

Catalyst Support Effects on Tar Reforming for the Production of Renewable Natural Gas and Hydrogen

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Ni/Fe/MgO Tar Reforming Catalyst

Originally Developed for Gas Cleaning for Dual Fluidized-Bed Gasifier Producer Gas

Güssing, Austria

8 MW_{fuel}



CHP

Gas Composition (mole percent)	Güssing, Austria Gasifier	Woodland, CA Gasifier
Hydrogen	42.0	40.23
Oxygen	0.1	0.18
Nitrogen	2.0	2.00
Methane	8.0	7.25
Carbon Monoxide	25.0	28.86
Carbon Dioxide	21.0	18.70
Ethylene	2.0	1.28
Ethane	0.5	0.18
H ₂ /CO	1.68	1.39

Woodland, CA

1 MW_{fuel}



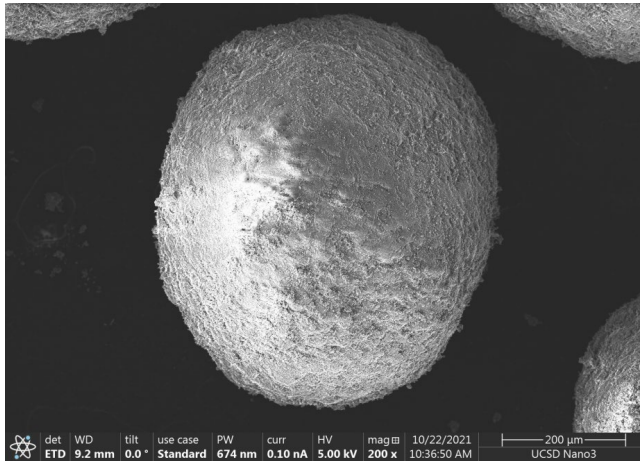
West Biofuels, LLC
Pilot Plant

Producer Gas for the Catalytic Production of Methane or Hydrogen Requires Tar Removal

Ni/Fe/MgO Tar Reforming Catalyst Performance

Catalyst Composition* 1.16% Loading (Ni 45%, Fe 21%, MgO 34%)

Objective: Evaluate the effect of catalyst supports on catalyst performance on tar and the constituents of producer gas.

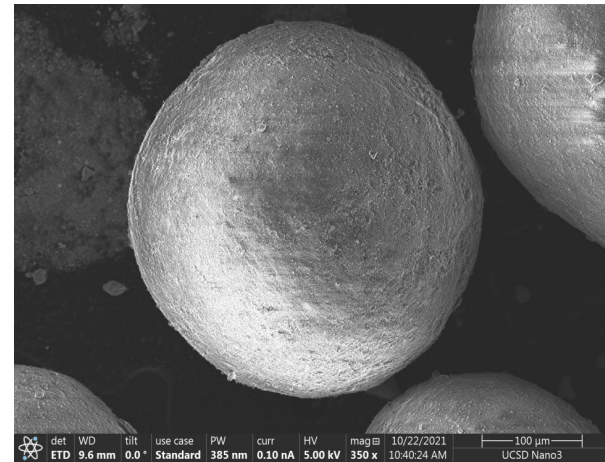


Carbo Ceramics

Carbo HSP - 430 µm average dia.

Surface area 0.18 m²/g

Sintered Bauxite



SASOL

Puralox 300/200 - 290 µm average dia.

