Development of Chemical Additives for CO_2 Capture Cost Reduction

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September 13-17, 2010

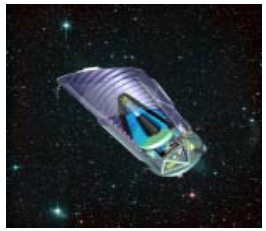
Berkeley Lab at a Glance

11 — Nobel Laureates; 55 — Nobel Laureates trained here ; 13 — National Medal of Science members; 800 — University students trained each year; 4,000 — Employees; 200 — Site acreage

Bringing Science Solutions to the World

Research Areas

- **Energy Efficiency and Sustainable Energy**
- **Biological Sciences for Energy Research and Health**
- **Climate Change and Environmental Sciences**
- **Computational Science and Networking**
- **Matter and Force in the Universe**
- **Soft X-Ray Science for Discovery**



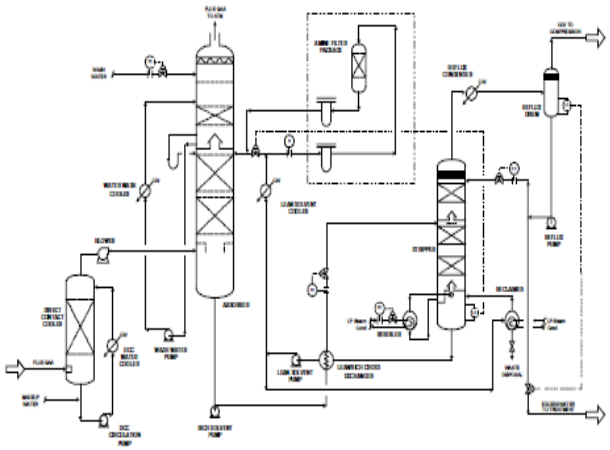
Overview

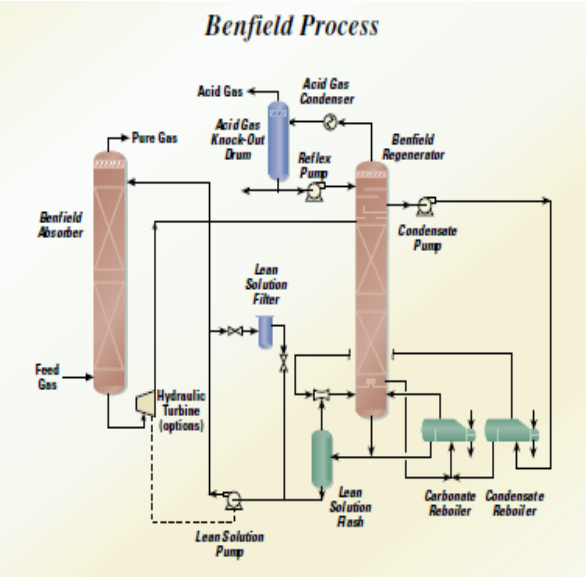
- **Funding: DOE $ 1.25 x 10^6**
- **Dates: June 1, 2008 – May 31, 2013**
- **Participants: Ted Chang, PI**
  Y. Li, X.L. Zhao, and Ray Dod
- **DOE/NETL Manager: David Lang**

Project Objective

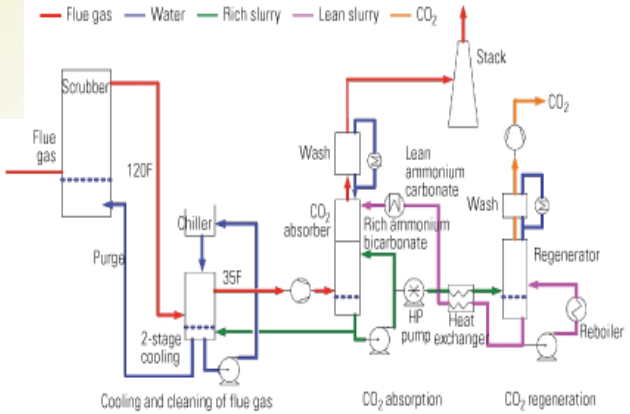
- **Develop a novel solvent system that will integrate amine, potassium carbonate, and ammonium solvents to obtain as much CO_2 absorption and as little solvent regeneration energy demand as possible.**

Econoamine Process





Chilled Ammonia Process



Project Tasks

- **Task 1: Absorption of CO_2 – Develop additives to promote CO_2 absorption by K_2CO_3 solution**

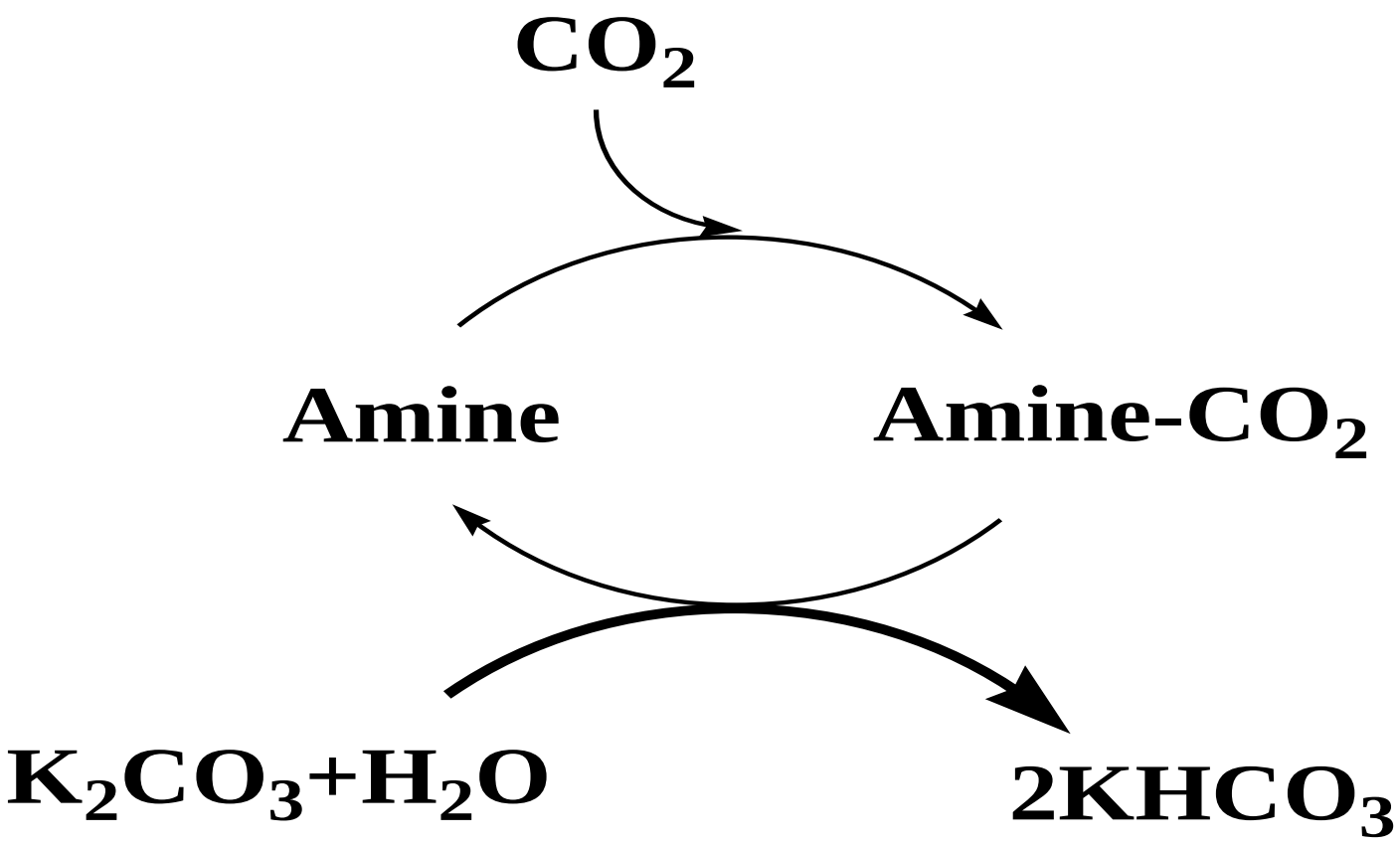
- **Task 2: Chemical transformation – Develop methods to convert $KHCO_3$ to NH_4HCO_3**

