N-36
Calorimetry

You can use the 1^{st} Law of Thermodynamics to solve “calorimetry problems” where you solve for information on one substance by knowing information on another substance.

Link to YouTube Presentation: https://youtu.be/s_2BJ7HgBmI

Concept Behind Calorimetry

- Sometimes it is hard to measure the thing you are actually interested in.

- You may be interested in a chemical reaction but you can't stick your thermometer inside the chemical bonds themselves!

- **BUT**...you could put the chemicals in water and put your thermometer in the water instead!

Concept Behind Calorimetry

- So...if you can't measure something you are interested in DIRECTLY...

- You can try measuring it INdirectly instead!

- If you can't measure the SYSTEM, you can measure the SURROUNDINGS instead!

Concept Behind Calorimetry

If one substance loses heat,
it has to go somewhere!
Has to go to *another* substance!

If one substance gains heat,
it had to come from somewhere!
Had to come from *another* substance!

Energy gained = -Energy lost
5 joules absorbed = -(-5 joules lost)
$Q_{in} = -Q_{out}$

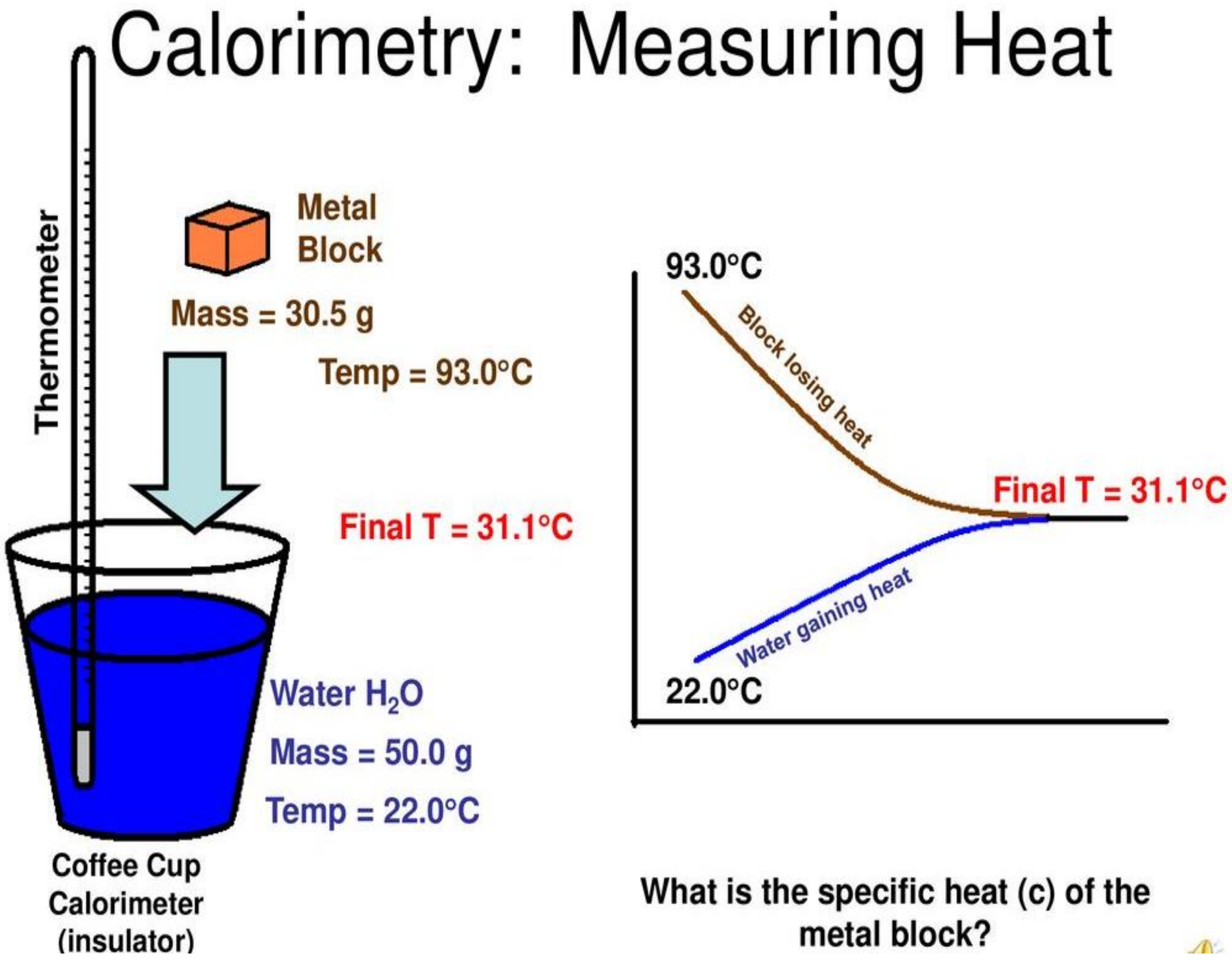
Concept Behind Calorimetry

Understanding that

$Q_{in} = -Q_{out}$

Can be a very helpful trick in the lab!