Surface area 125 m²/g

γ-alumina

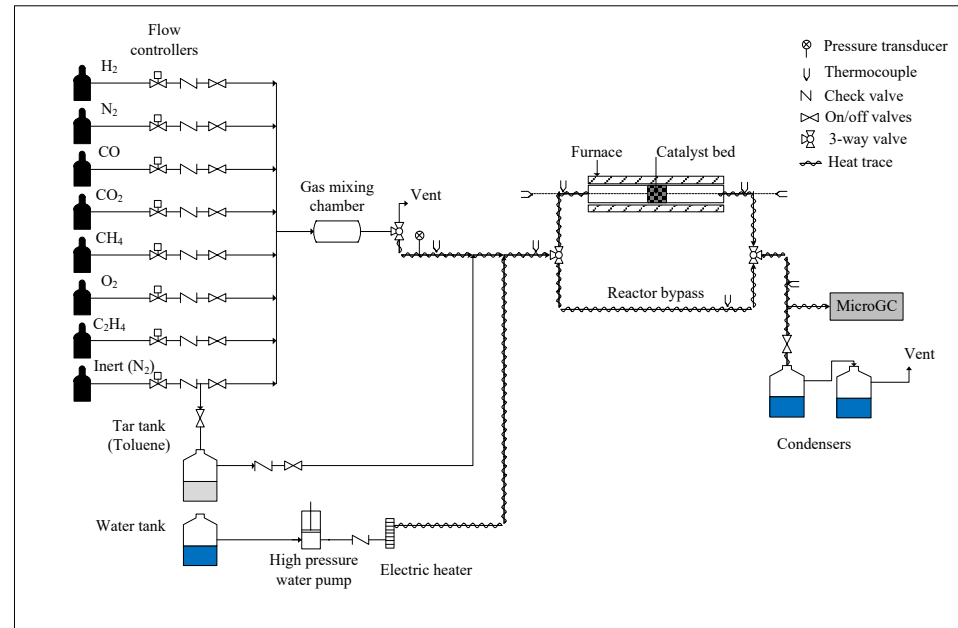
*Tinku Baidya, Robert Cattolica, and Reinhard Seiser, "High Performance Ni-Fe-Mg Catalyst for Tar Removal in Producer Gas," Applied Catalyst A, General 558 (218) 131-139.

Ni/Fe/MgO Tar Reforming Catalyst Performance

Experimental Method: Temperature-controlled flow reactor 600 to 800 °C
 Catalyst Loading: 500 mg + 5 g (1/32") quartz chips (10:1)
 Flow rate: 400 sccm , WHSV 48,000 scc/h/g
 Tar Surrogate: C₇H₈ , Toluene, carrier N₂, Nitrogen
 Study Gas: Producer gas constituents including H₂O injection
 Gas Measurements: Agilent 990 microGC

	C ₇ H ₈	CO	CH ₄	H ₂ O	N ₂
1	0.73%	-	-	25%	74.3%
2	-		19%	25%	56.0%
3	0.73%	-	19%	25%	55.3%
4	-	19.9%	-	25%	55.1%

Study Gas Compositions

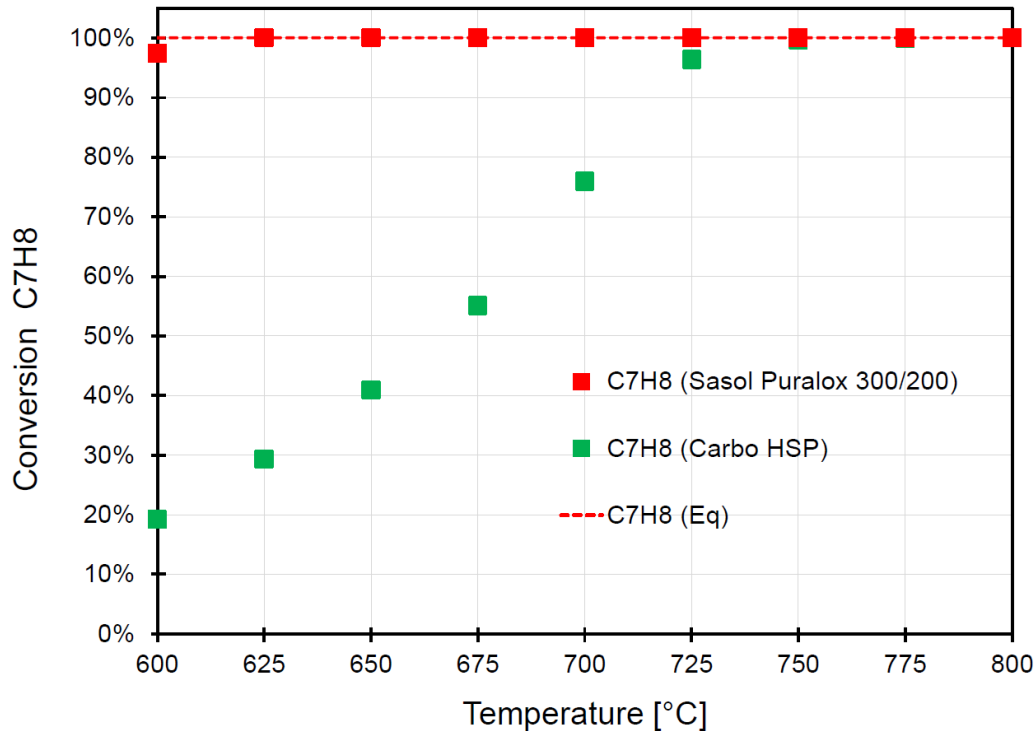


Experimental Setup

Ni/Fe/MgO Tar Reforming Catalyst Performance

Experiment:

C_7H_8	CO	CH_4	H_2O	N_2
0.73%	-	-	25%	74.3%



Sasol reforming extends C_7H_8 removal to 600 °C following equilibrium.