- **Task 3: Reagent regeneration – Develop additives to allow conversion of $KHCO_3$ to K_2CO_3 with low energy demand**

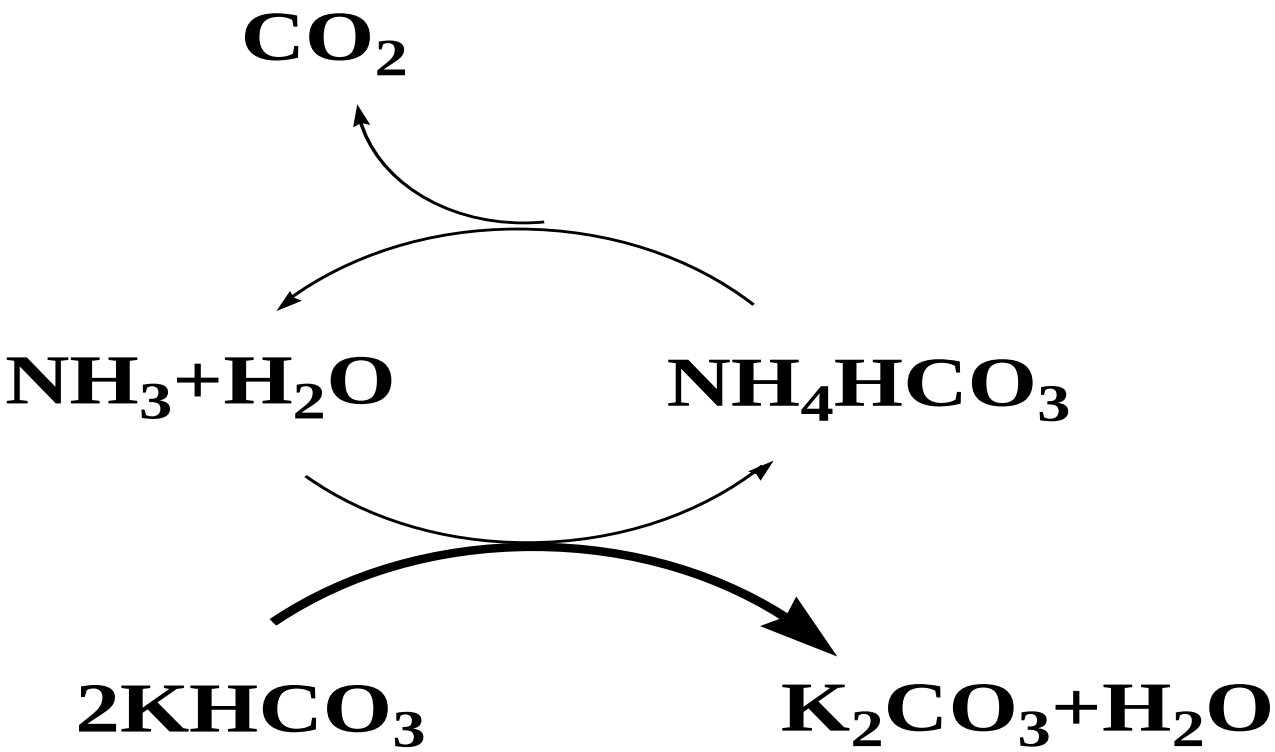
- **Task 4: Process assessment and technology transfer –**

  Investigate chemistry involved, develop process configuration, determine energy demand, and prepare for scale-up demonstration

