Spontaneous combustion of torrefied eucalyptus at different cooling temperatures: Combined effect of water sorption and air oxidation

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Biomass torrefaction

Raw biomass

Heating

Pre-drying

Post-drying

Torrefaction

Cooling

Torrefied biomass

Temperature

Self-heating

Chemical oxidation

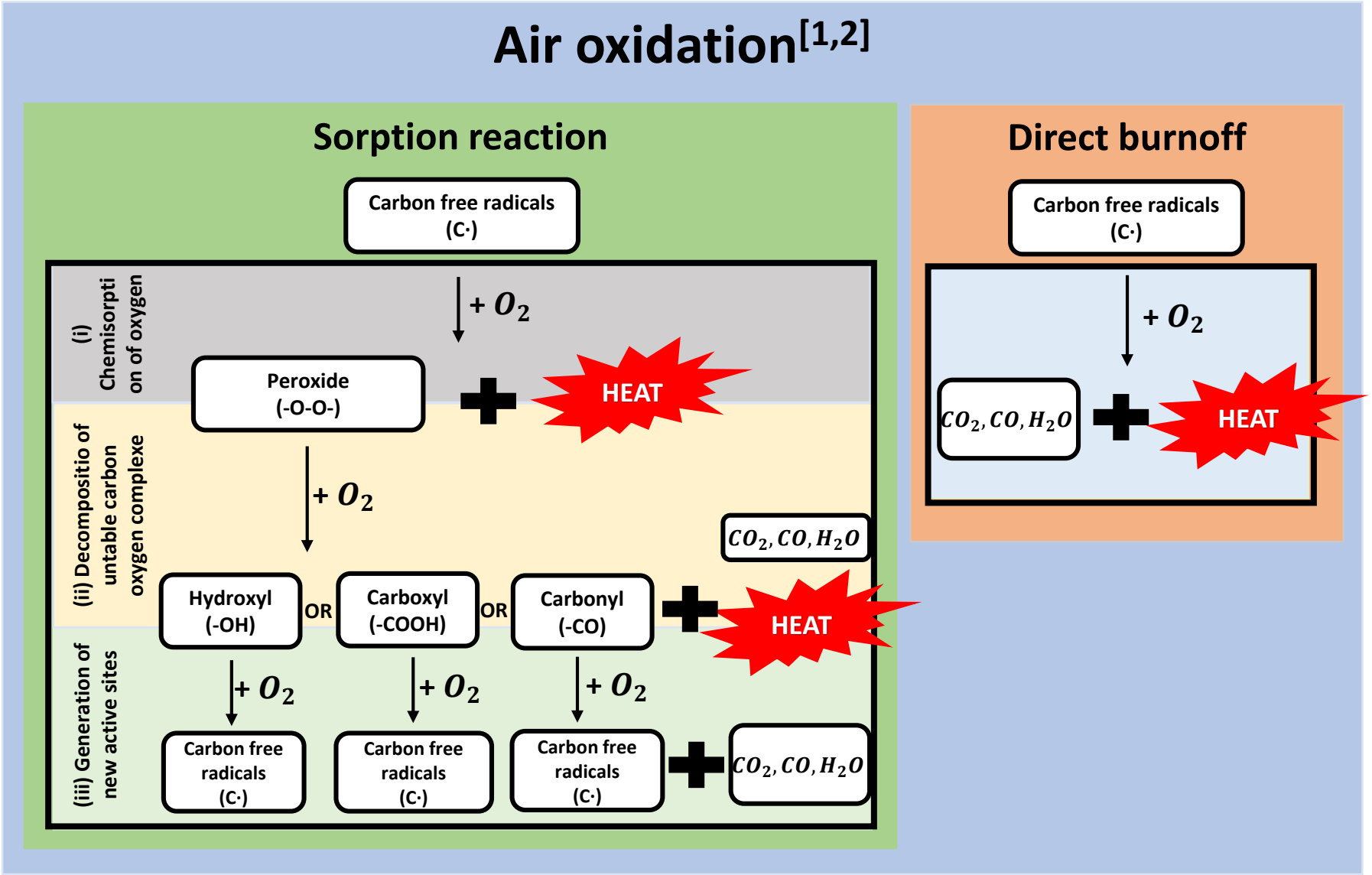
“Air oxidation”

Physical reactions

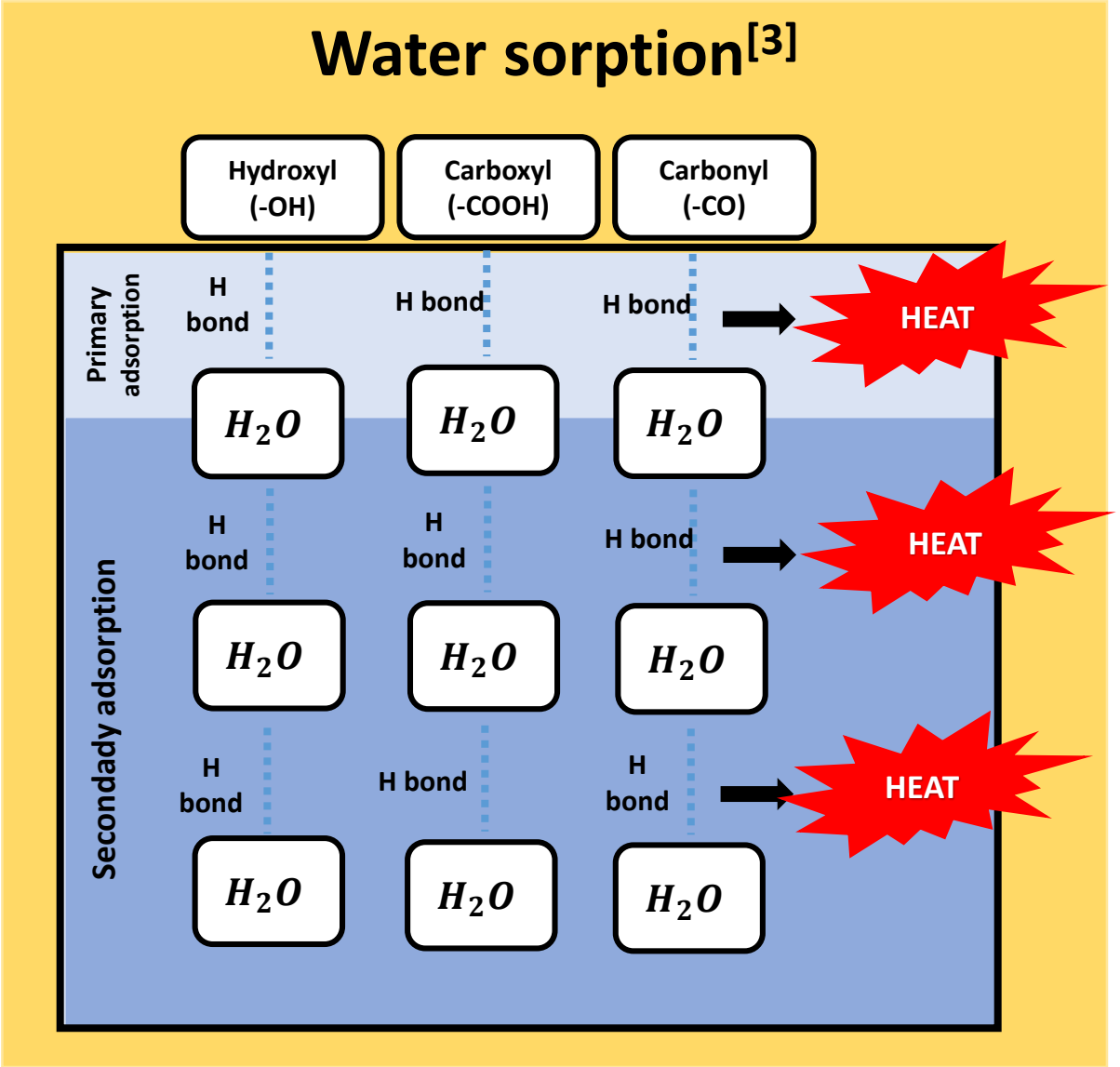
“Water adsorption”