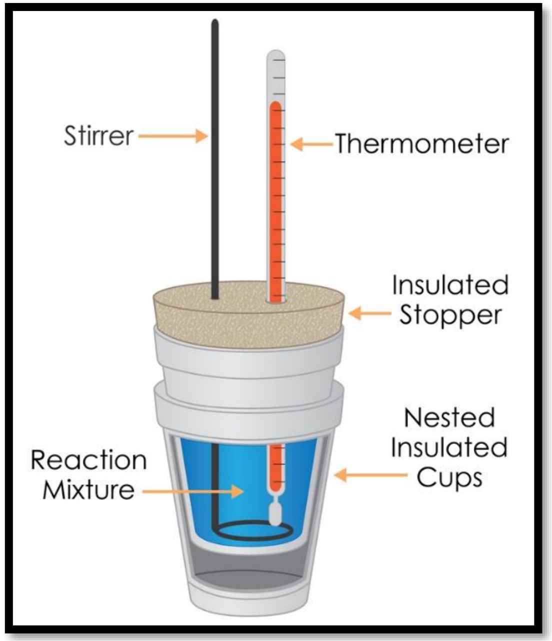
If you can't measure the thing you are actually interested in, you can measure the system instead!



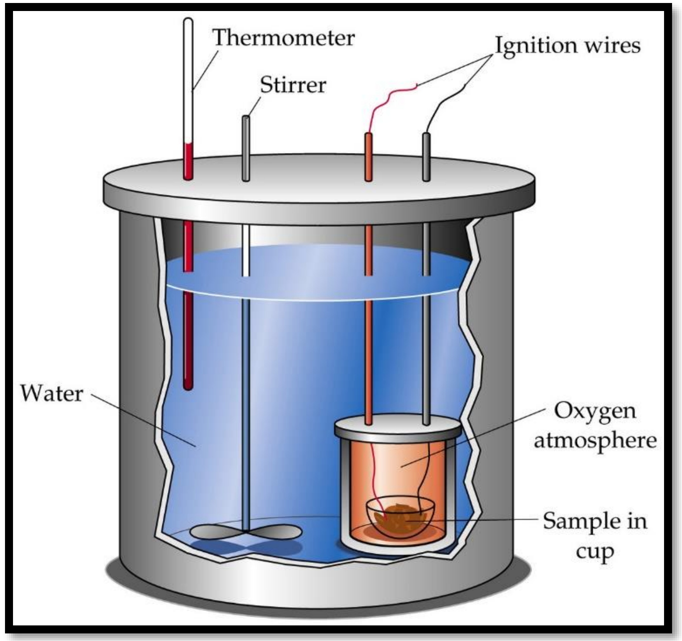
Purpose of Calorimetry

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 <u>each</u> substance…

We will have <u>*TWO*</u> $Q=mC\Delta T$ 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…

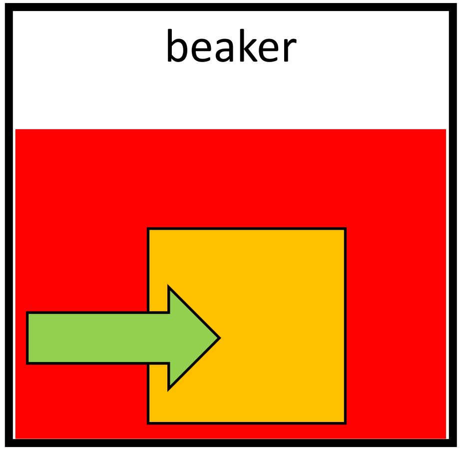
Q can end up + or -

Example with Pictures

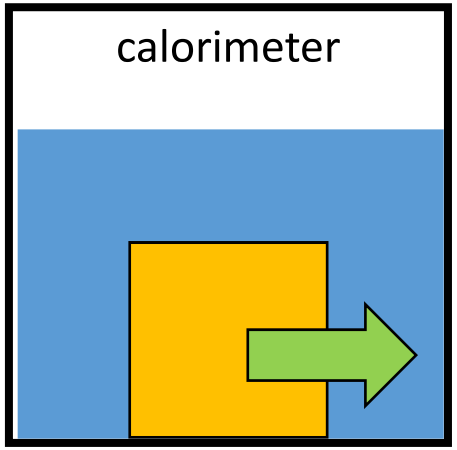
ENERGY IN = ENERGY OUT

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!

