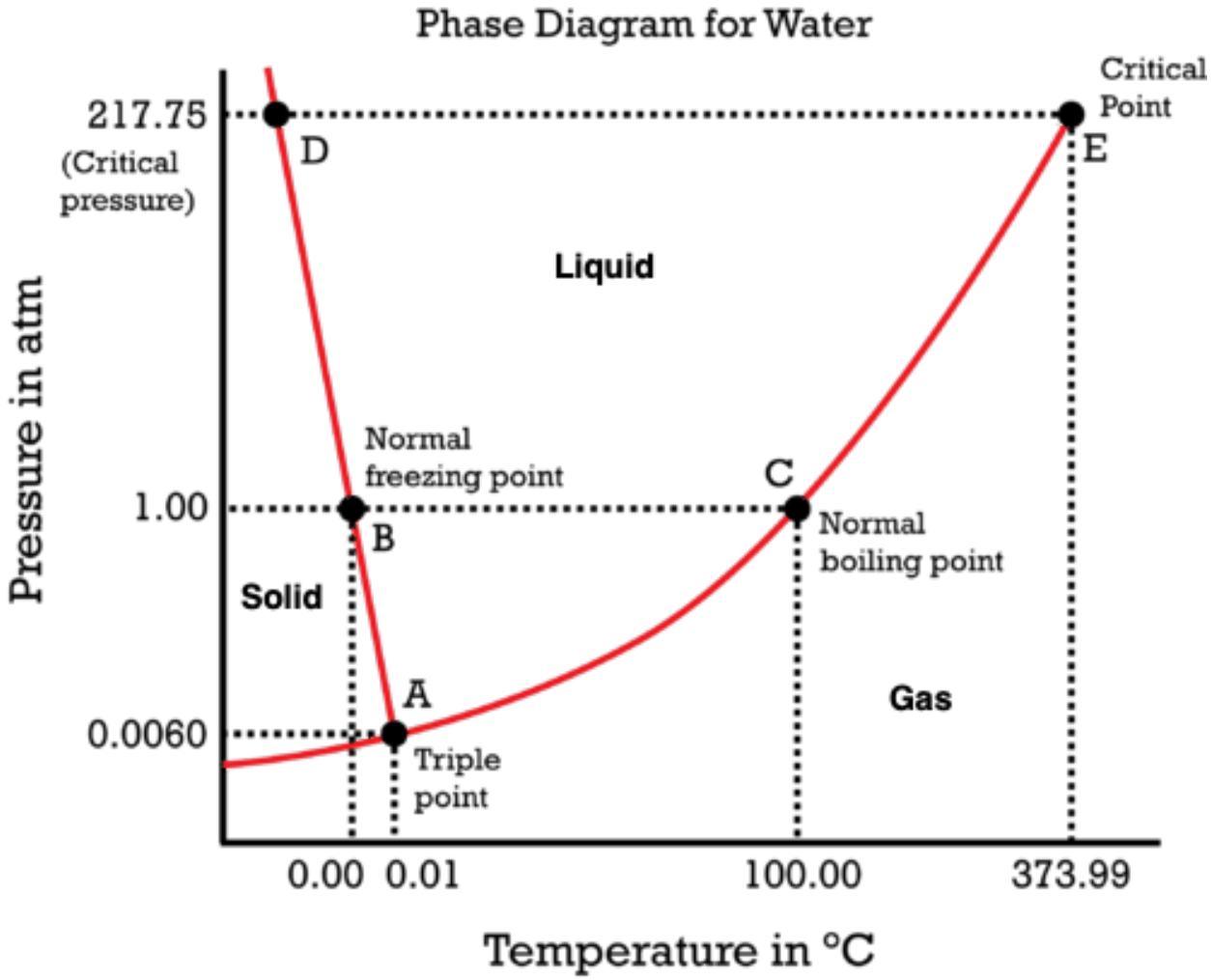
Phase Diagrams

A **phase diagram** is a convenient way of representing the phases of a substance as a function of temperature and pressure. For example, the phase diagram for water (below) shows which state exists at a given temperature and pressure.



It is important to note that a phase diagram describes conditions and events in a closed system, where no material can escape into the surroundings and no air is present.

To show how to interpret the phase diagram for water, we will consider heating a sample of water at several specific pressures.

Case 1 Pressure is 1 atm

Start with a container filled with ice at $-20°C$. As the container is heated, ice is the only thing present until we reach 0°C, where the ice changes to water as energy is added. This is the normal melting point of water. Once the ice has completely changed to water, the temperature again begins to rise. This continues until the temperature of the water reaches $100°C$. At this point the water

changes to water vapor. This is the normal boiling point of water. Once all of the water has changed to vapor, the temperature will again begin to rise.

Case 2 Pressure is 0.002 atm

Start with a container filled with ice at $-20℃$. As the container is heated, ice is the only thing present until we reach $-10℃$, where the ice changes directly to water vapor, skipping the liquid phase altogether. This process is known as *sublimation*.

Case 3 Pressure is 0.006 atm

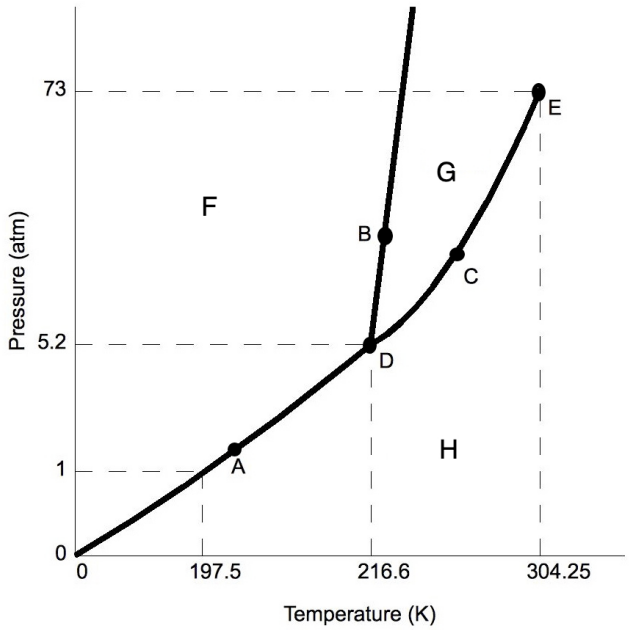
Start with a container filled with ice at $-20℃$. As the container is heated, ice is the only thing present until we reach $0.01℃$. At this point, called the **triple point**, solid and liquid water have identical vapor pressures. As a result, *all three states of water will coexist* at this exact temperature and pressure.

Case 4 The Critical Point

The **critical temperature** for a substance is defined as the temperature above which the vapor cannot be liquified no matter how much pressure is applied. The **critical pressure** is the pressure required to produce liquefaction *at* the critical temperature. Together, the critical temperature and the critical pressure define the **critical point**. For water, the critical point is $374℃$ and $218\ atm$. Note that the line separating the liquid and vapor phases ends at the critical point. Beyond this point, the transition from one state to another involves an intermediate "fluid" region that is neither true liquid or vapor.

Worksheet

1. Use the phase diagram given below to answer the following questions.



a) What phases are present at points A through H.
b) At what temperature and pressure does the triple point occur?
c) What is the critical temperature for this substance?
d) What is the critical pressure for this substance?
e) At 1 atm of pressure, describe what happens to this substance as it is heated from 0 K to 300 K.