Development of Chemical Additives for Reducing CO_2 Capture Costs

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Project Status

- Funding: DOE $ 1,250 K

- Project period: 6/1/08 – 5/31/13

- Participants: Ted Chang – PI
  Y. Li – Postdoc
  C.Y. Liao – Graduate student

- DOE/NETL Manager: Elaine Everitt/Dave Lang

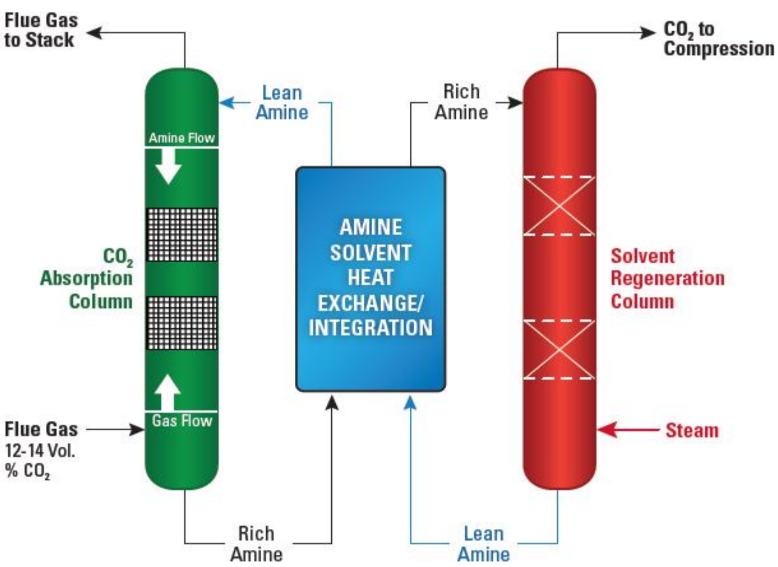
Basic Principles

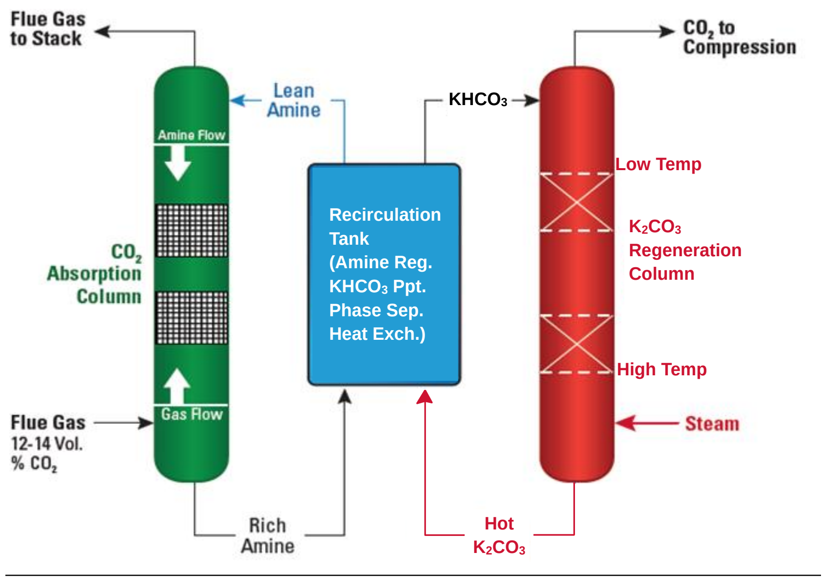
- **Concept → A novel aqueous solvent system that will integrate amine, potassium carbonate, and ammonia to attain high CO_2 capture rates, reduce energy demands and capital costs**
- **Principles → CO_2 captured is transferred from one solvent to another by chemical methods before the final solvent is thermally regenerated**

STEP		Purpose
12-15% CO_2		
1: Amine	→	High CO_2 capture rate
CO_2 ↓		
2: K_2CO_3	→	Precipitate $KHCO_3$ as a solid = much less water than amine solution
CO_2 ↓		
3: $KHCO_3$/Ammonia	→	Low regeneration temperature; low heat capacity
~100% CO_2		

