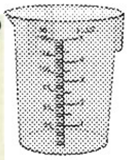
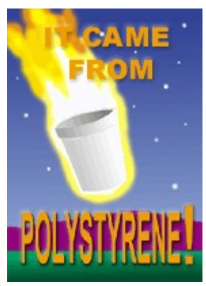
Heat from a Microwave

    Styrofoam cup or nested disposable paper coffee cups Thermometer 150-mL polypropylene beaker Digital balance	 Microwave

Calorimetry is an experimental way of finding the changes in thermal energy.
Calorimeters are to heat energy as balances are to mass.

Chemical reactions are performed in calorimeters so that the energy of the reaction can be trapped and measured. Calorimeters can be as complex as the Parr 2-Liter 4534 Floor Stand Reactor, which costs thousands of dollars, or as simple as a Styrofoam® cup or two nested paper cups.



4534 Floor Stand Reactor Parr Calorimeter[1] Styrofoam Cups

Calorimeters are used to measure the power of nuclear reactions, calories in a cup of yogurt, and the minute metabolism of bacteria. In any form, they isolate the energy of a system so that it can be measured.

Most 1st year college chemistry labs use Styrofoam® cups as their standard calorimeter

> From Dartmouth's Chem Lab 3/5 Week 8: Calorimetry 2: Hot and Cold Reactions
>
> "Calorimetry is used to determine the heat released or absorbed in a chemical reaction. The calorimeters shown here can determine the heat of a solution reaction at constant (atmospheric) pressure. The calorimeter is a double Styrofoam® cup fitted with a plastic top in which there is a hole for a thermometer. (It's crude, but very effective!) Key techniques for obtaining accurate results are starting with a dry calorimeter, measuring solution volumes precisely, and most importantly determining change in temperature accurately."

You will make your calorimeter by nesting two Styrofoam cups together. The Styrofoam acts as an insulator to hold the heat in from the experiment until you measure the temperature of the contents. If you don't have or want to use Styrofoam cups, you can use paper coffee cups. As the paper cups are not quite as good heat insulators as Styrofoam, you should nest the two cups together with a paper towel between the cups to create an insulating space.

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[1]The Parr Instrument Company specializes in calorimeters.
http://www.parrinst.com/

The thermal energy (heat[2]) will slowly dissipate out of your calorimeter as the molecular motions of the water cause molecular motions through the Styrofoam and to the air. So, it is important to make your measurements quickly. It's a lot like trying to measure the weight of a leaking bucket of water.

Of special note: In AP Chemistry, "heat" is used as the term for thermal energy (kinetic energy) in calorimetry. These statements from the AP Chemistry Course Guide describe how thermal energy is transferred.

1. The particles in a warmer body have a greater average kinetic energy than those in a cooler body.

2. Collisions between particles in thermal contact can result in the transfer of energy.This process is called "heat transfer," "heat exchange," or "transfer of energy as heat."

3. Eventually, thermal equilibrium is reached as the particles continue to collide. At thermal equilibrium, the average kinetic energy of both bodies is the same, and hence, their temperatures are the same.

Translated: Heat (thermal energy) always flows from a hotter temperature to a colder temperature.

In this experiment, the microwave oven radiation will cause the water in the calorimeter to increase in temperature (increased molecular motion) but that thermal energy will gradually be "escape" as it transfers energy to the colder surroundings.

A way of minimizing error is to start with cold water. So for the first part of the experiment, because the room temperature is warmer than the cold water in the calorimeter, thermal energy will "leak" into the calorimeter. Then once the water has been heated by the microwave energy, thermal energy will "leak" out of the calorimeter. So, the two sources of error will cancel one another.

History of the Microwave:

1947- Raytheon demonstrated the world's first microwave oven and called it a "Radarange," the winning name in an employee contest. The first microwave ovens weighed over 750 pounds, were housed in refrigerator-sized cabinets, and cost between $2,000 and $3,000.

1967 - Using Raytheon's microwave cooking technology, Amana introduced the world's first successful 115-volt countertop microwave oven for the home. Microwave ovens are now found in over 90% of US homes.

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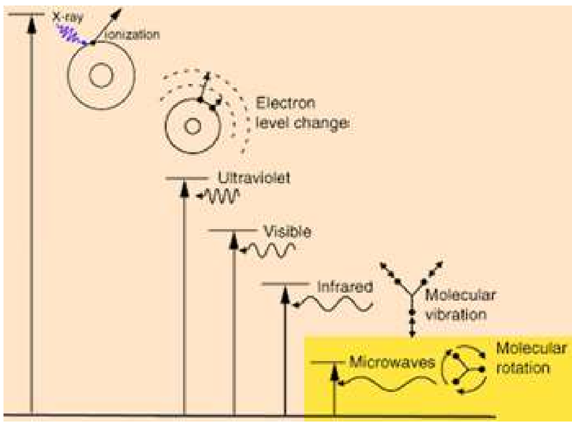
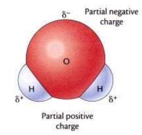
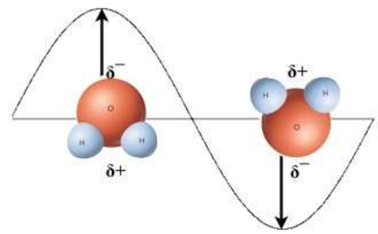
[2] Heat is a not a substance but a phenomenon of molecular motion. So technically, saying that "heat flows" is misleading. However, the usage is common and works. Just remember, heat is not a "caloric fluid" even though it acts as if it were.

