
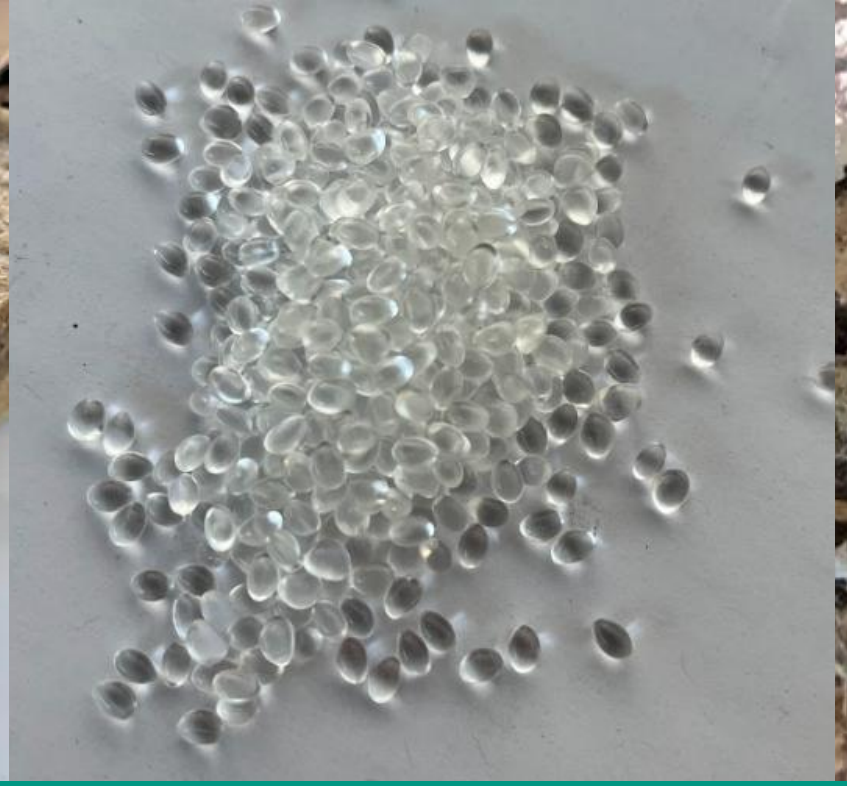


Pyrolytic Interactions of Polyurethanes with Thermoplastics

Implications for Chemical Recycling

13th IFC in Prague

Michael Zeller, Aylin Hannemann, Ankh-Erdene Erdenepurev, Niklas Netsch, Paul Schell, Daniela Merz, Salar Tavakkol, Dieter Stapf


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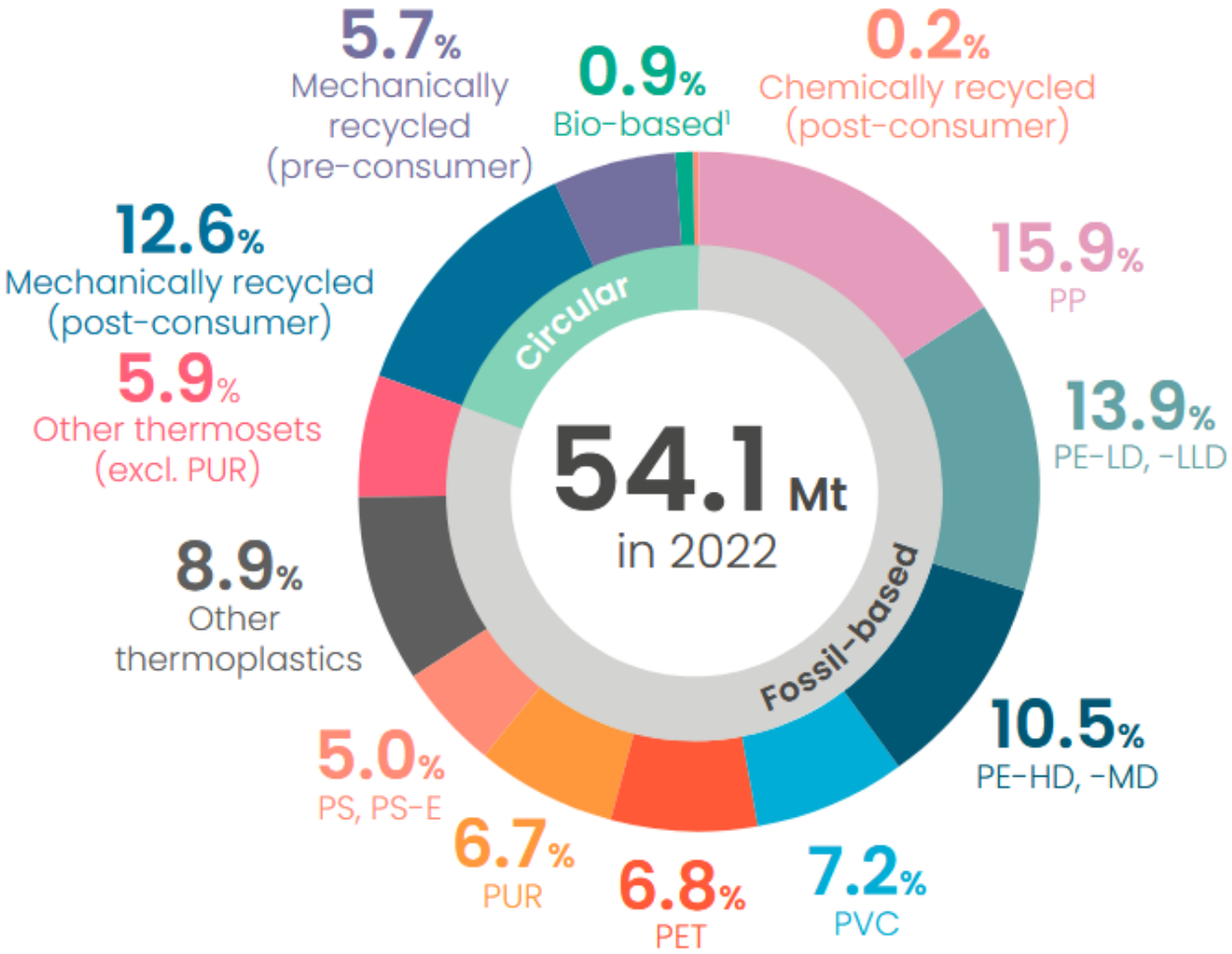
The Challenge of Plastics Pyrolysis

Commercial Waste



2022 European Plastics Production

https://plasticseurope.org/knowledge-hub/the-circular-economy-for-plastics-a-european-analysis-2024/

accessed 4.9.2025

The Challenge of Plastics Pyrolysis

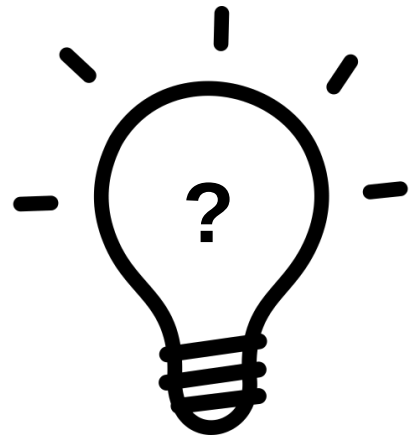
Commercial Waste

Process Design

- High value product yield
  → condensate
- Low contaminant levels
  → N, O, Halogens, Metals
- Reintroduction to chemical industry