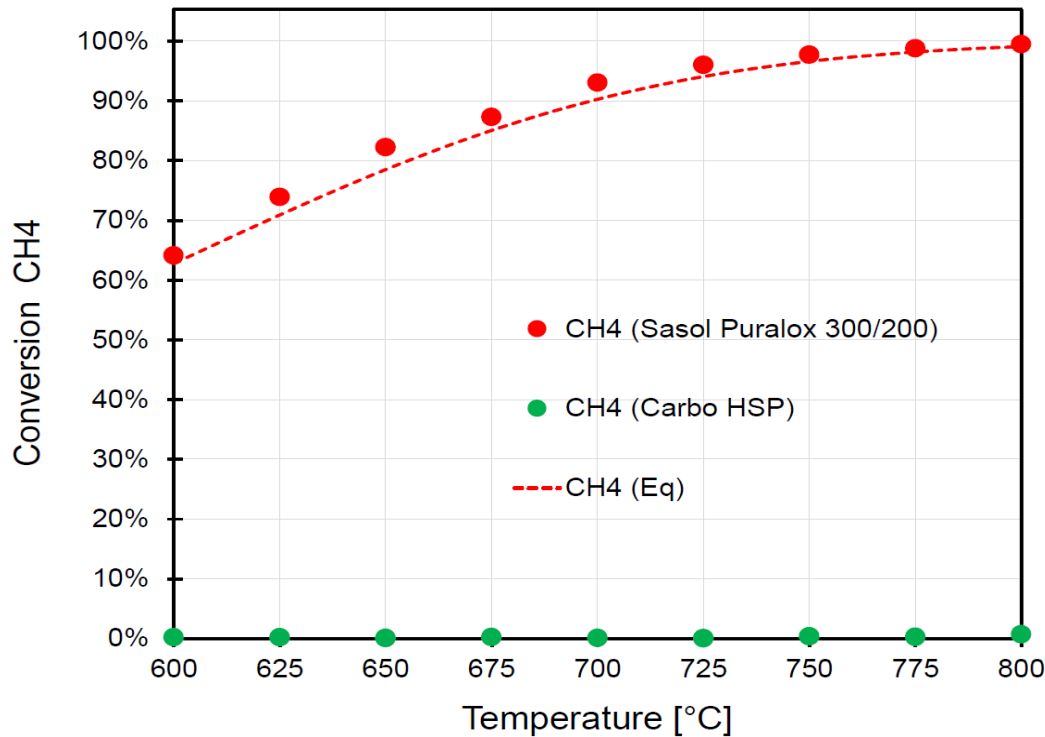
Carbo reforming consistent with original C_7H_8 experiments and drops below 725 °C.

C_7H_8 reforming with Sasol and Carbo supports compared to equilibrium.

Ni/Fe/MgO Tar Reforming Catalyst Performance

Experiment:

C_7H_8	CO	CH_4	H_2O	N_2
-	-	19%	25%	56%



Sasol reforming of CH_4 follows equilibrium over temperature from 600 to 800 °C.

