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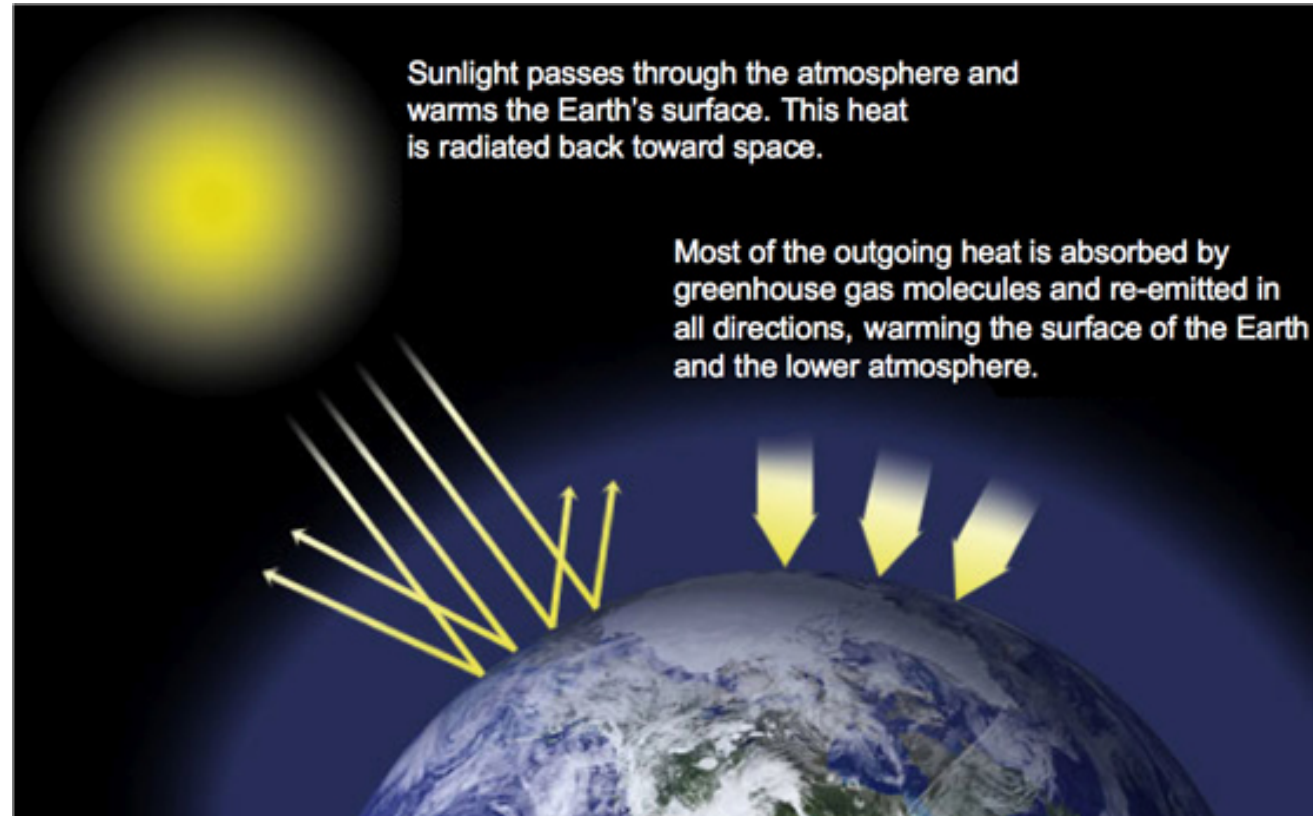
Carbon Dioxide: Challenges and Opportunities for Chemistry and Society

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Effect of Greenhouse Gases



The greenhouse gases make sure that our planet is warm enough to sustain (human) life

