Volatile Organic Compound Release from High Temperature Plastic Cooking Dishes

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Recently, there has been a proliferation of oven-ready high temperature plastic cooking dishes.

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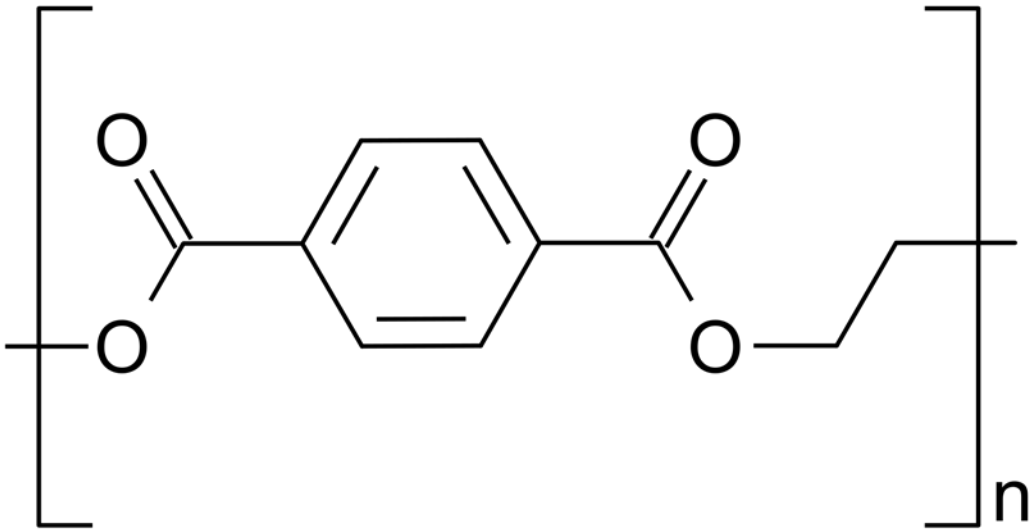
PETE

Polyethylene Terephthalate (PETE)



