Investigations on Release and Fate of Phosphorous Species during Co-Gasification of Sewage Sludge with Coal and Wood

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HOTVEGAS

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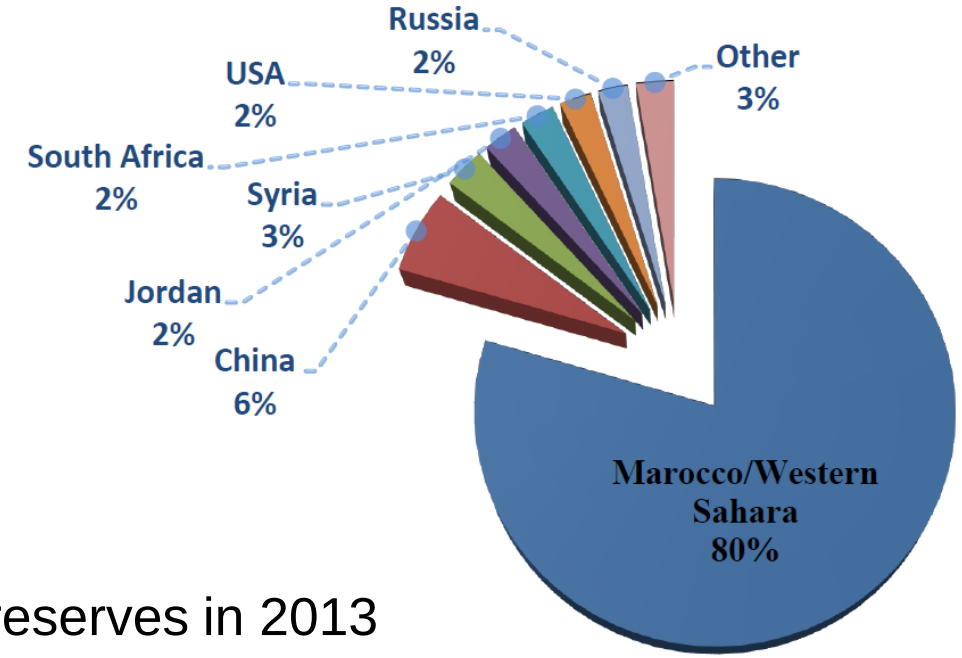
JÜLICH Forschungszentrum

Background

Why recovery of phosphorus?

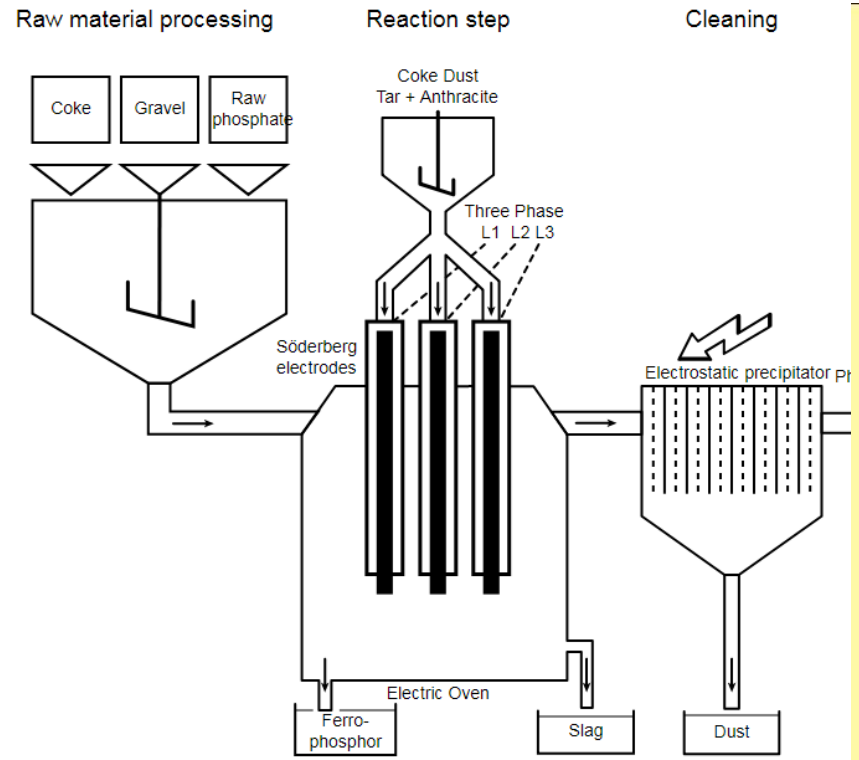
- AbfKlärV, 2017: sewage sludge from wastewater treatment plants has to be recycled for the recovery of phosphorus from 2029 onwards



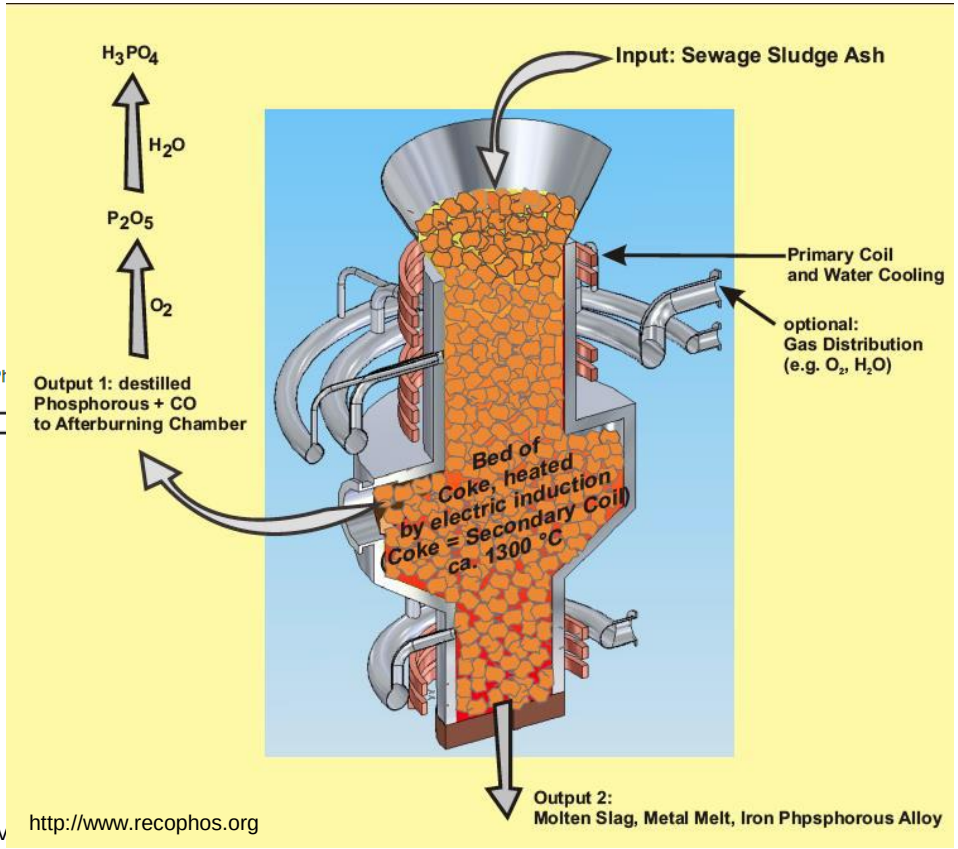
Explored raw phosphate reserves in 2013

Carbothermal Reduction

Wöhler-Process und RecoPhos

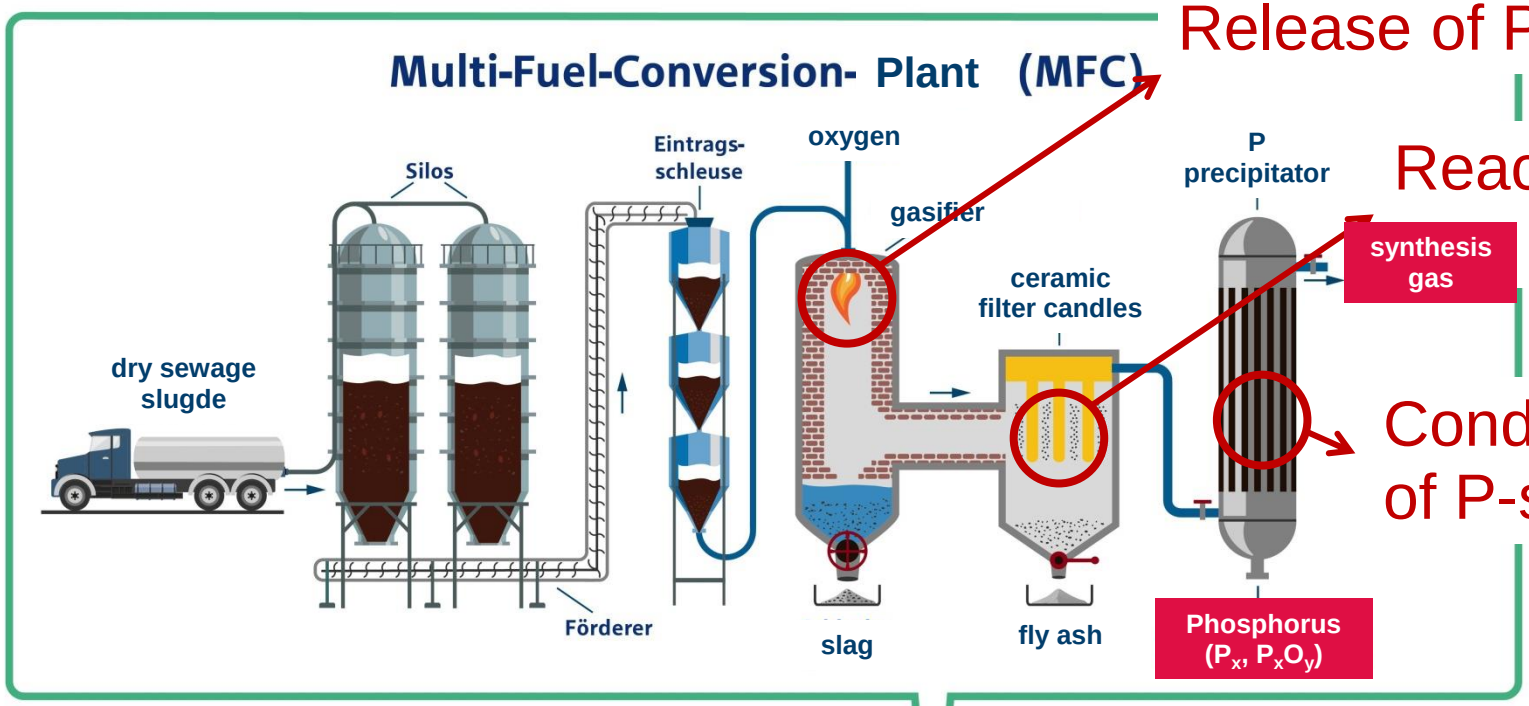


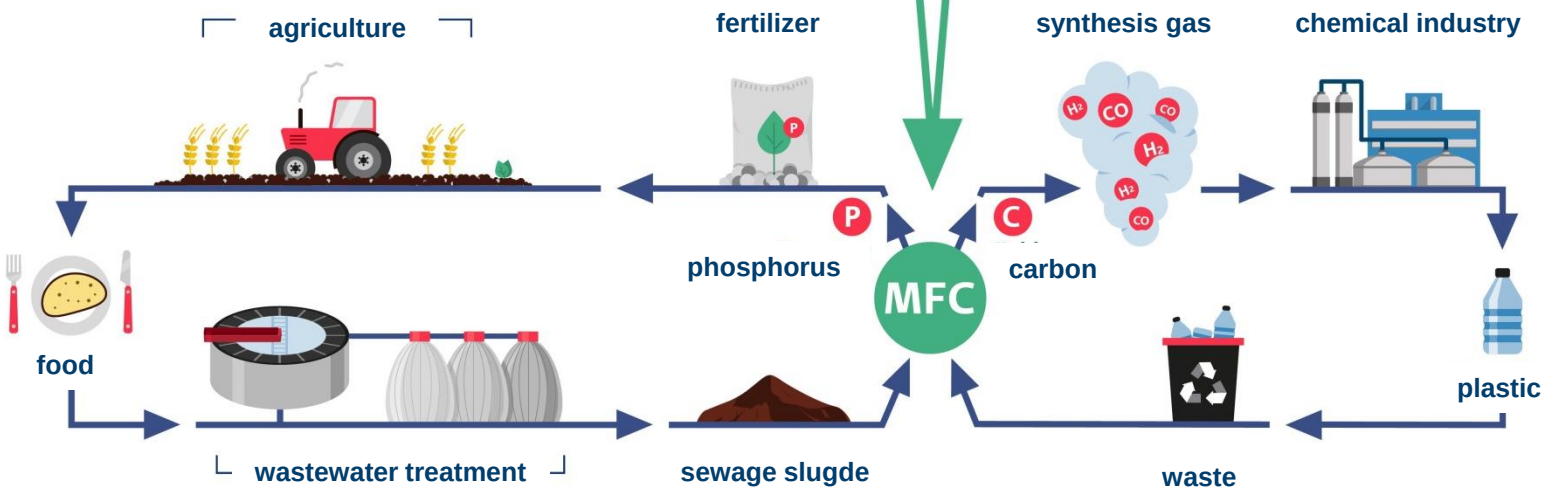
Corbridge, D.E.C. "Phosphorus: An outline of its chemistry, biochemistry and uses," Elsev