Too little or too much Greenhouse Gases

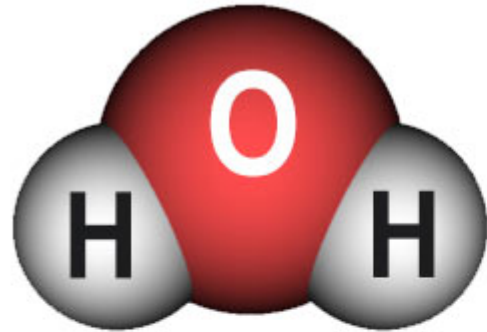


**Mars: Thin atmosphere, too little greenhouse gases.
Largely frozen surface.**



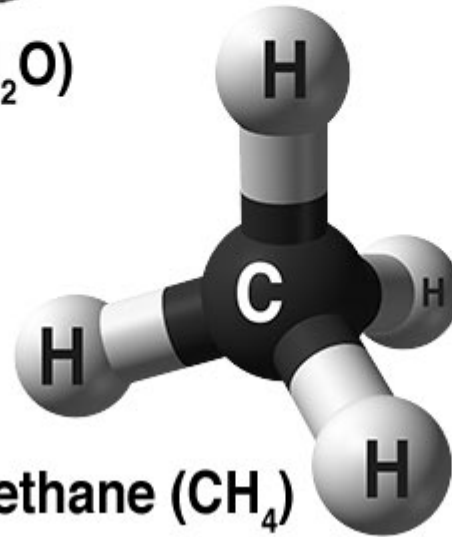
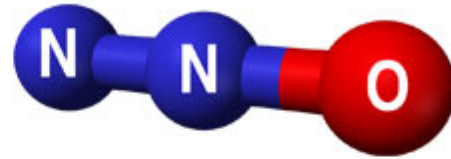
**Venus: 154,000 times more carbon dioxide than earth!
Very high surface temperature.
Hot enough to melt lead.**

Prominent Greenhouse Gases

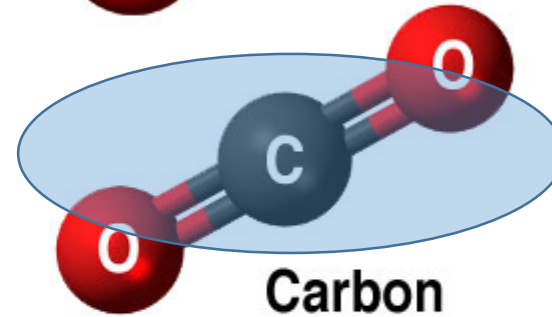


Water vapor (H_2O)

Nitrous oxide (N_2O)



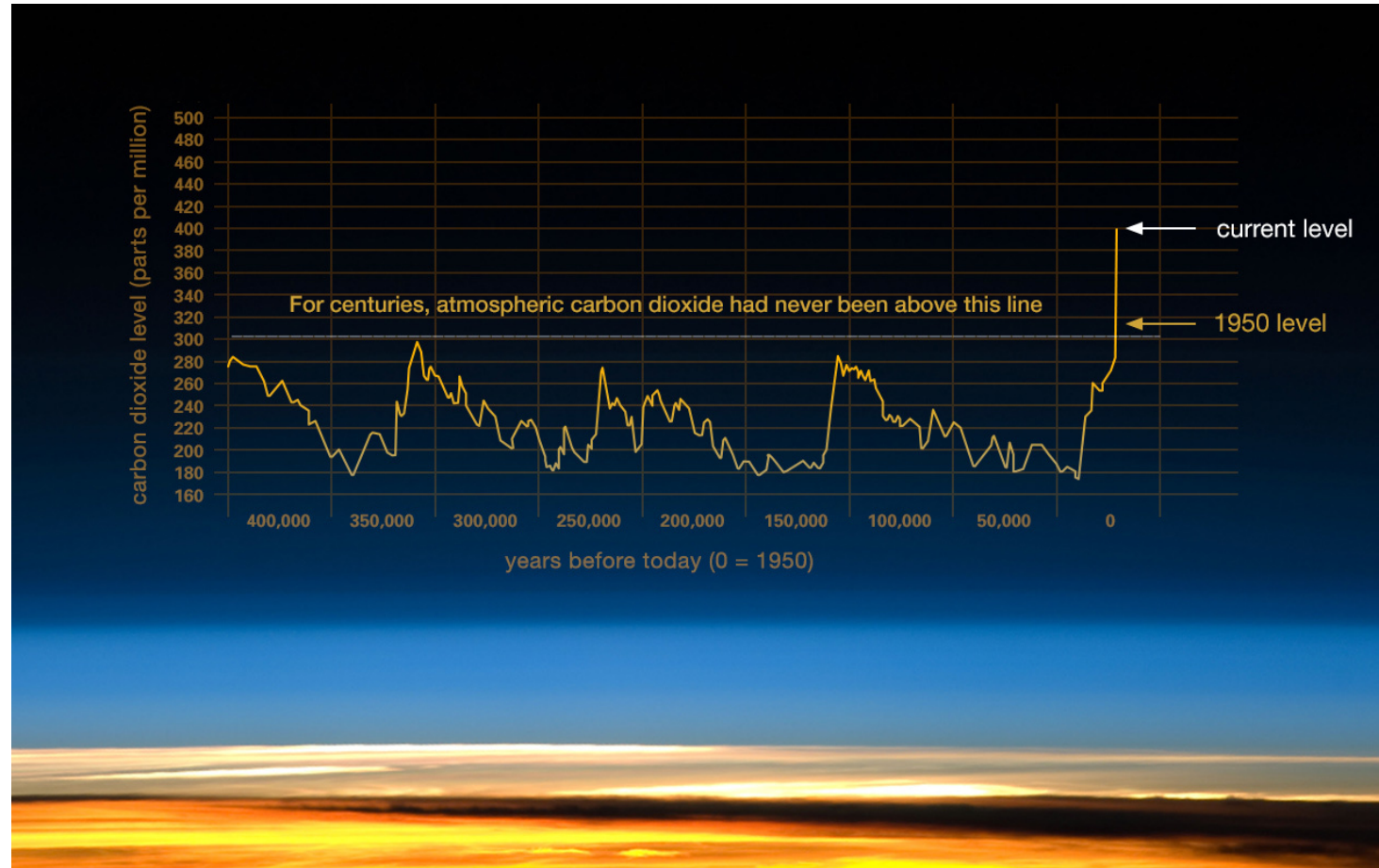
Methane (CH_4)



