Objective 2.2.1: Explain the energy content of a chemical reaction.

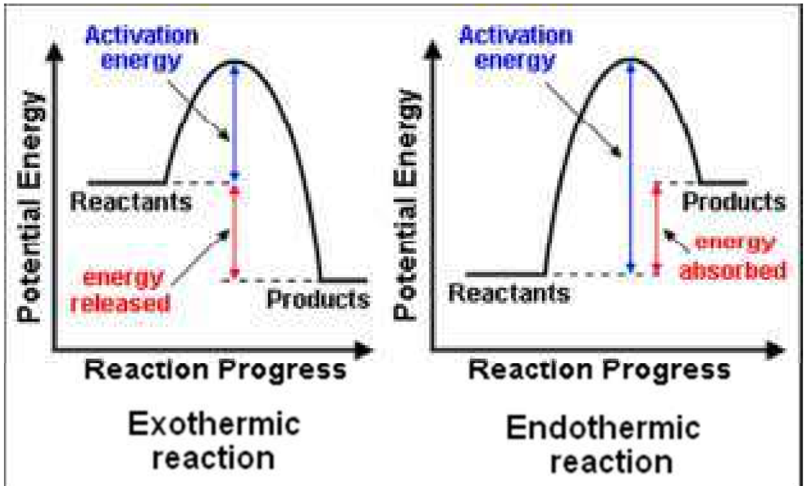
Reactions happen because molecules collide with one another with enough energy to break bonds, rearrange atoms and reform new bonds. This idea is called **collision theory**.

Factors that affect collision theory:

1. Temperature: Higher temperatures cause faster molecular movement, and more collisions. Lower temperatures slow down particle movement and reduce collisions.

2. Pressure: Higher pressures cause GASES to move faster resulting in more collisions. Lower pressures allow GASES to slow down and result in less collisions.

- With solids and liquids, pressure has no effect. However, then having a higher concentration will cause more collisions and a lower concentration will reduce collisions.



Source: Milton Beychok

Energy level diagrams of exothermic and endothermic reactions.[4][5][6]

<u>Endothermic v. Exothermic Reactions</u>

Exothermic reactions occur when energy is released during the reaction. Because of this, these reactions feel warm or hot because heat is being released. Notice the products have less energy than the reactants, because much of the energy was released.

Endothermic reactions occur when energy is absorbed during the reaction. Because of this, these reactions feel cold. Notice the products have more energy than the reactants because energy was absorbed.