CO_2 Absorption

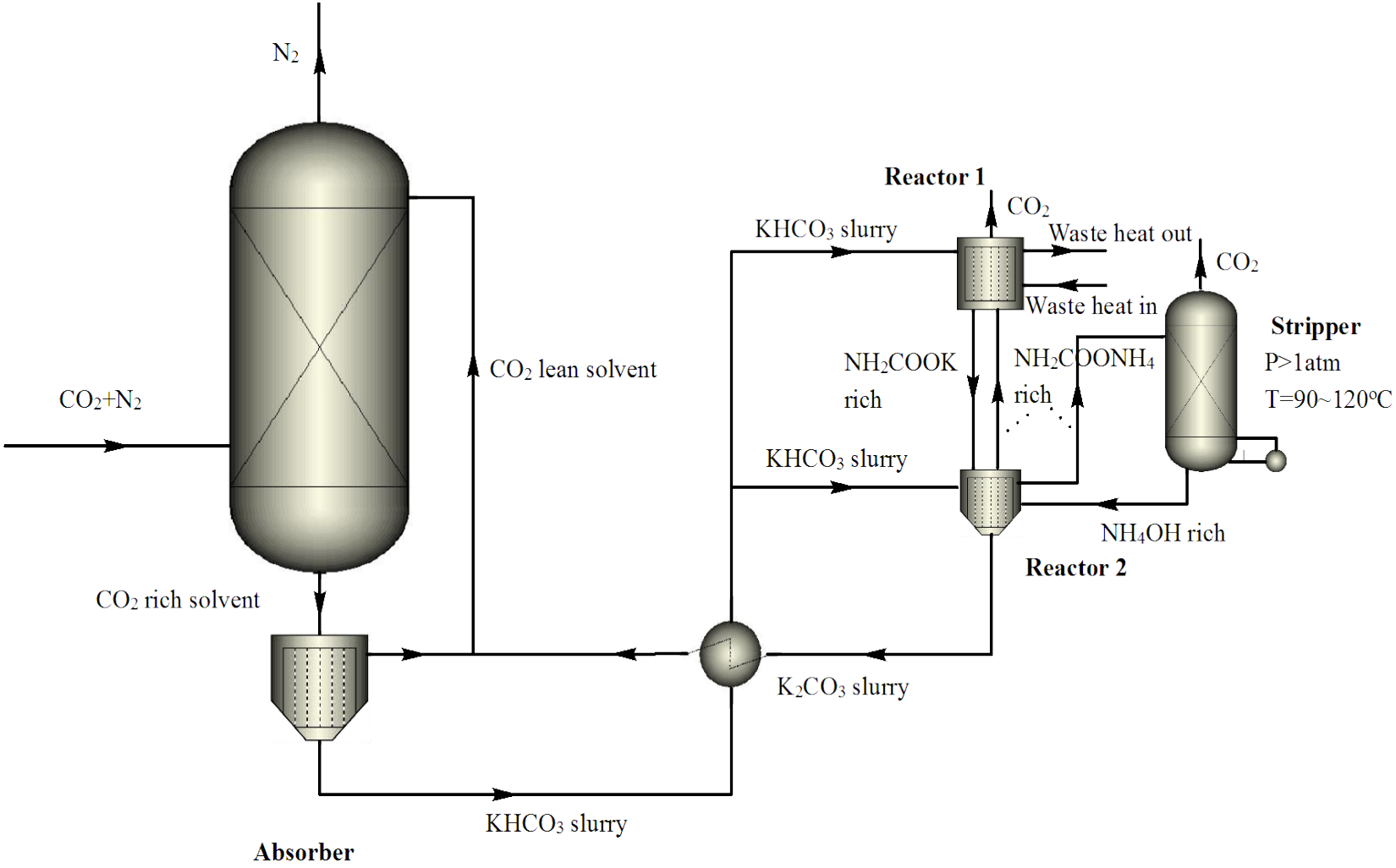


K_2CO_3 Regeneration - 1

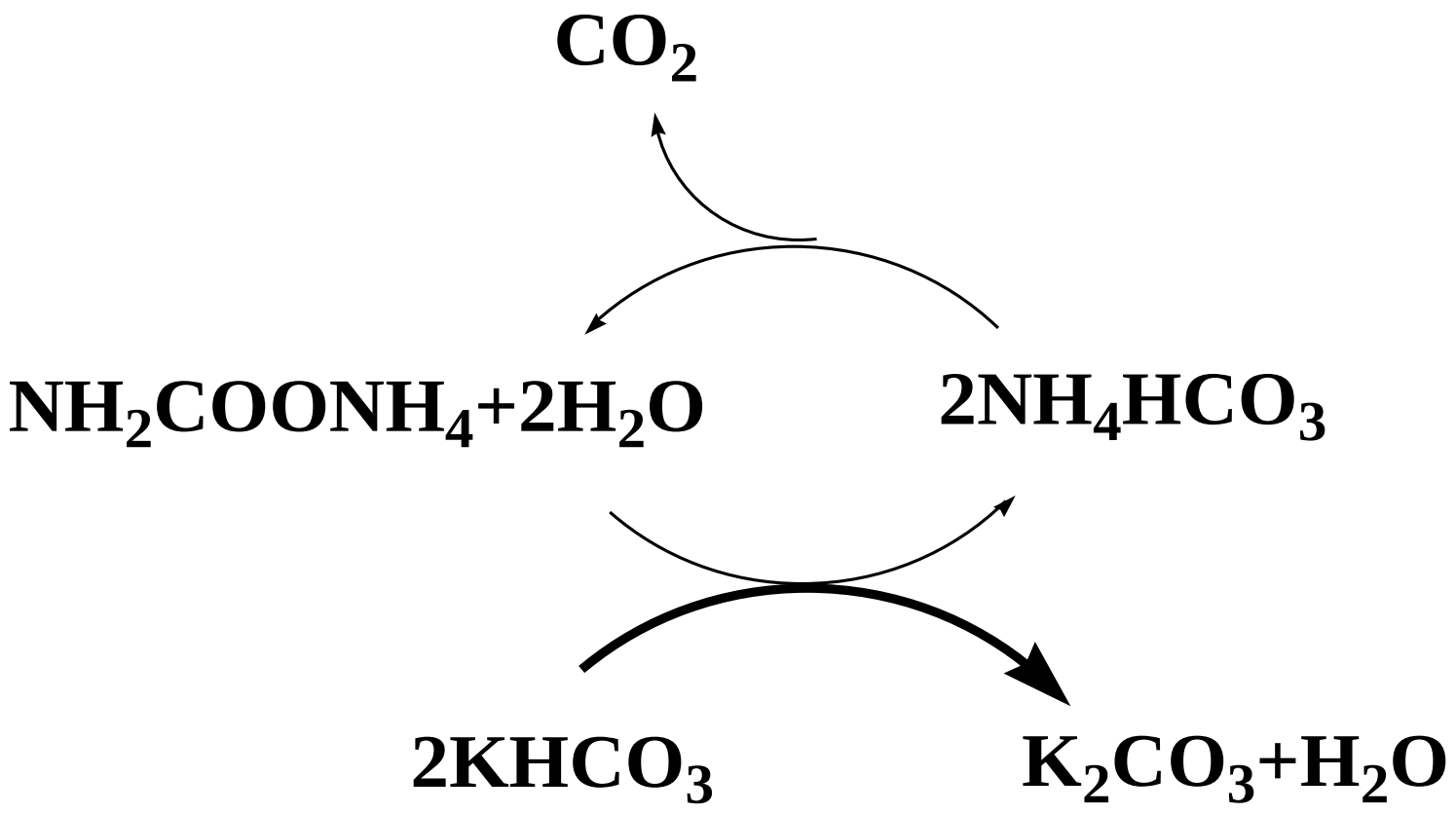


$$2\ KHCO_3(s) \rightarrow K_2CO_3(s) + H_2O(l) + CO_2(g) \quad \Delta H^o = 2180\ kJ/kg\ CO_2$$

