Temperature, Specific Heat, and Latent Heat

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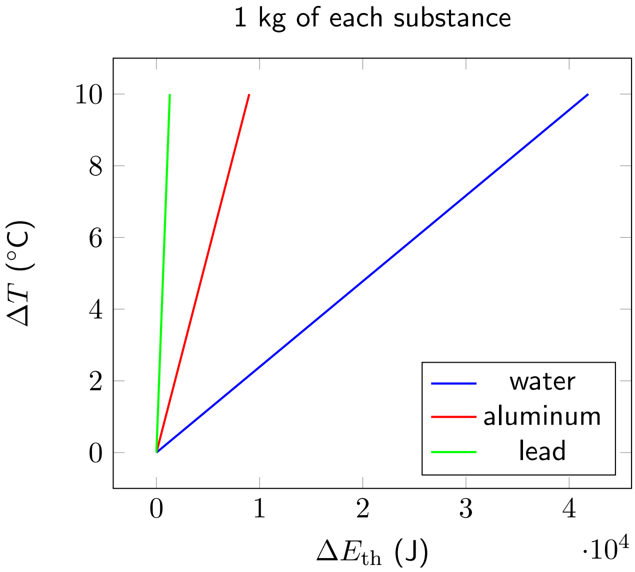
Temperature Scales

100°C	212.0°F
90°C	194.0°F
80°C	176.0°F
70°C	158.0°F
60°C	140.0°F
50°C	122.0°F
40°C	104.0°F
30°C	86.0°F
20°C	68.0°F
10°C	50.0°F
0°C	32.0°F

Thermal Equilibrium

- Two substances in contact will reach the same temperature.
- But temperature is not something one substance gives to the other.
- Substances don't give or receive temperature. They give or receive *energy*.

Specific Heat relates temperature and thermal energy



Specific Heat

- A hot substance has more thermal energy than an otherwise identical cold substance.
- How are thermal energy and temperature related?

$$\Delta E_{\text{th}} = mc\Delta T$$

- ΔE_{th} = change in thermal energy of the substance
- m is the mass of the substance
- c is the specific heat of the substance (J/kg°C)
- ΔT = change in temperature of the substance

Specific Heats of materials

Substance	Specific Heat (J/kg·°C)
Aluminum	900
Copper	390
Iron or steel	450
Lead	130
Silver	230
Water	
Ice (-5°C)	2100
Liquid (15°C)	4186
Steam (110°C)	2010

Specific heat problems: two methods

- Method 1: Heat Gained = Heat Lost

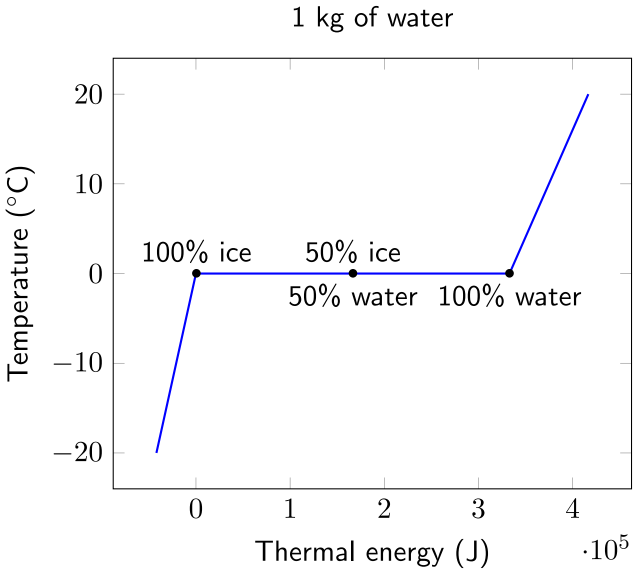
$$m_1 c_1 \left|\Delta T_1\right| + m_2 c_2 \left|\Delta T_2\right| = m_3 c_3 \left|\Delta T_3\right|$$

  - No negative numbers
  - Sometimes $|\Delta T| = T_f - T_i$ and sometimes $|\Delta T| = T_i - T_f$.
- Method 2: $\Delta E_{\mathrm{th}} = 0$

$$m_1 c_1 \Delta T_1 + m_2 c_2 \Delta T_2 + m_3 c_3 \Delta T_3 = 0$$

  - Negative numbers
  - Always $\Delta T = T_f - T_i$.
  - Latent heats can be tricky.

