Time and Temperature in Soapmaking

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Time and Temperature

- What is the “gel phase?”
- Why and when does it appear?
- Is it good or bad for my soap?

Acknowledgements

- Mike Lawson/Columbus Foods
- Hampden-Sydney College
  - John Campbell (NMR)
  - Andrew Basinger (Temp Profiles)
  - Tyler Bowman (Temp Profiles)
  - Drake Huzek (Kinetics)
  - Billy Eskridge (Kinetics)
  - Matt Huff (IR)

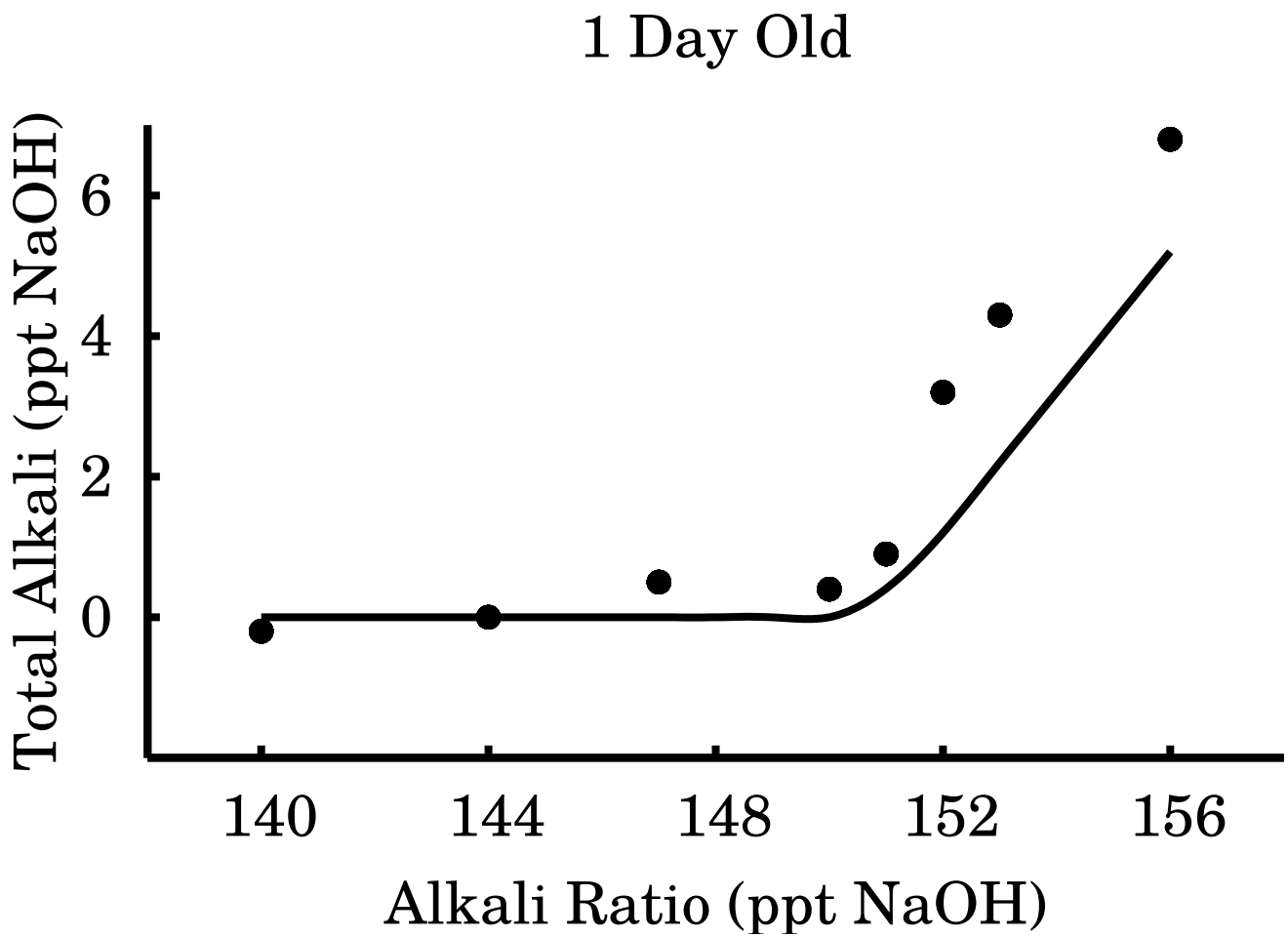
Acknowledgements

- Proctor and Gamble (DSC and XRD)
  - Jody Aiken
  - Steve Sealschott
  - David Bohlen
  - Kassy Pelzel
  - Pauline Vu

Saponification

- Oil + 3 NaOH = Glycerol + 3 Soap
- How much NaOH is needed?

Sodium Saponification Value



Delight

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- SSV of Delight is 150.8 ppt NaOH

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- 144/150.8 = 0.955, 4.5% lye discount

Lye Concentration

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- Anne Watson, *Smart Soapmaking* (2007)

  30-37%, 33% average

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- $\text{Delight}_{1000}\text{Lye}_{288}\text{Aq}_{0}$ (50.00% NaOH Lye)

  $\text{Delight}_{1000}\text{Lye}_{288}\text{Aq}_{72}$ (41.67% NaOH Lye)

  $\text{Delight}_{1000}\text{Lye}_{288}\text{Aq}_{144}$ (33.33% NaOH Lye)

  $\text{Delight}_{1000}\text{Lye}_{288}\text{Aq}_{216}$ (29.16% NaOH Lye)

  $\text{Delight}_{1000}\text{Lye}_{288}\text{Aq}_{288}$ (25.00% NaOH Lye)

More Lyes

- Lye = 50.00% NaOH, 50.00% distilled water
- $\text{Delight}_{1000}\text{Lye}_{288}\text{Aq}_{0}$ (11.18% Water)

  $\text{Delight}_{1000}\text{Lye}_{288}\text{Aq}_{72}$ (15.88% Water)

  $\text{Delight}_{1000}\text{Lye}_{288}\text{Aq}_{144}$ (20.11% Water)

  $\text{Delight}_{1000}\text{Lye}_{288}\text{Aq}_{216}$ (23.93% Water)

  $\text{Delight}_{1000}\text{Lye}_{288}\text{Aq}_{288}$ (27.41% Water)

More Lyes

- Lye = 50.00% NaOH, 50.00% distilled water
- $\mathrm{Delight}_{1000}\mathrm{Lye}_{288}\mathrm{Aq}_{0}$ (Low-Water)

  $\mathrm{Delight}_{1000}\mathrm{Lye}_{288}\mathrm{Aq}_{72}$

  $\mathrm{Delight}_{1000}\mathrm{Lye}_{288}\mathrm{Aq}_{144}$ (Medium-Water)

  $\mathrm{Delight}_{1000}\mathrm{Lye}_{288}\mathrm{Aq}_{216}$

  $\mathrm{Delight}_{1000}\mathrm{Lye}_{288}\mathrm{Aq}_{288}$ (High-Water)

Processing Soap

- 100 g oil + water + lye into 500 mL plastic bottle
- Shaken 15 sec on a paint shaker
- Gently swirled until trace
- Poured into a nest of styrofoam cups
- Temperature recorded every 15 min for 4 hours

Phases

- Ice, water, steam

Phases

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- Ice, cream, ice cream

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- Ice, cream, ice cream
- Gel, sol (Jello)

Phases

- Ice, water, steam
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- Flour, water, gravy

Phases

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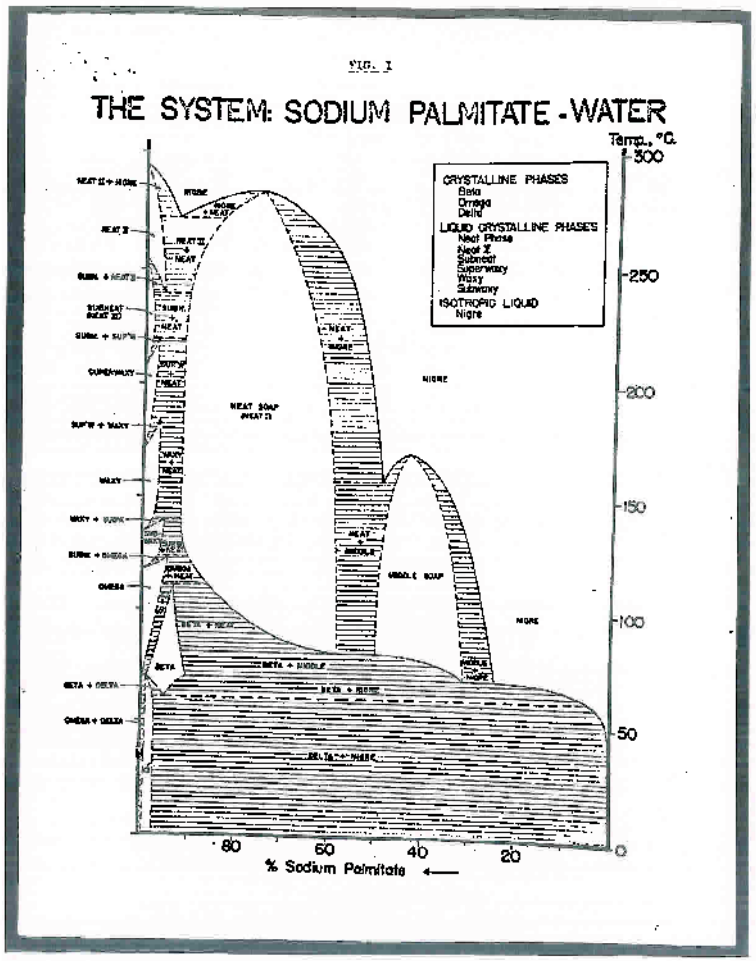
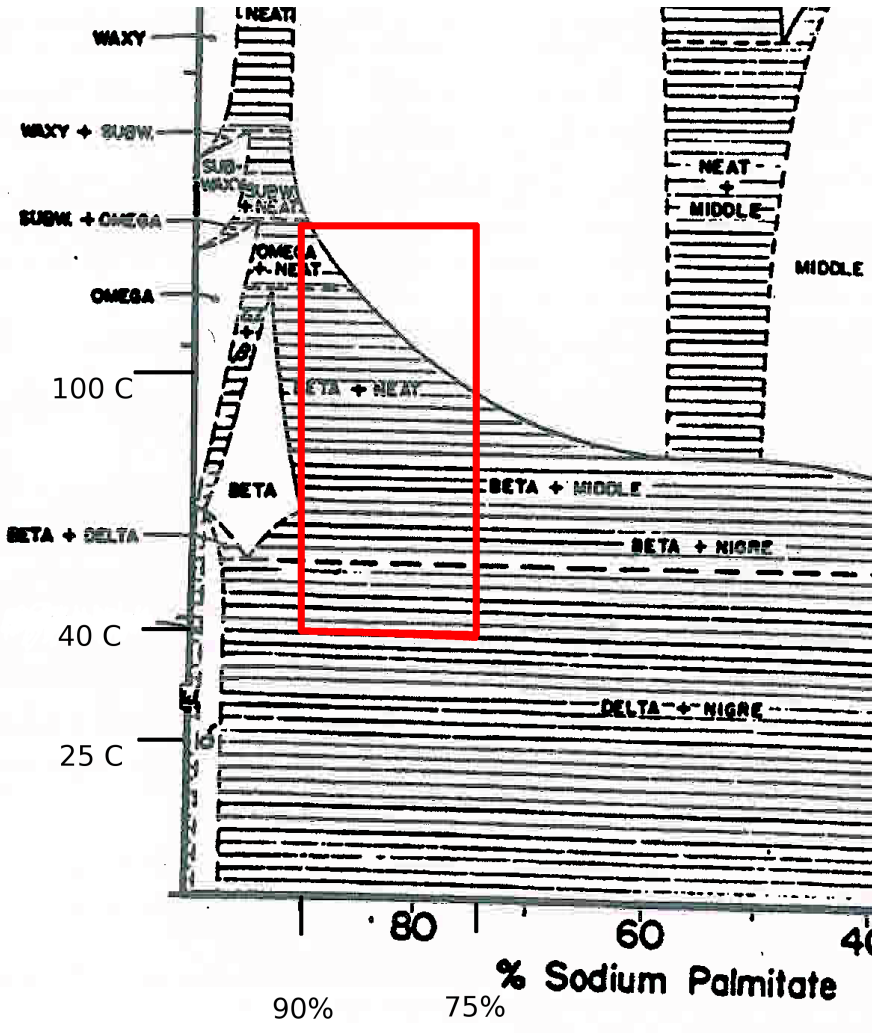
- Ice, cream, ice cream
- Gel, sol (Jello)
- Sugar, water, honey
- Flour, water, gravy
- Soap is more complex than any of these.