Conceptual Process Configuration - 1

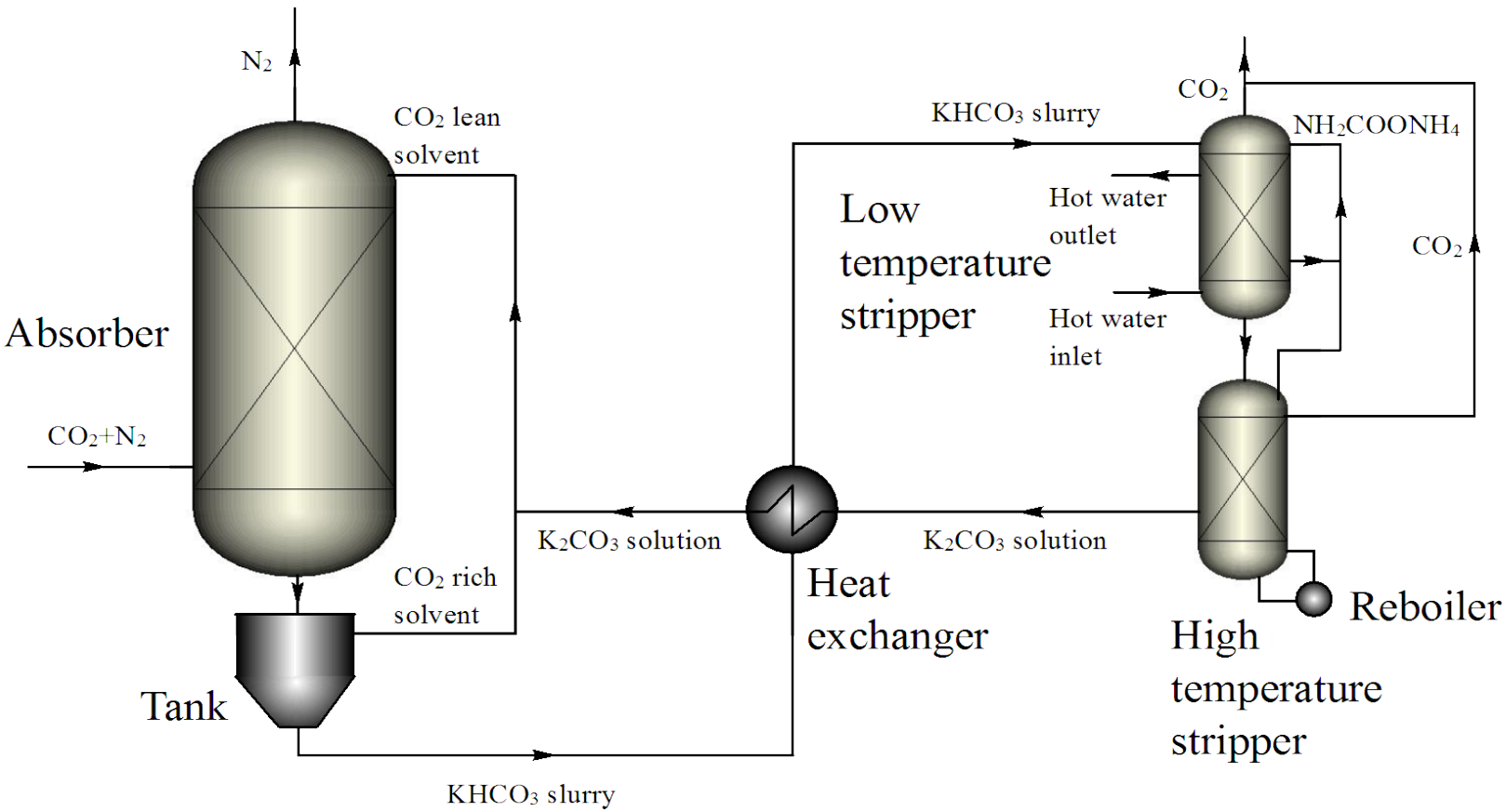


K_2CO_3 Regeneration - 2



$$2\ KHCO_3(s) \rightarrow K_2CO_3(aq) + H_2O(l) + CO_2(g) \quad \Delta H^o = 1479\ kJ/kg\ CO_2$$

Conceptual Process Configuration - 2



Technical and Economic Advantages

- **Low energy demand**

  * Slurries → reduce sensible and latent heat
  * NH_4HCO_3 → Low solvent decomposition temperature
  * Waste heat → CO_2 production

- **Reduced reagent loss and equipment corrosion**

  * Organic rate promoters not exposed to H.T. stripping

- **Avoid NH_3 emissions**

Technical and Economic Challenges

- CO_2 absorption rate promoters

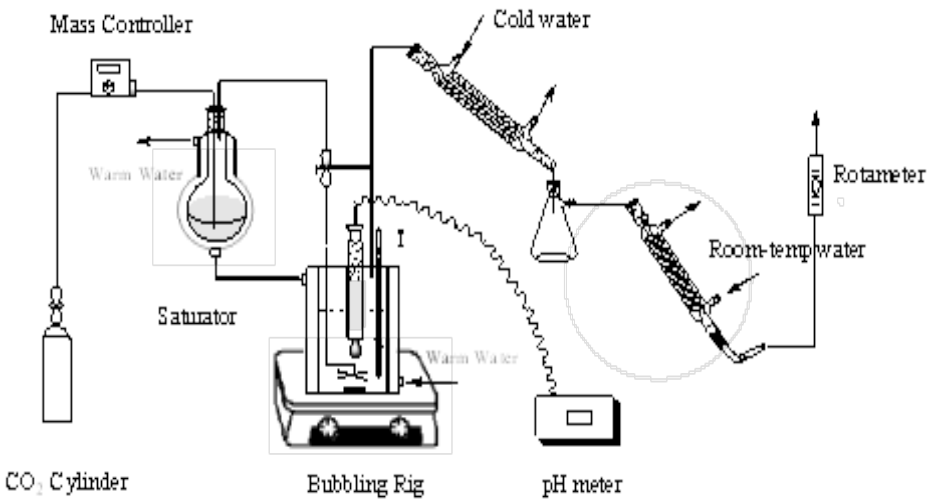
- Reaction mechanisms, kinetics, and thermodynamics

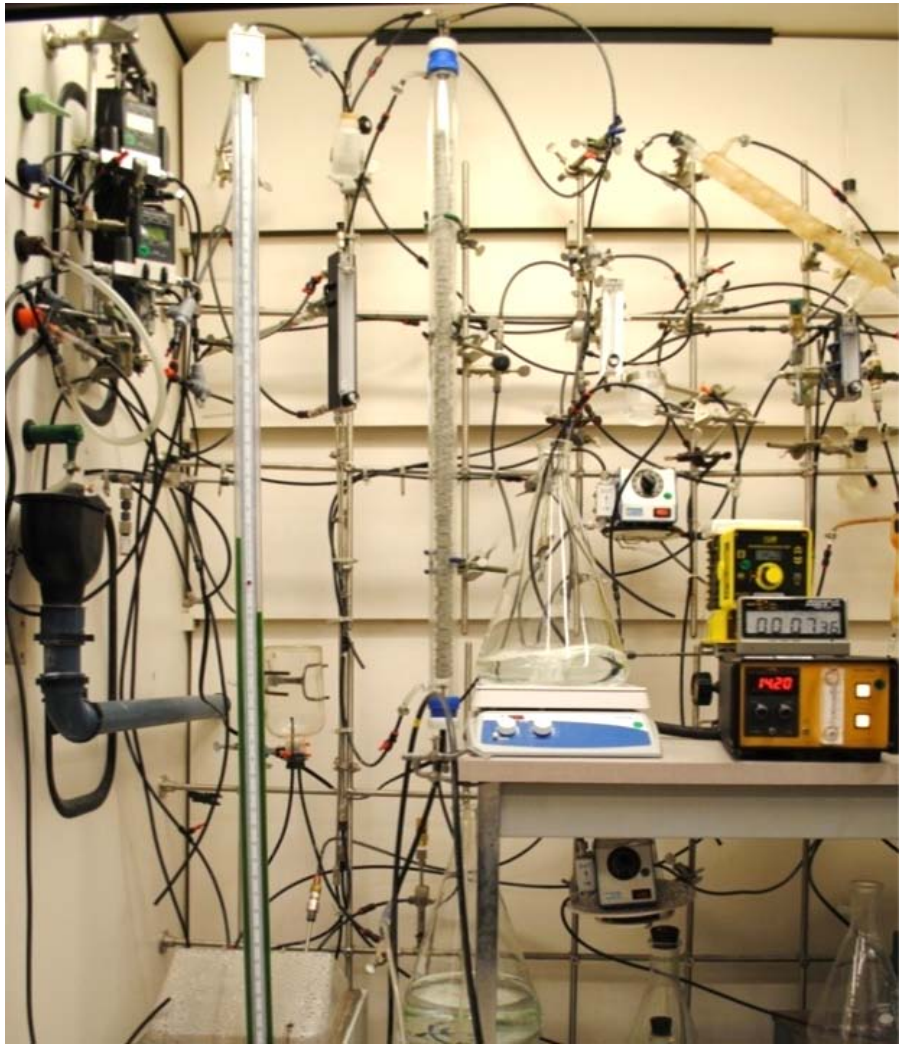
  Involving many chemical species, three phases, high concentrations, elevated temperatures, and pressure