Project Objective

- **Develop a solvent system that will reduce both energy demands and capital costs aiming at attaining DOE's goal of no more than 35% increase in COE**





Typical Amine Solvent Systems

Non-conventional Solvent System

Project Tasks

- **Additives**
  - Capable of capture CO_2 and transfer absorbed CO_2 to potassium carbonate with fast rates
  - Inexpensive, low vapor pressure, stable, and benign (low toxicity)

- **Transformation**
  - Chemistry of CO_2 transformation

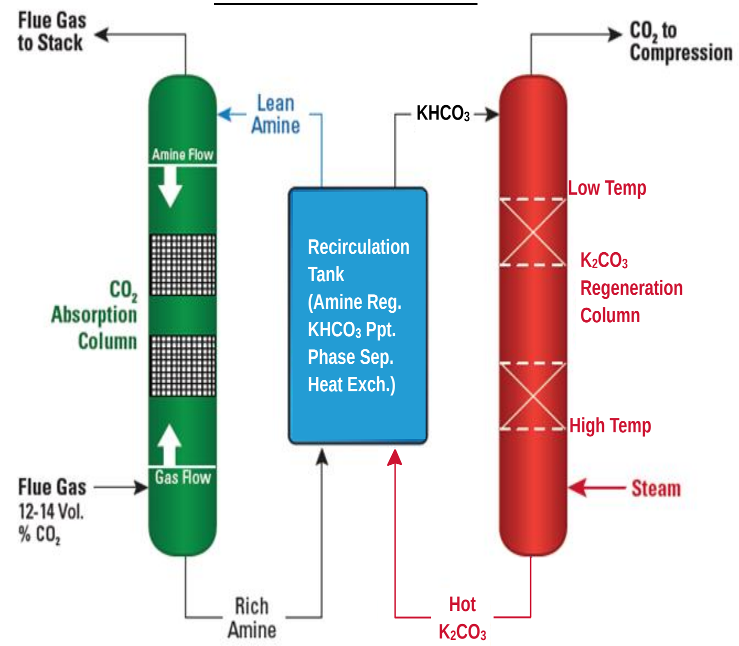
- **Energy demands**
  - Solvent regeneration mass/energy balance

- **Process Assessment and technology transfer**
  - Integrated absorption and regeneration
  - Preliminary techno-economic analysis

