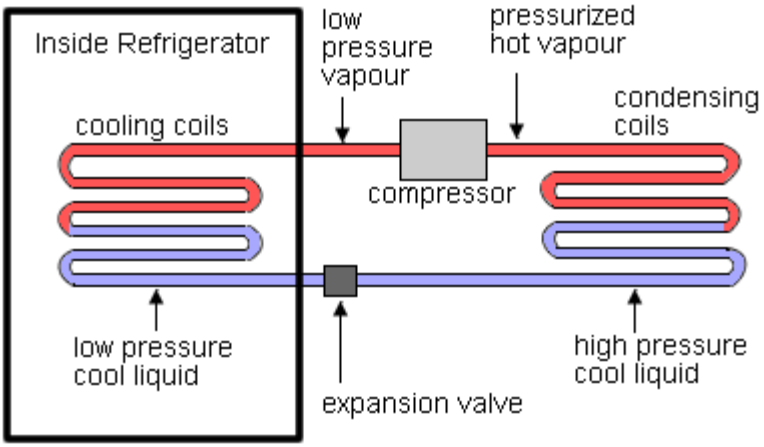
EPS 200 (Stapleton) Name: _____

Physical Chemistry Applications – Refrigerators, Air Conditioners, and Heat Pumps

**The diagrams on this sheet were originally color diagrams (red=warm; blue=cold). You might find it helpful to view this document on a computer so that you can see the colors.

Part I: A Refrigerator

The diagram on the right shows the inner workings of a simple refrigerator. Although the diagram does not tell you this, the refrigerant moves clockwise through the system.



1. Inside the refrigerator, the low pressure liquid slowly turns to a low pressure vapor. Why does this happen, and why is it important? **The liquid turns to a vapor because it is gaining heat (heat of vaporization). This is important, because refrigerator's job is to keep food cool. Refrigerators remove heat from food. The energy that the liquid refrigerant is gaining is coming from the food, causing the food to get colder.**

2. Outside the refrigerator, the high pressure vapor turns into high pressure liquid. Why does this happen, and why is it important? **The vapor is turning into a liquid because it is losing heat (heat of vaporization). The heat that leaves the condensing coils goes into the air in the room. This is important because the refrigerator needs to get rid of the heat that it takes from the food.**

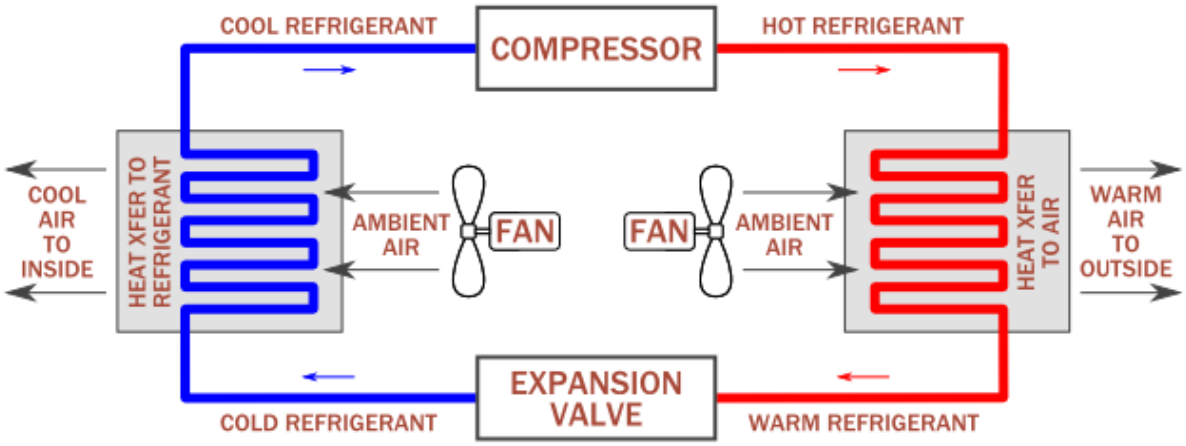
3. What purpose(s) does the expansion valve serve?
   - **Expansion cools the refrigerant so that it is colder than the food. This causes heat to flow out of the food and into the refrigerant.**
   - **Expansion lowers the pressure of the refrigerant, and that lower pressure helps the refrigerant boil/evaporate. Evaporation requires heat, which gets taken from the food.**

