Type: Single Date:________

Objective: Latent Heat

Homework: READ 12.8, Do CONCEPT Q. # (14)
Do PROBLEMS (40, 52, 81) Ch. 12

AP Physics "B" Date: ________
Mr. Mirro

Heat and Phase Change

When bodies are ***heated*** or ***cooled*** their ***temperatures*** increase or decrease respectively. However, there are situations in which the addition or removal of heat DOES NOT cause a temperature change.

Consider the situation where a substance changes ***state*** or "**PHASE**."

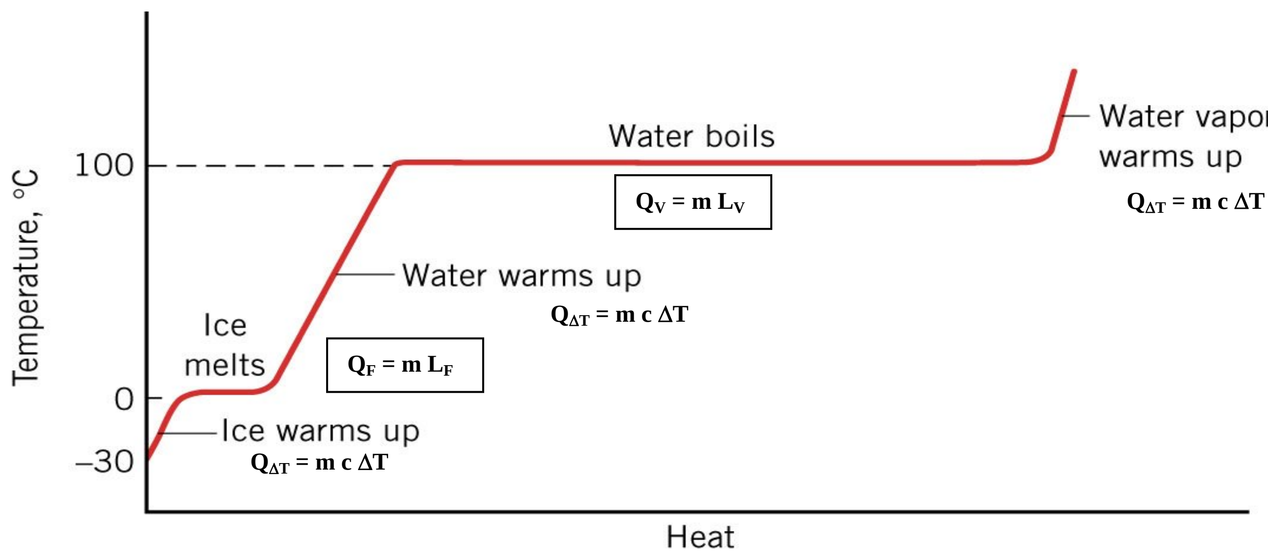
(I) Heated solid → Liquid

ie. Solid water (ice), turns into liquid water when **334** ***kilo joules*** of heat energy is added.

(II) Heated liquid → Gas

ie. Liquid water turns into water in the gaseous state (steam), when **2260** ***kilo joules*** of heat energy

While the substance is undergoing a change is phase, the temperature remains the same !



Heat being added to the systems seems to have ***disappeared*** into the heated substance without ***changing temperature***. If the heat energy is to be conserved, this ***hidden heat*** cannot be LOST !

- Apparently the heat is being used for some purpose other than raising the temperature of the substance.
- In fact, the heat is being used to change the phase of the substance, and only when all of the substance has changed phase will the temperature change accordingly.

For example, the thermal energy absorbed by ice goes into ***loosening*** the intermolecular bonds of the solid, thereby ***transforming*** it into ***liquid***. Once the ice is ***completely melted***, the temperature of the liquid water will rise until it reaches its ***boiling point***. At this point, ***additional heat*** does not increase the temperature of the water, it ***breaks*** the intermolecular bonds, ***transforming*** the liquid water into ***steam***.