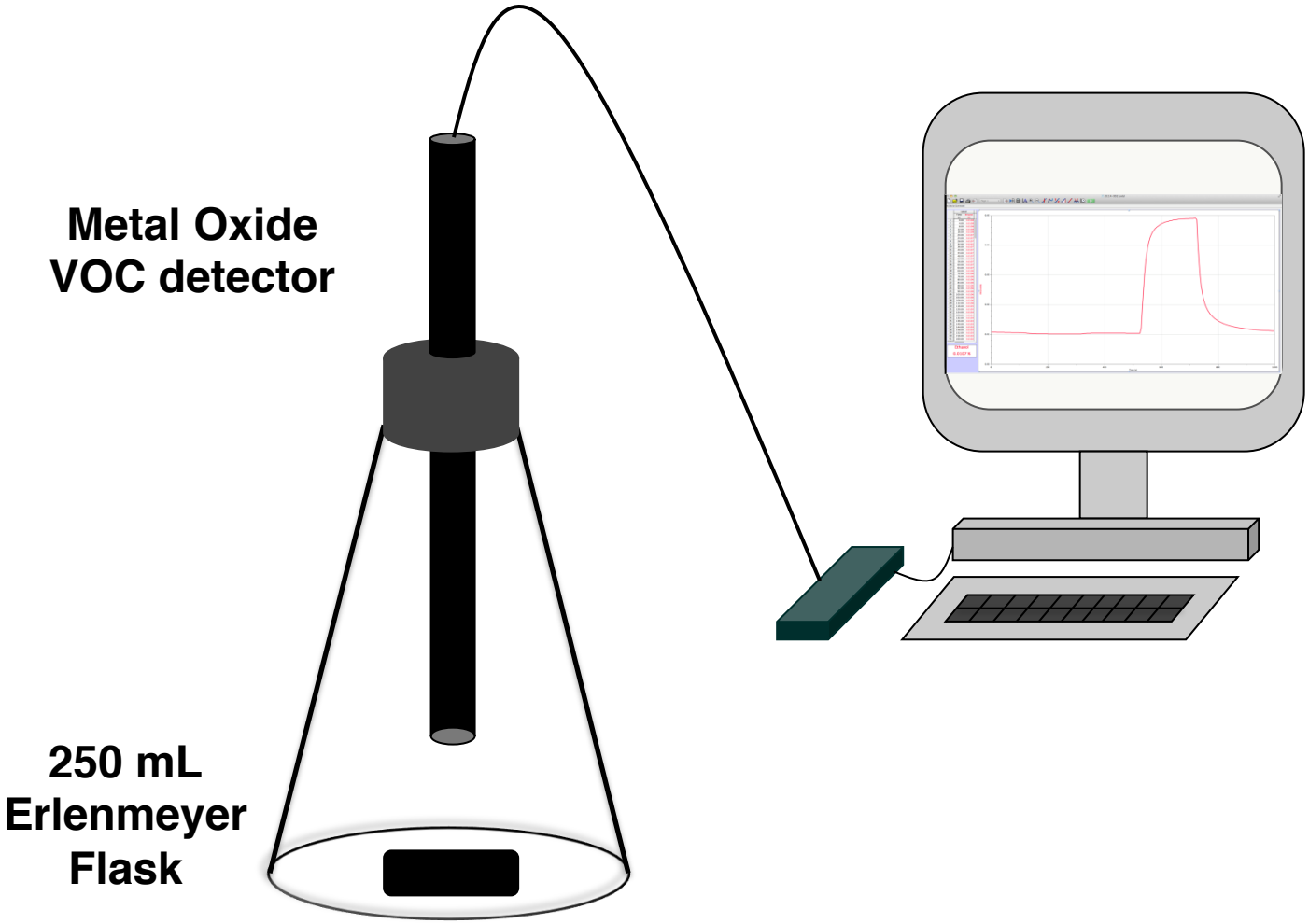
Objective

- To detect whether volatile organic compounds (VOCs) are released when high temperature plastic cooking dishes are heated in an oven
- To determine if the amount of VOC release is dependent on temperature
- To determine if VOC release can be correlated with mass loss of the plastic

