N-36
Calorimetry

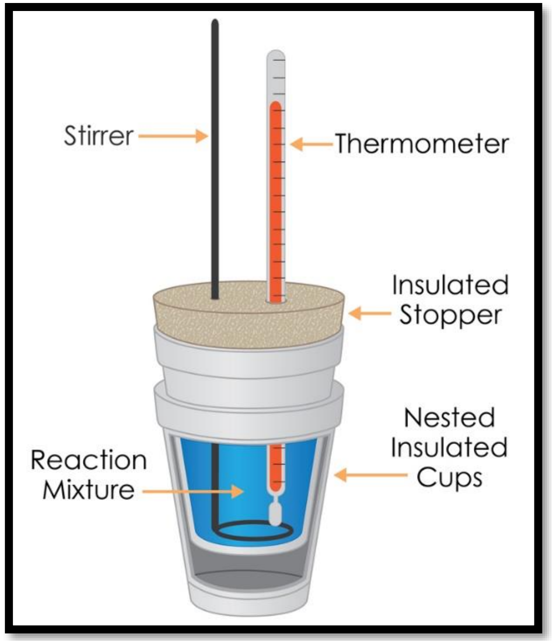
Target

I can use the 1st Law of Thermodynamics to solve "calorimetry problems" where I solve for information on one substance by knowing information on another substance.

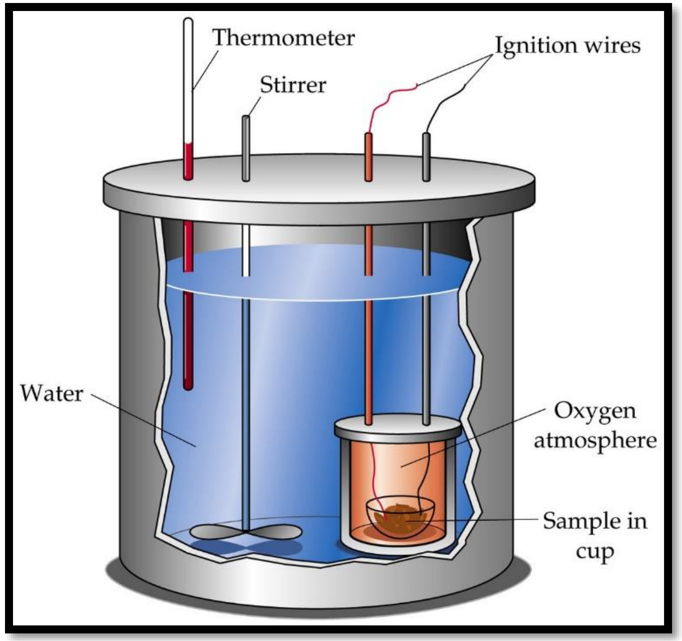
Purpose of Calorimetry

Measure heat transferred from one object to another, or the energy transferred during a reaction.

Coffee Cup Calorimeter



Bomb Calorimeter



Common Type of Question

- **Transferring a HOT object into a COLD liquid**
- **Transferring a COLD object into a HOT liquid**
- **Pouring two liquids together that start at different temperatures**
- **Calculating the heat released/absorbed during a chemical reaction**

Still Using $Q = mC\Delta T$

These problems still involve energy

So we still use the $Q = mC\Delta T$ equation

BUT THIS TIME…

We need $Q = mC\Delta T$ for each substance…

We will have ***TWO*** $Q=mC\Delta T$ equations

How can we solve for a substance when we don't have enough information?

1st Law of Thermodynamics!

1st Law of Thermodynamics

Energy cannot be created or destroyed

We are TRANSFERRING energy

Therefore…

Energy In = Energy Out

Energy Absorbed = Energy Released

20 J of energy absorbed = 20 J of energy released

We need our math to match our concepts…

Energy In = Energy Out

Energy Absorbed = Energy Released

$$Q_{substance\ 1} = -\ Q_{substance\ 2}$$

Negative sign will stand for "OPPOSITE" not necessarily negative. Makes it so it doesn't really matter which material you start with.