Carbon dioxide (CO_2)

Water vapor is the only one that can cause re-precipitation and subsequent cooling

Is the amount of CO₂ in the atmosphere increasing?



Human contribution (most important): Deforestation and burning of fossil fuels

Current CO₂ level: 408 ppm

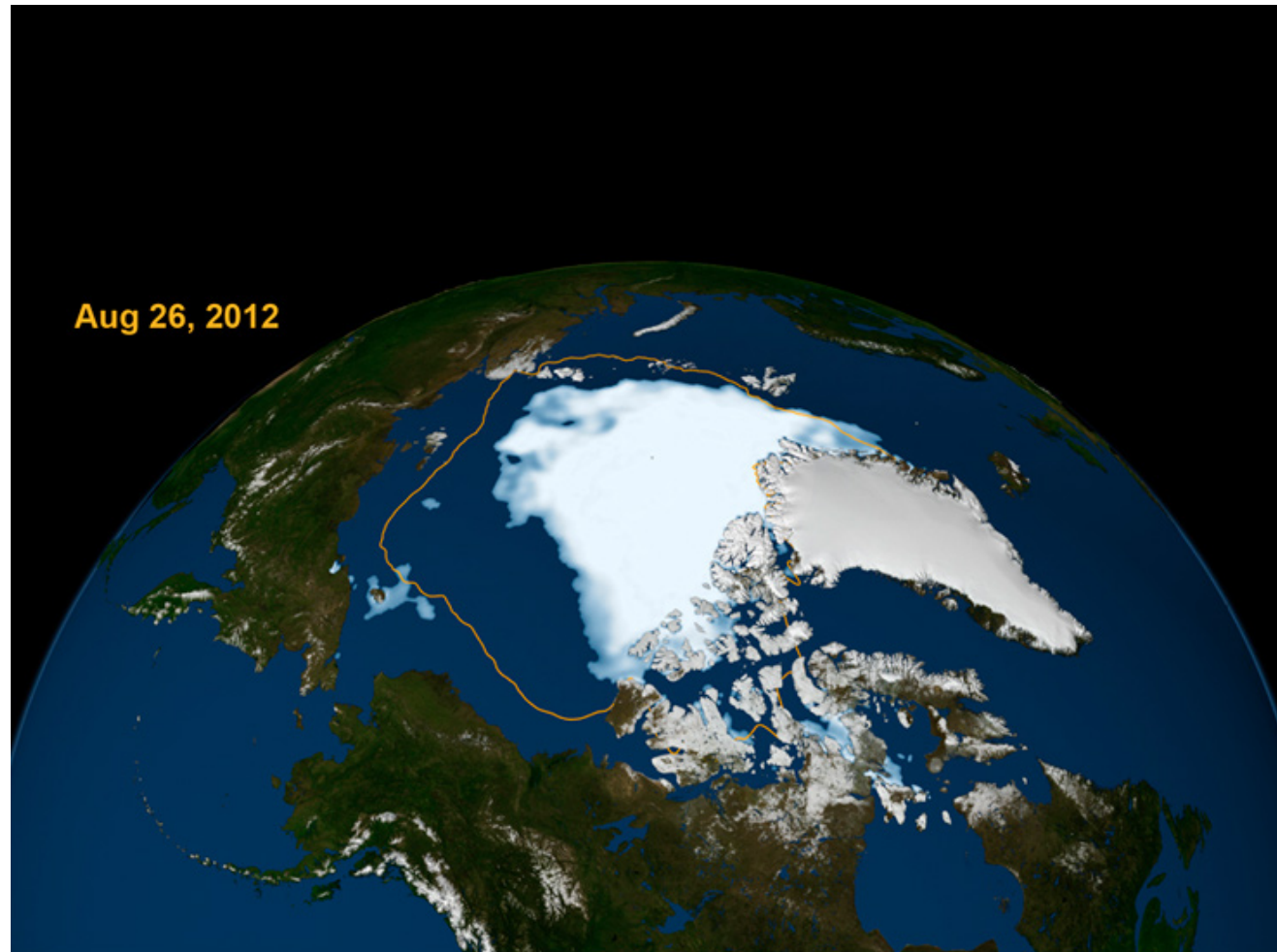
Some Effects of Greenhouse-Driven Climate Change



