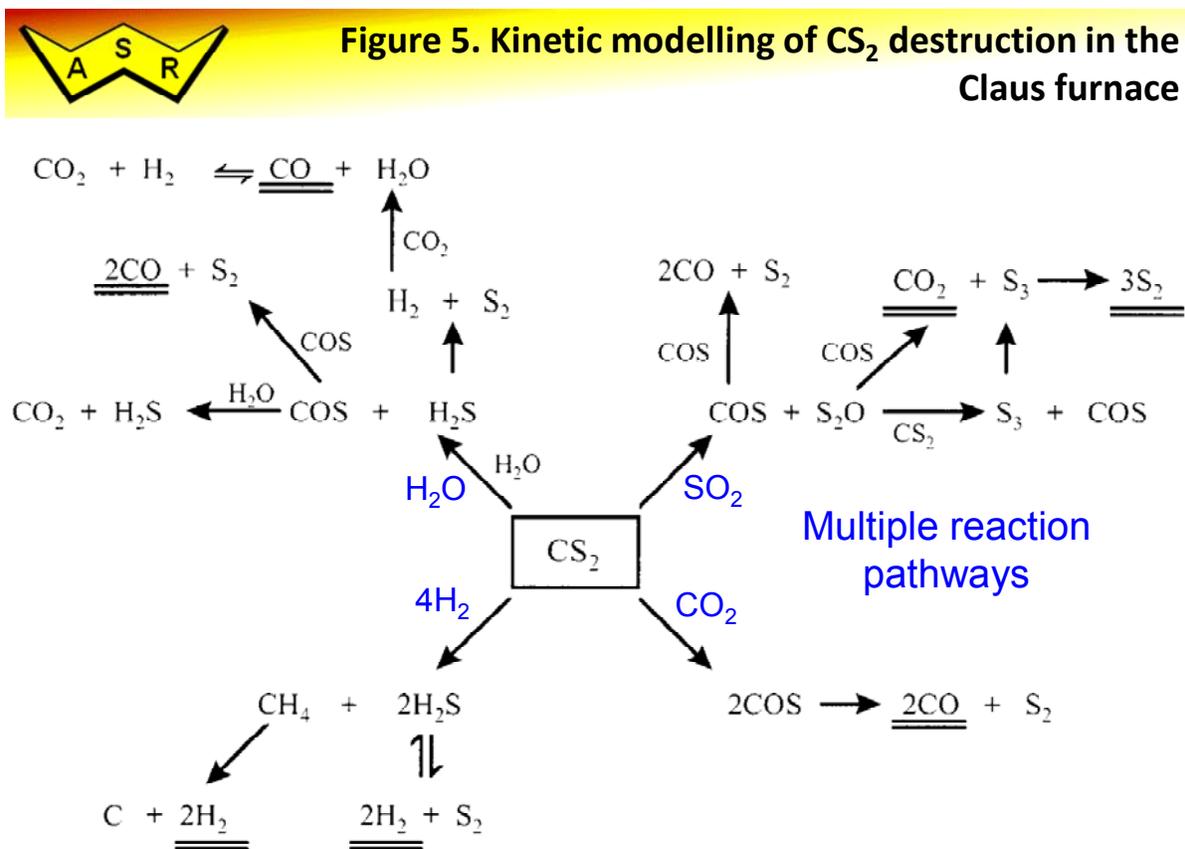
CRP 7. Kinetic modelling of CS₂ destruction in the Claus thermal reactor

Commercial Objective: To obtain experimental data that can be used to build a kinetic model for the Claus furnace

Project Description: In order to build a comprehensive rate based model of the Claus furnace, kinetic expressions for formation and conversion of all species are required. Recently, we have analyzed laboratory data for CS₂ conversion under several sets of conditions and deduced rate expressions for these data. Using simple reactant mixtures (CS₂ + H₂O and CS₂ + SO₂) and short residence time experiments, the initial rate method was employed to deduce these expressions. However, longer residence time experimental data, especially at temperatures exceeding 1,000°C, suggest a complex mechanism for CS₂ destruction (Figure 4). In these cases, the rate expressions obtained from the short residence time data will not describe the system accurately. The overall objective of this program of research is to collect kinetic data for CS₂ destruction using full Claus feed acid gas mixtures at typical operating conditions.

Specific Objectives

- Using full Claus acid gas feeds (low and high CO₂), determine the kinetics of CS₂ destruction at 900, 1000, 1100 and 1200°C



CRP 8. Formation of H₂S in shale gas reservoirs [NSERC Discovery Grant]

Commercial Objective: To better understand the delayed souring of shale gas reservoirs

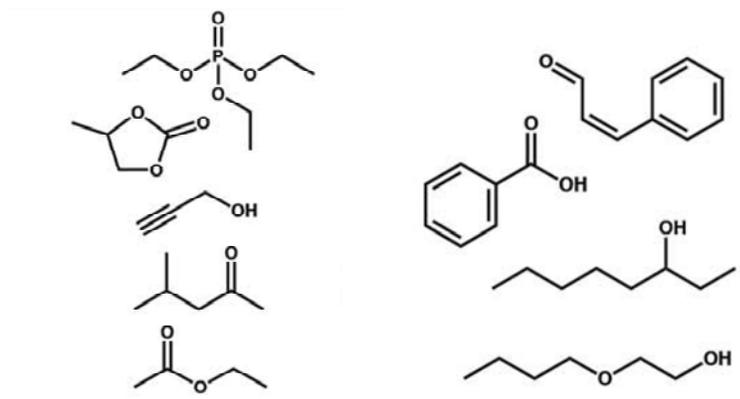
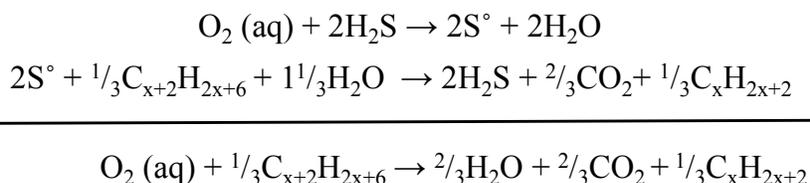
Project Description: During the early evaluation of a shale gas fluid, H₂S is often found in very small and sometimes negligible quantities; however, after some time (months) of production, H₂S and thiol concentrations can increase and often show inconsistencies when compared to the early flow test results. While several mechanisms for reservoir souring can be considered, we have been exploring the delayed souring of shale gas fluids through reactions involving fracture fluid additives (with and without sulfur in their structure). Laboratory studies demonstrated that native sulfide can be initially reduced and H₂S is reproduced over a long period of time through the sulfur oxidation of fluid additives. For the 2019/2019 year, the program will wrap up by reporting some studies for the 10 most common fracture fluid additives and three biocides containing elemental sulfur. This work is being supported by an NSERC discovery grant program.