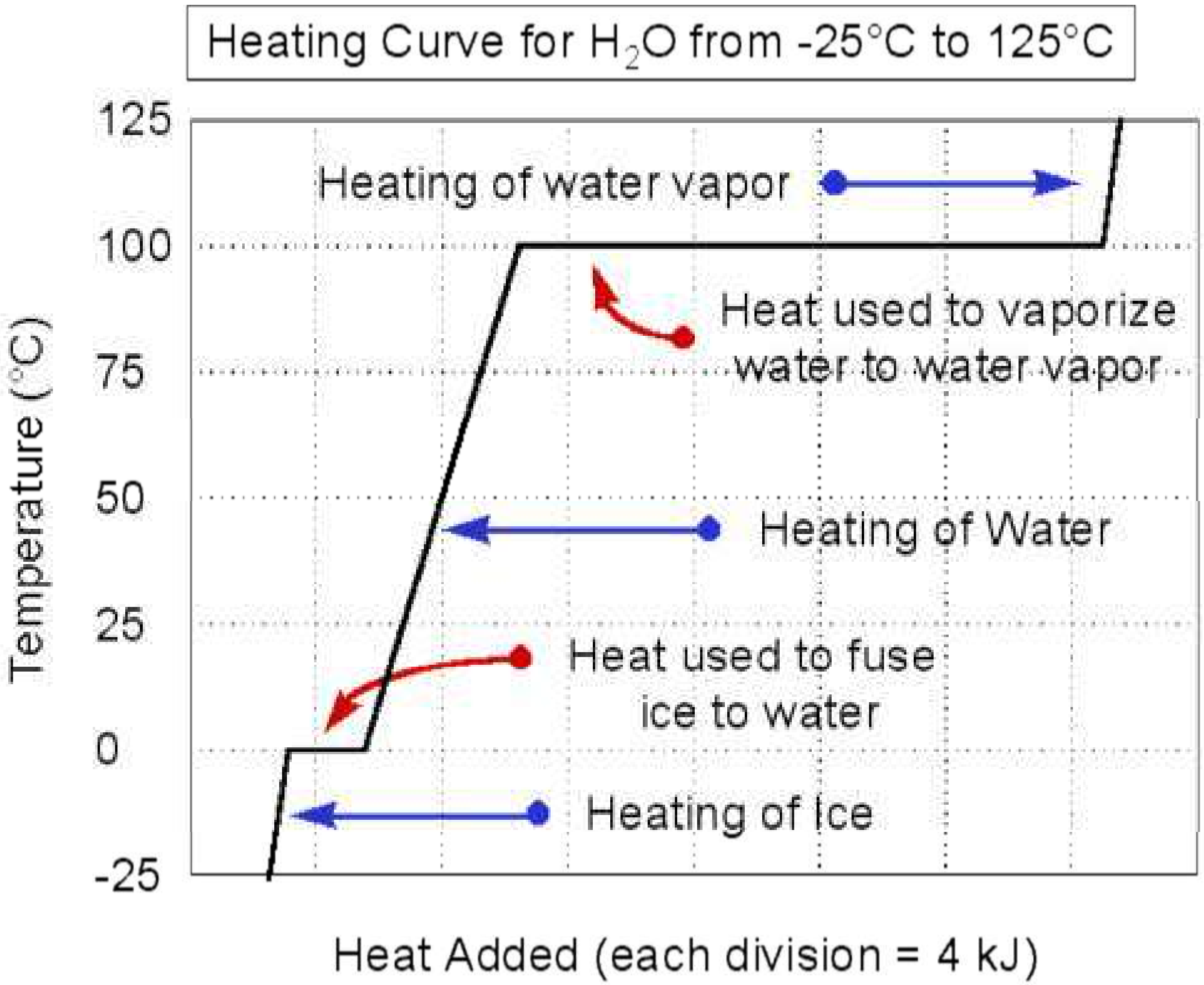
The **activation energy** is the amount of energy that must be present for the reaction to occur. Notice that endothermic reactions require more activation energy than exothermic reactions. Special chemicals called CATALYSTS can reduce the activation energy and allow the reaction to occur with less energy. (NOTE: catalysts DO NOT add energy to the reaction!)

Heat v. Temperature

Remember, HEAT and TEMPERATURE are NOT the same! Heat is a type of ENERGY. Temperature is a measurement of the AVERAGE KINETIC ENERGY of the particles of a substance. Think of something that you perceive as cold, such as ice. Even though ice is cold, it absorbs heat energy which breaks hydrogen bonds because the particles speed up allowing them to break bonds and become a liquid.

Objective 2.1.2: Explain heating and cooling curves (heat of fusion, heat of vaporization, heat, melting point, boiling point).

Heating/cooling curves show you the line graph that depicts the transition of a substance from a solid into a liquid, and then into a gas as energy is added (OR vice versa as energy is released).



Look at the Heating Curve on the left. Notice at temperatures under 0 degrees C, water is a solid. As energy is added, the temperature increases (so molecular movement AKA kinetic energy increases), but the water remains ice until it hits that melting point (0 degrees C). At the melting point, the energy being absorbed no longer raises the temperature because that energy is used to MELT the ice. Once all of the ice is melted, the substance has turned completely to liquid (as seen by the second diagonal line) and temperature begins to rise again as energy is absorbed. Temperature continues to rise until the boiling point (100 degrees C) is reached and once again, molecular motion stops increasing and the energy is used to vaporize the water, turning it into steam. Once all of the water is steam, as energy is absorbed, the temperature begins to rise again. The exact opposite happens as energy is released, and steam will drop in temperature as it approaches the boiling point. Once there, additional energy lost will allow Hydrogen bonds to form again and the gas is converted to a liquid (condensation). Once all gas is liquefied, energy lost results in a falling temperature until the melting point is reached and then energy will be released to the point that the liquid begins freezing. Temperature remains constant during this process, just like it did during melting, and once all of the liquid is frozen, the temperature will resume its dropping nature.

We can calculate how much heat is absorbed or released using the equations: $q = m(Tf-Ti)C$, $q = m(Hf)$, $q = m(Hv)$.

When phase is NOT changing, we use the long equation: $q = m(Tf-Ti)C$, thermal energy = mass x change in temp. x specific heat.

