Towards the Circularity of Flame-Retarded Expanded Polystyrene via Pyrolysis

Recovering Styrene and Addressing Bromine

Razan Alsharqawi, Daniela Merz, Michael Zeller, Niklas Netsch, Tim Kurtz, Britta Bergfeldt, Salar Tavakkol, Dieter Stapf

Karlsruhe Institute of Technology (KIT)

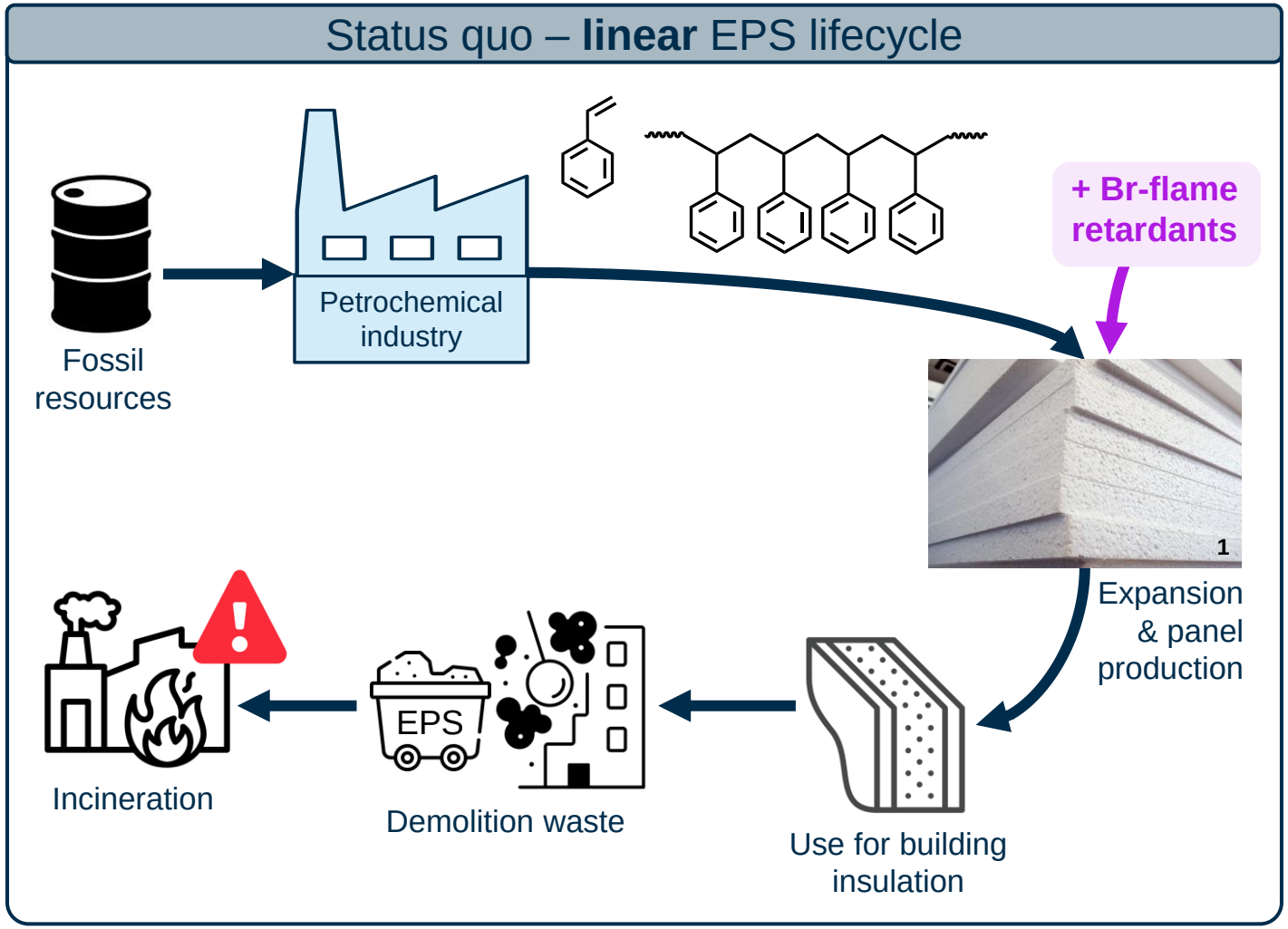
September 17th, 2025

PYROLIQ III: Pyrolysis and Liquefaction of Biomass and Wastes

September 14th – 19th, 2025 // Cetraro (Calabria), Italy

https://foamtechnologies.com.au/, accessed on 08.09.2025

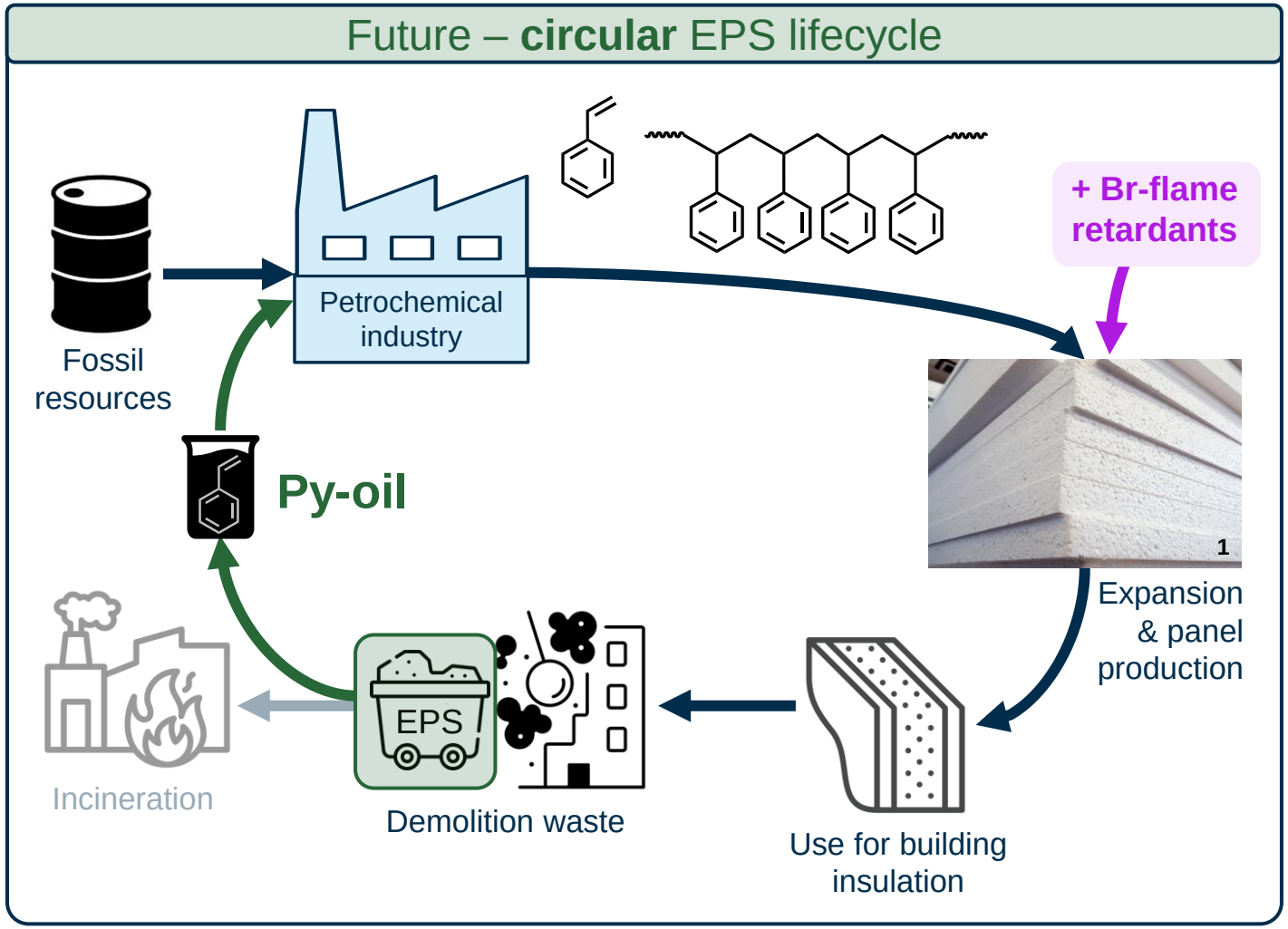
Background



[1] https://poytherm.com/de/was-ist-eps-und-wei%C3%9Fes-eps/blog/344, accessed on 10.03.2025