$$2\ Ca_3(PO_4)_2 + 10\ C + 6\ SiO_2 \rightarrow 6\ CaSiO_3 + P_4 + 10\ CO$$

Concept of RWE





Official Journal of Gemeinde Niederzier No. 17/2019

LICH ngszentrum

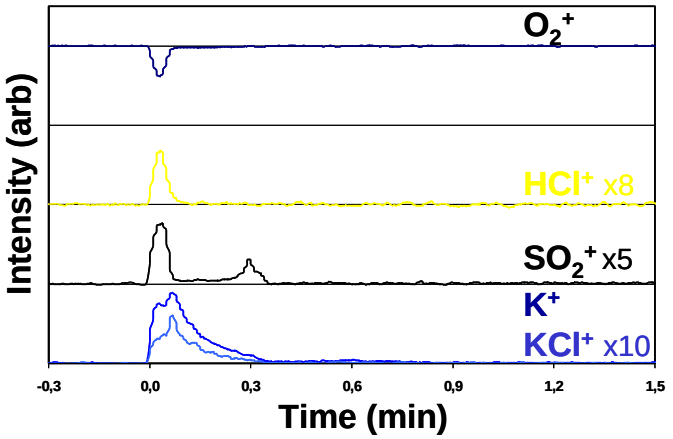
Samples

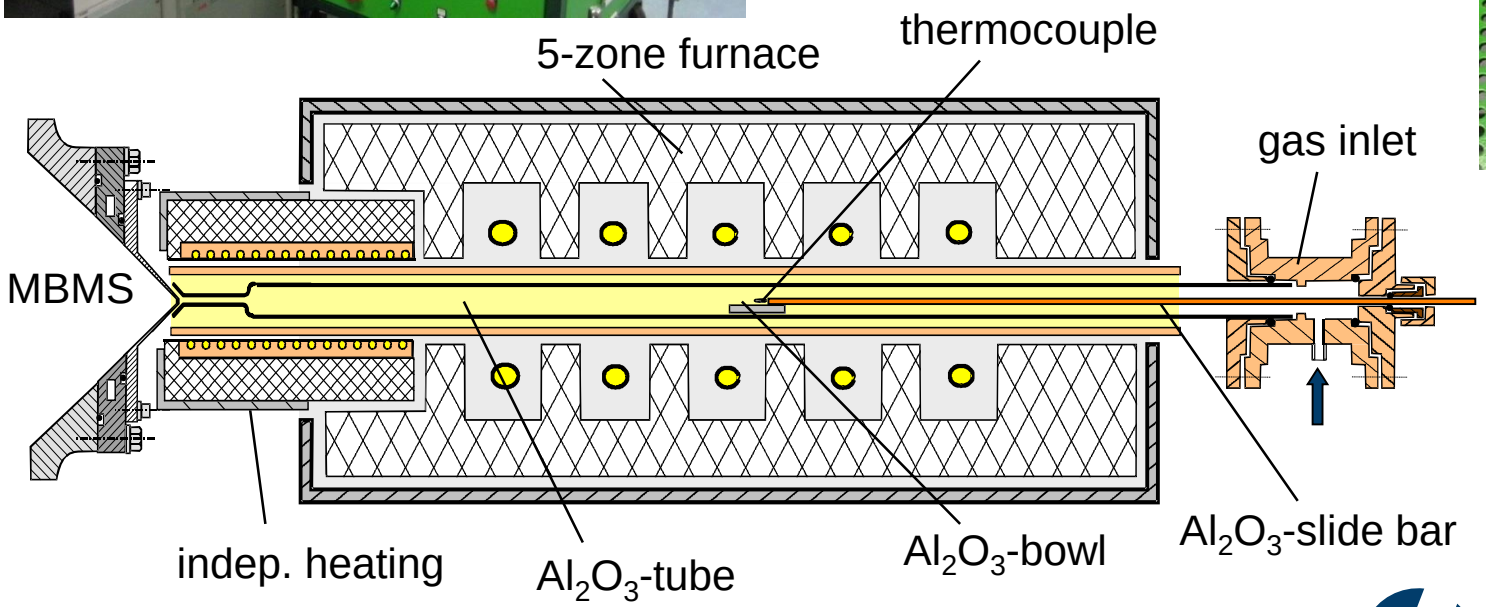
- **Phosphor compounds + carbon**
  - P_2O_5, $Ca_3(PO_4)_2$, $FePO_4*8H_2O$, $AlPO_4$, $Na_5P_3O_{10}$, Na_3PO_4, Adenosindi- (ADP) und -triphosphate (ATP)
  - P_2O_5:C = 1:5 (mol/mol) = P:C = 1:1.2 (g/g)

- **Sewage sludge + carbon / hard coal / lignite coal / wood**
  - 10, 50 or 90 mass.% sewage sludge (dry)

	C	H	O	N	S	P	Cl	Al	Fe	Ca	Mg	K	Na	Si
SS	17,9	3,0	43,9	2,7	0,7	2,4	0,06	1,7	3,7	2,5	0,4	0,5	0,2	20,3
HC	65.5	4.72	21.9	1.24	0.49	0.01	0.01	1.84	0.73	0.21	0.17	0.22	0.32	4.89
LC	53.1	4.48	29.8	0.44	0.43	0.01	0.01	0.09	0.47	1.44	0.26	0.02	0.13	6.40
W	46.4	6.05	45.7	0.2	0.02	0.01	0.01			0.08	0.01	0.03		0.02