A microwave oven produces electromagnetic radiation with a wavelength of 12.2 cm a frequency of 2.45 GHz. As these waves, traveling at 3×10^8 m/s, pass through water, some of the electromagnetic energy is converted into thermal energy. Note that other frequencies have different effects on atoms and molecules. You are expected to know the effects of different frequencies of electromagnetic radiation on matter.





Water molecules have partial charges, dipoles.



Microwave frequencies are capable of rotating molecules with dipoles.

Water molecules have a polarity (positive and negative charged portions). As the electromagnetic waves go through the water, the water molecules oscillate to orient themselves to the magnetic field of the wave. The rotations increase the kinetic energy of the water. This effect is a way of measuringthe polarity of molecules.

You will use your calorimeter to determine how much electromagnetic energy is converted into thermal energy absorbed by the water and the efficiency of your microwave in heating water.

To do this, you will have to know something about energy, power, and electricity. Power is energy per second. A joule per second is defined as a watt. A typical laptop runs at about 40 watts so as you do use laptop you are using about 40 joules of energy per second. A single AI chip can require 1000 joules per second.

Procedure:

1. Assemble your Calorimeter liner by nesting two paper cups together or a Styrofoam® cup.

2. Find the mass of the empty calorimeter and record it.

2. Fill your 150-mL plastic beaker with 100-mL of water (tap water will be fine) using the beaker graduations. Then pour the water into the calorimeter.

3. Place the calorimeter and water in a refrigerator for 15 minutes.

4. Take the calorimeter and water out of the refrigerator. Turn on the digital thermometer being sure the temperature scale is set to Celsius. Measure the temperature of the water gently stirring taking care not to puncture the Styrofoam of the calorimeter. It will take about 10 seconds for the thermometer to get a stable reading. Once you get the stable reading, take the thermometer out.

5. Place the calorimeter in the microwave. If you have a rotating plate, set the calorimeter off center. Run the microwave for 40 seconds. Do not heat longer than 40 seconds as there is a slight chance that you could superheat the water[3].

6. Take the calorimeter and water out of the microwave. Remove and gently stir with the thermometer to find the new temperature of the water till you have the highest stable reading.

7. Record the mass of the calorimeter and water to find the mass of the water that was heated.

8. Sometimes, the power rating (watts) of your microwave is listed somewhere on your microwave either on the inside of the door or on the back of the range. Rather than giving the watt rating, some microwaves list the current rating in amps. In this case, you will need to multiply the amps × voltage to get the watt rating. The voltage in most homes in the US is 120. (Amps × Voltage = Watts)

For students who do not have microwaves, you won't even need a Styrofoam cup. Place a pot a on a stove. After measuring the temperature of the cold water, pour the cold water into the pot, adjust the neat to medium high, start a timer and warm the water measuring its temp with the thermometer until the water is as far above room temp as it was below room temperature. Then stop timing.

Then do the calculations to determine the power of your stovetop burner.

As the data from your stove experiment in your lab notebook won't match the Webassign questions, you may use my data to complete the WebAssignment.

Read over my lab report to see how this lab is done and how to write up your own lab report.

[3] Super heating is unlikely since the Styrofoam container is not perfectly smooth. These small imperfections provide sites to break the surface tension of water. Without imperfections, surface tension can keep water from boiling at its normal boiling temperature. On removing superheated water from the microwave, movement will break the surface tension and the water can boil violently splattering scalding water.

	Heat from a Microwave	Unambiguous Date	02

Purpose: To find the heating efficiency of a Microwave

Equipment:

- Thermometer
- 150-mL graduated polypropylene beaker
- Nested cups and lid
- Microwave oven
- Balance

Procedure:

I filled my Styrofoam calorimeter with 100 g of water and chilled it in the refrigerator for 10 minutes so that the experimental error of the loss of heat energy in the second half of the experiment from the hot water in the calorimeter would be balanced by the gain in heat energy from the surrounding by the cold water in the start of the experiment.

I then took the temperature of the water, T_1*, and placed the water and calorimeter in my microwave.*
I ran the microwave for 40.0 seconds.

I took the hot water out of the microwave and while gently stirring determined the temperature of the water, T_2*.*

I then found the mass of the hot water and calorimeter.

I checked the rating of the microwave and found that it was rated at 6.8 amps at 120 V so the microwave is rated at 820 watts of power.

Amps × volts = watts
6.8 amps × 120 V = 820 J/s, watts

Data:

4.43 g mass of empty calorimeter

T_1 = 15.9°C T_2 =55.9°C *temperatures of the water before and after heating 30. s*

97.67 g mass of calorimeter and water

Calculations:

m = mass of water = 97.67 g – 4.43 g = 93.24 g water

c = specific heat of water = 4.18 J/g°C.

$\Delta T = T_2 - T_1 = 40.0°C$

Energy absorbed by water in calorimeter, $q_{water} = m_{water} \times c_{water} \times \Delta T_{water}$

$q_{water\ gained}$ = 15,600 J

Based on the power and time run, the microwave consumed 24,000 J of energy

820 J/s × 30. s = 24,000 J of electrical energy were used by the microwave

Not all the microwave's energy was used to heat the water because the microwave had a light, a turntable, and a vent that blew warm air. Also, the microwaves could have heated other material in the oven and the conversion of electrical energy to microwave radiation is not without its own inefficiencies. The magnetron that produces the microwaves gets hot, so some of the electrical energy heats the circuitry rather than producing microwave photons.

The efficiency of the microwave oven in heating water would therefore be:

$$\%\ Efficiency = \frac{energy\ water\ gained}{energy\ microwave\ consumed} \times 100$$

$$\%\ Efficiency = \frac{15,600\ J}{24,009\ J} \times 100$$