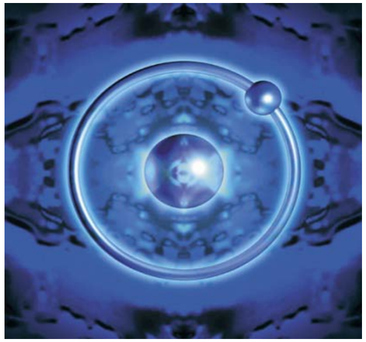




Solar Thermal Hydrogen Production

Using Molten Salt-Catalyst Mixture

P.I. Alan Gertler (DRI)

Presenter | Vaidyanathan (Ravi) Subramanian

University of Nevada, Reno | June 10 2010 DE0000272

PD077

Overview

Timeline

- 10/1/2009-9/30/2010
- 2/4/2010- current
  (date funds became available)
- 10% complete

Budget

- Total funding
  - 99,953 (DRI)
  - 258,235.00 (UNR)
- Funding received in FY 10
  - 99,953 (DRI)
  - 258,235.00 (UNR)

Barriers

- Role of metals in CH_4 decomposition
- Nature of carbon product formation
- Scale-up considerations

Partners

- Desert Research Institute
- University of Nevada, Reno

Objective – Relevance

- The main objective of this work is to evaluate hydrogen generation from carbon sources using simulated solar thermal energy and molten salt – catalyst mixtures
  - Goal – To improve the kinetics of hydrogen production from hydrocarbons at reduced temperature

Performance measure	Units	Qtr 1 and 2	Qtr 3 and 4
Salt-catalyst thermal stability	hours	Three	Eight
Temperature Range	Celsius	400-700	400-600
Volume of hydrogen	Milli-liter	<10	100

Milestones

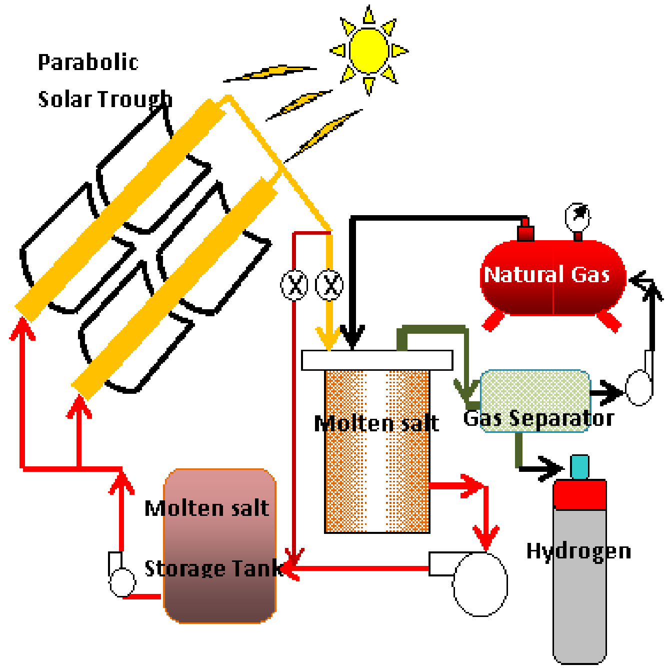
Activity	Progress	Plans	% activity completed
Experimental setup	Parts, chemicals, and custom devices obtained	Perform experiments over qtr 2,3,and 4	20 %
Modeling	Identify heat capacity, free energy of formation of potential byproducts	To be started	0 %
Product analysis	GC setup	Product gas, Carbon forms to be determined	10 %

Background

- Conventional hydrogen production
  - Conventional hydrogen generation from natural gas by steam reformation produces CO_2 as a byproduct.

    $CH_4 + H_2O \rightarrow CO + H_2$ (at 800 -1000 ° C)

    $CO + H_2O \rightarrow CO_2 + H_2$ (at 250 -450 ° C)
- Solar thermal hydrogen
  - Concentrated solar radiation leads to high temperature that can be used in hydrogen production
- Advantages
  - Non-fossil-based renewable source
  - Possibility for 24-hour operation