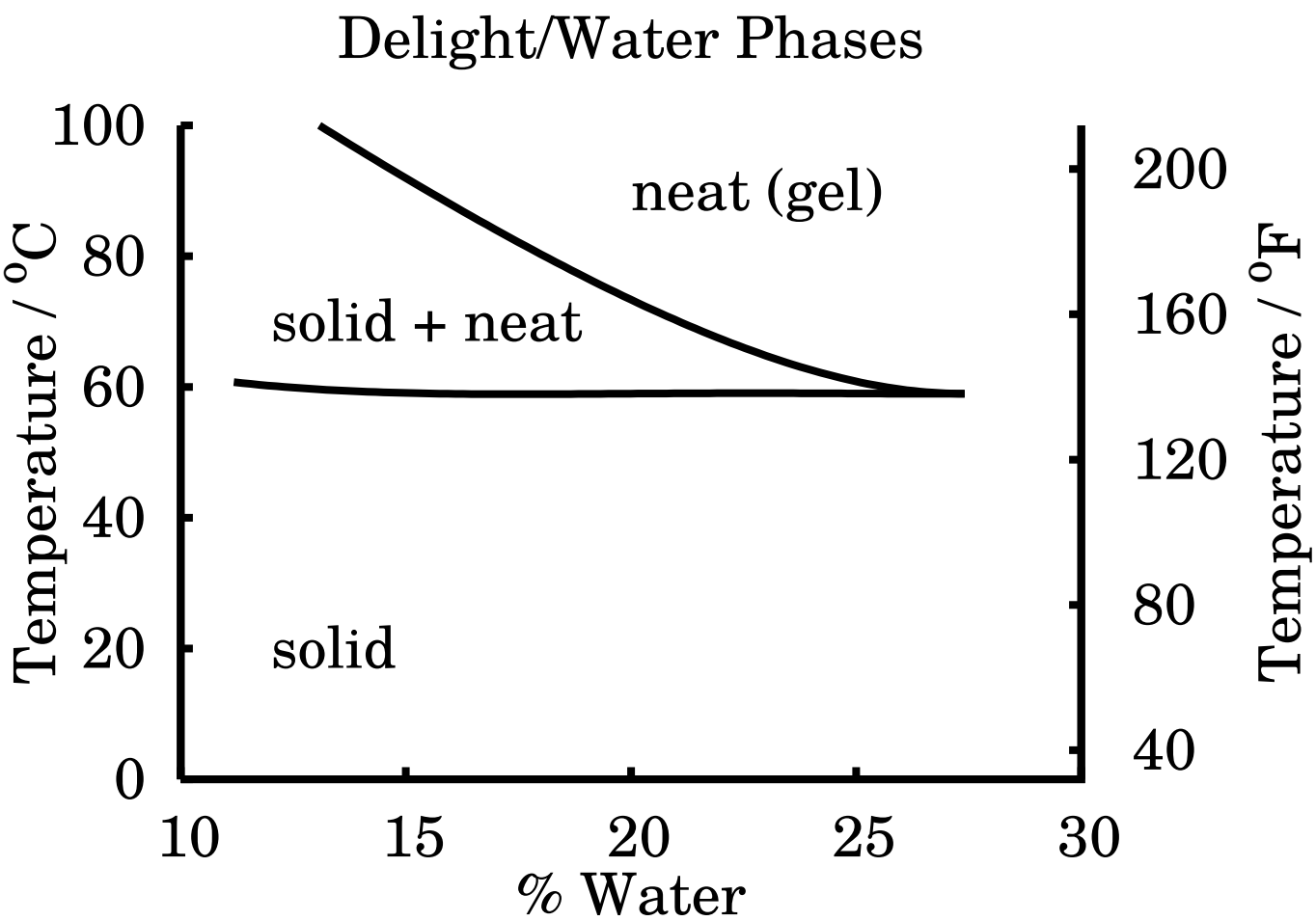
Phase Diagram



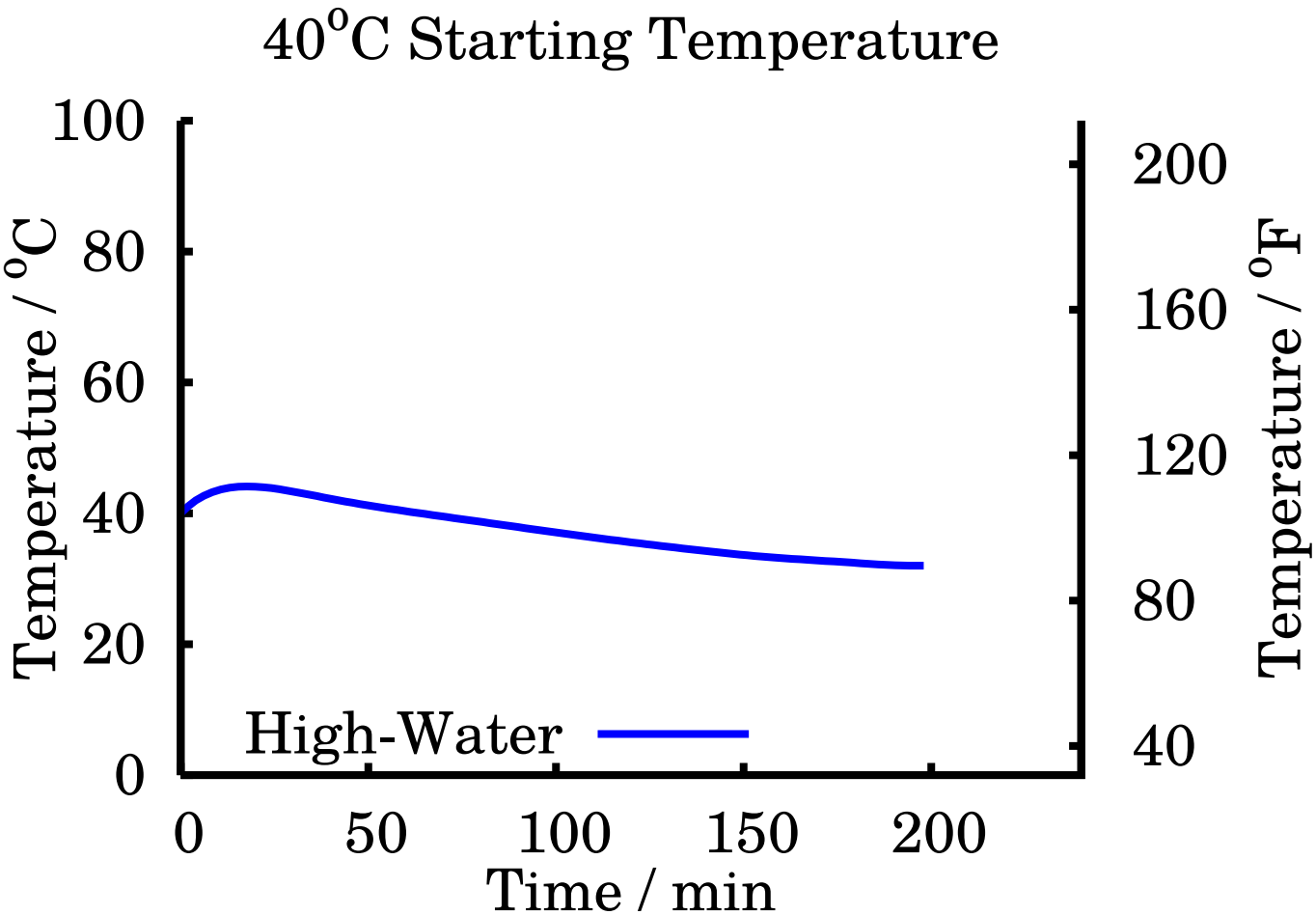
Where We Work



Delight


Delight/Water Phases
100
80
60
40
20
0
Temperature / °C
200
160
120
80
40
Temperature / °F
neat (gel)
solid + neat
solid
10
15
20
25
30
% Water