<u>Additives</u>

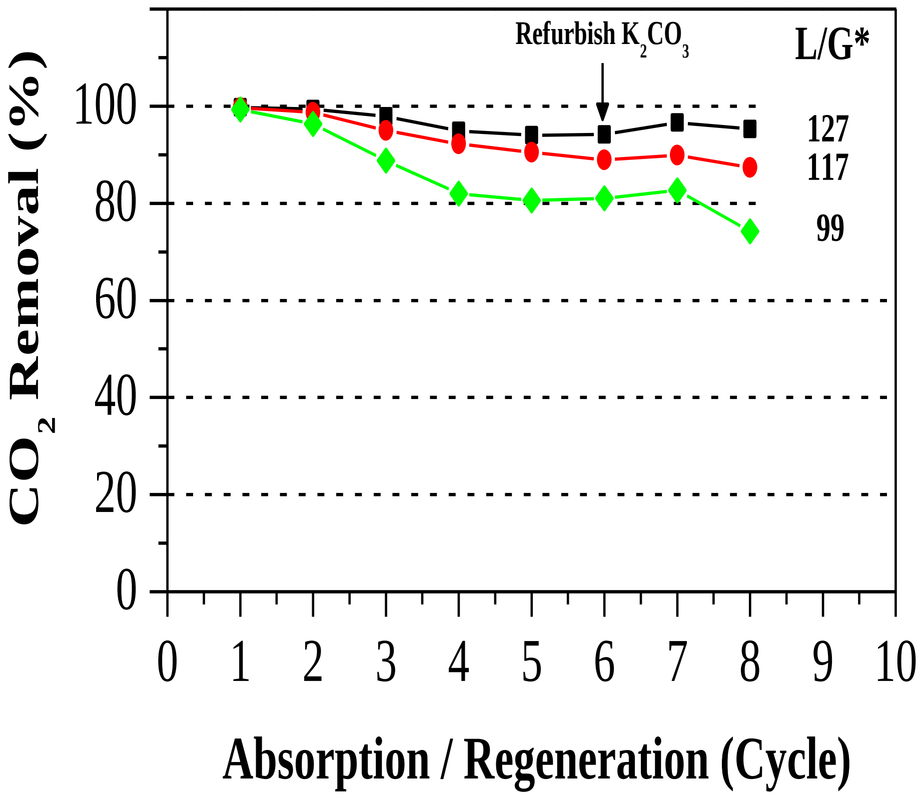
<u>Energy demands</u>

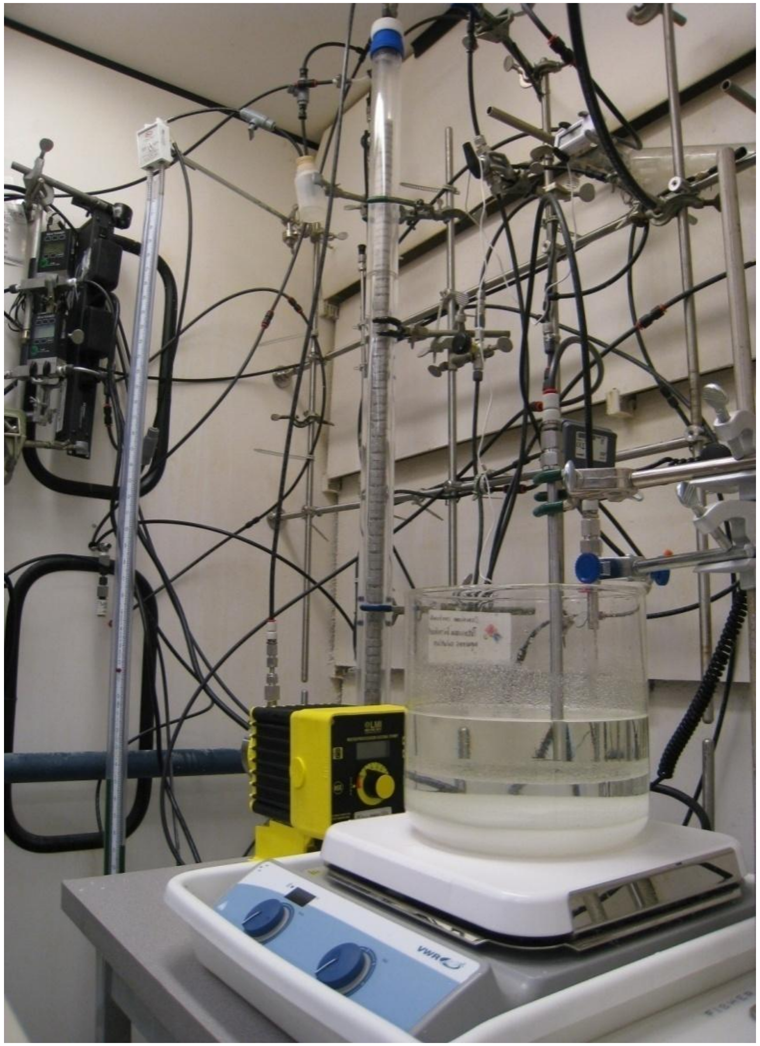
<u>Transformation</u>



<u>Process assessment and technology transfer</u>

