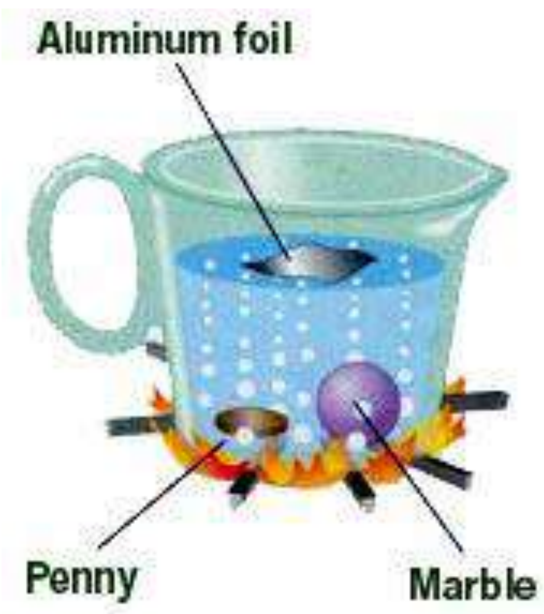
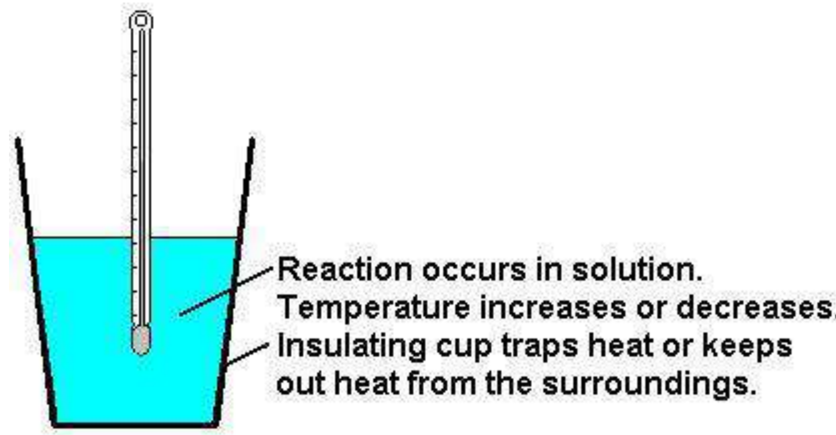
NOTES: 17.1-17.2 – Heat Capacity and Specific Heat; Calorimetry





Magnitude of Heat Flow

- The relationship between magnitude of heat flow, q, and temperature change, Δt, is:

$$\mathbf{q = C \cdot \Delta t}$$

  - q = magnitude of heat
  - C = heat capacity (J/°C)
  - Δt = change in temp

HEAT CAPACITY:

- **HEAT CAPACITY** = the amount of heat needed to increase the temperature of an object exactly 1ºC.

  -this value changes as the mass changes

  (the greater mass, the greater its heat capacity)

  -example: it takes more heat to raise the temp. of a large steel girder than a small steel nail.

<u>Magnitude of Heat Flow</u>

- For a **pure substance** of mass **m**, the expression of q can be written as:

$$\mathbf{q = m \cdot c \cdot \Delta t}$$

  - q = <u>magnitude of heat</u>
  - m = <u>mass</u>
  - c = <u>specific heat of substance (J/g·°C)</u>
  - Δt = <u>change in temp</u>

<u>SPECIFIC HEAT:</u>

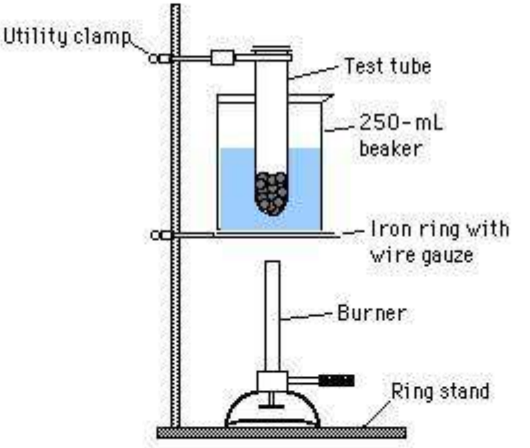
- **<u>SPECIFIC HEAT</u>** = the amount of heat it takes to <u>raise the temp. of 1 g of a substance by 1°C</u> (with no change in state)
- Specific heat values (in J/g·°C):

  $CO_{2\ (g)}$ = 0.843 J/g·°C

  $Cu_{\ (s)}$ = 0.382 J/g·°C

  $Fe_{\ (s)}$ = 0.446 J/g·°C

  $H_2O_{\ (l)}$ = 4.184 J/g·°C



Apparatus for heating metal sample.