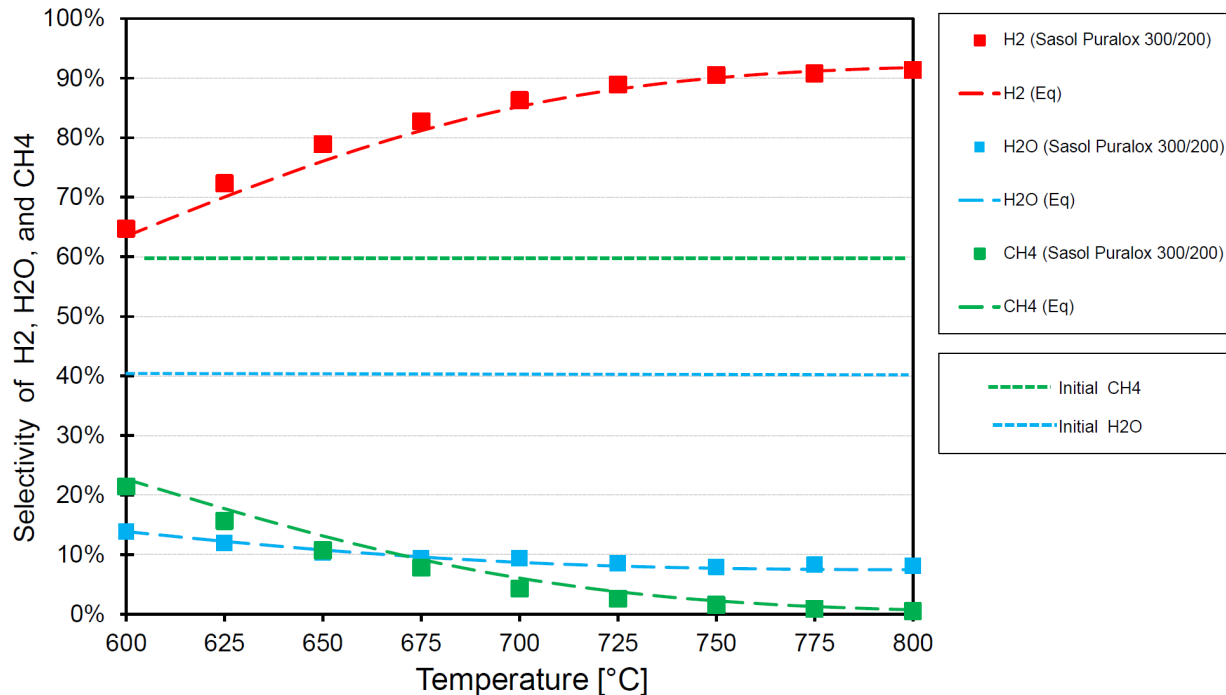
Carbo consistent with original experiments, no CH_4 reforming.

CH_4 reforming with Sasol and Carbo supports compared to equilibrium.

Ni/Fe/MgO Tar Reforming Catalyst Performance

Experiment:

C ₇ H ₈	CO	CH ₄	H ₂ O	N ₂
-	-	19%	25%	56%



Methane Steam Reforming
 $\text{CH}_4 + \text{H}_2\text{O} = 3 \text{H}_2 + \text{CO}$

Sasol reforming of CH₄ follows equilibrium with production of H₂.

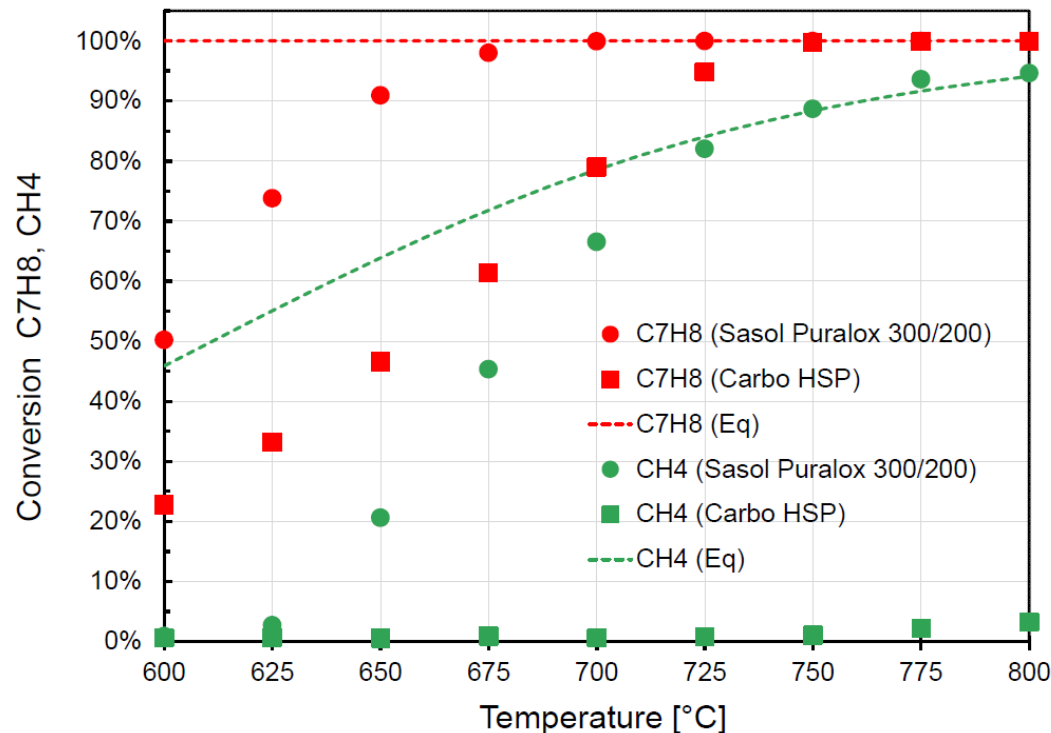
Carbo - no reforming of CH₄, selectivity of CH₄ and H₂O remain at initial level, no H₂ production.