Current Specific Objectives

- Thermodynamic and kinetic modelling is ongoing
- Report degradation rates for three common sulfur-containing biocides
- Study the delayed H₂S production through oxidation of the 10 most common fracture fluid additives



Figure 2. Delayed H₂S production with common fracture fluid additives at 150°C, 140 bar and pH = 2



CRP 9. More on BTX destruction

Commercial Objective: To further elucidate the mechanism of BTX destruction over Claus catalysts

Project Description: Previous research at ASRL revealed a likely mechanism for BTX destruction over Claus catalysts involving reaction between catalyst Brønsted acid sites and BTX to form coke and/or carsul species (ASRL QB Vol. L1 No. 2). However, recent laboratory observations suggest reaction with SO_2 might also be a pathway for the destruction of BTX. When flowing a typical direct oxidation feed with BTX added as a contaminant over a TiO_2 catalyst, it has been seen that SO_2 concentration in the product stream falls significantly below the predicted calculated equilibrium value. This work will aim to provide a more complete understanding of the mechanism for BTX destruction and potentially facilitate in the design of new generation catalysts.

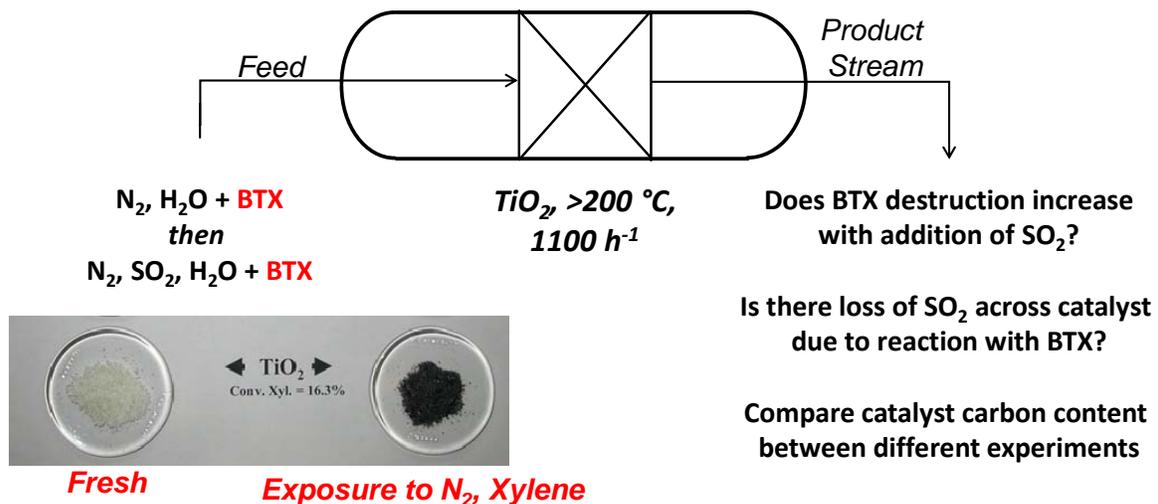
Specific Objectives

- Introduce different reactants to the feed in a stepwise manner to isolate all possible pathways for BTX destruction in a Claus environment with an emphasis on reaction with SO_2



Does BTX Also React with SO_2 over TiO_2 ?

Initial Test Experiment(s)



Project could potentially result in a more complete understanding of BTX destruction over TiO_2

ASRL QB Vol. L1 No.2

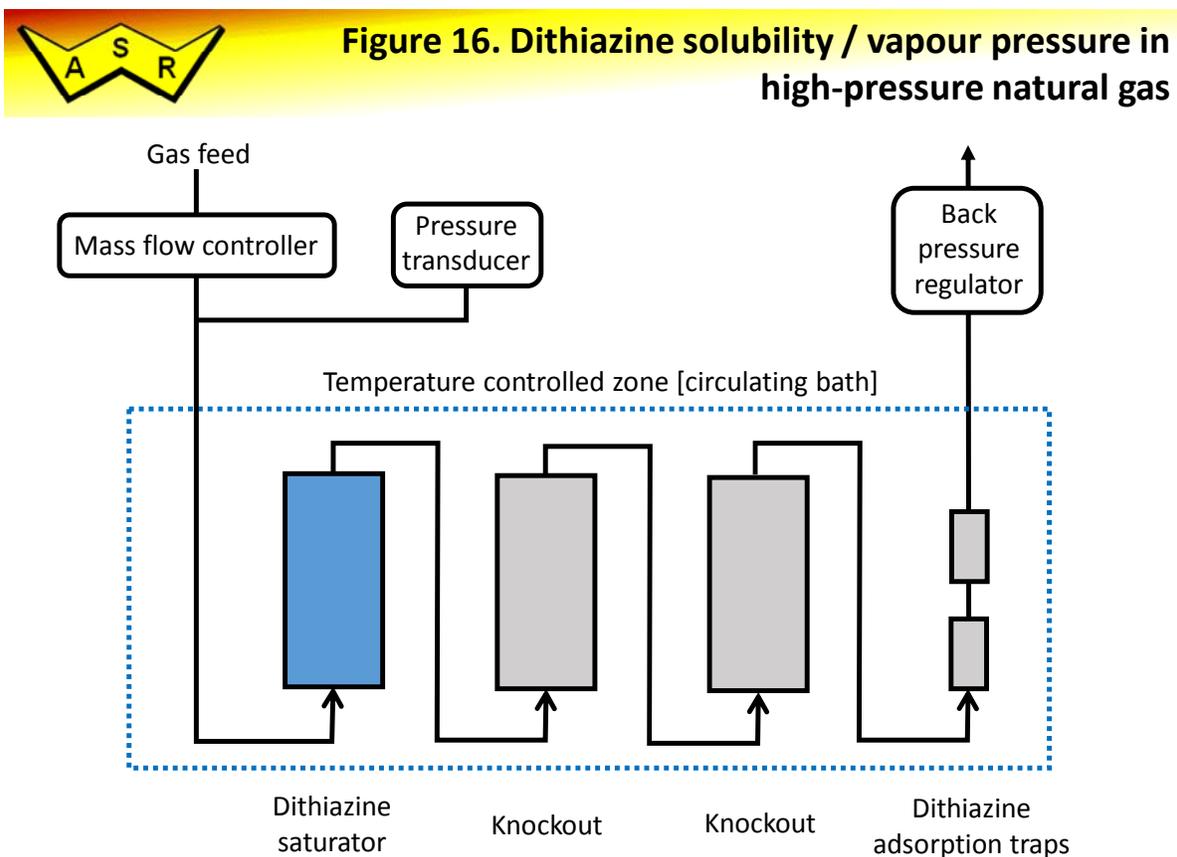
CRP 10. Dithiazine solubility / vapour pressure in high-pressure natural gas