The Challenge of Plastics Pyrolysis

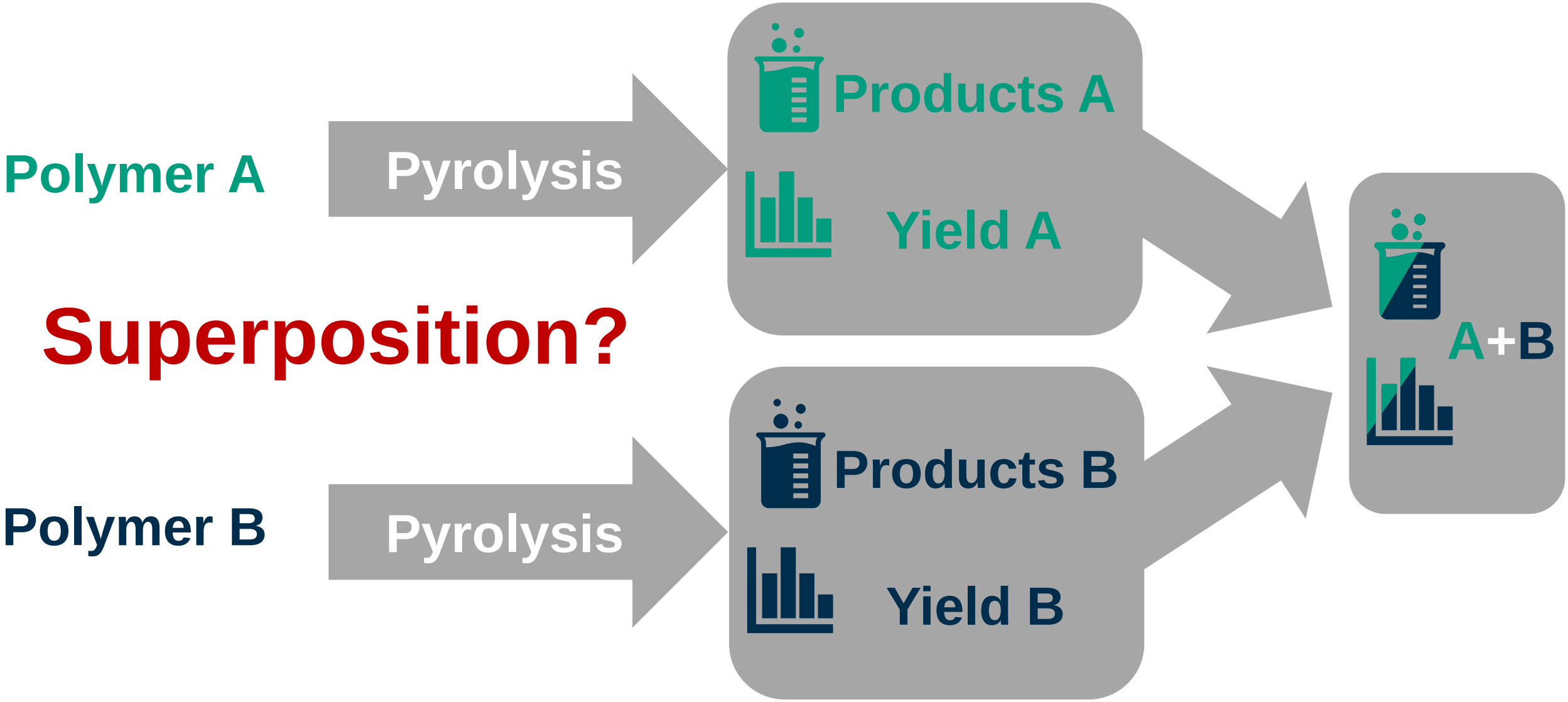
Commercial Waste



Understanding Pyrolysis Behaviour

Binary Model Mixes

Pyrolysis Pathways



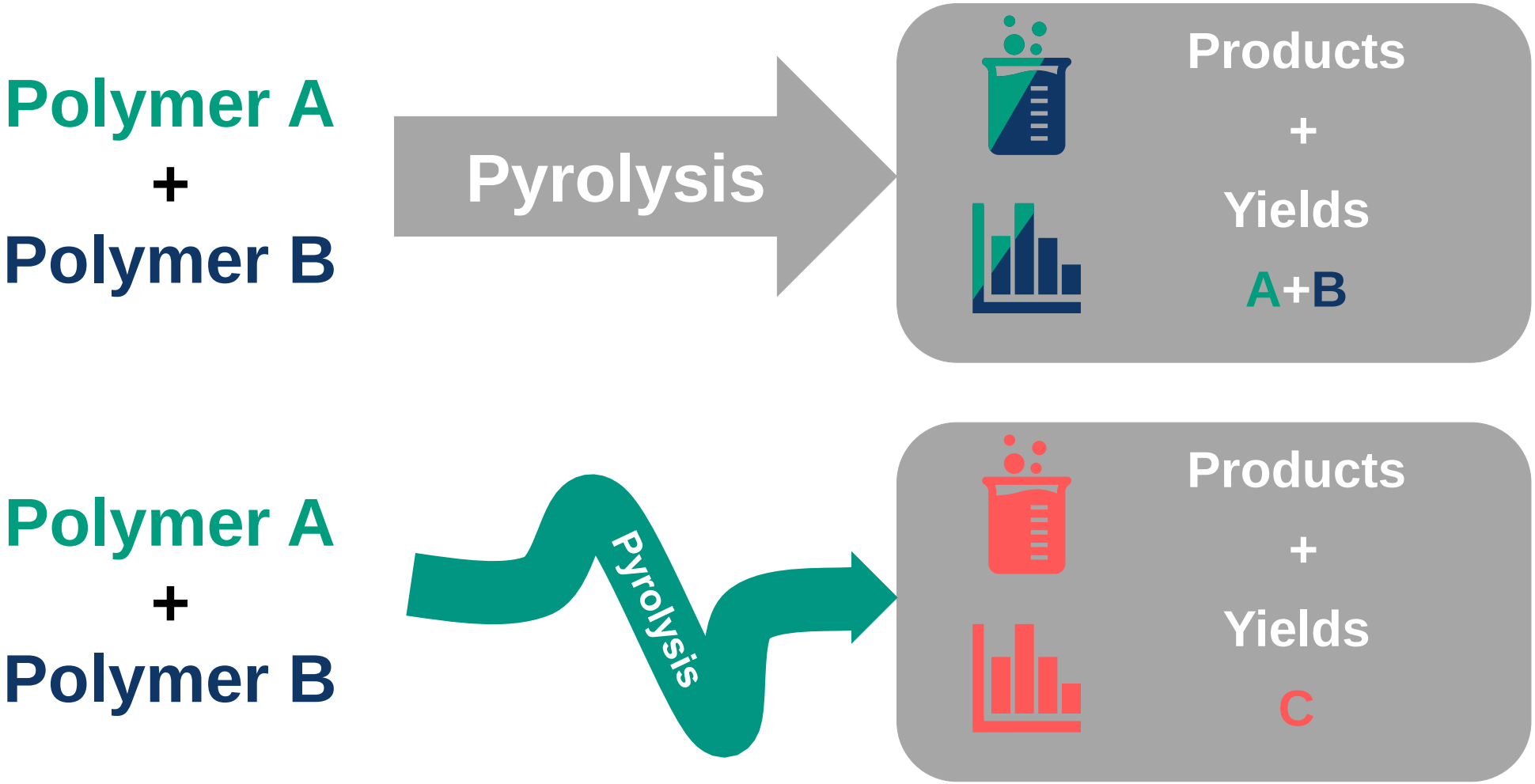
Pyrolysis Pathways

Polymer A

+

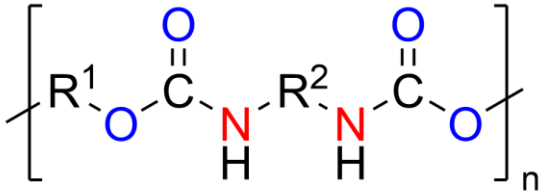
Polymer B

Pyrolysis Pathways

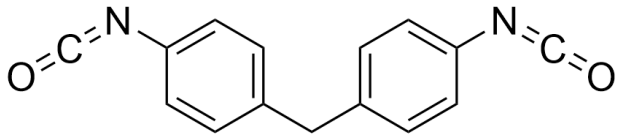


Polymers

Rigid Polyurethane Foam (RPUF)

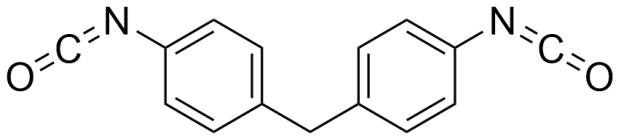


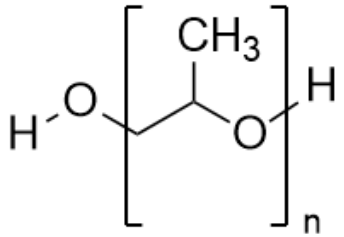
Thermoplastic Polyurethane (TPU)