What are VOCs?

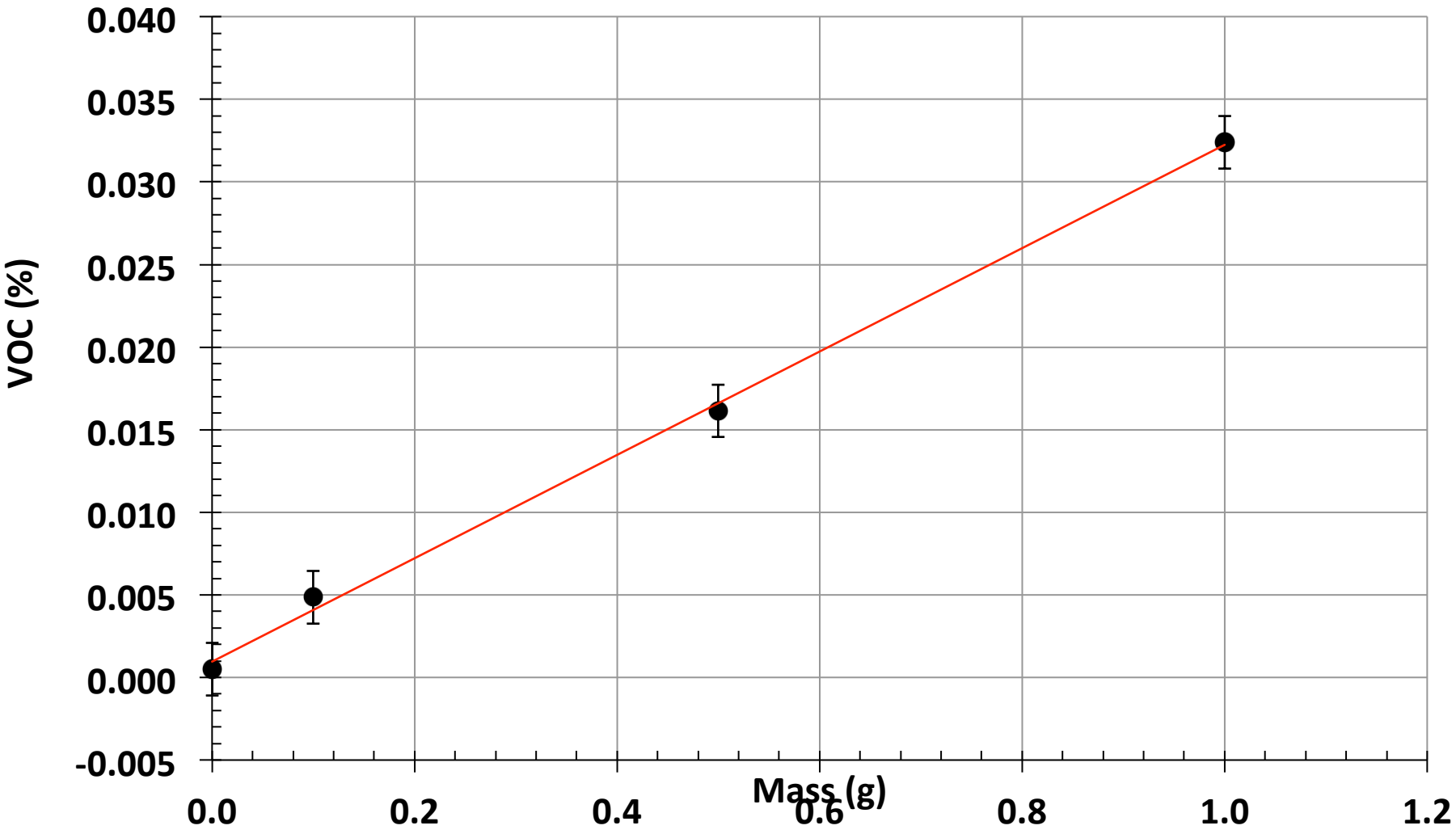
- VOCs have a significant vapor pressure and therefore are emitted as gases from solids and liquids.
- Some VOCs, particularly chlorinated ones, are easily absorbed through the body and are deposited in various organs.
- While not all VOCs are harmful, many are known carcinogens.