Commercial Objective: To provide an applicable model for understanding dithiazine fluid phase equilibria and the potential deposition of solids within sales gas lines

Project Description: While triazine scavengers are effective at removing low-levels of H_2S , the resultant dithiazine product can have a small vapour pressure, whereby dithiazine can be dissolved in the gas and transported downstream. Upon reaching cooler temperatures, a dithiazine saturated fluid may deposit solid and potentially foul equipment. In order to understand saturation conditions, ASRL will be measuring the saturated vapour pressure of dithiazine under natural gas transportation conditions. Data will be used to calibrate a solubility model which can be used in pipeline or process simulation.

Specific Objectives

- Measure dithiazine using a low-flow saturation bed and amberlite XAD-2 adsorbent traps [CH_4 , C_2H_6 and C_3H_8 ; $p < 200$ bar; $T = 0, 15$ & $25^\circ C$].
- Calibrate a solubility model based on infinite dilution fugacity coefficient correlation.



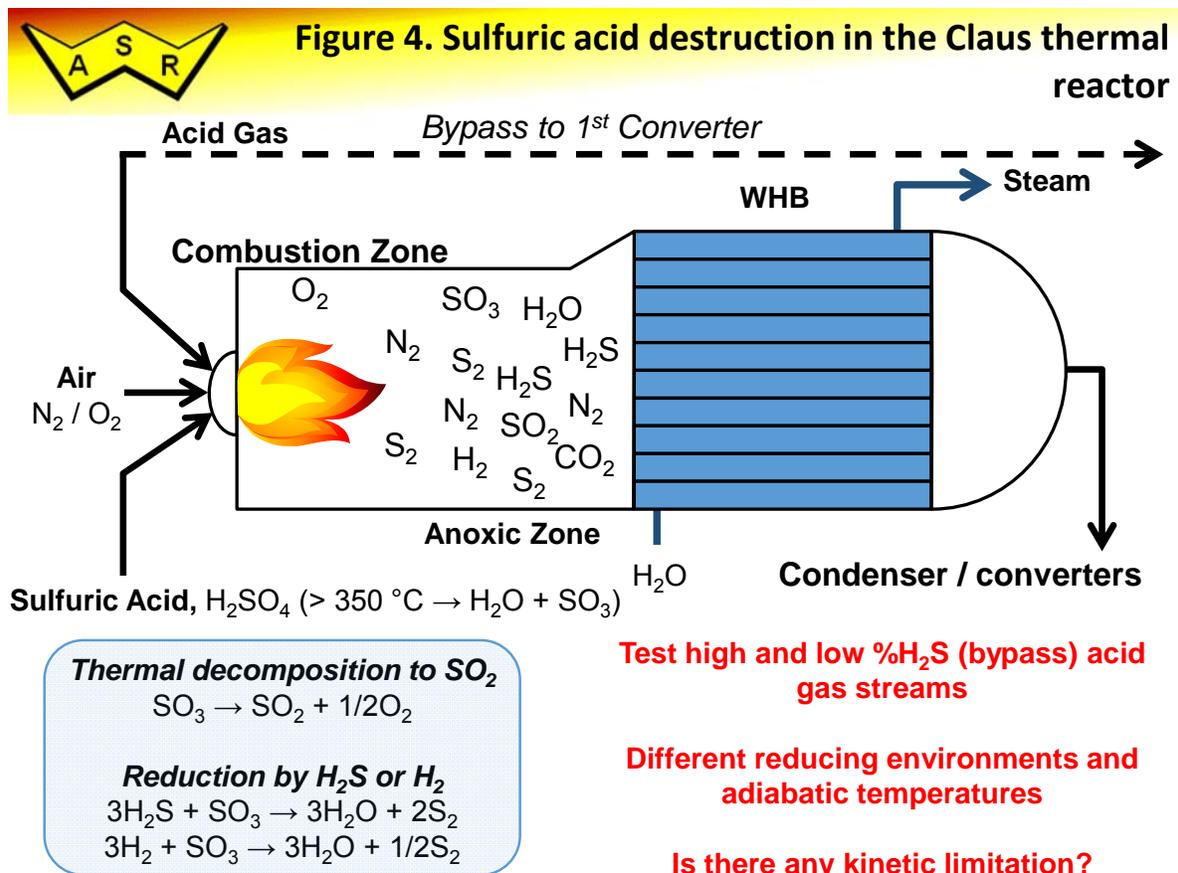
CRP 11. Sulfuric acid destruction in the Claus thermal reactor

Commercial Objective: To study feasibility of destroying sulfuric acid within the Claus thermal reactor

Project Description: One method for dealing with waster sulfuric acid streams is through destruction in the Claus thermal reactor (recovery). Above 350 °C, H₂SO₄ completely dissociates to H₂O and SO₃. At typical furnace temperatures, equilibrium predicts a high conversion of SO₃ to SO₂ and ½O₂ by thermal dissociation. It is presumed that the remaining SO₃ will readily undergo reduction by H₂S or H₂ to form more H₂O and elemental sulfur. Therefore, we suspect that sulfuric acid destruction within the Claus thermal reactor will be a facile process. However, laboratory experimental data supporting this transformation under such conditions is scarce. In this context, this project will aim to study the kinetics of sulfuric acid destruction within the thermal reactor under a variety of different Claus process conditions, residence times and temperatures.