Isocyanate

MDI

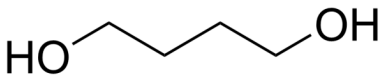




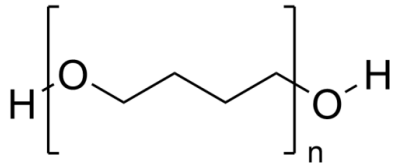
Polypropylene Glycol

Polyols

1,4-Butanediol

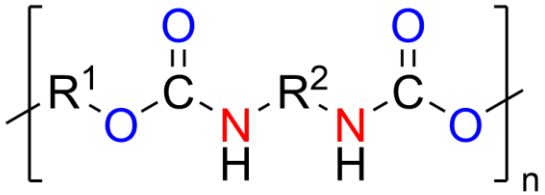


PolyTHF



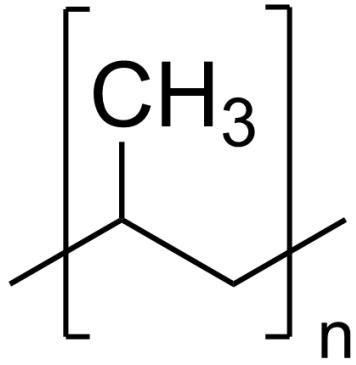
Polymers

RPUF

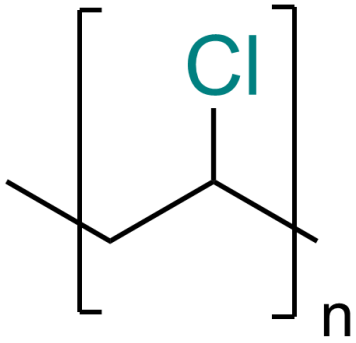


TPU

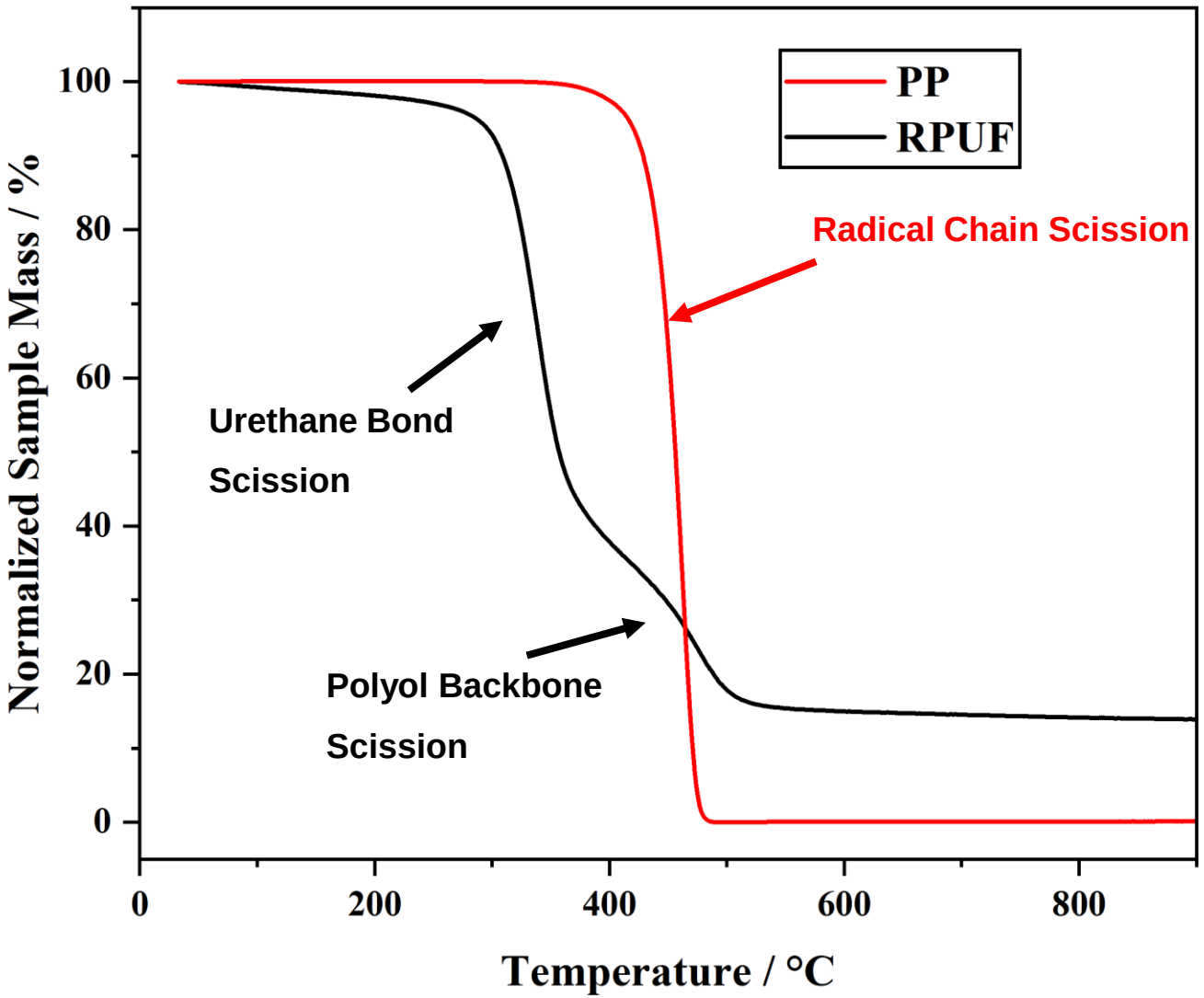
Polypropylene (PP)

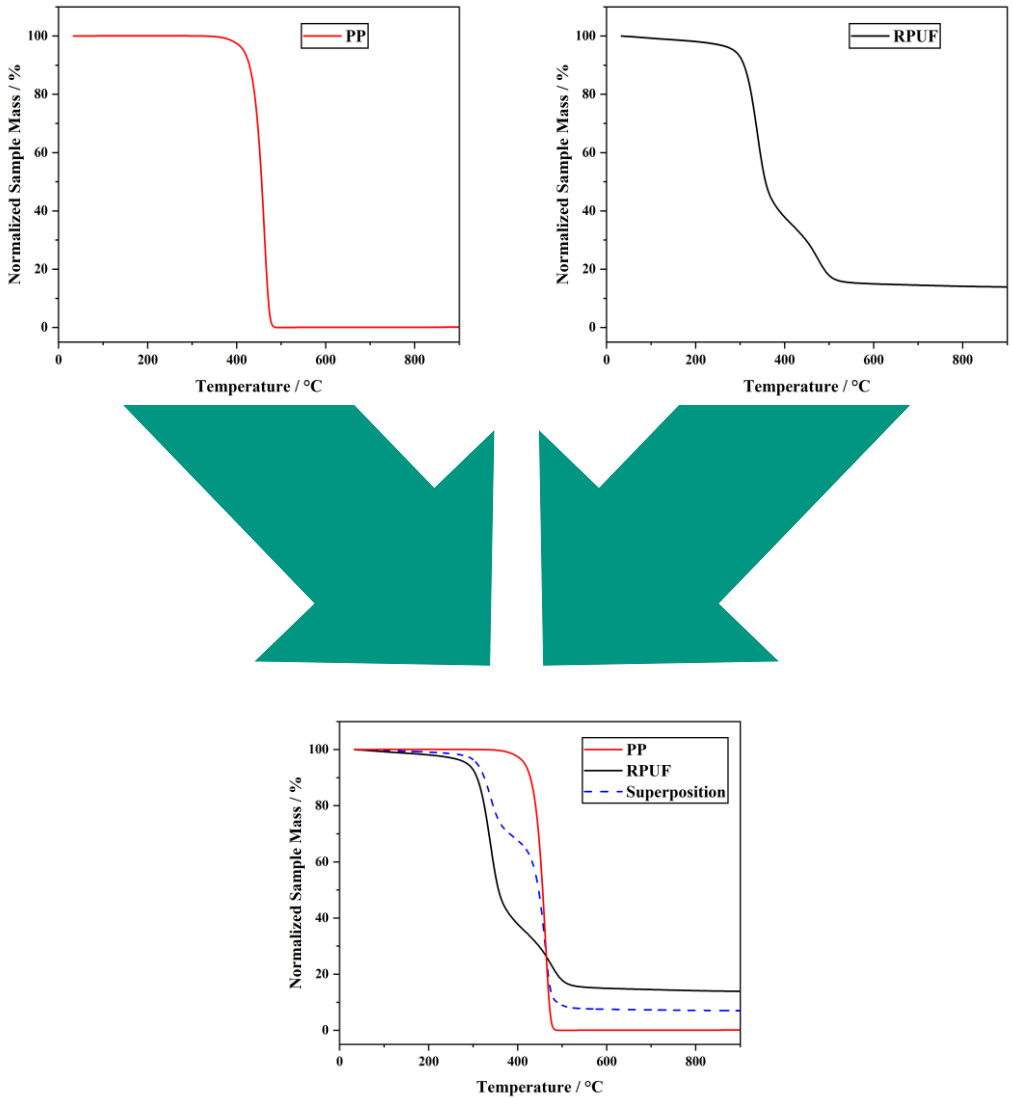


Polyvinyl chloride (PVC)