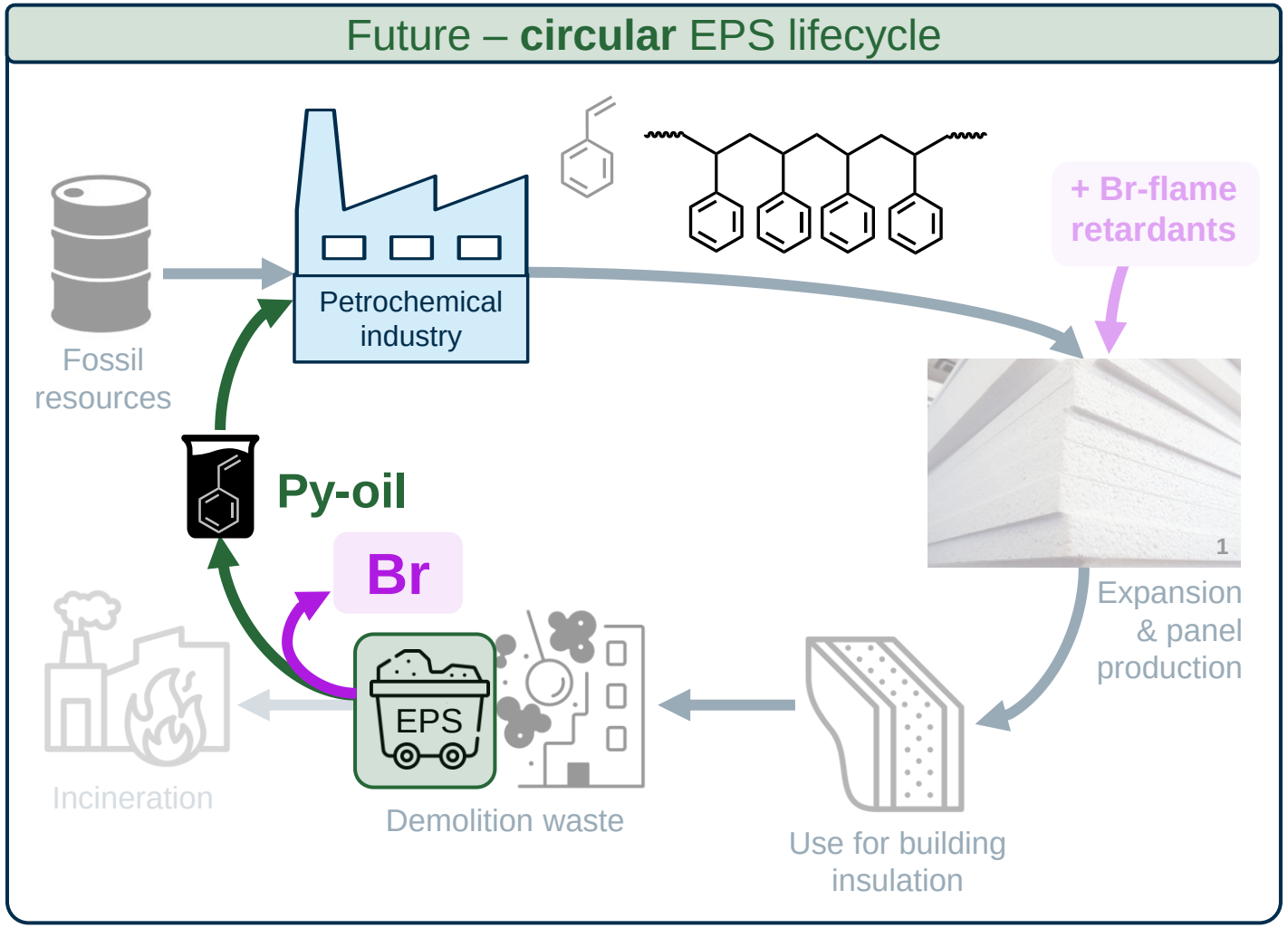
Incineration is a problem!

Objectives



[1] https://poytherm.com/de/was-ist-eps-und-wei%C3%9Fes-eps/blog/344, accessed on 10.03.2025

Objectives



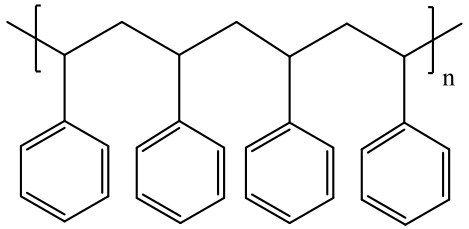
1 Investigate the effect of Br-FR on **styrene yield** in EPS pyrolysis

Br-FR: brominated flame retardant(s)

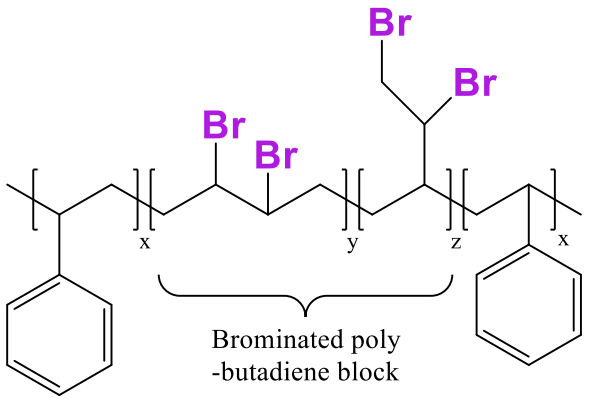
2 Investigate **bromine separation** in the gas phase

[1] https://poytherm.com/de/was-ist-eps-und-wei%C3%9Fes-eps/blog/344, accessed on 10.03.2025

Model samples

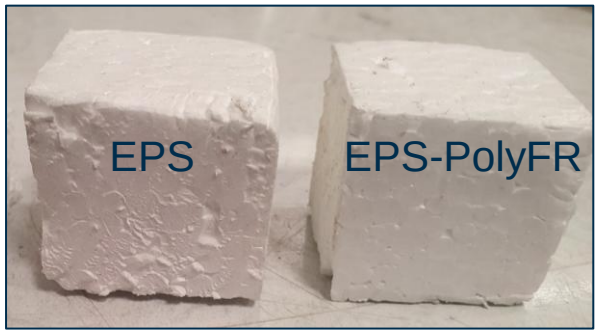


PolyStyrene (**PS**)



Brominated butadiene styrene copolymer (**PolyFR**)