Specific Objectives

- Kinetic investigation of sulfuric acid destruction in the Claus thermal reactor using two different feeds (backing out O₂ when adding H₂SO₄)
- Define the minimum destruction temperature at 0.5 seconds residence time.



CRP 12. Kinetics of CS₂ and COS hydrolysis under Claus converter conditions

Commercial Objective: To further elaborate on our initial kinetic data for CS₂ and COS conversion over Claus catalysts

Project Description: While employing typical first converter conditions, we have determined the standard kinetic Arrhenius parameters, E_a and A , for CS₂ and COS hydrolysis over commercially available Al₂O₃ and TiO₂ catalysts. Future work in this area could involve the inclusion of several other commercial Al₂O₃ and TiO₂ catalysts to investigating the influence of catalyst macroporosity.

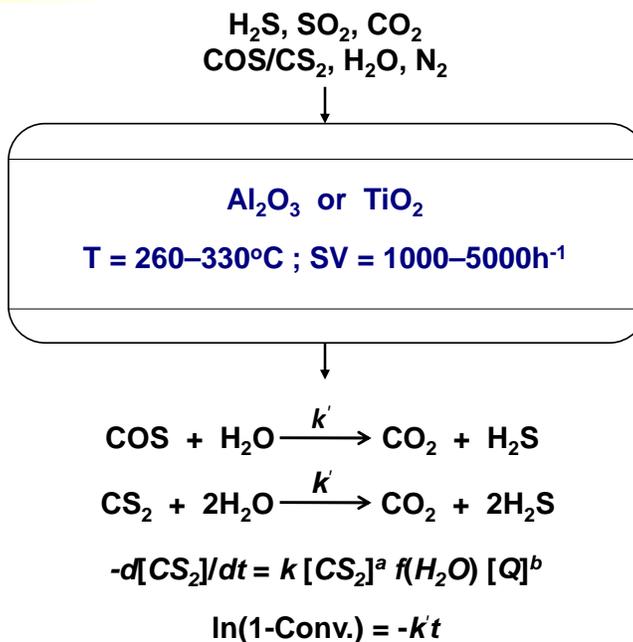
We have recently reported on the enhanced performance provided by novel TiO₂ nanofibers that have been developed in our lab. While interesting from a fundamental perspective, the application of such nanofibers in a Claus catalytic converter is unlikely. However, we have deposited TiO₂ nanofibers on an Al₂O₃ support and will be investigating if these new hybrid catalysts offer any reactivity benefits for CS₂ and COS hydrolysis under Claus conditions.

Specific Objectives

- Potentially extending study to include several commercial catalysts and reporting an average E_a and A for CS₂ and COS hydrolysis with a defined standard deviation
- Investigating relationship, if any, between catalyst macroporosity and activity for CS₂/COS hydrolysis
- Testing a new hybrid catalyst that consists of TiO₂ nanofiber that have been deposited on an Al₂O₃ support



Figure 17. Kinetics of CS₂ and COS hydrolysis under Claus converter conditions



Arrhenius kinetic parameters E_a and A have been established – more work needed

CRP 13. Sulfur solubility in natural gas liquids

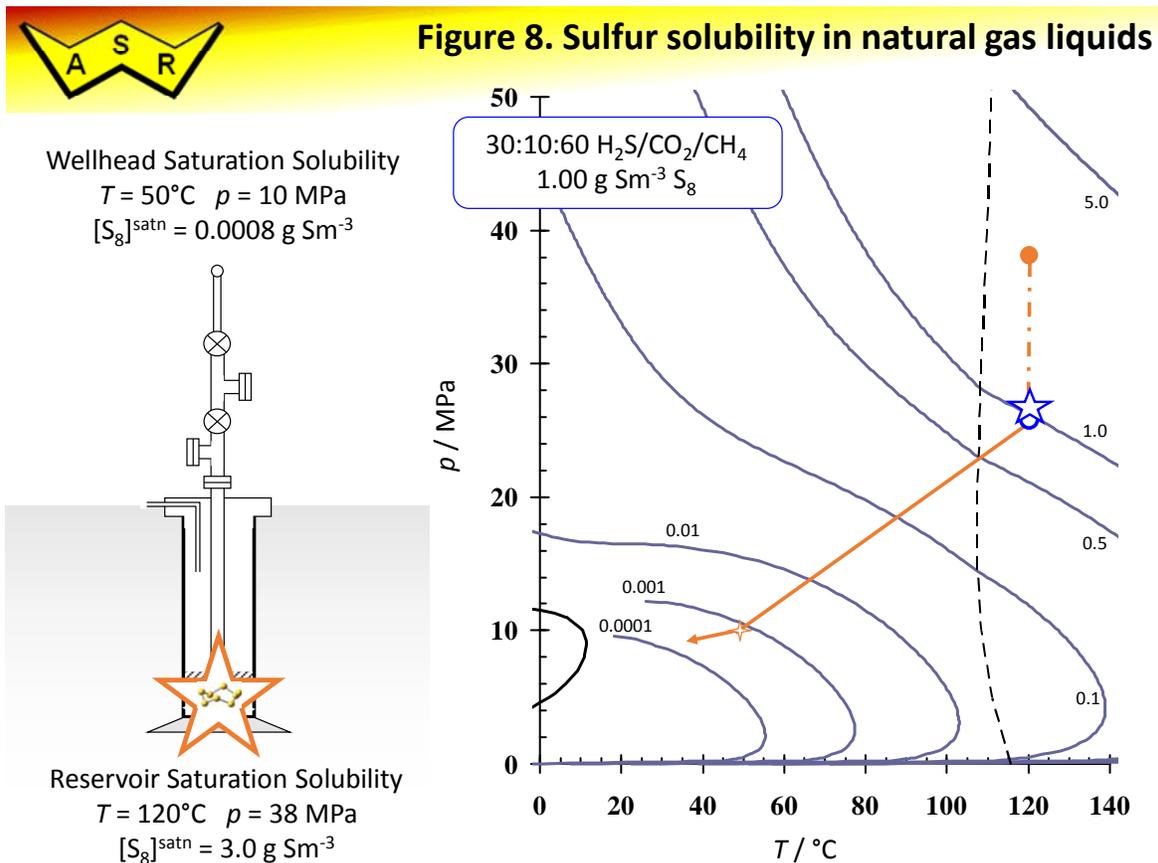
Commercial Objective: To update the ASRL sulfur solubility model to handle rich sour gas fluids, *i.e.*, fluids containing condensable hydrocarbons

