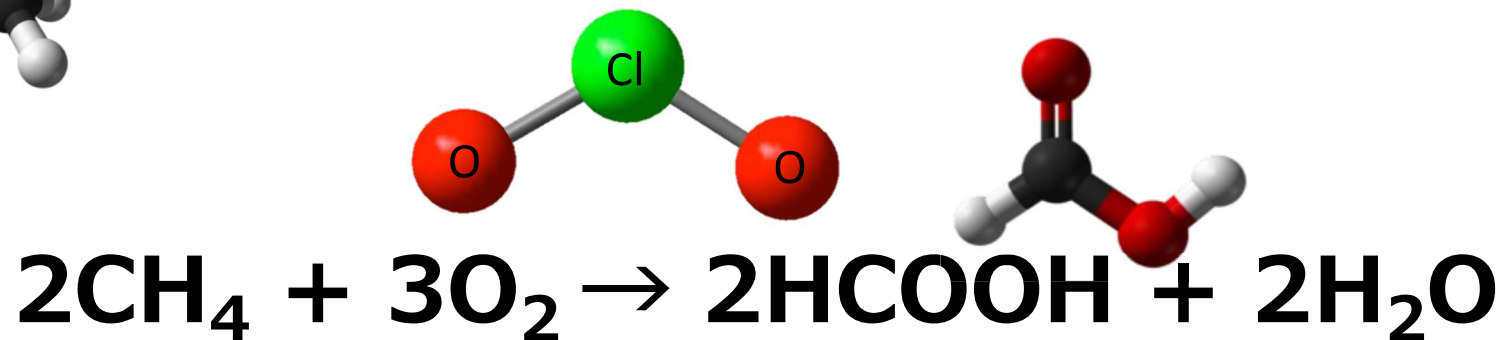
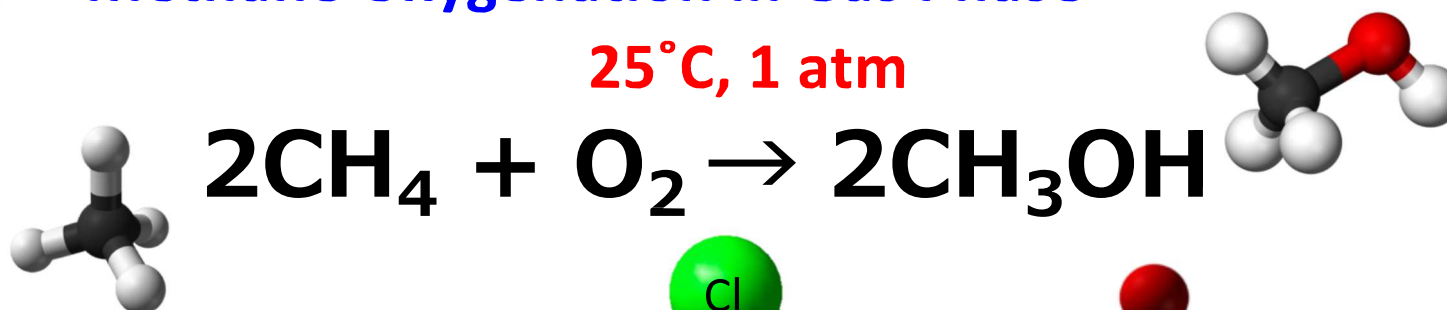
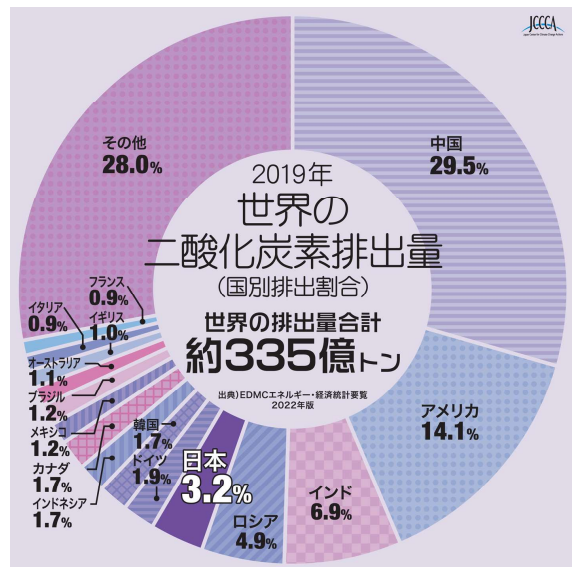