Ignition temperature

Spontaneous combustion



[1] H. Wang et al. (2003), [2} J. Zhan et al. (2014)



Water vapor adsorption is influenced by the presence of **oxygen containing groups** on material surface

[3] A. Liu (2021)

Methodology

100mg with size > 100 um
Mass and Heat flow

TGA/DSC

Air oxidation

Water adsorption

Air oxidation and Water adsorption

Methodology

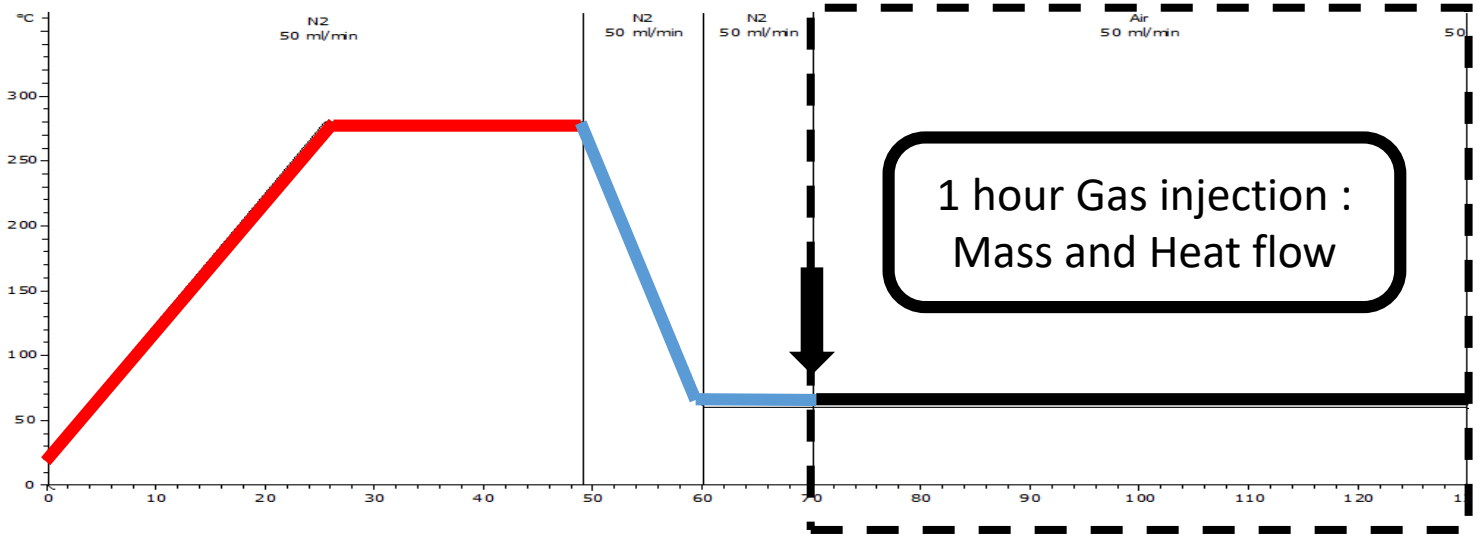
Torrefaction : 30% mass loss at 280°C under N_2 atmosphere