- Most appropriate process configuration

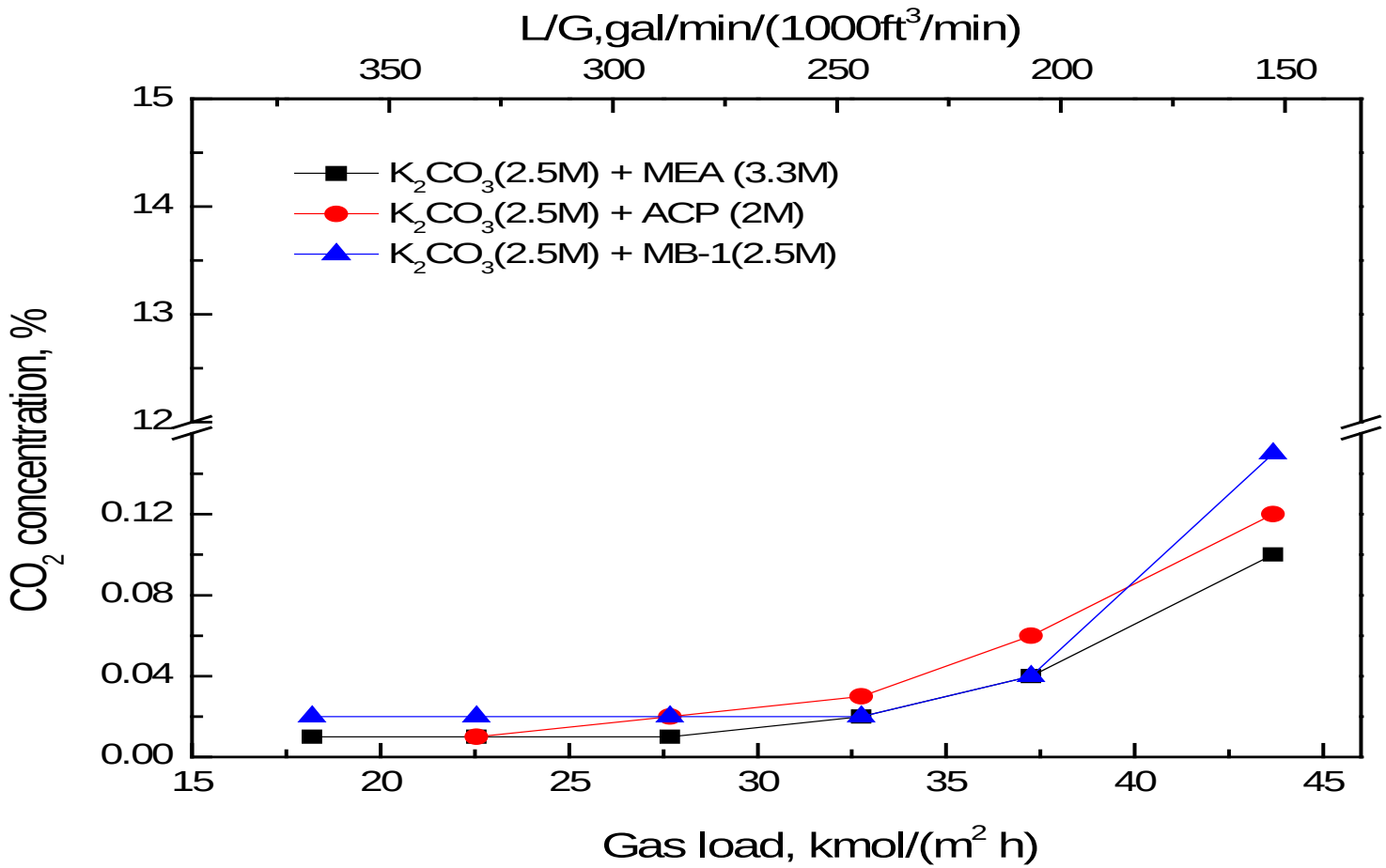
Apparatus for CO_2 Absorption

Investigation of
CO_2 absorption promoters

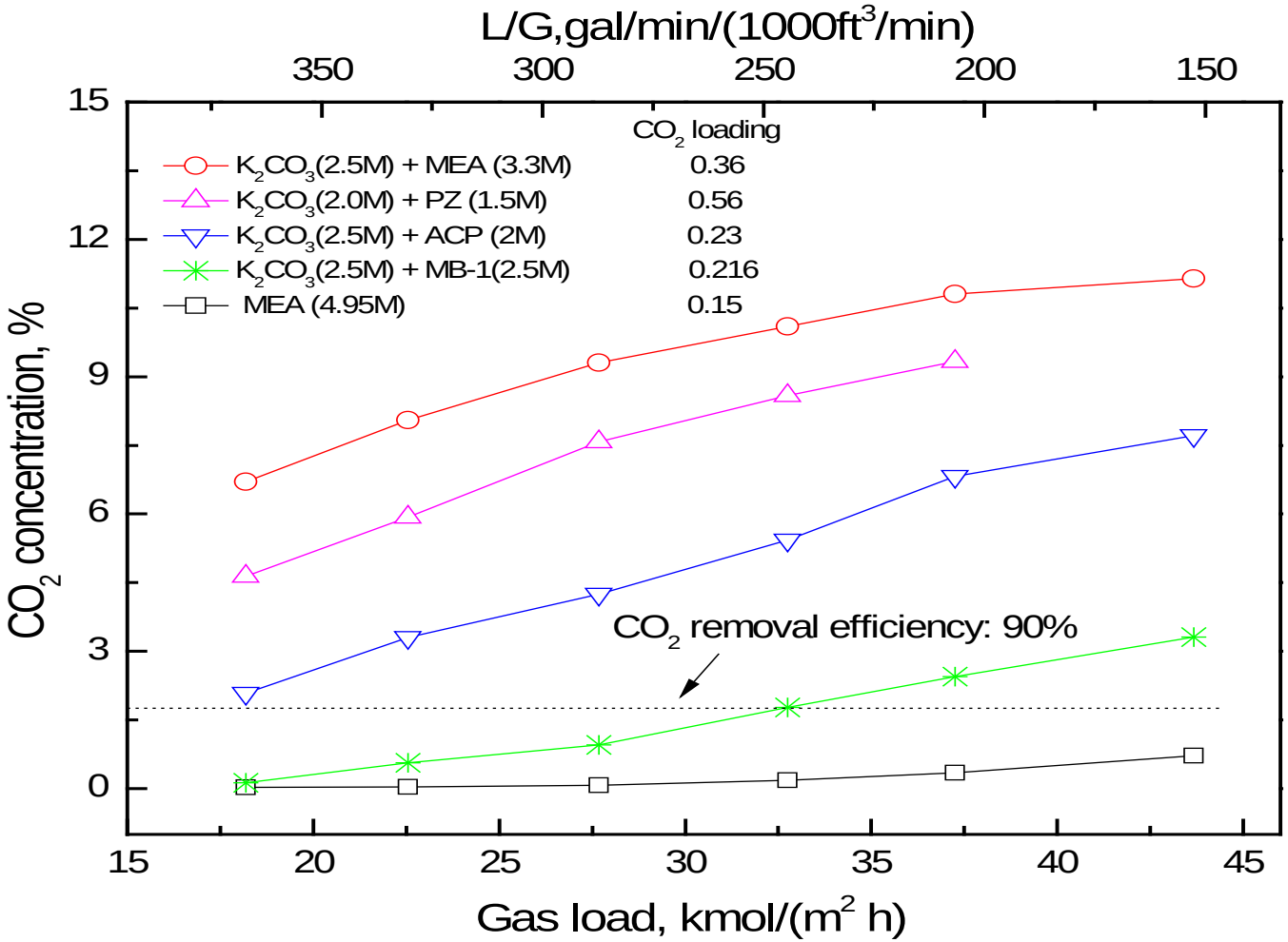