$Q = -Q$ shown with numbers

You put a hot piece of metal into a cold cup of water.

The water absorbs 50 Joules of energy, so the metal released 50 Joules of energy

$$Q_{water} = -Q_{metal}$$

endo *exo*

$+$ $-$

50 J = -(-50 J)

Since our negative sign in our equation means opposite, the negatives will sort themselves out!

Think about where the negatives are coming from…

m = always +

C = always +

ΔT = + or - !!!

Therefore…

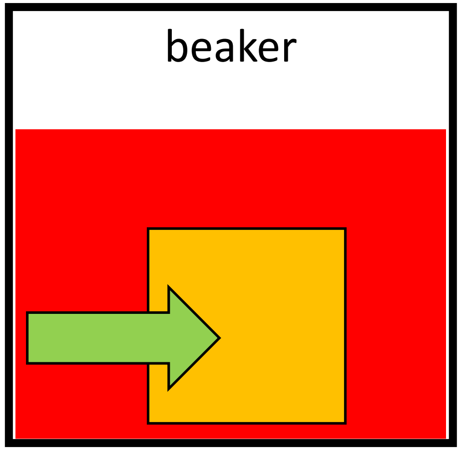
Q can end up + or -

Example with Pictures

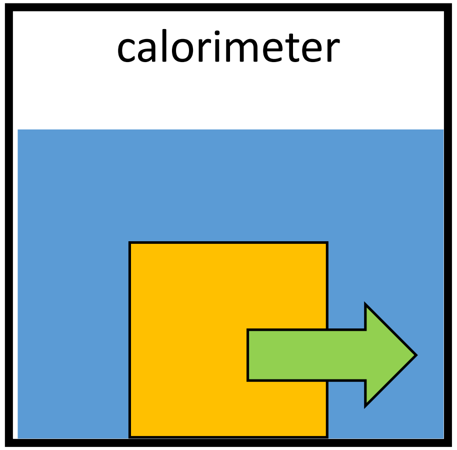
ENERGY IN = ENERGY OUT

Energy absorbed → Q = +
Energy released → Q = -

Qmetal = +
Qwater = -



Hot Water
Metal is heating up
Energy transfer into METAL



Qmetal = -
Qwater = +

Cold Water
Water is heating up
Energy transfer into WATER

Key Thing to Note About T_{final}

If you leave the object/liquid/solutions together long enough they will come to the same temperature!

Example:

$$T_{final,water} = T_{final,metal}$$

A very convenient fact that will simplify the algebra to allow us to solve for various things.

Q_{water} =	?
m_{water} =	From the water you put in the calorimeter 1mL = 1g
C_{water} =	4.184 J/g°C
ΔT_{water} =	Tf – Ti *(From your thermometer readings)*

Q_{metal} = $-Q_{water}$	*Energy IN must = energy OUT!* *(opposite sign, not necessarily negative)*
m_{metal} =	From your scale
C_{metal} =	?
ΔT_{metal} =	Tf – Ti Tf − 100°C From water — From boiling *(At the end the metal and water will be same temp)* *(The metal was put in the boiling water so it reached 100℃)*

Practice Problems

- **Glue the questions in your notebook**
- **Show your work the way I do!**
- **Annotate the practice problems with comments, tips, warnings, explanations, etc! These are NOTES not just practice problems!**

Practice Problems

1) Calculate the specific heat of a metal if 2.36×10^2 grams of it at 99.5°C is added to 125.0 mL of water at 22.0°C. The final temperature of the system is 25.4°C.
2) A lump of chromium (Cr) has a mass of 95.3 grams and a temperature of 90.5°C. It is placed into a calorimeter with 75.2 mL of water at 20.5°C. After stirring, the final temperature of the water, Cr metal, and calorimeter is 28.6°C. What is the specific heat of Cr metal?
3) A 100.0 gram sample of water at 50.0°C is mixed with a 50.00 gram sample of water at 20.0°C. What is the final temperature of the 150.0 grams of water?