Since there is <u>no</u> ***temperature*** <u>change</u> while the substance is <u>undergoing</u> a ***phase change***, the ***heat energy*** supplied to the substance is described by:

Heat Supplied or Removed in Changing the Phase of a Substance

The heat Q that must be supplied or removed to *change* the *phase* of a mass m of a substance is:

$$\mathbf{Q = m\,L} \qquad \text{Latent Heat of Transformation}$$

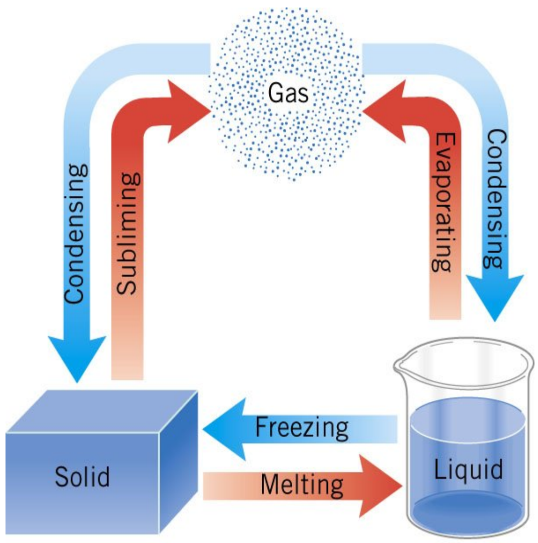
Where L, the *latent heat* of the substance has units J/kg.

This equation tells us <u>how</u> <u>much</u> ***heat*** must be ***transferred*** to cause a substance to ***completely*** undergo a ***phase change***.

- In the case of a <u>solid to liquid</u> or <u>liquid to solid</u>, the (L) is the Latent Heat of Fusion (L_F).
- In the case of a <u>liquid to a vapor</u> or <u>vapor to a liquid</u>, the (L) is the Latent Heat of Vaporization (L_V).

For example, a ***solid*** can ***melt*** or ***fuse*** into a ***liquid*** if ***heat*** is ***added***, while the ***liquid*** can ***freeze*** into a ***solid*** if ***heat*** is ***removed***.

Similarly, a ***liquid*** can ***evaporate*** into a ***gas*** if ***heat*** is ***supplied***, while the ***gas*** can ***condense*** into a ***liquid*** if ***heat*** is ***taken away***.



Finally, some solids can change (sublime) directly into a gas by undergoing a process called ***sublimation***.

- Solid carbon dioxide (CO_2) turns into gaseous CO_2
- Solid naphthalene (moth balls) turns into naphthalene fumes

Conversely, if heat is removed under the right conditions, the gas can condense directly into a solid.

AP Physics "B" Date: ________

Mr. Mirro

Heat and Phase Change

Ex 1: Consider a 100 gram (?? kg) sample of water initially frozen at zero degrees Celsius. [PrinctonReview9.4+9.5mod]

a. If the heat of fusion for water is 33.5×10^4 J/kg, how much thermal energy is required to completely melt the ice and turn it into 100 grams of liquid water at 0 °C ?

b. If the specific heat capacity of liquid water is 4186 J/kg°C, how much heat must be added to the sample to raise the temperature of the 100 gram sample to a boiling point of 100 °C ?

c. If the heat of vaporization of water is 22.6×10^5 J/kg, how much thermal energy would the water need to absorb in order to turn completely to steam ?

d. How much heat energy is necessary to turn 100 grams of ice at 0 °C completely into steam

Ex 2: Ice at 0 °C is placed in a Styrofoam cup containing 0.32 kg of lemonade at 27 °C. The specific heat capacity of lemonade is virtually the same as that of water (c = 4186 J/kg °C). After the ice and lemonade reach an equilibrium temperature, some ice still remains. If the latent heat of fusion for water is $L_F = 3.35 \times 10^5$ J/kg, determine the mass of ice that has melted. Assume that the mass of the cup is so small that it absorbs a negligible amount of heat and ignore any heat lost to the surroundings. [Cutnell12.13]

Ex 3: How could we determine and express the amount of heat necessary to change 1 kg of ice at 0 °C into steam at 100 °C graphically ? [General]

