

Chemical Heat Storage Technologies for Thermal Energy Transportation

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 - (b) CaO/CO₂ CHP
 - (c) Acetone/hydrogen/2-propanol CHP
- CHP for thermal energy transportation
- Chips for new CHP
- Conclusions

For instability of energy supply and demand

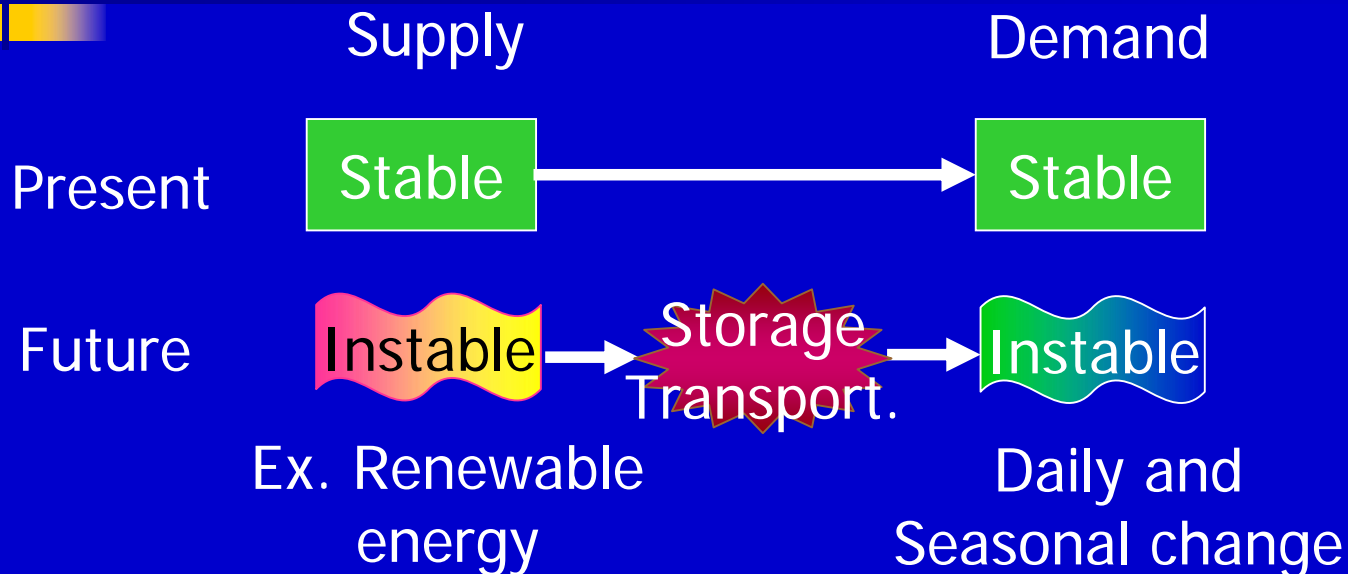
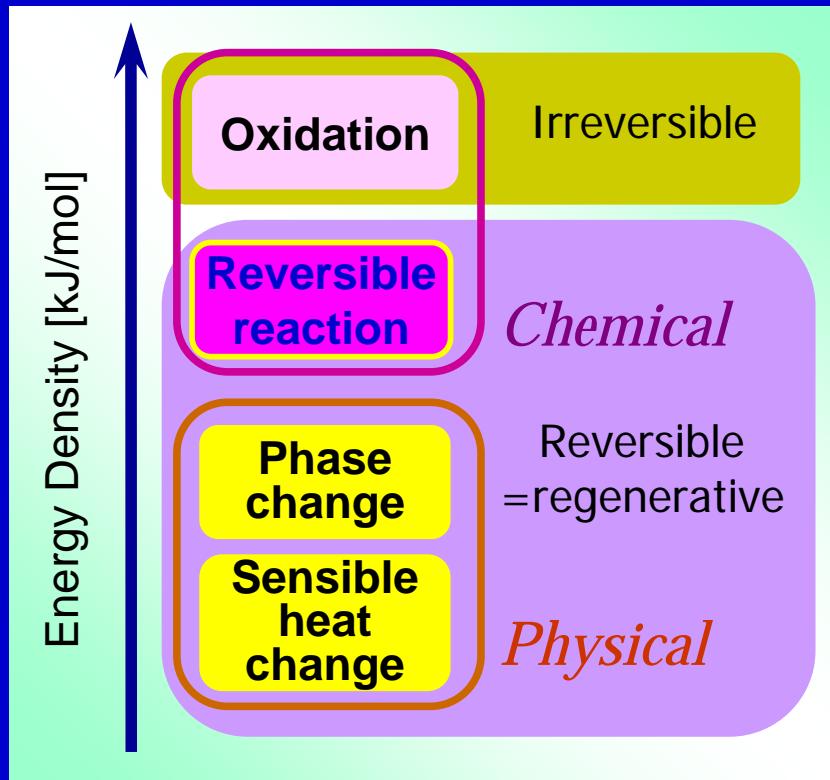


