Effect of changes of physical properties on CO_2 capture solvents on its absorption rate

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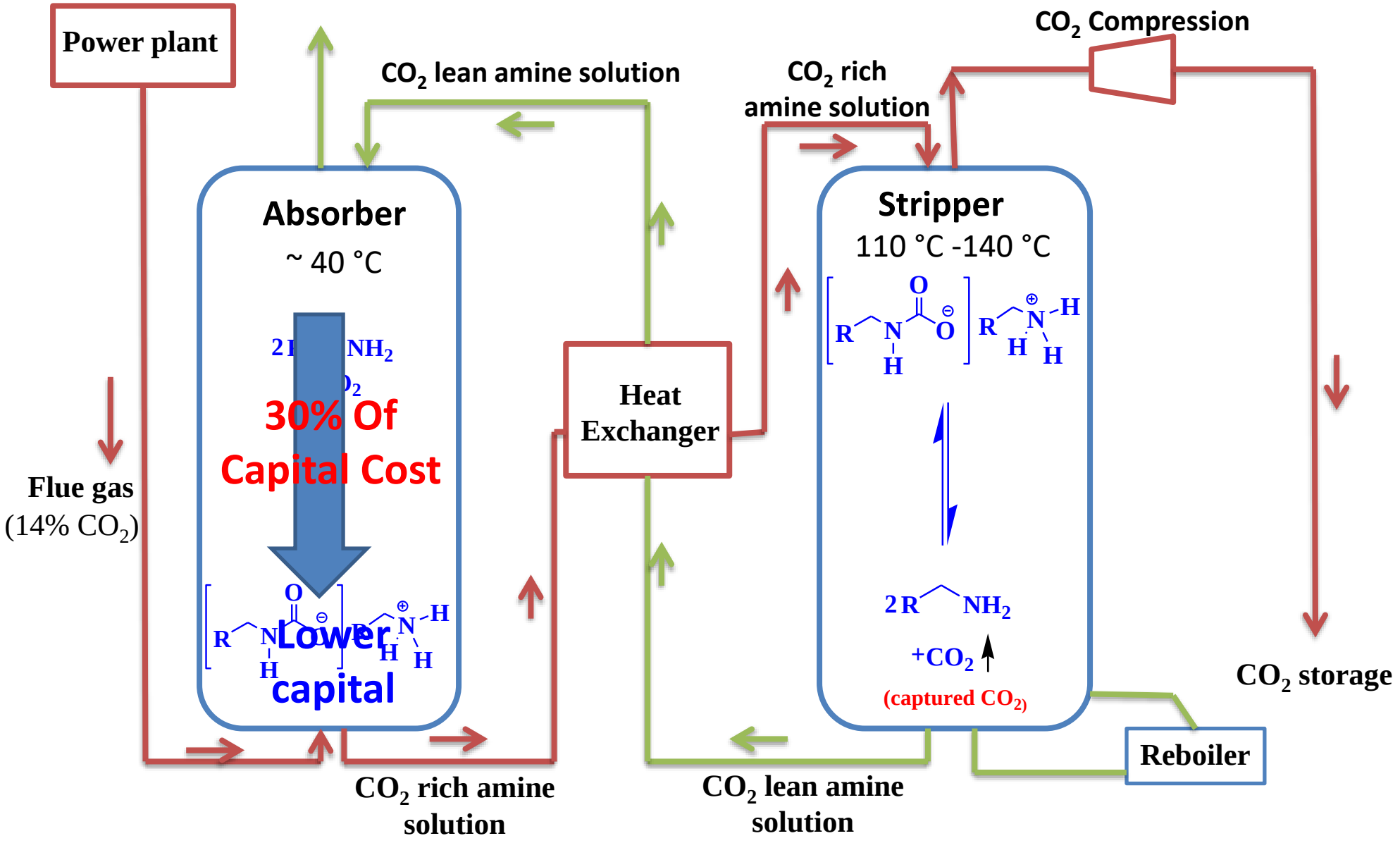
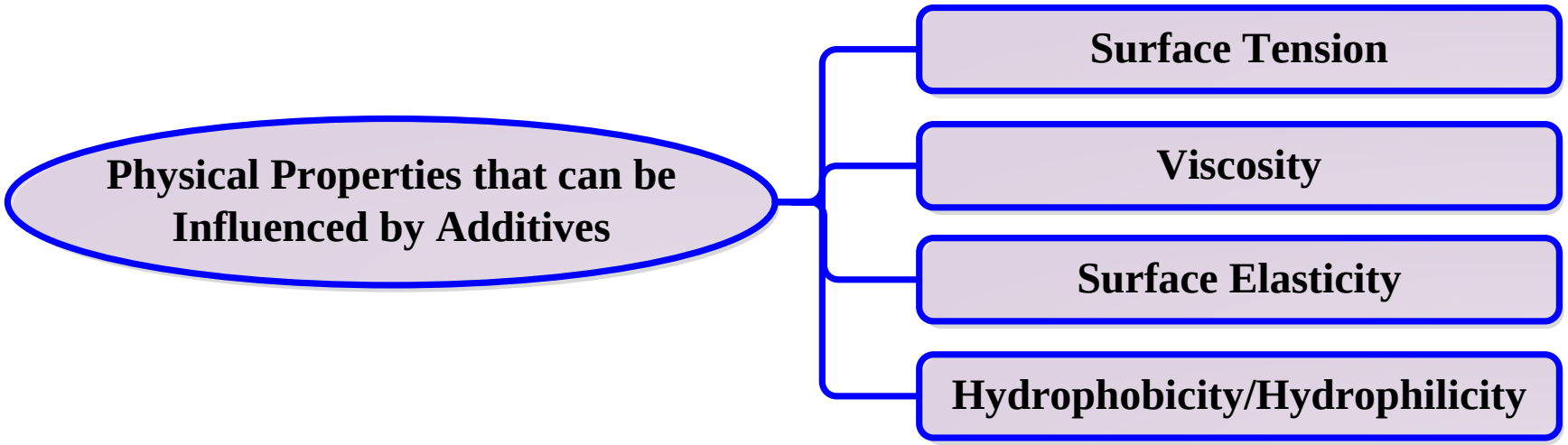
Overall CO_2 Capture Process by Amines