Project Description: ASRL has maintained a robust sulfur solubility model for many years. Depositable sulfur can be native to a sour gas reservoir when the reservoir contains only methane and very little C_{2+} , or can be generated through the oxidation of H_2S in produced fluids. In the case of natural gas liquids, oxidation of H_2S may produce enough elemental sulfur to exceed the solubility within surface operations. In the case of reservoir sulfur, stabilized condensate can be used as a low-cost sulfur solvent. For both of these cases, our current sulfur solubility model is not robust with significant levels of C_{2+} or natural gas liquids.

In order to better accommodate condensable hydrocarbons in the ASRL sulfur solubility model we will require high-pressure experimental data in natural gas liquids, such as propane. In order to incorporate the high-density fluids (liquid or supercritical), we intend on updating the model to a more robust correlation used in the previous work by Lee and Marriott (2018).

Specific Objectives

- Measure sulfur solubility in ethane and propane for $T > 25^\circ\text{C}$ and $p < 30$ MPa.
- Recalibrate the ASRL sulfur solubility model using a fluctuation solution theory correlation, see Lee and Marriott (2018).
- Test the correlation by measuring the sulfur solubility in a synthetic rich sour gas fluid.



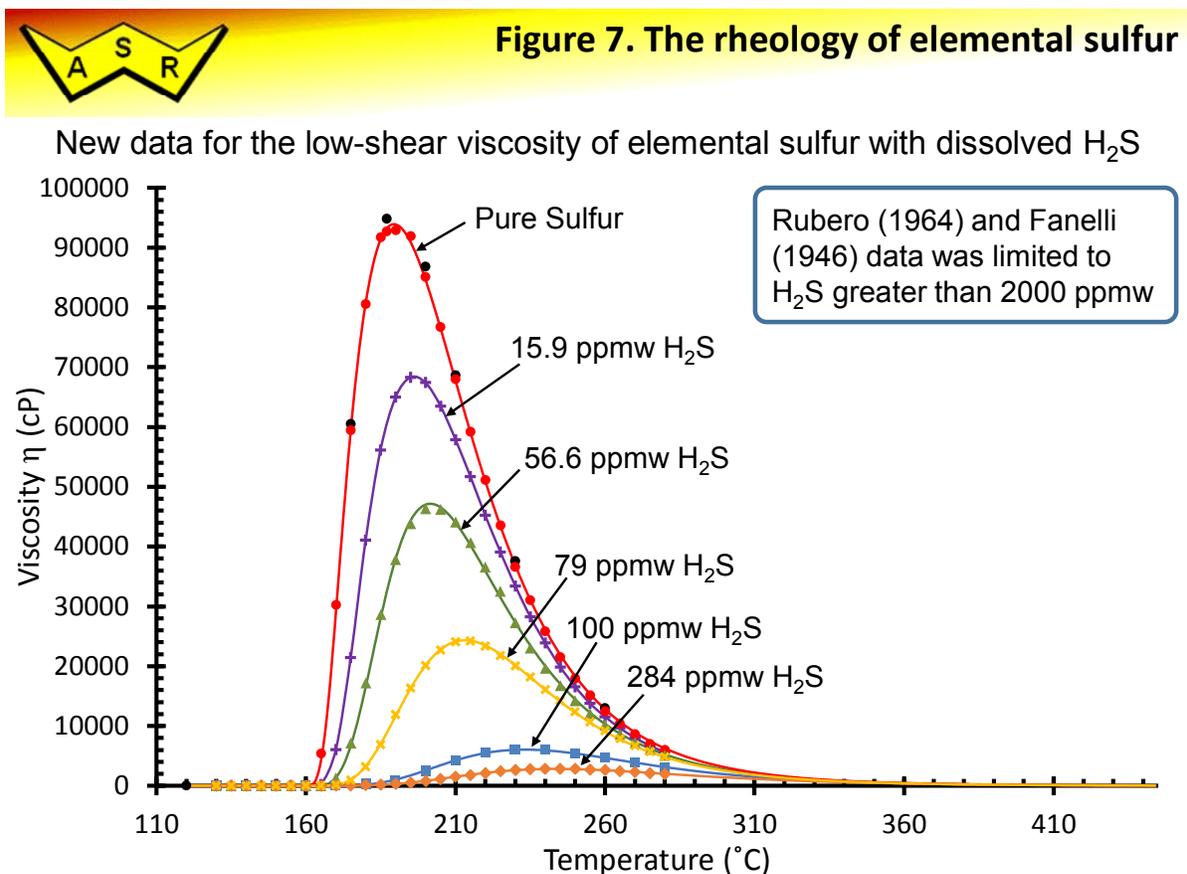
CRP 14. The Rheology of elemental sulfur [NSERC ASRL IRC Funding]

Commercial Objectives: To define the shear dependency for the viscosity of elemental sulfur for (i) the engineering/operating of sulfur pumps and (ii) the potential sub-surface injection of liquid sulfur for long-term storage

Project Description: The viscosity of elemental sulfur was investigated in the early 1900s, with and without viscosity modifying agents (amines, chlorides and H₂S). Because sulfur polymerizes above 160°C, it was expected that the viscosity also was shear dependant. Our recent reported work re-investigated sulfur's viscosity up to a shear rate of 3000 s⁻¹. Using a newly modified rheometer, we are now extending this work to include dissolved H₂S and H₂S_x. By combining the rheological information with our previously published solubility model, we intend to provide a complete model for elemental sulfur rheology with and without H₂S or other modifying solutes. This research is funded through NSERC-ASRL IRC grant program.

