Name Example

Stone Soup:
The Specific Heat of Water

Substance	Specific Heat (Joule/K/kg)
Air (50°C)	1050
Alcohol	2430
Copper	390
Iron or Steel	460
Glass	840
Quartz	762
Granite	**804**
Sandstone	1088
Shale	712
Soil (average)	1050
Wood (average)	1680
Ice	2100
Steam	2050
Water	**4186**

Water on Earth plays a significant role in the climate, both globally and locally. The major reason it does so is because it takes the input or removal of a lot of heat (energy) to change the temperature of water. This property is called a high *specific heat*.

For a rock dropped into a cup of water, the rock loses heat and the water absorbs heat and both come to a final temperature, T_f given by

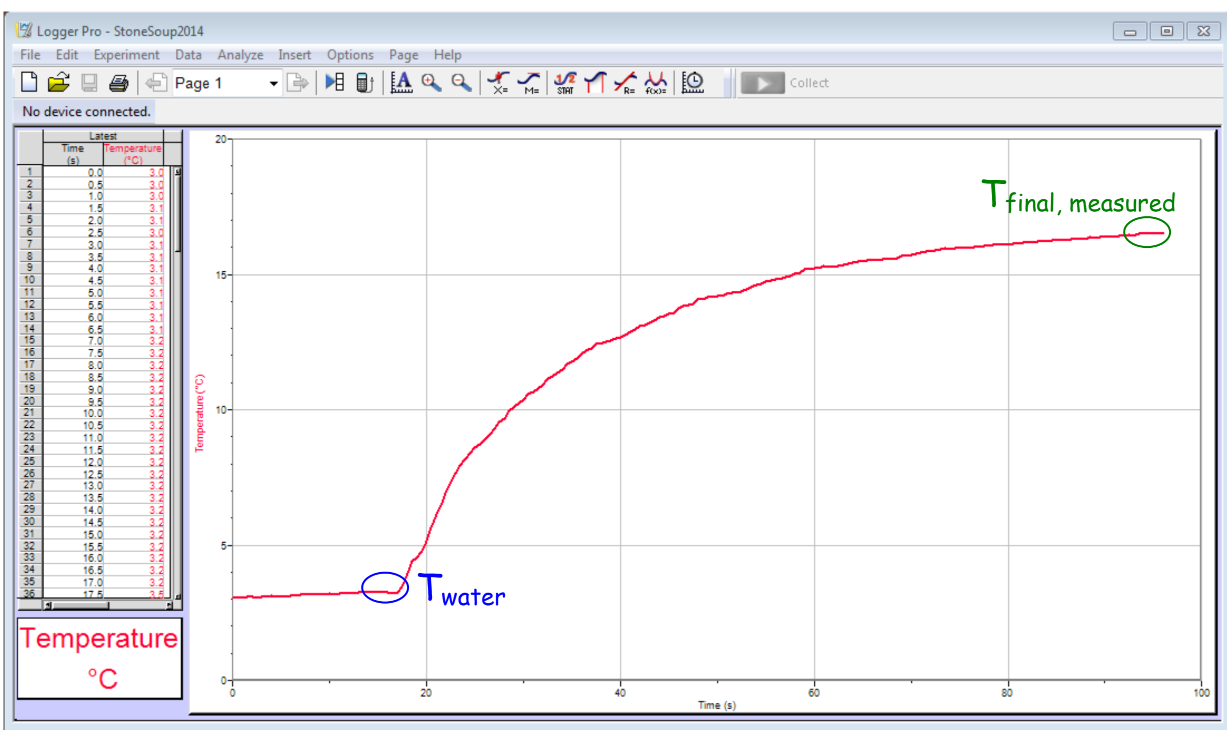
$$T_{final} = \frac{m_{water} c_{water} T_{water} + m_{rock} c_{rock} T_{rock}}{\left(m_{water} c_{water} + m_{rock} c_{rock}\right)}$$

Power up the laptop connected to the Vernier Lab-Pro Temperature probe. Open the Logger-Pro software by clicking on its icon on the task bar (shown to the right). The temperature detected by the probe will show up in the bottom left corner.

a) Place 150 mℓ of water (no ice!) from in your calorimeter and place the probe in it. The mass of the water is found from its volume knowing water has a density of 1 g/cm^3 = 1 g/mℓ:

Volume of water: V_w = 150 **mℓ** **Mass of water: m_w =** 150 **g ÷ 1000 =** 0.150 **kg**

b) Click the "Collect" button at the top of the Logger Pro window just before the rock is dropped in. Once it's dropped in, **stir the water continually** and the temperature should increase rather smoothly. Click "Collect" again to stop collecting data once the curve flattens out.



c) **Record** the temperature of the water just before the rock was dropped in and the final temperature of the mixture as the curve flattens out (it will keep warming slowly due to the heat in the room)

Initial Temperature of Water: T_{water} = _3.3____ °C + 273 = _276.45 K

Final Temperature of Mix: $T_{final,\ measured}$ = _16.5___ °C + 273 = __289.65 K

d) Since the rock has been submerged in boiling water for a significant time assume it's at 100°C. Also record the mass of the rock.