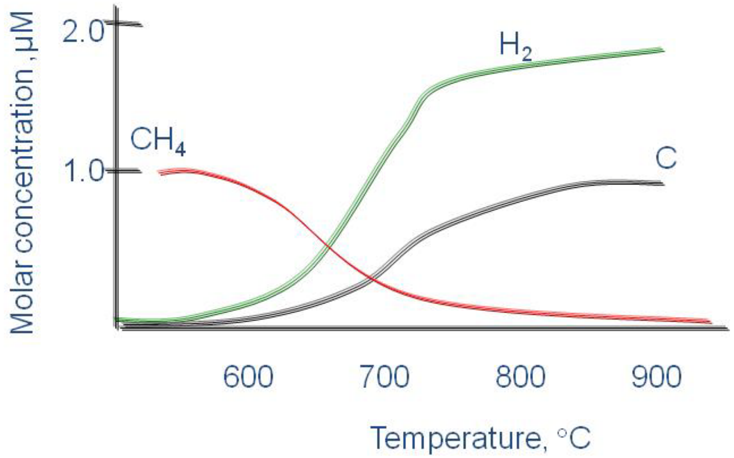
Schematic Arrangement for Conversion of Natural Gas into Hydrogen Using Solar Heating of Molten Salt

Using molten salt as a heat carrier and nano-structured metal particles or liquid metal-solid solutions as catalysts, natural gas can be converted to hydrogen and value added carbon product. There is a potential for the reaction temperature to be reduced.

Approach

- Thermal decomposition of methane or natural gas to hydrogen and carbonaceous materials occurs at high temperatures (>700 °C). We will study this process.

$$CH_4 \xrightarrow[\text{molten salt eutectic})]{\substack{\text{Solar thermal} \\ (\text{nano}-\text{catalyst in}}} 2H_2 + \underbrace{C}_{\text{value added}}$$



- The goals are to:
  - Utilize solar thermal energy as heat source for thermal decomposition,
  - Develop catalyst to reduce the conversion temperature, and
  - Increase the kinetics of hydrogen generation.

Approach…contd.

Tasks	Specifics
Identifying eutectics	Examining thermodynamic parameters that provide insight into eutectic point of custom molten salt mixtures.
Characterizing product(s)	Identifying carbon product(s) following methane decomposition.
Screening eutectics	Testing hydrogen generation kinetics and hydrogen yield from methane using eutectics identified in step 1.
Determining catalyst activity	Examining the contribution of catalysts to product composition and hydrogen yield.

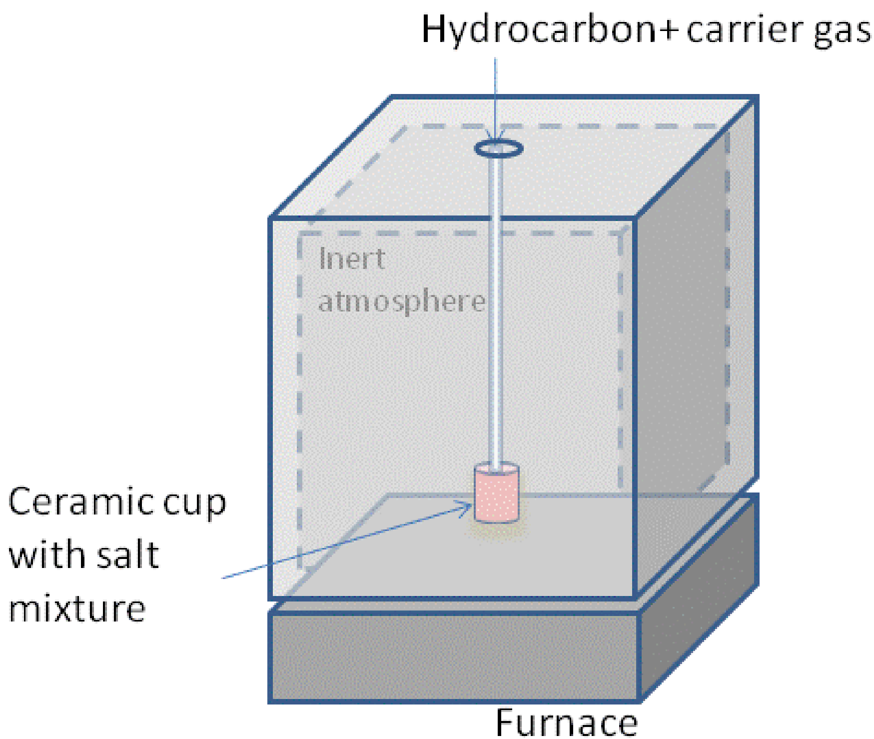
Approach…contd.