Short and long term effects.

The CO₂ already released in the atmosphere will stay on for quite a while!

Some Effects of Greenhouse-Driven Climate Change



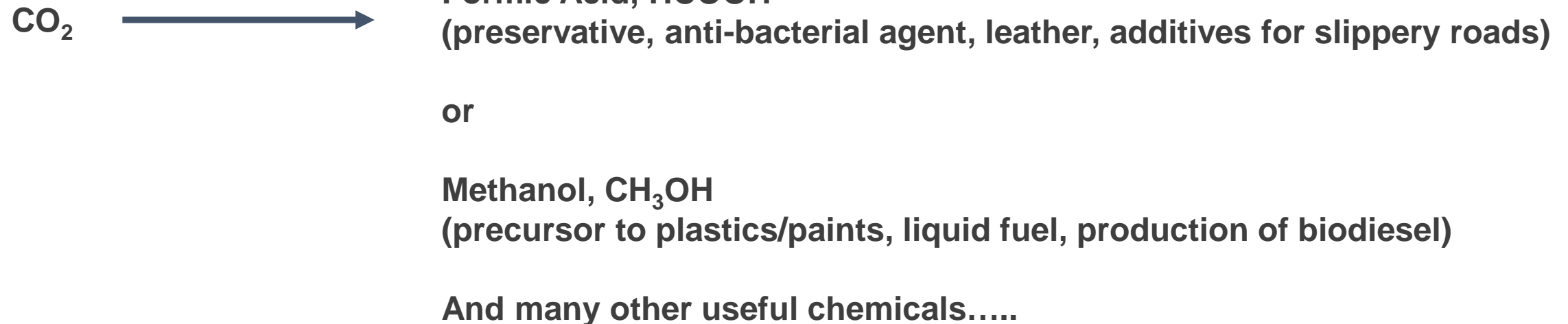
An arctic without ice in sommer!



- **There are no simple solutions to these problems.**
- **Any solution will have to take into account the „need“ of human beings for a comfortable/luxurious life.**
- **The above point will reflect in votes: Political changes are not always easy!**
- **We need to move to a carbon-free or a closed-carbon energy supply (Financially viable?).**
- **However, use of fossil fuels is not going to stop in the next years.**
- **We already have too much greenhouse gases in the atmosphere and we need a solution for that.**

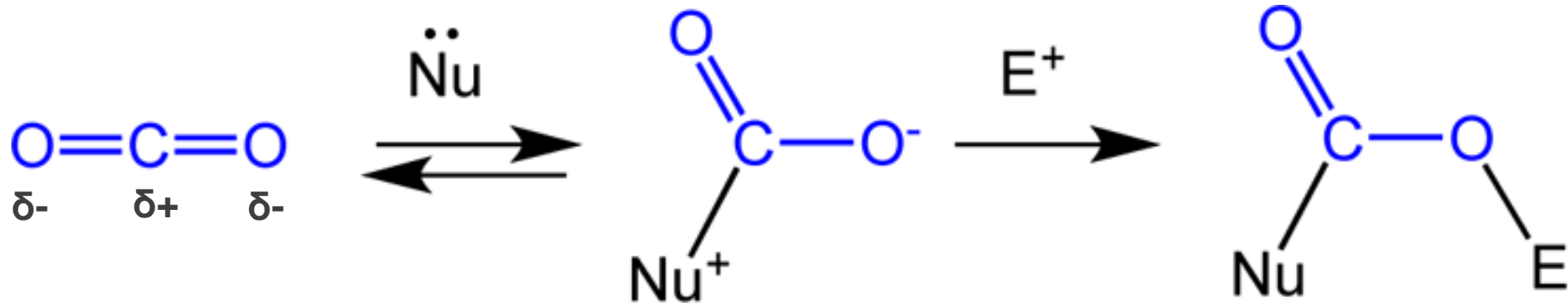
Find ways and means of trapping the greenhouse gases and convert them into something „harmless“ and useful.