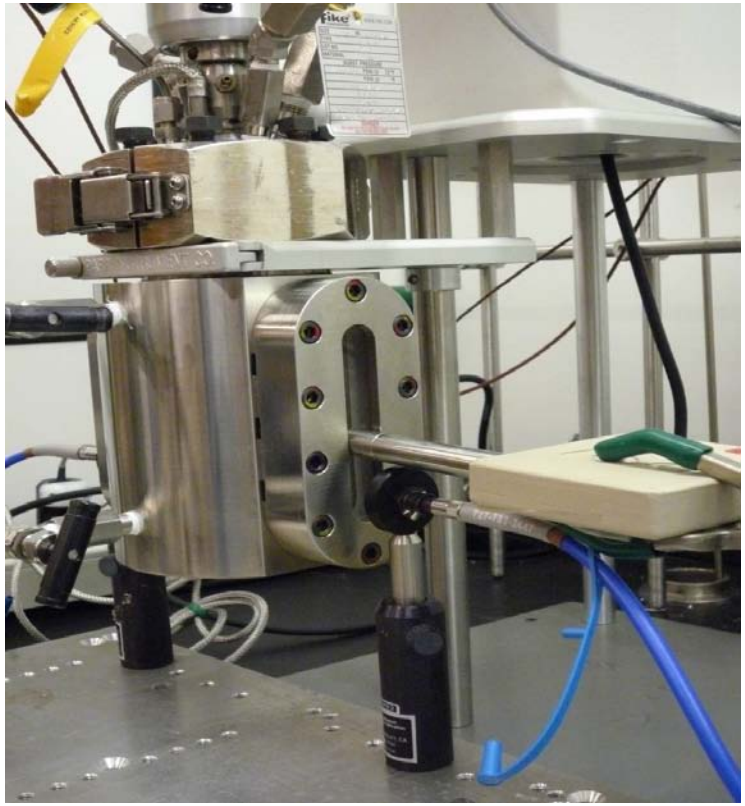
CO_2 Absorption w/ Fresh Solvents



CO_2 Absorption w/ Regenerated Solvents

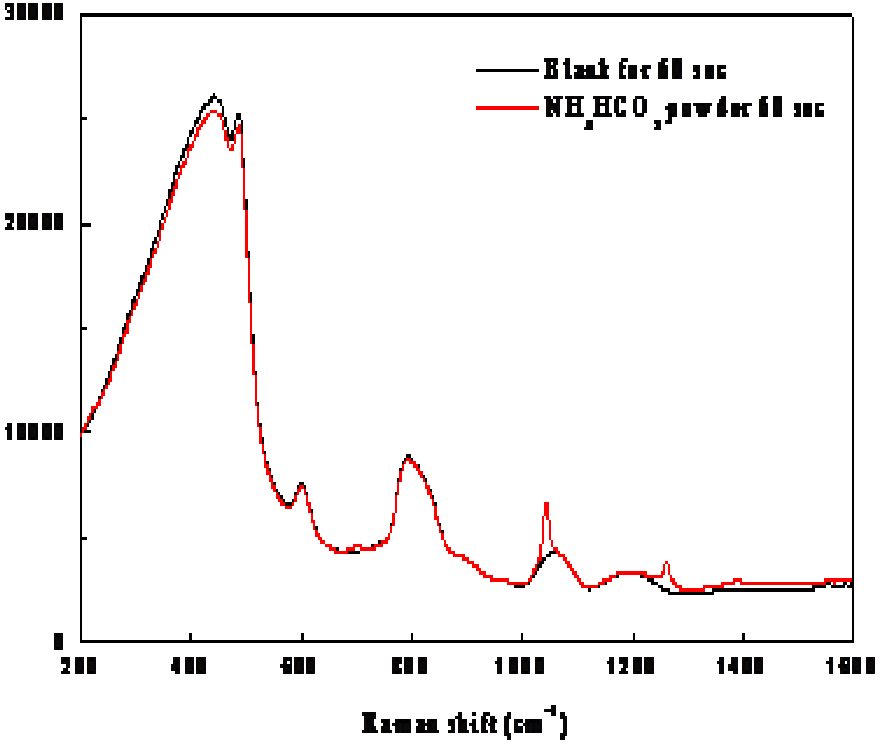