Specific Objectives

- Investigate the rheological properties of elemental sulfur over the λ-transition temperature (150 to 280°C) with dissolved H₂S. These studies will include heating, thermal equilibration time and cooling.



CRP 15. A review of specifications for commercial sulfur

A proper understanding of the physical and compositional specifications for commercially produced and internationally traded brimstone is essential. Much work has been done in the past to generate quality guidelines for export specifications that are used for sales contracts and characteristics of formed product that distinguish between standard and premium grades. However, the industry efforts of forty years ago are not well documented and the circumstances that defined international sulfur production and handling back then have changed. In an effort to clarify the development of specifications and assess the need, if any, to amend or add to product quality parameters (*e.g.*, polymeric sulfur content), a collaborative review project will be initiated.



Figure 20. A review of specifications for commercial sulfur

This item will be ongoing; however, the following areas of research were identified as potential future directions:

- Impact of residual H₂S on strength of formed sulfur
- Water retention in a variety of formed products
- Impact of water hold-up on corrosion rates
- Revisiting Ar, Se, Te as these relate to Claus recovered sulfur
- Revisiting shape and size criteria for premium product guidelines
- Exploring the merits of an “as loaded” guideline
- H₂S release on solidification and re-melt

CRP 16. Sulfur recovery in supercritical CO₂ [NSERC Discovery Grant]

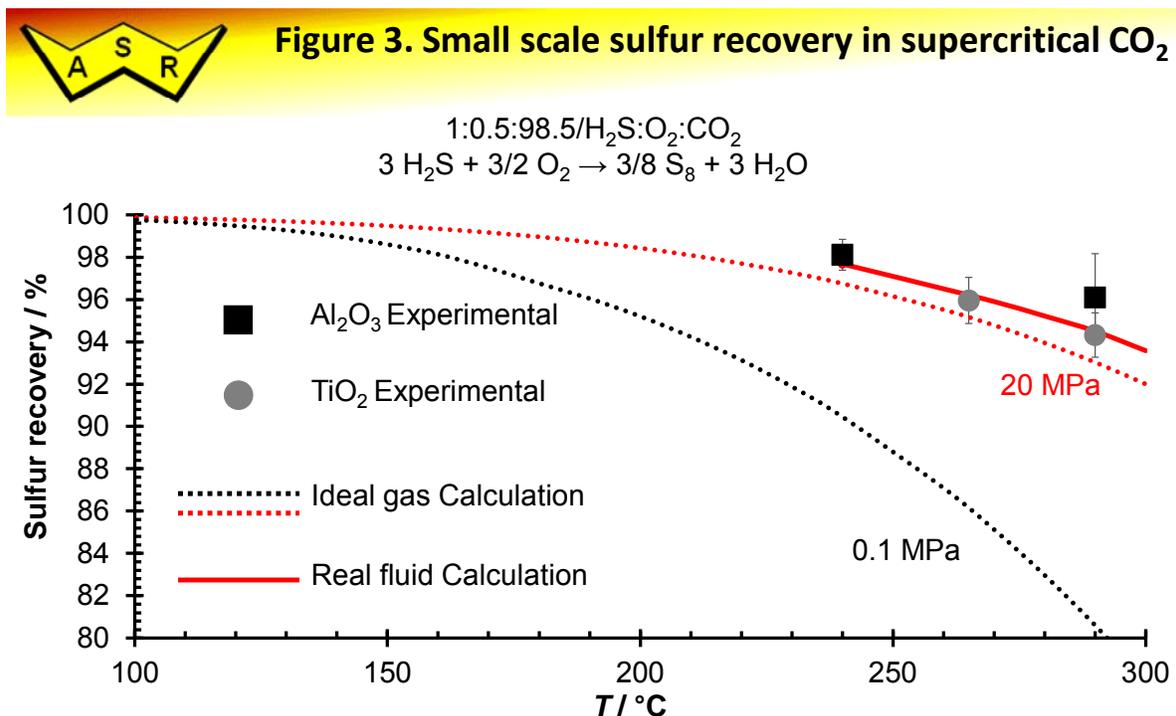
Commercial Objective: To explore the high-pressure oxidation of low-level H₂S (<1%) in dense phase CO₂ fluids

Project Description: Many sour fluids result in low level H₂S acid gas (< 1% H₂S; *e.g.*, acid gas removal from shale gas fluids); therefore, conventional Claus recovery is not viable and scavenging technologies may not be appropriate for a larger scale of production. In some cases, it is beneficial for the cryogenic removal of low-quality acid gas from a producing fluid which results in dense-phase high-pressure CO₂ fluid. Depending on the permitting of injection zones or the planned use of CO₂ for enhanced oil recovery, the low-levels of H₂S will need to be removed from the CO₂ fluid.

New sulfur solubility data for elemental sulfur in supercritical CO₂ has led to an extension of the ASRL Gibbs Energy Minimization models, where high-pressures and real fluids are now an option. The research has now turned to investigating high-pressure catalysis at 150 and 250°C. The upcoming research year will tackle mixed beds and high-macroporosity catalysts. This work is being supported by an NSERC discovery grant program.