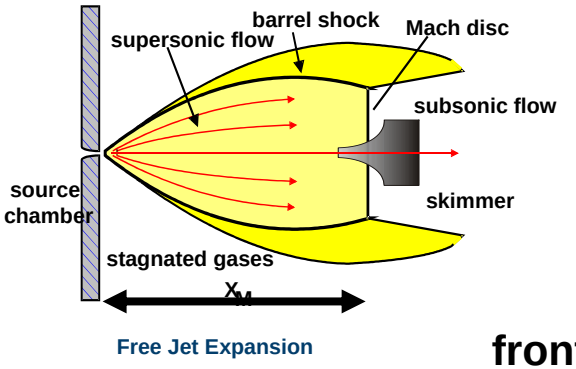
Release Experiments



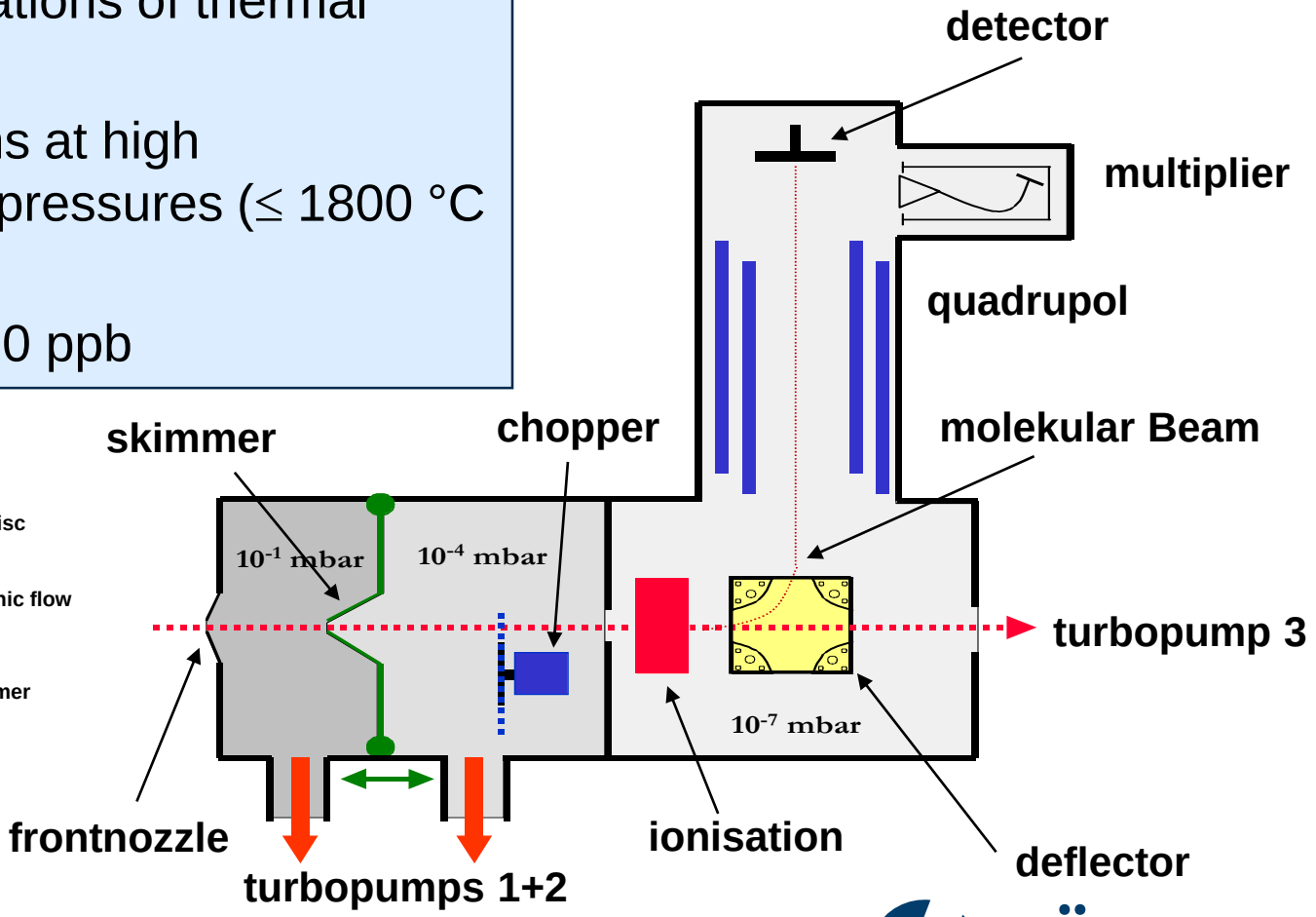


Molecular Beam Mass Spectrometry

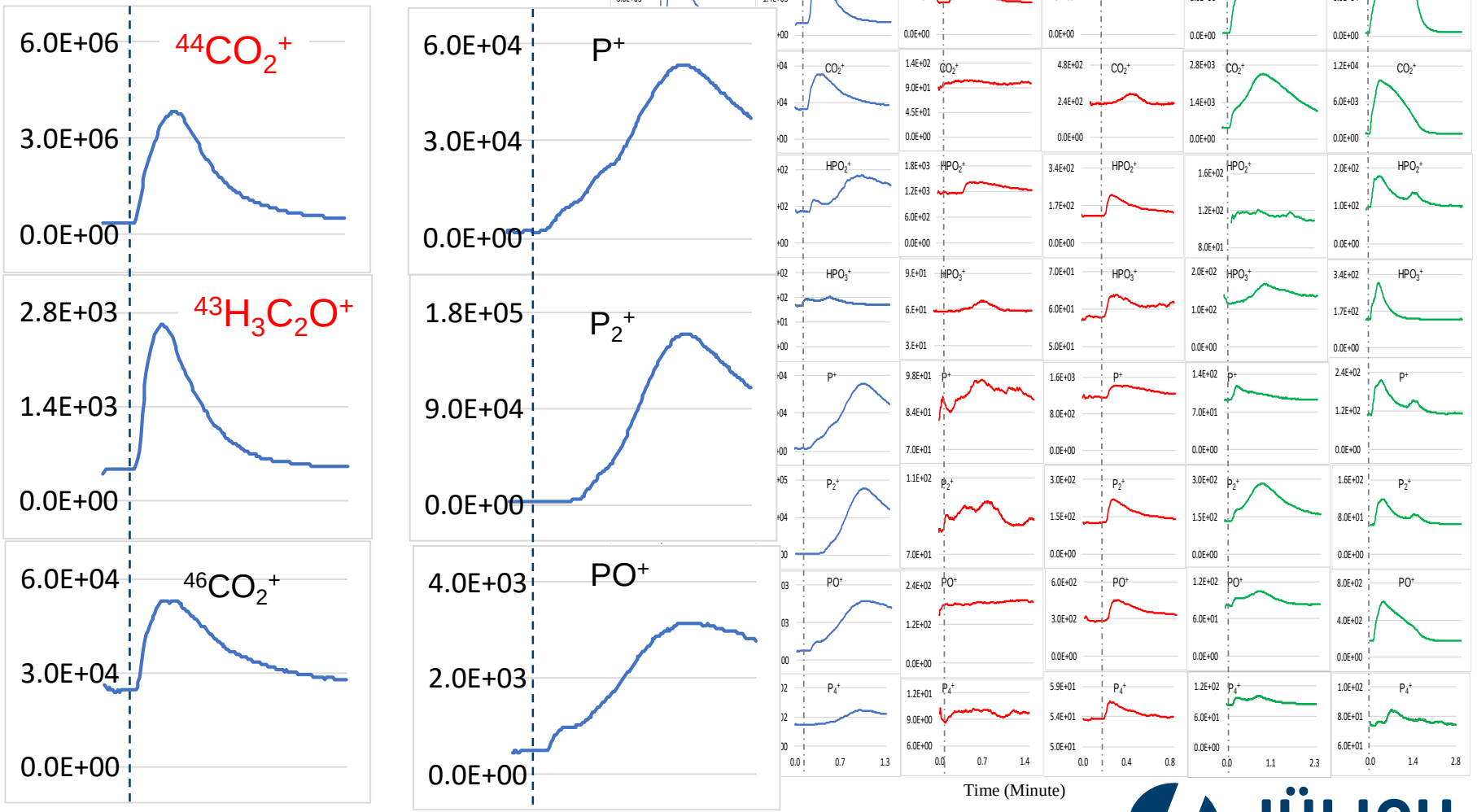
- Determination and specification of (condensable) vapour species
- Real time investigations of thermal processes
- Analysis of systems at high temperatures and pressures (≤ 1800 °C and 15 bar)
- Detection limit: < 10 ppb