① metal

$Q = -$
$m = 2.36 \times 10^2 g$
$C = ?$
$\Delta T = T_f \quad 25.4°C$
$\quad - T_i \quad - 99.5°C$
cooling down $\quad -74.1°C$

water

$Q = -$
$m = 125 g$
$C = 4.18\ J/g°C$ ← Known value, look it up! Not given in the Question
$\Delta T = T_f \quad 25.4°C$
$\quad - T_i \quad - 22°C$
heats up $\quad 3.4°C$

$Q = -Q$ So we dont need the actual Q values!

$\underbrace{Q = mC\Delta T}$

$Q = -Q \Rightarrow \boxed{\underset{\text{substance 1}}{mC\Delta T} = -\underset{\text{substance 2}}{mC\Delta T}}$

doesnt matter which subst. is #1 or #2

metal ⟵ ⟶ water

$$(2.36 \times 10^2 g)(C)(-74.1°C) = -(125 g)(4.18 \tfrac{J}{g°C})(3.4°C)$$

Solve!

Careful about negative signs!

$$\boxed{C_{metal} = 0.102\ J/g°C}$$

② Chromium

$Q =$

$m = 95.3\,g$

$c = ?$

$$\begin{array}{lr} \Delta T = T_f & 28.6°C \\ \quad - T_i & -90.5°C \\ \hline \text{cools down} & -61.9°C \end{array}$$

Water

$Q =$

$m = 75.2\,g$

$C = 4.18\,J/g\,°C$

$$\begin{array}{lr} \Delta T = T_f & 28.6°C \\ \quad - T_i & -\ 20.5°C \\ \hline \text{heats up} & 8.1°C \end{array}$$

$Q = -Q$

$mC\Delta T = -mC\Delta T$

* Don't be sloppy with negatives! they mean something! they matter!

Chromium

$$(95.3g)(C)(-61.9°C) = -(75.2g)\left(4.18\,\frac{J}{g°C}\right)(8.1°C)$$

$$\boxed{C_{\text{Chromium}} = 0.432\,\frac{J}{g°C}}$$

③ Water #1

$Q = -$

$m = 100g$

$C = 4.18\ J/g°C$

$\Delta T = T_f \quad ?$

$\underline{-T_i} \quad \underline{-50°C}$

$(T_f - 50°C)$

Water #2

$Q = -$

$m = 50\ g$

$C = 4.18\ J/g°C$

$\Delta T = T_f \quad ?$

$\underline{-T_i} \quad \underline{-20°C}$

$(T_f - 20)$

$Q = -Q$

* Both substances end at same temp! Same Tfinal values!

Water #1

$$(100g)(4.18\ J/g°C)(T_f - 50°) = -(50g)(4.18\ J/g°C)(T_f - 20°)$$

* dont be lazy! Show algebra steps to help! So many lost points on calorimetry problems because of algebra and calculator mistakes.

Continued on next slide! Cant fit it all here…

water #1 / water #2

$$(100g)(4.18\ J/g^{\circ}C)(Tf-50^{\circ}C) = -(50g)(4.18\ J/g^{\circ}C)(Tf-20^{\circ}C)$$

*TIPS

distribute everything then combine variables and then isolate

*still just solving for missing variable! Just more to rearrange!

* careful to distribute negative signs and with double negatives

Algebra Steps for #3

$$418\,Tf - 20900 = -209\,Tf + 4180$$
$$+209\,Tf \qquad\qquad +209\,Tf$$

$$627\,Tf - 20900 = 4180$$
$$+20900 \qquad +20900$$

$$\frac{627\,Tf}{627} = \frac{25080}{627}$$

$$\boxed{Tf = 40^{\circ}C}$$