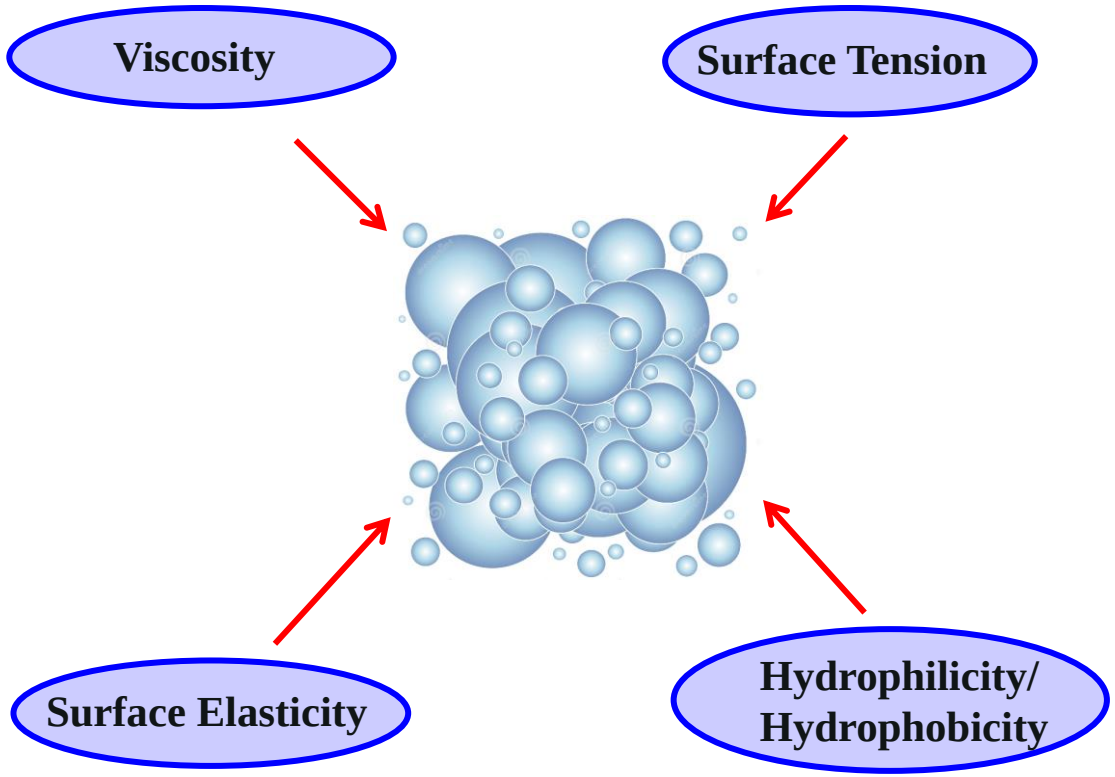
Introduction

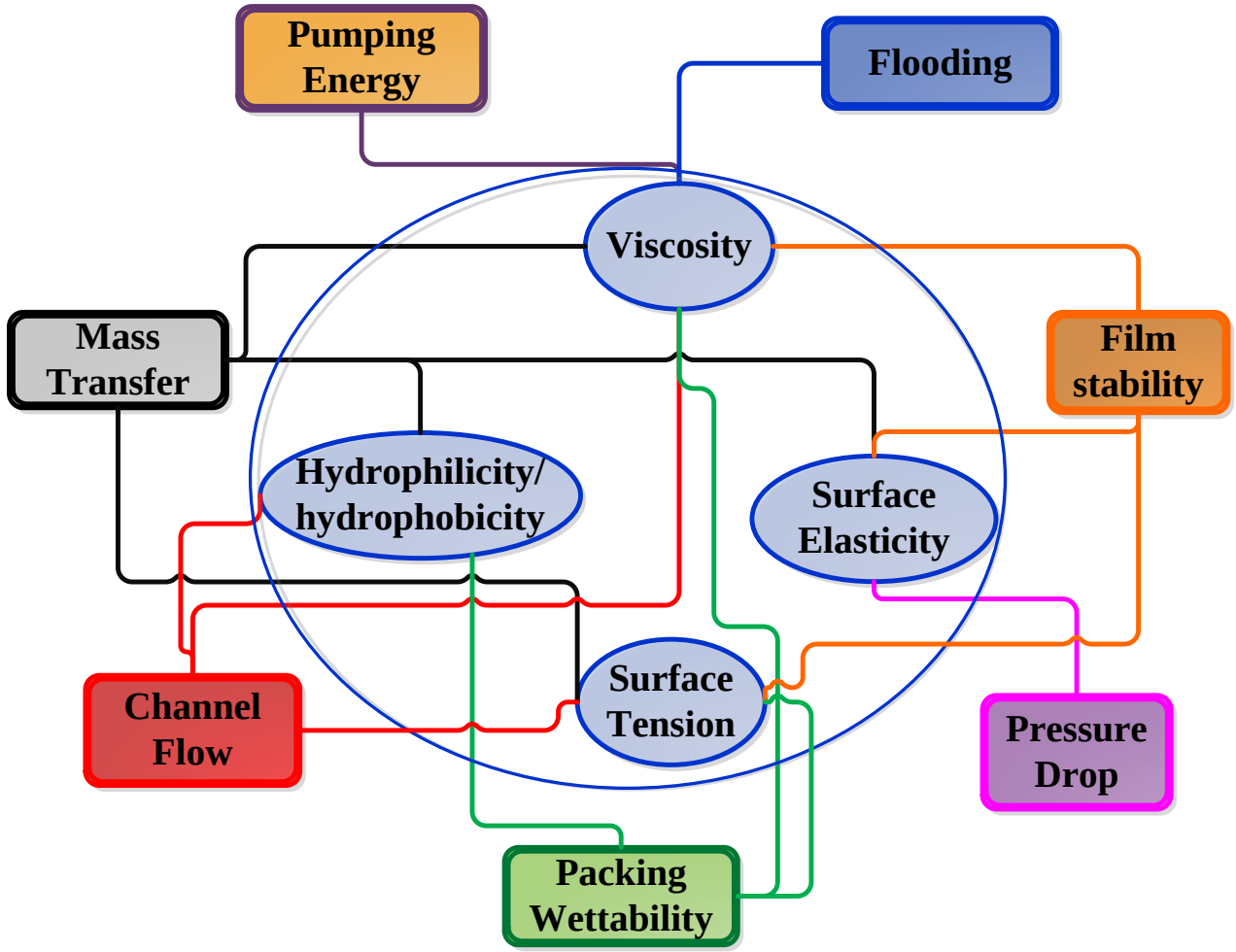
- **Limited number of amines** are available for carbon capture research after balancing the capital cost and energy penalty
- Another way to improve the solvent performance is **tuning the properties of the solvent** with additives
- **Our focus** is to understand how additives change the physical properties, and if we can use that to make our solvents better



Physical Properties of Solvents

- Our **ultimate goal** is to get **controlled micro-bubble formation** inside the packing material, to easily fit inside the packing and provide **much larger contact area**

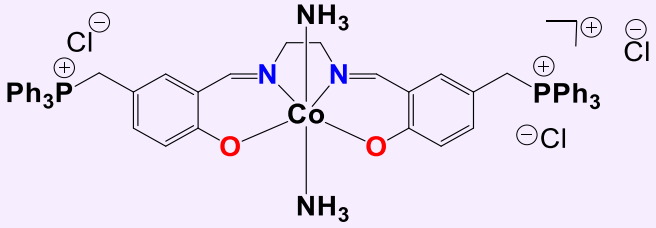




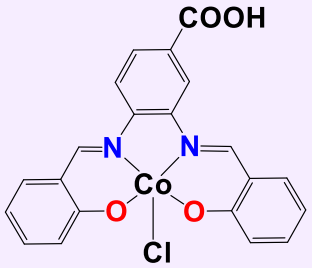
http://weclipart.com/foam+bubbles+clipart

Additives

CAER-Catalysts

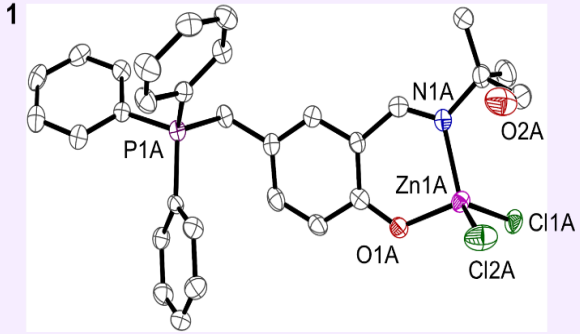


C1P

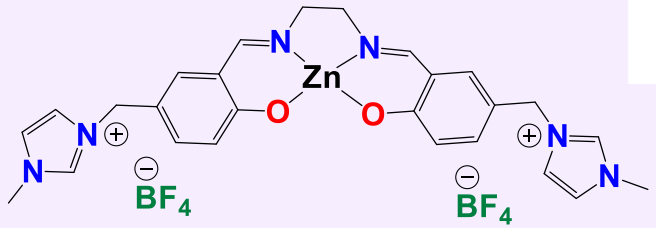


C5c

Rate



C7z

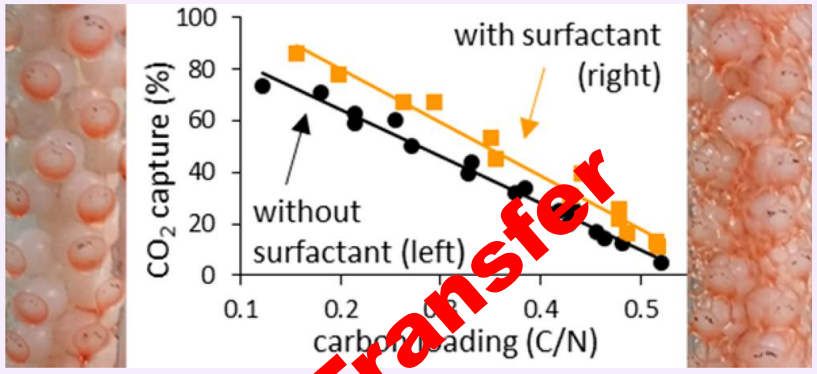


C3I

Catal. Sci. Technol., **2014**, *4*, 3620-3625
Int. J. Greenh. Gas Control, **2017**, *63*, 249-259
Ind. Eng. Chem. Res. **2017**, 56, 11644−11651
Int. J. Greenh. Gas Control, **2019**, 85, 156,-165