Commercial samples



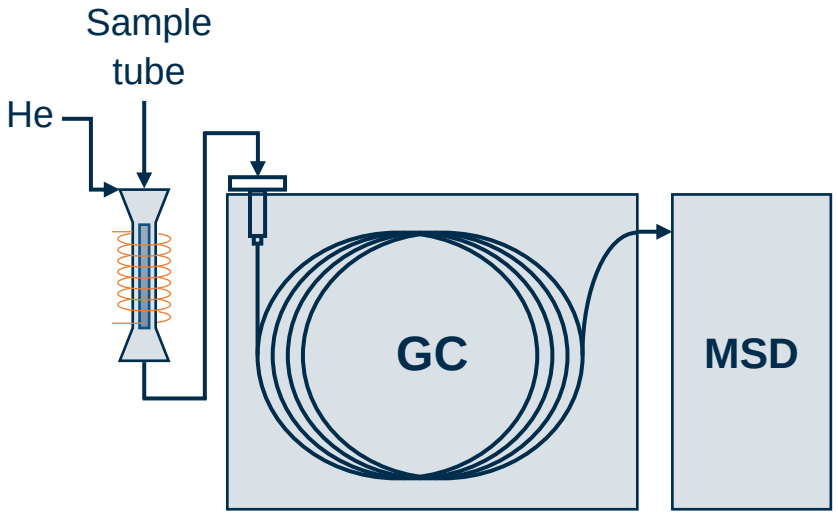
Mixed samples

Composition in mass-%

	PS	PolyFR	Br
EPS	100	–	–
EPS-PolyFR	> 99	< 1	0.4 [a]
PolyFR	–	100	64 [b]
PS**75**PolyFR	25	**75**	48 [b]
PS**50**PolyFR	50	**50**	32 [b]
PS**25**PolyFR	75	**25**	16 [b]
PS	100	–	–

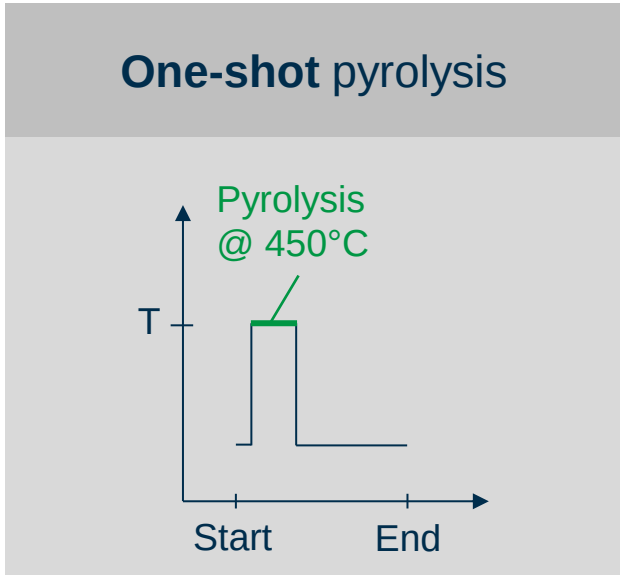
[a] Determined experimentally via C-IC.
[b] Calculated based on the amount of PolyFR mixed in.

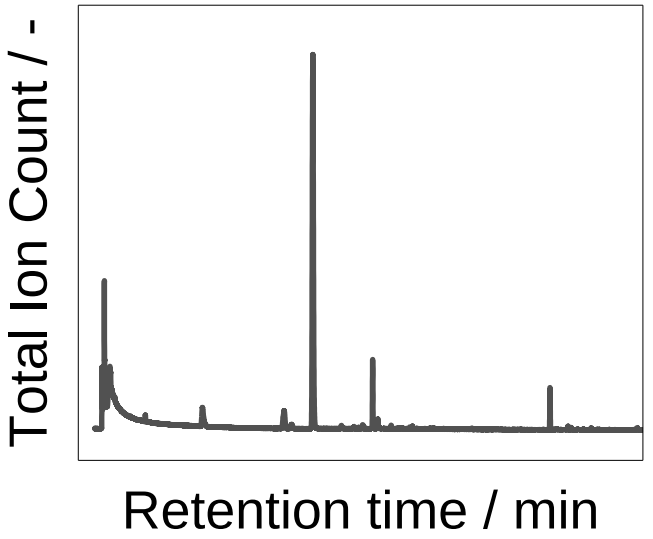
Decomposition behavior
How is styrene yield affected?



μ-Pyrolyzer

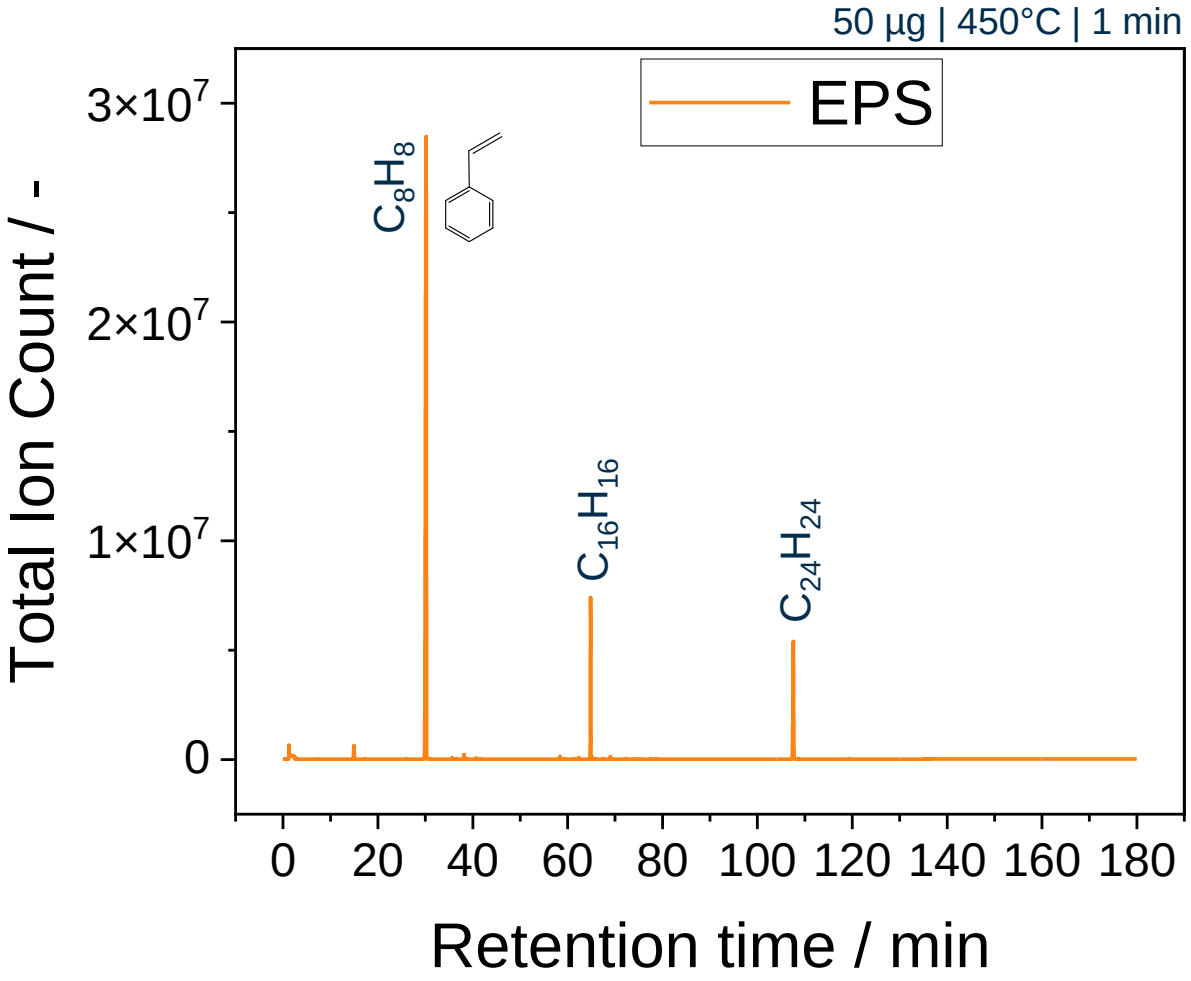
Sample mass:	50 µg
Reactor setpoint T:	450°C
Duration:	1 min
He atmosphere	