Time and Temperature



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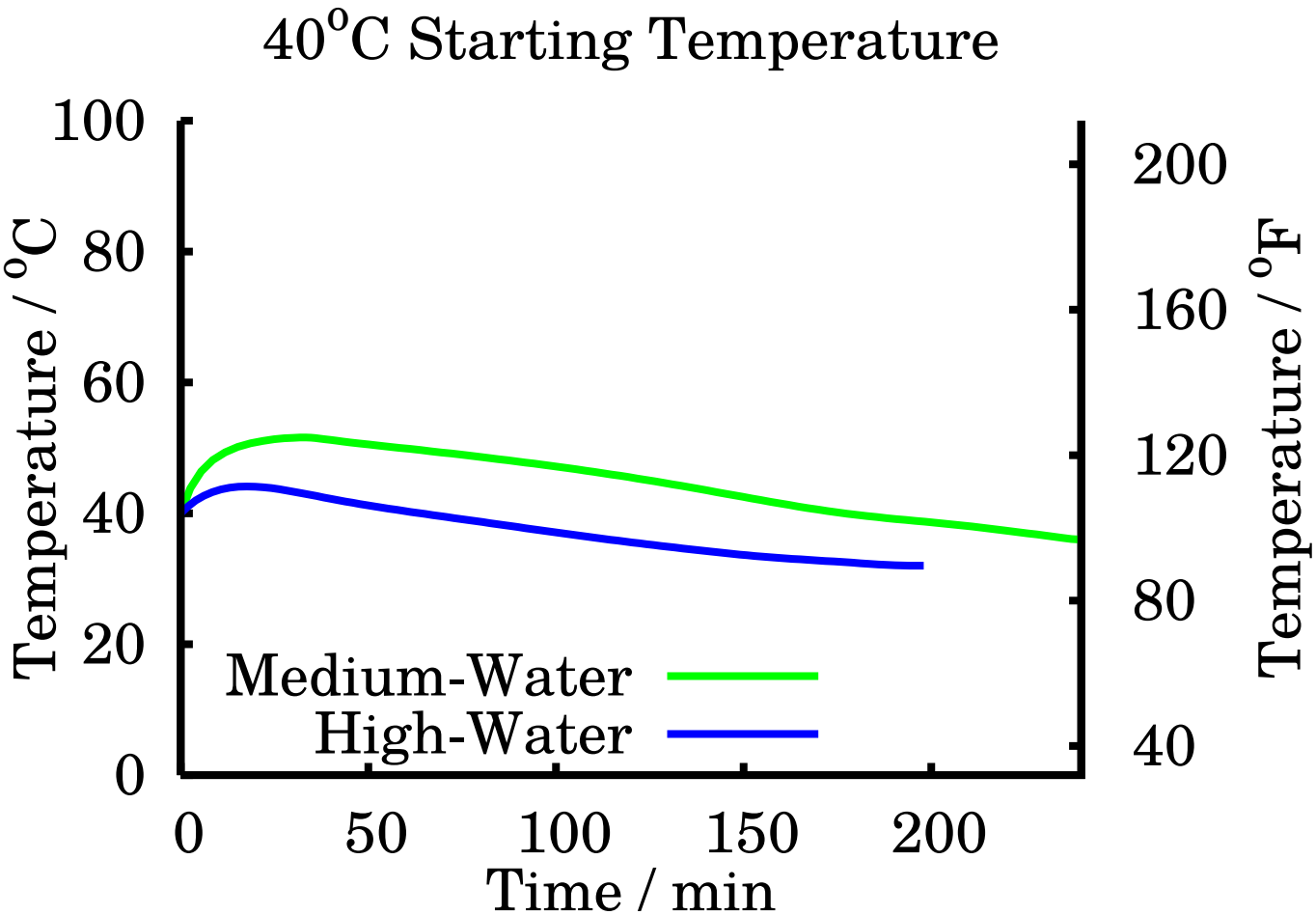

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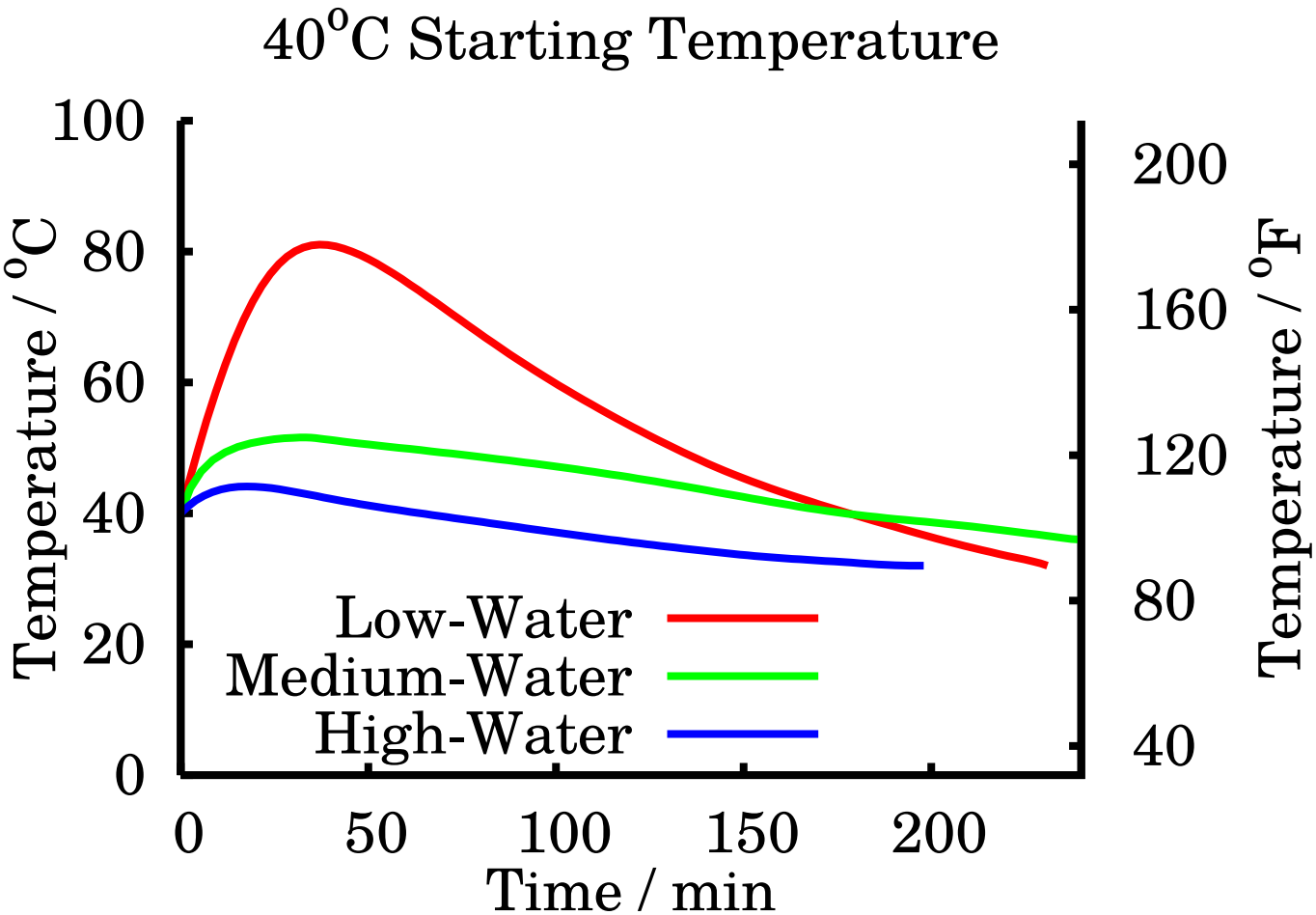
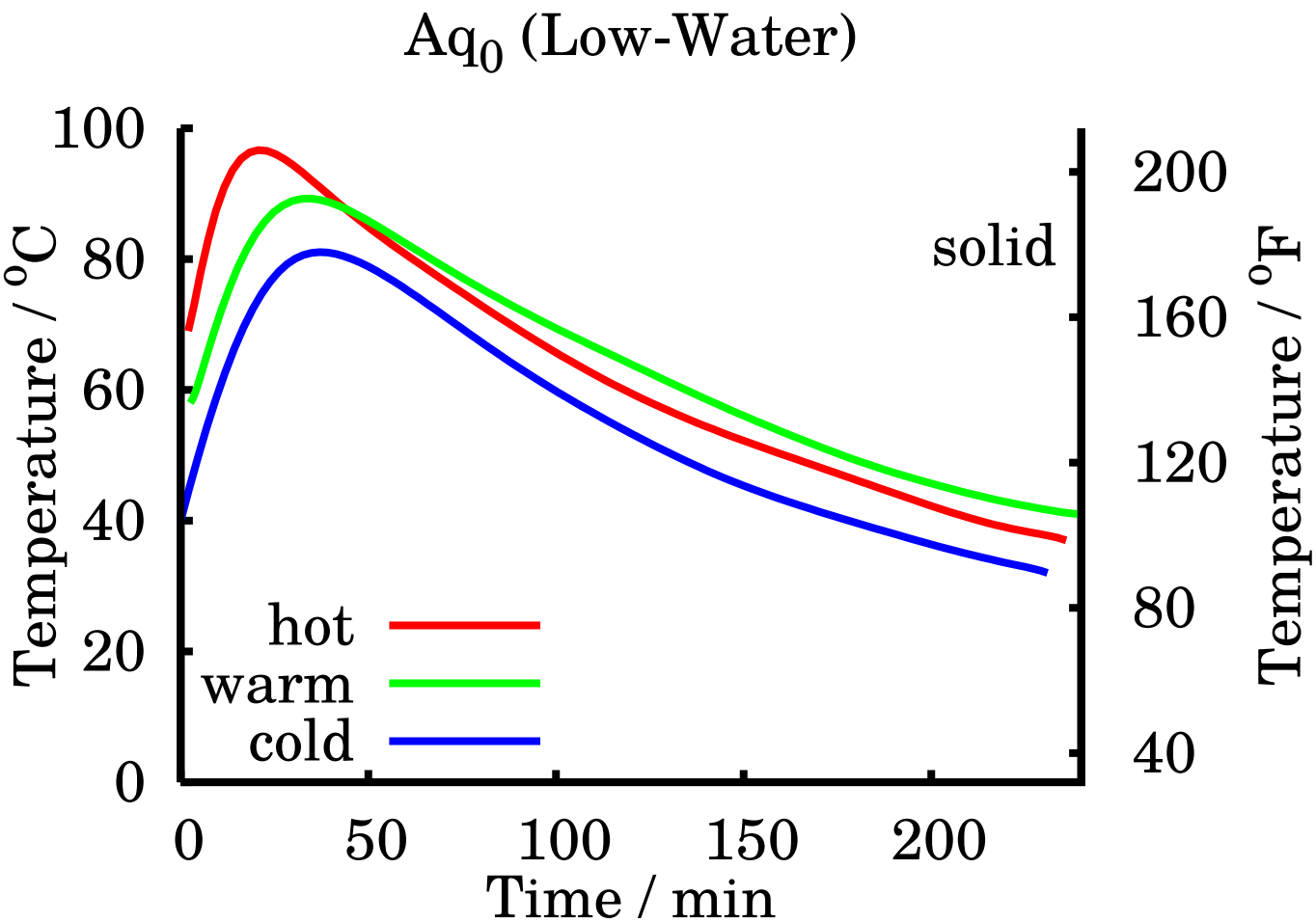
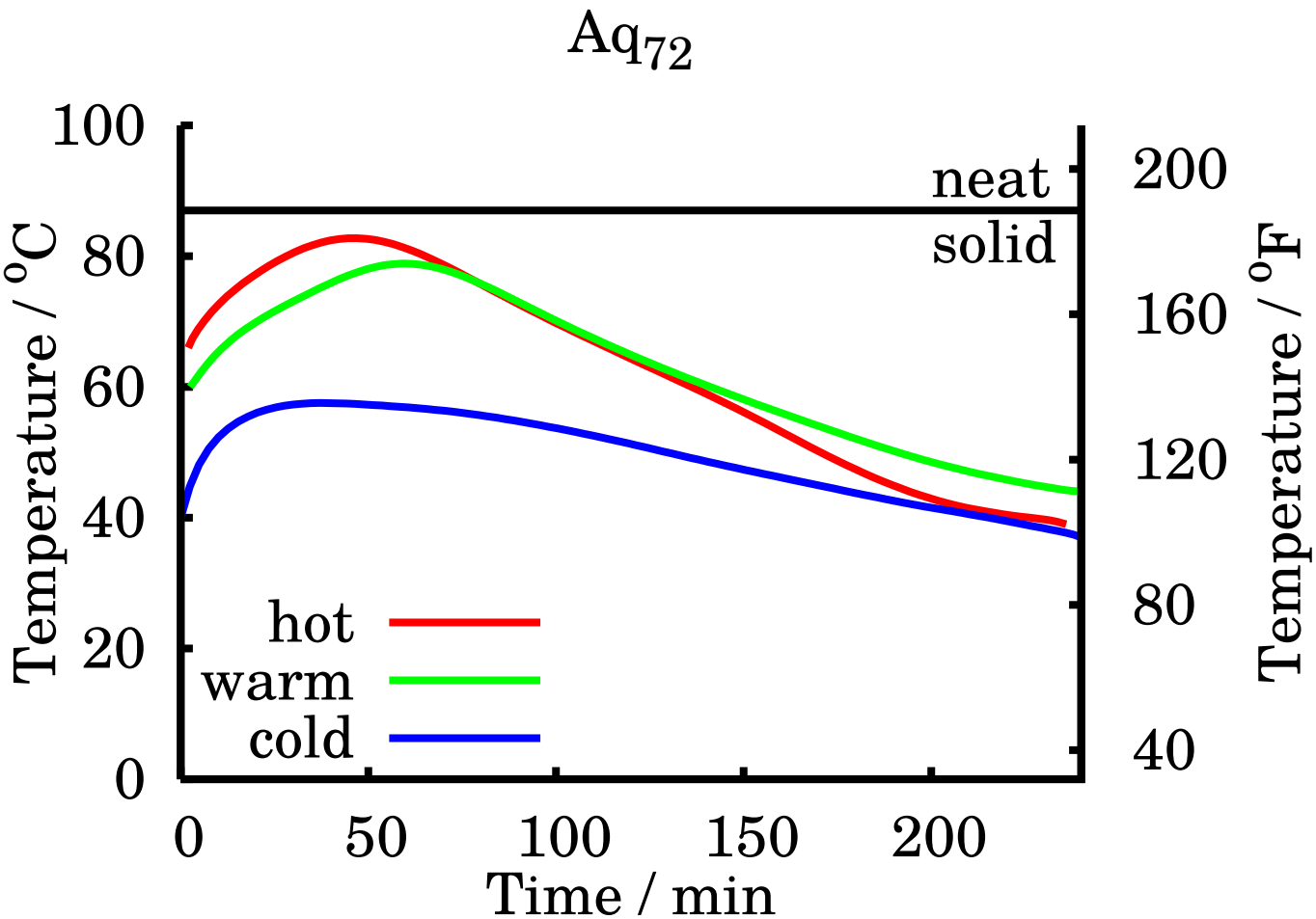