Solutions: What can we convert CO₂ to?



Solutions: How can we convert CO₂?

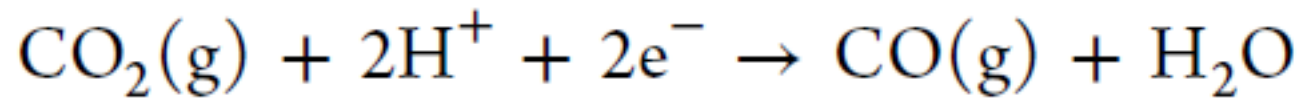
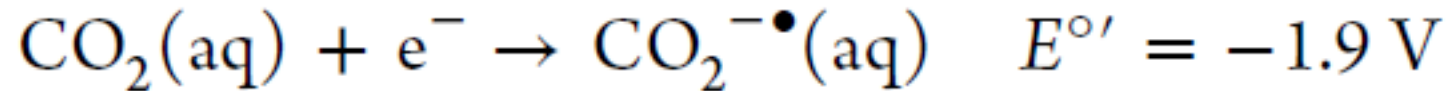
General Principle



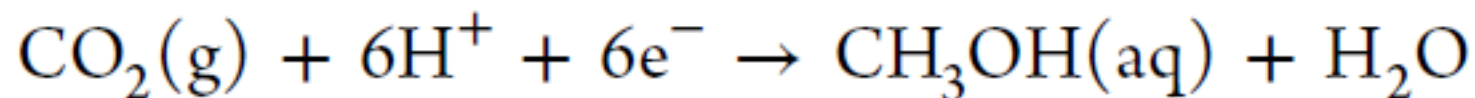
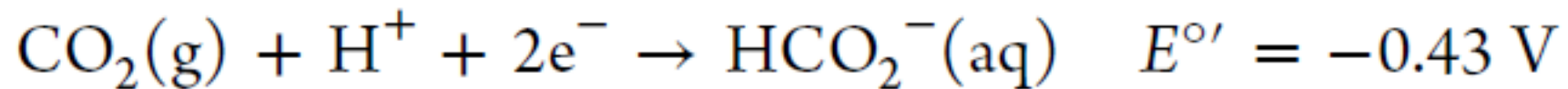


Solutions: How can we convert CO₂?

Electrocatalysis: Multiple electron and proton transfer



$$E^{\circ'} = -0.52 \text{ V}$$



$$E^{\circ'} = -0.38 \text{ V}$$

Solutions: How can we convert CO₂?



2008, Bell/DOE Report:

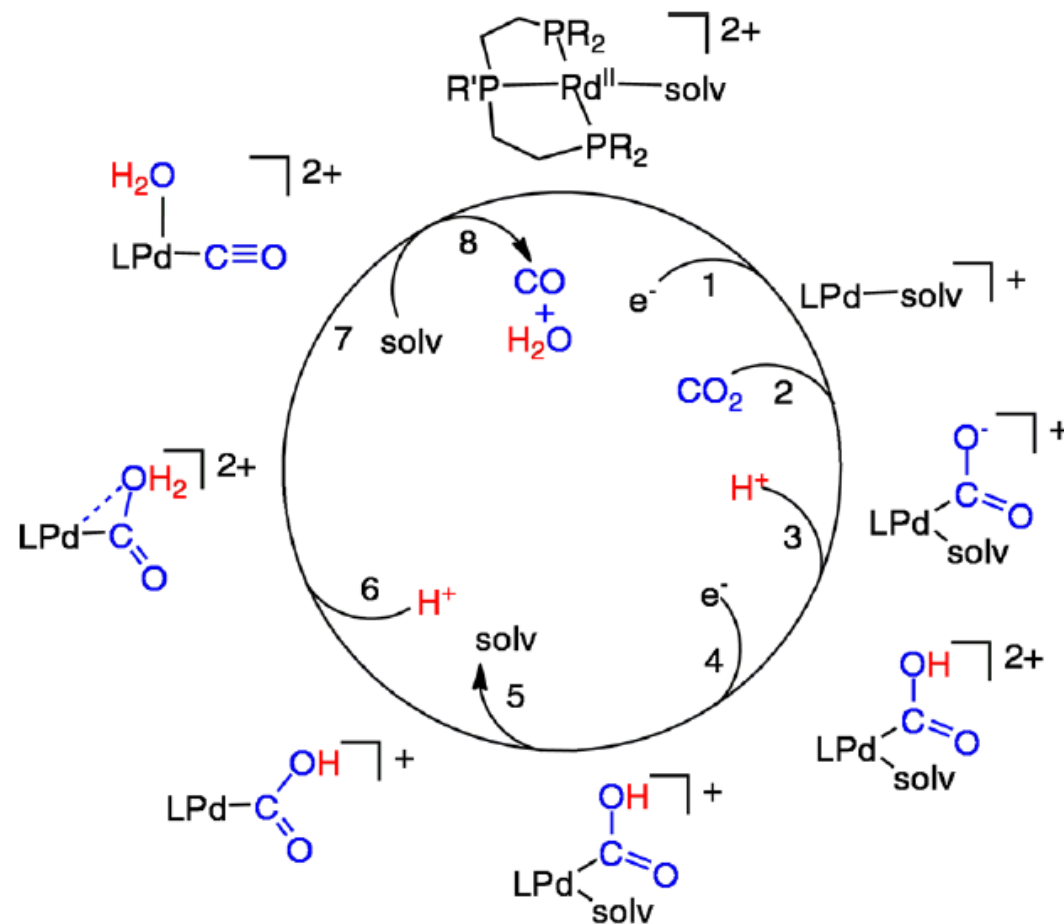
„The major obstacle preventing efficient conversion of carbon dioxide into energy-bearing products is the lack of catalysts“