Fig. Change of energy flow pattern

- Future society needs high-efficient tech. of,
 - Energy storage
 - Energy transportation
 - Energy conversion

→ Use of chemical reaction

Use of Chemical Reaction for Energy Utilization



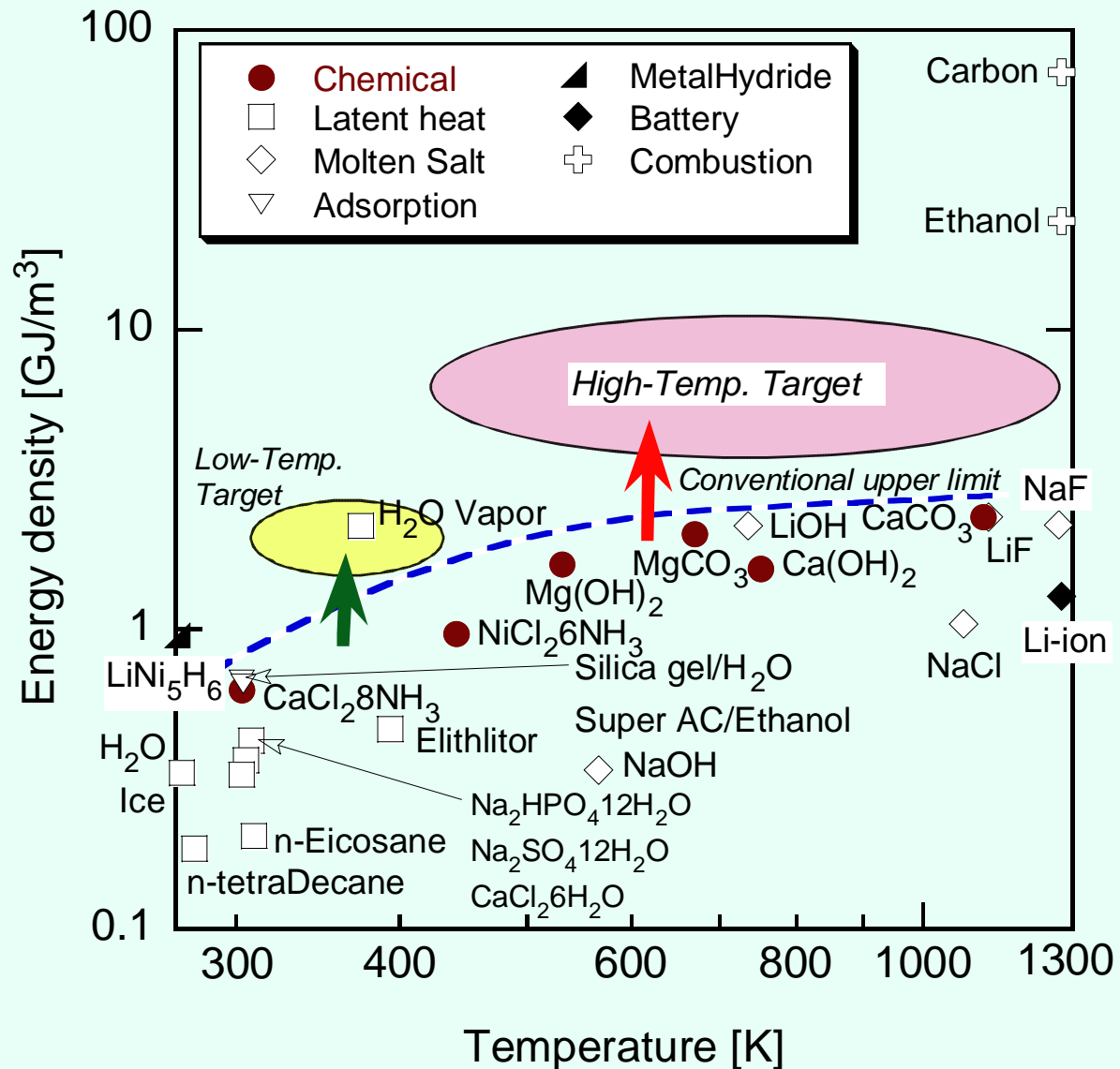
- Reversible chemical reaction has potential for energy utilization process because of its high-energy density and reversibility