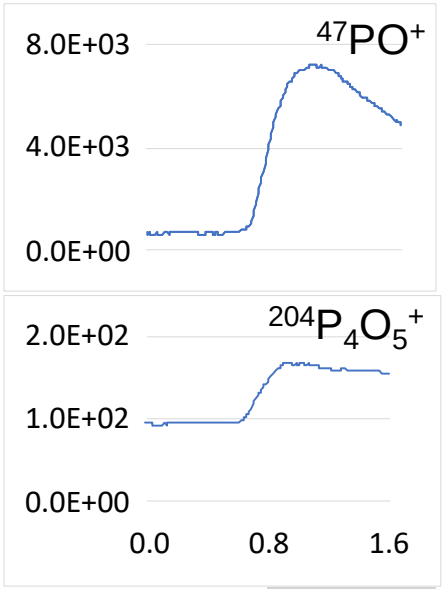
Free Jet Expansion

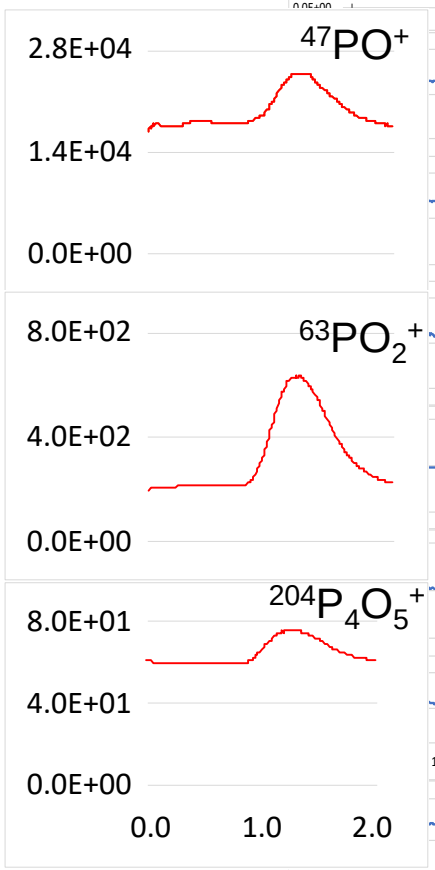


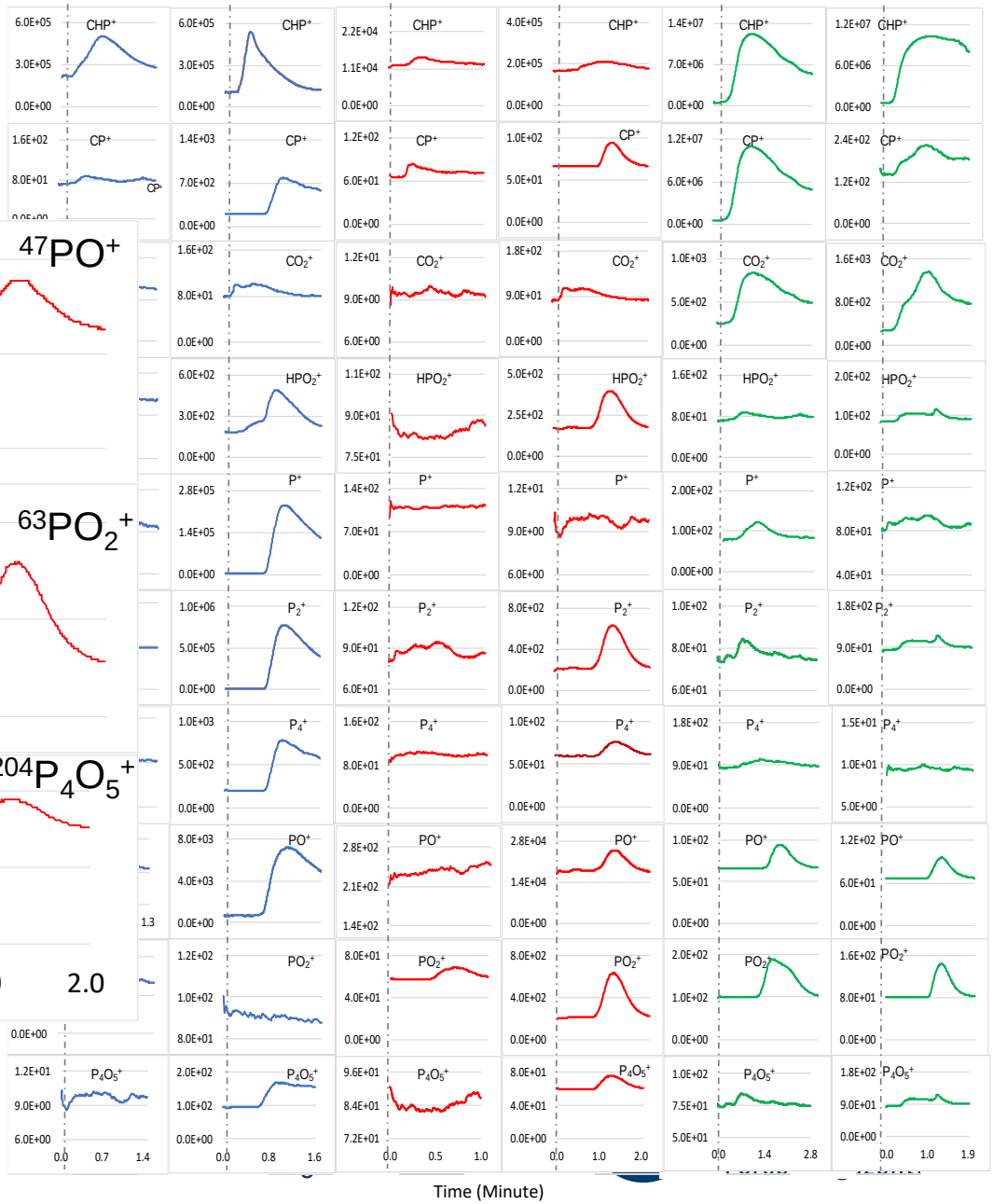
Release from ADP + C



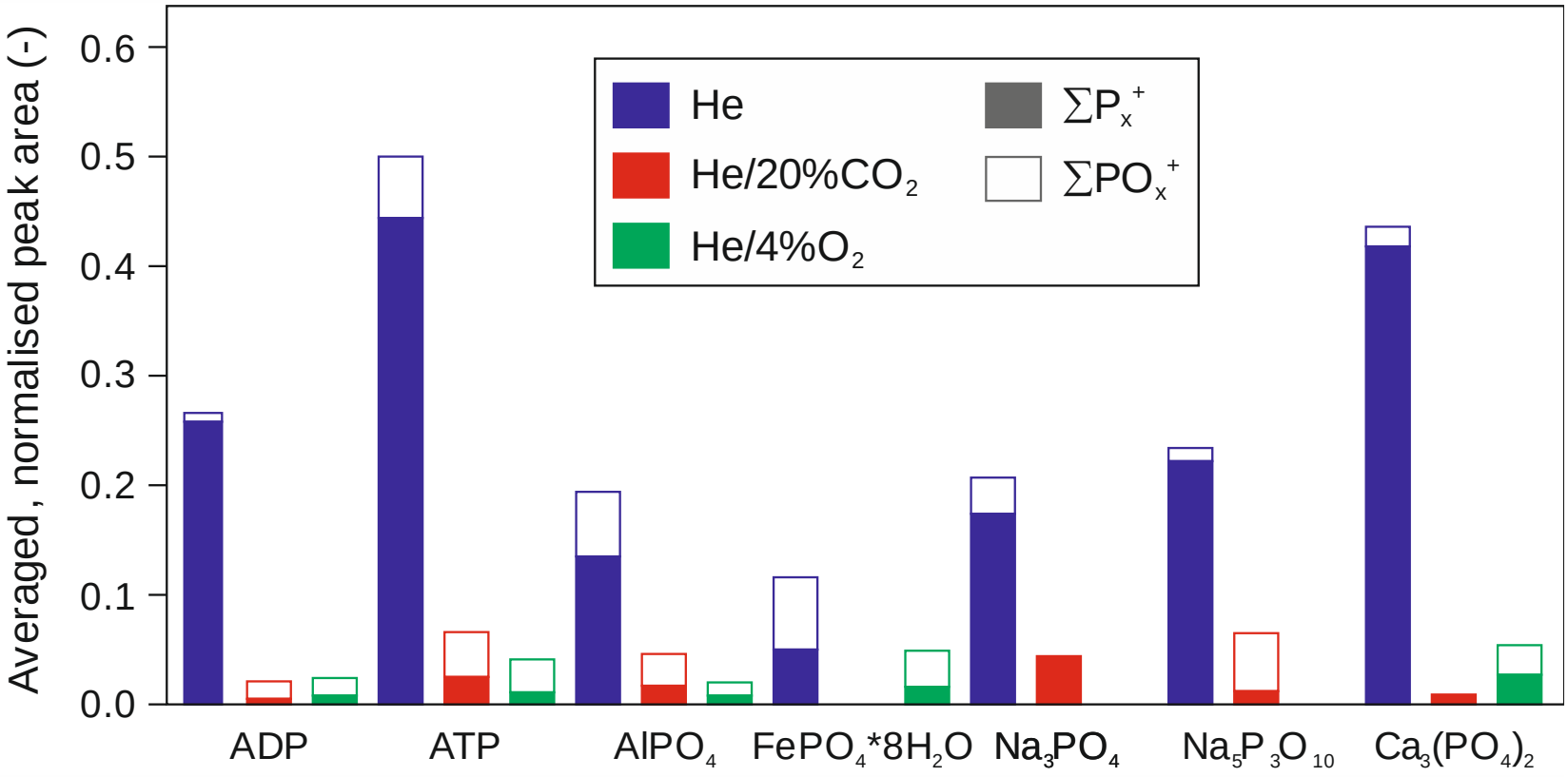
Release from $Na_5P_3O_{10}$ + C





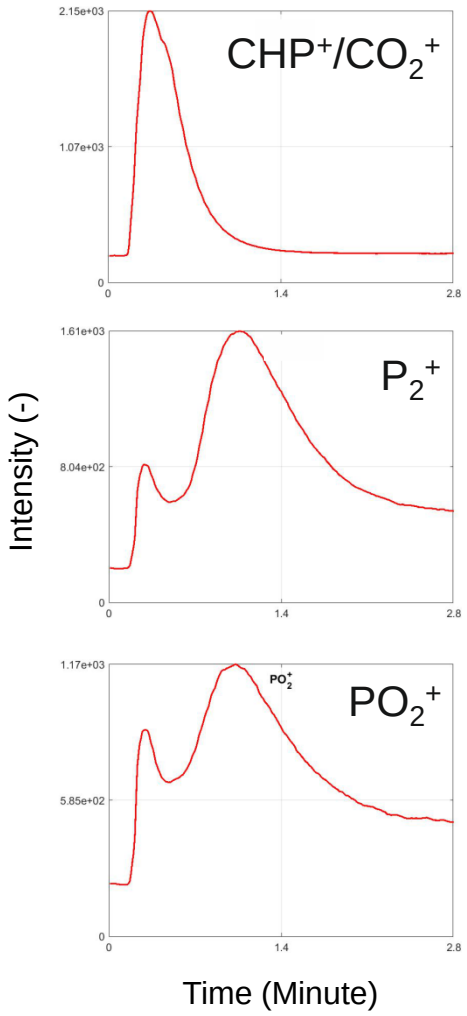


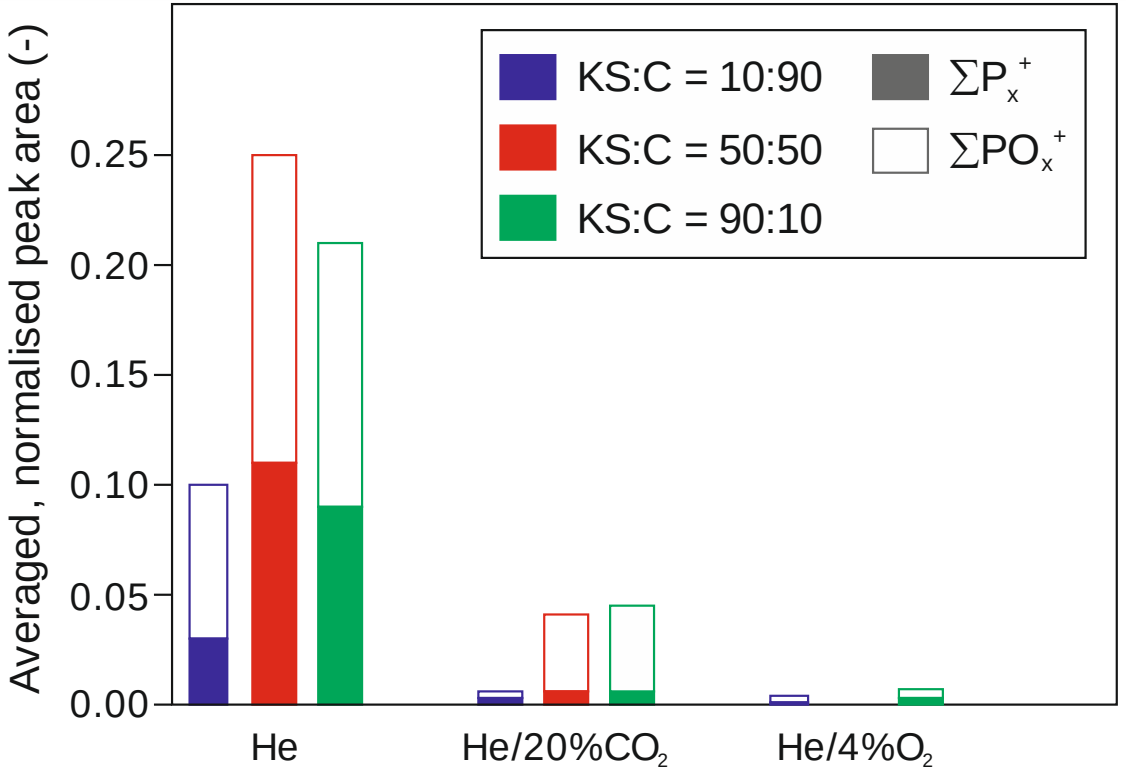
Release from Phosphates at 1200 °C



Release of P-Species from Sewage Sludge

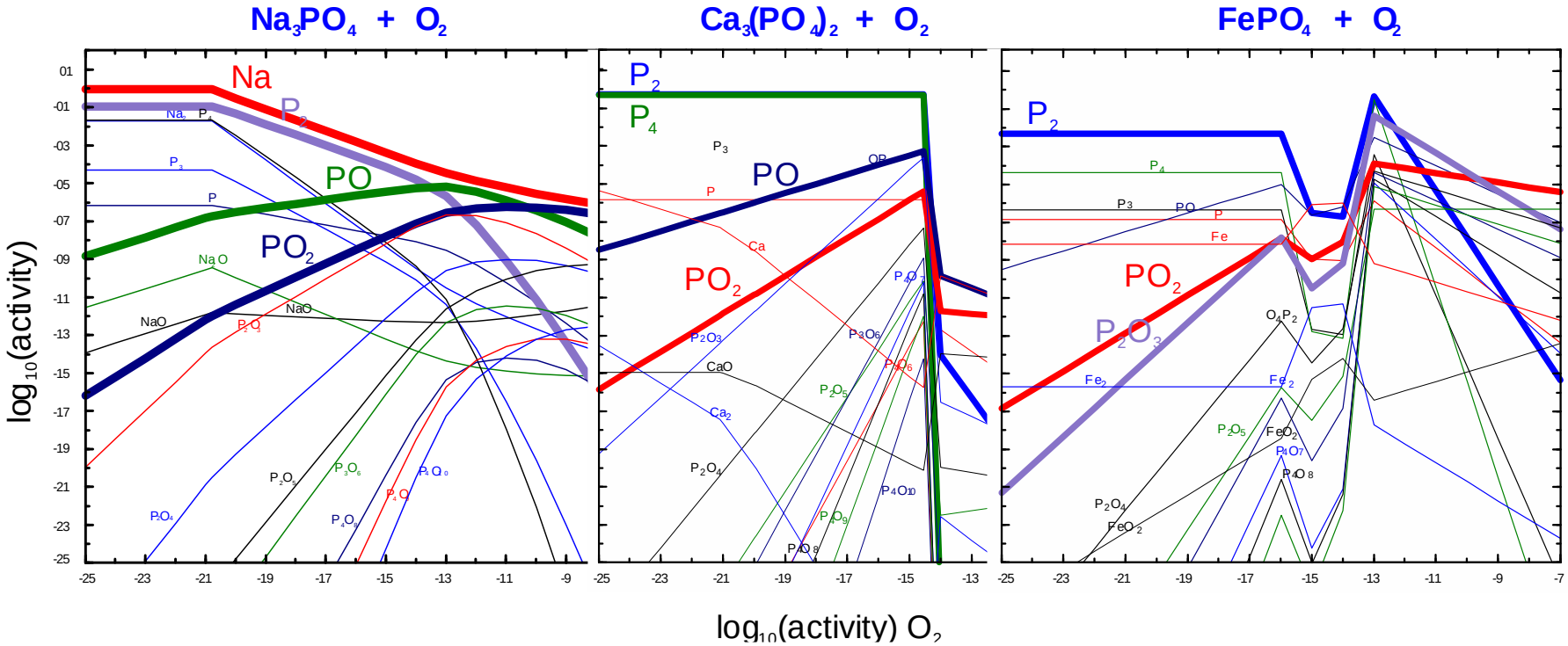
KS:C = 10:90, He, 1200 °C





Influence of Speciation and O_2 Partial Pressure

FactSage + GTOX, 1200 °C



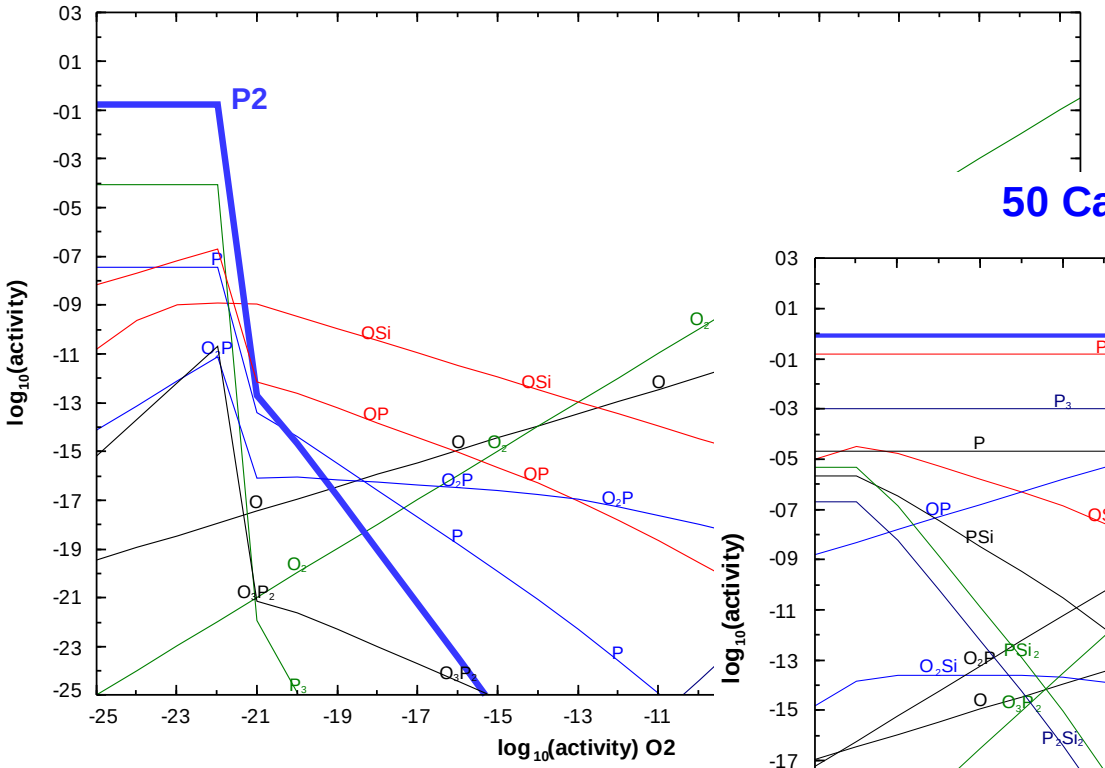
$Na_3PO_4 + 4\ C$
=>
$3\ Na + 4\ CO + P$