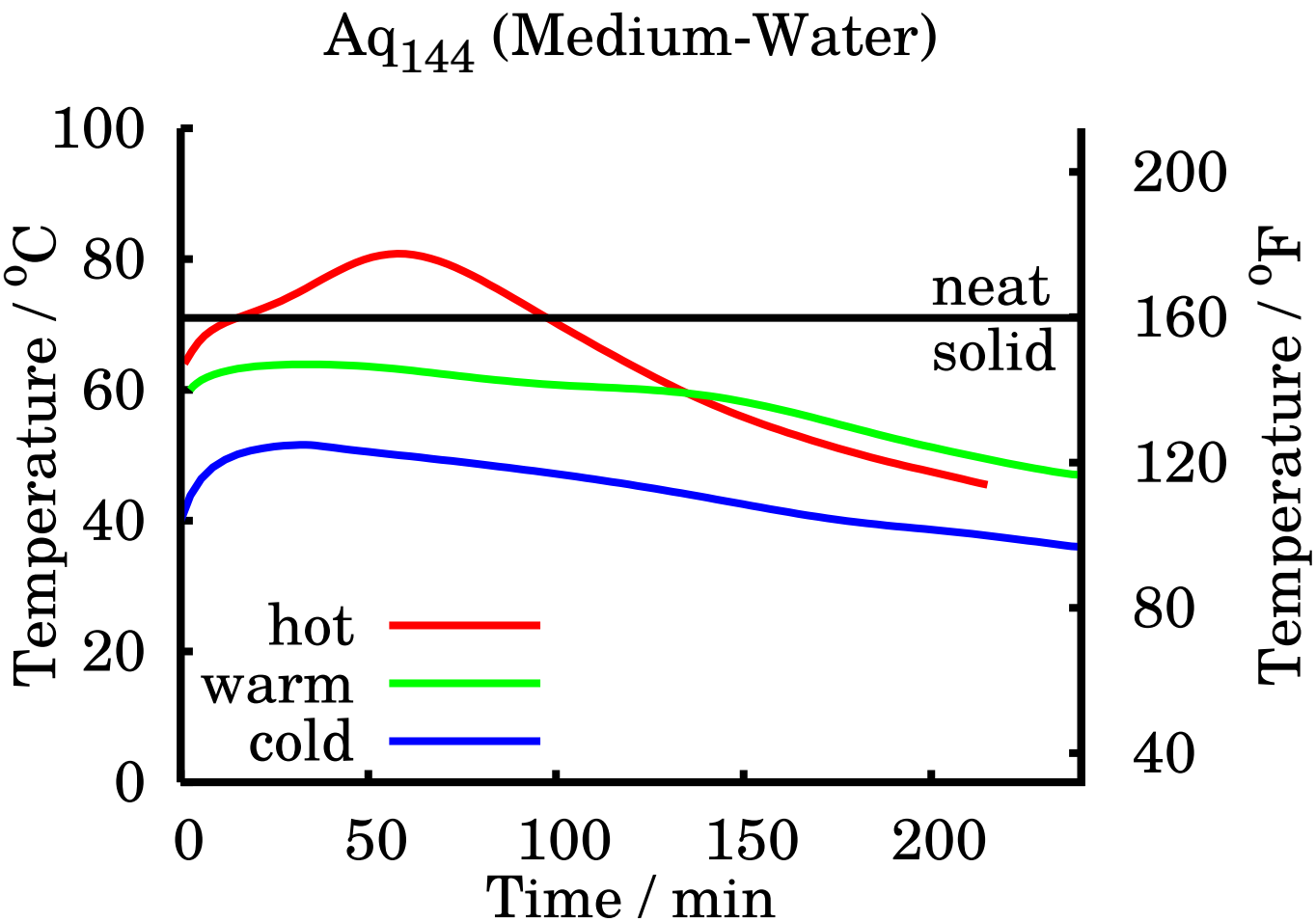
Delight


Aq0 (Low-Water)
Temperature / °C
Temperature / °F
100
80
60
40
20
0
200
160
120
80
40
0
50
100
150
200
Time / min
solid
hot
warm
cold