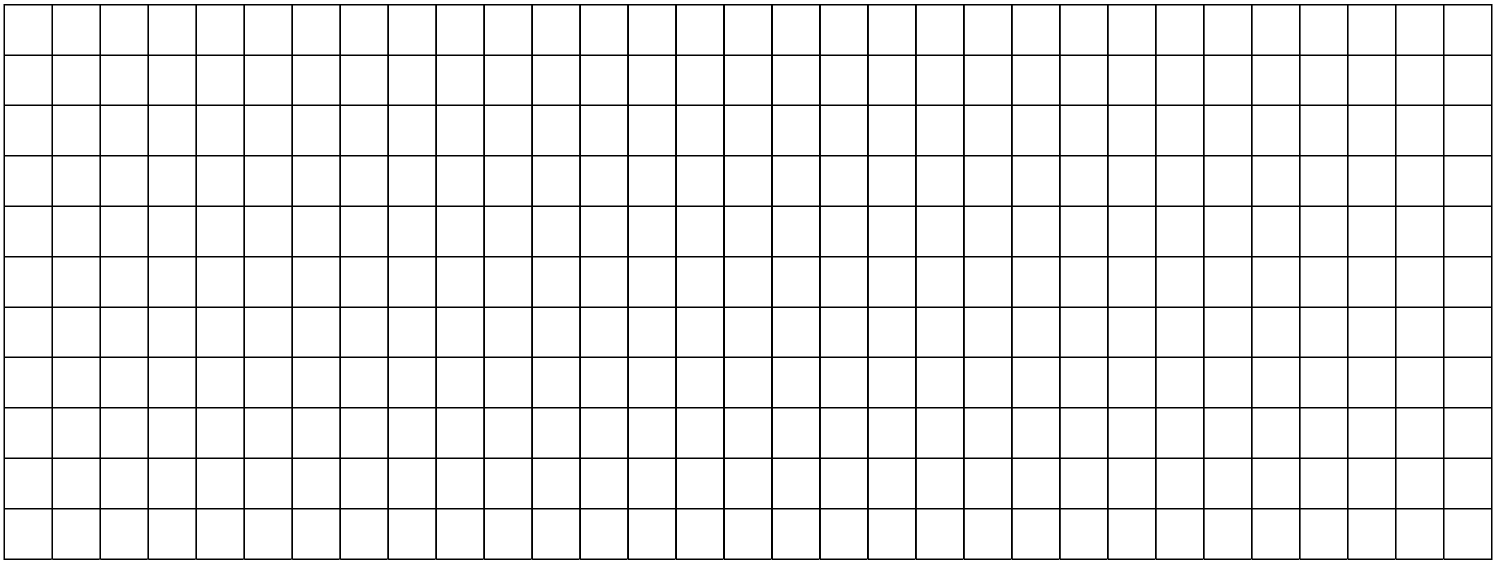
a. How much heat is required to melt 1 kg of ice at 0 °C ?

b. How much heat is required to raise the temperature of 1kg of cold water at 0 °C to 100 °C ?

c. How much heat is required to turn 1 kg of water into steam at 100 °C ?

d. Construct the Phase Diagram depicting the transformation of this substance into steam at 100 °C.

Temperature Vs. Amount of Heat



Amount of heat (1 x 10^5 Joules per box)

AP Physics "B"
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Heat and Phase Change

Ex 1: Consider a 100 gram (?? kg) sample of water initially frozen at zero degrees Celsius. [PrinctonReview9.4+9.5mod]

.10 kg

a. If the heat of fusion for water is 33.5×10^4 J/kg, how much thermal energy is required to completely melt the ice and turn it into 100 grams of liquid water at 0 °C ?

$$Q_F = ML_F = (.10\ kg)(33.5 \times 10^4\ J/kg) = 3.35 \times 10^4\ J$$

b. If the specific heat capacity of liquid water is 4186 J/kg°C, how much heat must be added to the sample to raise the temperature of the 100 gram sample to a boiling point of 100 °C ?

$$Q_{\Delta T} = MC\Delta T = (.10\ kg)(4186\ J/kg°C)(100°C) = 4.19 \times 10^4\ J$$

c. If the heat of vaporization of water is 22.6×10^5 J/kg, how much thermal energy would the water need to absorb in order to turn completely to steam ?

$$Q_V = ML_V = (.10\ kg)(22.6 \times 10^5\ J/kg) = 2.26 \times 10^5\ J$$

d. How much heat energy is necessary to turn 100 grams of ice at 0 °C completely into steam

$$Q_{TOTAL} = Q_F + Q_{\Delta T} + Q_V$$

$$Q_T = 3.35 \times 10^4 + 4.19 \times 10^4 + 2.26 \times 10^5 = 3 \times 10^5\ J$$