$Ca_3(PO_4)_2 + 5\ C$
=>
$3\ CaO + 5\ CO + 2\ P$

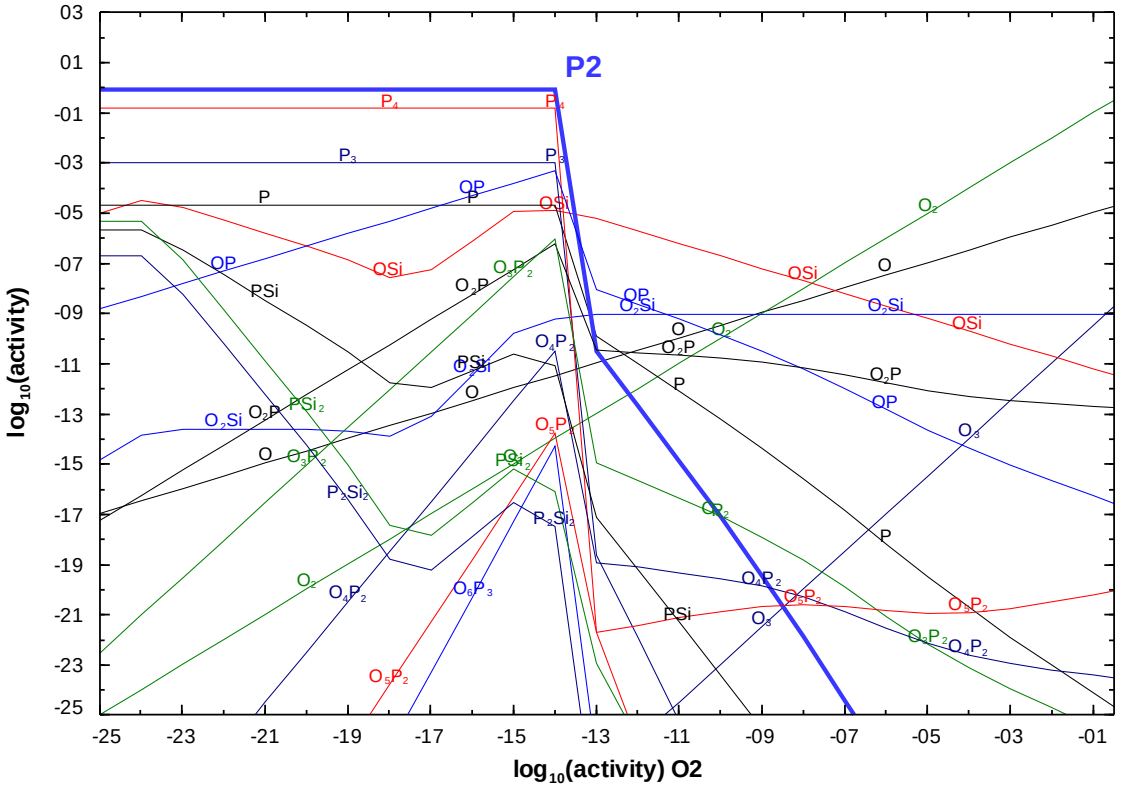
$FePO_4 + 4\ C$
=>
$FeP + 4\ CO$

Influence of Temperature

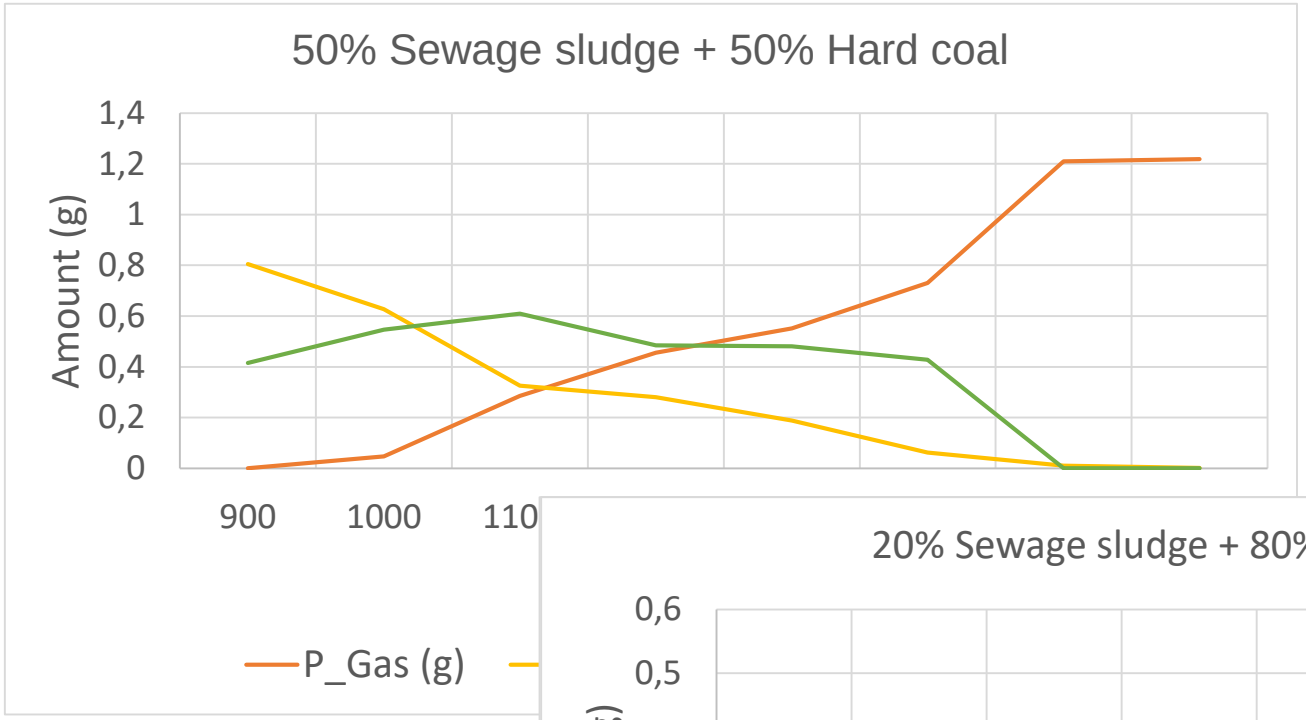
50 Ca3P2O8 + 50 SiO2, 1000 °C

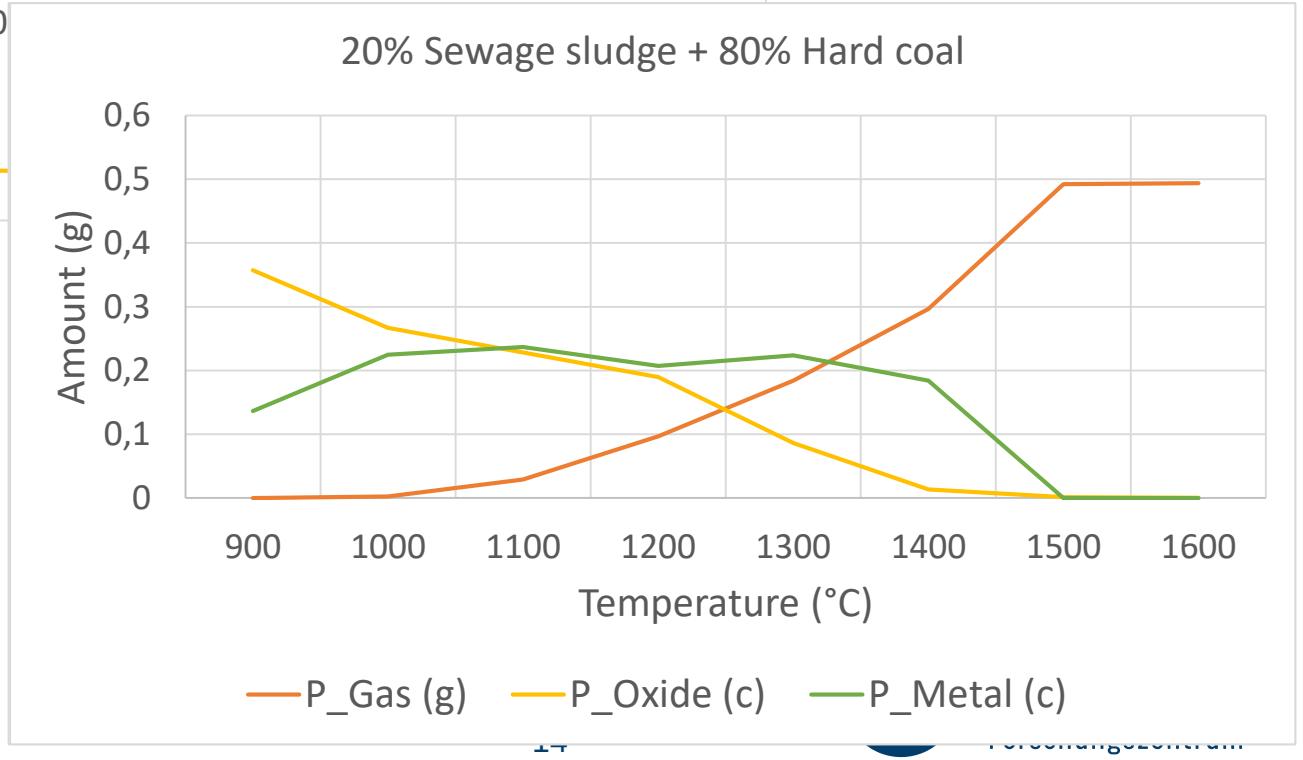