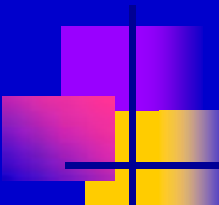
Fig. Energy densities of physical and chemical change properties for energy utilization.

Possibility of chemical thermal energy storage

Fig. Map of volumetric density on thermal energy storage of energy materials vs. operation temperature (chemical change is based on product considering practical particle vacancy. Temp. of 1000 deg. C is assumed for combustion and battery.)

Ref. Y. Kato, "HONEBUTO Energy Road Map", Kagaku-kogyo-sya, Japan (2005)





Merit of chemical thermal energy storage

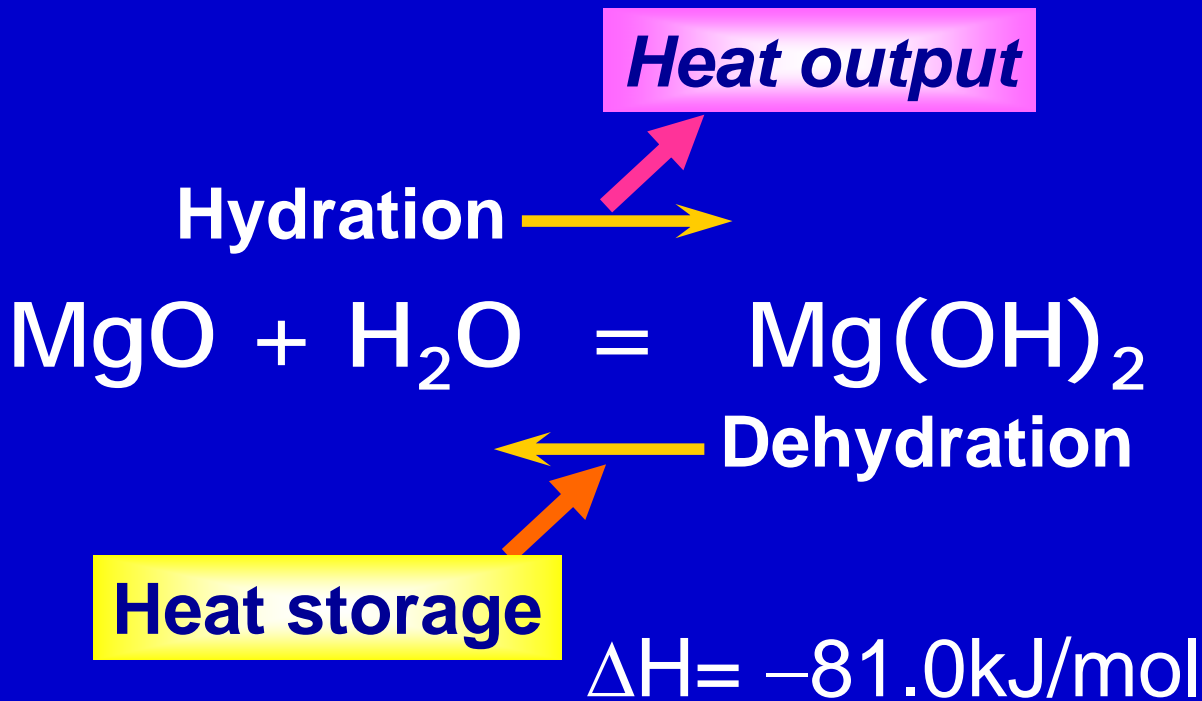
- Higher energy density compared with physical change -> Compact storage
- Long-term storage as reactants with small thermal loss
- Operation temperatures of storage and output are variable by choice of reaction conditions
- Theoretically!



