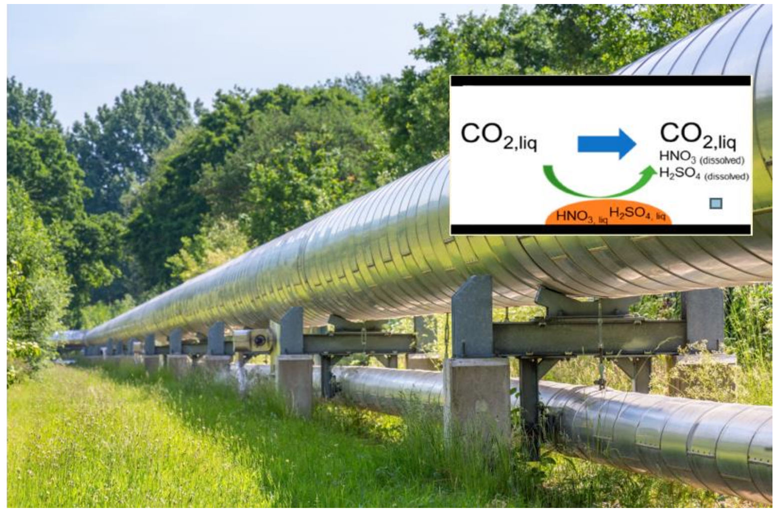

Carbon Transportation: Mitigating Corrosion Risk in Pipelines and Ships

Conversations with OLI Experts on Science of Electrolyte Chemistry
Issue 1.0

OLI Expert: Dr. Andre Anderko

Key Questions for the OLI Expert:

- What is carbon transportation? Why is it important and who is involved with this?

Global warming has become a reality. Mitigating global warming is rapidly becoming a priority for industry, governments and the society in general. It is now globally recognized that we need to reduce CO_2 emissions to limit the global temperature rise. One of the key paths to achieve it is through carbon capture, utilization and storage (CCUS). In short, we need to capture CO_2 from the biggest emitters and either dispose of it in geological repositories or convert it to useful products such as building materials. The captured CO_2 needs to be transported from the capture site to the storage location through pipelines or as bulk cargo on ships or trains. It is the CO_2 transportation that is the weak link in CCUS because it can suffer from corrosion problems.

- Why are we afraid of corrosion in carbon transportation? Is carbon dioxide corrosive?

Pure carbon dioxide is not corrosive. However, the reason for the possibility of corrosion is the fact that the captured CO2 is never pure. It always contains some impurities that result from prior combustion and capture processes. Such impurities include various nitrogen oxides, sulfur oxides, hydrogen sulfide, oxygen, and water. These impurities can react and form highly corrosive acids or elemental sulfur. The acids can form in minute quantities compared to the huge amounts of CO2, but they are extremely aggressive to carbon steel and can lead to catastrophic failure of the pipelines or tanks.

- If the acids are so dangerous in contact with carbon steel, then why not use corrosion-resistant alloys?

For pipeline transport, the material choice has a huge impact on the cost. Corrosion-resistant alloys are expensive and can probably be used only for very short pipelines, while carbon steel is the only economically realistic alternative for long pipelines. Corrosion-resistant materials (which are considerably more expensive) can probably be used only at the capture site where aggressive species are expected. Therefore, we are stuck with carbon steel for the transportation of CO2. Faced with this constraint, avoiding corrosion of carbon steel due to the formation of acids is of utmost importance. The key question is – what are the safe limits for specific impurities? If the concentrations of the impurities stay below the safe limits, one will not have to remove them through cleaning procedures, which are necessarily costly.

- How are electrolytes and water chemistry relevant to carbon transportation?

The reactions that lead to the formation of acids and/or elemental sulfur are electrolyte reactions. We need to be able to predict under what conditions the impurities can react and under what conditions they will remain innocuous. The conditions include the various combinations of impurities and their concentrations as well as pressure and temperature. If we can predict such conditions, we will be able to predict the safe limits.

- What is the science behind corrosion in carbon transportation?

The key scientific problem is the simultaneous prediction of both reaction equilibria and phase equilibria in dense phases dominated by CO2. We have already mentioned the reactions between the impurities. But phase equilibria are equally important because the acids will be corrosive only if they form as a separate phase, possibly in the form of droplets at the bottom of the pipelines. On the other hand, if the acids remain dissolved in the bulk CO2 phase, they can follow the stream without affecting the transportation pipeline. Therefore, the threshold for the formation of a separate, acid-rich phase (i.e., when the solubility limit is exceeded) needs to be known for a wide range of pressures and temperatures that are relevant to CO2 transport systems.

- What is OLI doing to mitigate corrosion risk in carbon transportation?

OLI has joint forces with the Norwegian Institute for Energy Technology (IFE) to develop a methodology for predicting when the impurities will pose a danger to the integrity of CO2 transportation facilities. We are currently in the middle of a six-year research effort co-funded by the Norwegian Research Council and a consortium of six oil and gas and metal manufacturing companies. IFE is drawing on its world-leading experimental facilities to investigate the chemical and phase behavior of impurities in CO2. OLI is combining its expertise in electrolyte thermodynamics with the experimental data generated by IFE to develop an accurate thermodynamic model for predicting the formation of corrosive components.

- What are the key technology elements of OLI's solution for predicting corrosion?

The key enabling technology that we are using is OLI's Mixed-Solvent Electrolyte (MSE) model. This model is the most appropriate framework for predicting both chemical and phase equilibria in CO2–dominated environments. This is due to the fact that the MSE model combined the standard-state properties of both electrolyte and nonelectrolyte species with an excess Gibbs energy model that allows us to span the whole range of conditions from aqueous to nonaqueous solutions. MSE offers a unique modeling tool because, while electrolyte reactions in aqueous systems are well known, those in dense CO2 environments are still at the frontier of electrolyte thermodynamics. The MSE model is implemented in the OLI software, including the OLI Analyzer Studio and OLI Flowsheet. While this work is still in progress, we already have demonstrated that our predictions are in agreement with the data that have been measured so far. Ultimately, after the experimental program is completed, we intend to use the model to generate guidelines for the acceptable levels of impurities in CO2 transportation.

- How can our viewers learn more about handling corrosion during carbon transportation?

For further details, please see our recent paper that we have written jointly with our IFE partners:

B.H. Morland, A. Tadesse, G. Svenningsen, R.D. Springer, and A. Anderko, "Nitric and Sulfuric Acid Solubility in Dense Phase CO2 ," Ind. Eng. Chem. Res., 58 (2019) 22924-22933

https://www.olisystems.com/nitric-sulfuric-acid (Link to Paper)

and the following paper published by IFE:

B.H. Morland, T. Norby, M. Tjelta, G. Svenningsen, G., Effect of SO_2, O_2, NO_2, and H_2O Concentrations on Chemical Reactions and Corrosion of Carbon Steel in Dense Phase CO_2. Corrosion 75 (2019) 1327-1338.

For more Information

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