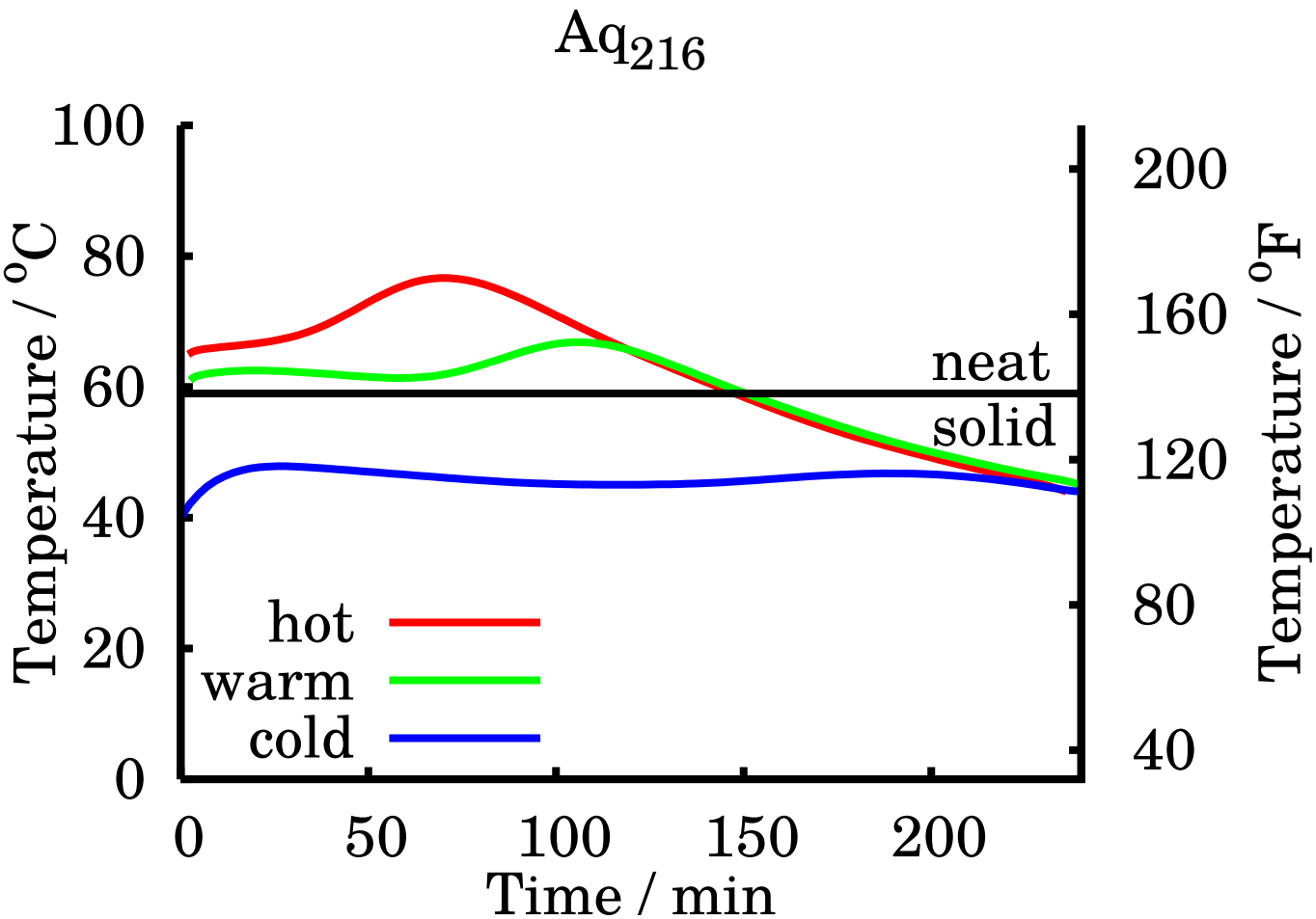
Delight


Aq72
100
80
60
40
20
0
Temperature / °C
200
160
120
80
40
Temperature / °F
neat
solid
hot
warm
cold
0
50
100
150
200
Time / min

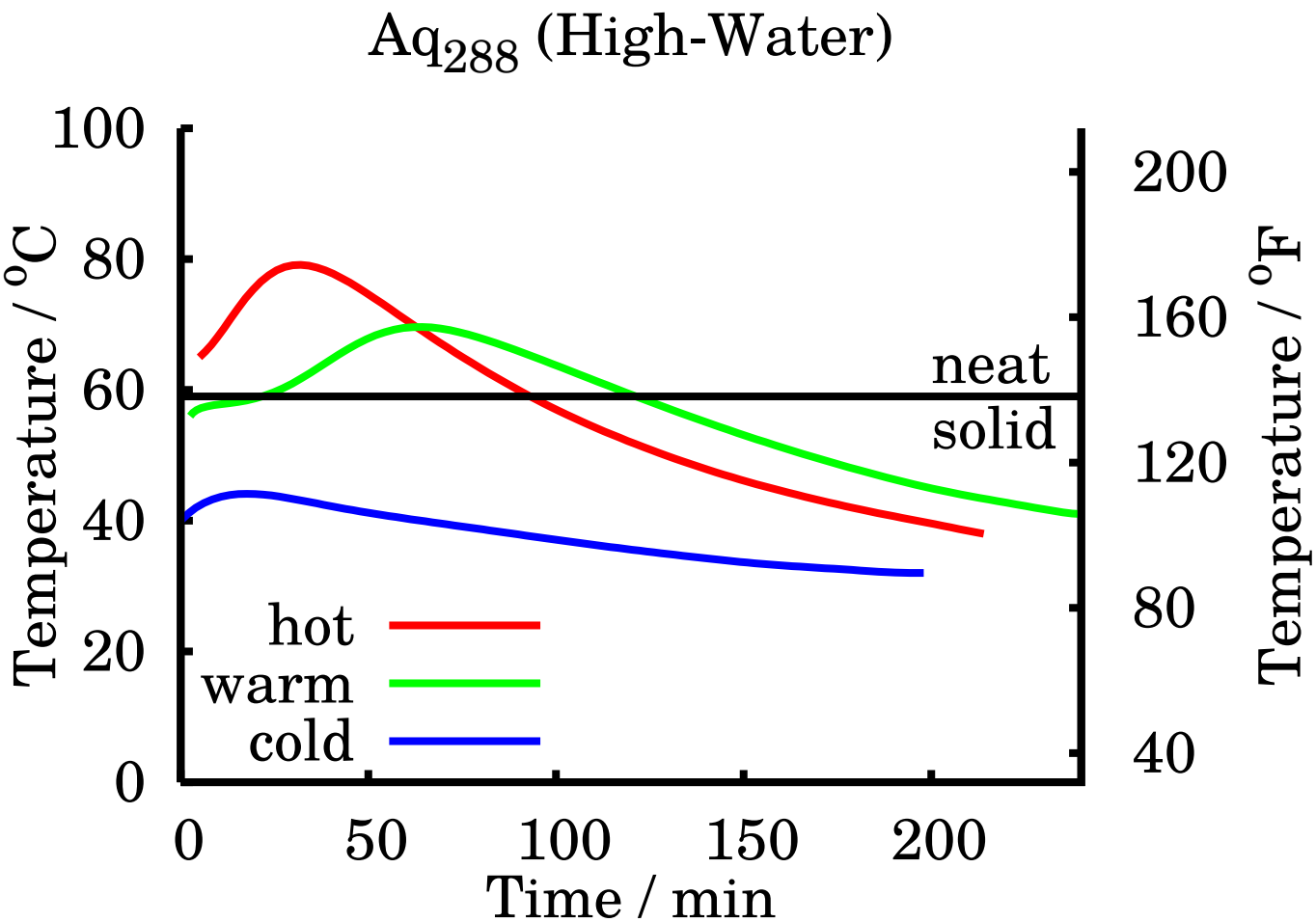
Delight


Aq144 (Medium-Water)
Temperature / °C
Temperature / °F
Time / min
0
20
40
60
80
100
40
80
120
160
200
0
50
100
150
200
neat
solid
hot
warm
cold

Delight


Aq216
Temperature / °C
Temperature / °F
100
80
60
40
20
0
200
160
120
80
40
0
50
100
150
200
Time / min
neat
solid
hot
warm
cold

Delight


Aq288 (High-Water)
Temperature / °C
Temperature / °F
Time / min
0
20
40
60
80
100
40
80
120
160
200
0
50
100
150
200
neat
solid
hot
warm
cold

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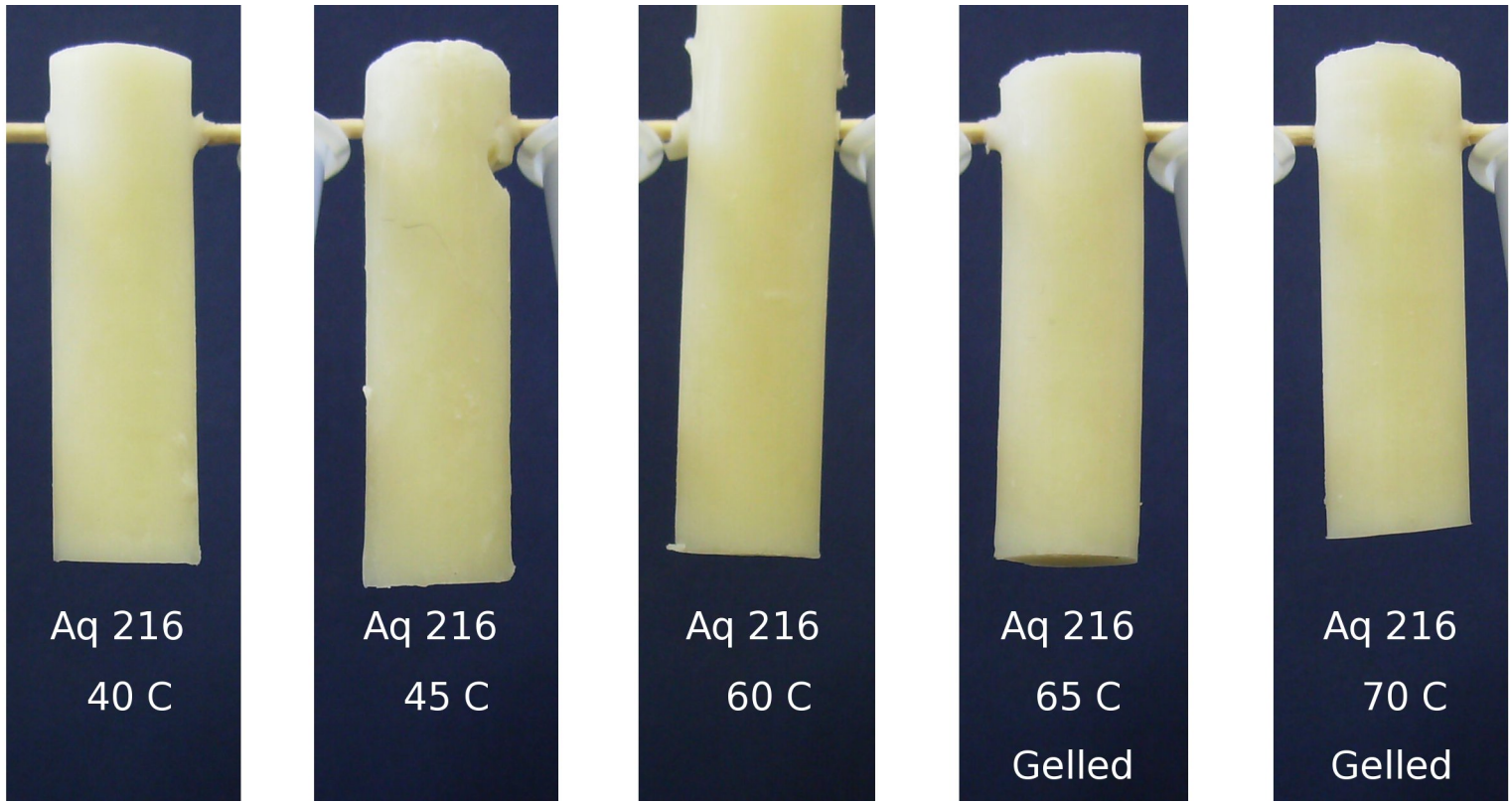
  - Soaps had the same alkalinity.
  - Soaps had the same hardness.
  - Soaps behaved differently when soaked in water.