Experimental Setup



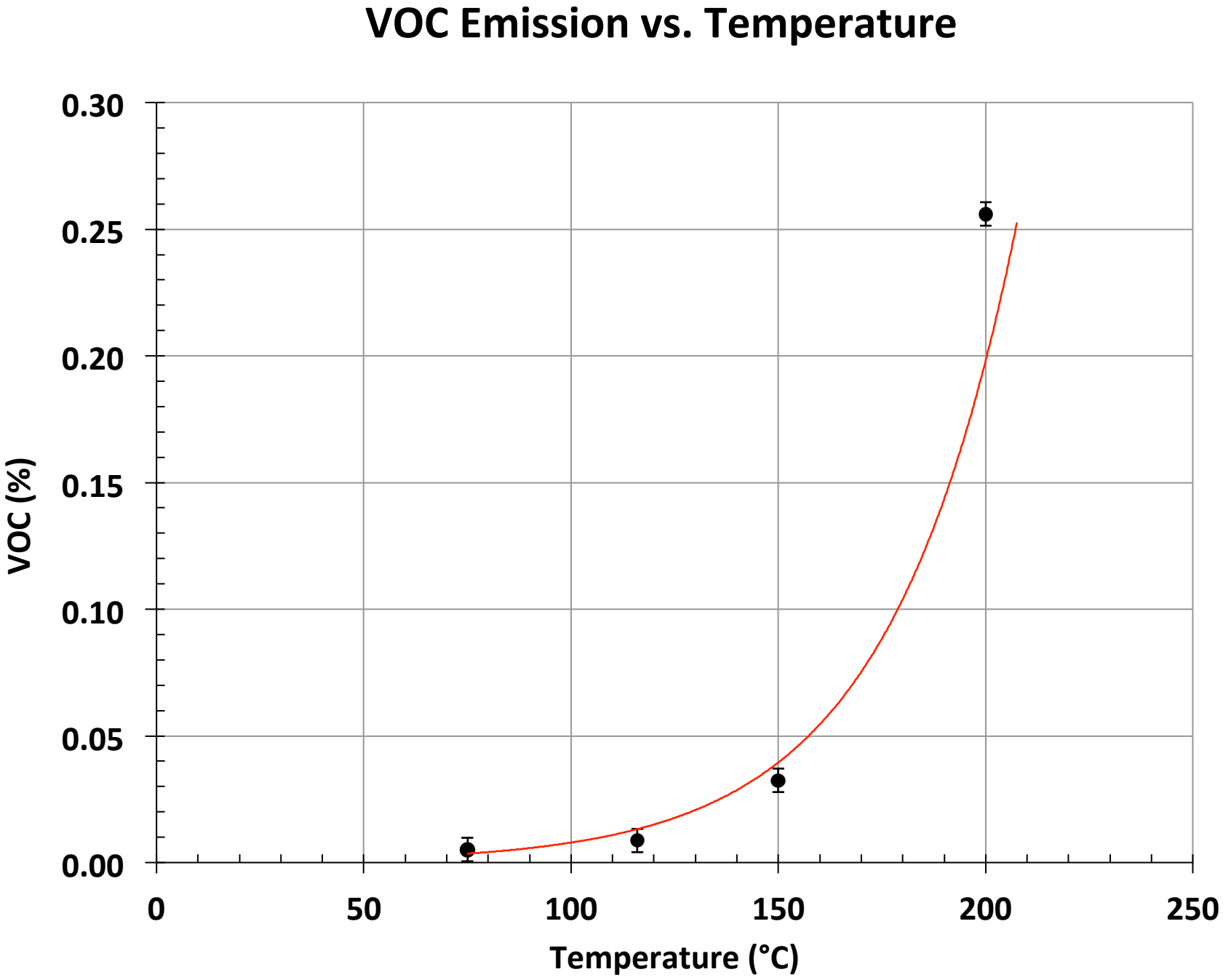
First Step: Is the VOC Detector Linear?