Cooling to 60°C, 120°C and 180°C under N_2 atmosphere

Dry air :
Air oxidation

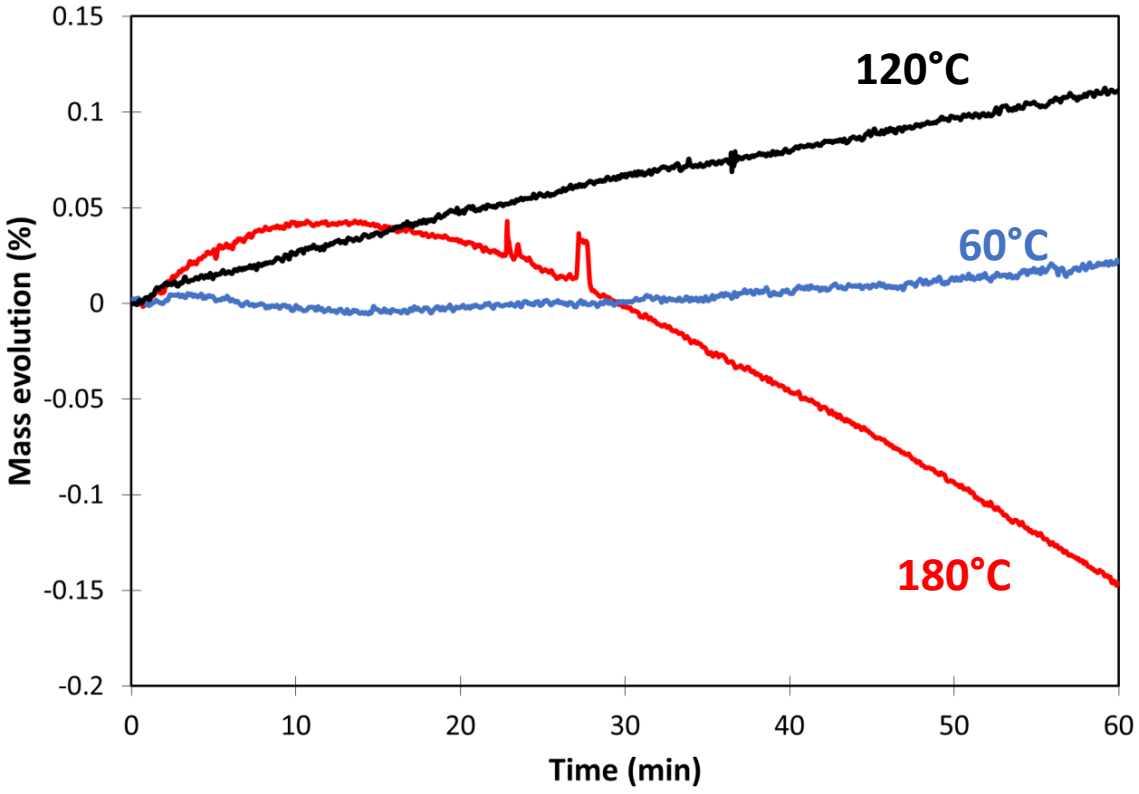
Humid nitrogen :
Water adsorption

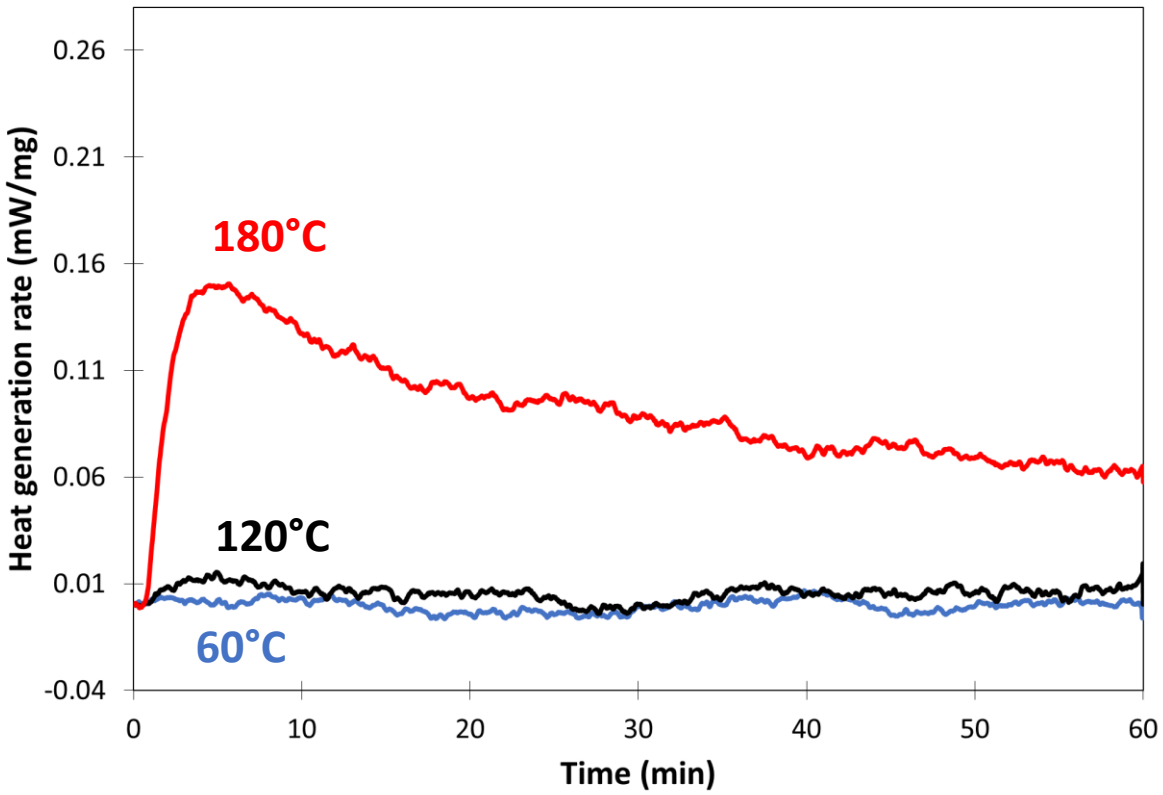
Humid air :
Air oxidation and Water adsorption

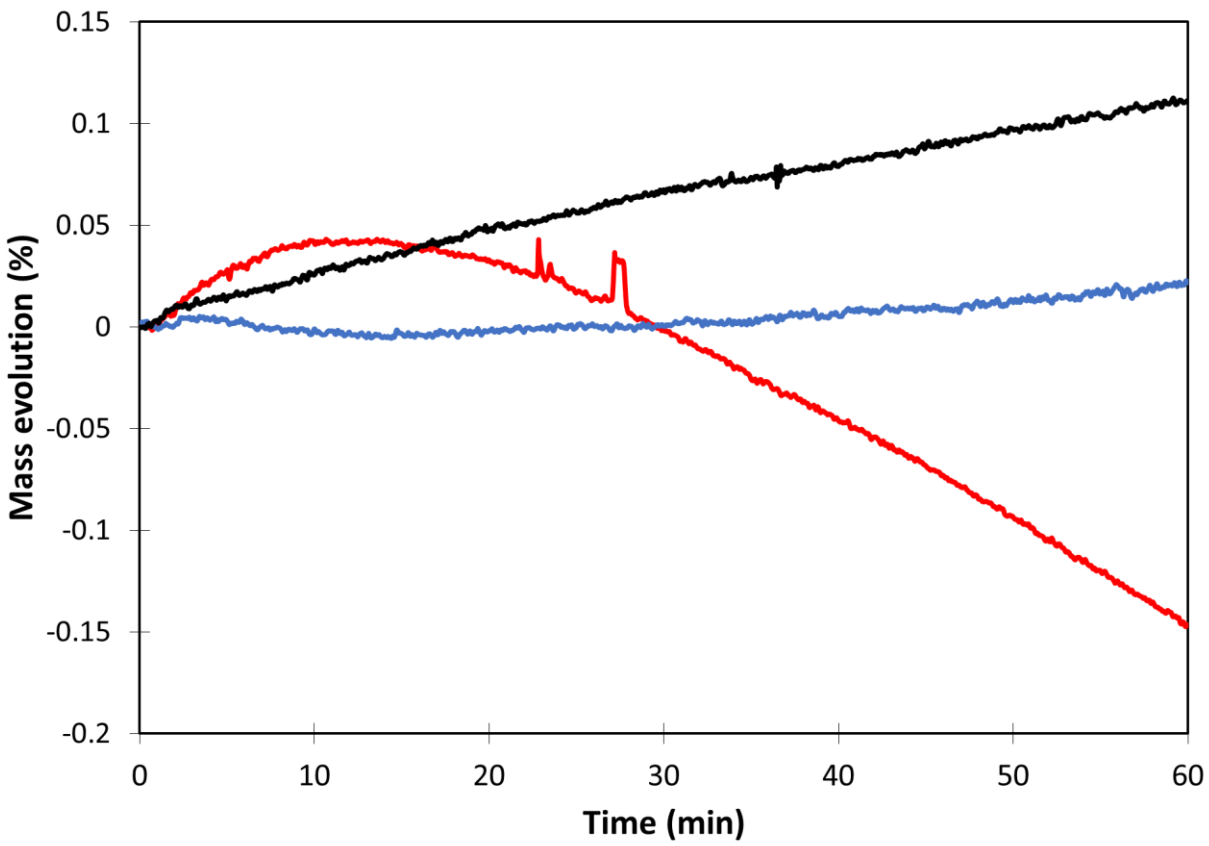


Effect of cooling temperature on air oxidation, water adsorption and the two reactions combined

