Methane activation: Inspiration from Nature

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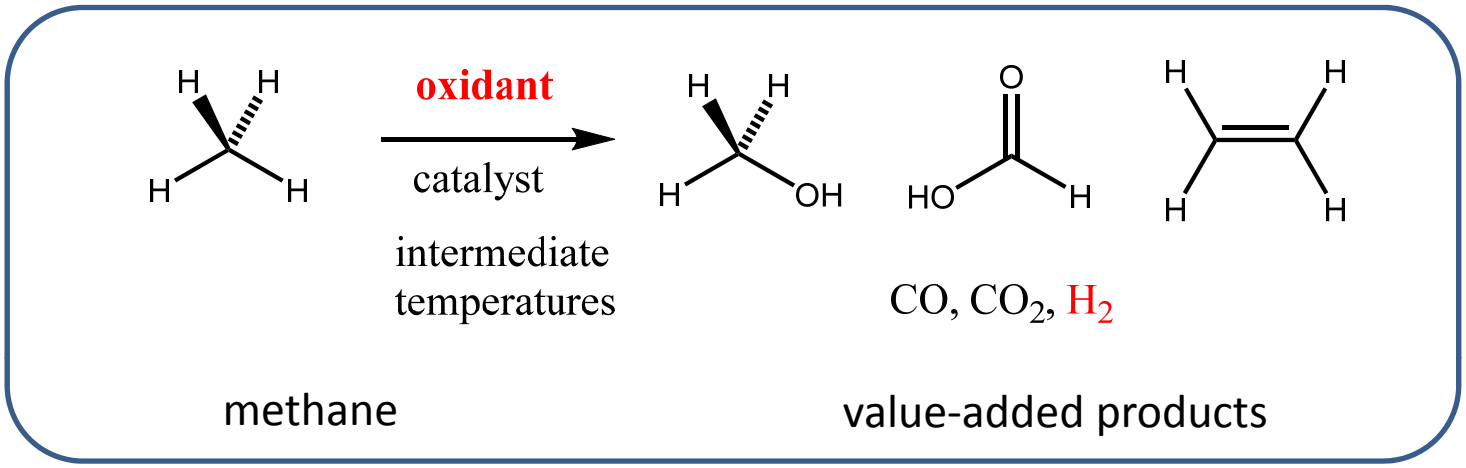
CHANGING WHAT'S POSSIBLE

a grand challenge for catalysis



large domestic reserves

steam reforming energy intensive

not ideal for transportation/portable devices

How can we achieve the selective partial oxidation of methane?

thermodynamics of the steam-methane reforming process

Hydrogen formation via methane reforming is highly endothermic

$$CH_4 + H_2O \rightleftharpoons CO + 3\,H_2 \qquad \Delta H = +206\ kJ/mol$$

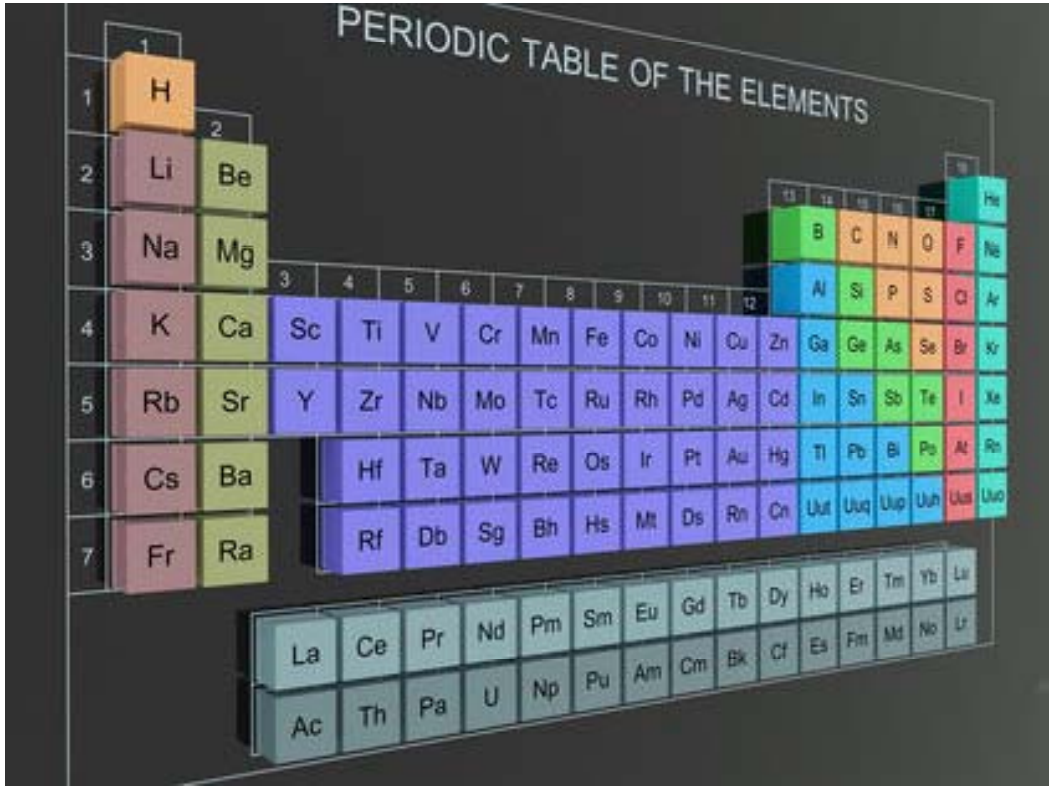
$$CH_4 + 2\,H_2O \rightleftharpoons CO_2 + 4\,H_2 \qquad \Delta H = +165\ kJ/mol$$