For example, suppose we had 125 grams of liquid H_2O that warmed from 35.0 degrees to 47.0 degrees. How much thermal energy was ABSORBED for this to happen? (We know it was absorbed because the temp. increased. Therefore, the answer should be positive).

q = m(Tf - Ti)C

q = 125g (47.0 - 35.0) 4.18*

*We know the specific heat of liquid water because it's on our REF. TABLE

q = 6270 Joules

Another example, suppose we had 67.0 grams of ice that we wanted to make even colder. We lowered the temp. from -2.00 degrees C to -5.00 degrees C. How much energy was released from the ice? (We expect a NEGATIVE answer here because energy must be released to lower the temperature).

q= m(Tf-Ti)C

q = 67.0 (-5.00 - -2.00) 2.05*

*We know the specific heat of ice because it's on our REF. TABLE

q = 67.0 (-3.00) 2.05

q = -412 Joules (Remember, the answer is negative because we released energy.

But what if phases ARE changing? Then, we must use the shorter equations, because if phases are changing, temperature is NOT changing (as seen on the graph above).

What if that 65.0 grams of ice absorbed enough energy to become liquid water? We use the equation q = mHf, mass x heat of fusion. The heat of fusion is the amount of energy needed to change 1 gram of a solid into a liquid. Every substance has its own unique heat of fusion. Water's heat of fusion is on our REF. TABLE.

q = mHf

q = 65.0 (334)

q = 21700 Joules

What if that same amount of water absorbed enough energy to become steam? We use the equation q = mHv, mass x heat of vaporization. The heat of vaporization is the amount of energy needed to change 1 gram of a liquid into a gas. Every substance has its own unique heat of vaporization. Water's heat of vaporization is on our REF. TABLE.

q = mHv

q = 65.0 (2260)

q = 147,000 Joules *Notice MUCH more energy must be absorbed to change a liquid to a gas than a solid to a liquid.

These equations can also be completed if phases are changing because of the release of energy. The only change you would make is that you would make the heat of fusion or heat of vaporization negative.

For example, suppose you had 87.0 grams of liquid water that you wanted to freeze.

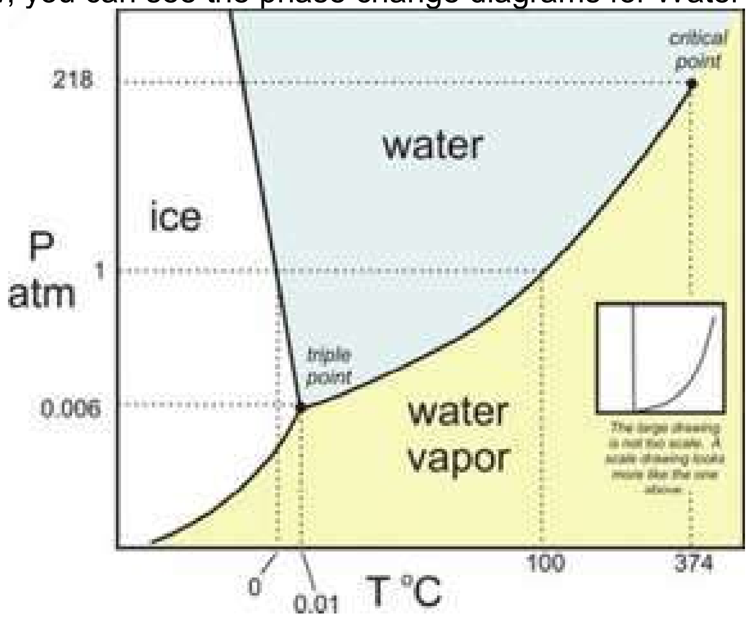
q = m(-Hf)

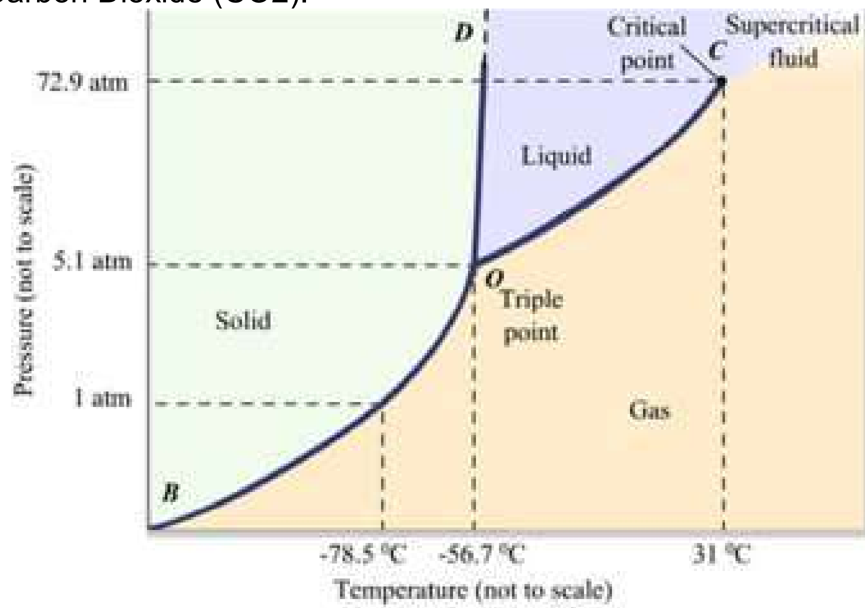
Q = 87.0 (-334)