Soap Soak Test

Soap cylinders soaked in water for 18 hrs.

Soap Soak Test: 0 hrs



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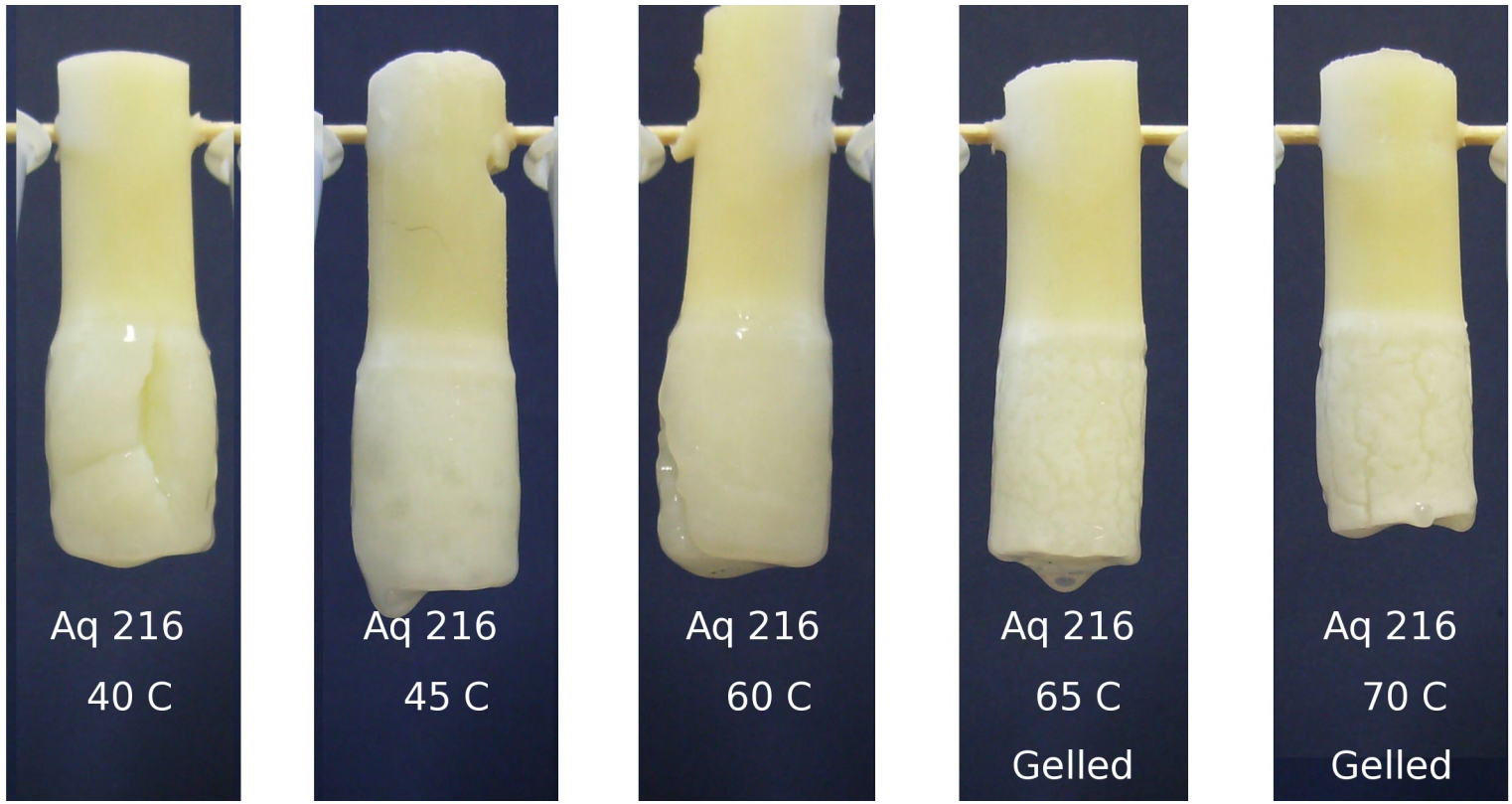

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- Did soaps “survive” because they got hot?
- Did soaps “survive” because they gelled?
- We can compare hot soaps with different moisture content.

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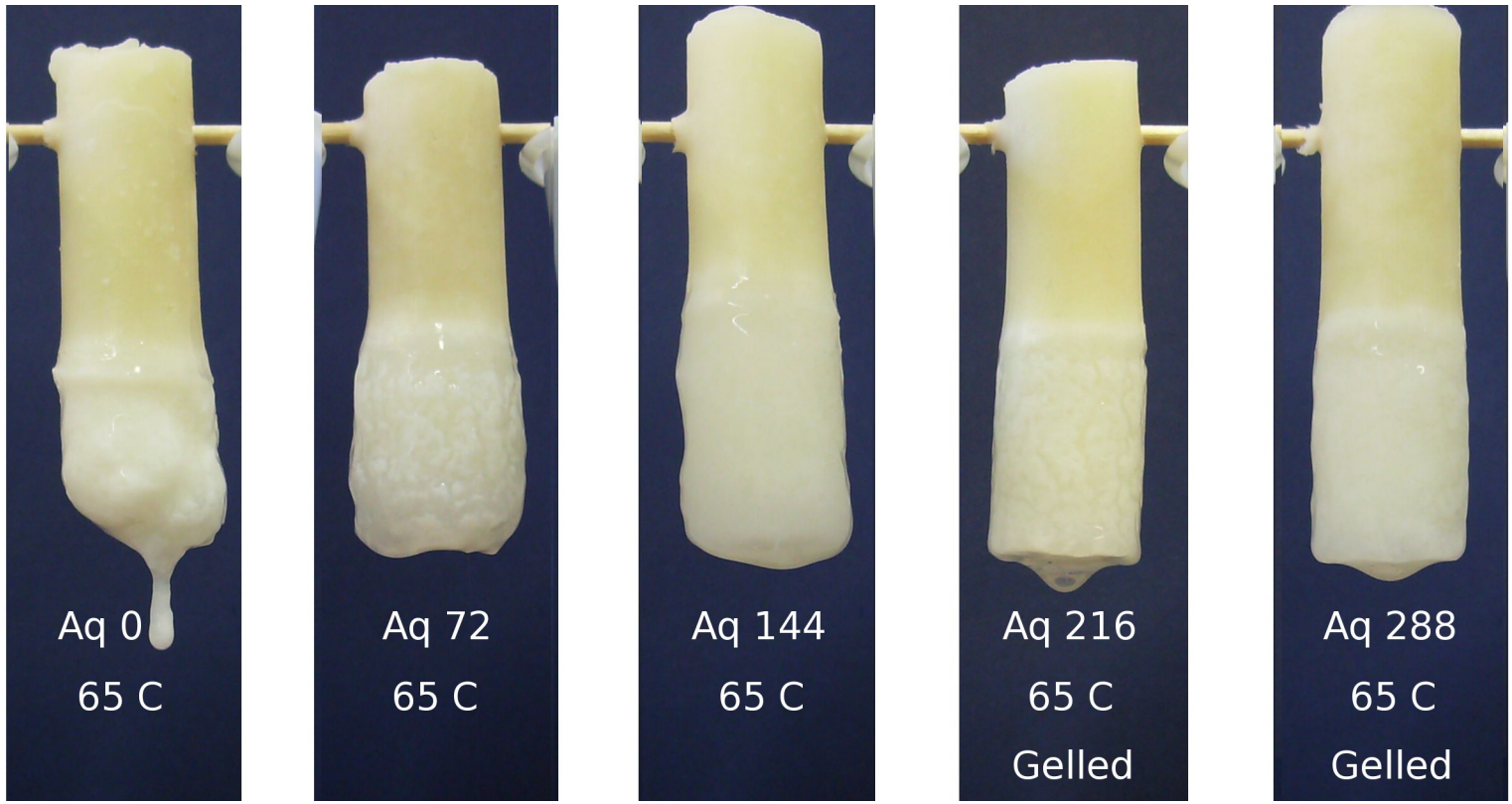

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- Fragrances and additives. Fragrances and additives may increase the speed of saponification and peak temperature.