Methane Oxygenation in Gas Phase

25°C, 1 atm

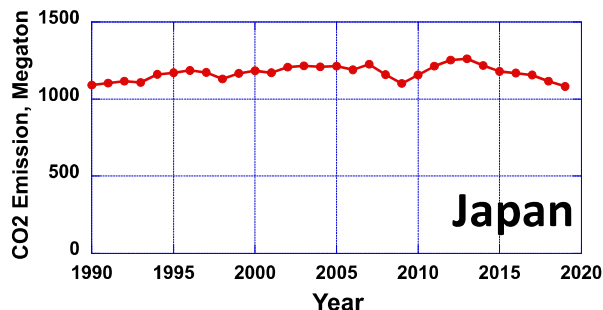


CO₂ Reduction



★World Rank of CO₂ Emission:

- 1 China
- 2 USA
- 3 India
- 4 Russia
- 5 Japan



COP21 (2015) Paris Agreement

Japan: 26% CO₂ Reduction

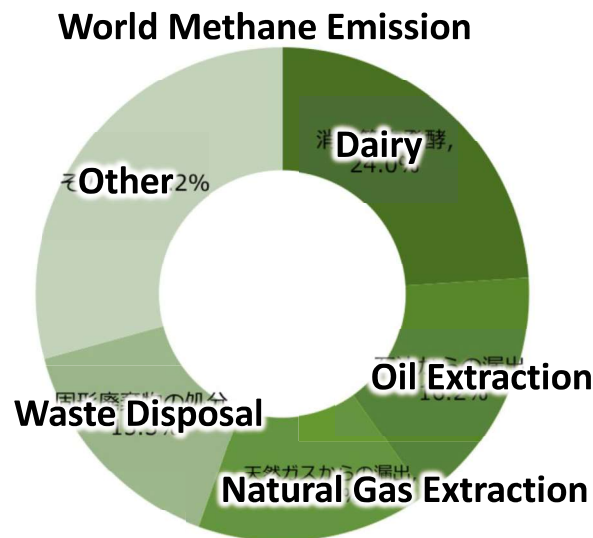


Methane Reduction

COP26 (2021) Glasgow Climate Pact

★Methane: 25 times Global Warming Gas Coefficient vs CO₂

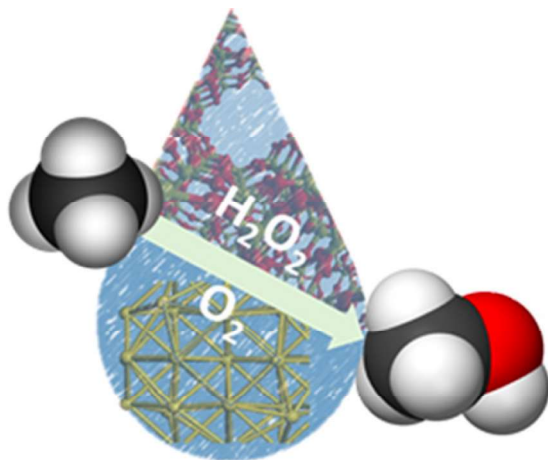
★Reduction of Methane Emission <30%



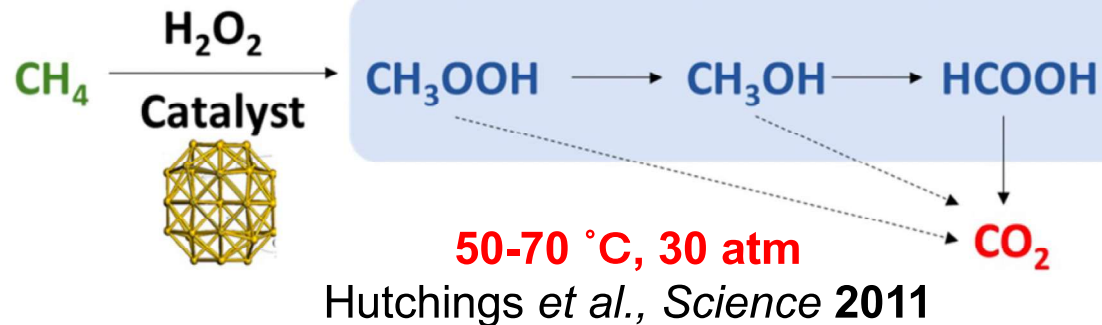
COP27 (2022) Sharm el-Sheikh, Egypt

★Reduction of Gas Flare 🔥🔥

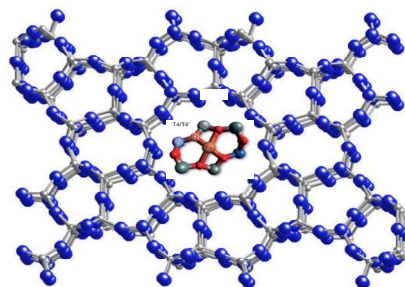
🔑 Key Point: Effective Utilization of Gas