Dry air: Low temperature oxidation







Air oxidation

Sorption reaction

Oxygen chemisorption

Mass increase

Decomposition of unstable complexes

Mass decrease

Generation of new active site

Mass decrease

Direct burnoff

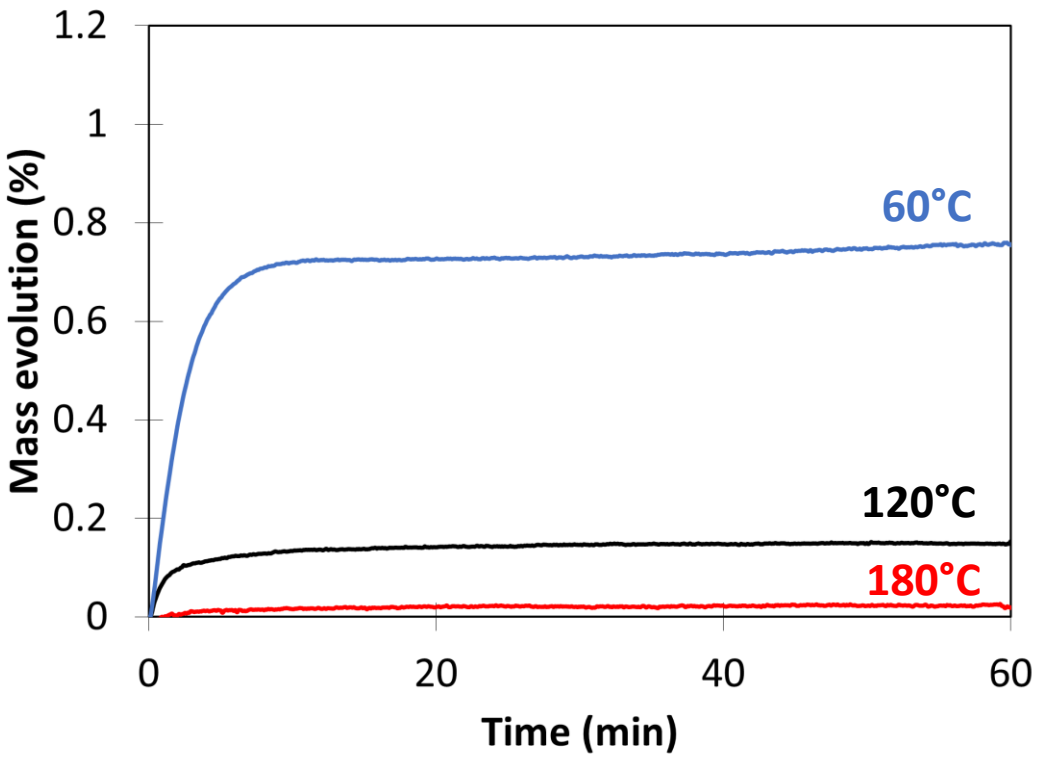
Direct burn off

