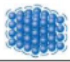
SPH3U 6.1 Warmth and Coldness

1. Vibrations of atoms and molecules

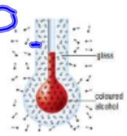
Kinetic molecular theory:	objects are made up of particles that attract each other (potential energy) and move around (kinetic energy).

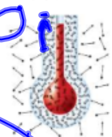
Solids	Liquids	Gases
heat: particles vibrate faster.	heat: particles vibrate faster and move from place to place.	heat: particles move around faster.
	melting → / ← freezing 	boiling → / ← condensation 

Thermal energy:	total kinetic and potential energy possessed by a substance's particles.
transfer	only transferred from hot objects to cold objects.

2. Temperature and thermometers

Temperature:	the average kinetic energy of the particles.
thermometer	a device to measure temperature. made of glass, with mercury or alcohol inside the tube.





Celsius scale	Fahrenheit scale	Kelvin scale
0°C: melting point of water. 100°C: boiling point of water.	0°F: Melting point of brine. 100°F: Boiling point of brine. (32°F → 212°F: water)	Celsius + 273. 0 K = absolute zero (no KE)

$T_C = T_K - 273$

$T_K = T_C + 273$

Ethyl alcohol boils at 78.3°C. What is this temperature in kelvins?

$T_K = T_C + 273 = 78.3 + 273 = 351.3\,K$.

Ethyl alcohol freezes at 159 K. What is this temperature in degrees Celsius?

$T_C = T_K - 273 = 159 - 273 = -114\,°C$.

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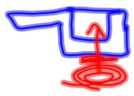
SPH3U 6.2 Heat

1. Thermal energy and temperature

Thermal energy:	total kinetic and potential energy.
temperature	average kinetic energy only.
heat	transfer of thermal energy.

Same temperature...	2.0 g, iron	1.0 g, iron
2.0 g, iron	same thermal energy.	2.0g has 2x energy.
2.0 g, aluminum	aluminum > iron.	aluminum >> iron.

2. Methods of transferring thermal energy

Method	Description	Example
Conduction.	when warmer objects touch cooler objects.	·pot on a stove. 
Convection (only in liquid or gas)	inside a fluid, cooler fluids fall down and push warmer fluids up (heat rises)	·water in a pot.  ·air on the ocean coast.
Radiation. (can go through a vacuum).	- thermal energy is transferred as electromagnetic waves (light)	·sun. ·everything radiates heat. ·humans emit infrared radiation.

3. Thermal conductors and thermal insulators

Thermal conductors:	materials that conduct heat well. ·metals (pots and pans).
Thermal insulators:	materials that don't conduct heat well. ·plastic (pot handles), air, wall insulation (air bubbles). ·vacuum is the best! → Thermos

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SPH3U 6.3 Heat Capacity

1. Specific heat capacity

Specific heat capacity: c	amount of energy (J) to increase the temperature of 1 kg of a substance by 1°C $\left(\frac{J}{kg°C}\right)$

Substance	Specific Heat Capacity, *c*	Substance	Specific Heat Capacity, *c*	Substance	Specific Heat Capacity, *c*
water	4.18×10^3	aluminum	9.2×10^2	copper	3.8×10^2
ethyl alcohol	2.46×10^3	glass	8.4×10^2	silver	2.4×10^2
ice	2.1×10^3	iron	4.5×10^2	lead	1.3×10^2

Quantity of heat:	Q, amount of energy transferred between 2 objects.
equation	$Q = mc\Delta T = mc(T_f - T_i)$. Units: J.

When 200.0 mL of water is heated from 15.0 °C to 40.0 °C, how much thermal energy is absorbed by the water?

$c = 4.18 \times 10^3 \frac{J}{kg°C}$. $m = 0.2000\ kg$. (1 mL of water = 1 g).

$Q = mc\Delta T = (0.2)(4.18 \times 10^3)(40 - 15)$

$= 20900\ J = 20.9\ kJ$.

An empty copper pot is sitting on the stove, with a mass of 1.2 kg and a temperature of 130.0 °C. If the pot cools down to 21.0 °C, how much thermal energy does it release?

$c = 3.8 \times 10^2$, $m = 1.2\ kg$.

$Q = mc\Delta T = (1.2)(3.8 \times 10^2)(21 - 130)$

$= -50\ kJ$.

A block of iron starts off at a temperature of 22.0 °C. It is heated t o100.0 °C by placing it in boiling water. The energy required is 4.91×10^5 J. Calculate the mass of the iron block.

$c = 4.5 \times 10^2$, $Q = 4.91 \times 10^5\ J$, $\Delta T = (100 - 22)$.

$Q = mc\Delta T \qquad m = \frac{Q}{c\Delta T} = \frac{4.91 \times 10^5}{(4.5 \times 10^2)(100 - 22)}$

$= 14.0\ kg$.

2. The principle of thermal energy exchange

Principle of thermal energy exchange:	When a warmer object touches a cooler object, the heat it loses = the heat the cooler object gains.
equation	$Q_{released} = -Q_{absorbed}$ $Q_R = -Q_A$.

