Platinum Group Metals and Earth-Abundant Oxides for Catalytic Combustion of Methane

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ARPA-E REMEDY Workshop

October 20, 2020

Introduction/Background

- Director of the National Science Foundation Engineering Research Center for Innovative and Strategic Transformation of Alkane Resources – CISTAR (www.cistar.us) – Professor of Chemical Engineering at Purdue University

- CISTAR motto is "Responsibly Realizing the Potential of Shale Resources". Methane is the principal component. Methane emissions need to be controlled
- Worked in industry in the development of methane catalytic combustion for gas turbine applications (Catalytica, Inc.) and with Cummins on engine emissions
- Associate editor for Journal of Catalysis covering this area 2010-2018

The Technology

- $CH_4 + 2O_2 \rightarrow CO_2 + 2\,H_2O$ + heat

The parameters

Reaction time: flow rate (volume/time), volume of the device

Rate of reaction: moles/(second.volume) depends on concentration, temperature

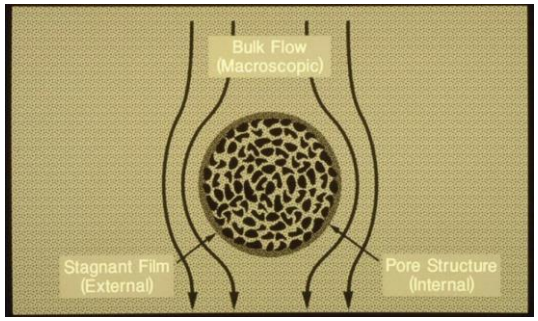
Concentration: For a first order reaction, rate at 1% methane concentration will be 100 times higher than at 100 ppm

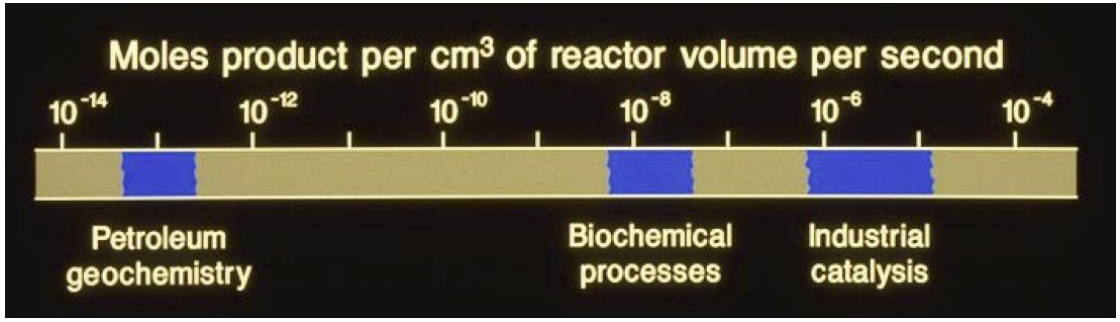
Temperature: Most effective handle. Can overcome the concentration variation of 100 times by increasing the temperature by 150°C

- Gas Phase
  - High temperature (900 °C) chemistry driven by radicals. The process is very well understood and utilized when possible
  - The reaction cannot be self sustained for lean mixtures (<5%). One needs to keep the temperature around 800-900 °C for lean mixtures

The Technology

– Catalysis





A Practical Guide to Catalyst Testing, Catalytica, Inc.

- Catalytic rates of reaction many orders of magnitude higher than in the gas phase at around 300 °C
- The rate on platinum group metals at around 300 °C are adequate for many applications (flow rates, concentrations)
- The gases need to be preheated to sustain the reaction. There are many well established technology providers
- Platinum group metals (expensive) have rates that are 1,000-100,000 higher than earth-abundant oxides (cheap). On oxides, the temperature will need to be > 600 °C.

Practical System

- Recent technology advances that create new approaches
  - Integration of best technologies could make a much better device
- Catalytic combustion potentially address
  - "underground" – mines, wells
  - Ambient temperature methane streams – ie gas escaping from surface, point sources, gas going to flare. Note possible wide range of concentrations and flow rates
  - Warm or hot streams – ie methane in gas engine or flare emissions
- What's needed to make a system, and where are there gaps:
  - No new core technology in catalytic combustion has appeared in many decades
  - "Packaging" the system – better hardware and software are possible. Innovation with process intensification
  - "Finding a catalyst that would actually oxidize methane in oxygen-rich exhaust of a lean-combustion compressed natural gas engine, in the typical temperature range of its operation, remains a major challenge even with platinum group metal-based catalysts, and it would be even more exciting if the same could be accomplished by a non-PGM catalysts."
- What would a team need to address gaps/succeed
  - Technology - Integration. Use of renewable energy sources (e.g., direct solar heat, renewable electricity), 3-D printed heat recuperators.