**Challenge for Chemistry:
Development of efficient catalysts for CO₂ conversion.**

Solutions: How can we convert CO₂?

Catalysts: Cost and lifetime

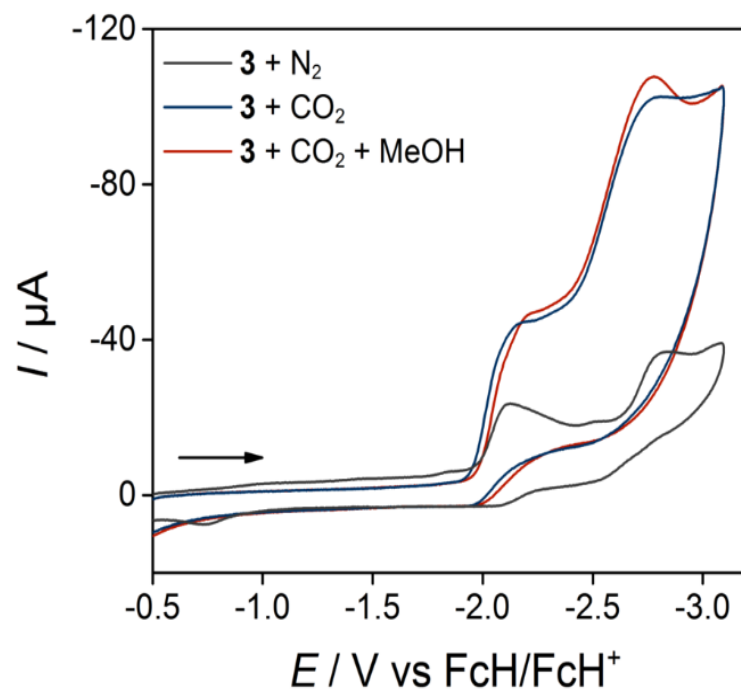
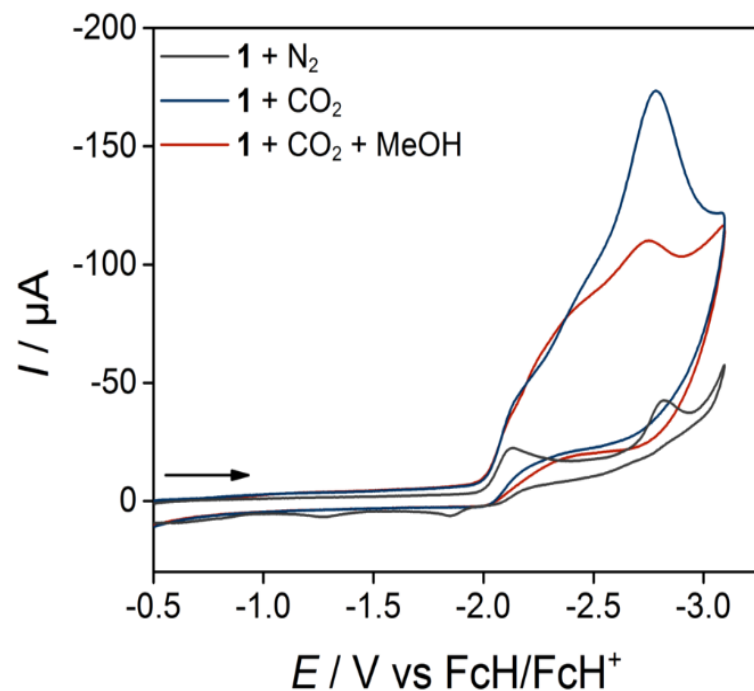
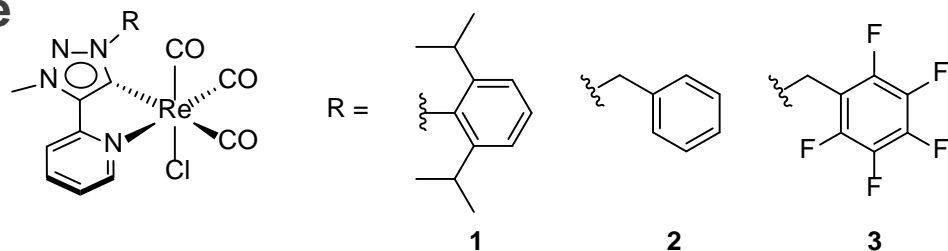
CO production