Example 1:

How much heat is given off by a 50.0 g sample of copper when it cools from 80.0 to 50.0°C?

$q = m \cdot c \cdot \Delta t$

$q = (50.0\ g)(0.382\ J/g \cdot °C)(50.0\ °C - 80.0\ °C)$

$q = (50.0\ g)(0.382\ J/g \cdot °C)(-30.0\ °C)$

$q = -573\ J$ (neg. sign because heat is given off)

Example 2:

The temperature of a piece of copper with a mass of 95.4 g increases from 25.0 °C to 48.0 °C when the metal absorbs 849 J of heat. What is the specific heat of copper, C_{Cu}?

$q = m \cdot c \cdot \Delta t$

$849 \text{ J} = (95.4 \text{ g})(C_{Cu})(48.0\ °\text{C} - 25.0\ °\text{C})$

$C_{Cu} = (849 \text{ J}) / (95.4 \text{ g})(23.0 °\text{C})$

$C_{Cu} = 0.387 \text{ J/g} \bullet °\text{C}$

Example 3:

Iron has a specific heat of 0.446 J/g•°C. When a 7.55 g piece of iron absorbs 10.33 J of heat, what is the change in temperature? If it was originally at room temp. (22.0°C), what is the final temperature?

$$q = m \cdot c \cdot \Delta t$$

$$10.33\ \text{J} = (7.55\ \text{g})\ (0.446\ \text{J/g}\cdot{}^{\circ}\text{C})\ (\Delta t)$$

$$\Delta t = \boxed{3.07\ {}^{\circ}\text{C}} = t_f - 22.0\ {}^{\circ}\text{C}$$

$$t_f = \boxed{25.1\ {}^{\circ}\text{C}}$$

Example 4:

The specific heat of copper is 0.382 J/g•°C. How much heat is absorbed by a copper plate with a mass of 135.5 g to raise its temperature from 25.0°C to an oven temperature of 215°C?

$$q = m \cdot c \cdot \Delta t$$

$$q = (135.5\ g)(0.382\ J/g \cdot °C)(215°C - 25.0\ °C)$$

$$q = \boxed{9835\ J}$$

CALORIMETRY

To measure the heat flow in a reaction, it is carried out in a calorimeter.

$$\mathbf{q_{rxn} = -q_{calorimeter}} = \Delta H$$

It is possible to calculate the amount of heat absorbed or given off by the reaction if you know the heat capacity, C_{cal}, and the temp. change, Δt, of the calorimeter:

$$q_{rxn} = - C_{cal} \cdot \Delta t$$

Coffee Cup Calorimeter

The cup is filled with water, which absorbs the heat evolved by the reaction, so:

$$q_{ice} = -m_w \cdot c_w \cdot \Delta t$$

Coffee Cup Calorimeter Example:

When 1.00 g of ammonium nitrate, NH_4NO_3, is added to 50.0 g of water in a coffee cup calorimeter, it dissolves,