Surfactant

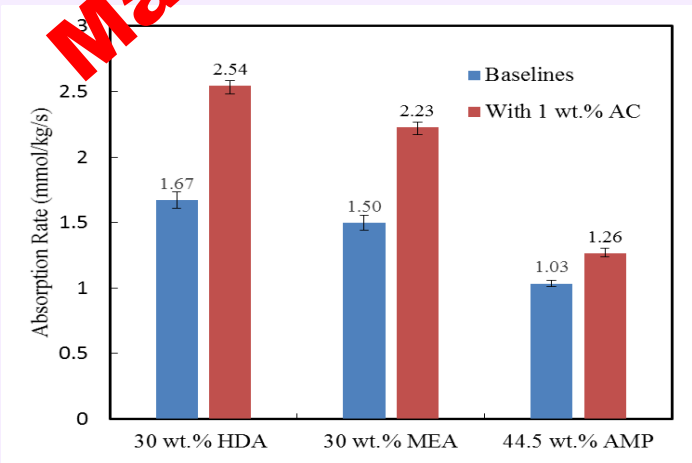
Surfactant S-554



Ind. Eng. Chem. Res. **2016**, 55, 7456−7461

Mass Transfer

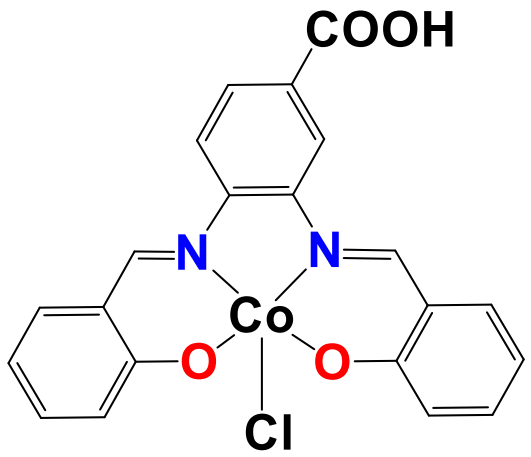
CAER-Particles



Int. J. Greenh. Gas Control , 2017, 61, 138–145

Additives

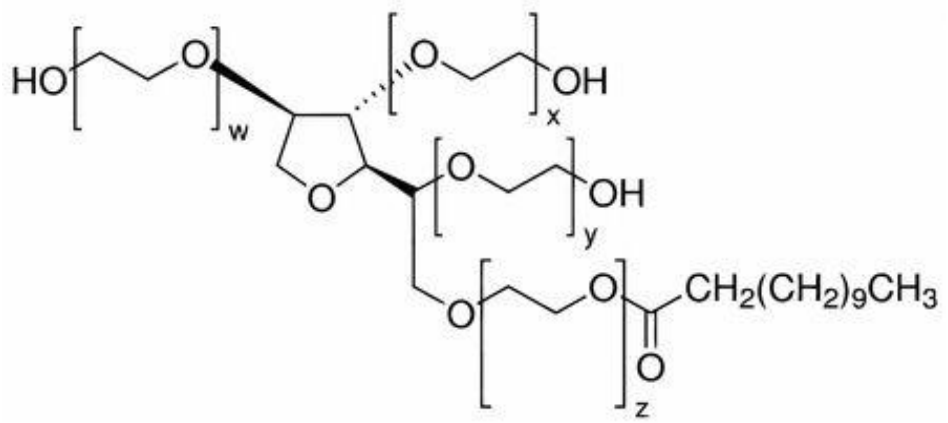
CAER-Catalyst



C5c

0.23 wt.%

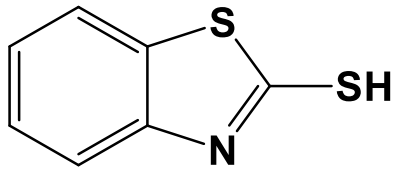
Surfactant



Tween 20

0.1 wt.%

Oxidation Inhibitor



2-Mercaptobenzothiazole (MBT)

200 ppm

Anti-Foam

XIAMETER™

food-grade silicone emulsion

0.01 wt.%

Anti-Corrosion

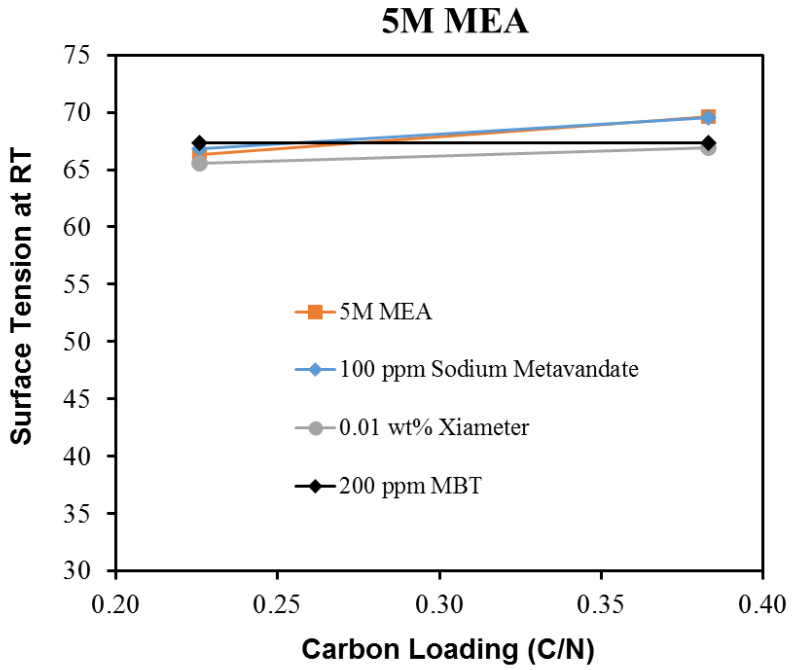
$NaVO_3$

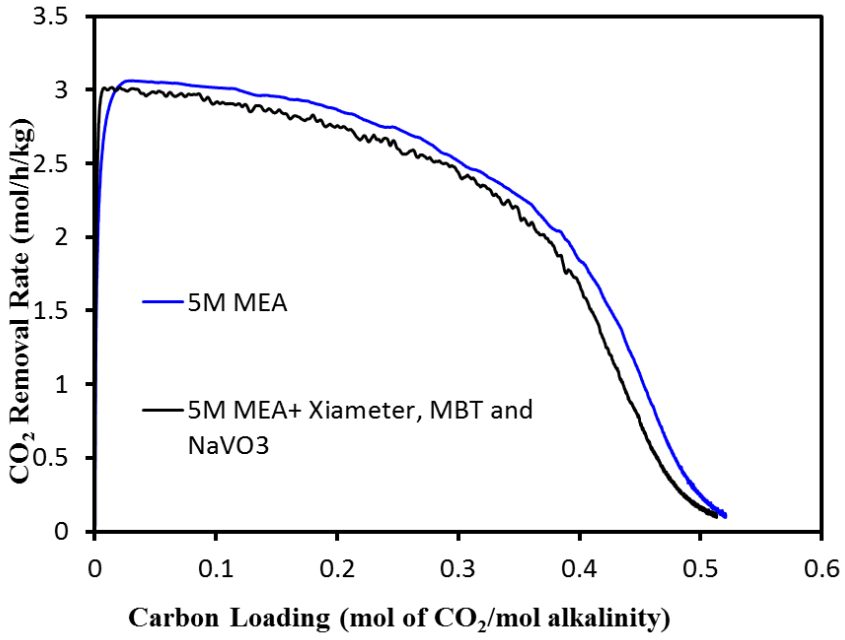
Sodium metavanadate

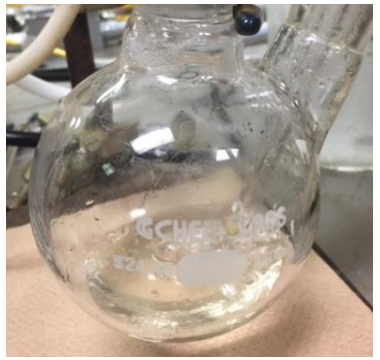
100 ppm

Effect of presence of Xiameter, MBT and $NaVO_3$

- Xiameter, MBT and $NaVO_3$ have **no effect** on viscosity, surface tension, Contact angle and surface elasticity of a solvent
- **No enhancement** in CO_2 capture with these three additives
- **No Froth formation** is observed during carbon loading process
- Xiameter, MBT and $NaVO_3$ are examples of **physical property neutral additives**