Specific Objectives

- A high-pressure heterogeneous catalyst rig is being used to investigate oxidation kinetics in CO₂ fluids
- Potential impurities will be explored to assess possible catalyst deactivation over multiple sub-dewpoint cycles



Gibbs Energy Minimization predictions and experimental oxidations matched well over H₂S concentrations range of 0.5 – 1.7 %

CRP 17. Water content of acid gas in the presence of a hydrate phase [NSERC ASRL IRC Funding]

Commercial Objectives: Provide reference quality models for water content above acid gas and NGL hydrates

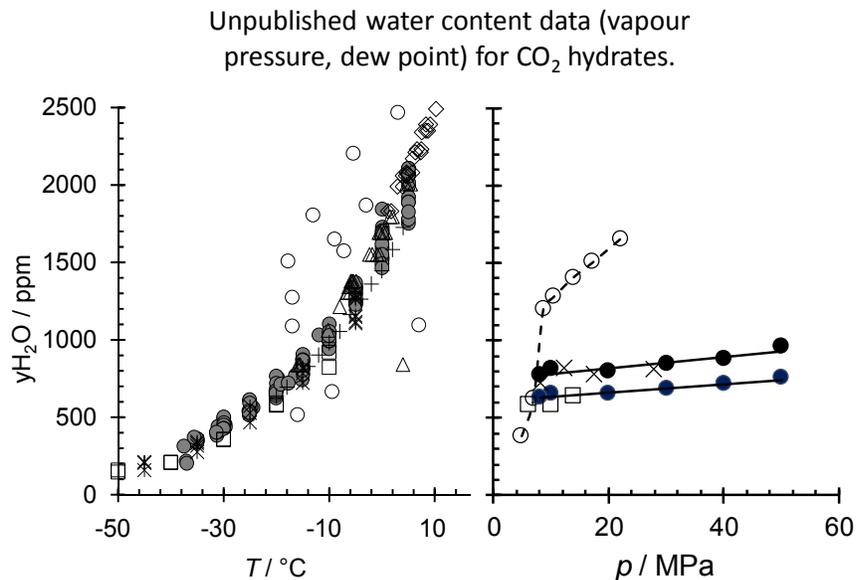
Project Description: The formation and decomposition conditions for hydrates in the presence of liquid water have been studied for H₂S, CO₂ and propane (Figure 13). With LNG and cryogenic separation processes, there is the need to understand and simulate how low water streams behave, e.g., how much water is too much? For many of these fluids, gas-hydrate compounds are the potential solids being formed and high-pressure liquids will have a different water holding capacity when compared to a high-pressure gas. In this work the water vapour pressure (dew point or water content) will be studied using a tunable diode laser which is coupled with a small equilibration loop. This instrument is aimed at measuring very low water contents in fluids which are in equilibrium with their respective water hydrate and no liquid water. There is an immediate need for high-pressure water contents in liquid CO₂, H₂S and propane. This research is funded through NSERC-ASRL IRC grant program.

Specific Objectives

- Complete modelling efforts for new CO₂ and C₃H₈ hydrate data to $T > -35^{\circ}\text{C}$
- Expand measurements to include H₂S hydrate in equilibrium with liquid H₂S
- Investigated mixed acid gas hydrates which are relevant to cryogenic separation



Figure 13. Water content of acid gas in the presence of a hydrate phase



○: Song and Kobayashi (Rice university), ×: Wiltec, +: Chapoy *et al.*,
□: Burgass *et al.*, Δ: Korea University data, ◇: Do Seo *et al.*, colour circles denotes this study's measurements.

CRP 18. The age and friability for different forms of elemental sulfur

Commercial Objectives: Measure several key properties during the aging of sulfur products

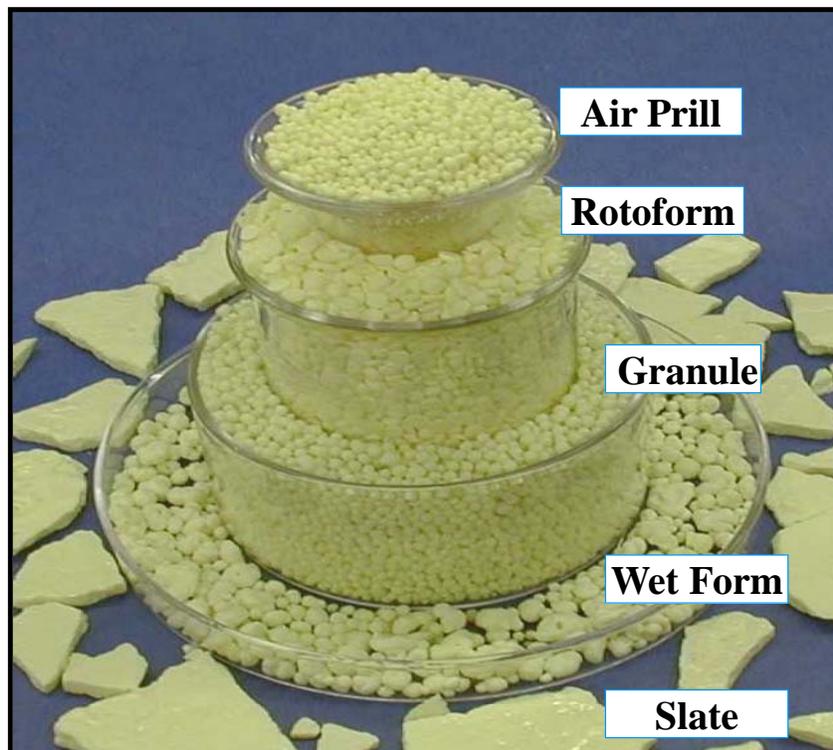
Project Description: Both sulfur pastilles and prills are common commercial products. Several properties are of interest to producers and consumers of these products, such as H₂S content, friability, water capacity, porosity, etc. Many of these properties change during the aging of the products and/or might differ depending on the use of degassed or non-degassed liquid sulfur. With several controlled batches of product (product made within the ASRL labs), we intend on following the properties over a year from formation to look at any changes and/or identify other properties which might be important for product handling.