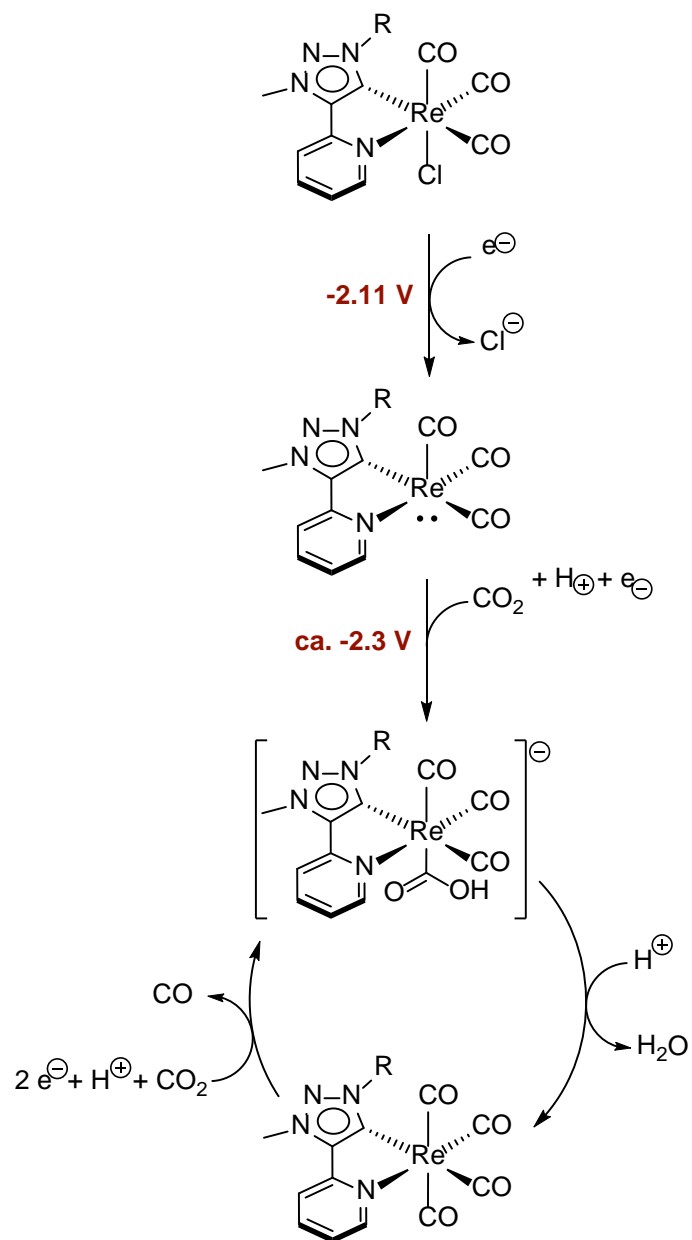
Chelating Neutral MICs: Electrocatalytic CO₂ Reduction