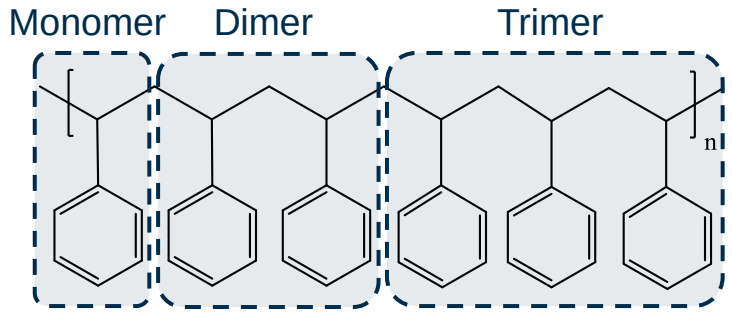


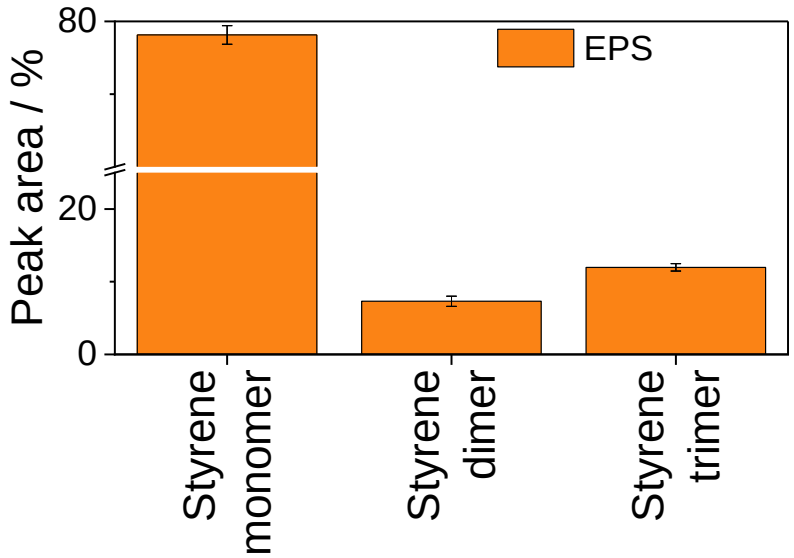


Decomposition behavior

How is styrene yield affected?