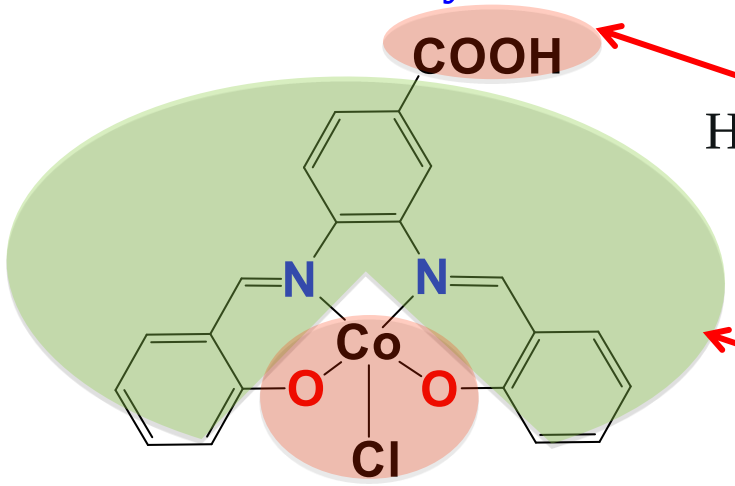




MBT in 5M MEA at rich condition

CAER-Additives

CAER-Catalyst



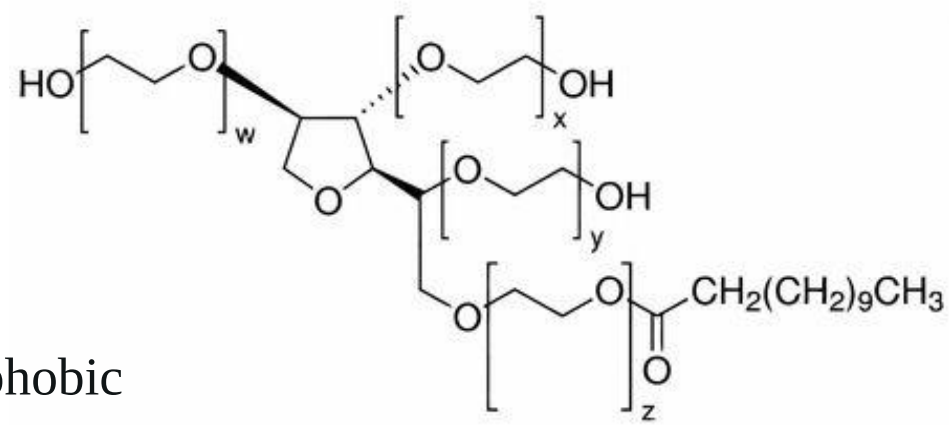
Hydrophilic

Hydrophobic

Hydrophilic

C5c

Surfactant



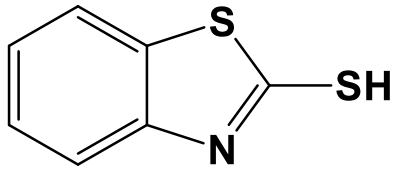
Tween 20

Anti-Foam

XIAMETER™

food-grade silicone emulsion

Oxidation Inhibitor



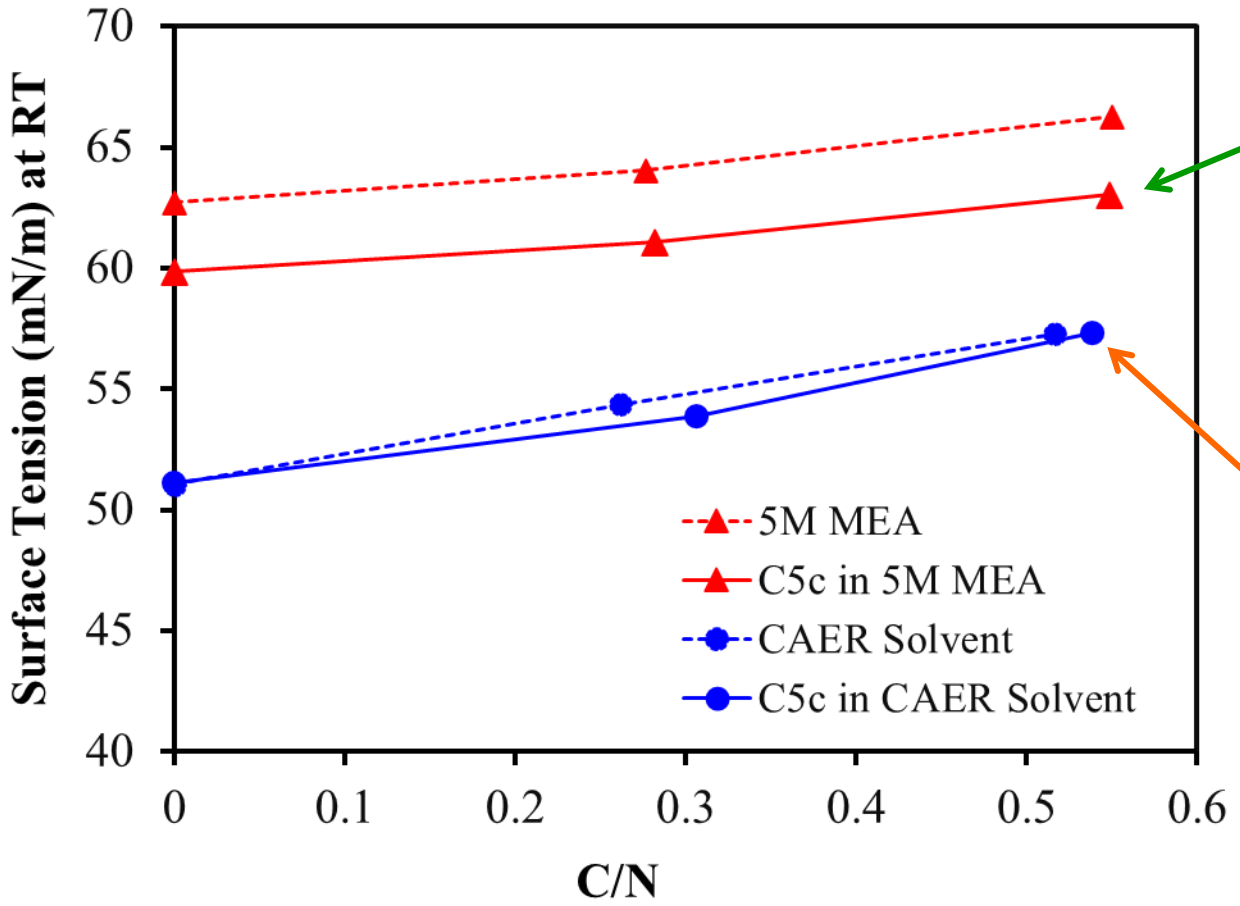
2-Mercaptobenzothiazole

Anti-Corrosion

$NaVO_3$

Sodium metavanadate

Effect on Surface Tension

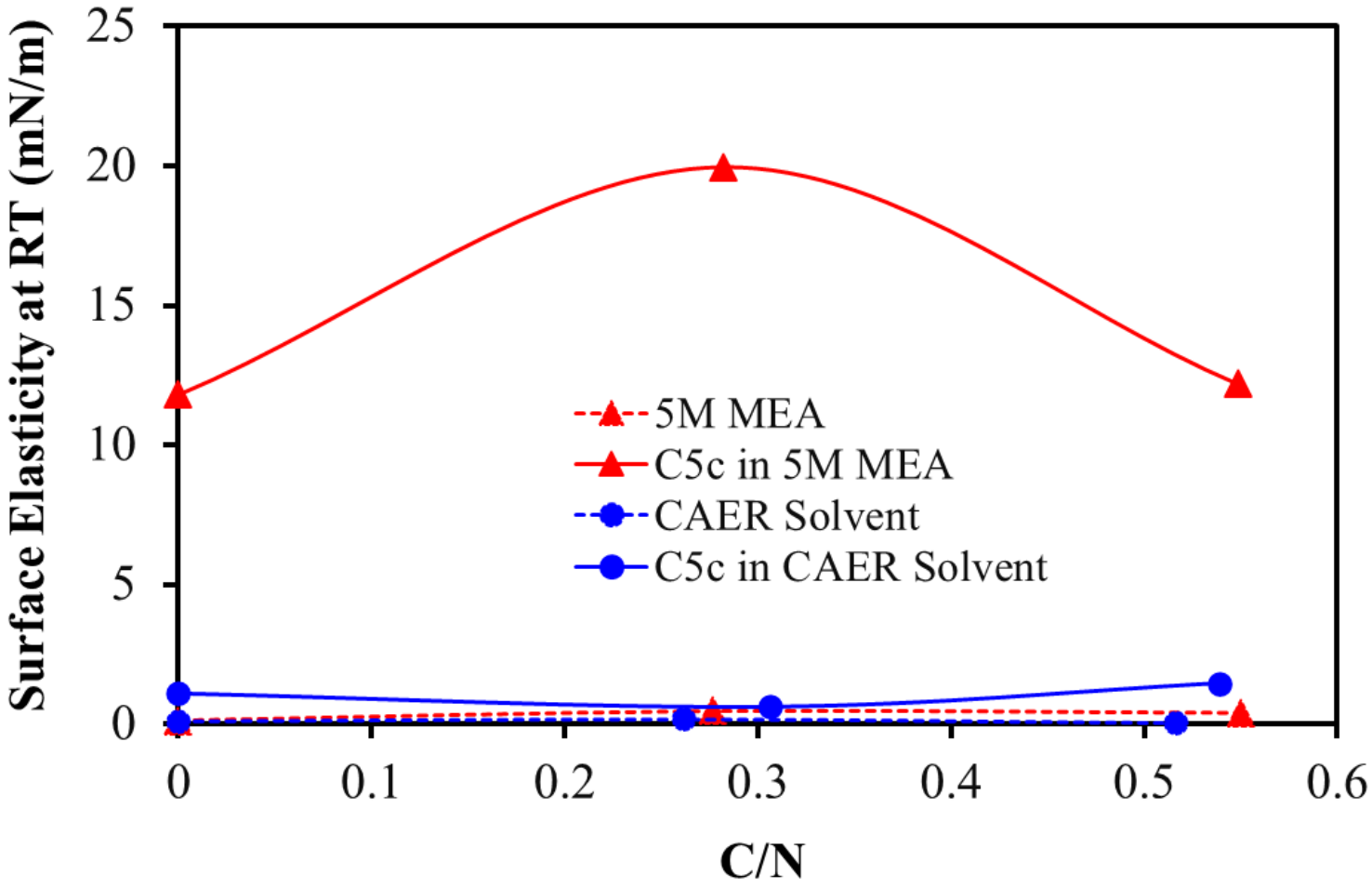


Froth formation

No Froth

- The catalyst **C5c** lowers the surface tensions of 5M MEA , but not in CAER Solvent
- Lowering of surface tension suggests **surfactant-like behavior** in 5M MEA

Effect on Surface Elasticity



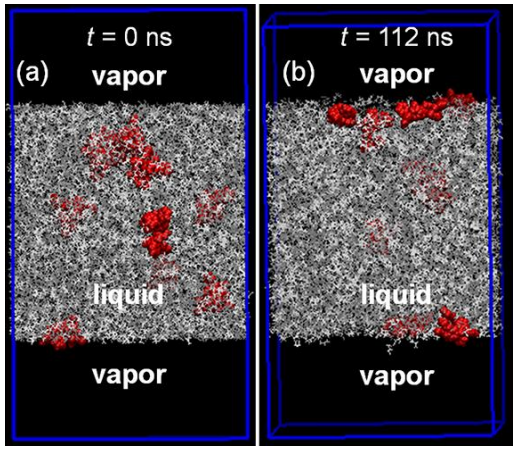
- The catalyst **C5c** does show surface elasticity in 5M MEA, but not in CAER Solvent