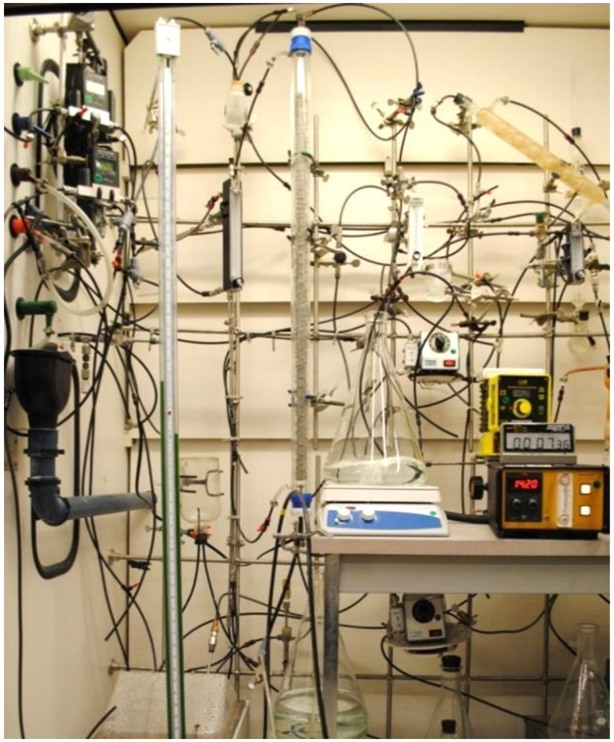
Performance of Chemically Regenerated Amine





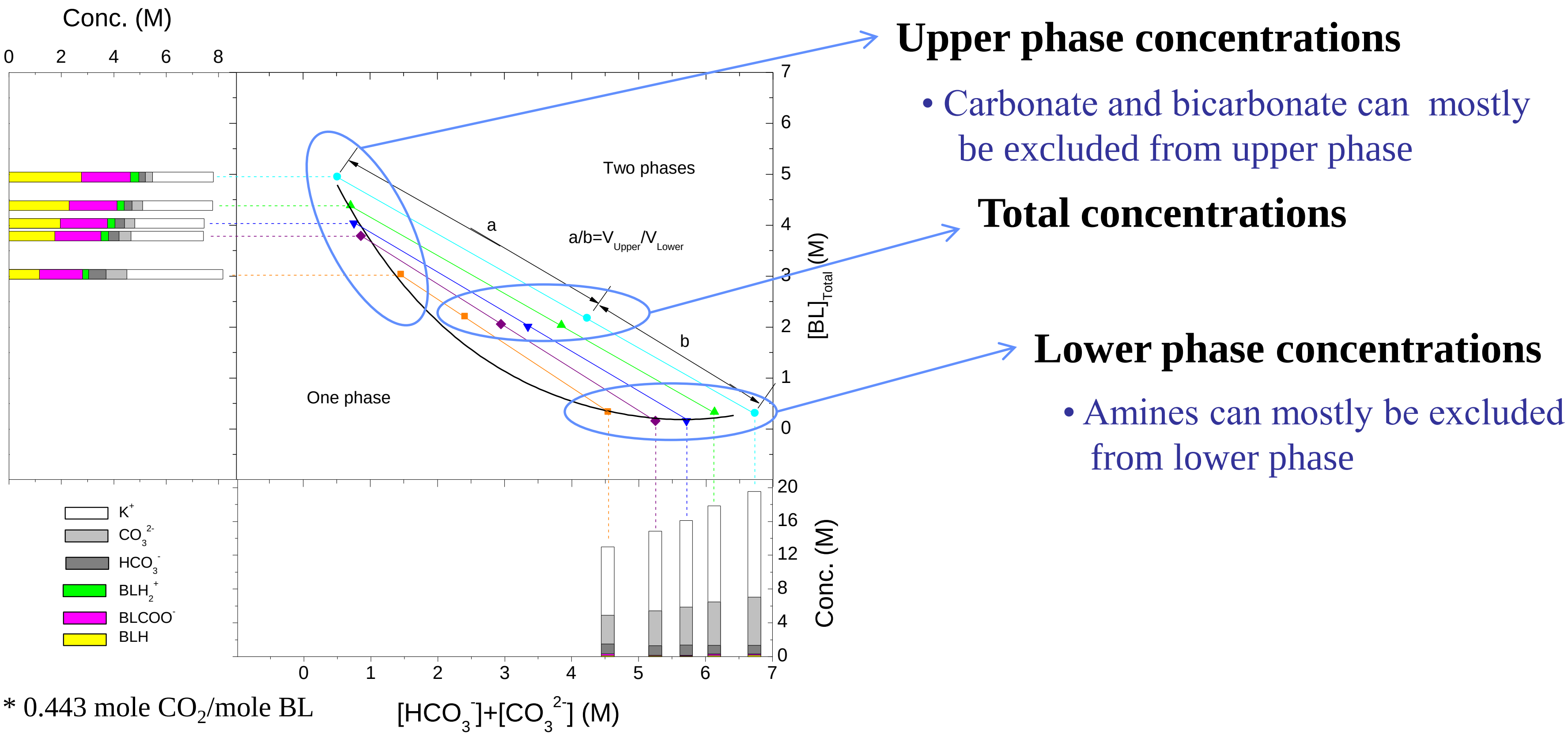
- CO_2 capture rates can be maintained with repetitive absorption/regeneration cycles