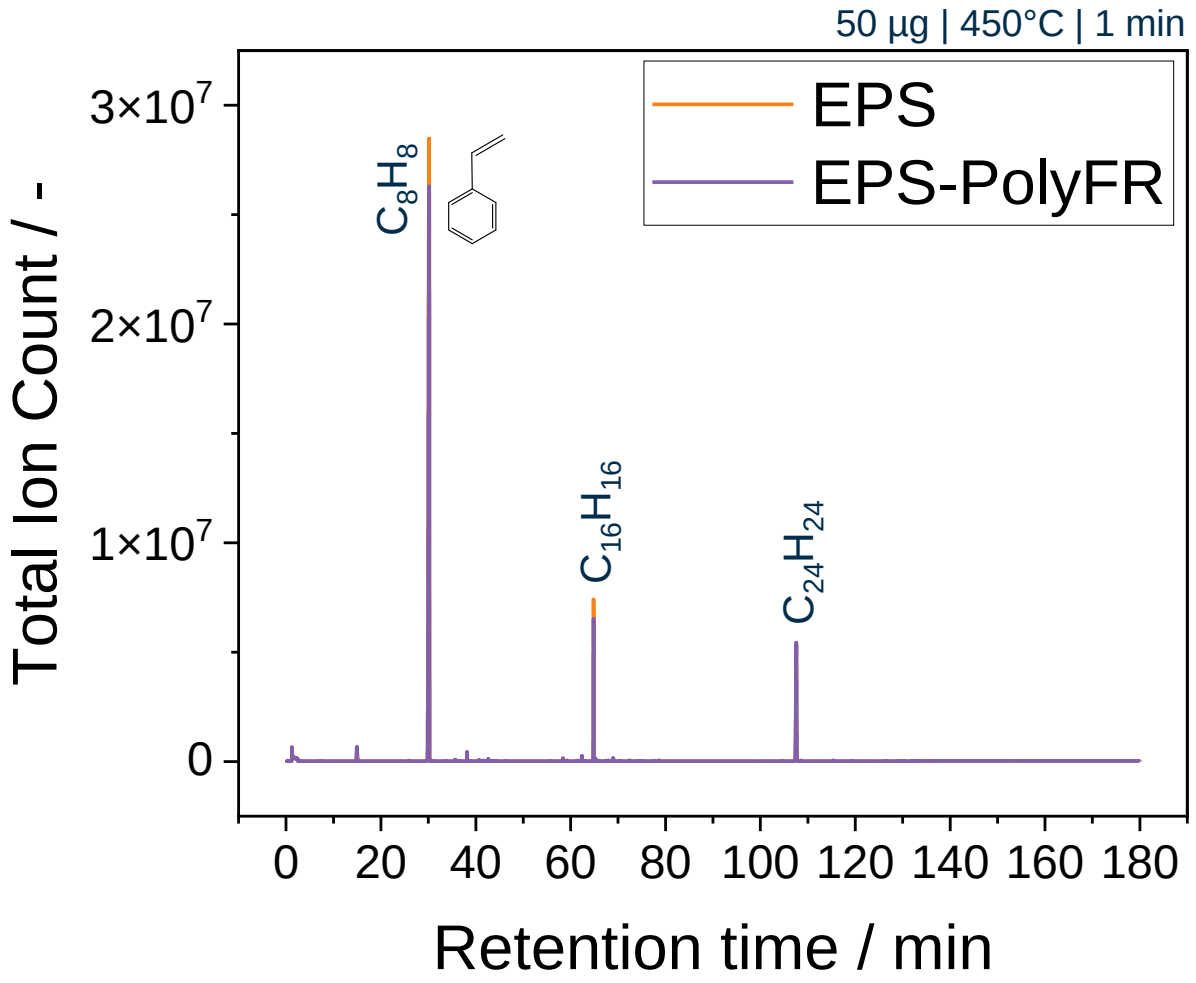




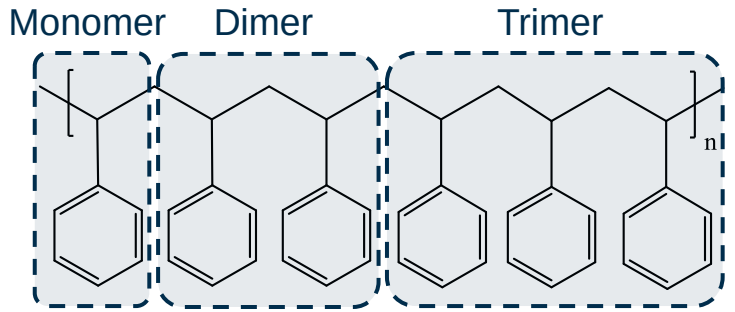


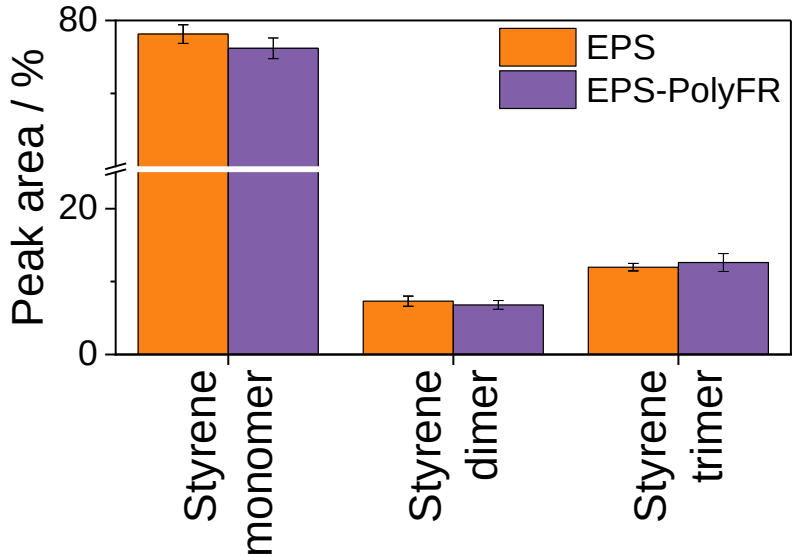
Decomposition behavior

How is styrene yield affected?



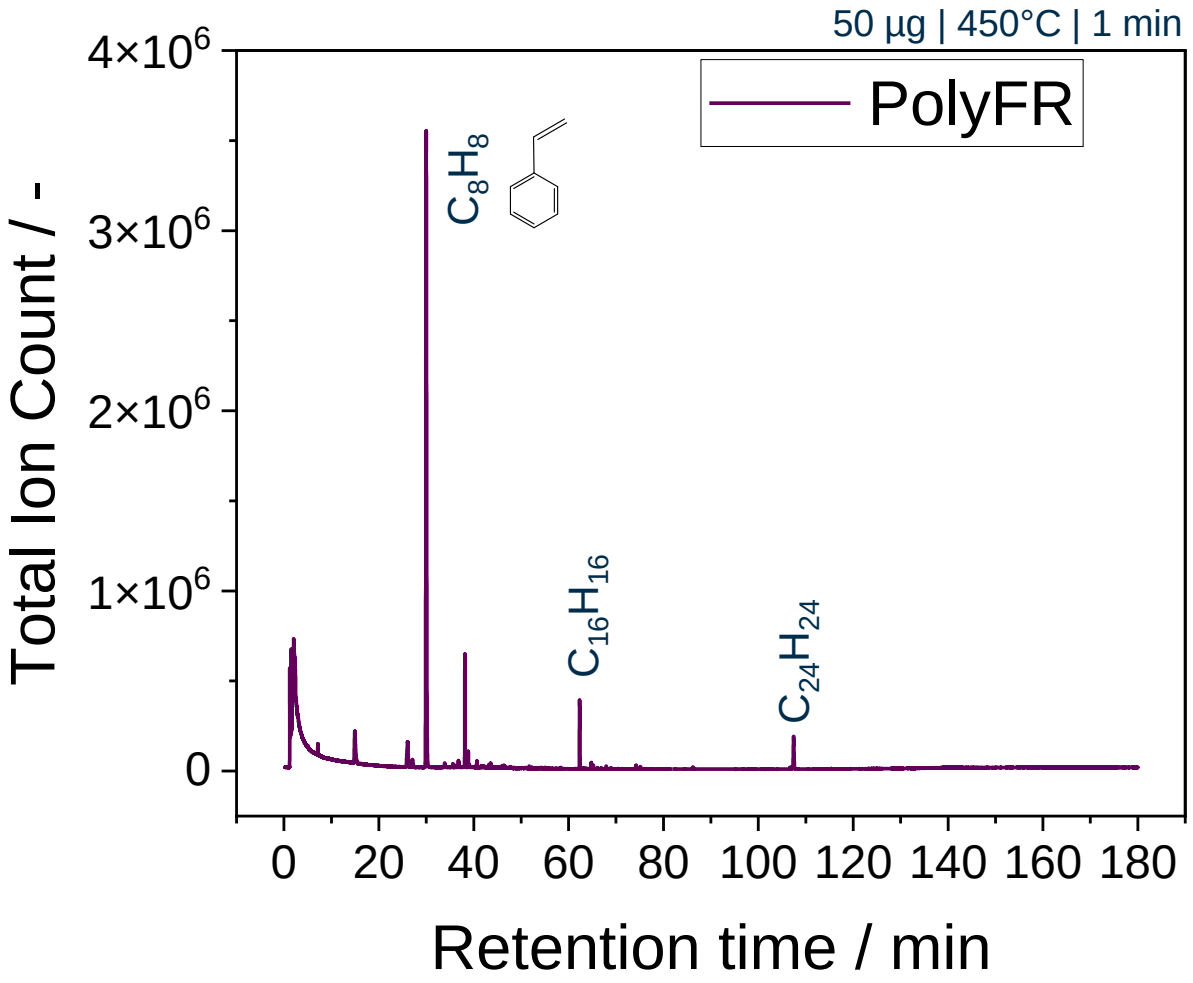
✓ **PolyFR** does **not significantly** affect the **styrene** yield.