Temperature of rock: $T_{rock} = T_{boiling\ water}$ = 100°C + 273 = 373 K

Mass of rock: m_R= _122.9__ g ÷ 1000 = _0.122__ kg

e) **Calculate** the expected final temperature using T_{wi}, T_{Ri}, m_w, and m_R {masses must be in kg and temperatures in Kelvin (c_{water} = 4186 J/kg-K, c_{rock} = 804 J/kg-K) }. Convert back to Celsius (C = K – 273)

$$T_{final,\ calculated} = \frac{m_{water}c_{water}T_{water} + m_{rock}c_{rock}T_{rock}}{\left(m_{water}c_{water} + m_{rock}c_{rock}\right)} = \_\_\_\_\_\_ K - 273 = \_\_\_\_\_\_ {}^{\circ}C$$

$$T_{final,\ calculated} = \frac{(0.150)(4186)(246.45) + (0.122)(804)(373.15)}{\left((0.150)(4186) + (0.122)(804)\right)}$$

$$T_{final,\ calculated} = 289.52\ K = 16.4^{\circ}C$$

f) **Discuss** your measured and calculated final temperatures. How close are they? Did the specific heat of water compared to the rock's show up as a significant effect in this experiment? Think about what the result would have been if you dropped water of the mass and temperature of your rock into the cold water.

Measured Temperature of the final mix: $T_{final,measured}$ = _16.5_ °C
Calculated Temperature of the final mix: $T_{final,\ calculated}$ = _16.4_ °C

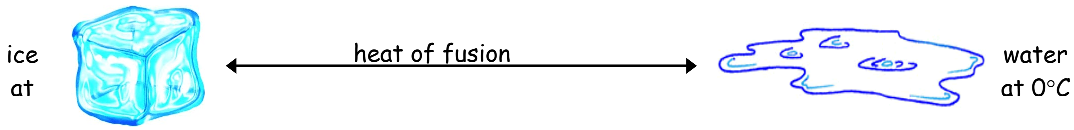
Don't skip this!

The measured final temperature came out really close to the calculated one … so the equation works!

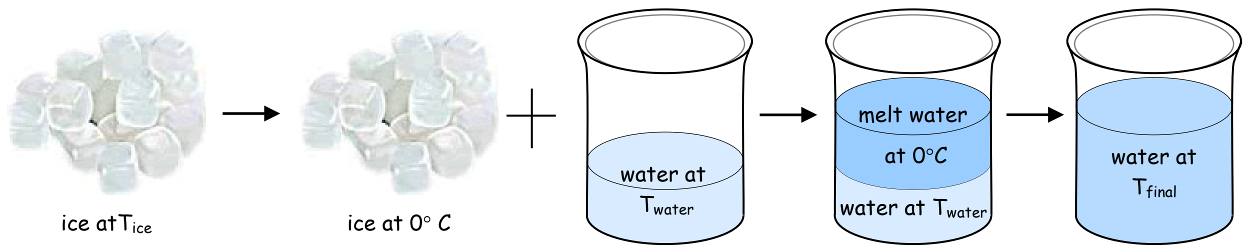
The fact that the rock heated the water up so little is surprising. I would have expected the water to heat up to closer to 50°C since we're blending stuff at around 0°C with stuff at 100°C.

FIRE AND ICE

When a substance changes phase, it absorbs or releases energy. This energy is called latent heat:



We will investigate the heat exchanged between warm water and ice



a) Get an ice cube, find its mass and note the temperature in the cooler:

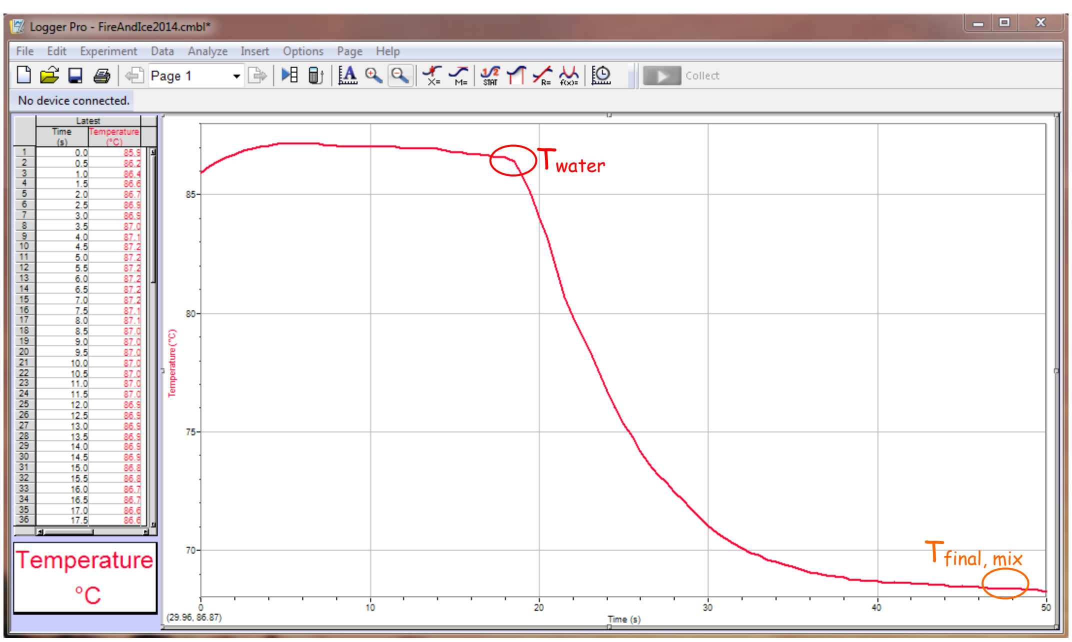
Mass of ice: m_{ice} = ___18___ g ÷ 1000 = __0.018__ kg