Q = -29100 Joules *this value is negative because that's how much energy must be released to freeze the liquid.

Objective 2.1.3: Interpret the data presented in phase diagrams.

Below, you can see the phase change diagrams for Water (H2O) and Carbon Dioxide (CO2).





0.01 degrreeeUsing the phase change diagrams above, you should be able to point out certain things about the substances.

*The first thing you can see is what phase the substance is in at a given temperature and pressure.

For example, what phase is water in at 1 atm and 70 degrees C? It's a liquid! (just look at where those two lines would meet!)

What phase is water in at 1 atm and -10 degrees C? It's a solid!

What about CO2 at 1 atm and 70 degrees C? It's a gas!

What about CO2 at 1 atm and -10 degrees C? Still, a gas!

What about CO2 at 1 atm and -80 degrees C? It's a solid at that very low temperature!

*Using these diagrams you can also describe what happens if one variable is changed but the other is held constant. For example, what happens to water at 1 atm, if the temperature increases from 25.0 degrees C to 75.0 degrees C? Nothing! It remains liquid! But, what happens if it goes from 25.0 degrees C to 105 degrees C? It changes from liquid to gas.

Also what if you had CO_2 at 1 atm and -80 degrees C (it's a gas). However, if the pressure is increased to 5 atm, it changes from gas to solid!

*We can also use these graphs to find the melting and boiling point at a certain pressure.

For example, at 1 atm, the melting point of water is 0 degrees C and the boiling point of water is 100 degrees C.

*Finally, we can use phase change charts to point out the TRIPLE POINT. It's the point where at that given temperature and pressure, it is possible to have ALL 3 PHASES at once! For water, the triple point is at 0.006 atm of pressure, and 0.01 degrees C. For CO2, the triple point is at 5.1 atm of pressure and -56.7 degrees Celsius.

Objective 2.1.4: Infer simple calorimetic calculations based on the concepts of heat lost equals heat gained and specific heat.

In a closed system, energy can neither be created nor destroyed, only transferred (Law of Conservation of Energy). Therefore, if we take one heated object and put it into another object, the heat should be transferred to a cooler object (Second Law of Thermodynamics). So any energy "lost" from the hot object should be "gained" by the cooler object. Because of that, we can set up a system of equations to solve for a mystery variable.

In class, we modeled this by heating a metal rod and dropping it into a beaker of water. We hypothesized that the temperature of the water would increase once the metal rod had been placed into it. We then used this information to calculate the mystery variable--how hot was the metal rod that we put into the water?

<u>Sample Data:</u>

46.0 gram Iron rod

Initial temperature as it sat on hot plate ????

Final temperature after it was dropped into water: 39.0 degrees C

Specific heat of Iron: 0.449 J/gC

50.0 mL Water = 50.0 grams Water

Initial temperature of water: 25.0 degrees C

Final temperature of water after iron was dropped in: 39.0 degrees C (the iron and water had the same final temp.)

Specific heat of Water: 4.18 J/gC

The only variables we are missing is the Ft of the Iron and the q values for each of the substances. BUT--if the heat energy from the iron was released into the water, then the water absorbed it! Therefore, they are equal but opposite!

$-q_{iron} = q_{water}$

-(m)(Tf-Ti)(C)iron = (m)(Tf-Ti)(C)water

-(46.0)(39.0 - Ti)(0.449) = (50.0)(39.0-25.0)(4.18)

-46.0(0.449)(39.0 - Ti) = 2926

-20.654(39.0 - Ti) = 2926

39.0 - Ti = -141.7

-Ti = -180.7

Ti = 180.7 = 181 degrees C *So, we heated the iron to 181 degrees C! That makes sense because it got really hot and sizzled when we placed it into the water!