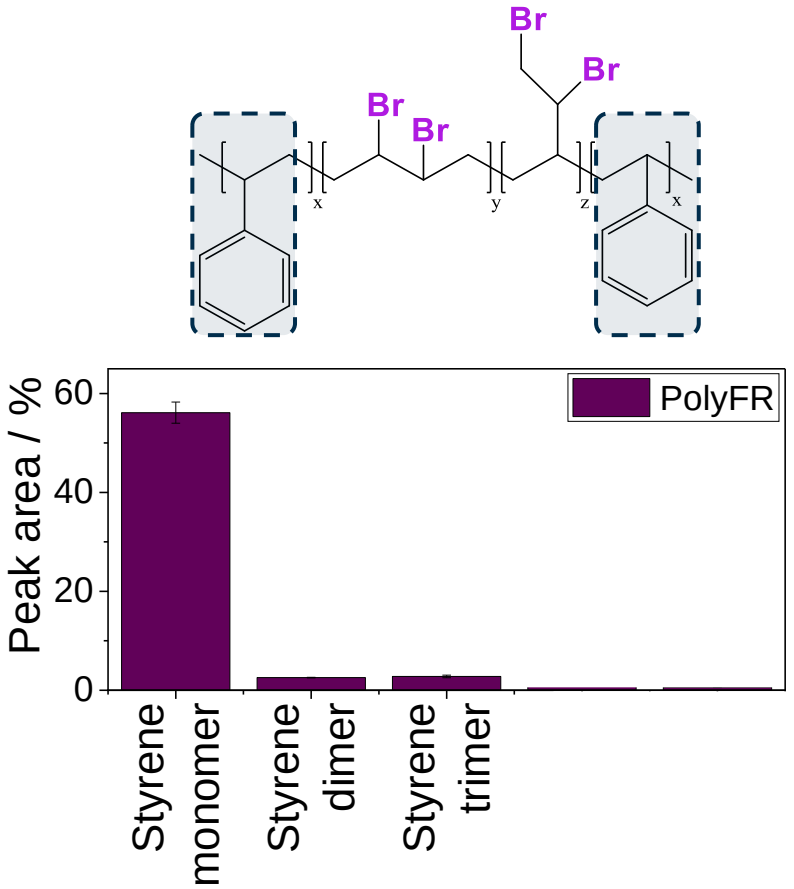




Addressing bromine

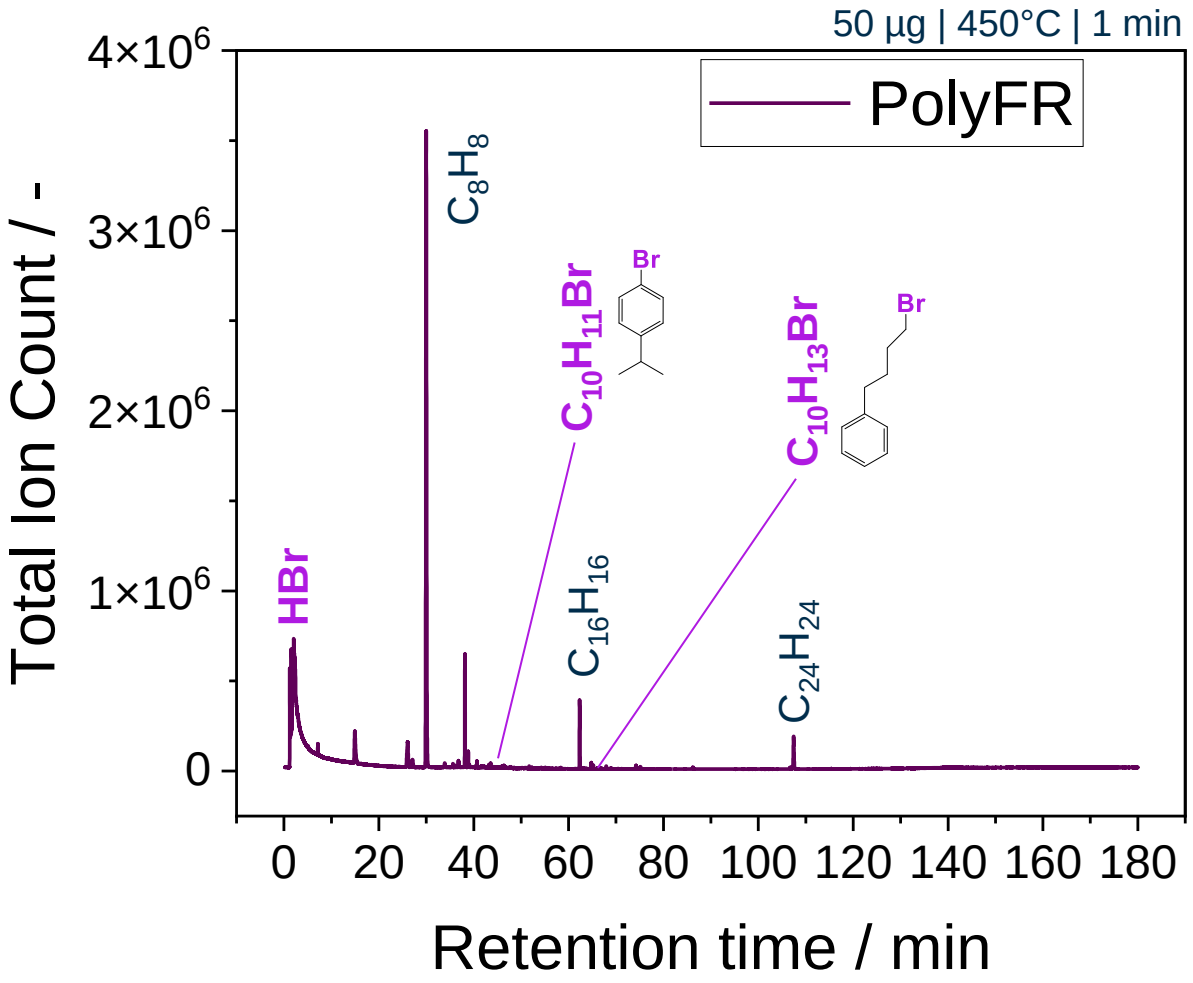
In which chemical form is bromine released?



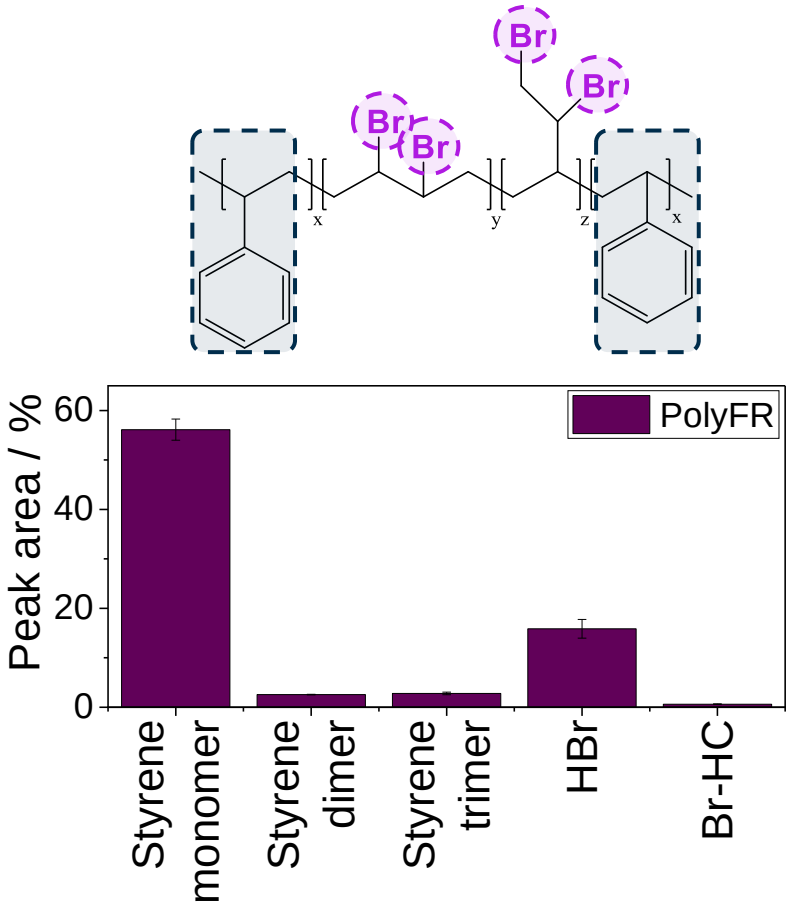


Addressing bromine

In which chemical form is bromine released?

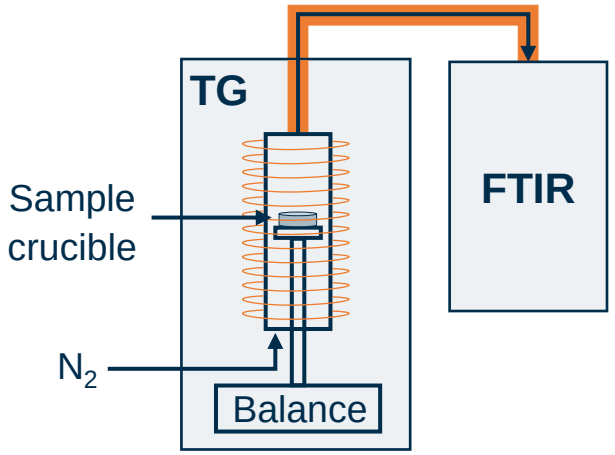


✓ **Br** is released primarily as **HBr**.