A 60.0 g sample of metal is heated to 100.0 °C before being placed in 200.0 mL of water with an initial temperature of 10.0 °C. Together, they reach a final temperature of 15.6 °C. What is the metal?

$m_1 = 0.06\ kg,\ T_{i1} = 100°C,\ m_2 = 0.2\ kg,\ T_{i2} = 10°C,\ T_f = 15.6°C.$
$c_2 = 4.18\times10^3$

$Q_R = -Q_A,\ Q = mc\Delta T \rightarrow m_1c_1(T_f - T_{i1}) = -m_2c_2(T_f - T_{i2}).$

$$c_1 = \frac{-m_2c_2(T_f - T_{i2})}{m_1(T_f - T_{i1})} = \frac{-(0.2)(4.18\times10^3)(15.6-10)}{(0.06)(15.6-100)} = 9.24\times10^2\ \frac{J}{kg°C}$$

∴ the metal is aluminum.

A sample of iron is heated to 80.0 °C and placed in 100.0 mL of water at 20.0 °C. The final temperature of the mixture is 22.0 °C. What is the mass of the iron?

$m_1c_1(T_f - T_{i1}) = -m_2c_2(T_f - T_{i2})$

$$m_1 = \frac{-m_2c_2(T_f - T_{i2})}{c_1(T_f - T_{i1})} = \frac{-(0.1\ kg)(4.18\times10^3)(22-20)}{(4.5\times10^2)(22-80)}$$

$= 3.2\times10^{-2}\ kg.$

200.0 g of silver is heated to 90.0 °C. The hot silver is then placed into 300.0 g of ethyl alcohol with an initial temperature of 5.0 °C. What is the final temperature of the mixture?

$m_1c_1(T_f - T_{i1}) = m_2c_2(T_f - T_{i2})$ $T_f(m_1c_1 + m_2c_2) = m_1c_1T_{i1} + m_2c_2T_{i2}$

$$T_f = \frac{m_1c_1T_{i1} + m_2c_2T_{i2}}{m_1c_1 + m_2c_2} = \frac{(0.2)(2.4\times10^2)(90) + (0.3)(2.46\times10^3)(5)}{(0.2)(2.4\times10^2) + (0.3)(2.4\times10^3)}$$

$= 10°C.$

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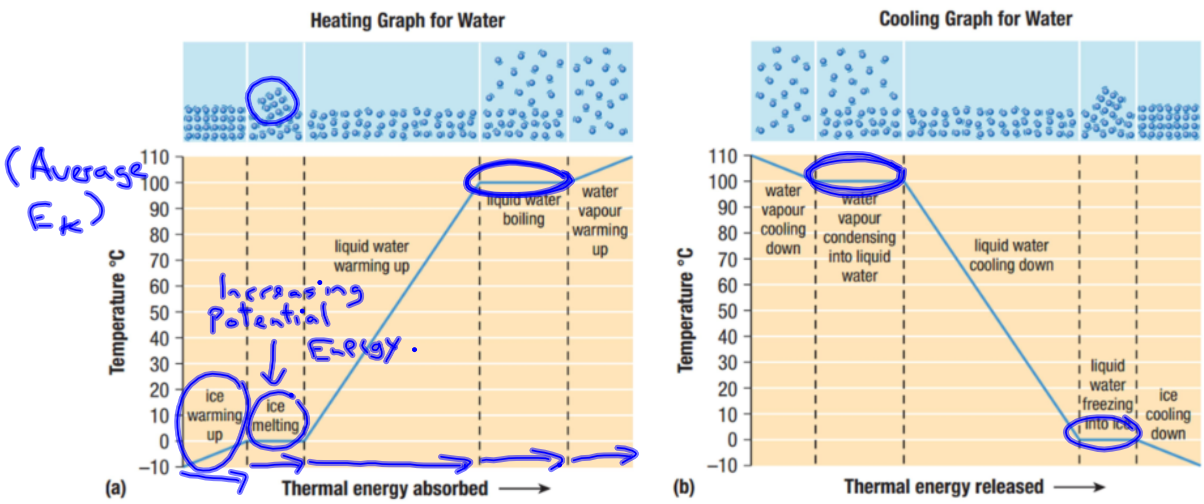
SPH3U 6.4 States of Matter and Changes of State

1. Changes of state

Fusion: (Melting) S → L	Vaporization: L → G	Sublimation: S ↔ G (skips over L).
Condensation: G → L	Freezing: L → S	

2. Heating and cooling graphs

Thermal Energy = PE + KE.



3. Latent heat

Latent heat:	total thermal energy to change states.
specific latent heat	energy to change 1 kg of a substance from one state to another.

Substance	Specific latent heat of fusion, L_f (J/kg)	Melting point (°C)	Specific latent heat of vaporization, L_v (J/kg)	Boiling point (°C)
aluminum	6.6×10^5	2519	4.0×10^5	10900
ethyl alcohol	1.1×10^5	−114	8.6×10^5	78.3
carbon dioxide	1.8×10^5	−78	5.7×10^5	−57
gold	1.1×10^6	1064	6.4×10^4	2856
lead	2.5×10^4	327.5	8.7×10^5	1750
water	3.4×10^5	0	2.3×10^6	100

Latent heat during a change of state:	Melt/freeze: $Q = mL_F$	Boil/condense: $Q = mL_V$

How much thermal energy is released by 652 g of molten lead when it changes into a solid?

