WS 6.8 Boiling *I recommend you do this worksheet* **in pencil!**

Use class notes & direct observations of the boiling process to fill out the following explanation sheet. Also, fill in the figures at right showing a liquid & its vapor in a closed container.

Evaporation and vapor pressure:

In a liquid, some of the ___________ moving near the surface have enough energy to escape into the ___________ state. This process is known as ___________. If this takes place in a(n) ________ container, the liquid will eventually all evaporate away. But if it takes place in a _______ container (with a lid), then the vapor molecules will start to accumulate over the liquid's surface as shown in **Fig 1** at right. These vapor molecules might bounce back into the liquid and get "re-captured". This is known as __________. As more evaporation takes place, the concentration of vapor molecules ___________, which in turn increases the rate of ___________. In a relatively short time, the ___________ rate will increase to the point where it equals the ___________ rate, and the system will be at a state of ___________ as shown in **Fig 2** at right. This vapor exerts a ___________ against the inside walls of the container. This is known as the ________ ________ of the liquid. If the temperature of the system were increased, it would cause the ___________ rate to increase (as shown in **Fig 3**), which would in turn cause the concentration of ________ molecules to increase. This would cause the ___________ rate to increase, and the system would reach a new ___________ as shown in **Fig 4**. Since there are more vapor ___________ bouncing around at higher ___________, the ________ ________ would also be higher. In general, as ___________ increases, ________ ________ also increases. The chart at right below shows the ________ ________ (in mmHg) of various ________ at a range of different ________ (in ˚C). Note that at 20˚C, water has a vapor pressure of ____ mmHg, whereas liquid A has a vapor pressure of _____ mmHg. This higher vapor pressure is caused by liquid A evaporating at a ________ rate than water, which is a result of its molecules having a weaker attraction for one another. Something that evaporates quickly is said to be ________. Note that liquid B has a much _________ vapor pressure than water at any given ___________. This would imply that it is less _________ than water and thus the attractive forces between its molecules are _________.

Fig 1

Fig 2

Fig 3

Fig 4

temp (˚C)	vapor pressure (mmHg)		
	water	liquid A	liquid B
0	5	25	2
20	18	108	4
40	55	303	9
60	149	701	27
80	355	1420	75
100	760	2514	178
120	1520	4276	380
140	2710	7278	748
160	4515	11051	1321
180	7600	16728	2219

Boiling:

When water is heated (from beneath) in an open container, some of the ___________ at the bottom might absorb sufficient _________ to cause them to fly apart and form a small ________ of water vapor. If the temperature of the surrounding water is only 60˚C, then the ________ ________ pushing outward on the walls of that bubble will only be ____ mmHg. The atmospheric pressure pushing downward on the water's surface (assuming standard pressure) will be ____ mmHg. This greater pressure from the outside causes the bubble to collapse back into a _______ state. If one watches a pot of water on the stove, one can easily observe these _______ form and then _______ long before the water comes to a true ________.

Ans for side 1 (IAO+3): boil bubble bubbles closed collapse condensation condensation condensation condensation energy equilibrium equilibrium evaporation evaporation evaporation greater high increases liquid liquids lower mmHg molecules molecules molecules open pressure pressure pressure pressure pressure pressure pressure stronger temp. temp. temps. temps. vapor vapor vapor vapor vapor vapor vapor volatile volatile 18 108 149 760

When the temperature is increased further, up to 80˚C, the bubbles that form will have vapor molecules pushing outward with a ________ of 355 mmHg. Still, this pressure will not be great enough to withstand the ________ ________ of 760 ______ pushing downward from the outside of the container, thus the bubble will again ________. At 99˚C, the ________ ________ of water is 733 mmHg, still not enough... and then finally at ____ ˚C, the vapor pressure of water reaches _____ _____, where it can finally match the outside pressure of __________ __________. This allows the bubble to persist, so that more molecules can vaporize into it. As the bubble grows, it quickly breaks lose from the bottom and floats upwards. If on the way up it encounters water that has not quite reached ____ ˚C, the bubble will again collapse. It is not until the entire container of water has reached ____˚C that the water will be at a full ______.

Now... if you were trying to boil water at high _________, like Denver, where the surrounding atmospheric pressure is a lot ________ than the standard ____ mmHg, then the water would _____ at a somewhat ______ _________. If you had water in a bell jar and brought the _________ down to 55 mmHg, then the water would _____ at only ____˚C. By the same token, if you put water in a ______ pressure environment, such as a _________ cooker or an auto-_______, where the pressure is taken way up to _____ mmHg, then the water needs to be 160˚C before it could _____.

Looking back at the table on side #1, we can see that liquid A, which was ______ volatile than water would have its ______ pressure reach standard pressure (______ mmHg) at a much ______ temperature. This means that liquid A would _____ at a much ________ ________ than water. In fact, it would boil around ____˚C (estimating from the table). Similarly, liquid B which was _____ _________ than water, would have to be taken to a ________ ________ for its ________ ________ to reach 760 mmHg. Thus it would have a much _________ boiling point (around _____˚C, estimated from the table).

In general then, it can be said that a _________ will always ________ when its _______ __________ matches the __________ __________ pushing down on the liquid's _________. To say that the boiling point of water is ____˚C is a bit misleading. One should say that the _________ ________ depends on the ___________ ___________, and that it just *happens* to be ____˚C at standard pressure!!!

Ans for side 2(IAO+4): altitudes atmospheric-**(x 4)** boil boil boil boil boil boil boiling clave collapse evaporation high higher higher less liquid low lower lower lower lower mmHg mmHg molecules more point pressure pressure pressure pressure pressure pressure pressure pressure pressure pressure surface temp. temp. temp. vapor vapor vapor vapor volatile 40 62 80 100 100 100 100 100 141 760 760 760 4515

Follow-up questions:

Identical eggs are placed in identical pots of water on identical stoves, one here in St. Louis, and one in Denver. The stoves are turned on at the same time.

1) Which water will heat up faster **(St. Louis, Denver, neither, both)** and *why*?

2) Which water will boil sooner **(St. Louis, Denver, neither, both)** and *why*?

3) Which water will boil at a higher temperature **(St. Louis, Denver, neither, both)** and *why*?

4) Which water will boil when its vapor pressure matches atmospheric pressure, and *why*?

5) Which egg will get done first **(St. Louis, Denver, neither, both)** and *why*?