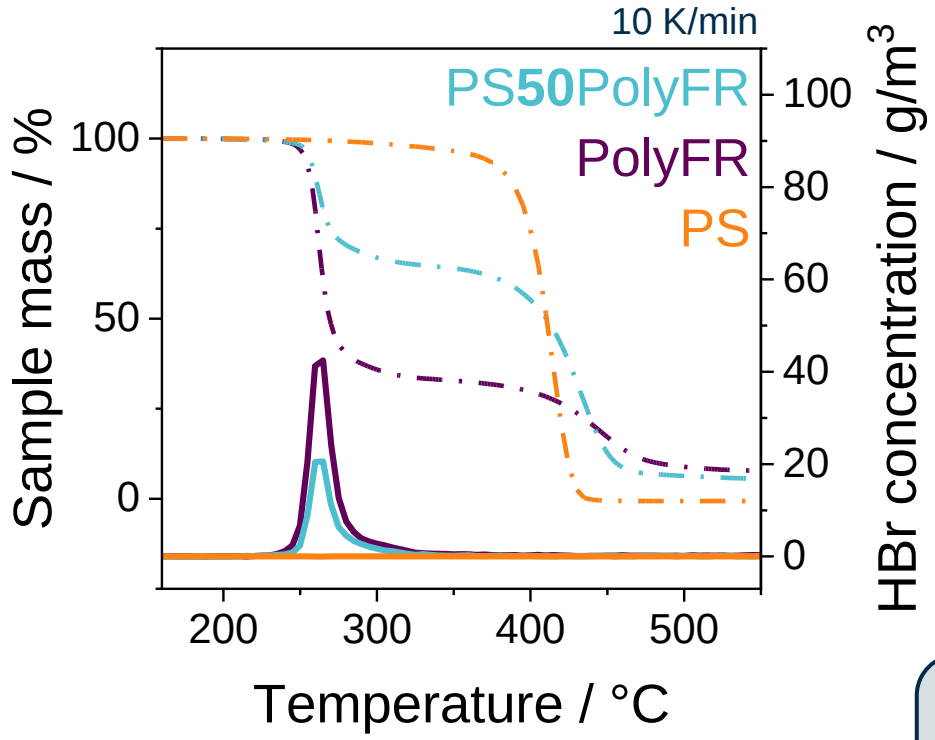
Addressing bromine

How much bromine is released as HBr?



TG-FTIR

Sample mass: 5, 10 mg
Heating rate: 5, 10, 100 K/min
N_2 atmosphere



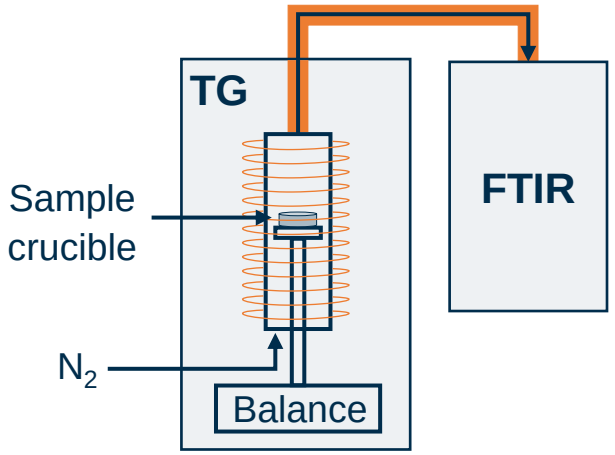
Br released as HBr in mass-% of the initial Br input

	Br as HBr (mass-%)
PolyFR	89.0 ± 2.2
PS**75**PolyFR	89.8 ± 0.9
PS**50**PolyFR	87.2 ± 1.2
PS**25**PolyFR	92.3 ± 2.5

HBr formation and release are **independent** of **PolyFR loading**.

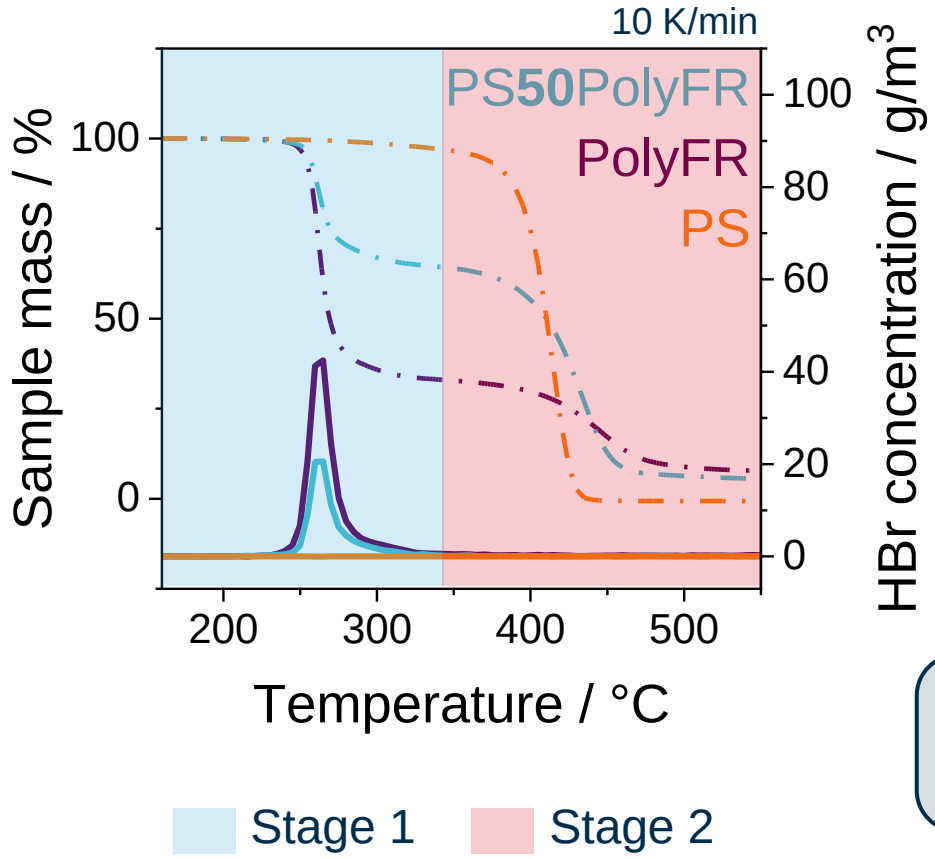
Addressing bromine

How much bromine is released as HBr?



TG-FTIR

Sample mass: 5, 10 mg
Heating rate: 5, 10, 100 K/min
N_2 atmosphere

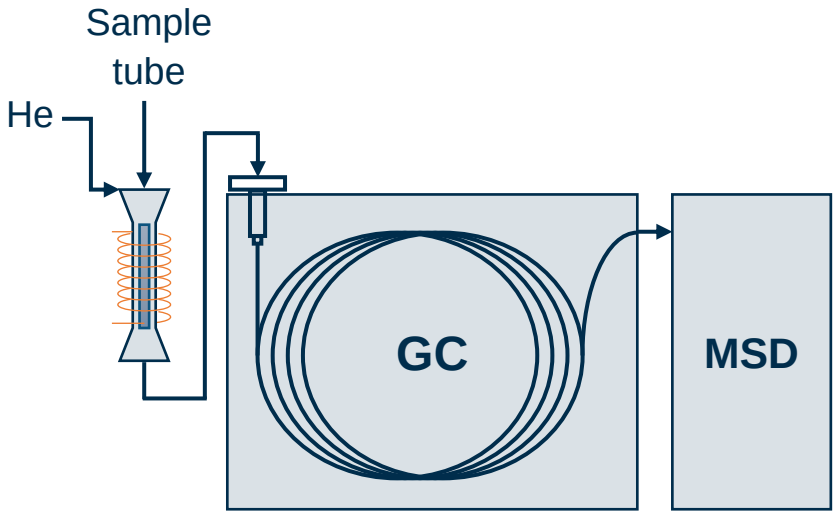


Br released as HBr in mass-% of the initial Br input

	Br as HBr (mass-%)
PolyFR	89.0 ± 2.2
PS**75**PolyFR	89.8 ± 0.9
PS**50**PolyFR	87.2 ± 1.2
PS**25**PolyFR	92.3 ± 2.5

HBr formation and release are **independent** of **PolyFR loading**.