Latent Heat of Fusion



Latent Heat

- It takes energy to change phase.
- The energy required to go from a solid to a liquid is called the *latent heat of fusion*.
- The energy required to go from a liquid to a gas is called the *latent heat of vaporization*.
- During the phase change, energy is added, but no increase in temperature takes place.

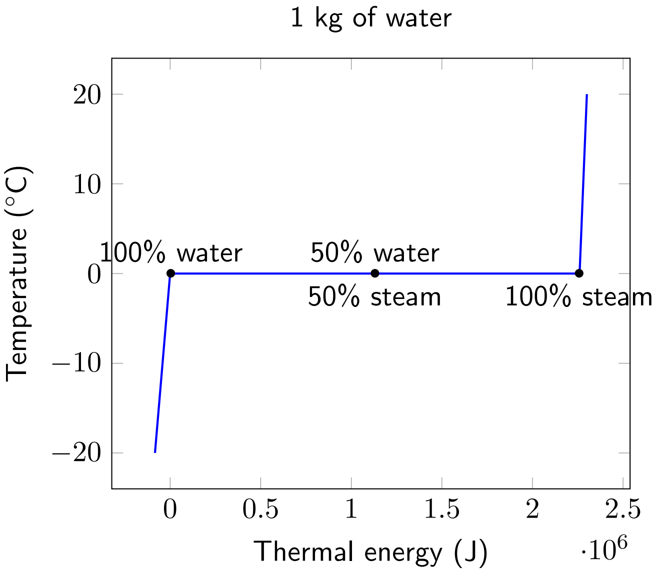
$$\Delta E_{\text{th}} = mL$$

- $\Delta E_{\text{th}} =$ change in thermal energy of the substance
- m is the mass that changes phase
- L is the latent heat of the substance (J/kg)

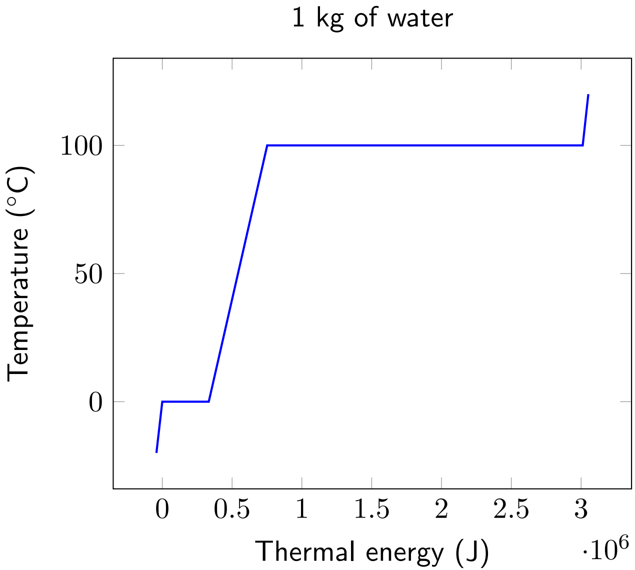
Latent Heats of materials

Substance	Melting Point (°C)	Heat of Fusion (J/kg)	Boiling Point (°C)	Heat of Vaporization (J/kg)
Water	0	333,000	100	2.26×10^6
Lead	327	25,000	1750	870,000

Latent Heat of Vaporization



Temperature-Energy relationship for 1 kg of water



Conceptual Latent Heat Question

A mass M_I of ice at a certain initial temperature T_I is combined with a mass M_W of water at a higher initial temperature of T_W. The two are allowed to come to thermal equilibrium without gaining or losing thermal energy to the surroundings. Consider the following energies that would be needed or released *if* the processes described were to occur.

Energy required to heat mass M_I of ice from T_I to 0°C	172,000 J
Energy required to melt mass M_I of ice at 0°C	28,000,000 J
Energy released in freezing mass M_W of water at 0°C	32,000,000 J
Energy released in cooling mass M_W of water from T_W to 0°C	8,420,000 J

Will the final state be all water, all ice, or a mixture of ice and water? Explain how you know.