C5c Migrates to Solvent Surface

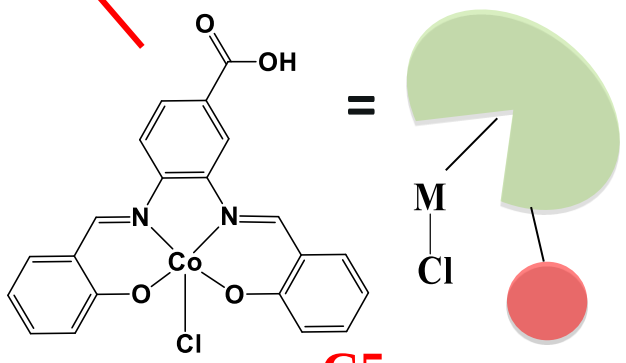
In MEA Solution

Hydrophobic

Hydrophilic

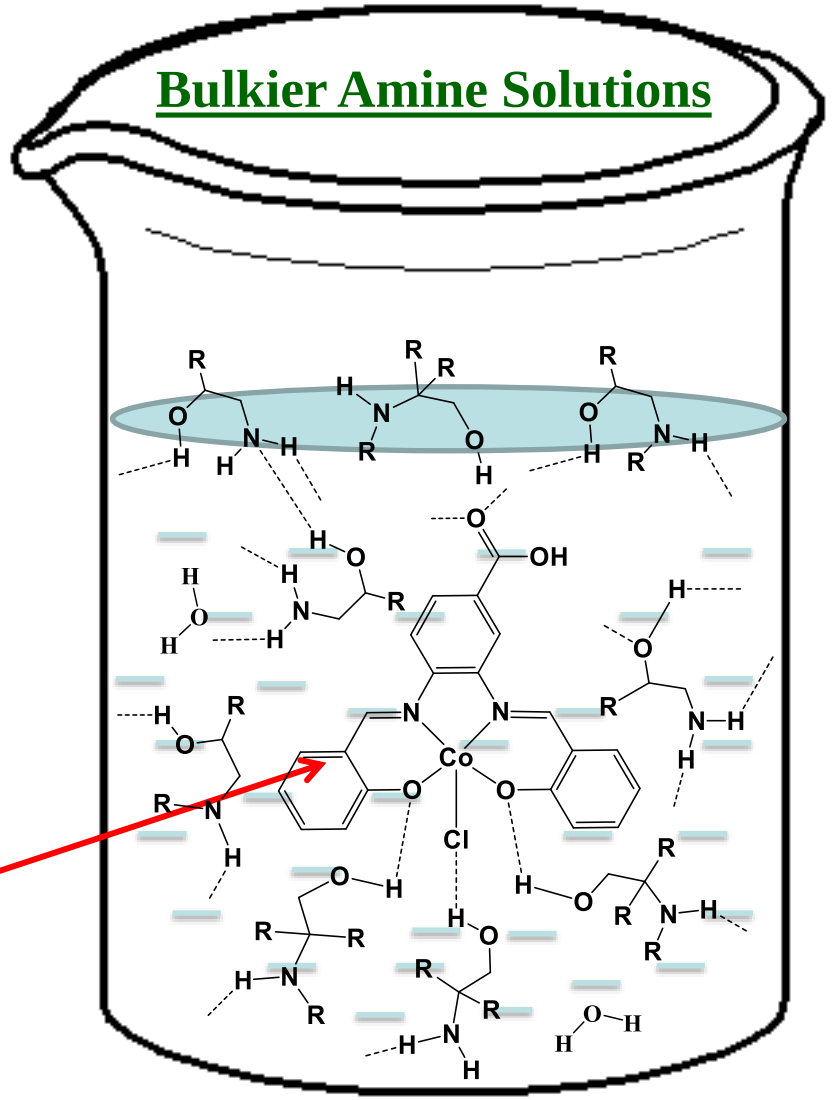


Ind. Eng. Chem. Res. **2017**, 56, 11644−11651



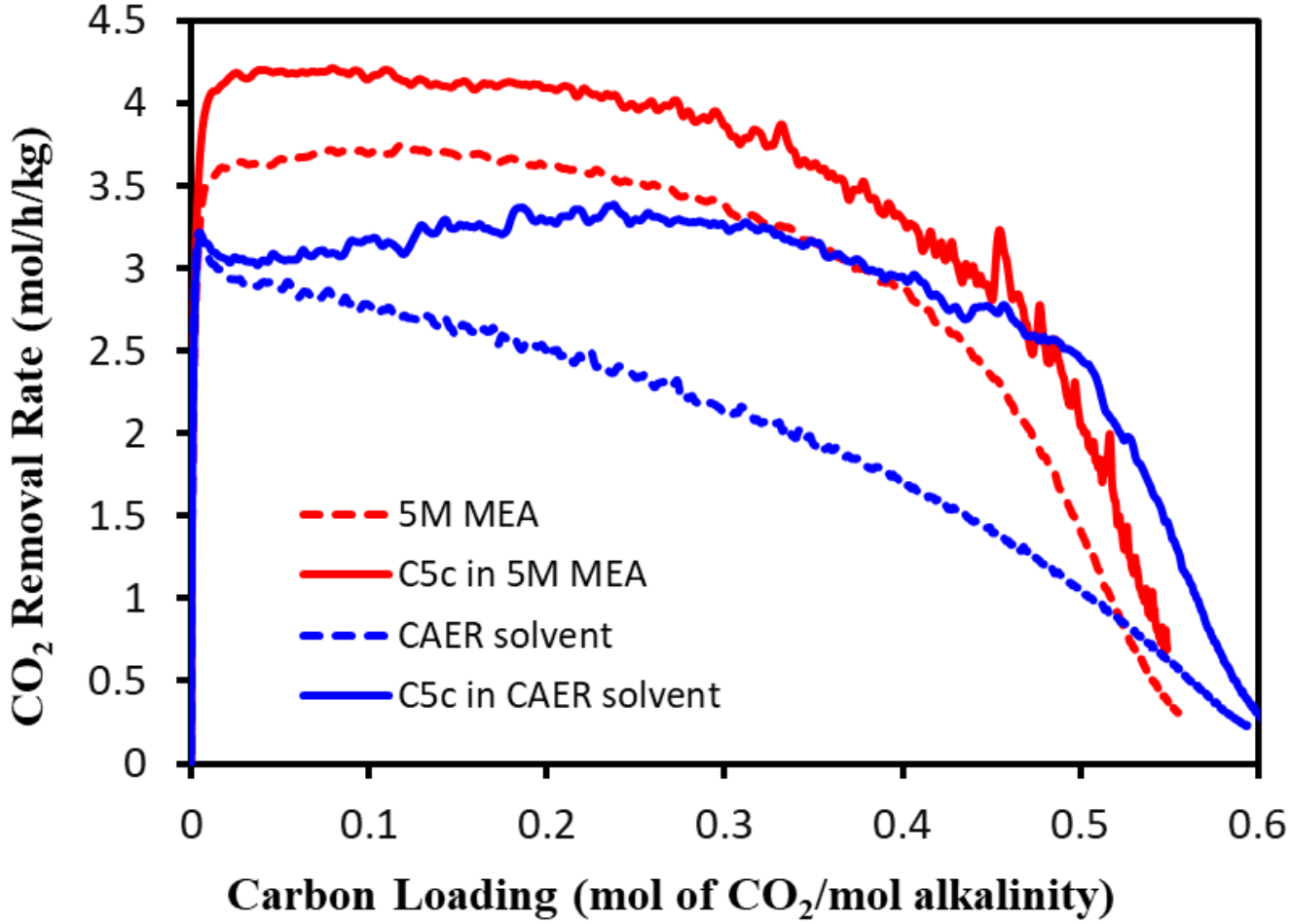
C5c

Bulkier Amine Solutions



Reactivity of C5c in CAER-Solvents

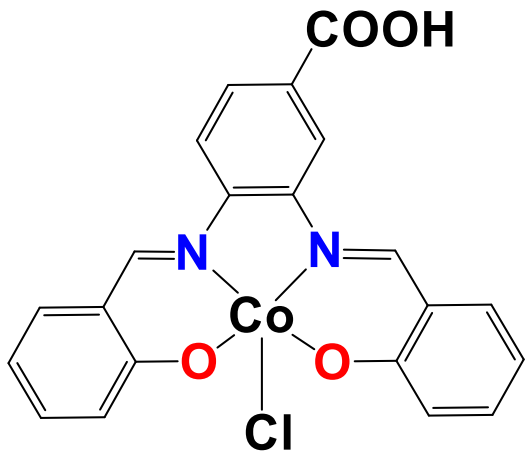
C5c in 5M MEA



C5c in CAER Solvent

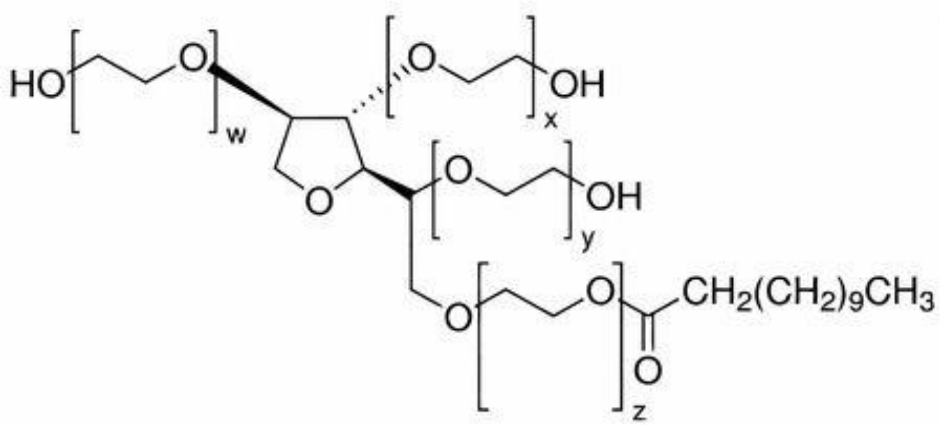
CAER-Additives

CAER-Catalyst



C5c

Surfactant



Tween 20

Anti-Foam

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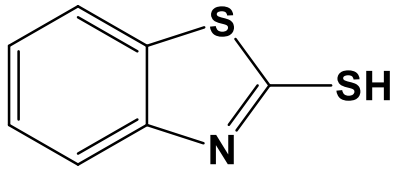
food-grade silicone emulsion

