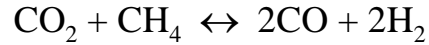
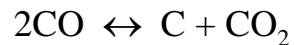
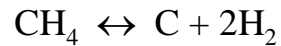

이산화탄소의 재활용기술 현황 (III)

➤ Synthesis Gas from CO₂

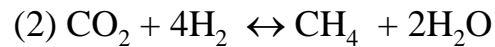
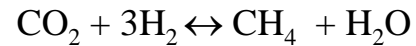
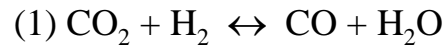


- Highly endothermic reaction
- Catalyst : Rh/Al₂O₃, Ru/Al₂O₃, Pt/Al₂O₃, Ir/Al₂O₃, KNiCa/Zeolite, Ni_{0.03}Mg_{0.97}O, Pt/ZrO₂
- Coking by carbon deposition



- Resistance : Ru > Rh = Pt > Ir
 - Combining of Y₂O₃, Eu₂O₃ to minimize coking
-
-

➤ Synthesis of Methane



- Catalyst : Ru/SiO₂, Co/SiO₂, Ni/SiO₂, Fe/SiO₂
 - Need of Excess H₂ (4H₂/CH₄)
 - Difficulty of storage and transportation of methane
-
-

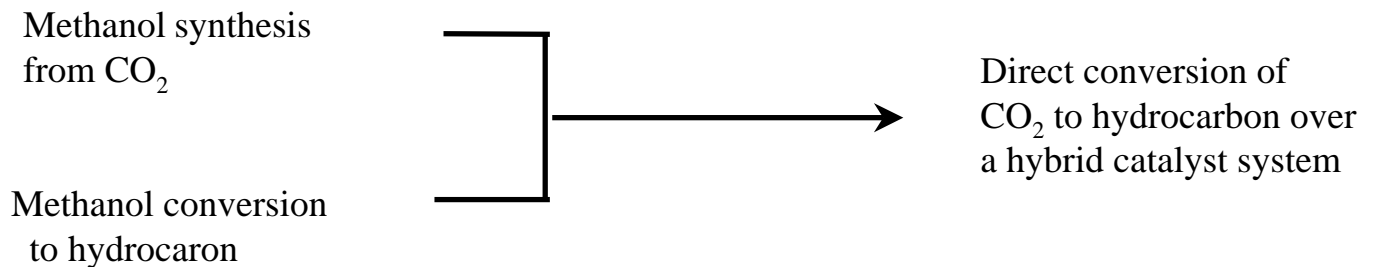
-
-
- Synthesis of chemicals by microwave
 - Catalyst : Supported Ni in microwave reactor
 - Conversion : 5%, Products : methane(55.1%), C₄+ alcohol(28.4%)

 - Methylamine synthesis(Baiker et al., J. Chem. Soc. Chem. Commun., 1995)
 - Commercial process is operated with MeOH and NH₃
 - Direct methylamine synthesis from H₂/CO₂/NH₃
 - Catalyst : Cu/Al₂O₃
-
-

➤ Higher Hydrocarbon Synthesis

- Methanol synthesis from CO/CO₂ and H₂
 - ICI process
 - Catalyst : CuO/ZnO/Al₂O₃, CuO/ZnO/Cr₂O₃
 - Reaction: 230~300°C, 50~100bar
- Methanol-to-Hydrocarbon process
 - MTG/MTO process
 - Catalyst : HZSM-5, SAPO
 - Reaction: 300~500°C, 1~20bar

Hybrid Catalyst



➤ Overall approaches to the hybrid catalysts for CO₂ hydrogenation

- Lower hydrogenating ability of methanol synthesis catalyst
 - The effect of zeolites characteristics on the hydrocarbon formation
 - structure, acidity, pore size
-
-

CO₂ hydrogenation over hybrid catalysts composed of CuZnOZrO₂ and zeolites

Hybrid catalyst	H.C. yield (wt%)	C ₂₊ H.C. Yield(wt%)	Main product
A + HZSM-5	2.7	2.2	Ethane
A+ Cu/HZSM-5	4.2	3.8	Ethane
A + SAPO-5	9.1	8.8	Butane
A+ Cu/SAPO-5	14.9	14.4	Butane
A + SAPO-34	11.0	10.6	Propane
A+ Cu/SAPO-34	15.8	15.5	Propane