H₂ and H₂O selectivity from CH₄ reforming with Sasol and Carbo supports compared to equilibrium.

Ni/Fe/MgO Tar Reforming Catalyst Performance

Experiment:

C_7H_8	CO	CH_4	H_2O	N_2
0.73%	-	19%	25%	55.3



C_7H_8 and CH_4 interaction

Sasol follows equilibrium CH_4 until 725 °C and C_7H_8 until 675 °C. Presence of both degrades activity as temperature is lowered.

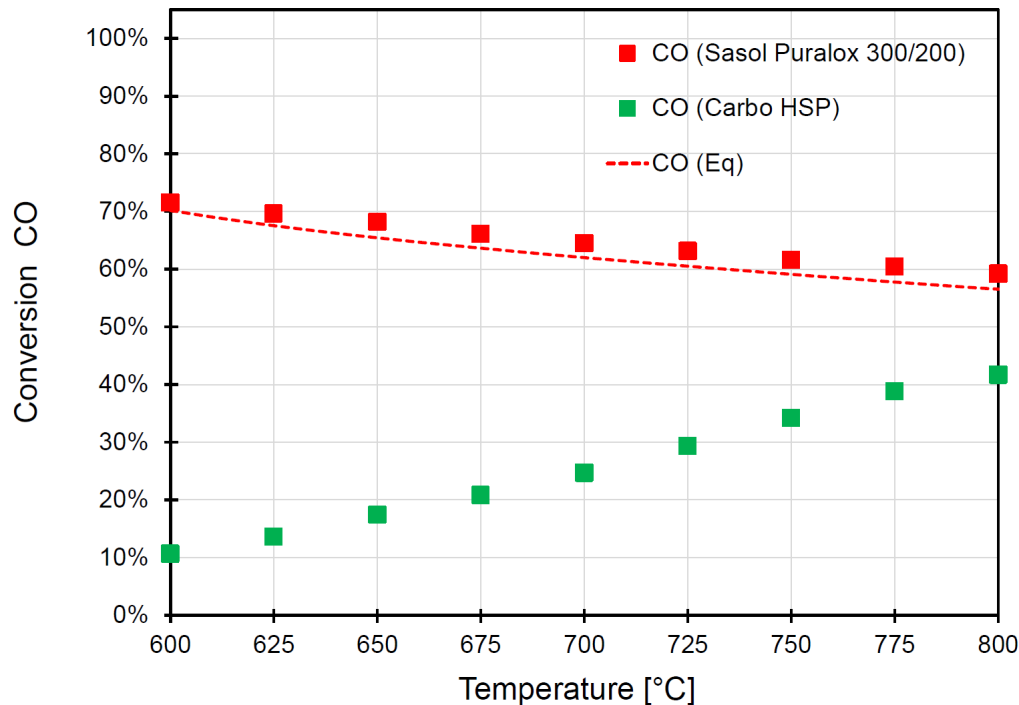
Carbo reforming of C_7H_8 consistent with original experiments with no CH_4 removal. Presence of both has caused no significant effect on the Carbo performance.

C_7H_8 and CH_4 reforming with Sasol and Carbo supports compared to equilibrium.

Ni/Fe/MgO Tar Reforming Catalyst Performance

Experiment:

C ₇ H ₈	CO	CH ₄	H ₂ O	N ₂
-	19.9%	-	25%	55.1%



Sasol follows CO equilibrium conversion from 600 to 800 °C.