Phase Separation, Species Distribution, Phase Diagram, and Chemistry



- **Samples taken: 1. during absorption, 2. after absorption/before regeneration, and 3. after regeneration/before absorption**
- **Upper and lower liquid phases analyzed by NMR (Bruker AVB-400 & 600)**
- **Solid precipitates analyzed by laser Raman Spectroscopy**

Phase Diagrams*



* 0.443 mole CO_2/mole BL

Benefits of phase separation:

- **Increase capture efficiency due to smaller bicarbonate and carbonate conc. in upper lean solvent**
- **Prevent amine from degradation due to its confinement in chem. transformation loop**

Regeneration of K_2CO_3

Pathway	ΔH° (kJ/kg CO_2)	Drawback	Benefits
$2KHCO_3(s) \rightarrow K_2CO_3(l)+H_2O(l)+CO_2(g)$	1479	Slurry handling	Reduce sensible,
$2KHCO_3(s) \rightarrow K_2CO_3(l)+H_2O(g)+CO_2(g)$	2479		latent to < 1000;
$2KHCO_3(s) \rightarrow K_2CO_3(s)+H_2O(l)+CO_2(g)$	2180		Reagent stable
$2KHCO_3(s) \rightarrow K_2CO_3(s)+H_2O(g)+CO_2(g)$	3180		Low heat capacity
Water < 40%			
$2KHCO_3+NH_2CO_2NH_4+H_2O \leftrightarrow K_2CO_3+2NH_4HCO_3$			
$2NH_4HCO_3 \rightarrow NH_2CO_2NH_4+CO_2+2H_2O$			Low decomp. temp
MEA carbamate $\rightarrow$ MEA + $CO_2(g)$	1636	Sensible 2191	Mature
Water ~ 70%		latent 676	
		Reagent degrade	

KHCO$_3$ decomposition rates:

	Steam only	w/ NH_4 species 1	w/ NH_4 species 2
Avg. CO_2 production rate (kg/h)	0.0487	0.0621	0.108

- May reduce stripper size

Advantages

- Reduce energy penalty
  - Low sensible and latent heat

    Solid/slurry, small heat capacity, Low regeneration temp.
  - Using low quality steam and/or waste heat

- Reduce capital costs
  - High regeneration rates

- Reduce reagent loss and equipment corrosion
  - Amines not exposed to high temp.
  - Employ benign, low cost, and thermal stable chemicals

Challenges

Challenges	Mitigation
• Could precipitate in absorber	Control L/G and/or temp.
• Solid/slurry handling	Engineering system analysis

Performance Schedule

Task	June 2008 - May 2009	June 2009 - May 2010	June 2010 - May 2011	June 2011 - May 2012	June 2012 - May 2013
1. Project management and planning					
2. Install walk-in fumehoods Acquire system components	100%				
3. Setup CO2 capture system Determine Raman efficiencies	100%				
4. Absorption of CO2			100%		
5.Chemical transformation			85%		
6. Reagent regeneration and CO2 production				60%	
7. Process assessment and technology transfer				40%	

- **Chemical transformation: slightly behind schedule as additional effort required to figure out the chemistry**
- **Reagent regeneration and CO_2 production: slightly ahead of schedule**
- **Process assessment and tech transfer: on schedule**

Plans for Future Development

- In this project
  - Mass and energy balance
  - Integrated absorption and regeneration tests
  - Process chemistry and assessment
  - Industrial collaboration and technology Transfer

- After this project – team approach
  - Scale up demonstration
  - Techno-Economic analysis
  - EH&S implications

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