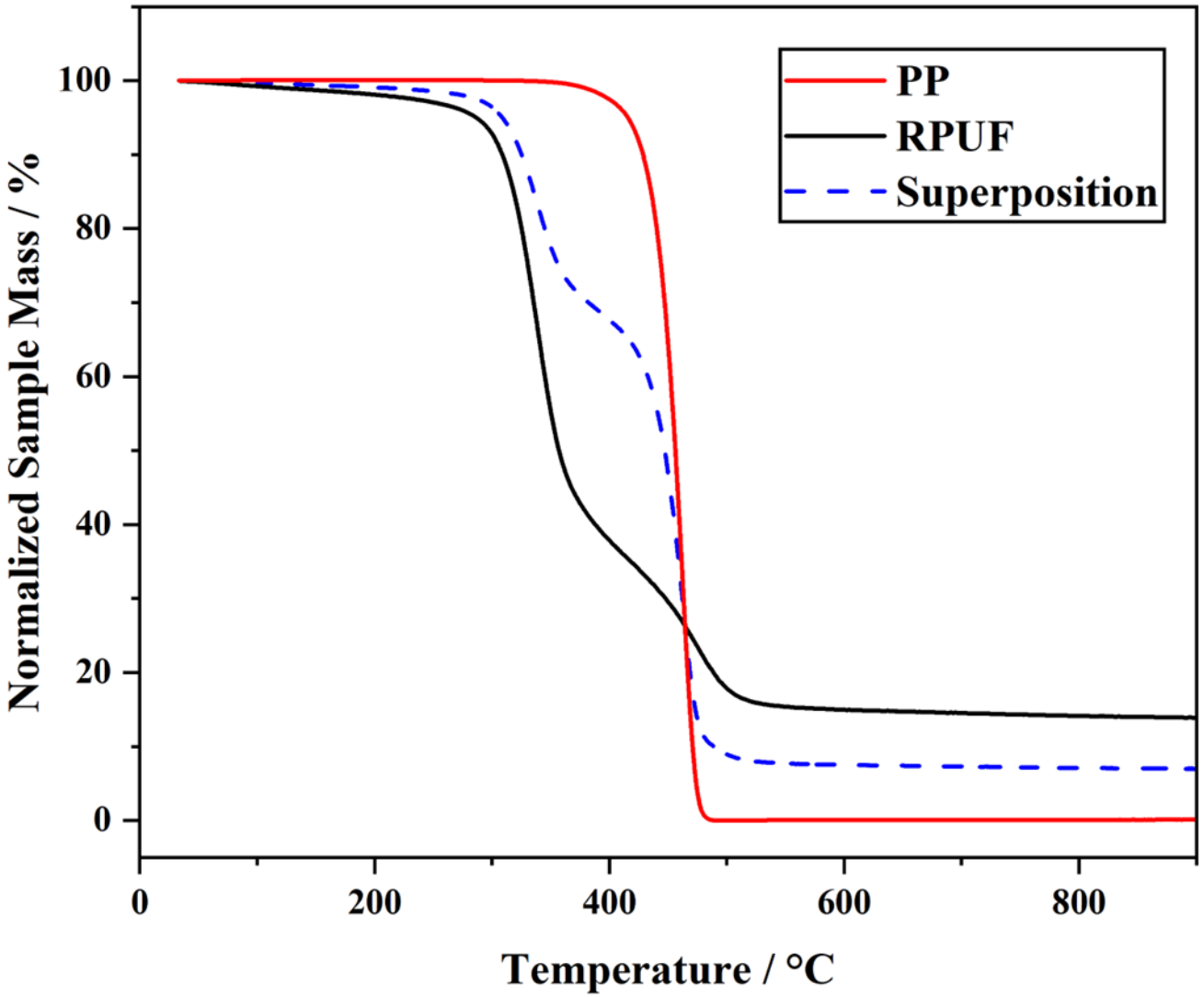


Thermogravimetry of binary mixtures



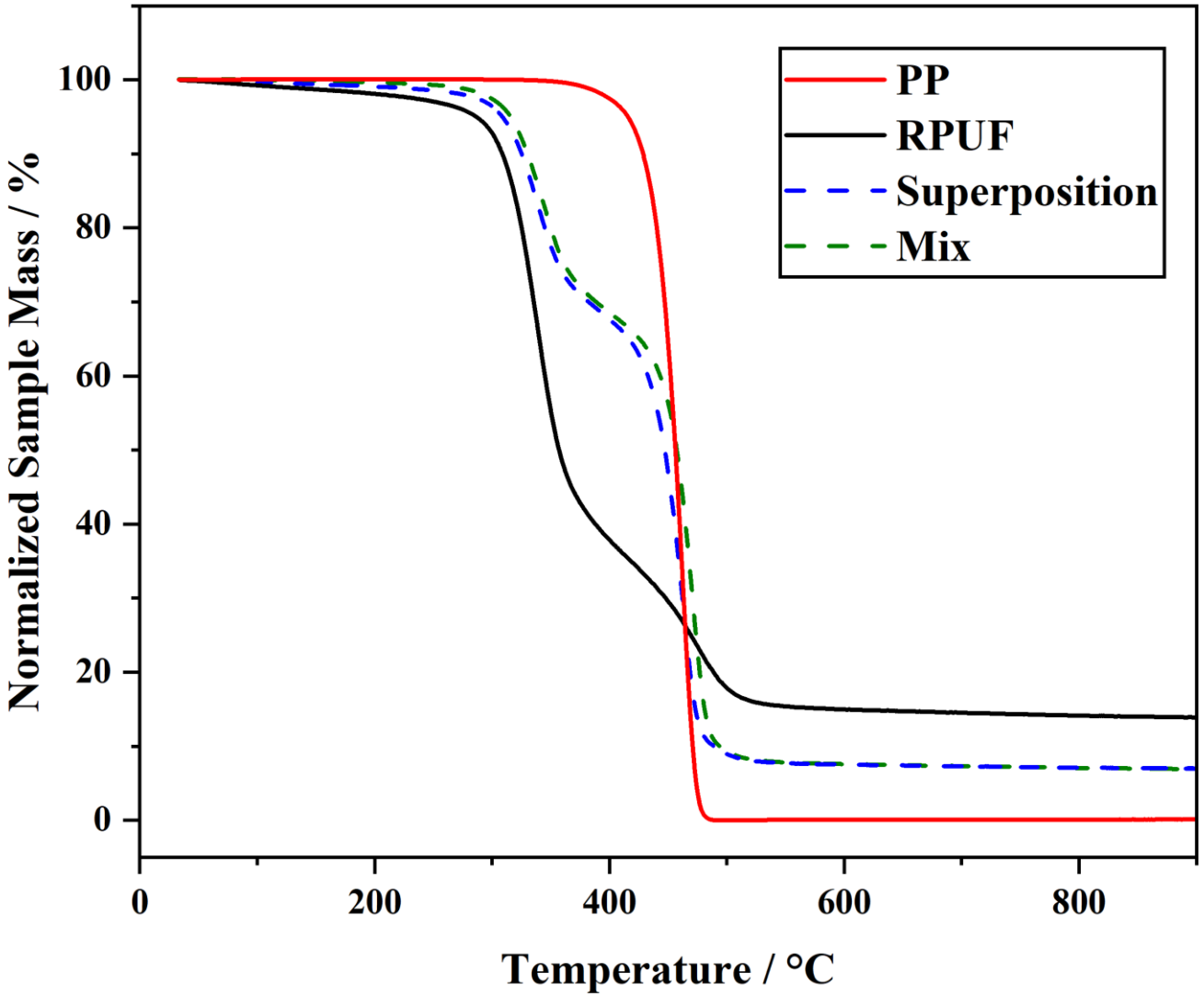


Thermogravimetry of binary mixtures



Powder
<500µm

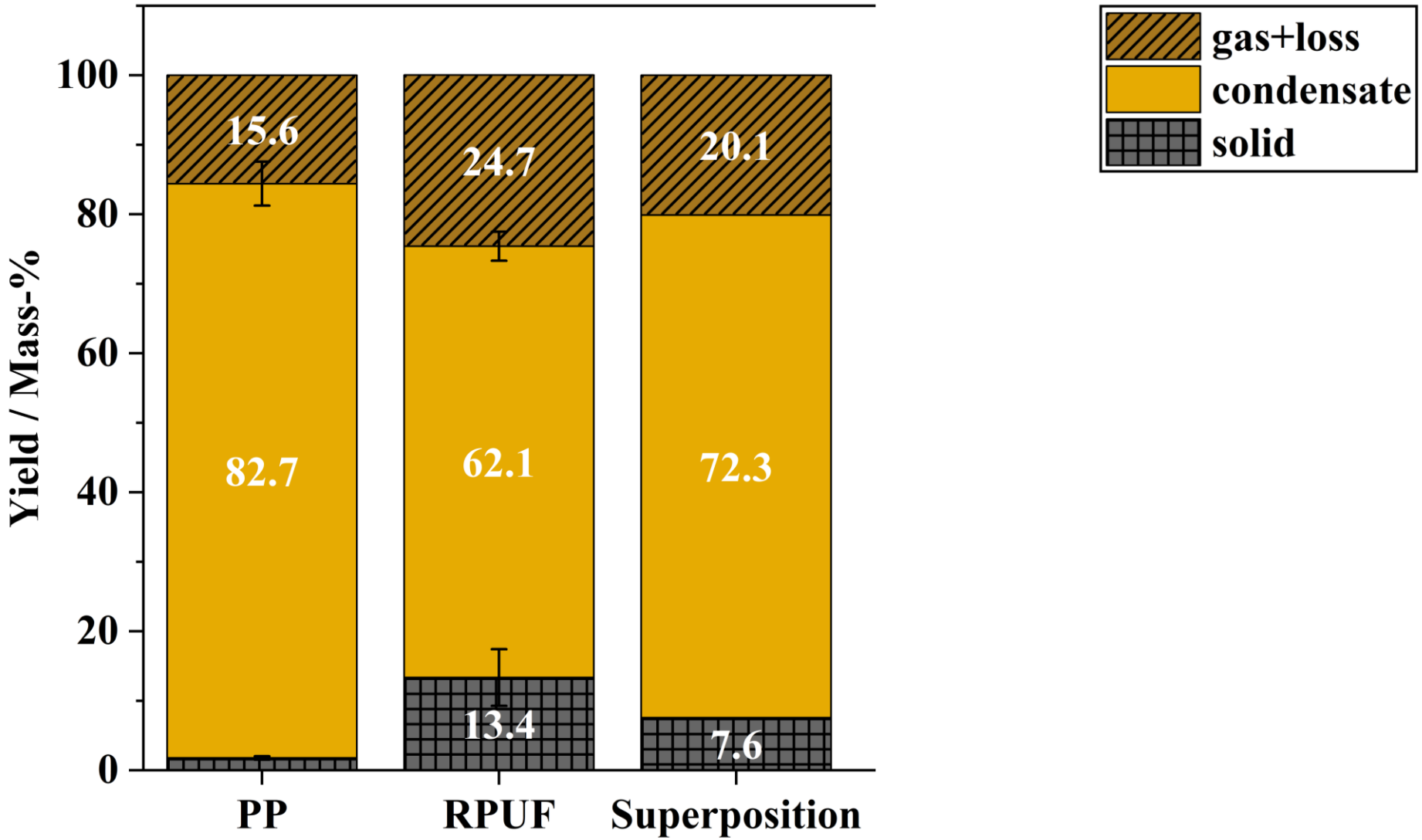
Thermogravimetry of binary mixtures



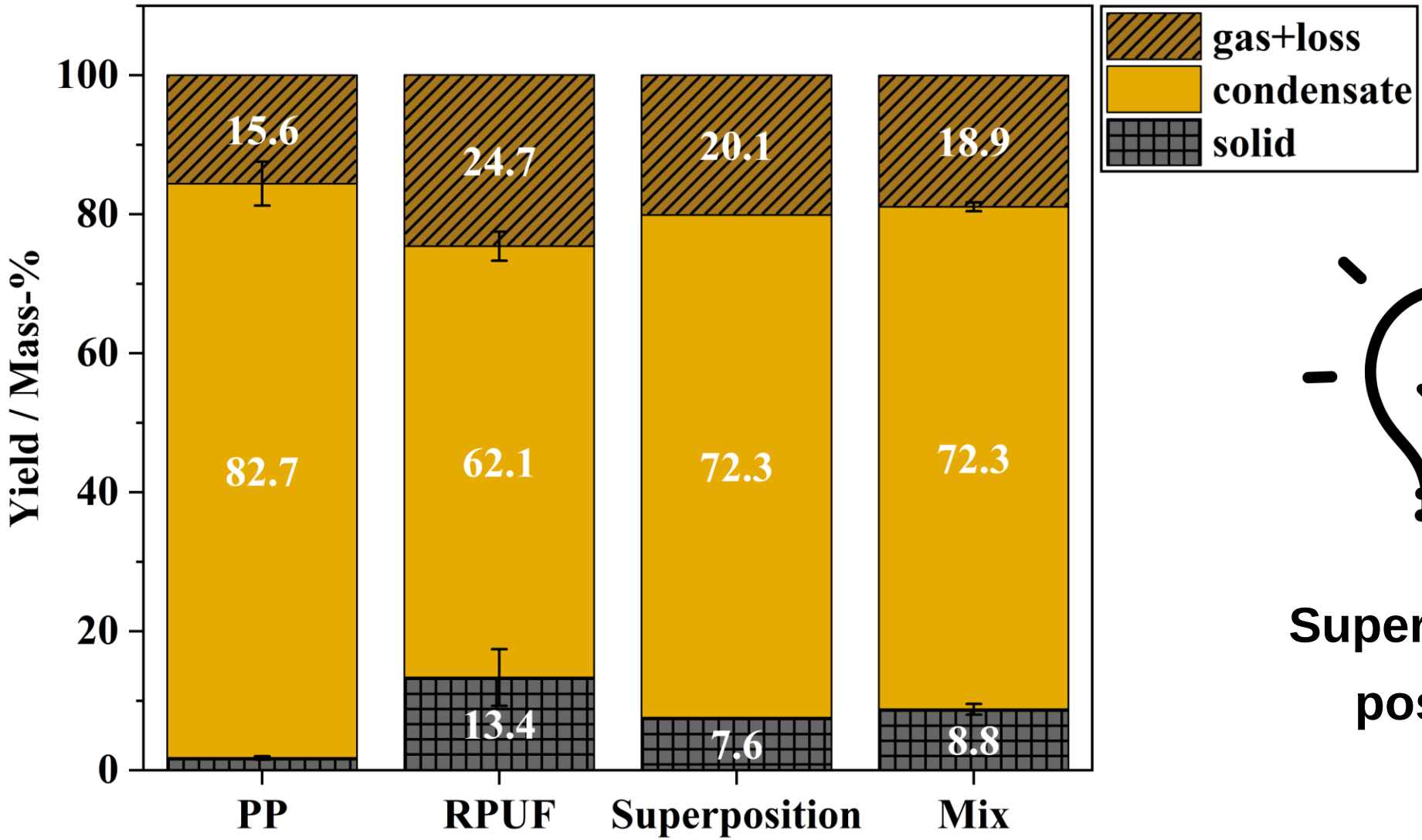
Superposition possible

no pyrolytic interaction?!