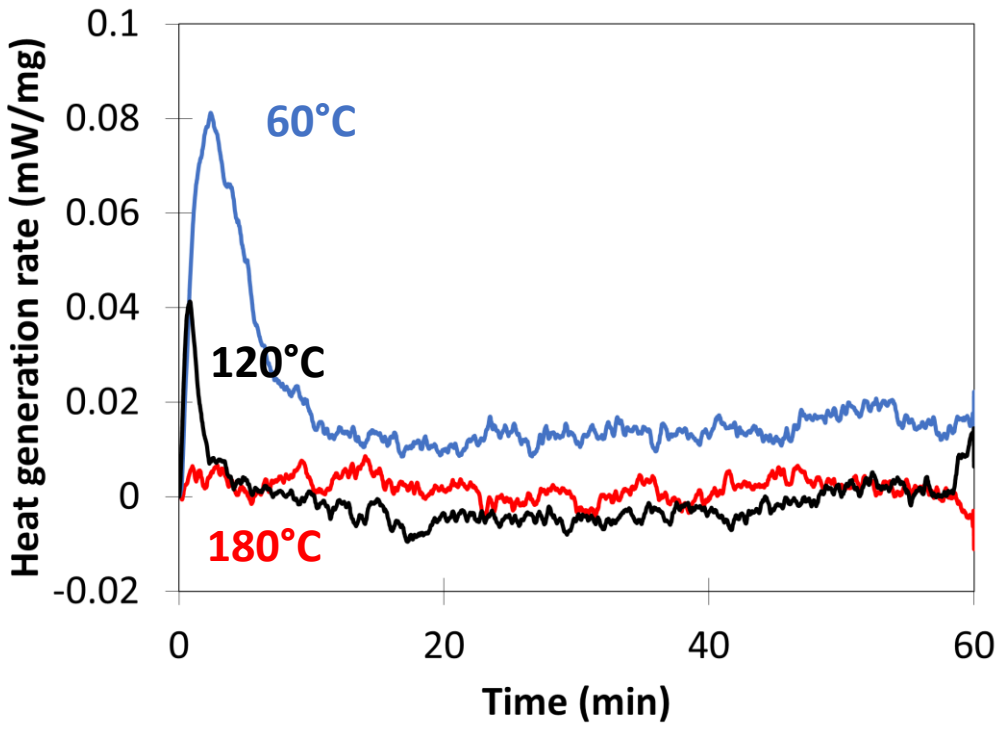
Mass decrease

Temperature

Low temperature oxidation

Humid nitrogen: Water adsorption

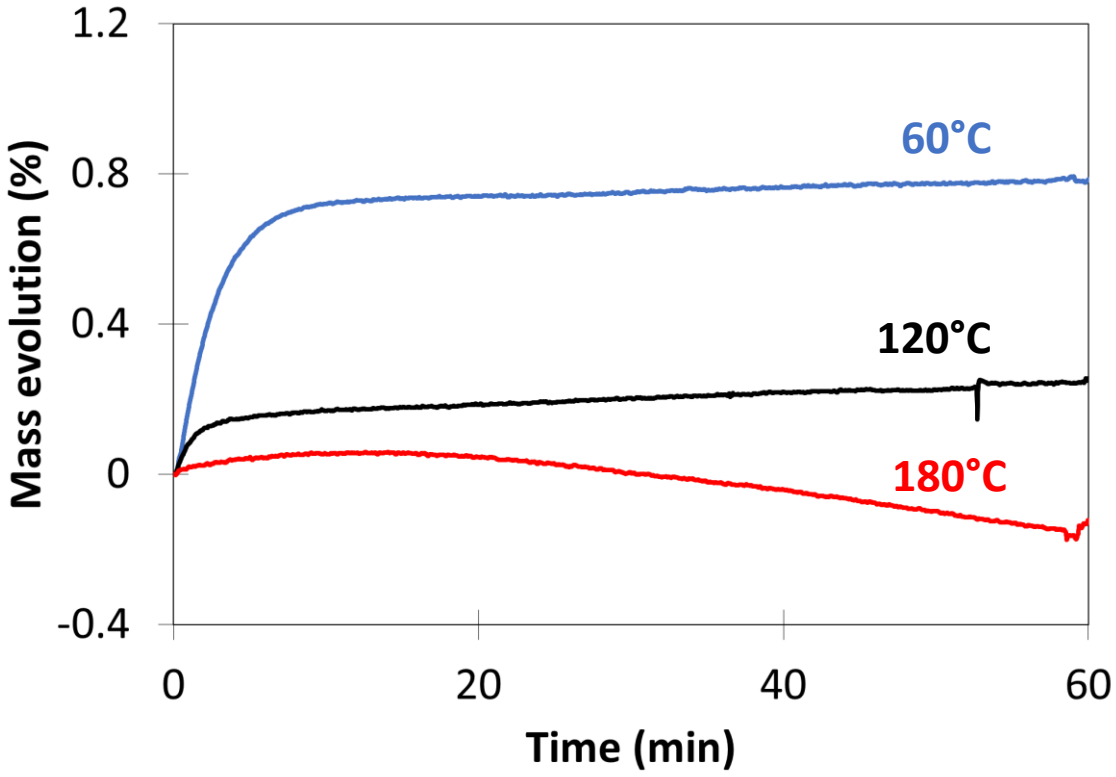


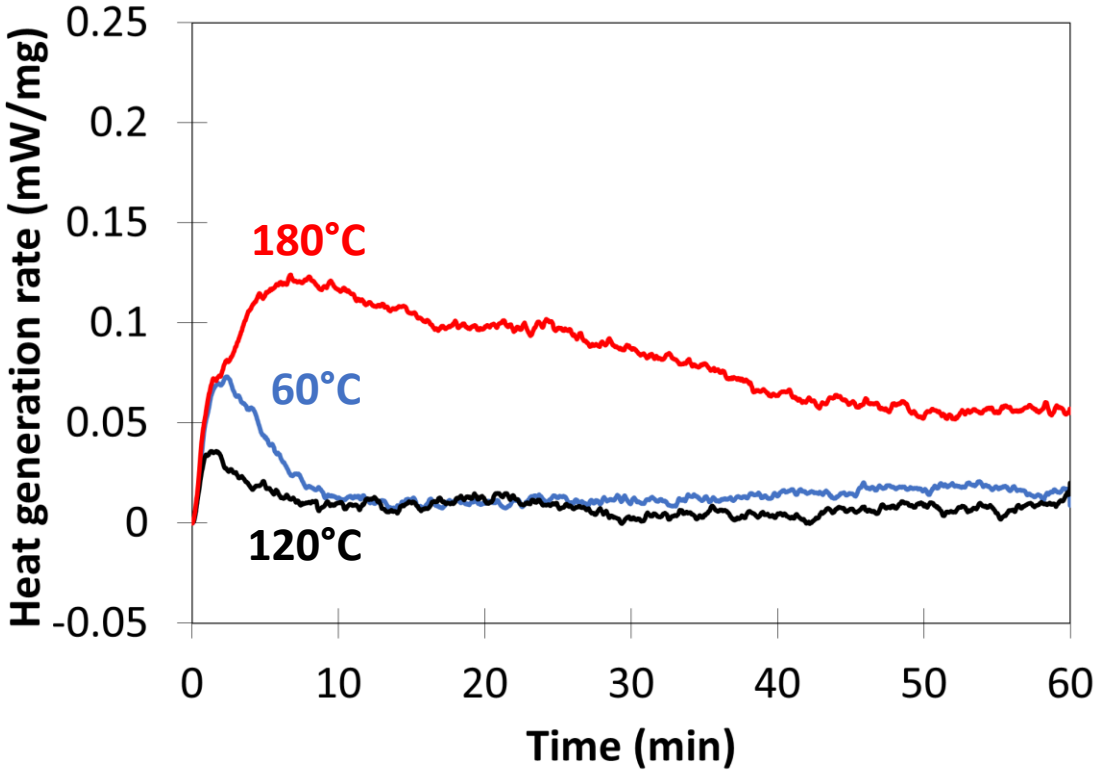


↑ Temperature

↓ Relative Humidity ↓ Water adsorption

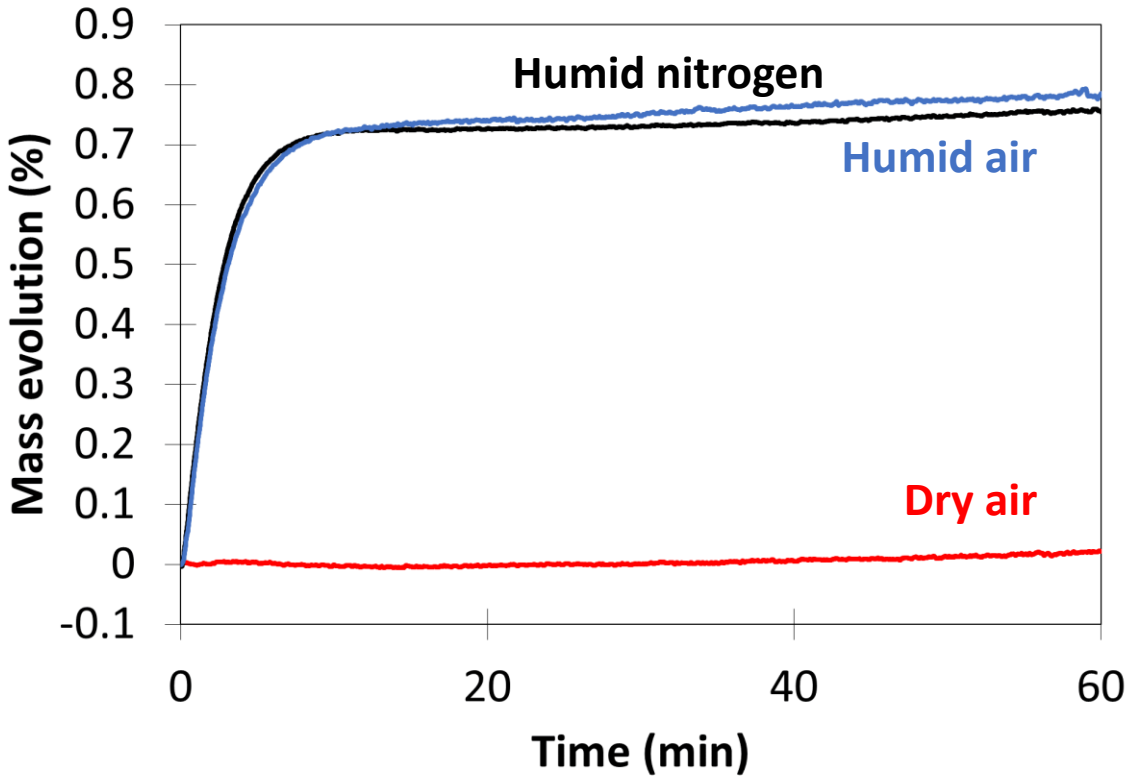