H_2 formation via water-gas shift is slightly exothermic

$$CO + H_2O \rightleftharpoons CO_2 + H_2 \qquad \Delta H = -41\ kJ/mol$$

at intermediate temperature: coking challenge with Nickel

many homogenous catalysts can activate C-H bonds



Pioneering studies by Bergman, Bercaw, Graham, Jones, Crabtree, Periana, and more
Recent studies by Hartwig, Smith, Mindiola, Goldberg, Sanford, White, Yu, and more

reforming with molecular oxygen

$$CH_4 + O_2 \rightleftharpoons CO_2 + 2\,H_2 \qquad \Delta H = -319\ kJ/mol$$

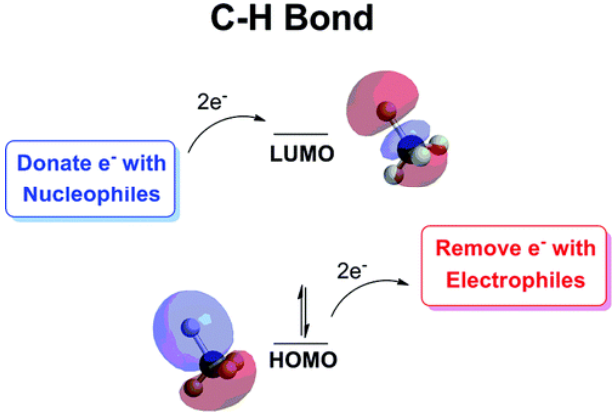
$$2\,CH_4 + O_2 \rightleftharpoons 2\,CO + 4\,H_2 \qquad \Delta H = -\ 71\ kJ/mol$$

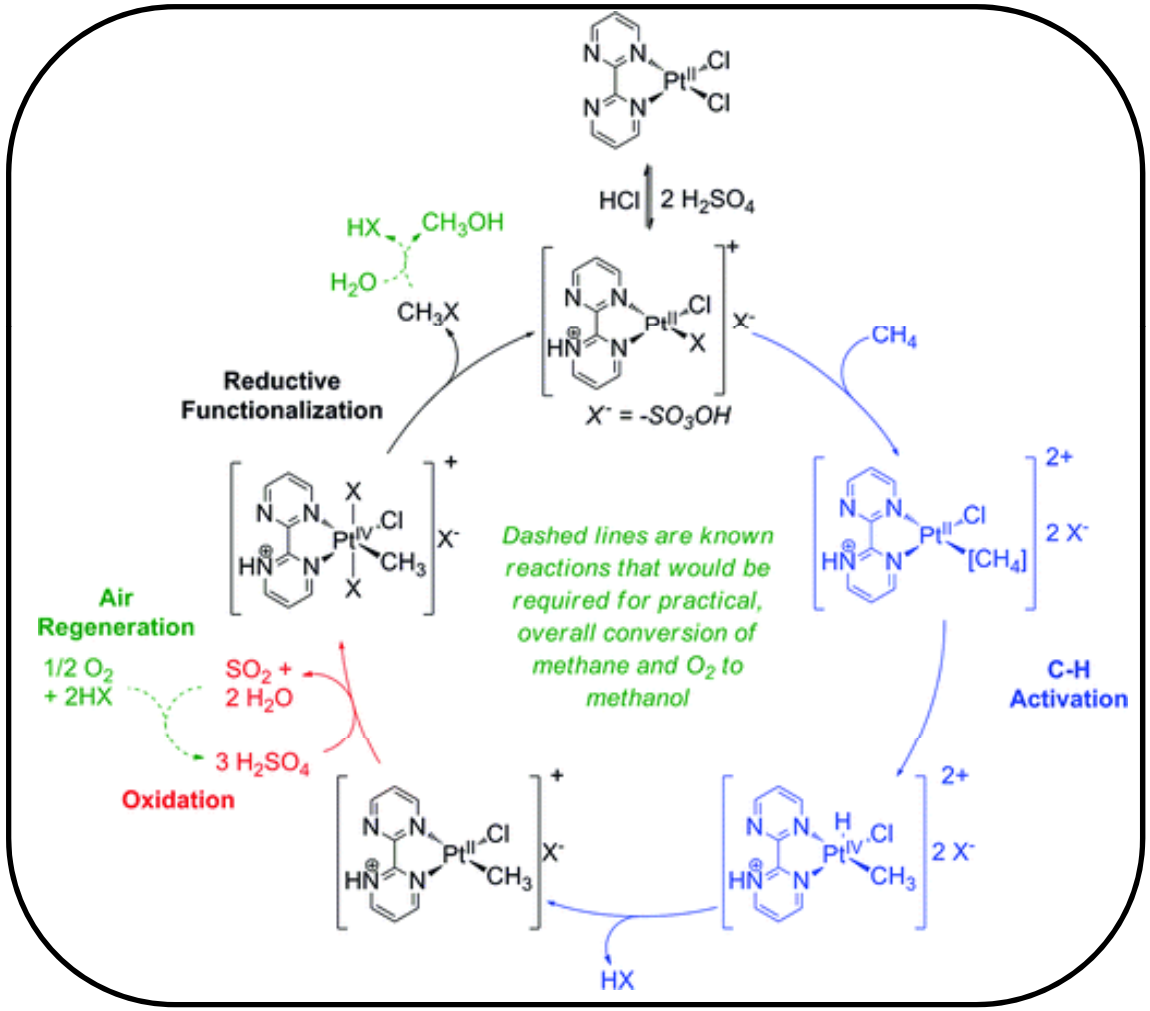
Oxygen renders process highly exothermic