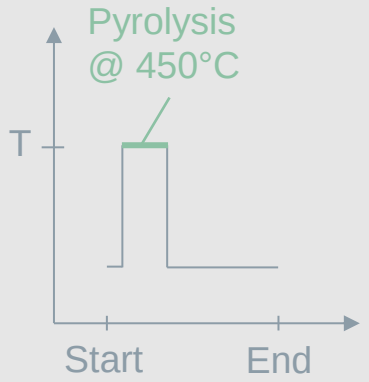
Can HBr be separated?
Temperature-staged pyrolysis



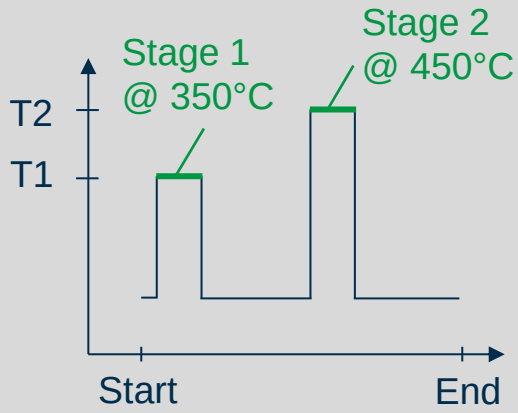
μ-Pyrolyzer

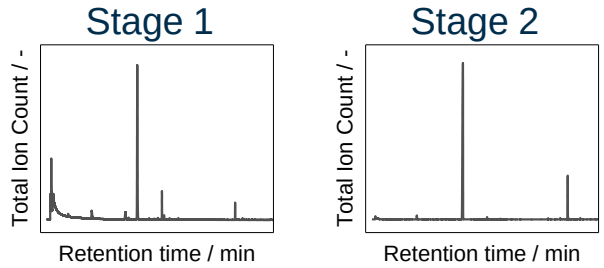
Sample mass: 50 µg
He atmosphere

One-shot pyrolysis



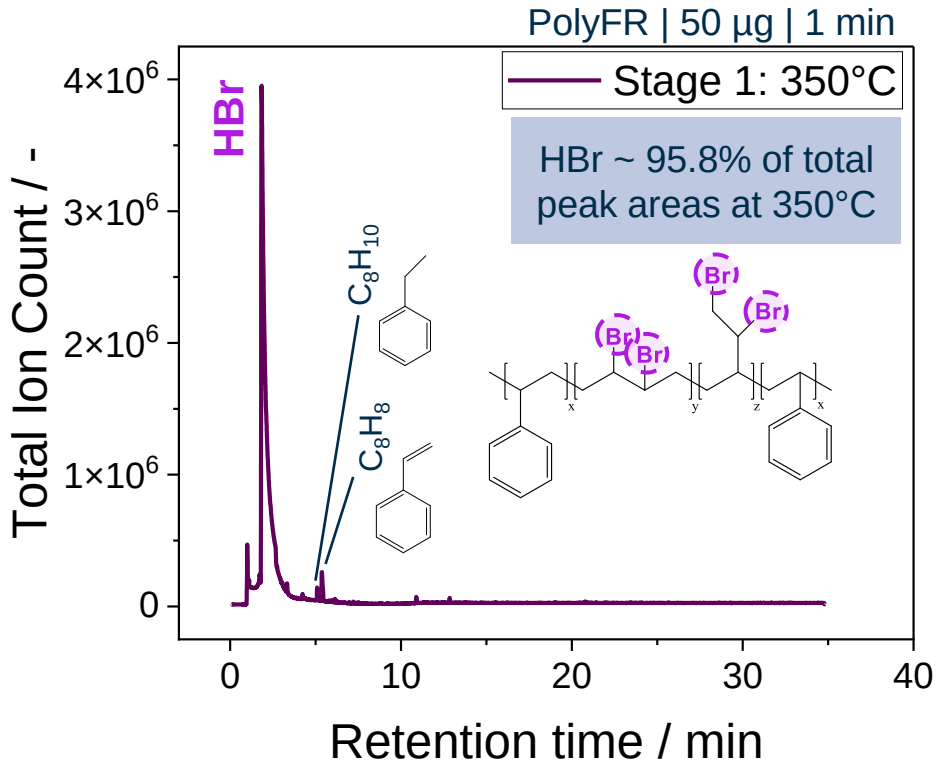
Temperature-staged pyrolysis

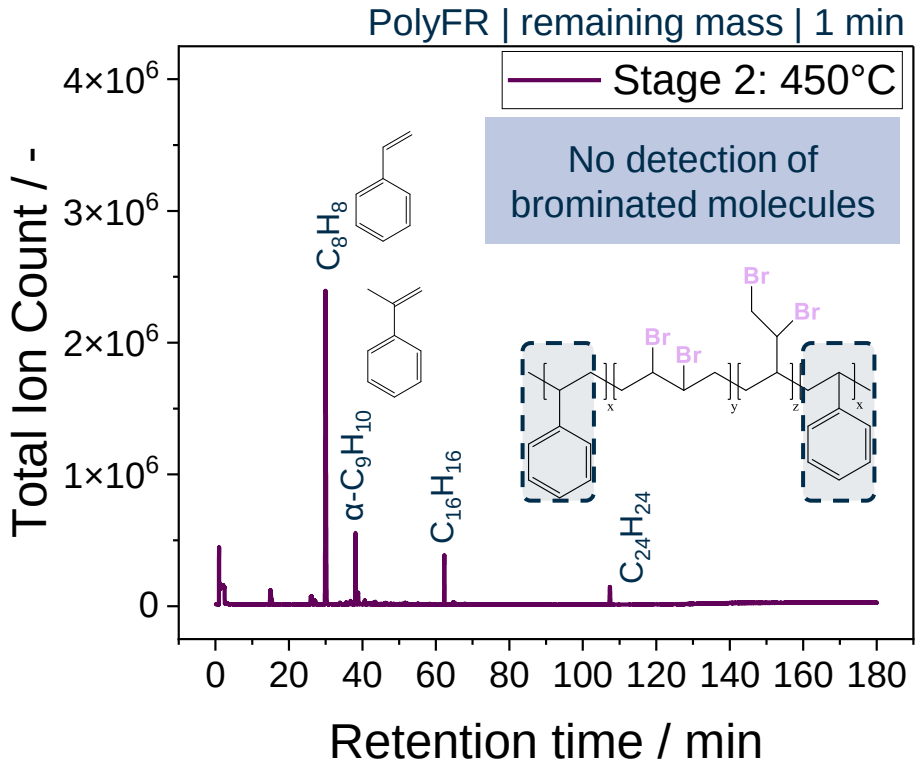




Can HBr be separated?
Temperature-staged pyrolysis

✓ **HBr separation** is possible via **temperature-staging**.
→ TG-FTIR confirms HBr separation potential.





Summary

- ☑ Commercial EPS and EPS-PolyFR mainly yield **styrene monomer**

- ☑ PolyFR mainly releases Br as **HBr**
- ☑ **HBr formation** occurs **< 350°C**
- ☑ **PS decomposition** occurs around **400°C**

- ☑ **HBr** formation and release are **independent** of **PolyFR loading**
- ☑ **HBr** separation is possible via temperature-staging

In cooperation with

LANXESS
Energizing Chemistry

https://www.kore-system.com/6-reasons-why-you-should-choose-eps-over-the-competition/, accessed on 10.03.2025