Humid air: two reactions combined

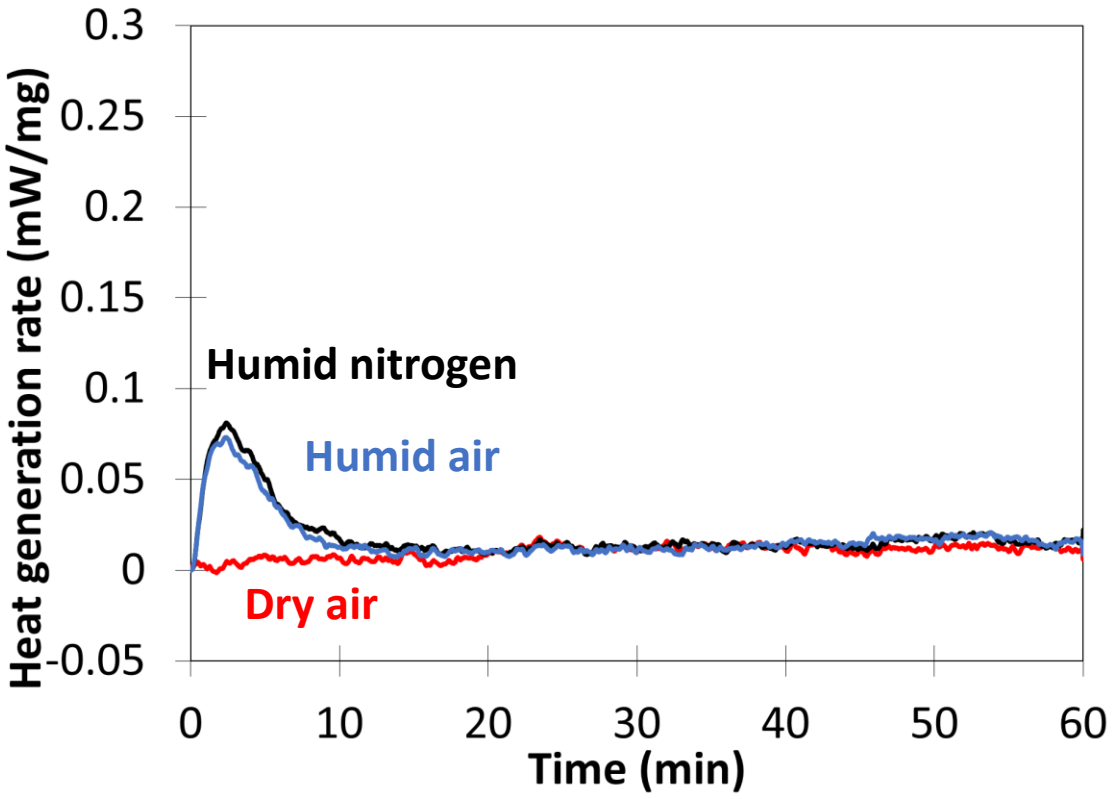




Effect of different atmospheres

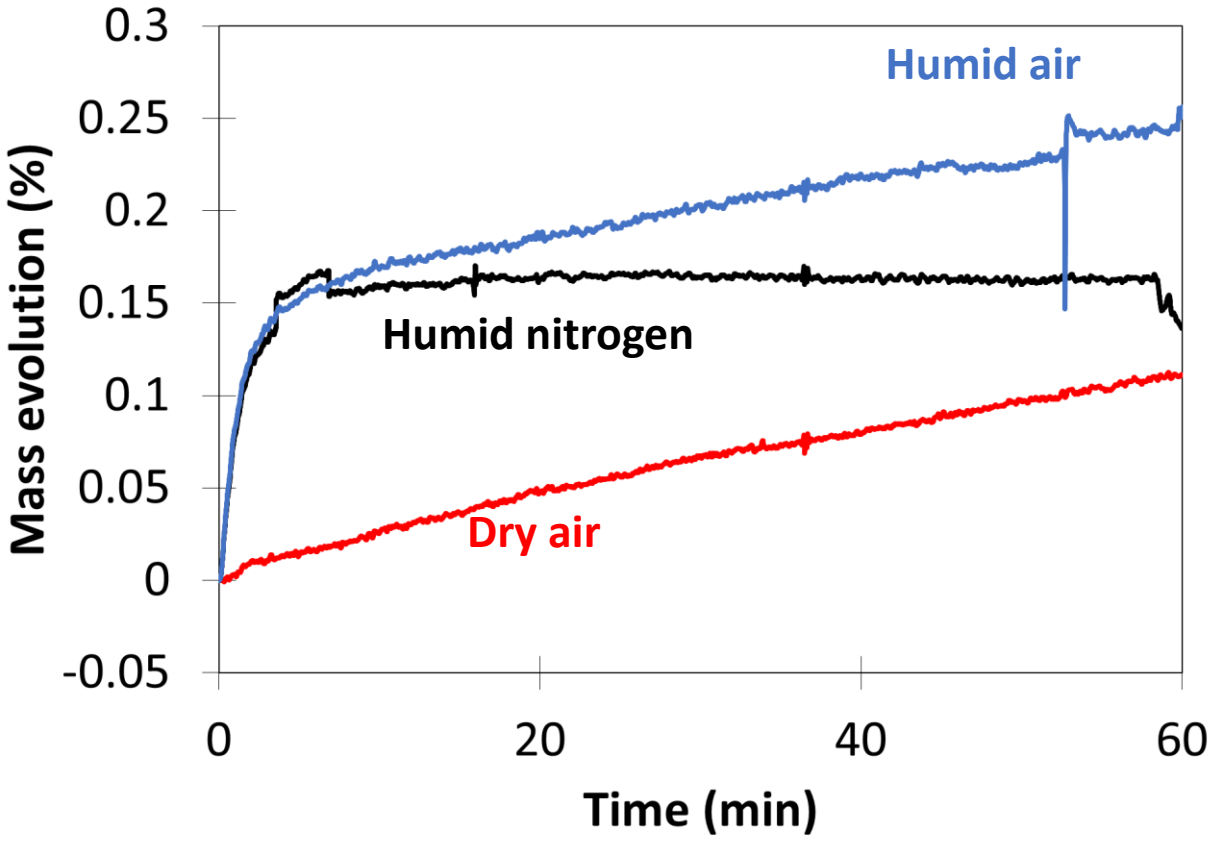
60°C

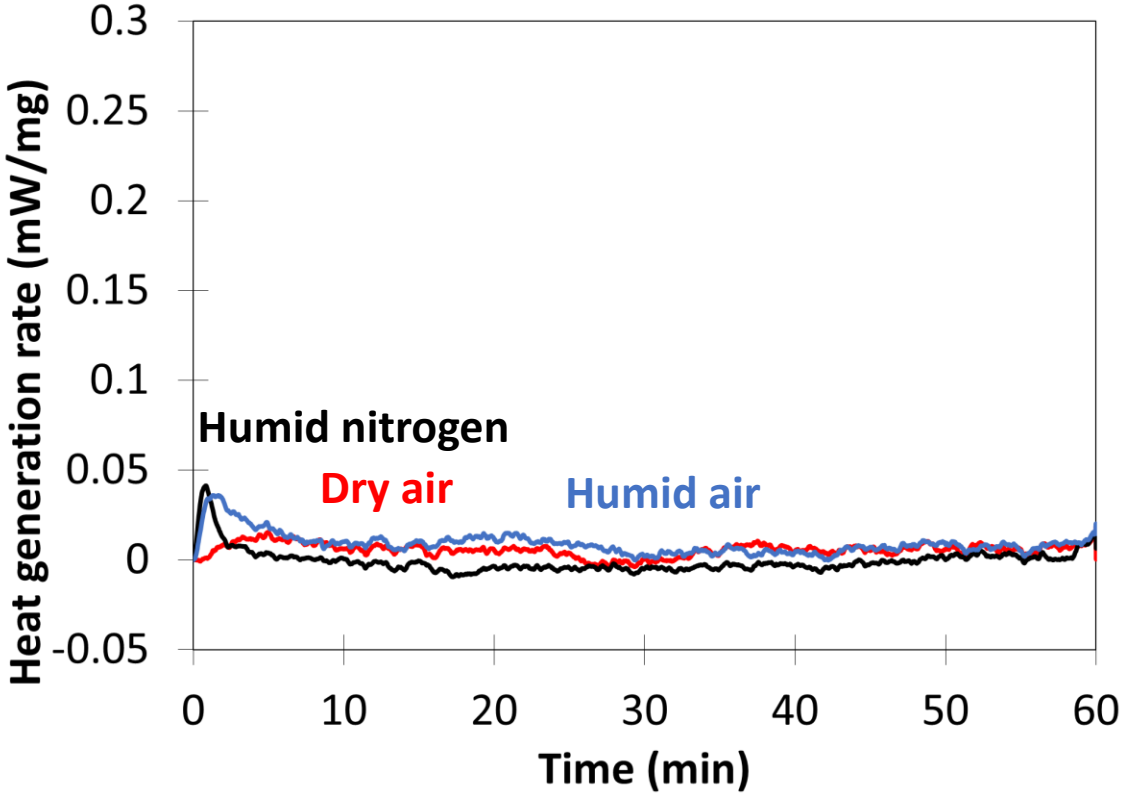




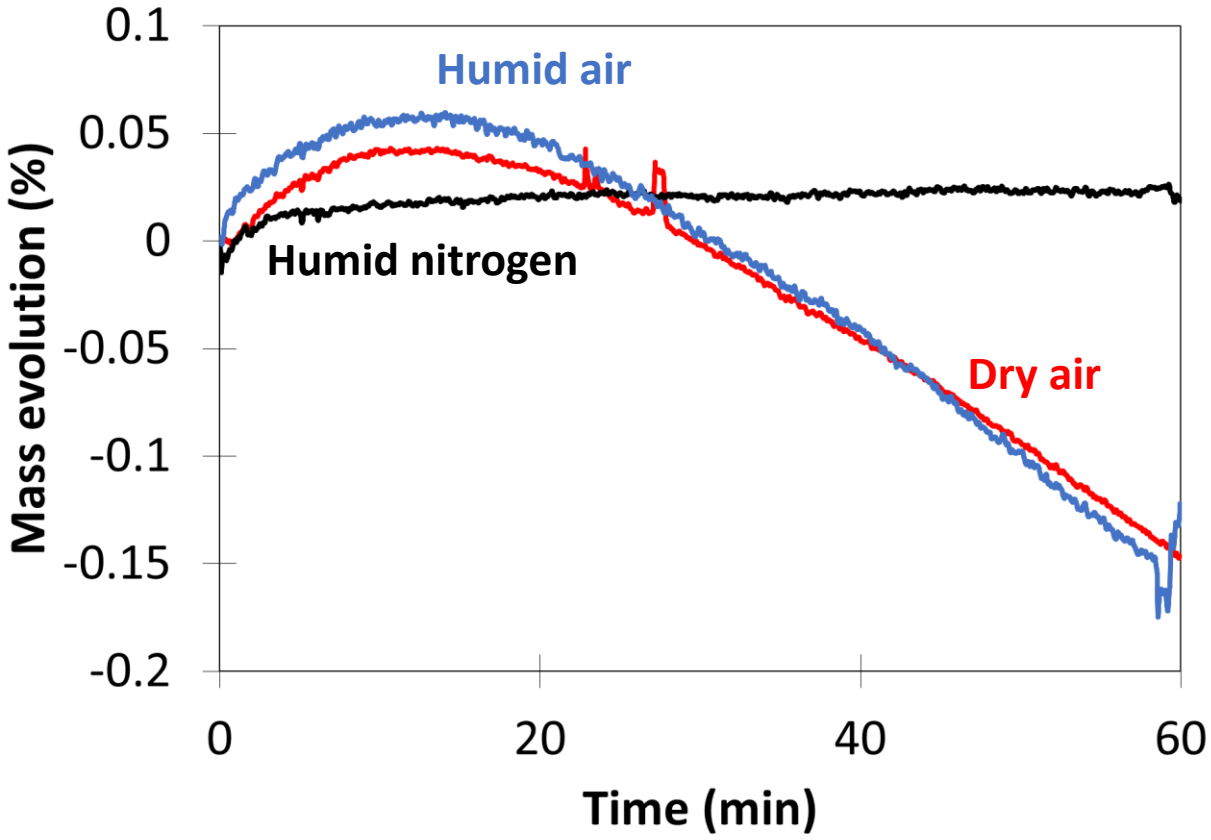
60°C
Water adsorption > Air oxidation

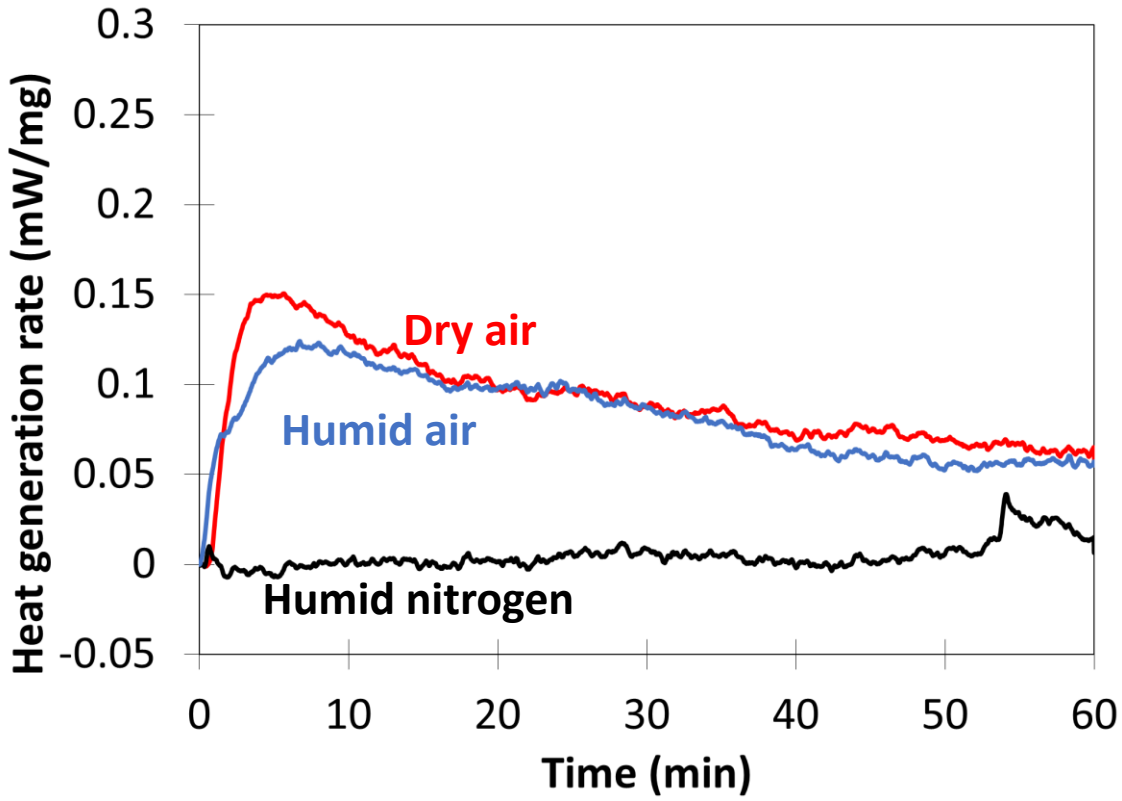
120°C


Humid air
Humid nitrogen
Dry air
Mass evolution (%)
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
0
20
40
60
Time (min)


Humid nitrogen
Dry air
Humid air
Heat generation rate (mW/mg)
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
0
10
20
30
40
50
60
Time (min)