Could the right system result in partial oxidation?

methane to methanesulfonic acid

Periana and coworkers, *Accounts of Chemical Research*, **2012**



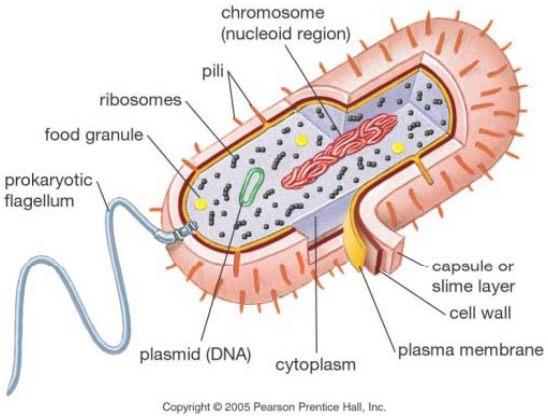


(1) activate catalyst

(2) protect product

highly acidic medium essential, but not yet practical

lessons from methanotrophs



bacteria that can metabolize methane

methane monooxygenase (MMO)

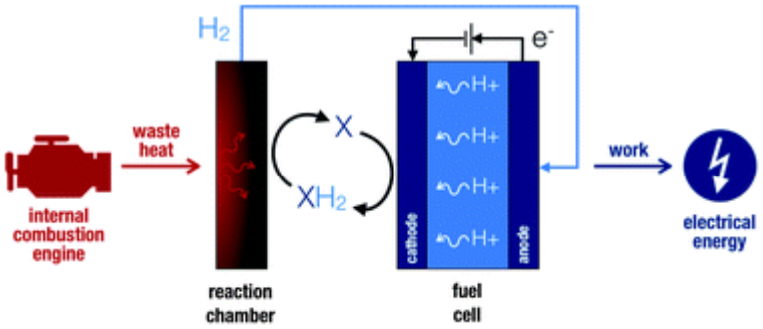
Can we design a catalytic system inspired by MMO?

Ideas for selective methane activation

Design of novel catalysts, oxidants, systems needed

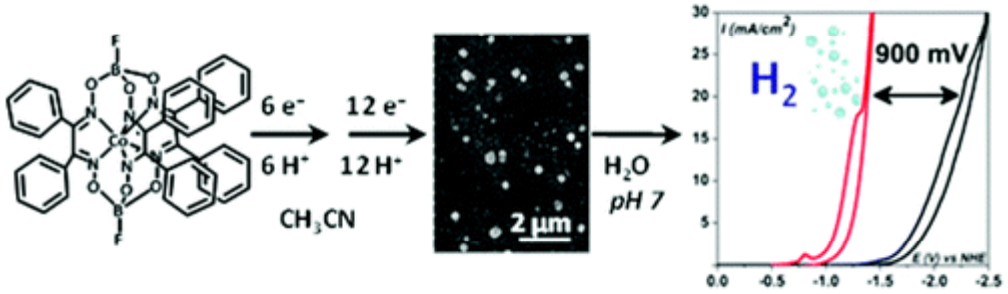
why not IT fuel cells?

fuel cell coupled to an internal combustion engine



By Phillip Jessop

renewable sources of hydrogen or other fuels in the future



By Jean-Michelle Saveant

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