Lab-Scale Pyrolysis –Mass Balance

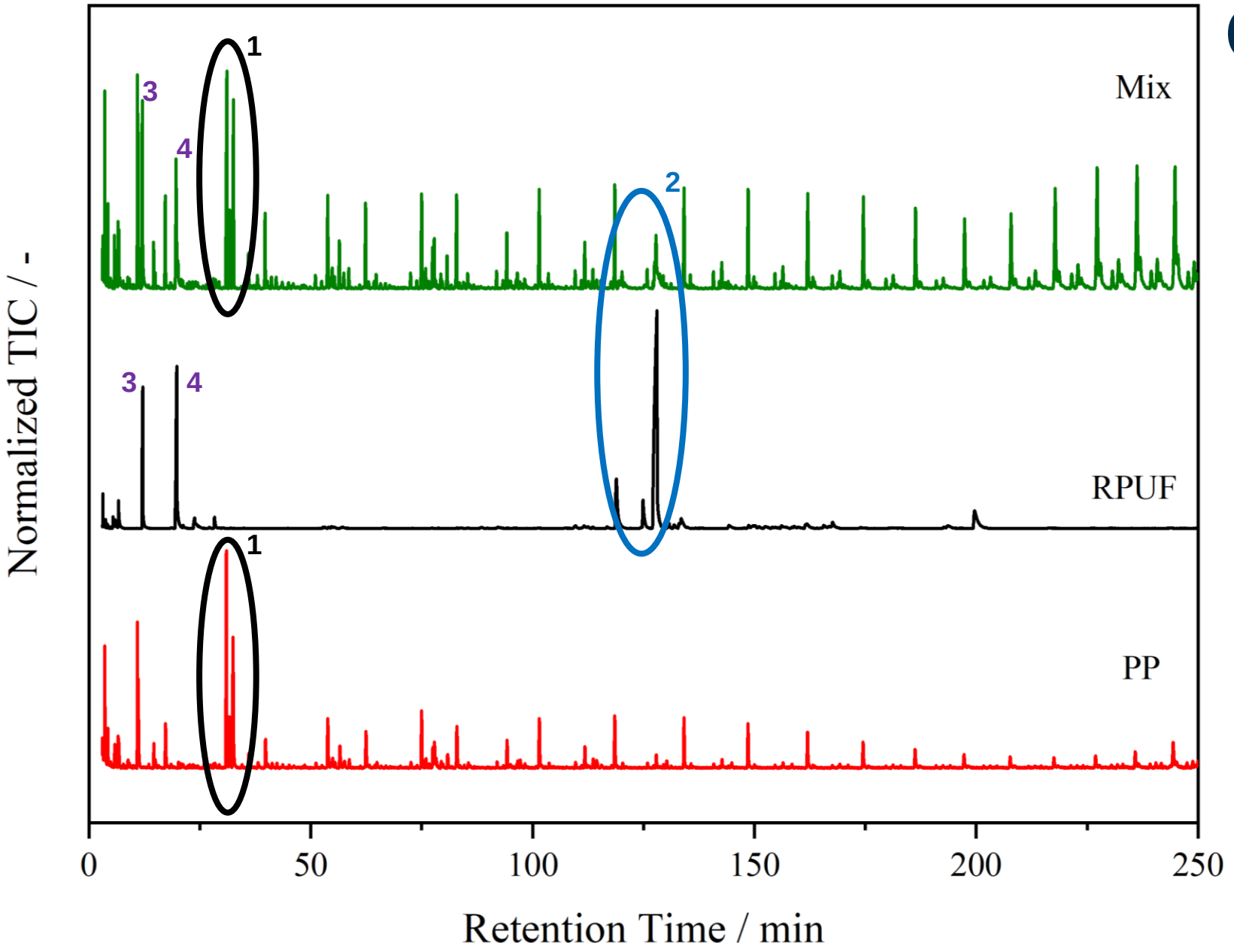


Lab-Scale Pyrolysis – Mass Balance



Superposition possible

Condensate Analysis



1 C_{15} + C_{16} Hydrocarbons

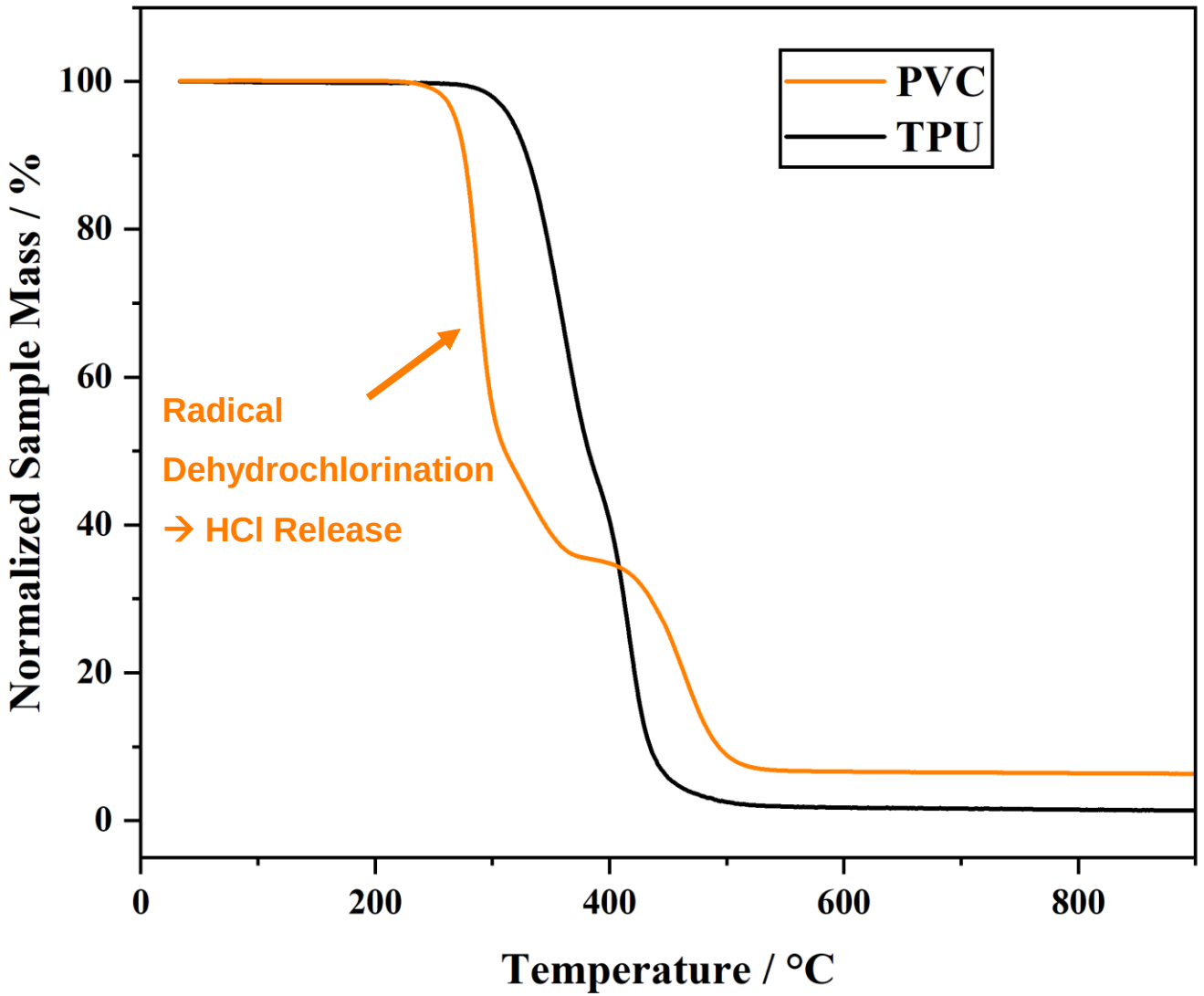
2 4,4‘-MDA and isomers