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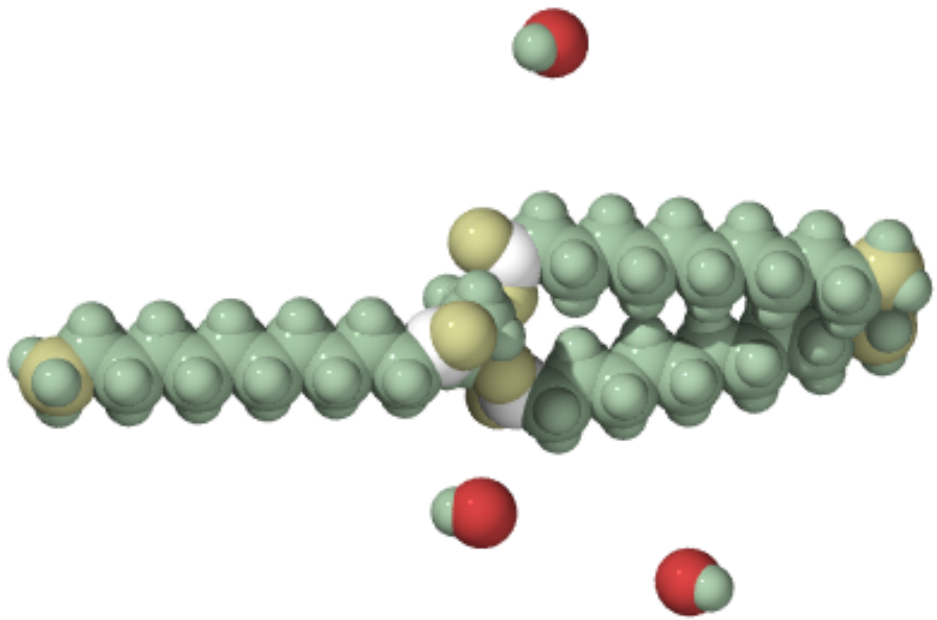
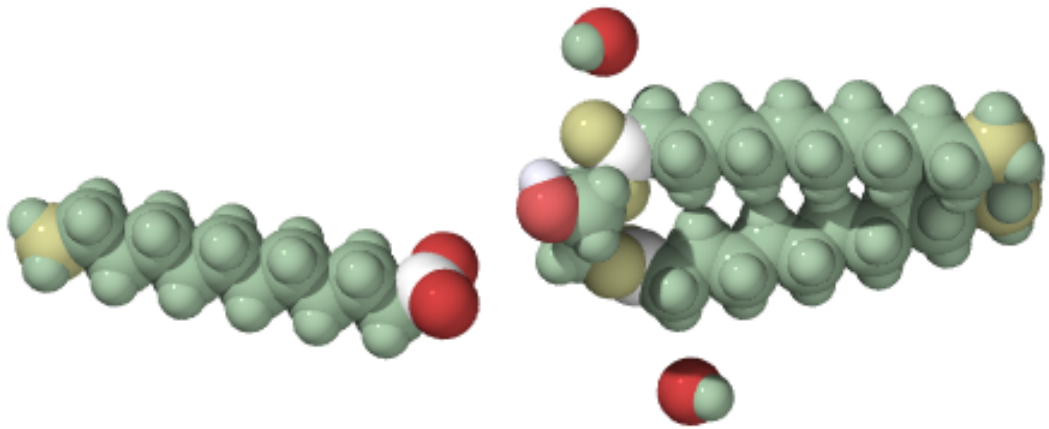
- So.. What are the two kinds of molecules and why do they behave this way?

