CO_2 and H_2O adsorption-desorption cycles for multifunctional Ni-Fe based catalysts in the production of Synthetic Natural Gas

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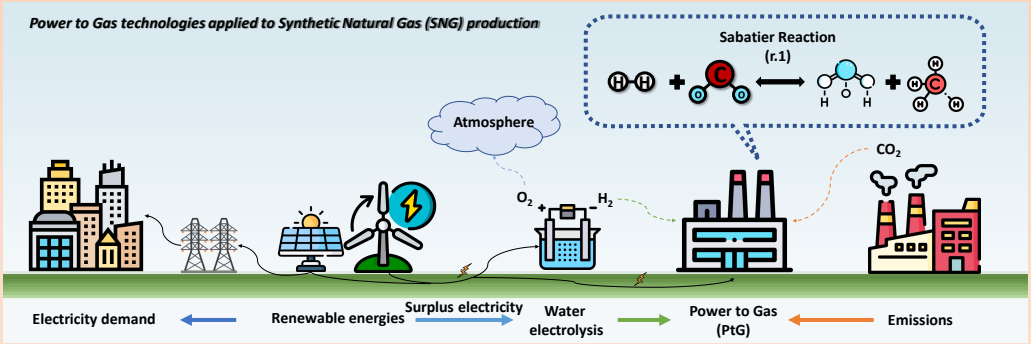
Power to Gas: key role in the energy transition

ENERGY CHALLENGE

Power to Gas (PtG) technologies have the potential to generate an alternative vector able to cover the energy intermittency of renewables [1]. The surplus electricity from renewables could be used to generate green hydrogen from water electrolysis [1]. That green hydrogen would be combined with a concentrated CO_2 flow, producing high concentrate methane through Sabatier reaction.

$$4H_2 + CO_2 \leftrightarrow CH_4 + 2H_2O \quad (r.1)$$



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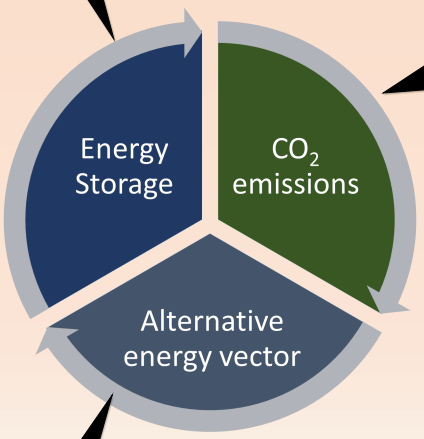

The CO_2 captured by (r.1) can have different sources such as industrial CO_2 process emissions or sweetened biogas (70 %^{v} CH_4 / 30 %^{v} CO_2). Transforming the CO_2 contained in the biogas into methane, the CO_2 cycle can be closed. Eventually, this technology could have and important role into achieving carbon neutral emissions in energy production.

Upgraded biogas (also called synthetic natural gas) would have a concentration of methane close to 100%, fulfilling the requirements to inject it directly into the preexisting natural gas network. Thus, PtG technologies might produce an alternative energy vector easy to store and transport., whereas H_2 storage and transportation is a challenge with the current technology limitations.

PtG catalysts intensification

The inclusion of an alkali or an alkaline earth in a nickel-based catalyst could improve the CO_2 affinity of the catalyst, creating chemical bonds between the basic groups and CO_2 [2]. As result, the interaction between the fixed CO_2 with H_2 could be improved. Thus, the selectivity and conversion to methane might increase. In order to study the previously mentioned assumptions, three nickel-based catalysts supported on gamma alumina were synthesized including an alkali or alkaline earth in their composition.

Experimental

The multifunctional catalysts were synthesized by incipient wetness impregnation from their nitrate or carbonate metallic precursors. In addition, a commercial γ-Al_2O_3 (200 m^2/g, *Puralox, SASOL*) was selected as support material for the catalysts. A *STA 449 F3 Jupiter* (Netzsch) was used for the experiments. The objective of the adsorption-desorption cycles is to spot the interaction of different gaseous species in the adsorption on the catalyst.

SAMPLES PRETREATMENTS

The pretreatments included the following steps:

1. Preconditioning: the catalysts were heated at 500 ºC in inert atmosphere for 1h.
2. Activation of the catalyst with a 50%^{v} flow of H_2 for 1 hour.
3. Decreasing the temperature until 400 ºC and keeping it constant for 1 hour in inert atmosphere.

Table 1. TGA analysis conditions

Catalyst load	20.0 ± 0.1 mg
Total volumetric flow	100 mL (STP) / min
CO_2 concentration (inlet flow)	40 ^{v}%
H_2O concentration (inlet flow)	10 ^{v}%
H_2 concentration (activation)	50 ^{v}%
Inert gas (dilutant)	N_2
Pressure	1 bar
Adsorption steps duration	30 min (each)

Results and Discussion

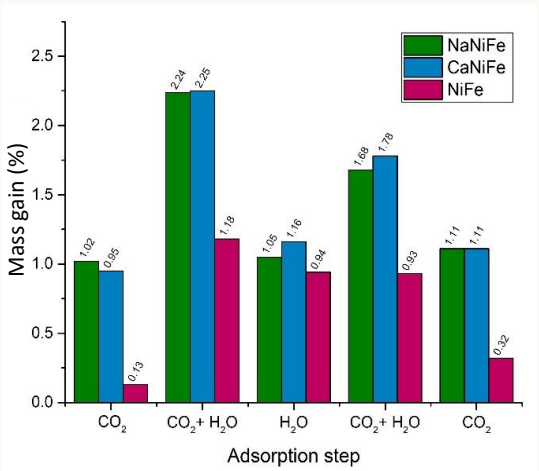

Figure 1. TGA mass gain for catalyst samples subjected to different atmospheres.

MAIN CONCLUSIONS

The inclusion of alkali and alkaline earth species significantly improved the CO_2 adsorption capacity of multifunctional catalysts. CO_2 was totally removed in step 3rd as effect of temperature (400 ºC). Water and CO_2 partially compete for the adsorption sites of the catalysts, as it can be observed in the reduction of the mass gain in the 4th step in comparison with the 2nd one. H_2O competes partially with CO_2 for the adsorption centers. CO_2 adsorption capacity was recovered after removing the H_2O from the gas inlet.

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