Catalysts: Cost and lifetime

CO production



Chelating Neutral MICs: Electrocatalytic CO₂ Reduction

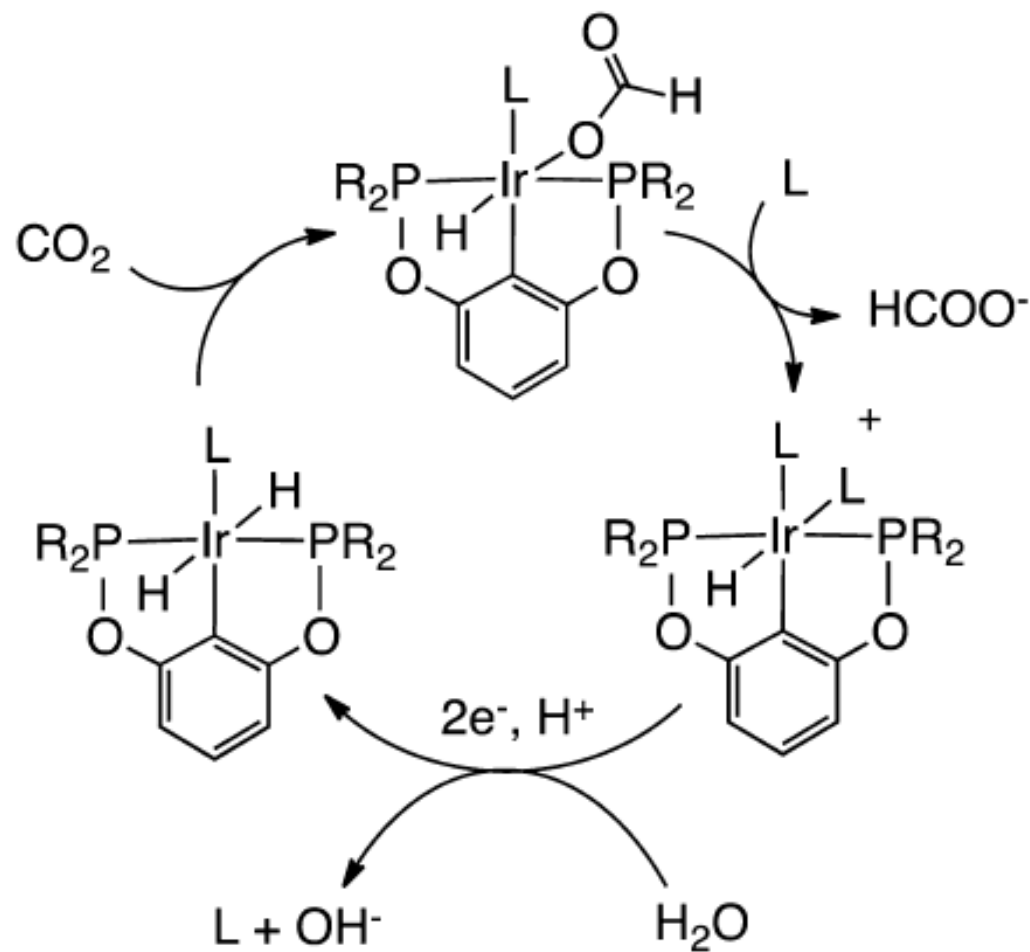


B. Sarkar, L. Suntrup *et al*, *Inorg. Chem.* 2017, **56**, 5771 and unpublished results.

Solutions: How can we convert CO₂?

Catalysts: Cost and lifetime

Formate production



Solutions: How can we convert CO₂?

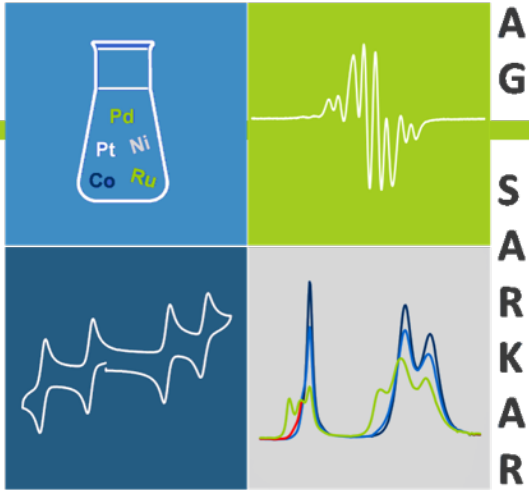


Problems:

- **Catalysts contain expensive and metals with low abundance**
- **Catalyst lifetime is not very high**
- **Recycling is not very efficient**

Solutions:

- **Catalysts based on inexpensive and earth-abundant metals (iron/cobalt/nickel/copper)**
- **Combine concepts from homogeneous and heterogeneous catalysis to get high selectivity and high lifetime**



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