180°C

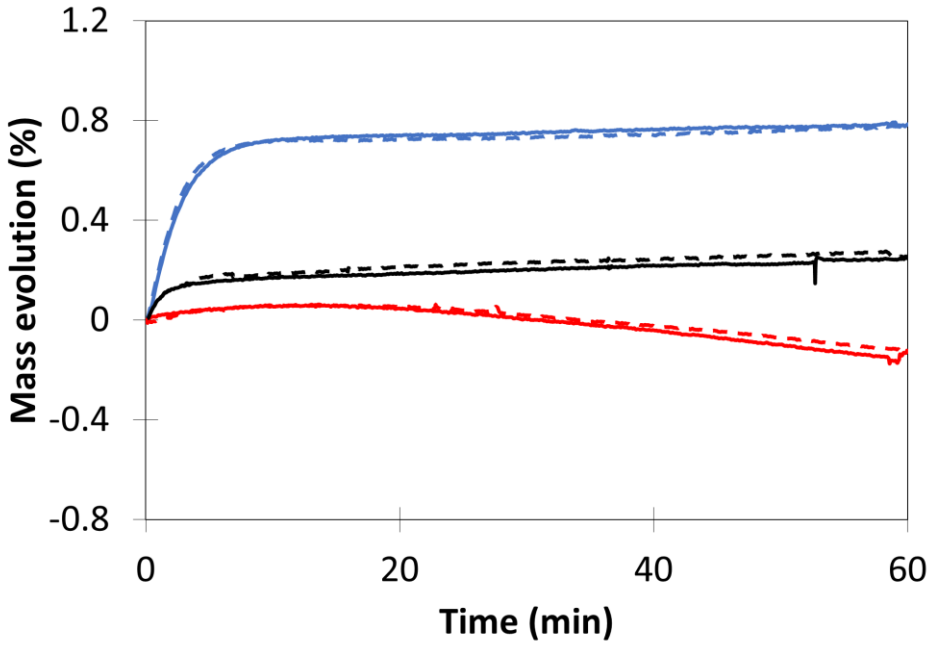




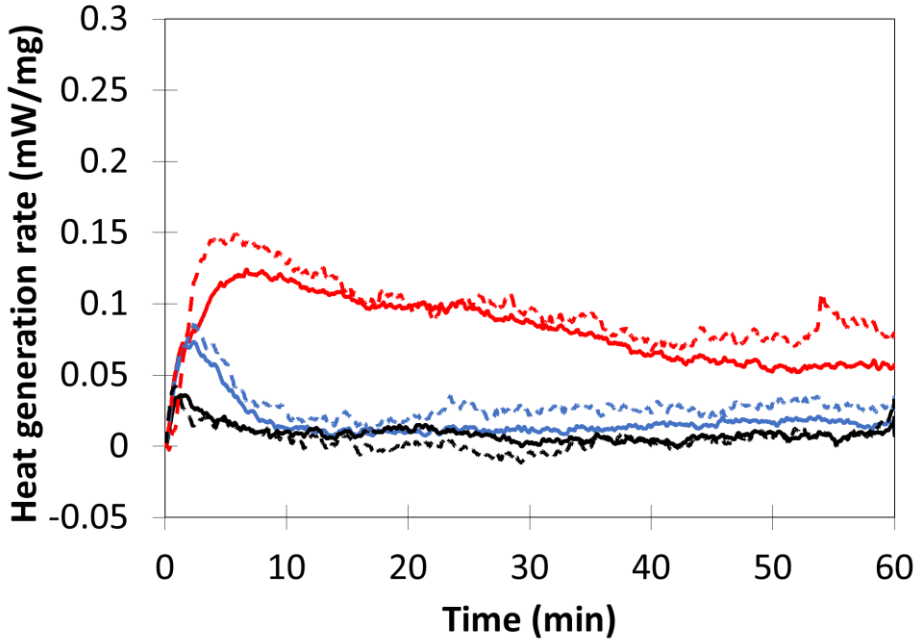
180°C
Air oxidation > Water adsorption

Additivity law

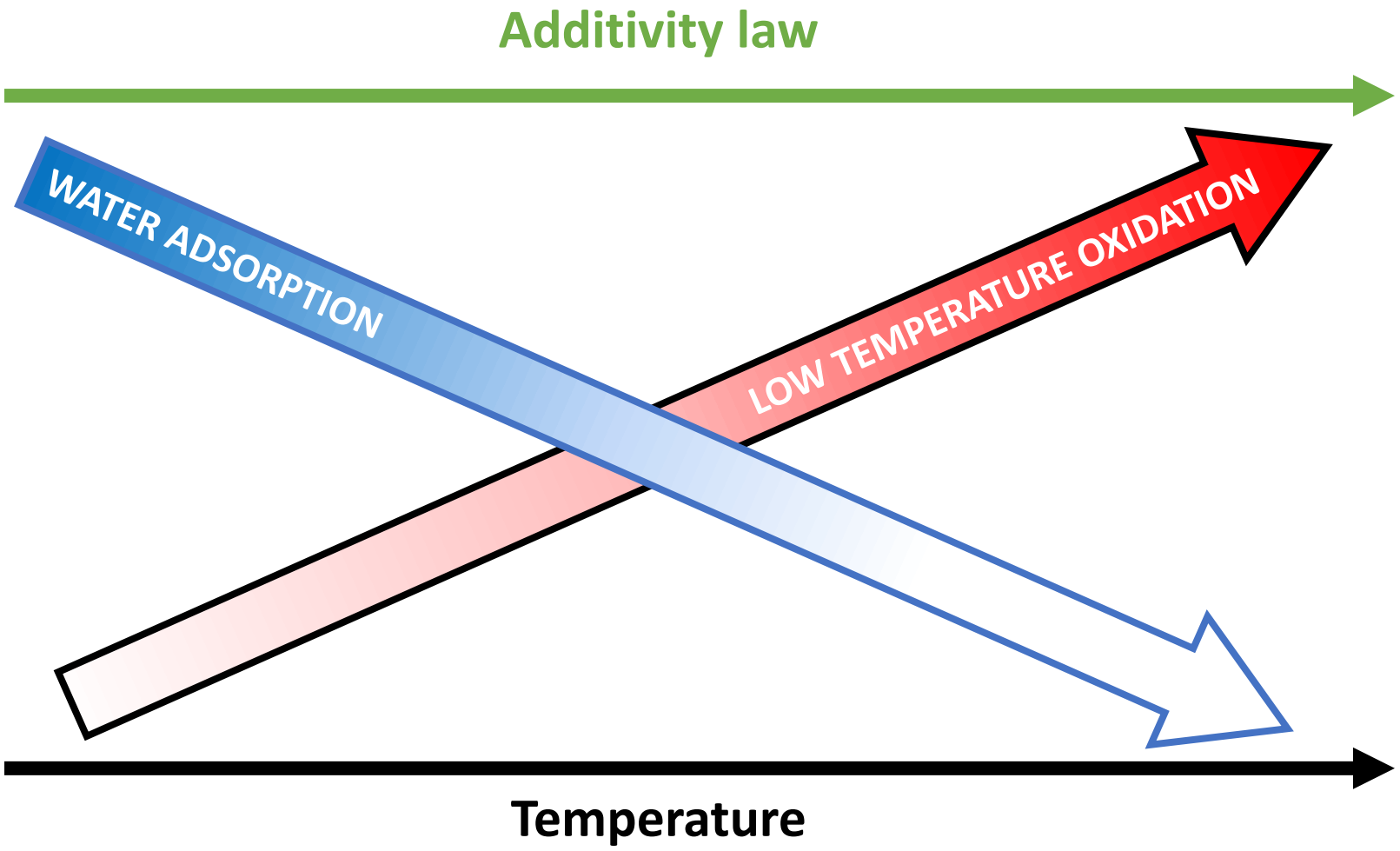
$$\left(\frac{dM}{dT}\right)_{humid\ air} = \left(\frac{dM}{dT}\right)_{humid\ nitrogen} + \left(\frac{dM}{dT}\right)_{dry\ air}$$



$$\left(\frac{dQ}{dT}\right)_{humid\ air} = \left(\frac{dQ}{dT}\right)_{humid\ nitrogen} + \left(\frac{dQ}{dT}\right)_{dry\ air}$$



Conclusion



60°C
Water adsorption > Air oxidation

120°C
Humid air = Dry air + Humid nitrogen

180°C
Air oxidation > Water adsorption