Specific Objectives

- Create 6 batches of sulfur [water prills and pastilles from liquid at <1, 10 and 200 ppm H₂S(Total)]
- Over one year, we will be monitoring compressible strength (load test), friability (stress level II), H₂S recovery during controlled remelt, porosity, water retention and water holding capacity



Figure 12. The age and friability for different forms of elemental sulfur



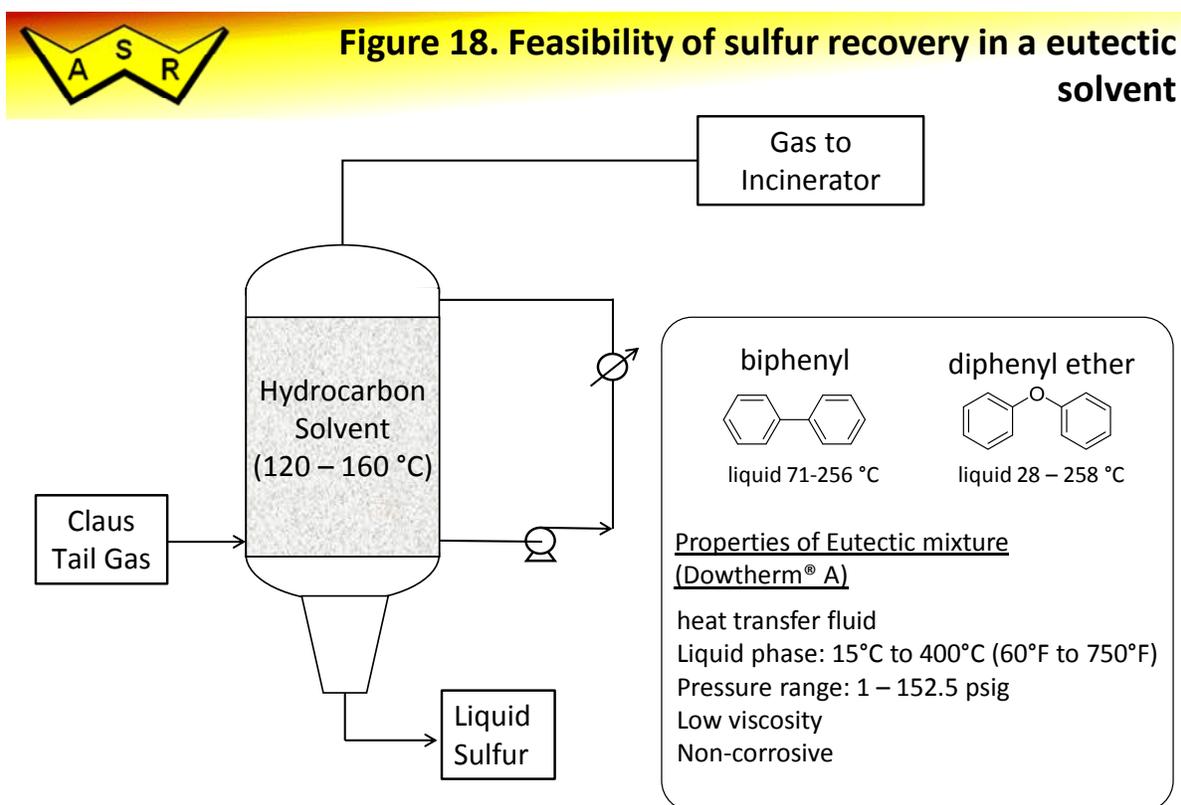
CRP 19. Feasibility of sulfur recovery in a eutectic solvent [NSERC Discovery Grant]

Commercial Objective: To explore sulfur chemistry in Dowtherm A®

Project Description: Various sulfur recovery processes involve liquid phase reactions either for low-level H₂S recovery by direct oxidation in aqueous liquids (LO-CAT®/Sulferox) or by typical Claus chemistry (Clauspol®) which utilizes an organic solvent, namely polyethylene glycol (PEG). Although the quality grade of sulfur produced in organic solvents is much higher than aqueous systems, with fewer contaminants, other complications arise such as degradation of the solvent due to the reaction of saturated hydrocarbons with the produced sulfur. The PEG process is therefore restricted to $T < 140^{\circ}\text{C}$ to limit these reactions. Dowtherm A® is a hydrocarbon eutectic mixture of diphenyl ether and biphenyl which shows thermochemical stability for $T < 450^{\circ}\text{C}$ and is sold commercially as a heat transfer fluid. The absence of saturated hydrocarbons coupled to the well studied thermophysical properties, justifies exploration of Dowtherm A® as a novel sulfur process solvent.

Specific Objectives

- Determine stability of Dowtherm A® and solubilities with S₈, H₂S, SO₂, CS₂, COS and H₂O
- Explore liquid Claus tail gas chemistry
- Explore sulfur assisted dehydrogenation of NGL for olefin production



CRP 20. Low CO₂ emission technology for manufacture of propylene and butylenes

Commercial Objective: To improve the potential technology for selective conversion of propane and butane to propylene and related olefins

Project Description: Previously ASRL has examined production of ethylene, propylene and butylene by partial oxidation of small hydrocarbons with sulfur. The sulfur may be added directly to the feed hydrocarbons or formed in situ by reaction of H₂S with O₂ (Figure 7). The advantage of the latter process is that olefins can be formed selectively and the process is nearly auto-thermal. Recently, member companies have expressed renewed interest in this potential technology because of increased amounts of propane and butane produced with shale gas and because the technology is a low CO₂ emissions process. Although ASRL has already conducted a large amount of work in this area, there are still improvements to be explored for coke reduction and product clean-up. A catalyst system is being explored to lower the temperature for conversion (lower coke), an acid gas feed containing CO₂ will be tested, and a SWSG feed will be tested. The key drivers are (i) to lower H₂S and/or SO₂ in the product to reduce clean-up costs, (ii) to lower the temperature to reduce coke formation and (iii) to potentially explore a larger pressure for higher thermal efficiency.

Specific Objectives

- Further explore using V₂O₅/SiO₂ at longer residence times / lower temperatures
- SWSG feeds, where NH₃ may allow for clean-up of H₂S and SO₂ upon quench



Figure 9. Low CO₂ emission technology for manufacture of propylene and butylenes