$L_F = 2.5\times10^4$ J/kg. $m = 0.652$ kg.

$Q = mL_F = (0.652)(2.5\times10^4) = 16.2$ kJ.

Ethyl alcohol is a liquid at room temperature. How much thermal energy is absorbed when 135 g of ethyl alcohol at 21.5 °C is heated until all of it boils and turns into vapour?

① 21.5°C → 78.3°C: $Q = mc\Delta T$, $c = 2.46\times10^3 \frac{J}{kg°C}$.

$Q = (0.135\,kg)(2.46\times10^3)(78.3 - 21.5)$

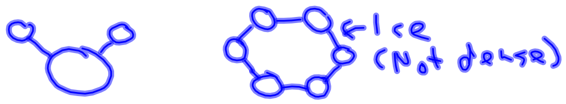
$= 18863$ J.

② L → G: $Q = mL_v$. $L_v = 8.6\times10^5 \frac{J}{kg}$.

$Q = (0.135)(8.6\times10^5) = 116\,100$ J.

Combined: $Q_1 + Q_2 = 18863 + 116100 = 135$ kJ.

4. Water: A special liquid

Most solids:	Water is more dense than most liquids.	(Sinks)
solid water	(ice) less dense than liquid water.	(Floats)
water molecule shape		

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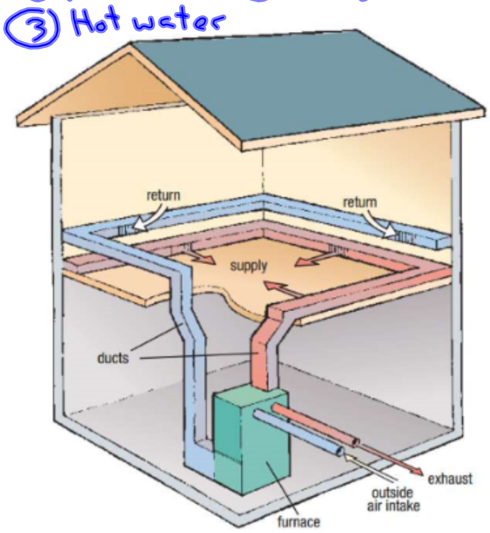
SPH3U 6.5 Heating and Cooling Systems

1. Conventional heating systems

3 conventional heating systems:

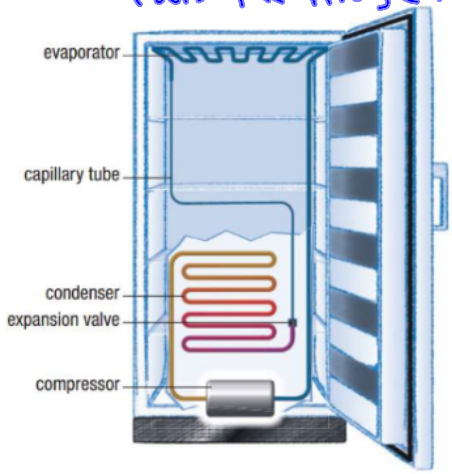
(1) Electrical (2) Forced-Air. (3) Hot water



2. Conventional ~~heating~~ cooling. systems

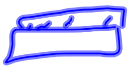
Condenser: cools the refrigerant, G→L, releases energy

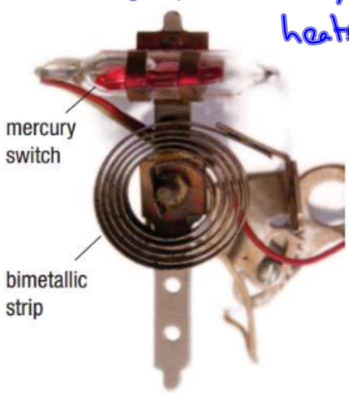
Evaporator: L→G, absorbs energy, cools the fridge.



3. Controlling heating and cooling

Bimetallic strip: two different metals that curl when they're heated.

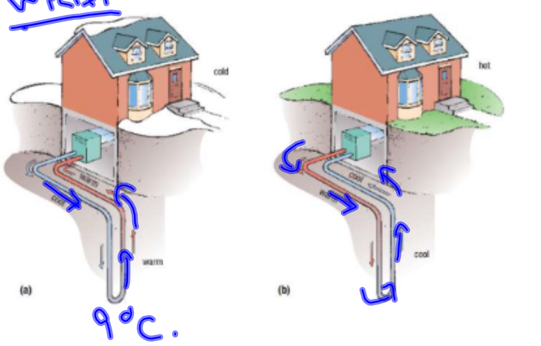




4. Geothermal systems

Temperature 3 m below ground: around 9°C at all times of year.

Winter



Homework: page 299: #1, 4