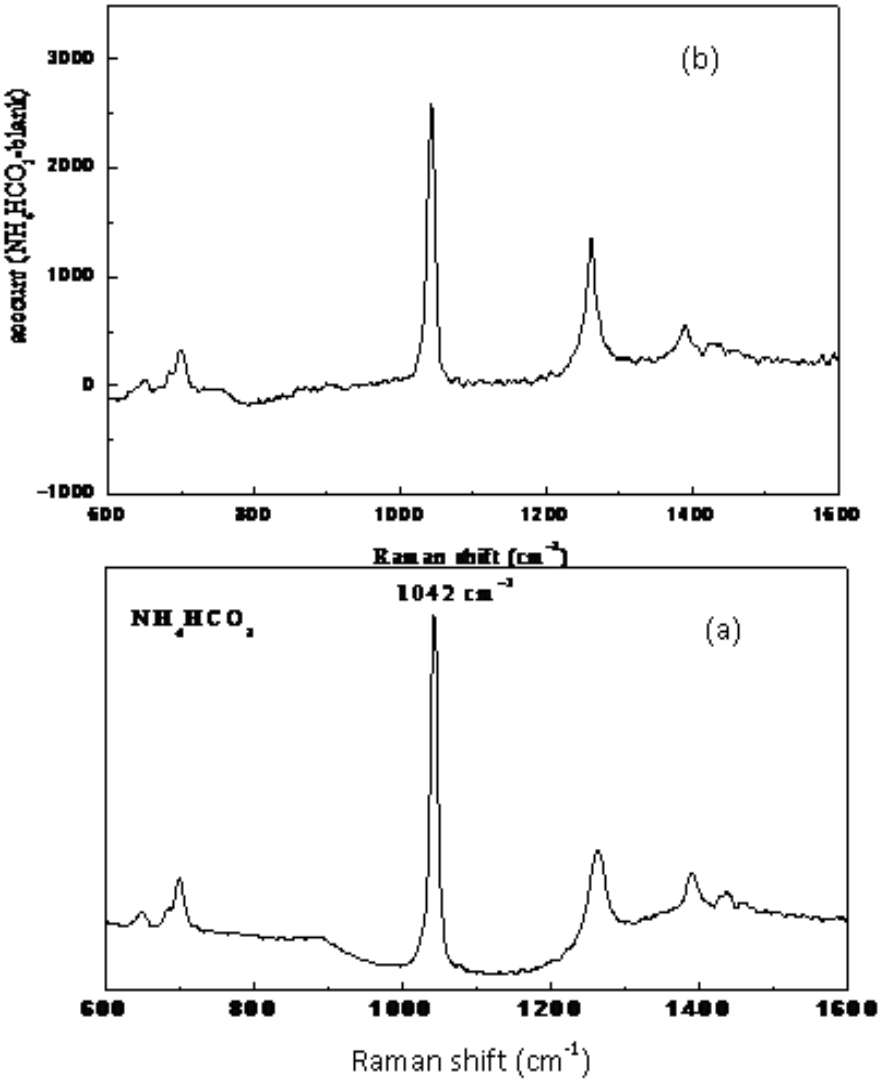
Chemical Reactions in Autoclave



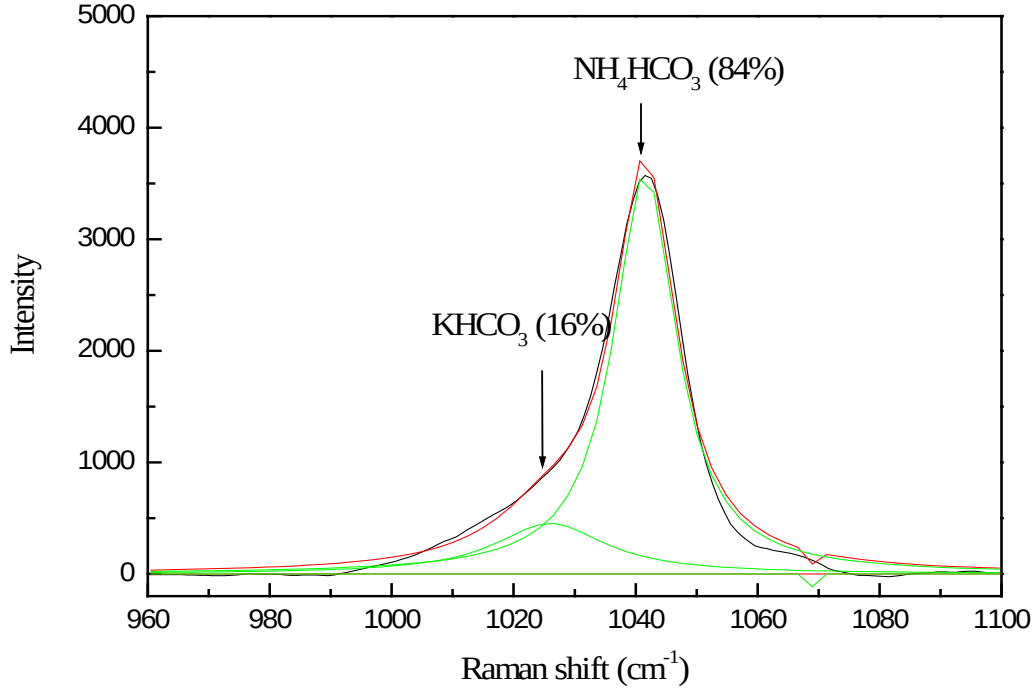
In situ monitoring of reactions in autoclave by laser Raman and uv-visible spectroscopy