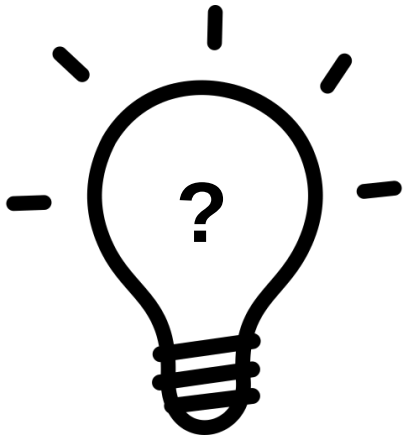
3 Aniline

4 Toluidine

Superposition possible

Thermogravimetry of binary mixtures

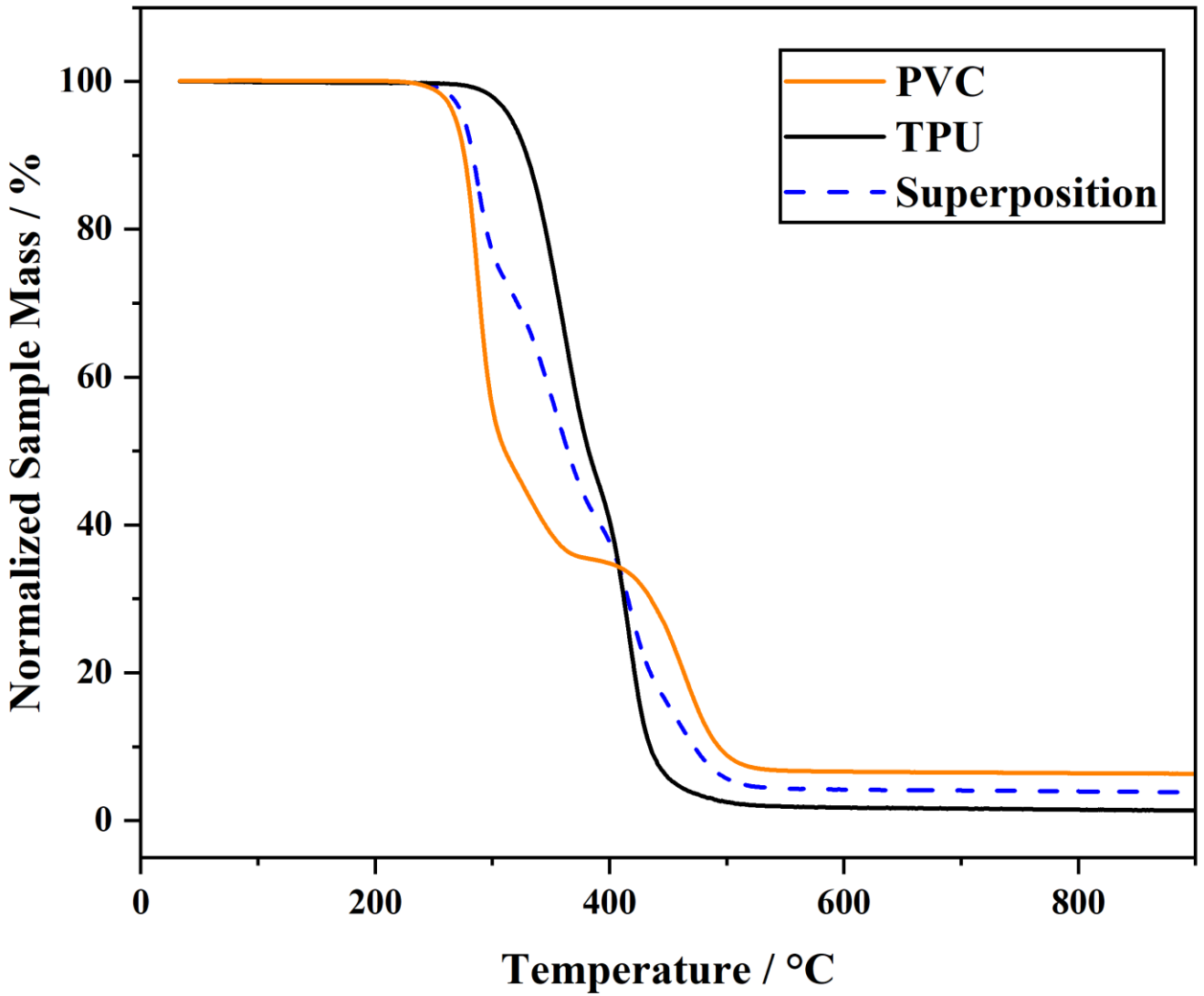




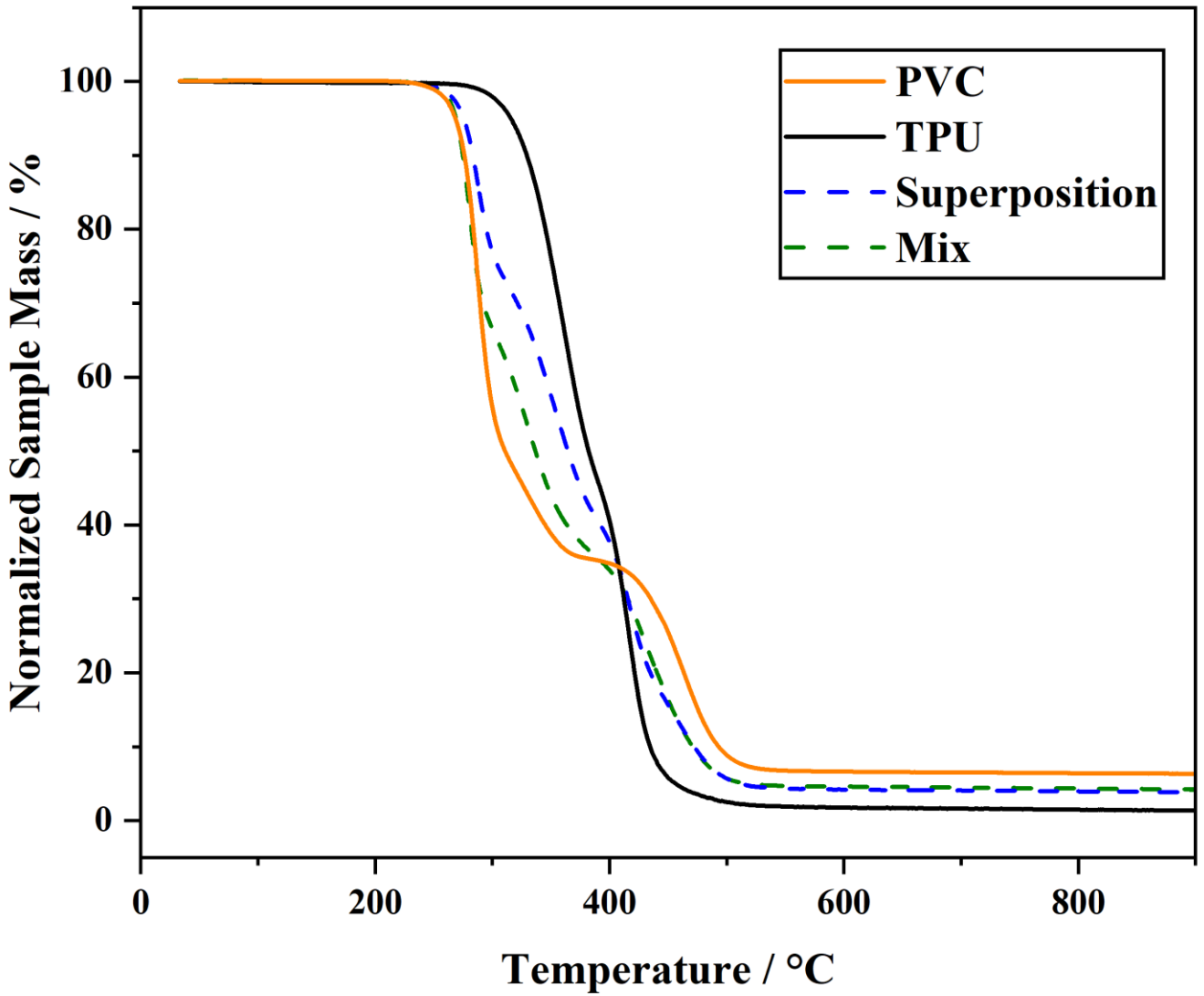
Superposition Possible?

pyrolytic interactions?!