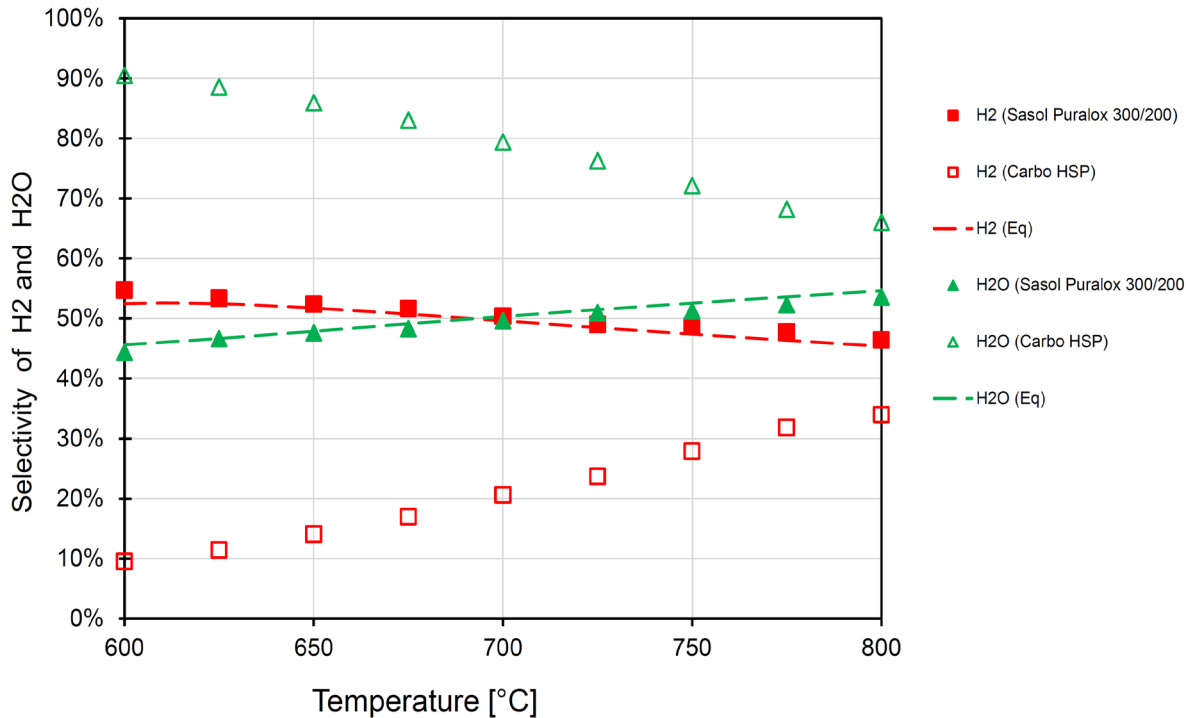
Carbo reforming of CO is low with some improvement as temperature is raised to 800 °C.

CO reforming with Sasol and Carbo supports compared to equilibrium.

Ni/Fe/MgO Tar Reforming Catalyst Performance

Experiment:

C ₇ H ₈	CO	CH ₄	H ₂ O	N ₂
-	19.9%	-	25%	55.1%



Water gas shift reaction
 $\text{CO} + \text{H}_2\text{O} = \text{H}_2 + \text{CO}_2$

Sasol drives water gas shift to equilibrium 600 to 800 °C.

Sasol at 700 °C follows equilibrium and converts 50% of the H₂O to H₂.

Carbo cannot attain equilibrium even at the highest temperature.

H₂ and H₂O selectivity CO reforming with Sasol and Carbo supports compared to equilibrium result.

Ni/Fe/MgO Tar Reforming Catalyst Performance

Conclusions

Tar Reforming Catalyst Producer Gas Applications

- **Sasol support:** High CH_4 and CO conversion along with tar surrogate in producer gas generates H_2 to complement subsequent H_2 production.
- **Carbo support:** No CH_4 conversion along with high tar removal in producer gas supports subsequent CH_4 production.

Deactivation Characteristics (not shown)

- **Sasol support:** shows deactivation but at highest temperature activation appears to be stable (needs further work).
- **Carbo support:** Original experiments demonstrates very high stability with little to no deactivation (reference original publication).