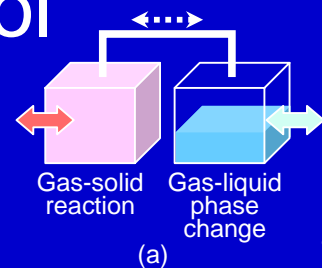
Chemical heat pumps

- Heat to Heat energy converter
 - Heat transformer, heat pump
 - Heat storage
- Developed system (examples from Kato)
 - For 60°C → Isobutene/Water CHP
 - For 80°C → Acetone/Hydrogen CHP
 - For 300°C → Magnesium Oxide/Water CHP
 - For 800°C → Calcium Oxide/CO₂ CHP

Example of chemical heat pump



(a) reaction & phase change batch type

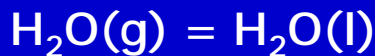


MgO/H₂O chemical heat pump

■ Reaction



$$H_1 = -81.02 \text{ [kJ/mol]}$$



$$H_2 = -40.66 \text{ [kJ/mol]}$$

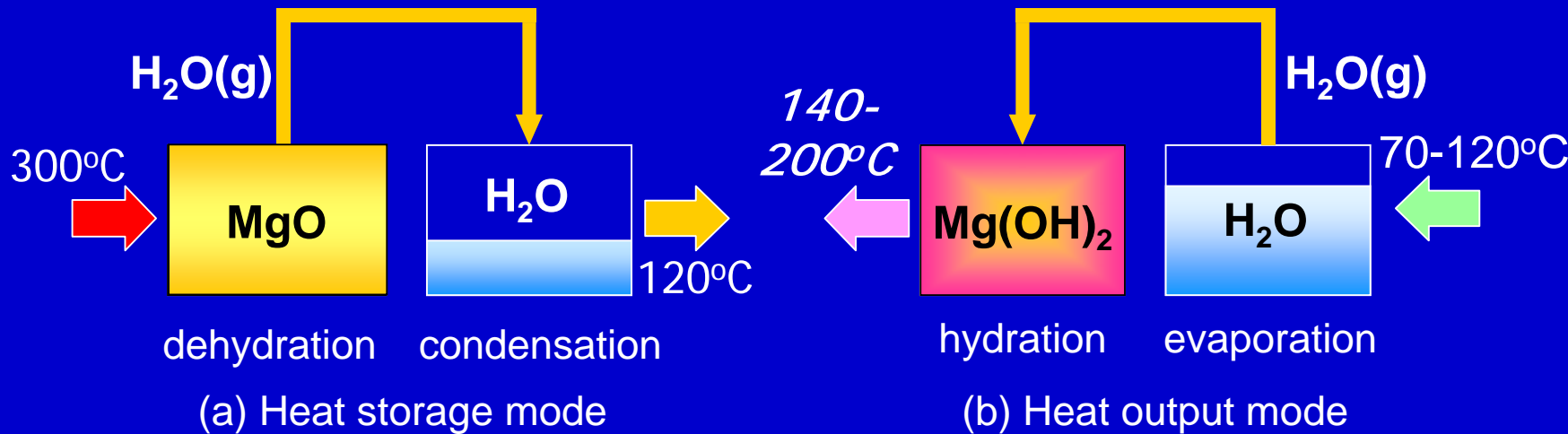
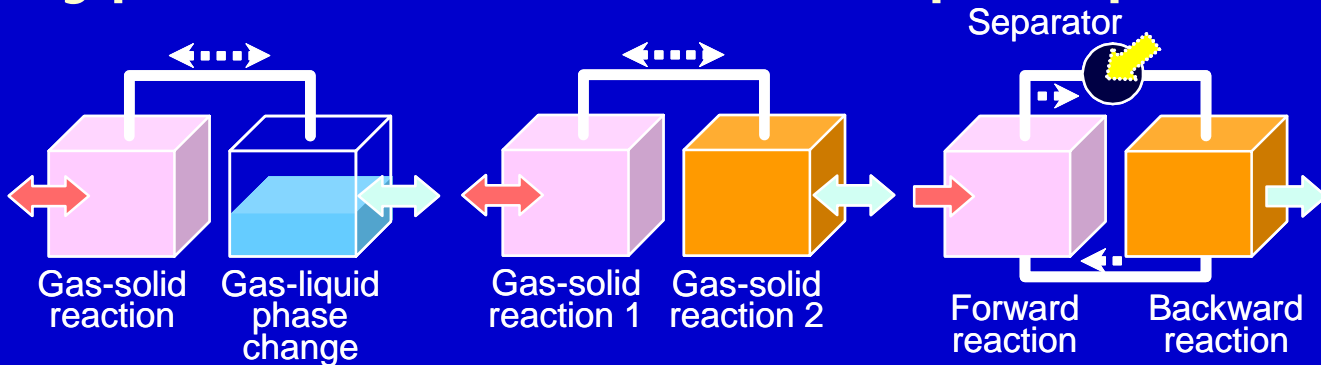


Fig. Principle of MgO/H₂O chemical heat pump in heat amplification mode

Type of chemical heat pump



(a) Reaction-Phase change (b) Reaction-Reaction (c) Reaction-Separation

↔, →: thermal energy, →: separation work, ↔: gas flow

Operation	batch		Continuous	
Reaction phase	Gas-solid		Gas-liquid	
Driving operation	Gas-liquid phase change	Chemical reaction	distillation, membrane separation	compressor
Driving force	Reaction pressure	Reaction pressure	concentration	Reaction pressure
Reactor system	(a)	(b)	(c)	
Reaction example	CaCl ₂ /NH ₃ , CaO/H ₂ O, MgO/H ₂ O, Adsorption heat pump	CaO/PbO/CO ₂ , Metal hydrate/H ₂	Acetone/H ₂ , Absorption heat pump	Isobutene/ H ₂ O, benzene/H ₂



Key requirements for a CHP

- For closed cycle
 - Two reactors for reactant and product
 - Well airtight reactor
- To make potential difference of concentration or pressure between two reactors by consuming some works
 - Gas-Liquid reaction system: Δ concentration
 - Separation process for reactant and product
 - Gas-solid reaction system: Δ pressure
 - Enhancement of heat or mass transfer which control reactions
 - Condensation of gas



Conclusions

- Fair!
 - Chemical heat pump has higher energy density
 - Long-term heat storage
 - Wide temperature range
- Con!
 - Two airtight reactors
 - Make difference of concentration and pressure between the two reactors
 - Thermal and mass transfer controls reactions and total system operability > Well designed reactor
 - Durable material and catalyst development
- Applicability to thermal energy transfer
 - CHP can have potential to brake a way to the thermal energy transfer market



Danke Shöen