4. What purpose(s) does the compressor serve?
   - **Expansion heats up the refrigerant so that it is hotter than the room. This causes heat to flow out of the refrigerant and into the room.**
   - **Expansion increases the pressure of the refrigerant, and that higher pressure helps the refrigerant condense. Condensation requires the release of heat. This heat is released into the room.**

Part II: An Air Conditioner

5. Compare the refrigerator diagram above and the air conditioner diagram below. What differences do you see? **The air conditioner uses fans to move air past the hot and cold pipes.**

6. Air conditioners not only cool the air, they also dry it out. In the process of removing water from the air, car air conditioners tend to create puddles. Show where the puddle will form in the diagram below. **When air blows past the cold pipes, it often cools to its dew point. Water condenses on the surface of the cold pipes and then drips downward to form a puddle. The puddle will form beneath the cold pipes.**


COOL REFRIGERANT
COMPRESSOR
HOT REFRIGERANT
COOL AIR TO INSIDE
HEAT XFER TO REFRIGERANT
AMBIENT AIR
FAN
FAN
AMBIENT AIR
HEAT XFER TO AIR
WARM AIR TO OUTSIDE
EXPANSION VALVE
COLD REFRIGERANT
WARM REFRIGERANT

Part III: A Heat Pump

Consider the heat pump in the diagram below…

7. Convert the Celsius temperatures in the diagram to Fahrenheit. $°F = \left(°C \times \frac{9}{5}\right) + 32$
60°C **= 140**°F **65**°C **= 149**°F **-3**°C **= 26.6**°F **2**°C **= 35.6**°F

8. Why does the temperature of the outdoor pipe heat up from -3 to +2 degrees Celsius?
It passes through the ground, which must be warmer than the pipe (at least 2 degrees). Heat flows from the warmer ground into the cooler pipe, warming up the glycol/water.

9. Why does the temperature of the outdoor pipe cool down from +2 to -3 degrees Celsius?
The glycol/water passes by evaporator, which must be cooler than the glycol/water (no higher than -3 degrees). Heat flows from the warmer glycol/water into the cooler refrigerant in the evaporator. The refrigerant uses this heat to evaporate.

10. Why does the temperature of the indoor pipe heat up from 60 to 65 degrees Celsius?
It passes by the condenser, which must be warmer than the pipe (at least 65 degrees). Heat flows from the warmer condenser into the cooler pipe, warming up the hot water.