Oxidation Inhibitor



2-Mercaptobenzothiazole

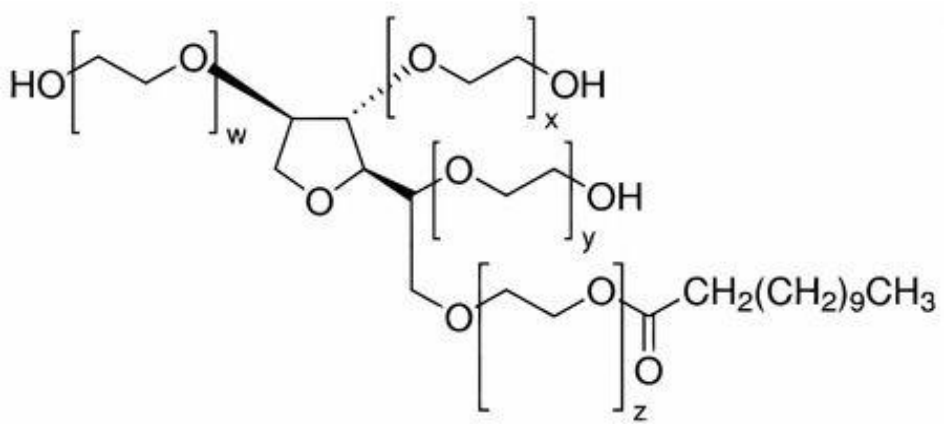
Anti-Corrosion

$NaVO_3$

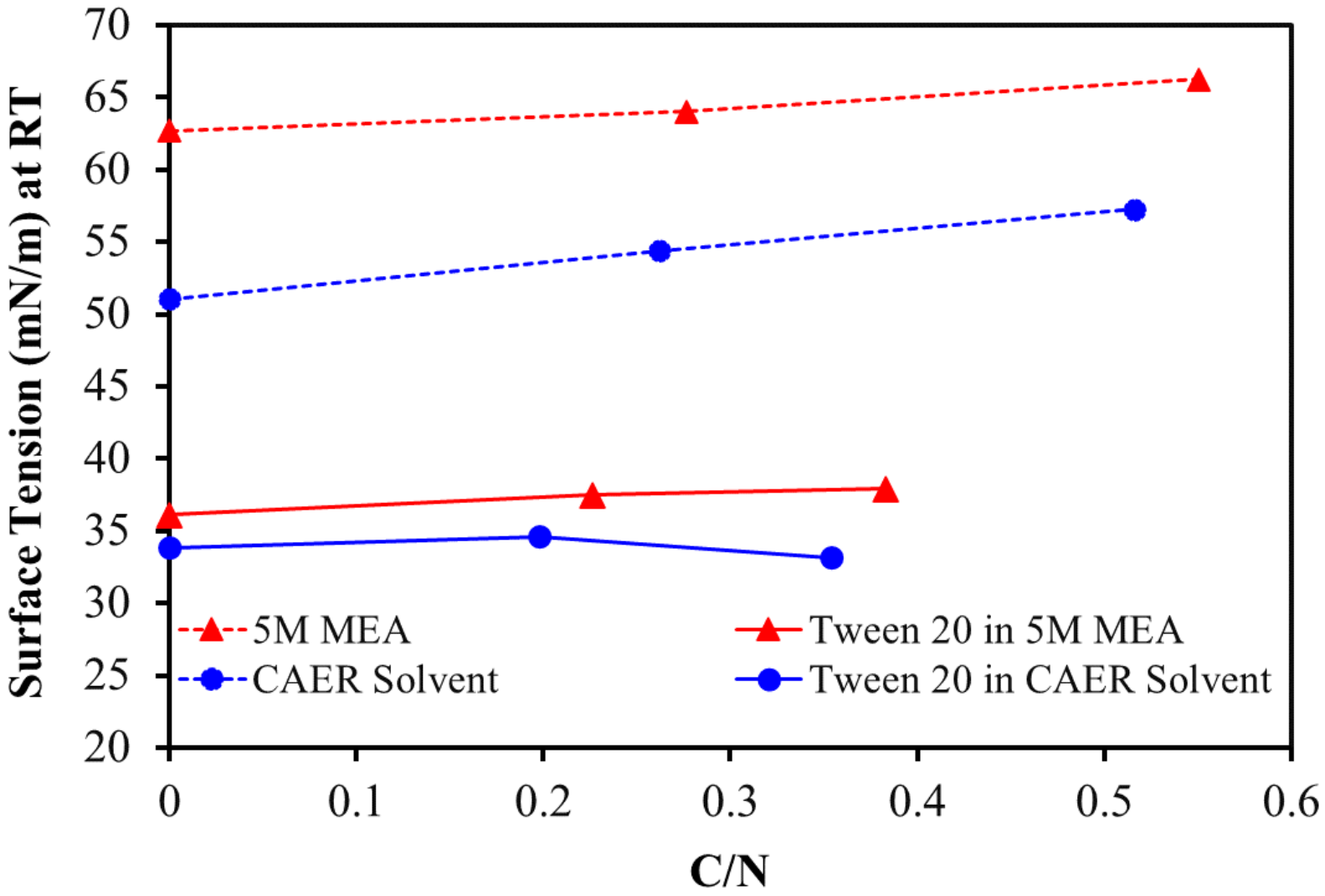
Sodium metavanadate

What we know about Tween 20?

- Tween®20 is a polyoxyethylene sorbitol ester that belongs to the polysorbate family
- It is a nonionic surfactant
- The ethylene oxide subunits are responsible for the hydrophilic nature of the surfactant, while the hydrocarbon chains provide the hydrophobic environment.