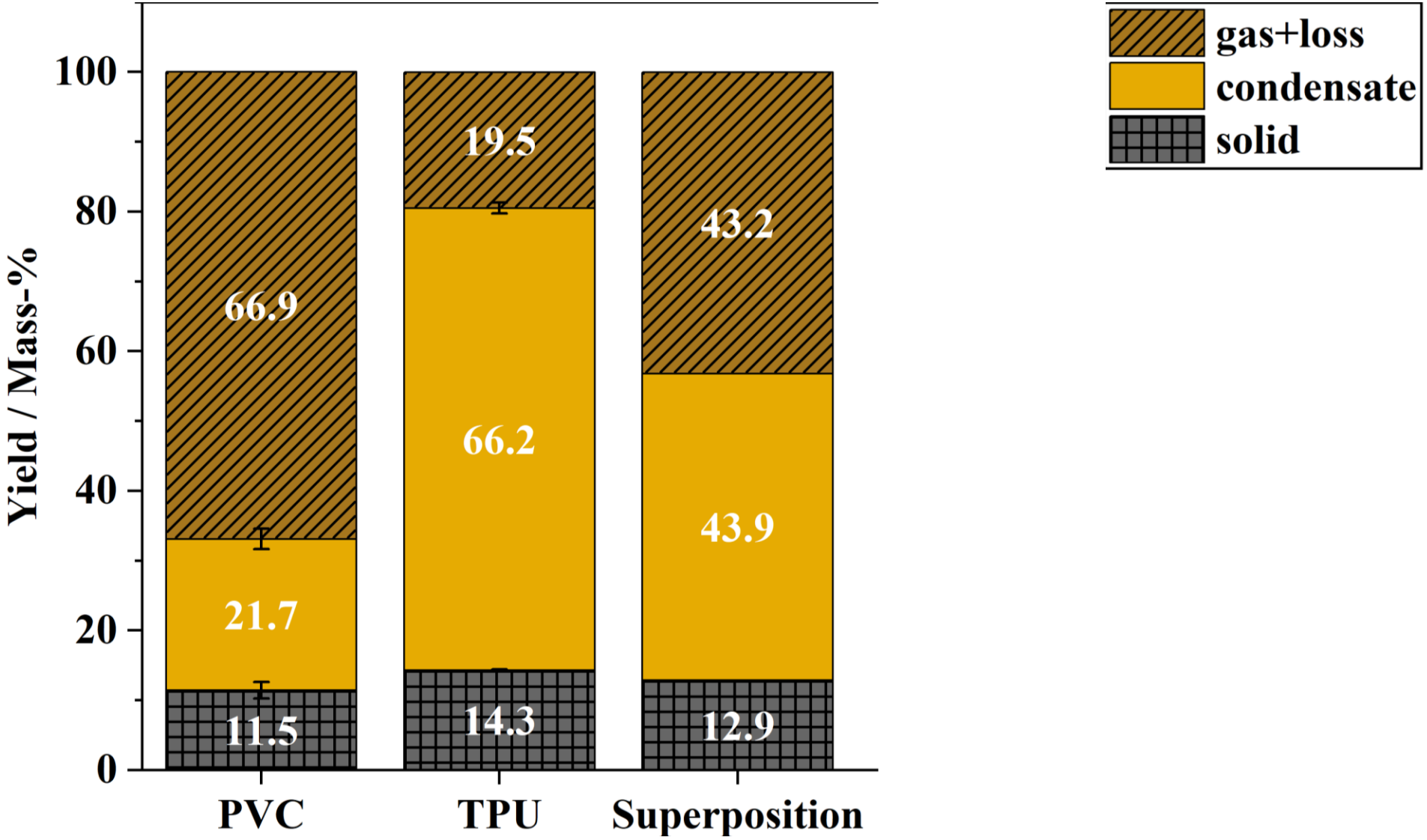
Thermogravimetry of binary mixtures



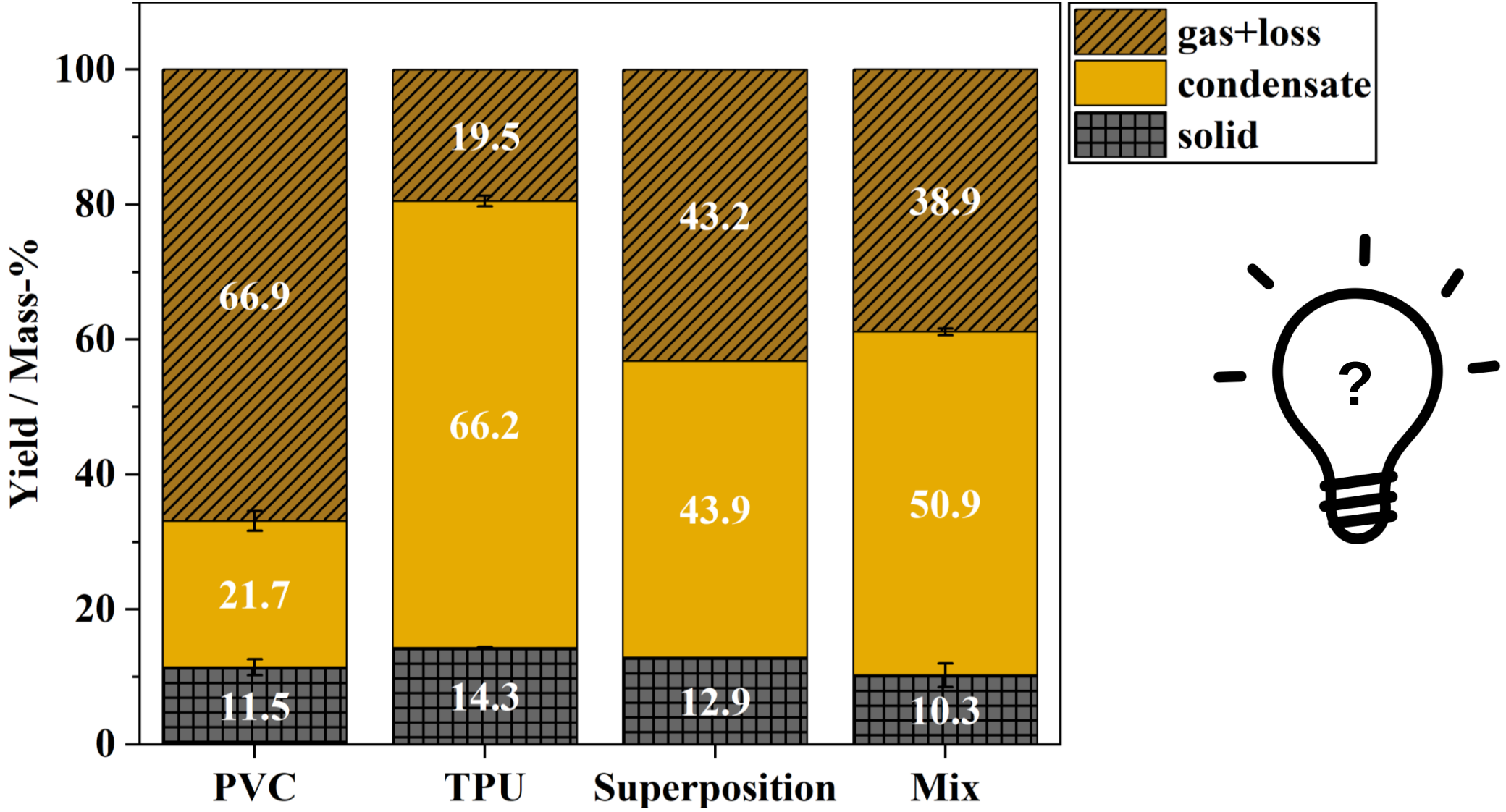
Thermogravimetry of binary mixtures



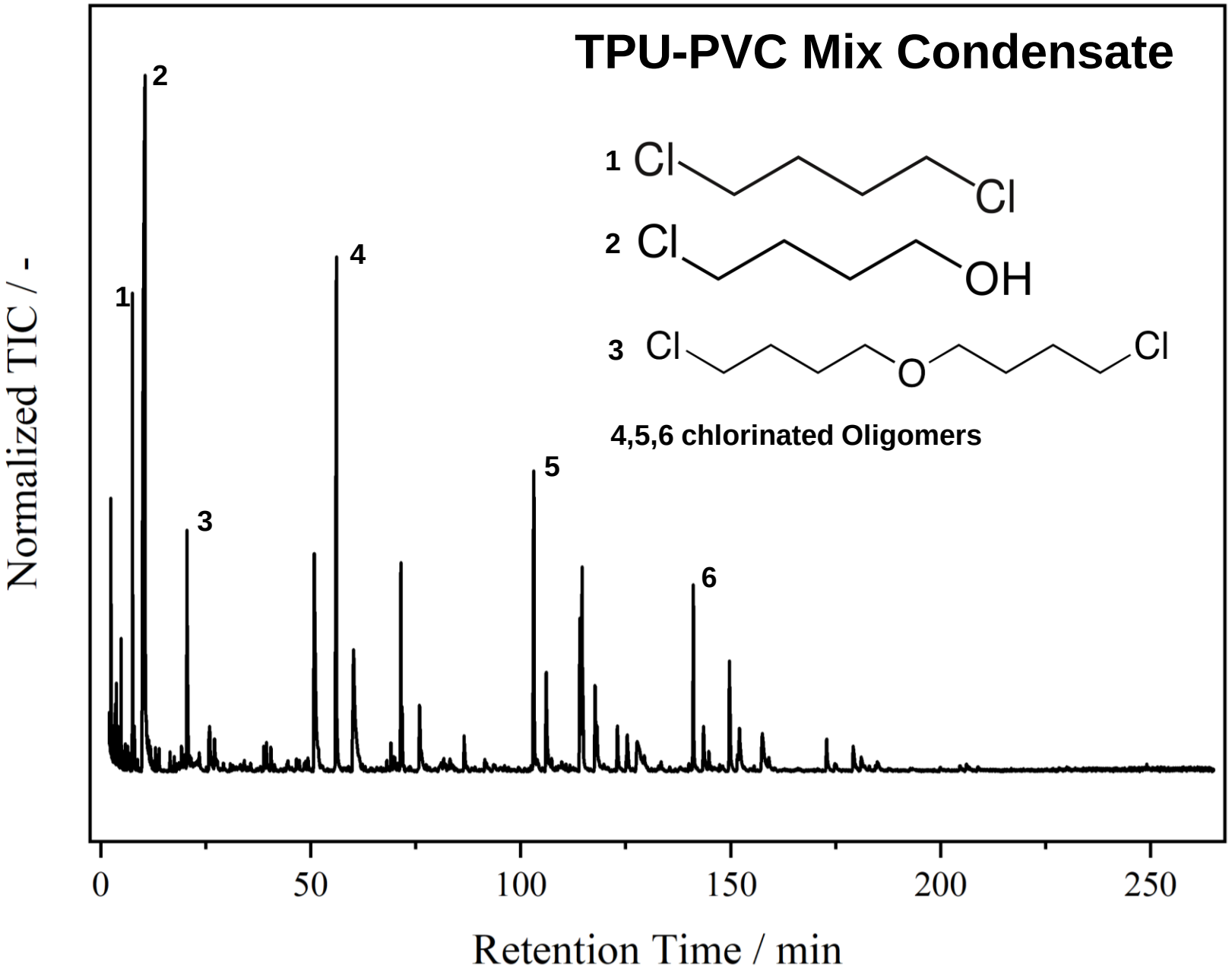
Lab-Scale Pyrolysis – Mass Balance

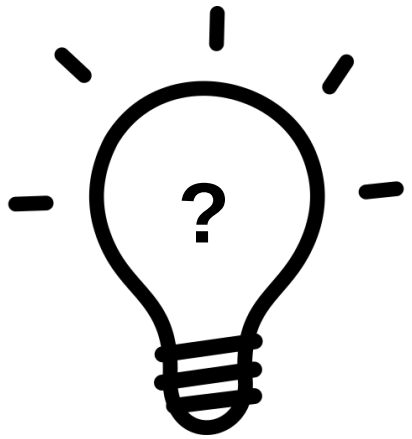


Lab-Scale Pyrolysis – Mass Balance



Condensate Analysis



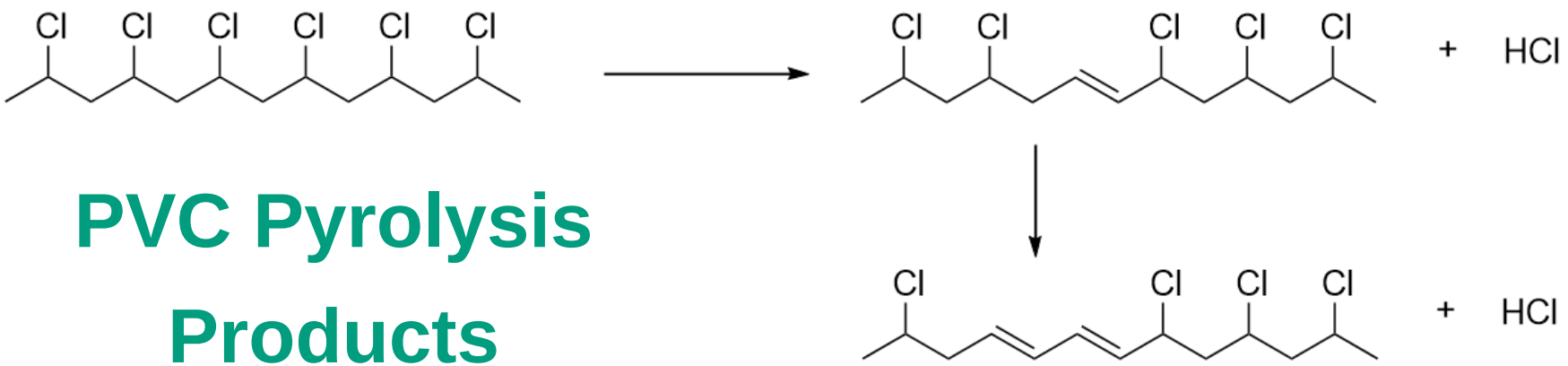


Pyrolytic Interactions!