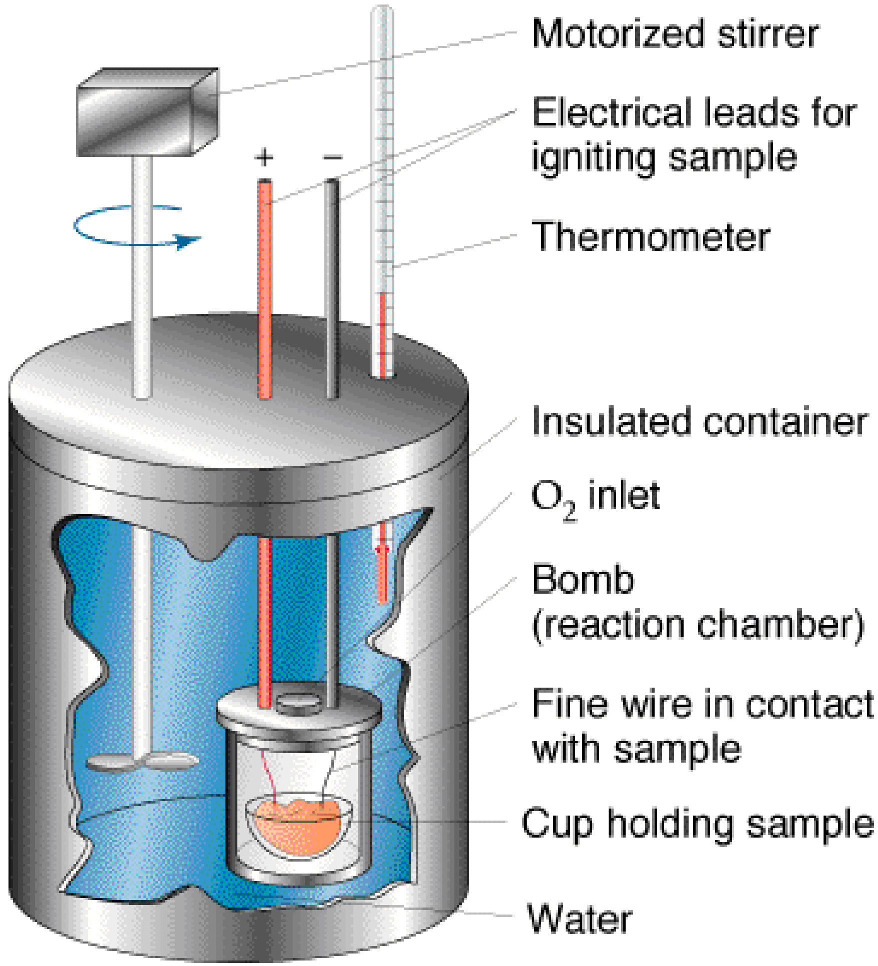
$NH_4NO_{3\ (s)} \rightarrow NH_4^+{}_{(aq)} + NO_3^-{}_{(aq)}$, and the temperature of the water drops from 25.00°C to 23.32°C. Calculate q for the reaction system.

$\mathbf{q_{rxn} = -m_w \cdot c_w \cdot \Delta t}$ $\Delta t = -1.68°C$

$q_{rxn} = -(50.0g)(4.18\ J/g\cdot°C)(-1.68\ °C)$

$\mathbf{q_{rxn}}$ **= 351 J (pos. sign, so endothermic)**

Bomb Calorimeter



BOMB CALORIMETER EXAMPLE 1:

The reaction between hydrogen and chlorine, $H_2 + Cl_2 \rightarrow 2HCl$, can be studied in a bomb calorimeter. It is found that when a 1.00 g sample of H_2 reacts completely, the temp. of the bomb calorimeter rises from 20.00°C to 29.82°C. Taking the heat capacity of the calorimeter to be 9.33 kJ/°C, calculate the amount of heat given off in the reaction.

$$q_{rxn} = - C_{cal} \cdot \Delta t$$

$$q_{rxn} = -(9.33\ \text{kJ/°C})(9.82\ \text{°C})$$

$$q_{rxn} = \boxed{-91.6\ \text{kJ}}$$

(neg. sign b/c rxn is exothermic)

<u>BOMB CALORIMETER EXAMPLE 2</u>:

When twenty milliliters of ethyl ether, $C_4H_{10}O$ is burned in a bomb calorimeter, the temperature in the calorimeter rises from 24.7°C to 88.9°C. The calorimeter heat capacity is 10.34 kJ/°C.

(a) What is q for the calorimeter?

(b) What is q for the 20.0 mL of ether that was burned?

$$q_{cal} = C_{cal} \cdot \Delta t$$

$$q_{cal} = (10.34\ \text{kJ/°C})(64.2\ \text{°C})$$

$$q_{cal} = 664\ \text{kJ}$$

BOMB CALORIMETER EXAMPLE 2:

When twenty milliliters of ethyl ether, $C_4H_{10}O$ is burned in a bomb calorimeter, the temperature in the calorimeter rises from 24.7°C to 88.9°C. The calorimeter heat capacity is 10.34 kJ/°C.

(a) What is q for the calorimeter?

(b) What is q for the 20.0 mL of ether that was burned?

$$q_{rxn} = -q_{cal}$$

$$q_{rxn} = -664 \text{ kJ}$$