A : Cu/ZnO/ZrO₂ , Cu : 1.5 wt %
400°C, 28 atm, W/F = 20g-cat•h/mol

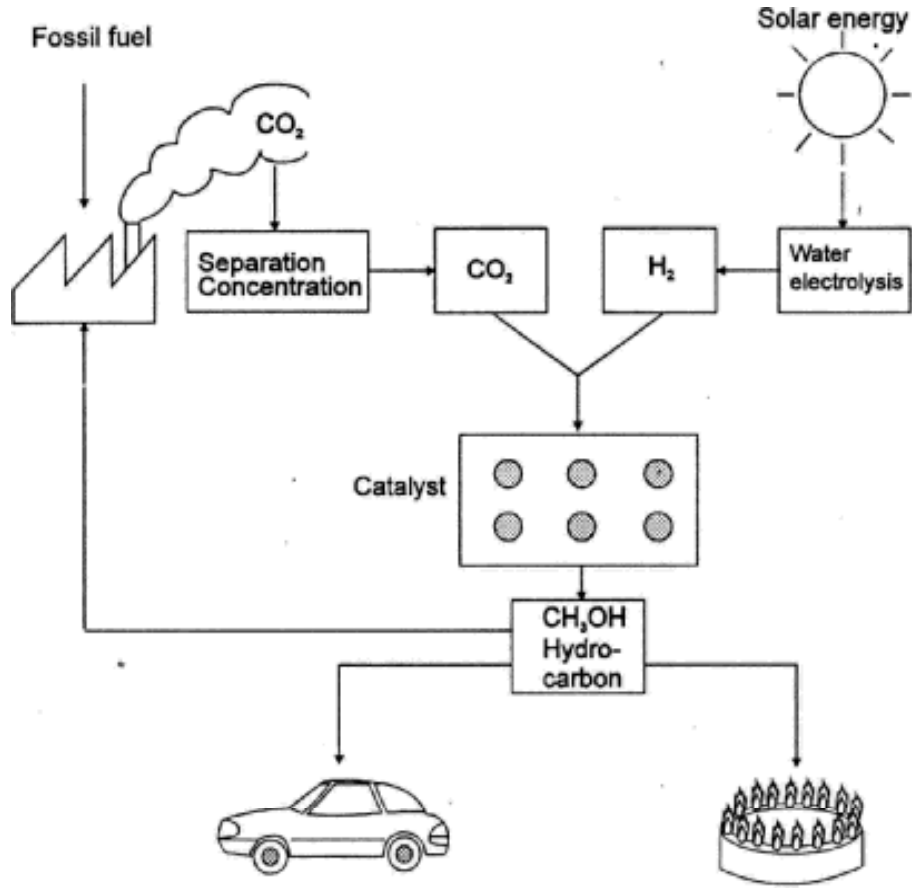
➤ Hydrogen Supply

- Steam Methane Reforming
 - $\text{CH}_4 + \text{H}_2\text{O} \leftrightarrow \text{CO} + 3\text{H}_2$
 - CO_2 reforming without carbon formation
 - $\text{CO}_2 + \text{CH}_4 \leftrightarrow 2\text{CO} + 2\text{H}_2$
 - Solar energy for water electrolysis
 - Biomass conversion
-
-

➤ Solar Hydrogen Production by Photocatalyst

- To realize CO₂ hydrogenation process as a solution for the global warming, solar hydrogen providing system from water should be established
 - photocatalytic production of H₂ from water is needed
 - Catalyst : Na₂CO₃ + 5wt%NiO/TiO₂ system
 - Products : 400ml/m² of H₂ and 200ml/m² of O₂ for 6.5hrs solar light irradiation
-
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➤ 이산화탄소의 재활용에 의한 연료생산 과정의 개념도



➤ Summary

- Catalytic conversion technology → not yet feasible(economically)
but increasingly urgent (environmental regulations)
 - CO₂ : Chemically too stable → thermodynamical constraints for high conversion
 - Main products : Alcohol(MeOH, EtOH, PrOH, BuOH), Fuels (Hydrocarbon), Fine Chemicals (ester, acid, pyrone, lactone)
 - Hydrogen supply : Solar energy for water electrolysis, Steam Methane Reforming, CO₂ reforming without carbon formation etc
 - Separation and Recovery of CO₂ connected with catalytic utilization
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