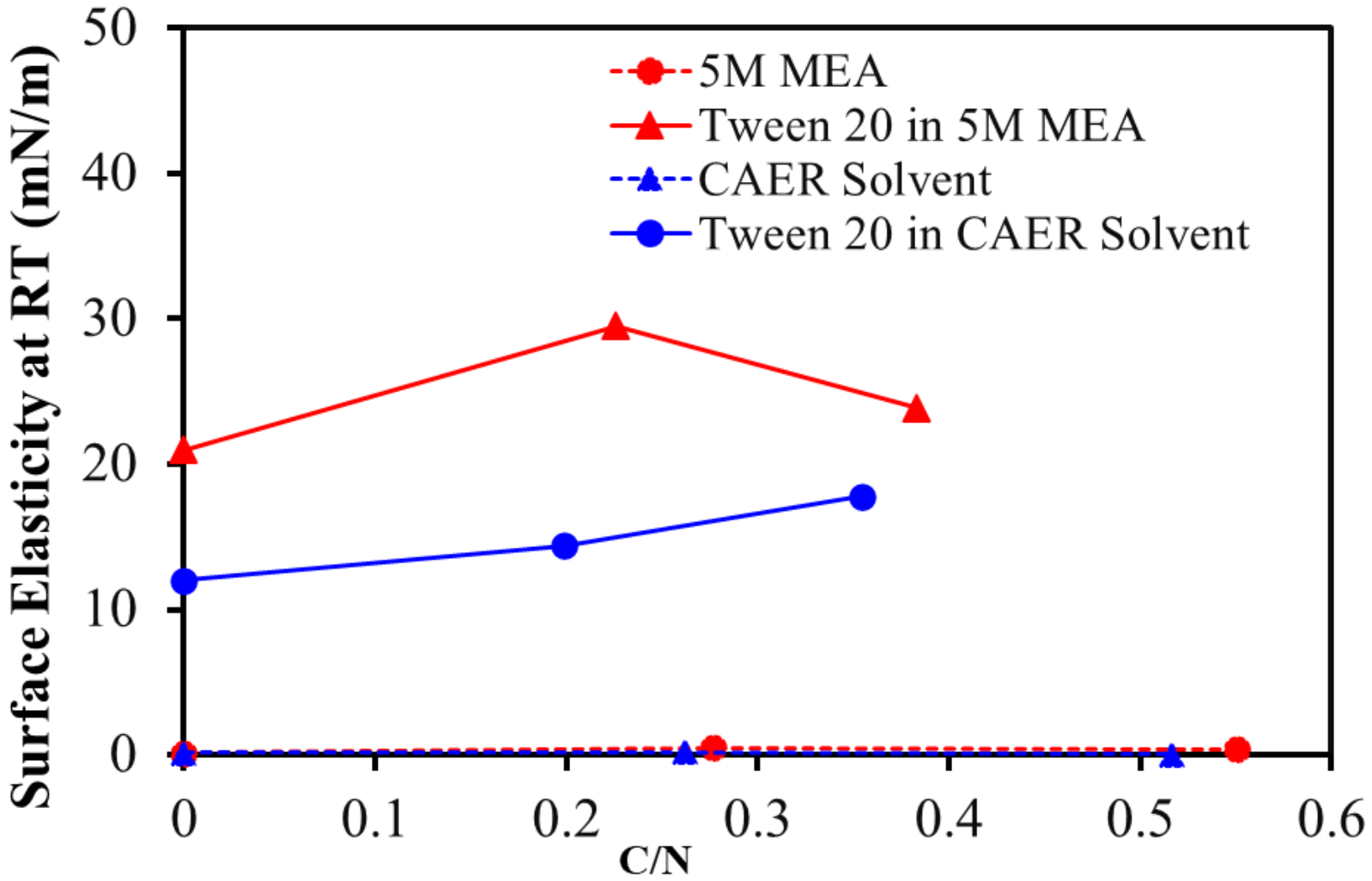


Effect on Surface Tension



- The Surfactant Tween 20 lowers the surface tensions of both 5M MEA and CAER Solvent

Effect on Surface Elasticity

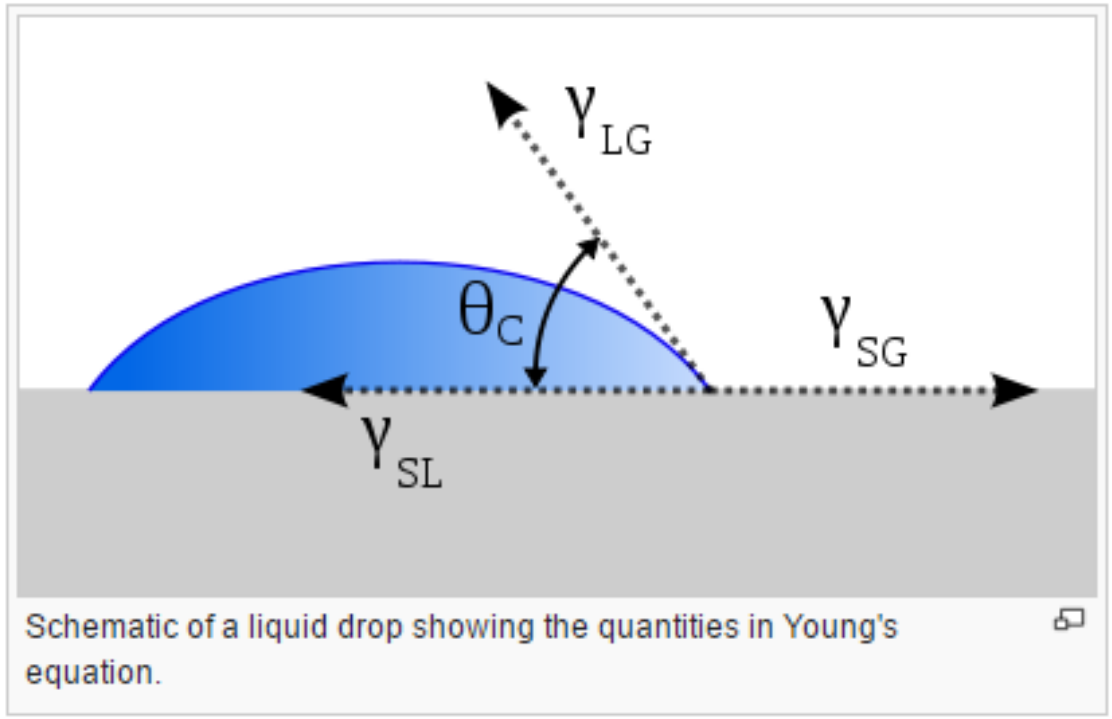


- The Tween 20 does show higher surface elasticity in both 5M MEA and CAER Solvent

Contact Angle

- Contact Angle measurements provide information about the additive's **hydrophobicity/hydrophilicty** nature

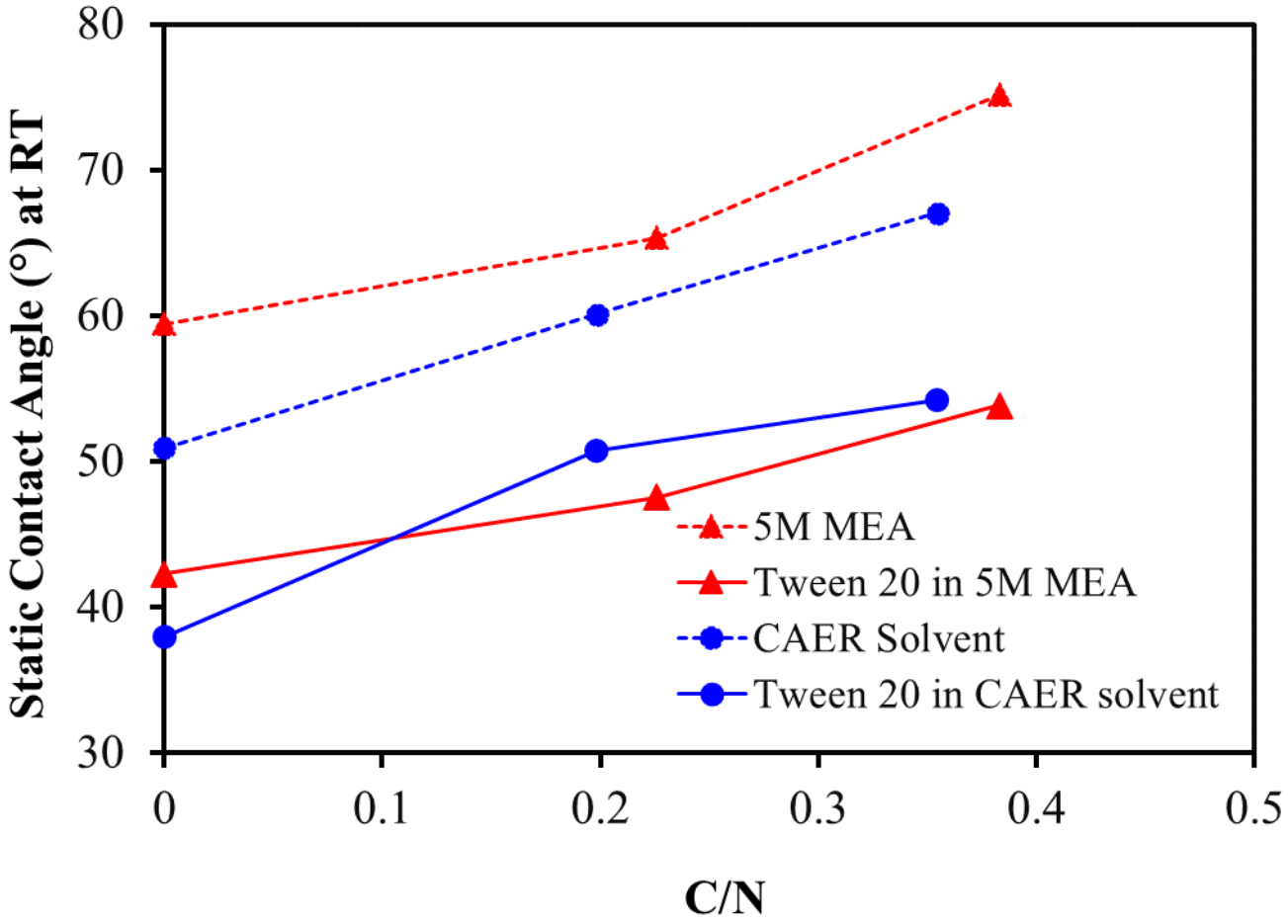
- Contact Angle is a method to measure the **wettability** of a surface or material, and provides information on how a liquid surface and substrate interact



Schematic of a liquid drop showing the quantities in Young's equation.