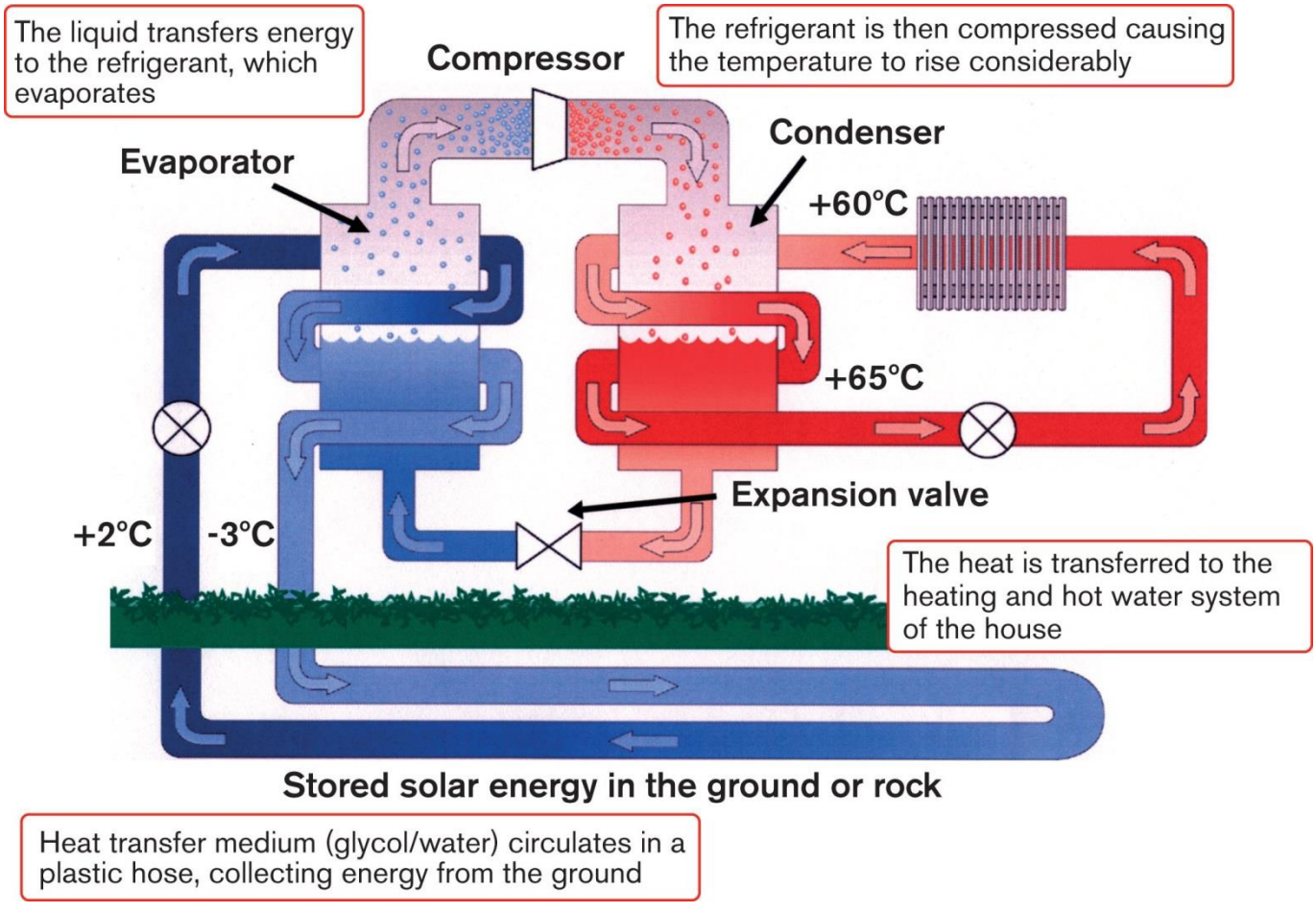
11. Why does the temperature of the indoor pipe cool down from 65 to 60 degrees Celsius?
It passes by house air, which must be cooler than the pipe (no higher than 60 degrees). Heat flows from the warmer water pipe into the cooler house air. This heats up the air in the house and cools down the water in the pipe. ***[This transfer is made more efficient by passing the radiator. When water passes through the radiator, its surface area is increased, allowing heat to leave the warm water more readily.]***

12. The diagram is meant to show the operation of a heat pump in the winter. How could the operational mode of the heat pump be changed for summer use?
The compressor needs to be reversed, so that the refrigerant flows in the opposite direction. This will increase the pressure in the evaporator, turning it into a condenser. The condenser will be turned into an evaporator (low pressure).

13. How is this heat pump different from the refrigerator and the air conditioner on the previous page?
- **Heat is taken from the ground (instead of taking it from the air or from food).**
- **In the current mode, the purpose of the heat pump is to heat air (The AC and refrigerator are cooling devices)**
- **The heat pump uses flowing glycol/water (propelled by pumps) to move heat from one location to another. The air conditioner uses flowing air (propelled by fans) to move heat. The refrigerator in the diagram does not actively circulate air or water, it relies on natural convection currents and conduction to transfer heat.**

14. Estimate the temperatures of the a) evaporator b) condenser c) ground d) house room air
Evaporator $<$ **-3**°C **(26.6**°F**)**
Condenser $>$ **65**°C **(149**°F**)**
Ground $>$ **2**°C **(35.6**°F**)**
House Room Air $<$ **60**°C **(140**°F**)**

Diagram from http://www.baystarenergy.co.uk/wp-content/uploads/2013/05/how-a-heat-pump-works.jpg


The liquid transfers energy to the refrigerant, which evaporates
Compressor
The refrigerant is then compressed causing the temperature to rise considerably
Condenser
Evaporator
+60°C
+65°C
Expansion valve
+2°C
-3°C
The heat is transferred to the heating and hot water system of the house
Stored solar energy in the ground or rock
Heat transfer medium (glycol/water) circulates in a plastic hose, collecting energy from the ground