Temperature of ice: T_{ice} = __-2___ °C + 273 = __271.1__ K

b) Place 150 mℓ of hot water in your calorimeter and place the probe in it. The mass of the water is found from its volume knowing water has a density of 1 g/cm^3 = 1 g/mℓ:

Volume of water: V_w = __150__ mℓ Mass of water: m_w = __150__ g ÷ 1000 = __0.150__ kg

c) Click the "Collect" button at the top of the Logger Pro window just before the ice is dropped in. Once it's dropped in, **stir the water continually** and the temperature should decrease rather smoothly. Click "Collect" again to stop collecting data once the curve flattens out.



d) Record the temperature of the water just before the rock was dropped in and the final temperature of the mixture as the curve flattens out (it will keep coolming slowly due to the heat in the room)

Initial Temperature of Water: T_{water} = 86.6 °C + 273 = 359.75 K

Measured Final Temperature of Mix: $T_{final,measured}$ = 68.4 °C + 273 = 341.55 K

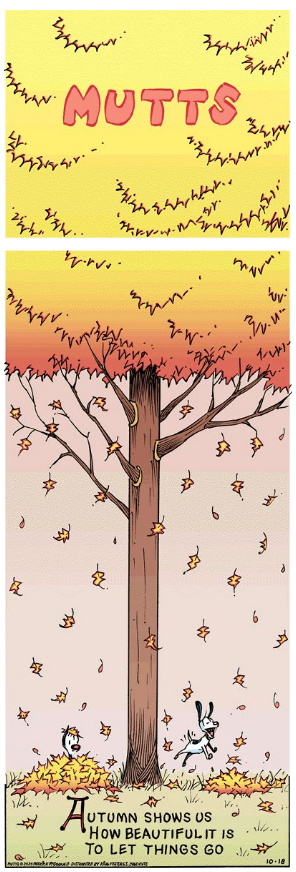
e) Calculate what the final temperature would be if we mixed m_{ice} of **WATER at T_{ice}** with **water at T_{water}**. {Masses must be in kg and temperatures in Kelvin}. Convert back to Celsius (C = K – 273)

$$T_{final,\ water\ mix} = \frac{m_{water}T_{water} + m_{ice}T_{ice}}{(m_{water} + m_{ice})} = \underline{\ 350.3\ }\ K - 273 = \underline{\ 77.1\ }\ °C$$

f) Calculate the final temperature for ice and hot water: {masses must be in kg and temperatures in Kelvin (c_w = 4186 J/kg·K , L_{fusion} = 334000 J/kg) }. Convert back to Celsius (C = K – 273)

$$T_{final,\ calculated} = \frac{(m_{ice}T_{ice} + m_{water}T_{water})c_w - m_{ice}L_{fusion}}{(m_{water} + m_{ice})c_w} = \underline{\ 341.7\ }\ K - 273 = \underline{\ 68.6\ }\ °C$$

$$T_{final,\ calculated} = \frac{[(0.150)(359.75) + (0.018)(271.15)](4186) - (0.018)(334000)}{((0.150) + (0.018))(4186)}$$



$$T_{final,\ calculated} = 341.7\ K = 68.6°C$$

g) Comment on how the measured final temperature compares to the two calculated final temperatures. Is the energy used to melt the ice significant?

Measured Temperature of the final mix: $T_{final,measured}$ = 68.4 °C

Calculated Temperature of WATER mix: $T_{final,\ water\ mix}$ = 77.1 °C

Calculated Temperature of the final mix: $T_{final,\ calculated}$ = 68.6 °C

Don't skip this!

The measured final temperature came out really close to the calculated one … so, again, the equation works!

The little bit of ice, 12% of the mass of the water, cooled the water down over 30%! If it had just been water at -2°C, it would only have cooled the hot water down by 33°C. So melting the ice uses up almost 10 more Celsius degrees! That's significant!