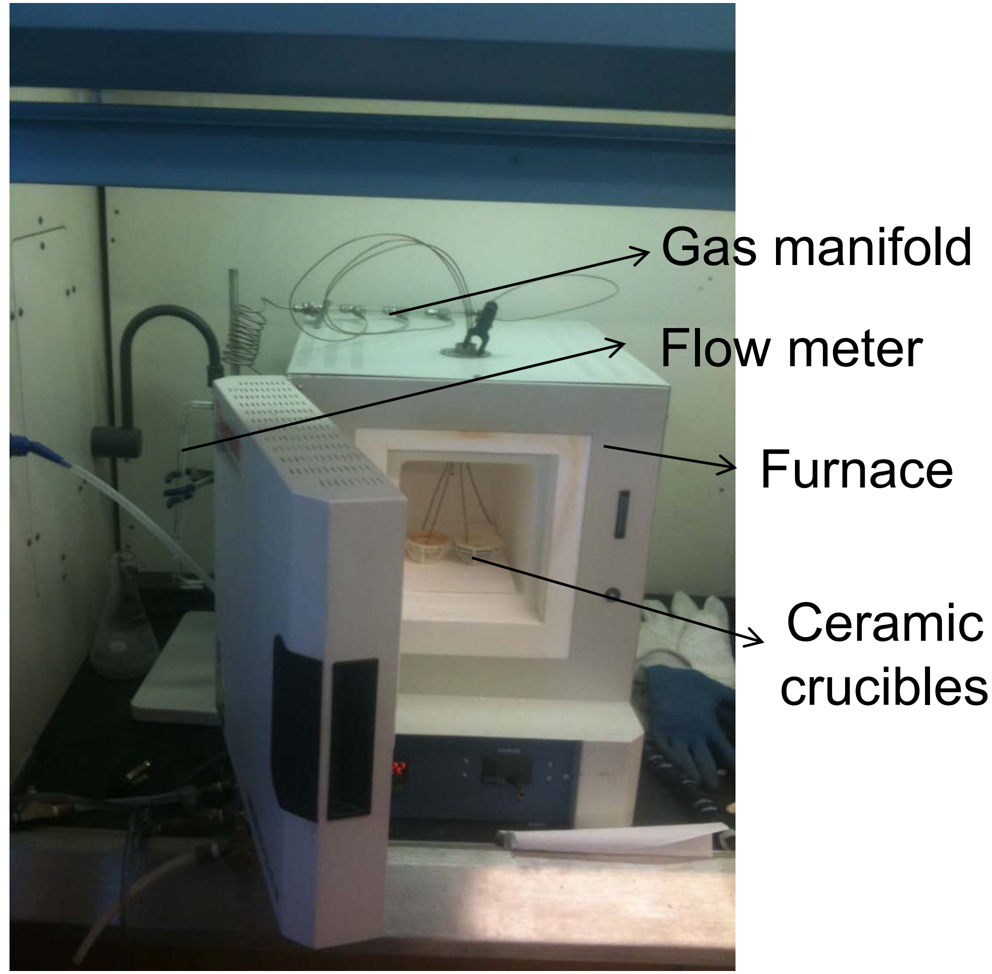
Design parameters and methodology for experimentation

- Reactor configuration
- Combinatorial approach to screen molten salt +catalyst system. The main steps are:
  - Prepare various molten salt + catalyst mixtures
  - Introduce methane
  - Identify mixtures that produce hydrogen using gas chromatograph
  - Identify the carbonaceous residue
- Other experiments
  - Examine effect of temperature on hydrogen and carbon product(s) formation
  - Examine effects of gas flow rate on composition

Approach…contd.

- Schematic and picture of the experimental setup





Accomplishments

- The dissociation of methane in the presence of a metal catalyst follows a sequence of dehydrogenation steps:
  - $CH_{4,s} \rightarrow CH_{3,s} + H_s$
    $CH_{X,s} \rightarrow CH_{X-1,s} + H_s$
    (X=3,2, 1 and s=surface)
  - The activation energy of dissociative adsorption of methane on transition metal surfaces:

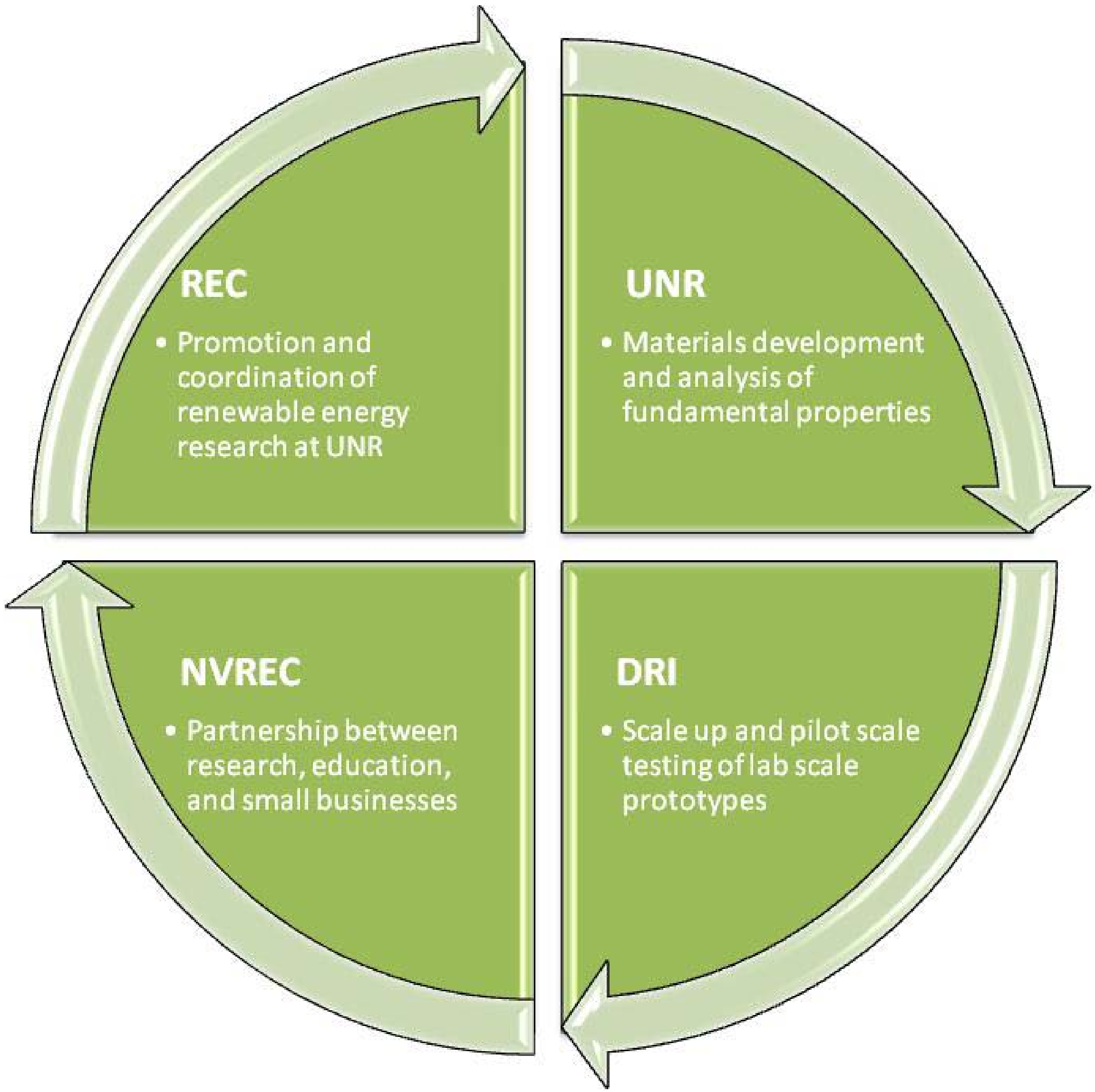
Metal	Activation Energy kJ/mol
Ni	52.6
Pt	71.6
Fe	158

- Preliminary results
  - The presence of Fe, Ni, and Co show hydrogen generation

Catalyst system	% conversion at:		
	500°C	600°C	700°C
LiCl+KCl eutectic	0	0	0
Fe catalyst in LiCl+KCl	5	8	17.5
Ni catalyst in LiCl+KCl	11.5	28.0	30
Co catalyst in LiCl+KCl	7.2	11	16

J. Molecular Catalysis.A: Chem 136 (1998) 185-194
Appl. Catal. A. (2004) 135-144

Collaborations



Summary

- Relevance – Examine feasibility of hydrogen production using solar heat and cost-effective heat storage media
- Approach – Abundantly available molten salt and inexpensive metal catalyst will be used to store solar heat and recover for H2 production on-demand
- Technical accomplishments – Preliminary results suggest that Ni is a better catalyst than Co and Fe
- Collaboration
  - DRI – Alan Gertler, Kent Hoekman. Amber Broch
  - UNR – Ravi Subramanian (experimental), Manoranjan Misra (NV-REC), Victor Vasquez (modeling)
- Proposed future research
  - Validate the objectives of this project
  - Evaluate feasibility of scale up.