Chlorine migration to condensate!

Derivatization of PUR pyrolyzates?

Potential Interaction Mechanism?

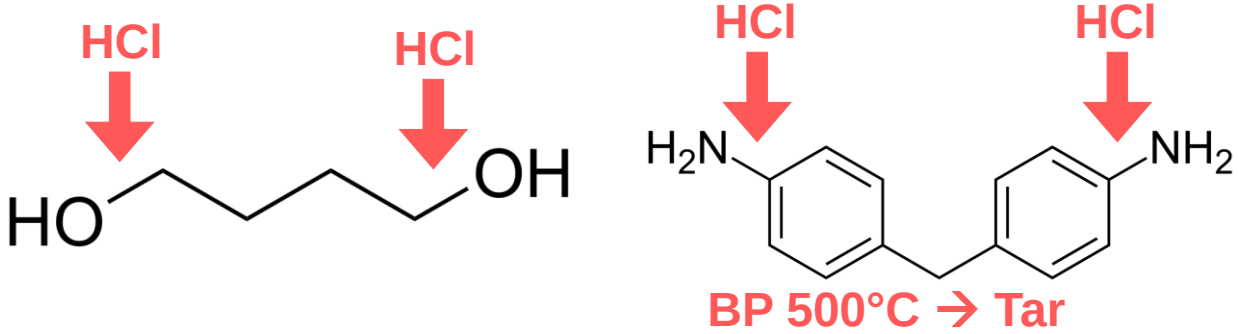


Own illustriation, scheme from:

Rouane, A., *et al.*. *J Polym Res* **27**, 12 (2020). https://doi.org/10.1007/s10965-019-1984-1

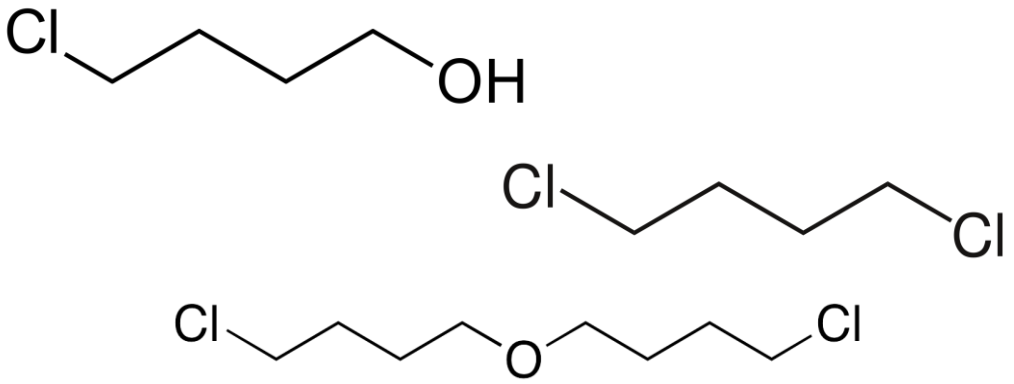
PVC Pyrolysis Products

TPU Pyrolysis Products



BP 500°C → Tar

Co-Pyrolysis Products

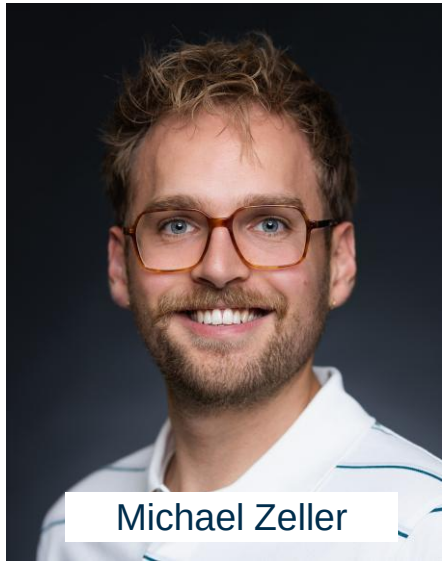


Conclusions

- **Functional groups & heteroatoms provoke interactions**
- **Heteroatoms migrate to value products**

- **Test further polymer combinations**
- **Elucidate mechanisms**
- **Control of heteroatom migration**

Want to know more?


Michael Zeller

outdated

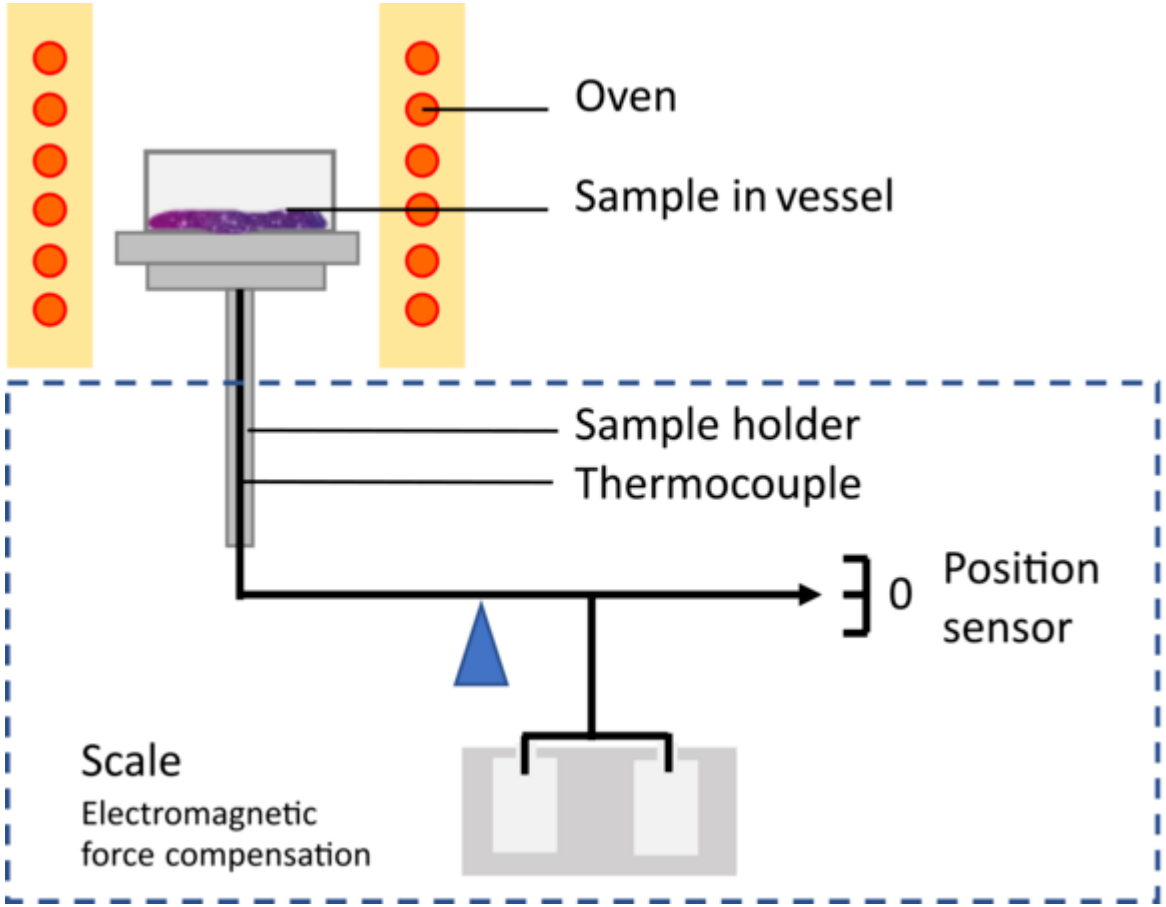

Salar Tavakkol


Dieter Stapf

Scan me!

Thermogravimetry Experimental Setup

Experiment Parameter	Value
Temperature	ambient - 900 °C
Heating Rate	10 °C min^{-1}
Flushing Gas Flow	60 ml min^{-1} (N_2)
Total Sample Amount	10 mg
Polymer Mixing Ratio	1:1
Crucible Material	Corundum (Al_2O_3)



https://sgs-institut-fresenius.de/en/material-failure-analysis/measuring-and-analysis-methods/chemical-analytics/thermogravimetry

Accessed 11.09.2025

Lab-Scale Pyrolysis Experimental Setup

Experiment Parameter	Value
Temperature	ambient - 550 °C
Experiment Duration	3 h
Flushing Gas Flow	50 ml min^{-1}
Flushing Gas Ratio ($Ar:N_2$)	1:4
Total Sample Amount	~ 3.5 g
Polymer Mixing Ratio	1:1
Condenser Temperature	-5 °C