50 Ca3P2O8 + 50 SiO2, 1400 °C



Release during Pyrolysis





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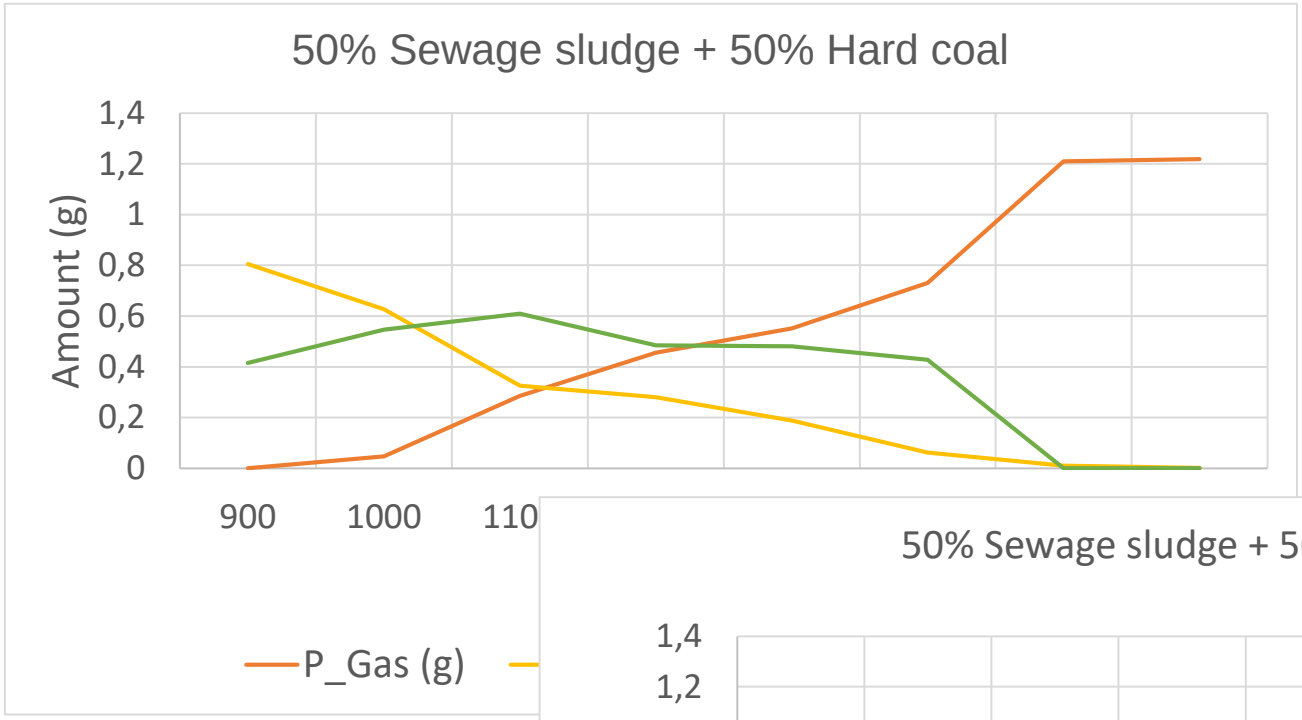
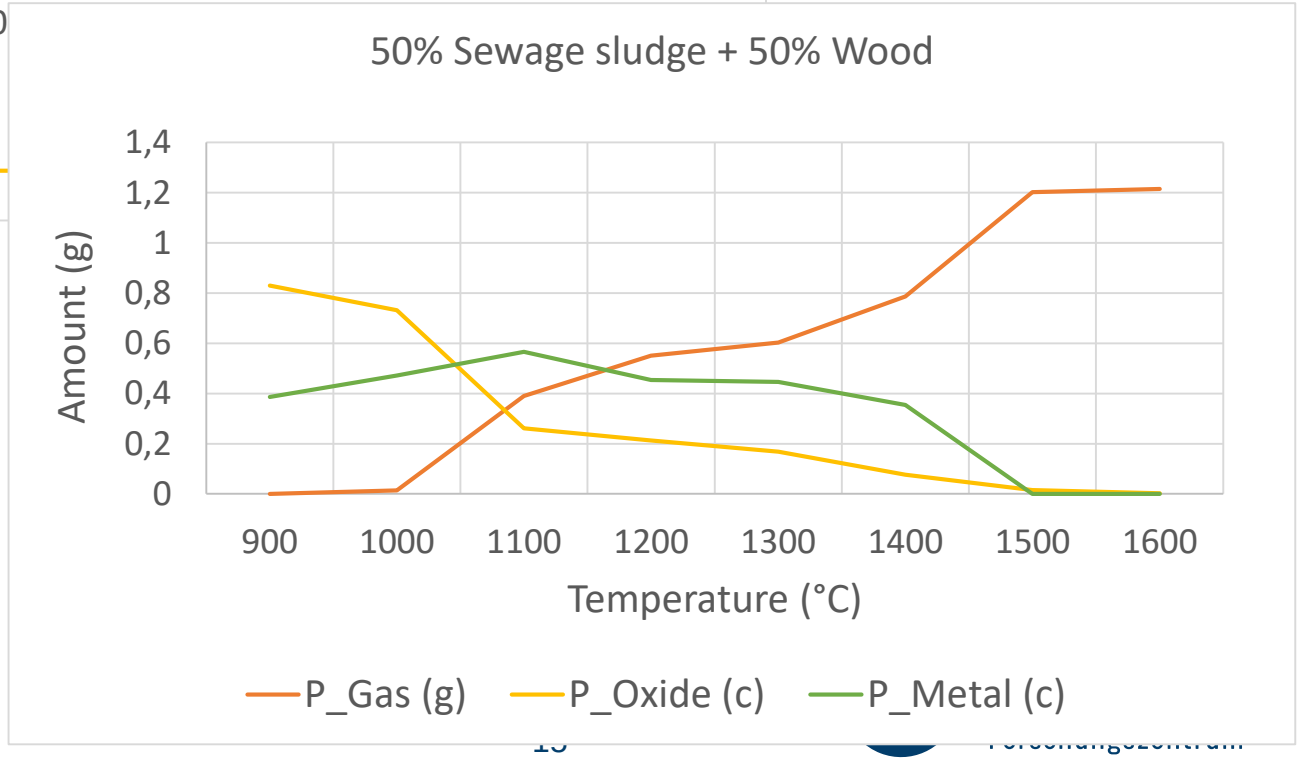
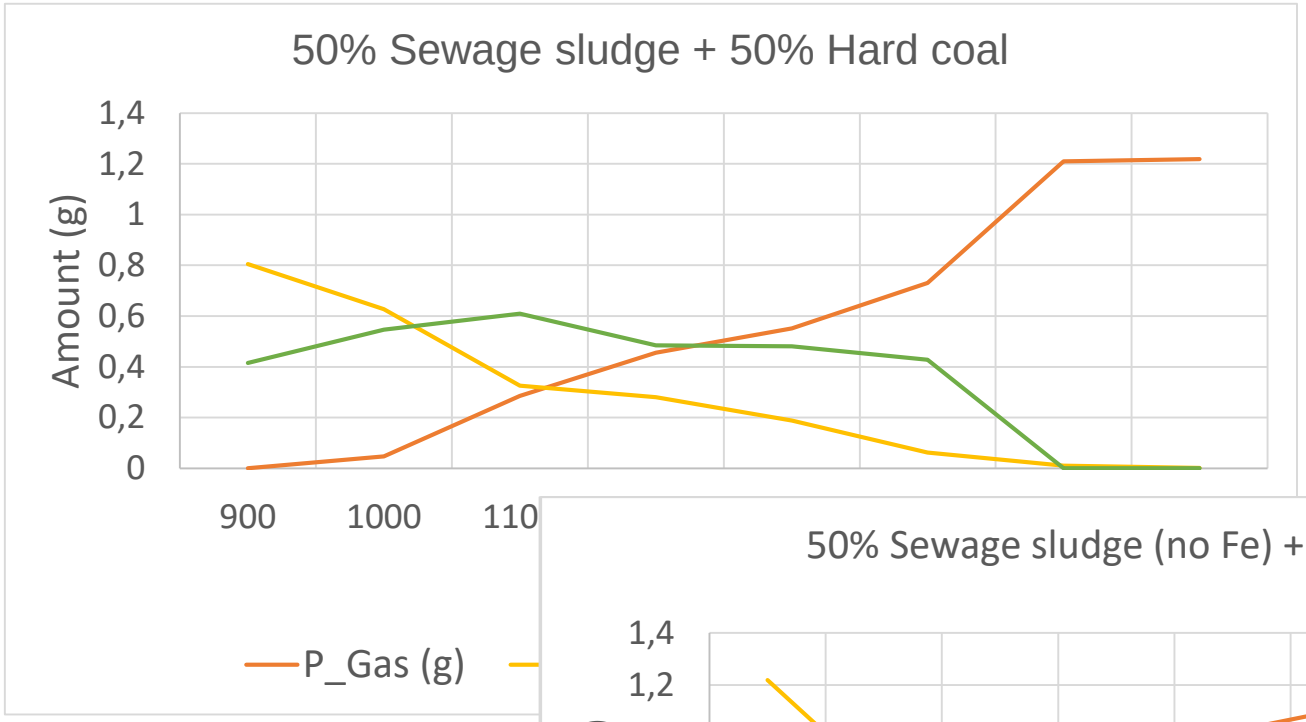
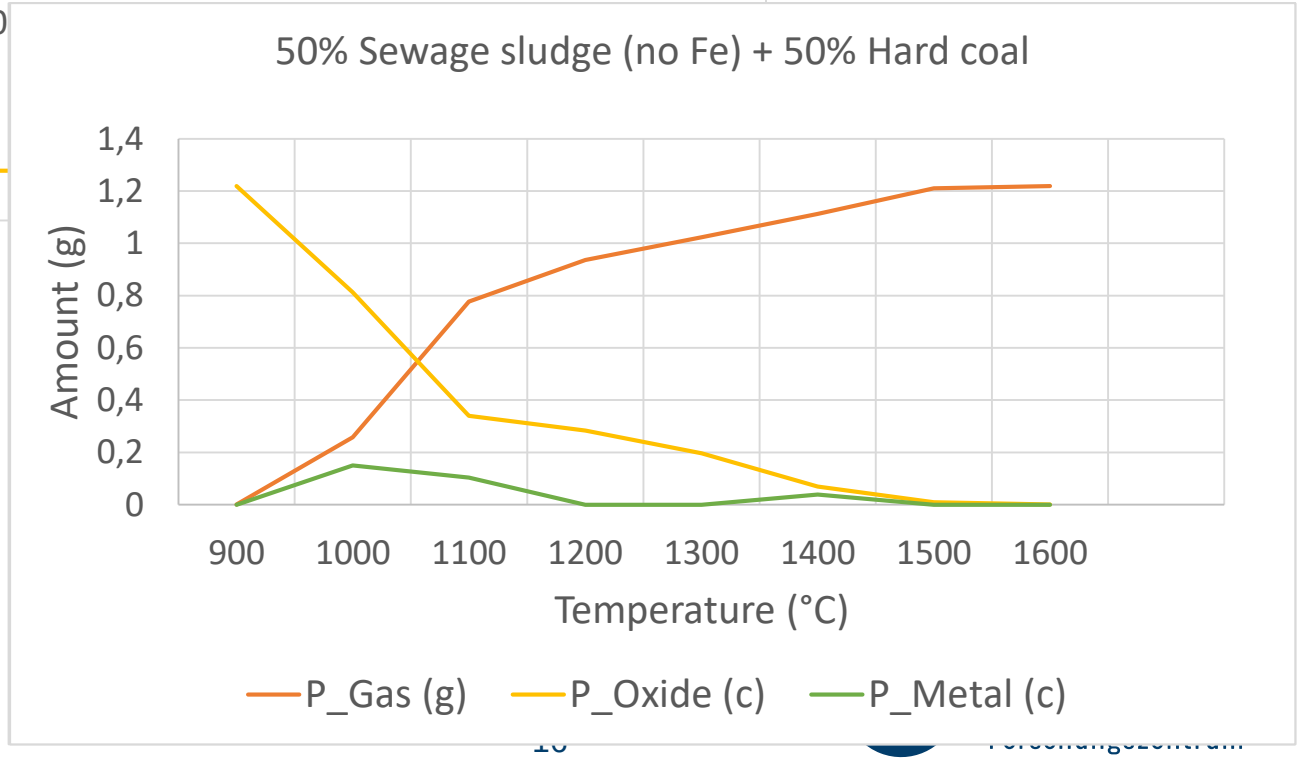