Raman spectrum of solid NH_4HCO_4 in autoclave



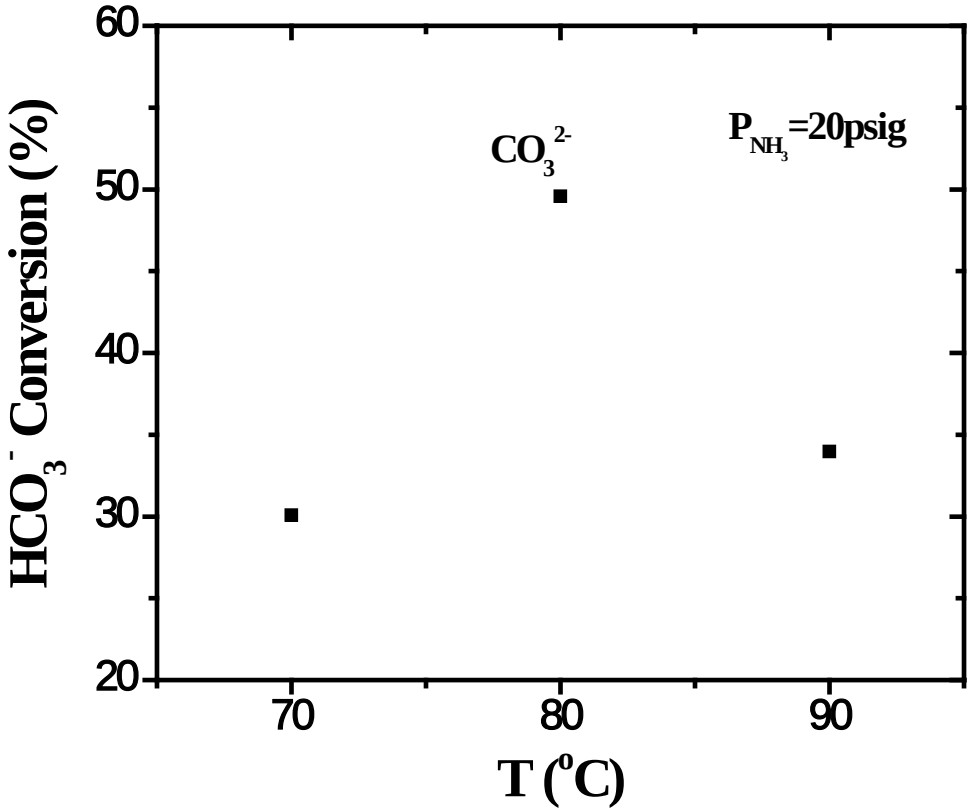


Conversion of $KHCO_3$ to NH_4HCO_3



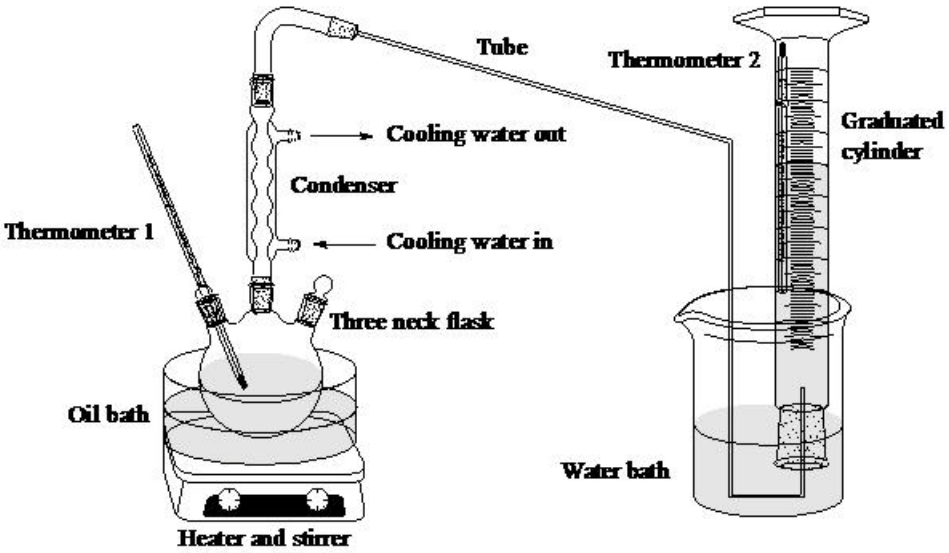
- Reaction of $KHCO_3$ slurry with $(NH_4)_2CO_3$ produced NH_4HCO_3 slurry

Conversion of $KHCO_3$ to K_2CO_3



- CO_3^{2-} formed at high pH → applying NH_3 pressure
- CO_3^{2-} : $NH_2CO_2^-$ increases; but, NH_3 solubility decreases w/ temp.

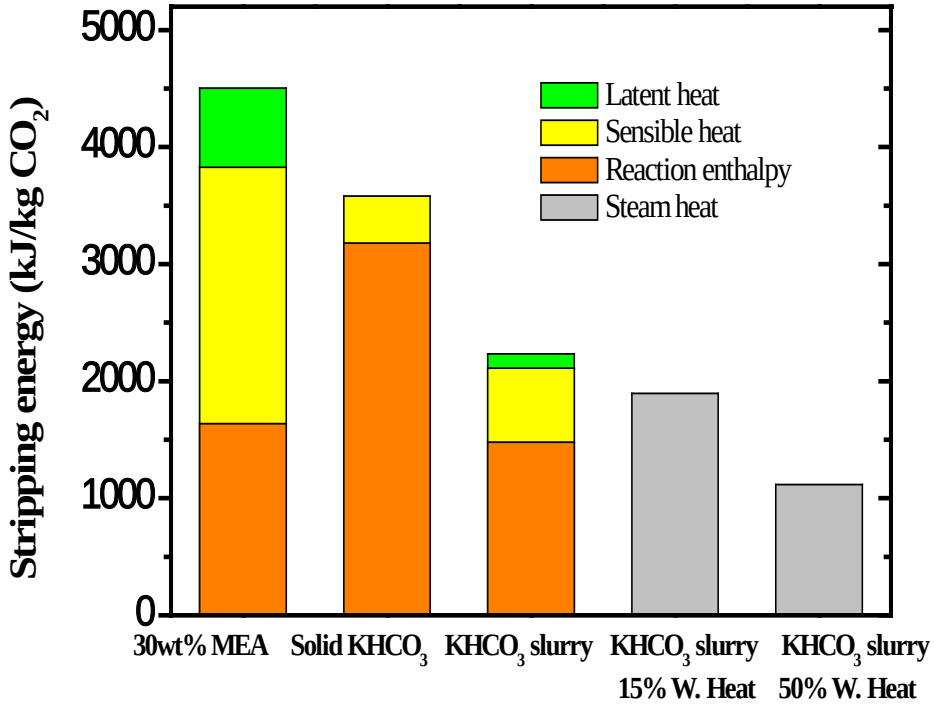
Preliminary Energy Demand Determination



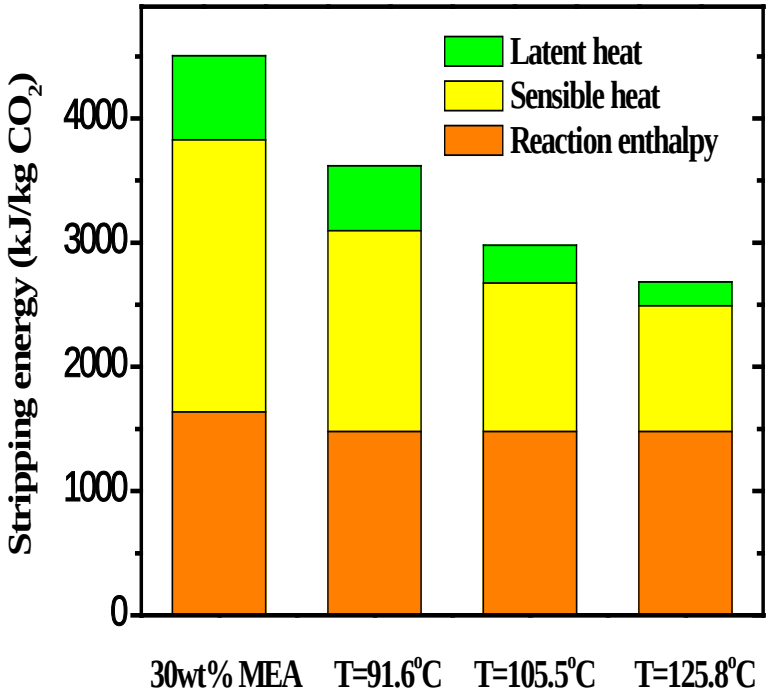
Energy Demand for Regeneration of 30% MEA

CO_2 loading of rich phase (mole CO_2/mole amine)	0.4
CO_2 loading of lean phase (mole CO_2/mole amine)	0.15
Absorption temperature (^oC)	55
Regeneration temperature (^oC)	120
Latent heat (kJ/kg CO_2)	676
Sensible heat (kJ/kg CO_2)	2191
Reaction enthalpy (kJ/kg CO_2)	1636
Total regeneration heat (kJ/kg CO_2)	4503
Mass of MEA (kg/kg CO_2)	5.55
Mass of water (kg/kg CO_2)	12.95

Estimated Energy Demands



Calculated



Bench-scale results

Plans for Future Development

- **In this project**
  - * Look for better CO_2 absorption promoters
  - * Investigate chemistry involved
  - * Use Aspen modeling to determine energy demands for various conditions and process configurations
  - * Technology Transfer & partner with industry

- **After this project**
  - * Scale up demonstration