Au-Pd/Supported Catalyst

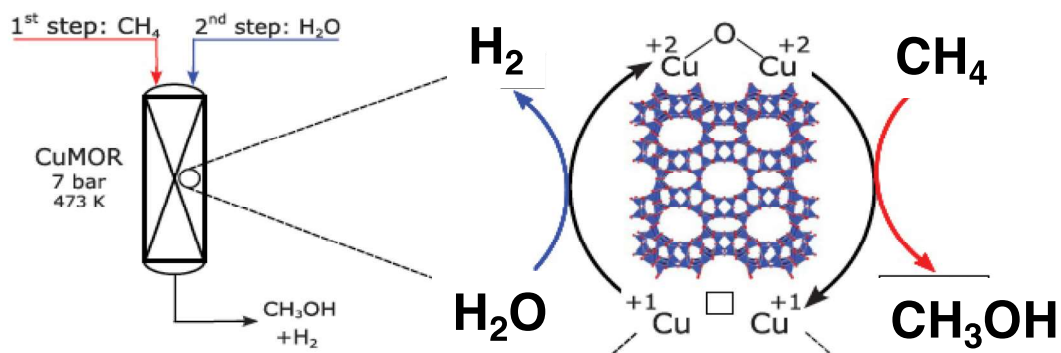


Hutchings, G. J. and coworkers, *Acc. Chem. Res.* 2021, 54, 2614

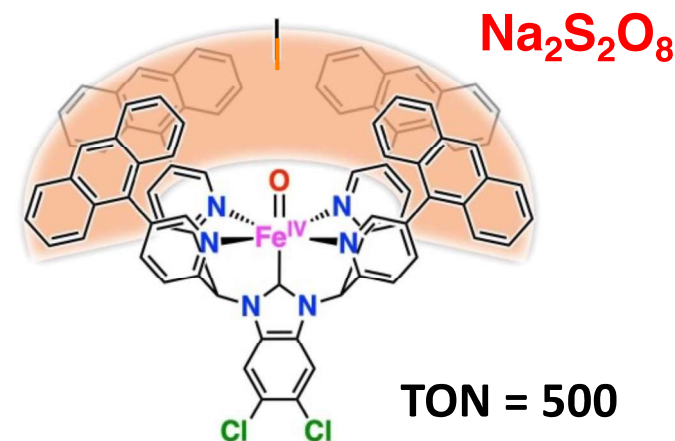


ZSM-5 Zeolite

$[\text{Fe}(\text{IV})=\text{O}]^{2+}/\text{N}_2\text{O}$
 $75\text{ }^\circ\text{C}, 7.5\text{ atm}$
 Snyder, *et al.*, *Nature* 2016



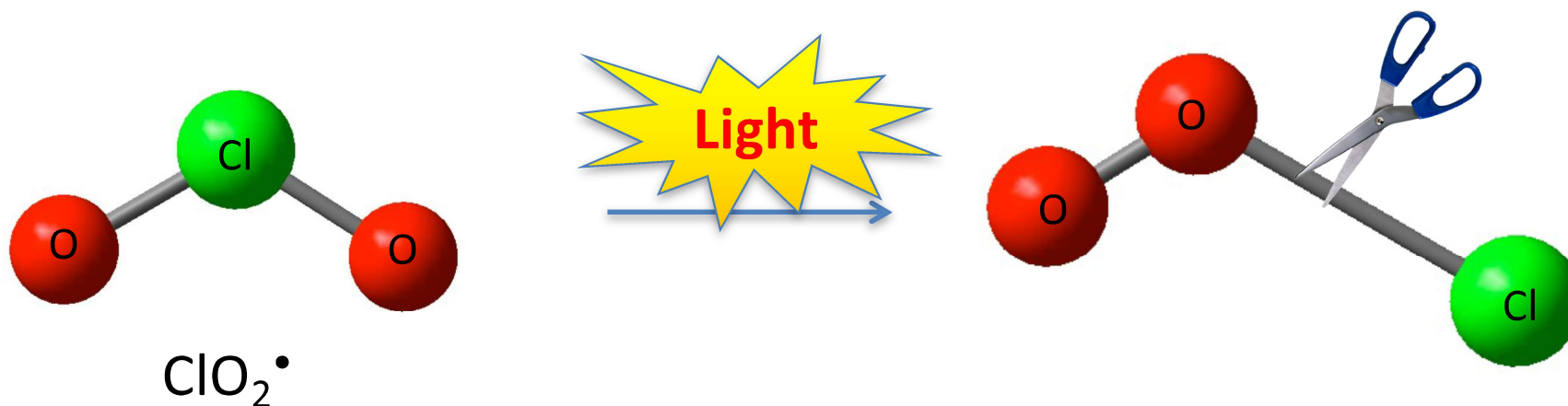
$[\text{Cu}_2\text{O}]^{2+}/\text{H}_2\text{O}; 200\text{ }^\circ\text{C}, 7\text{ atm}$
 0.2 mol MeOH / 1 mol Cu
 Sushkevich, *et al.*, *Science* 2017