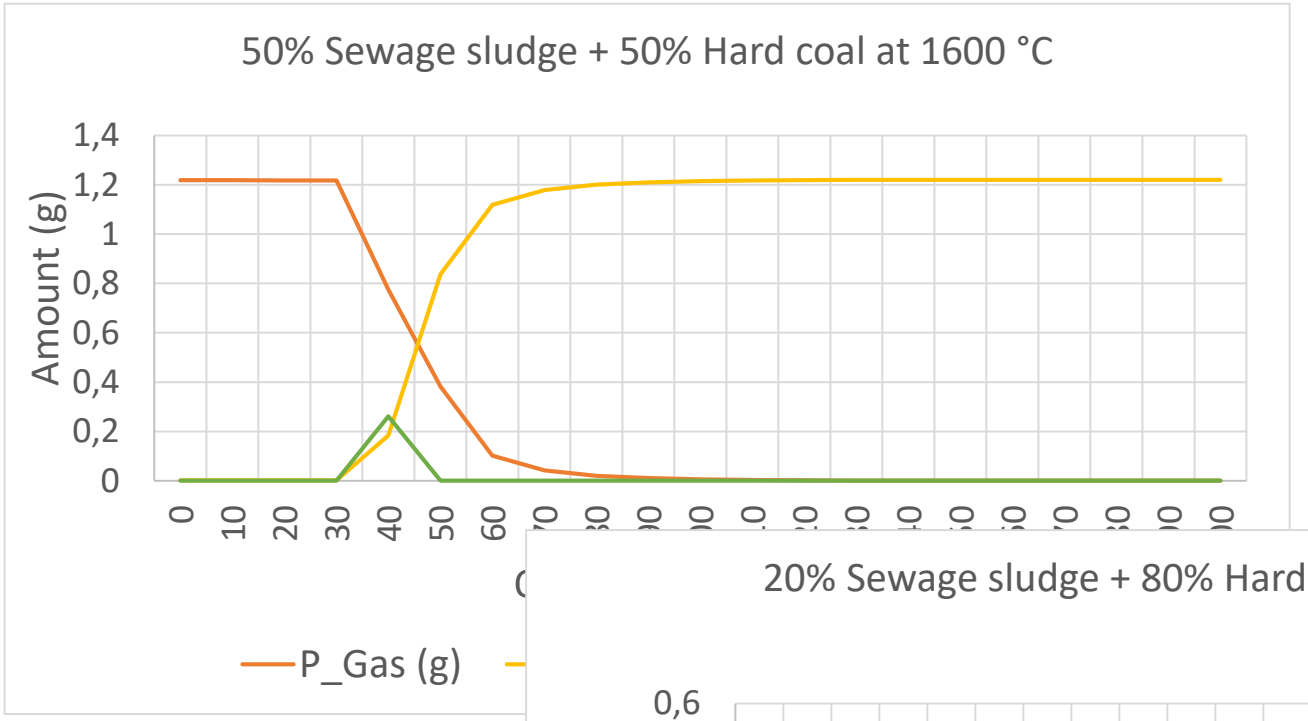


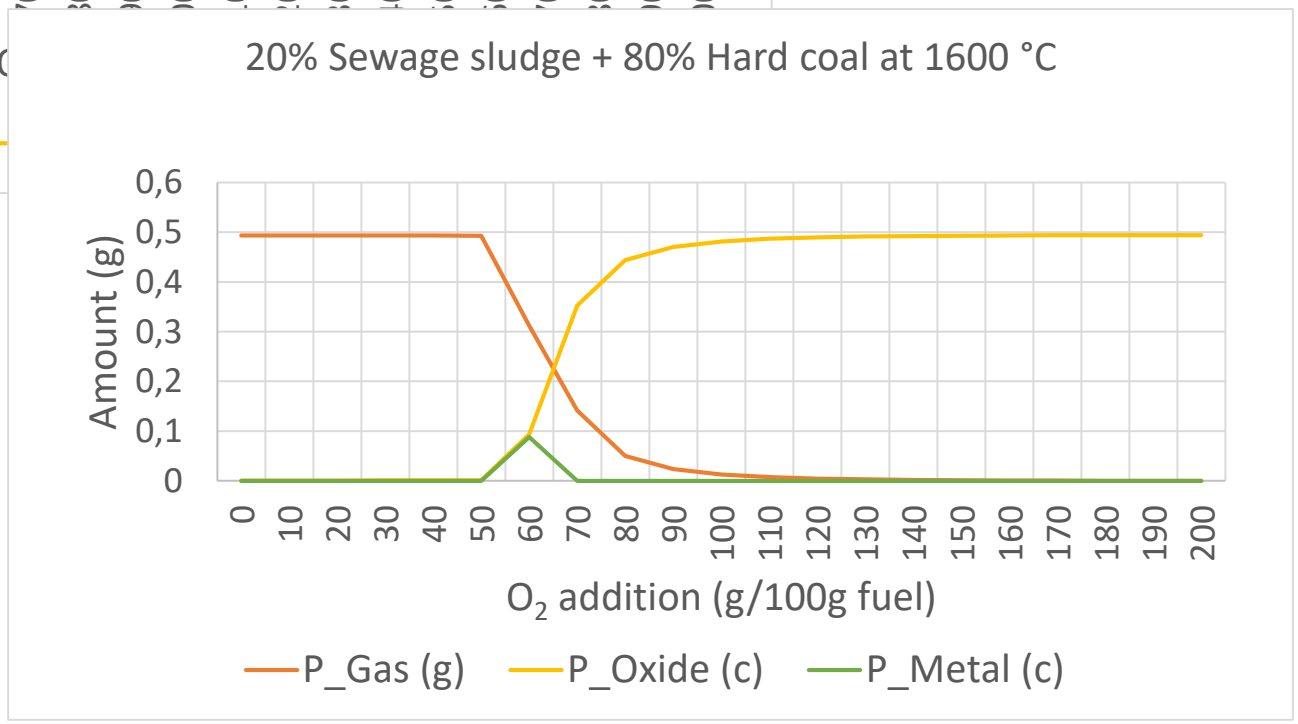
Release during Pyrolysis



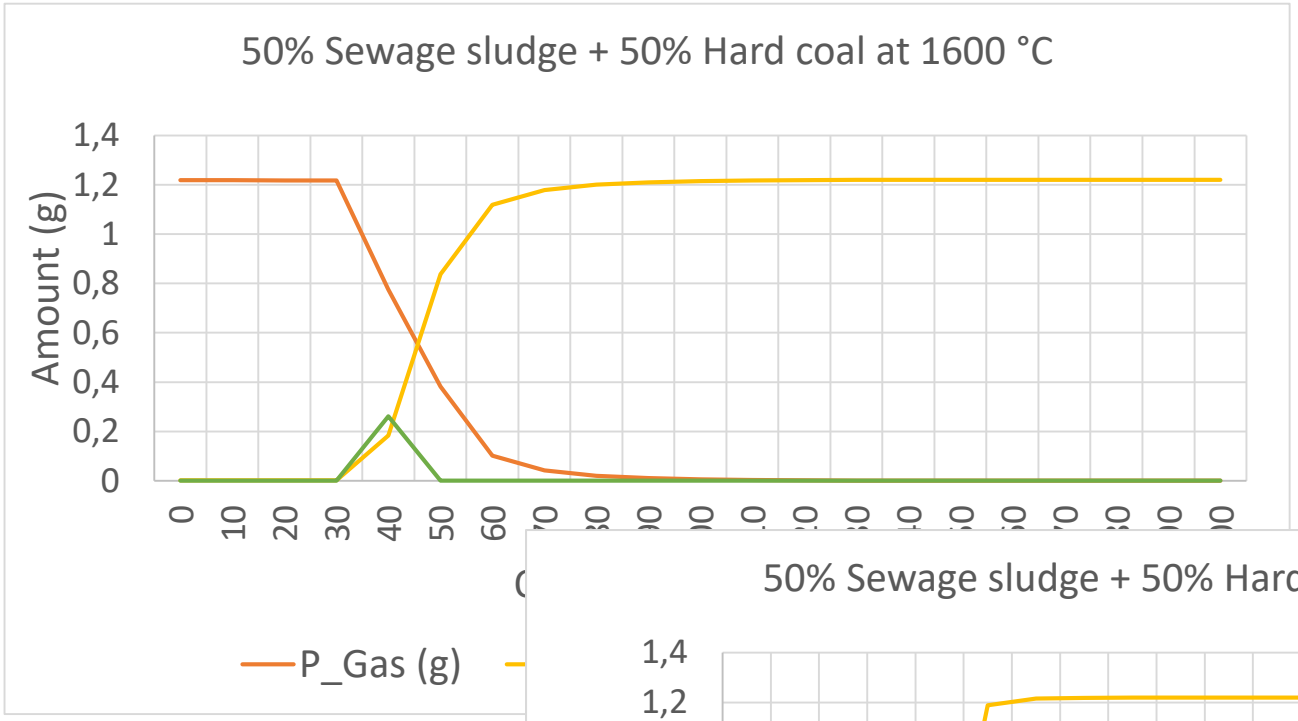


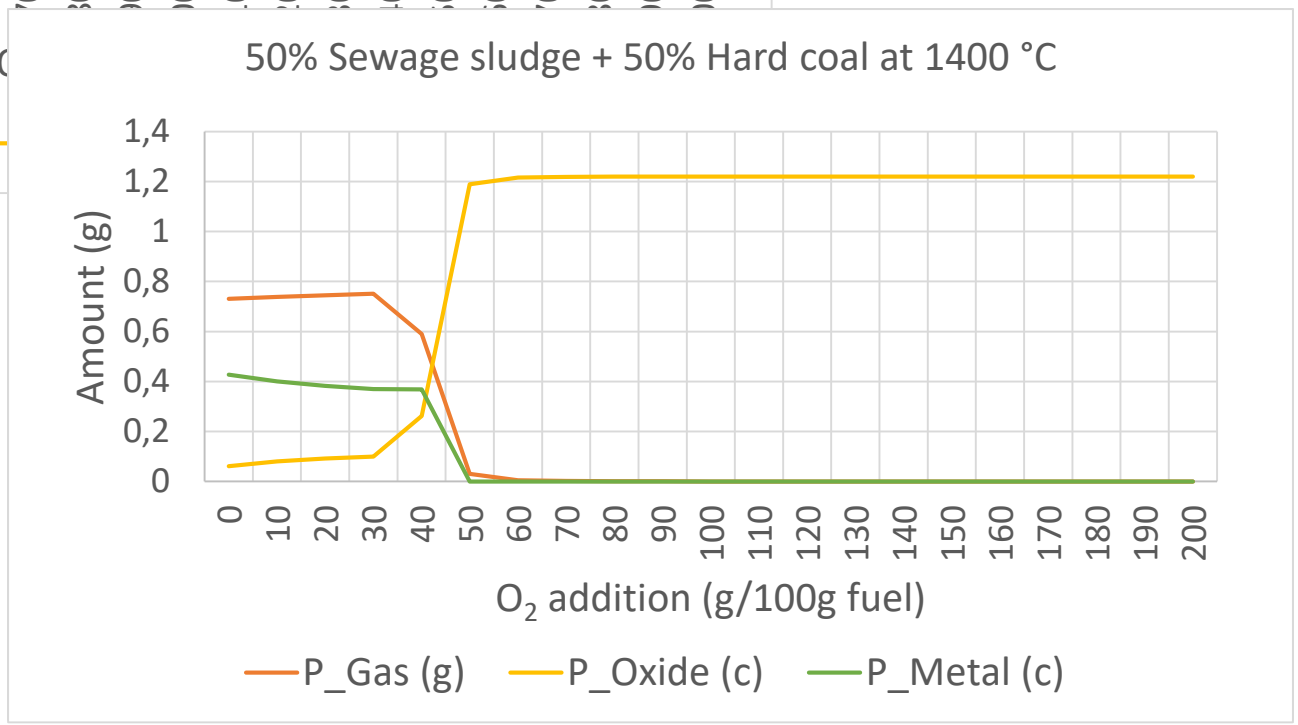
Release during Gasification



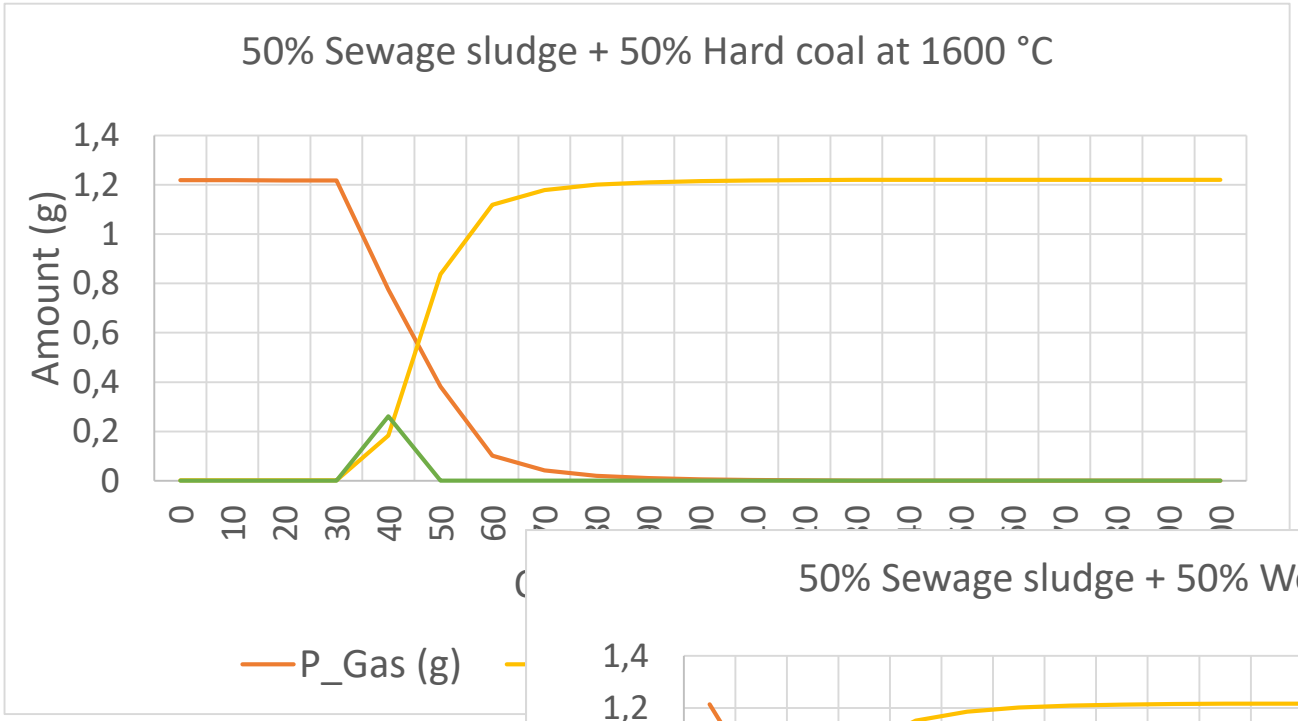


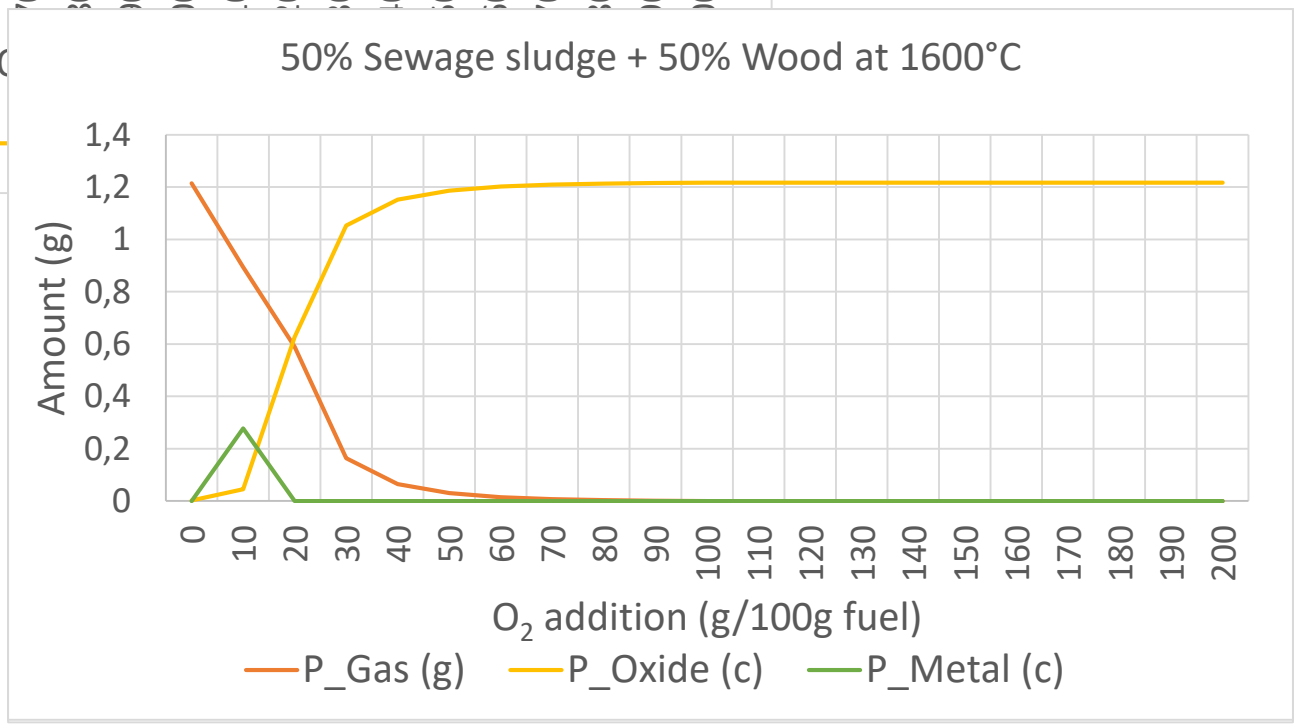
Release during Gasification



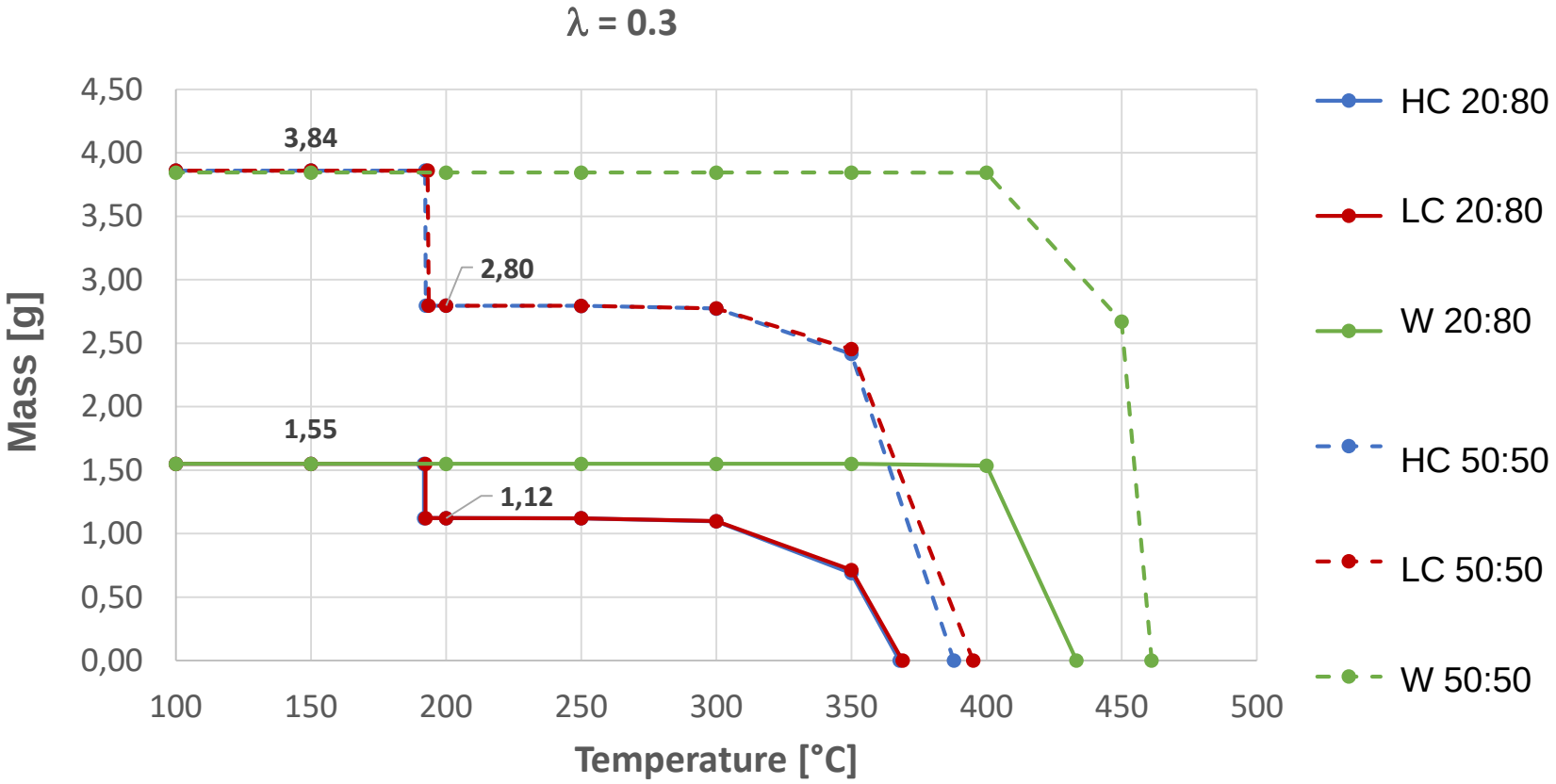


Release during Gasification





Condensation of P-Species (H_3PO_4, P_2O_5)



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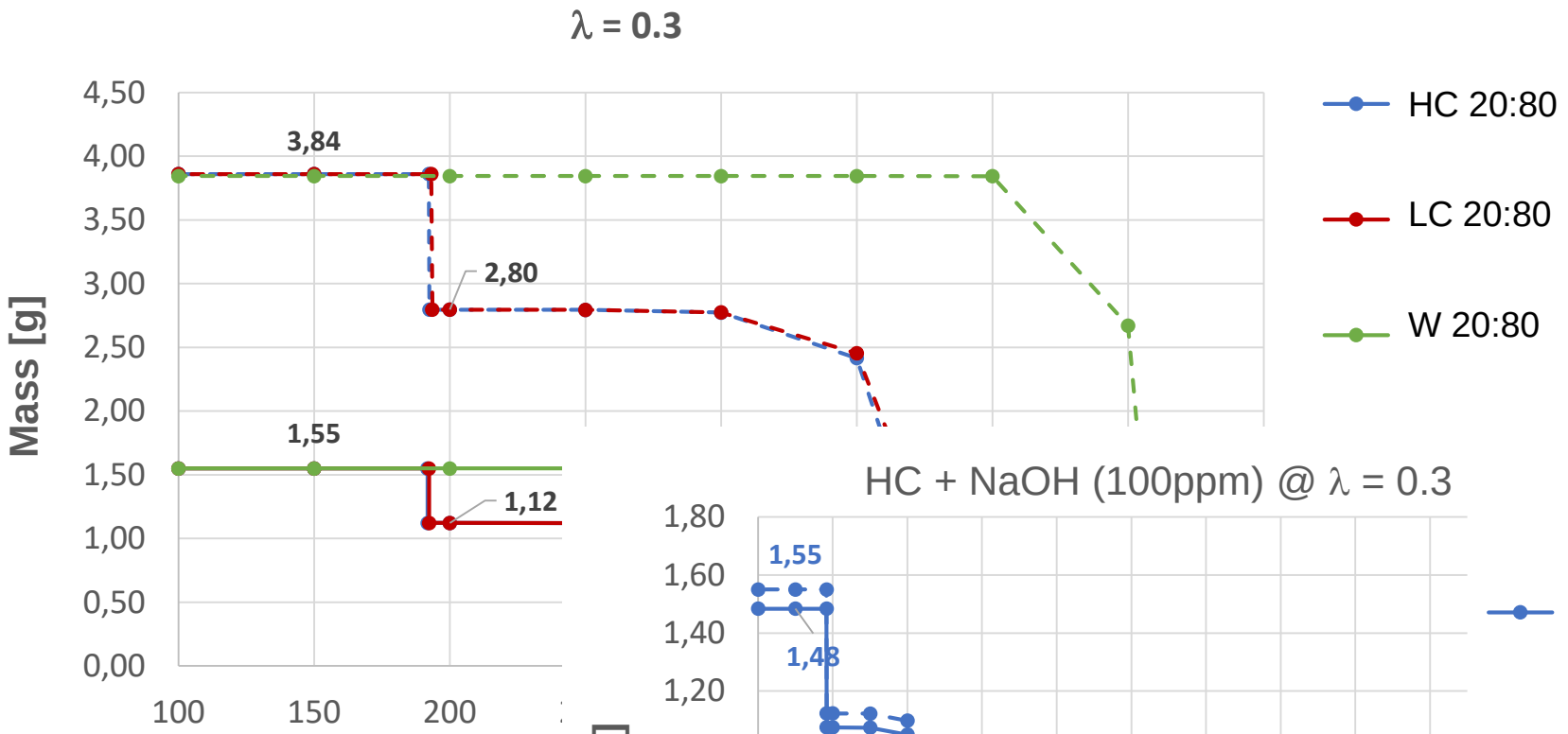
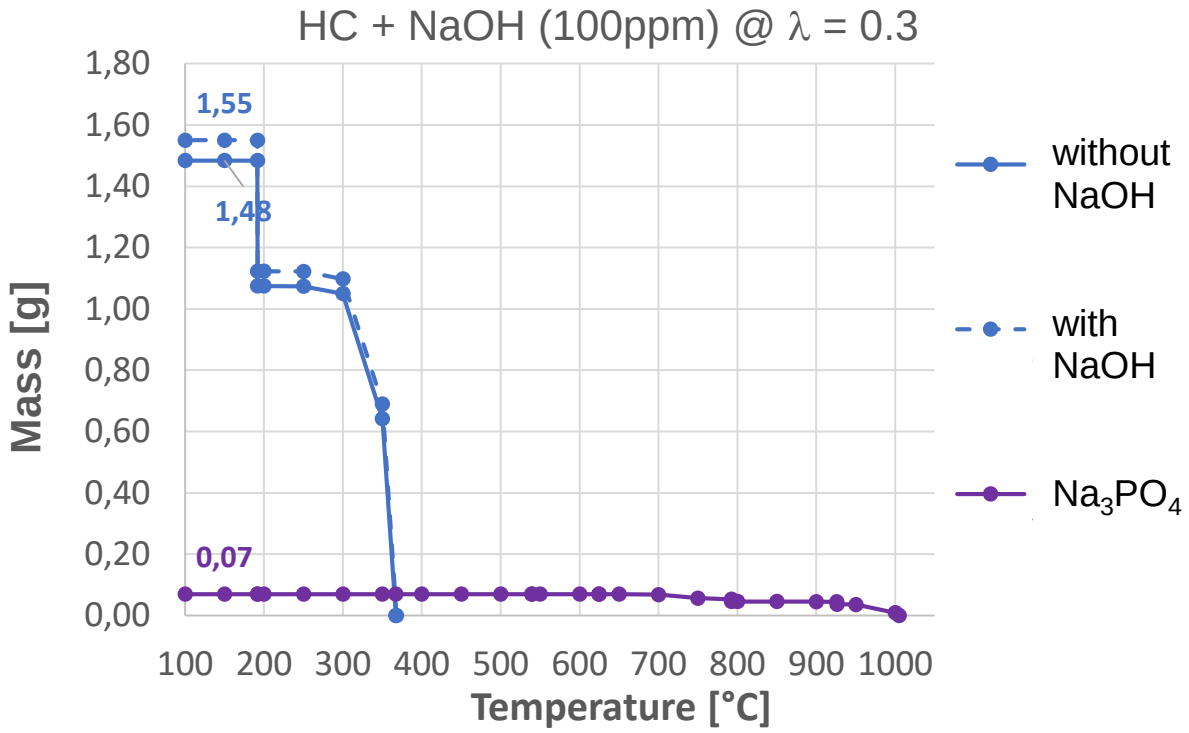
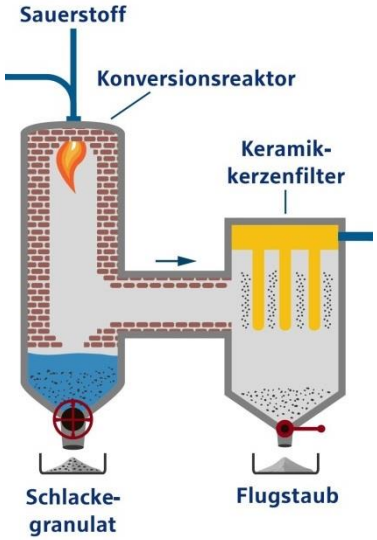




Conclusions

- Release of phosphorus mainly influenced by
  - O_2 partial pressure (determined by λ and O in fuel)
  - Temperature
  - Ash components, e.g. Fe
- Phosphorus in gas phase
  - P_x @ high T and low λ
  - P_xO_y @ low T and high λ
- Condensation of P-species
  - P_2O_5, H_3PO_4 @ T << 500 °C
  - Reaction with alkalis possible



Modern Gasifiers @ Work

Thank you for your attention!

Merci de votre attention!

Tack för er uppmärksamhet!

Спасибо за внимание!

आपका ध्यान के लिए धन्यवाद!

非常感谢您的参与！

Dziękuję za uwagę!

Gracias por su atención!

Dank u voor uw aandacht!

Σας ευχαριστώ για την προσοχή σας!

Terimakasih atas perhatiannya!

Vielen Dank für Ihre Aufmerksamkeit!