https://en.wikipedia.org/wiki/Contact_angle

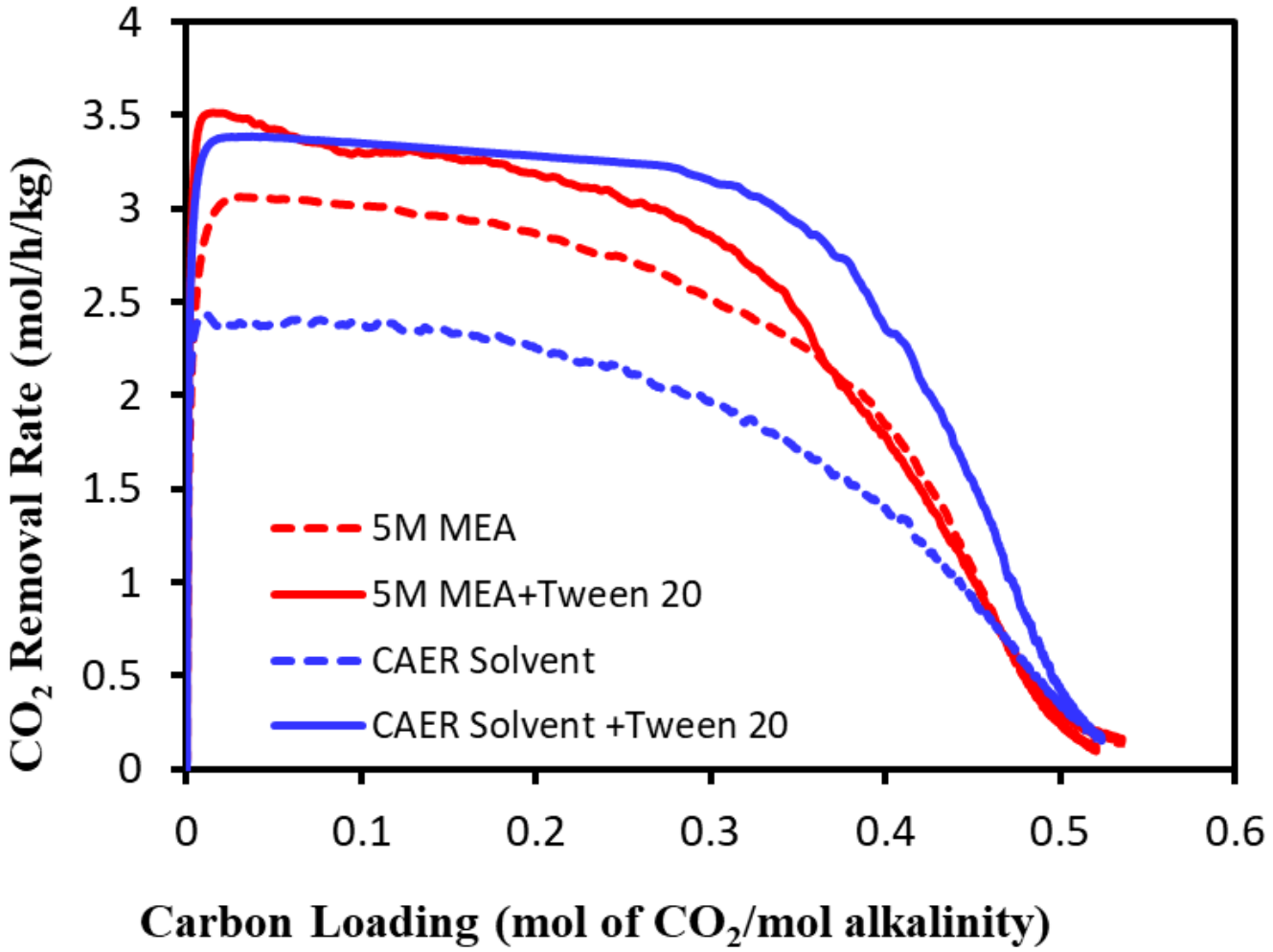
Effect on Wettability



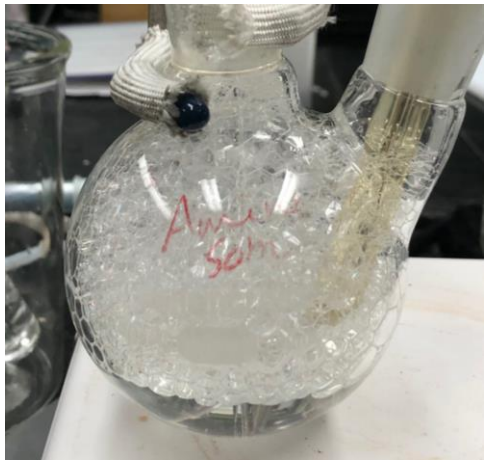
Picture of Contact angle measurements on 3D printed polymer during one experiment

- The Tween 20 does wet the surface of packing material better in comparison to baseline 5M MEA and CAER Solvent

Reactivity of Tween 20 in CAER-Solvents



Tween 20 in 5M MEA



Tween 20 in CAER Solvent

- The Tween 20 does show enhancement in CO_2 absorption in both 5M MEA and CAER Solvent

Conclusion and Future Direction

- Antifoam Xiameter, MBT and $NaVO_3$ have no effect on physical properties as well as on activity
- **C5c** shows surfactant-like behavior in MEA
  - ✓ Two factors determined the froth formation
    - Lower Surface Tension
    - Higher Surface Elasticity
- **Tween 20** shows similar behavior
- **Tween 20** increases the wettability of the solution
- **Surface Elasticity** and **Surface Tension** seem to determine the froth formation in a solution
- Proposed desirable range of physical properties:
  - ✓ Surface Elasticity : **10 mN/m or higher**
  - ✓ Surface Tension : **30-60 mN/m**
  - ✓ Viscosity : **1.75-5 cP**
- **Changes of physical properties can increase the CO_2 absorption rate of a solvent**

Acknowledgements

PGUF and UK-CAER

- Jesse Thompson
- Keemia Abad
- Solvent Development Team
- PowerGen Group
- Kunlei Liu

DOE-NETL

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- Surya Prakash Tiwari
- Janice Steckel
- David E. Alman

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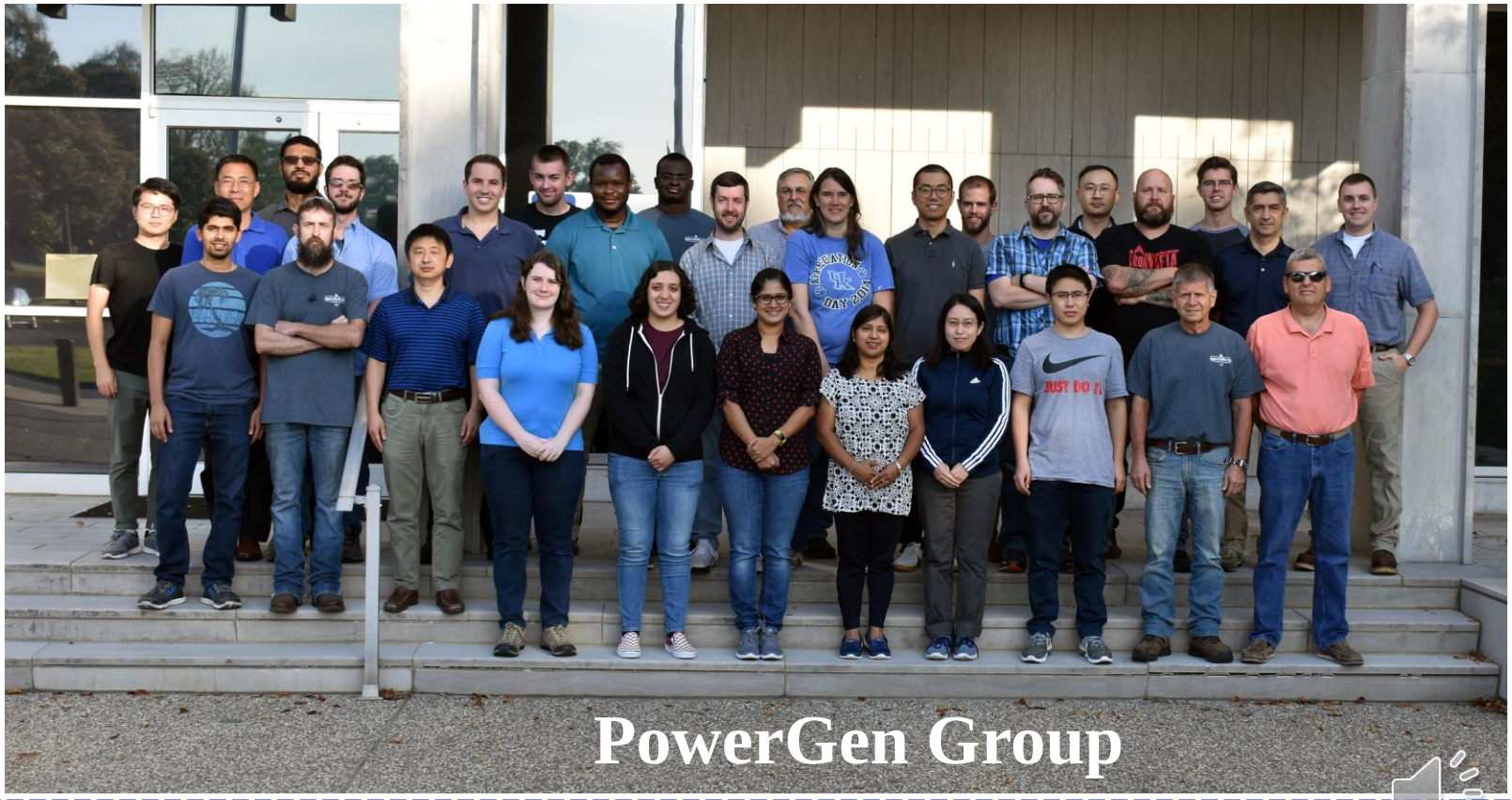

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