- Metal oxide VOC detectors are notoriously nonlinear: “Vernier” unit is software corrected.
- Cut samples of plastic into pieces of 0.1g, 0.5g, and 1g each.
- Place each piece in flask and seal all flasks with Al foil.
- Heat in oven at 150°C for 1 hr. and let all four flasks cool for ½ hr.
- Place VOC detector in flask.


VOC Signal vs. Sample Mass
150°C for 1 Hour
VOC (%)
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
-0.005
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Mass (g)

1st Experiment: VOC Release vs. Temperature

- Cut four - 1g samples of plastic and place in a flask sealed on top with Al foil.
- Heat one flask at 75°C, the second at 116°C, the third at 150°C, and the last at 200°C in oven for 1 hr.
- Cool flask for ½ hr.
- Place VOC detector in each flask and record signal.


VOC Emission vs. Temperature
0.30
0.25
0.20
0.15
0.10
0.05
0.00
VOC (%)
0
50
100
150
200
250
Temperature (°C)

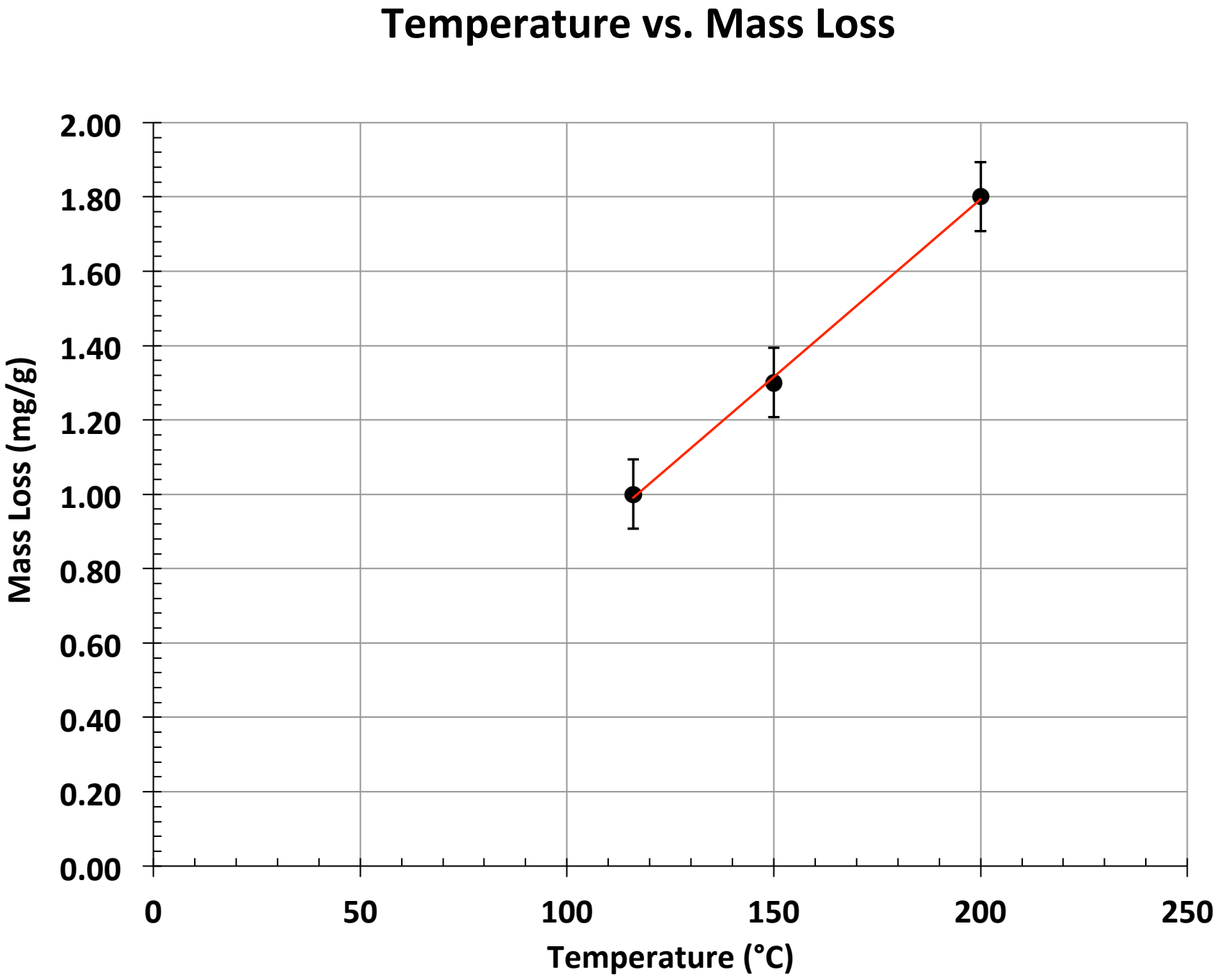
VOC Results

- When plastic samples were heated to product-specified cooking temperatures for product-specified periods of time, VOCs were released.

- The relationship between VOC emission and the temperature was exponential, typical of thermally activated chemical reactions.

2nd Experiment
Mass Loss vs. Temperature

- Cut three - 1g samples of plastic.
- Heat at 116°C, 150°C and 200°C for ½ hr.
- Weigh samples and note any change in mass.
- I observed a ca. 2 mg/g loss at 200°C.
- Assuming one molecular species: Formula weight of 50g, Ideal Gas Law predicts a VOC concentration of 0.4%, similar to what was observed (0.25%).


Temperature vs. Mass Loss
Mass Loss (mg/g)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
0
50
100
150
200
250
Temperature (°C)

Ideal Gas Law

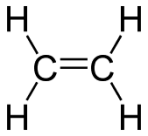
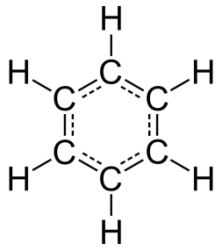
- $\frac{2 \times 10^{-3}\ g}{50\ g}$
- $(4 \times 10^{-5}\ \text{moles}) \times (22.4\ L)$
- $\frac{8.96 \times 10^{-4}\ L}{0.25\ L}$
- $3.58 \times 10^{-3} \approx 0.4\ \%$
- VOC concentration at 200°C was 0.25 %

Conclusions

- Disposable polyethylene terephthalate (PETE) plastic cooking dishes released VOCs with an exponential dependence on temperature.
- It was also determined that the mass loss of the plastics had a linear relationship to temperature.
- It seems likely that there are multiple thermo-chemical pathways to VOC release and mass loss and that the overall phenomenon is complicated and deserves more complete study.

Implications and Further Study

- Chemicals introduced into our environment, particularly those introduced to food, are a growing epidemiological concern.
- Do we really need to be cooking our food in plastic containers?
- Further studies would include using gas chromatography and mass spectroscopy to identify the individual VOCs being released from PETE plastic.

Degradation Product	Structure
aldehyde CO	
CO_2	
ethylene	
benzene	
biphenyl