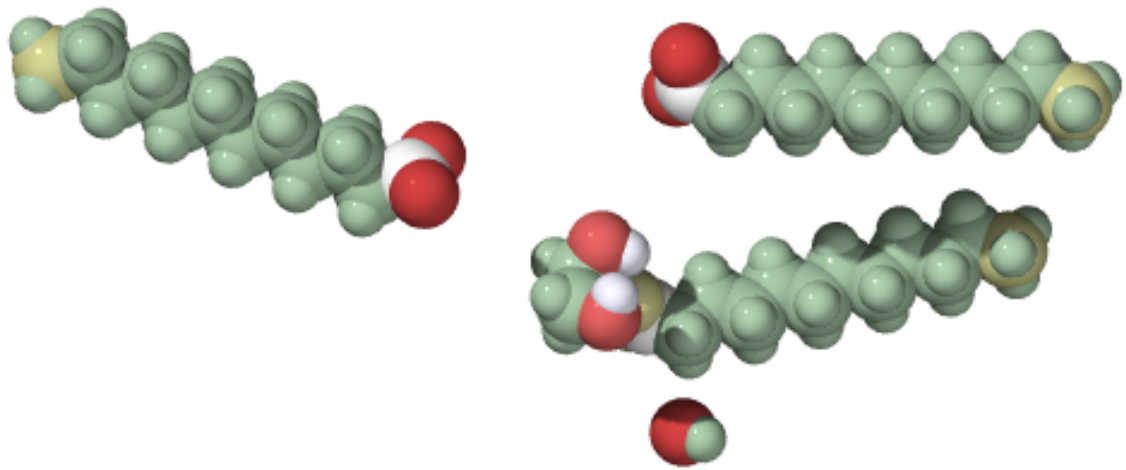
Oil and Lye



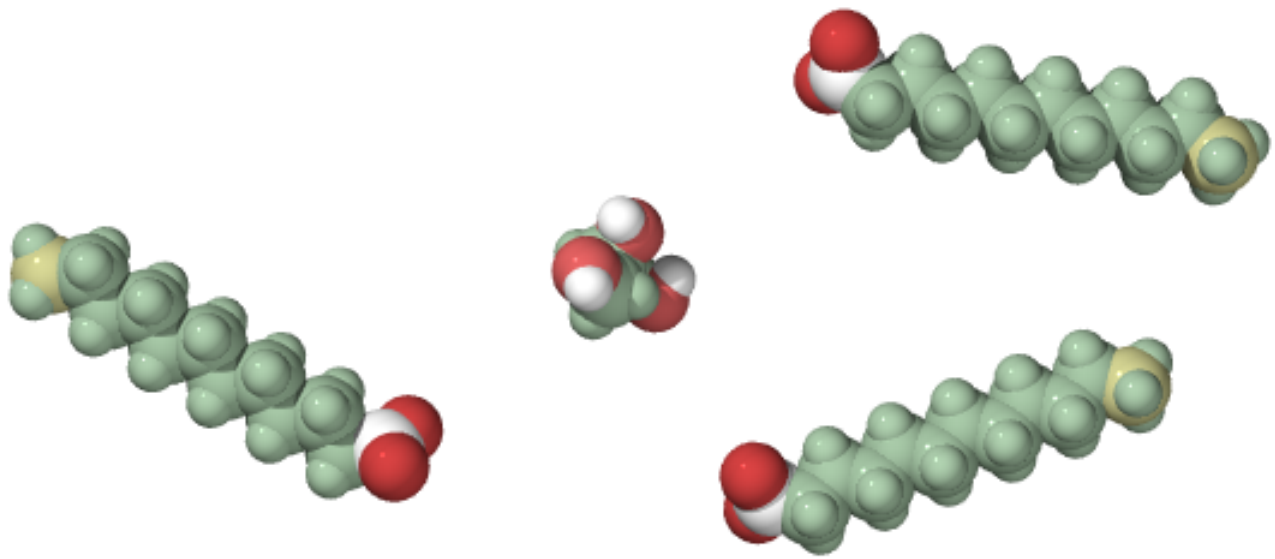
One Soap



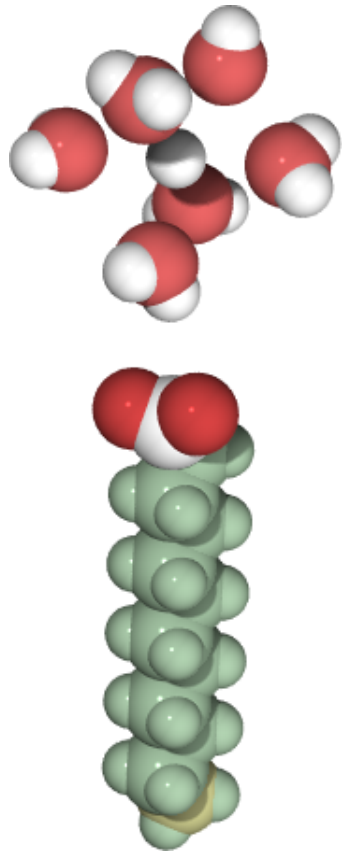
Two Soaps



Three Soaps and a Glycerin

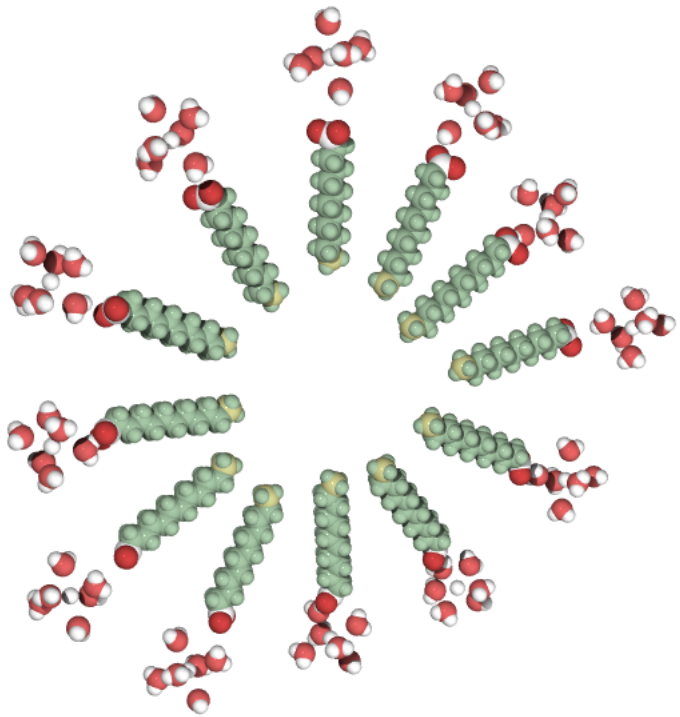


Soap and Water

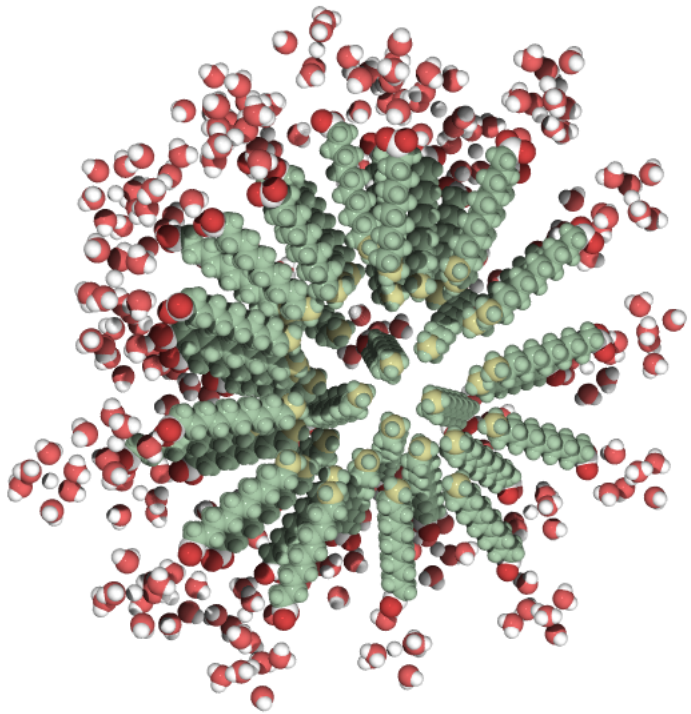


Nerds and Cheerleaders

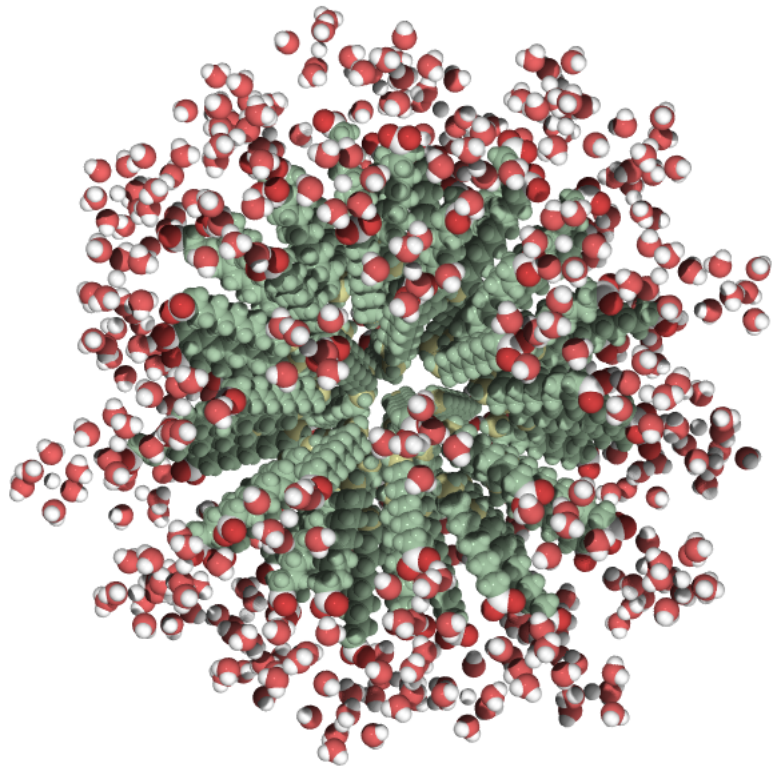
Soap Micelle



Soap Micelle

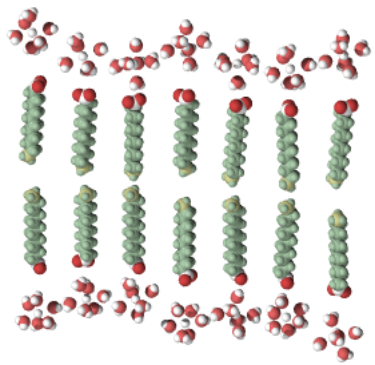


Soap Micelle

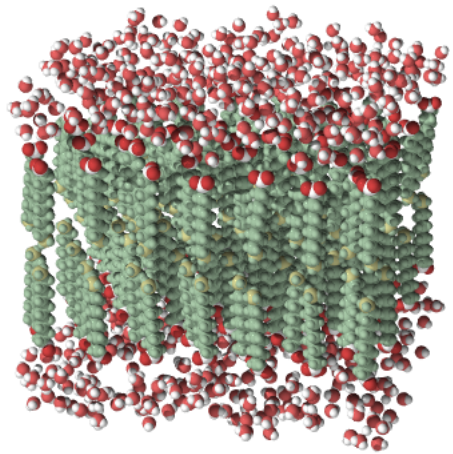


Animation: (http://cavemanchemistry.com/graphics/Micelle.gif)

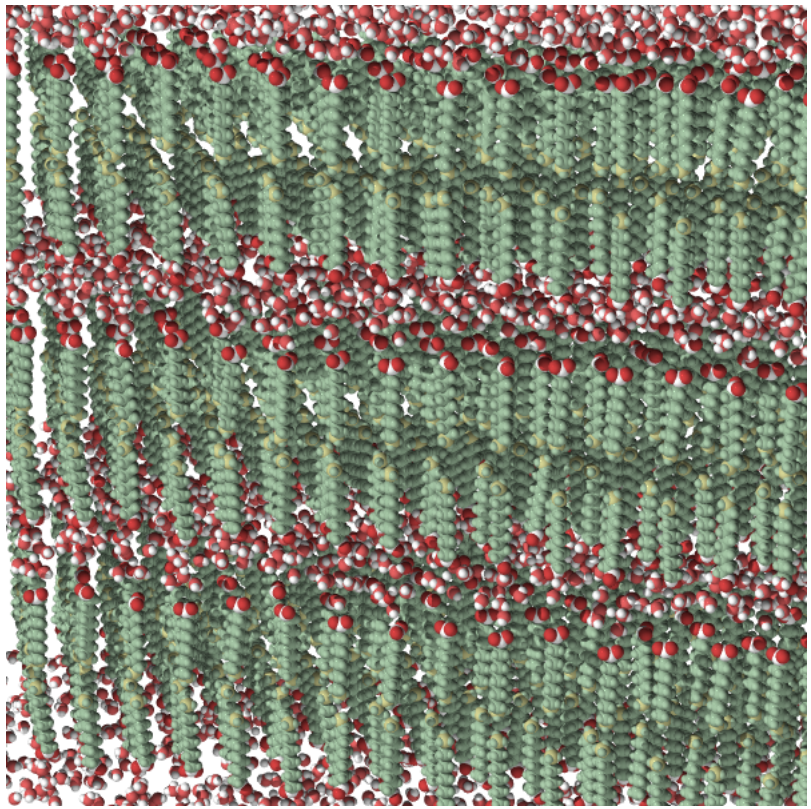
Neat Soap



Neat Soap

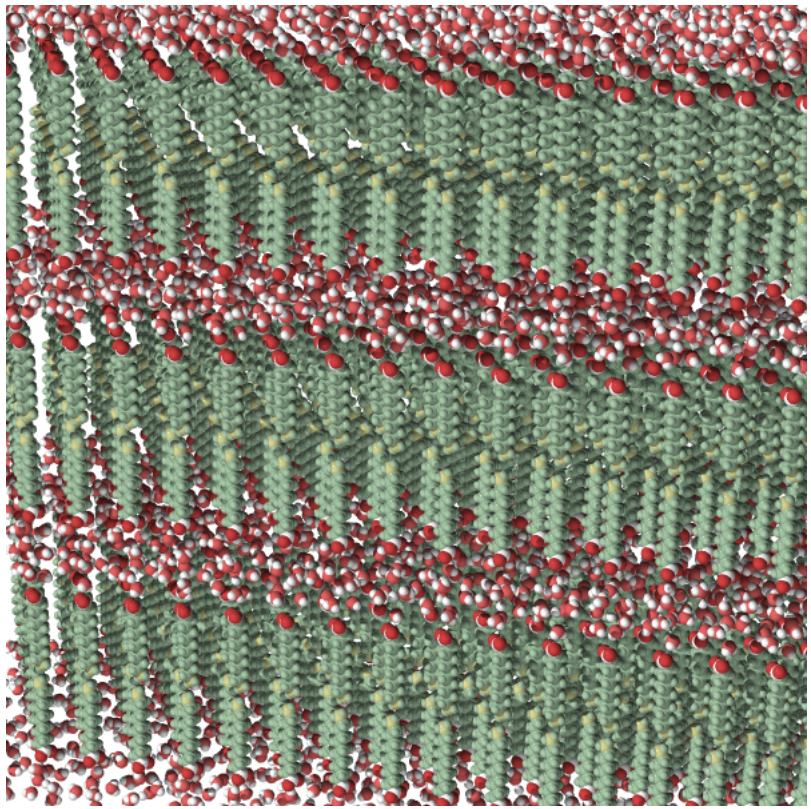


Neat Soap



Animation: (http://cavemanchemistry.com/graphics/Neat.gif)

Solid Soap



Animation: (http://cavemanchemistry.com/graphics/SolidSoap.gif)

Conclusions

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- Neat soap is a lamellar lyotropic liquid crystalline phase of soap and water.
- The structure of solid soap is similar to that of neat soap, but the fatty tails of the soap molecules are “frozen” in a crystal lattice.

Recommendations

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- If you want to prevent a gelling soap from doing so, decrease the water portion and/or the starting temperature.
- Gelled soap is neither better nor worse than non-gelled soap, but it is subtly different in its water-absorbing properties.

Questions

Questions?

Scientific Soapmaking

- The textbook for the course you *wish* you had taken in high school.
- To be completed this summer.
- Available now in draft form: ScientificSoapmaking.com.

References

- "Structure of the Liquid Crystal Phases of the Soap-Water System: Middle Soap and Neat Soap," Luzzati, Mustacchi, and Skoulios, *Nature* Sept 21, 1957.
- "Solid Soap Phases," Ferguson, Rosevear, and Stillman, *Ind. Eng. Chem.*, 35(9), 1938.