Ex 2: Ice at 0 °C is placed in a Styrofoam cup containing 0.32 kg of lemonade at 27 °C. The specific heat capacity of lemonade is virtually the same as that of water (c = 4186 J/kg °C). After the ice and lemonade reach an equilibrium temperature, some ice still remains. If the latent heat of fusion for water is $L_F = 3.35 \times 10^5$ J/kg, determine the mass of ice that has melted. Assume that the mass of the cup is so small that it absorbs a negligible amount of heat and ignore any heat lost to the surroundings. [Cutnell12.13]

$$+Q_{ICE} = -Q_{LEMONADE}$$

$$(ML_V)_{ICE} = -(MC\Delta T)_{LEMONADE}$$

$$M_{ICE} = \frac{(MC\Delta T)_{LEMONADE}}{L_{V\,ICE}}$$

$$M_{ICE} = \frac{.32(4186)(27)}{3.35 \times 10^5} = .108\ kg$$

Ex 3: How could we determine and express the amount of heat necessary to change 1 kg of ice at 0 °C into steam at 100 °C graphically ? [General]

a. How much heat is required to melt 1 kg of ice at 0 °C ?

$$Q_f = mL_f = 1kg\left(33.5\times10^4 \frac{J}{kg}\right) = 33.5\times10^4 J = 3.34\times10^5 J$$

b. How much heat is required to raise the temperature of 1kg of cold water at 0 °C to 100 °C ?

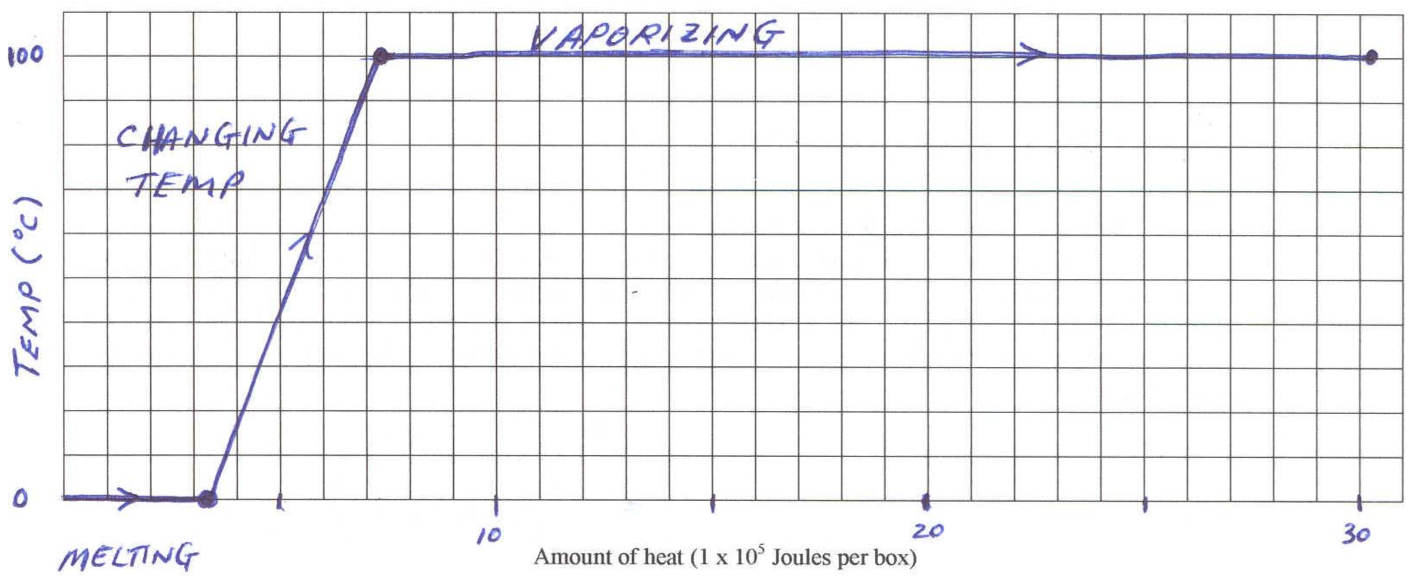
$$Q_{\Delta T} = mc\Delta T = 1kg\left(4186 \frac{J}{kg°C}\right)(100°C) = 4.19\times10^5 J$$

c. How much heat is required to turn 1 kg of water into steam at 100 °C ?

$$Q_v = mL_v = 1kg\left(22.6\times10^5 \frac{J}{kg}\right) = 22.6\times10^5 J$$

d. Construct the Phase Diagram depicting the transformation of this substance into steam at 100 °C.

Temperature Vs. Amount of Heat



Amount of heat (1 x 10^5 Joules per box)