Kojima, *et al.*, *Nature* 2023

Chlorine Dioxide Radical

4



Reactivity: Moderate



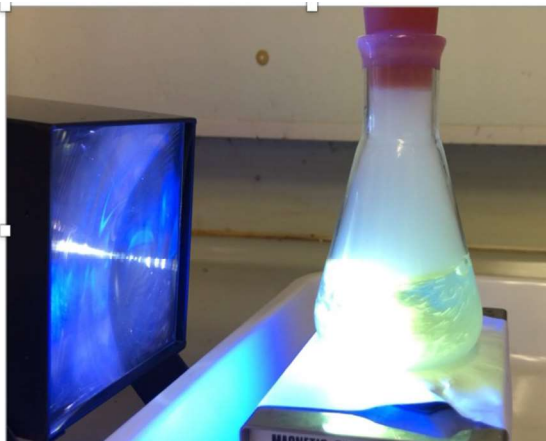
Oxidant H Abstraction Agent

Chlorine Radical Cl^\bullet Hydrogen abstraction from CH_4

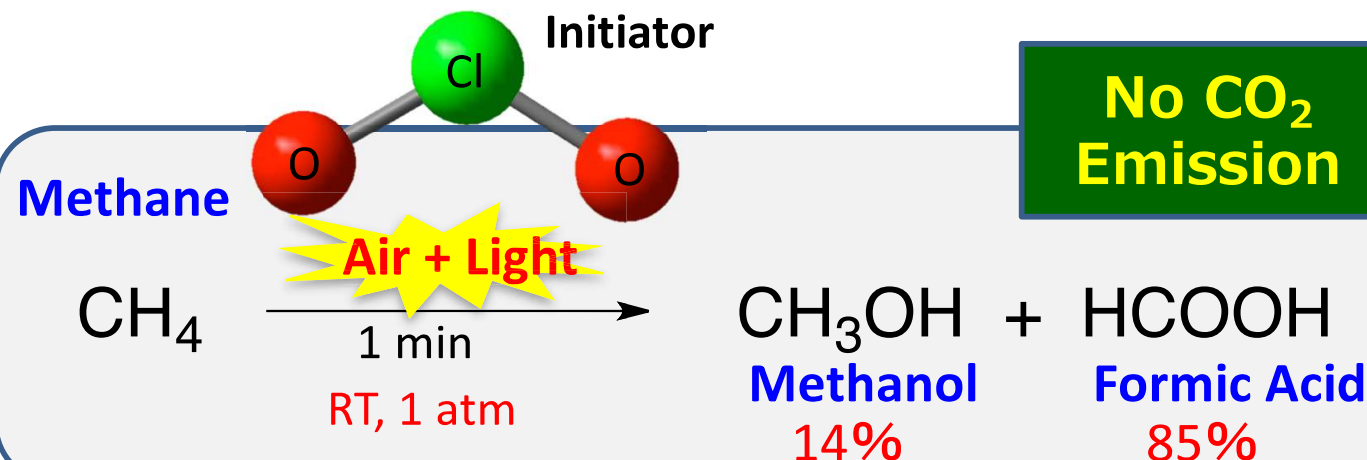
Singlet Oxygen $^1\text{O}_2^*$ O_2 addition toward CH_3^\bullet

BEST COMBINATION!!

Previous Work



LED Light



Angew. Chem. Int. Ed. 2018, 57, 2126

JP6080281B, JP6745452B, WO2017104798A1, US10947190B

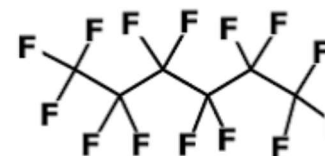
EP.3398925.B1, CN.108602740.B, SA.518391862.B1

Fluorous Solvent

- No C-H Bond
- Resistance to Oxidation
- High Solubility for Gas
- Low Water Solubility



Perfluorohexane



GWP: 5000

PFAS Problems