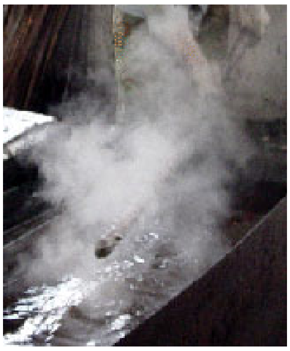
2.B.2 - Specific Heat & Calorimetry



Quench This!

Specific Heat Capcity (c)

Specific Heat Capacity: symbol = c (NOT speed of light). Amount of heat required to raise the temperature of 1 kg of a substance 1°C.

$c = \frac{Q}{m\Delta T}$	c = Specific Heat (J/(kg·K) or J/(kg·°C)) Q = heat gained OR Lost (J) m = mass (kg) ΔT = temperature Change (K or °C)

See Table 2.B.1 in Resources.

Note that water has a fairly high specific heat compared to other substances.

You may have burned your mouth on a hot food item with like a potato or hot chocolate, but not on one with a low water content like toast.

Specific Heat Example

1. What is the specific heat of a 1200 gram chunk of material whose temperature increases from 125 °C to 450 °C after absorbing 179 kJ of heat?

2. What is the material? (Use Resources Table 2.B.1)

Specific Heat Answer

Data:
Mass = 1200 g: 1.2 kg
ΔT = 450 °C - 125 °C = 325 °C
Q = + 179,000 J.

$$c = \frac{Q}{m \bullet \Delta T}$$

$$= \frac{+179{,}000 J}{1.2 kg \bullet 325 ^\circ C} = 460 J / kg \bullet ^\circ C$$

The material is Iron or Steel.

Calorimetry

The calculation of specific heat is straightforward, but how does one find an amount of energy gained or lost?

A calorimeter is a device that assists in measurements. Demo: Lab Calorimeter.

This unit's lab explores this through Calorimetry, quantitatively measuring heat exchanges.

Bomb Calorimeter

Specific Heat Calculations

Several quantities can be determined using calorimetry
1. Specific heat of an unknown material,
2. Temperature change of a material,
3. Mass of a material.

Isolate energy in specific heat equation first:

$Q = cm\Delta T$	Q = heat lost (-J) or gained (+J) c = specific heat (J/(kg·K) or J/(kg·°C)) m = (kg) ΔT = temperature change (K or °C)

It's important to record whether heat is lost or gained with a +/- sign, or whether a temperature is increasing or decreasing (with +/-).

3. Hot Items Example: Demonstration or Calculation

Consider this!

Copper can be heated and submerged in water, which raises the temperature of the water!

Using calorimetry, we can determine the initial temperature of a hot chunk of Cu ($T_{i\ Cu}$).

(If the demonstration is to be done: gather data BEFORE heating copper)

Hot Item Demontration

First, gather data to find $T_{i\ Cu}$:

c_{Cu}: (Table 2.B): 390 J/(kg°C)
c_{H2O}: (Table 2.B): 4186 J/(kg °C)
$Mass_{water}$: ________
$Mass_{metal}$: ________
$T_{i\ H2O}$: ________
$T_{f\ Cu/H2O}$: ________

Write all on Board

Calculation 1: If Demo.

Then, calculate how much energy water gained:

Q_{H_2O} = ____________

$$Q_{H_2O} = c_{H_2O} m_{H_2O} \Delta T$$

Write on Board

Calculation 2: If Demo

Apply this value to determine the energy change of copper, then calculate initial temperature.

Remember: energy gained by water equals energy lost by copper:

$Q_{H_2O} = - Q_{Cu}$
Q_{Cu} = __________

$T_{i\ Cu}$: __________

$$Q_{Cu} = c_{Cu} m_{Cu} \Delta T$$

$$Q_{Cu} = c_{Cu} m_{Cu} (T_f - T_i)$$

$$\frac{Q_{Cu}}{c_{Cu} \bullet m_{Cu}} = T_f - T_i$$

$$\frac{Q_{Cu}}{c_{Cu} \bullet m_{Cu}} - T_f = -Ti$$

$$T_f - \frac{Q_{Cu}}{c_{Cu} \bullet m_{Cu}} = T_i$$

Hot Item Calculation Process

1. Find specific heat constants.
2. Find copper & water mass; initial water temp.
2. Heat copper in a flame until it's hot.
3. Put copper in water; measure final temperature of water and copper mixture.

Data:

c_{Cu}: (From Table 2.B) 390 J/(kg°C)
c_{H2O}: (From Table 2.B): 4186 J/(kg °C)
$mass_{water}$: 0.10 kg
$mass_{metal}$: 0.068 kg
$T_{i\ H2O}$: 22.0°C
$T_{f\ Cu/H2O}$: 30.0°C

Hot Item Calculation 1

Then, calculate how much energy water gained:

$$Q_{H_2O} = c_{H_2O} m_{H_2O} \Delta T$$

$$= 4186 \frac{J}{kg \bullet {}^\circ C} \bullet 0.10\,kg \bullet (30.0\,{}^\circ C - 22.0\,{}^\circ C)$$

$$= 3{,}348.8\,J$$

Hot Item Calculation 2

Energy gained by water equals energy lost by copper. Apply this energy value (as a negative number, since copper LOST heat) to determine copper's initial temperature.

$$Q_{Cu} = c_{Cu} \bullet m_{Cu} \bullet \Delta T$$

$$= c_{Cu} \bullet m_{Cu}(T_f - T_i) \qquad algebraic\ shuffle$$

$$\frac{Q_{Cu}}{c_{Cu} \bullet m_{Cu}} - T_f = -T_i$$

$$T_i = T_f - \frac{Q_{Cu}}{c_{Cu} \bullet m_{Cu}}$$

$$= 30.0\,^{\circ}C - \frac{-3{,}348.8\,J}{390\,J/kg \bullet {}^{\circ}C \bullet 0.068\,kg} = 156.3\,^{\circ}C$$

Homework

2.B.2 Problems.
Due next class.