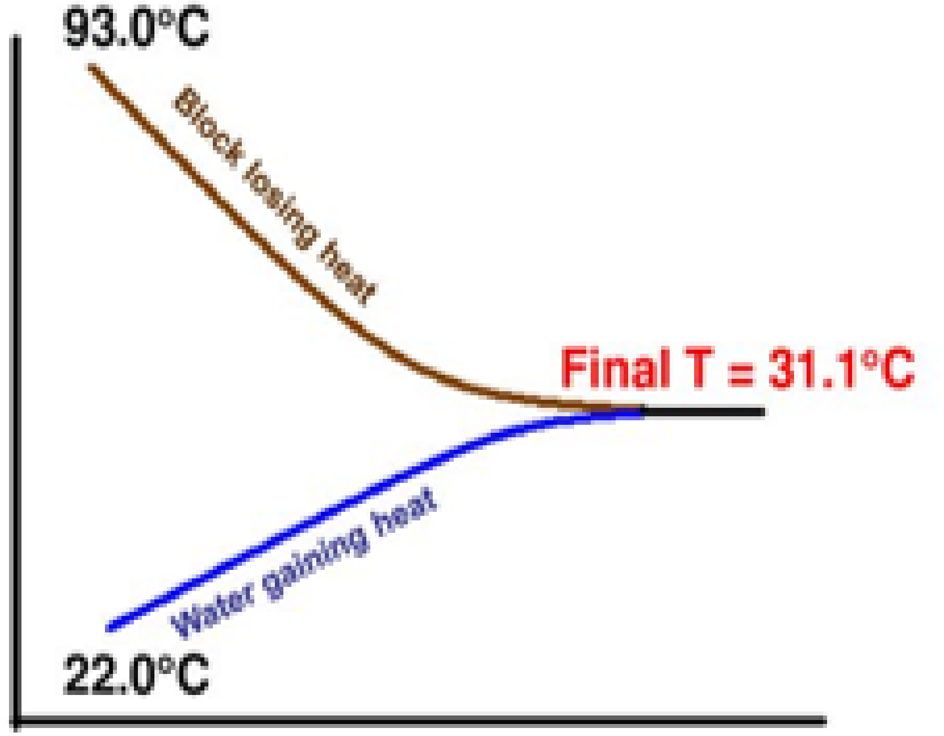
Example:

$$T_{final_{water}} = T_{final_{metal}}$$

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

Key Thing to Note About T_{final}

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



Q_{water} = **?**	Q_{metal} = $-Q_{water}$ *Energy IN must = energy OUT!* *(opposite sign, not necessarily negative)*
m_{water} = From the water you put in the calorimeter 1mL = 1g	m_{metal} = From your scale
C_{water} = 4.184 J/g°C	C_{metal} = **?**
ΔT_{water} = Tf – Ti *(From your thermometer readings)*	ΔT_{metal} = Tf – Ti Tf (From water) – 100°C (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.

① metal

$Q =$

$m =$

$C =$

$\Delta T =$

water

$Q =$

$m =$

$C =$

$\Delta T =$

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

Practice Problems

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?

(2) <u>Chromium</u>

Q =

m =

c =

ΔT =

<u>water</u>

Q =

m =

C =

ΔT =

$$Q = -Q$$

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

② Chromium

$Q =$
$m = 95.3\,g$
$c = ?$
$\Delta T = T_f - T_i$: $28.6°C - 90.5°C = -61.9°C$
cools down

Water

$Q =$
$m =$
$c =$
$\Delta T = T_f - T_i$: $28.6°C - 20.5°C = 8.1°C$
heats up

$$Q = -Q$$

$$mc\Delta T = -mc\Delta T$$

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

Chromium = Water

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

$$c_{Chromium} = 0.432\,\frac{J}{g°C}$$

Practice Problems

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?

Who cares if it is two waters instead of a metal and a water?! Still two substances! Nothing changes! Actually easier because the specific heats on each side will cancel out if you want! I don't always do it in my keys because people always ask what happened to them ☺

③ <u>water #1</u>

Q =

m =

C =

ΔT =

<u>Water #2</u>

Q =

m =

C =

ΔT =

$Q = -Q$

Continued on next slide! Cant fit it all here…

③ water #1

$Q = -$

$m = 100g$

$C = 4.18\ J/g°C$

$\Delta T = T_f \quad ?$

$-T_i \quad -50°C$

$(T_f - 50°C)$

water #2

$Q = -$

$m = 50g$

$C = 4.18\ J/g°C$

$\Delta T = T_f \quad ?$

$-T_i \quad -20°C$

$(T_f - 20)$

$Q = -Q$

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

water #1 = water #2

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

* 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

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

*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

water #1 | water #2

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

$$100T_f - 5000 = -50T_f + 1000$$

$$+50T_f \quad +5000 \qquad +50T_f \quad +5000$$

$$\frac{150T_f}{150} = \frac{6000}{150}$$

$$\boxed{T_f = 40^\circ}$$

* 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

$\underline{\text{water \#1}}$ $\underline{\text{water \#2}}$

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

What if you forgot to cancel out the matching specific heats? No big deal! You will get the same answer!

water #1 — water #2

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

What if you forgot to cancel out the matching specific heats? No big deal! You will get the same answer!

$$418\,T_f - 20900 = -209\,T_f + 4180$$

$$+209\,T_f \qquad\qquad +209\,T_f$$

$$627\,T_f - 20900 = 4180$$

$$+20900 \qquad +20900$$

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

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

YouTube Link to Presentation

- https://youtu.be/s_2BJ7HgBmI