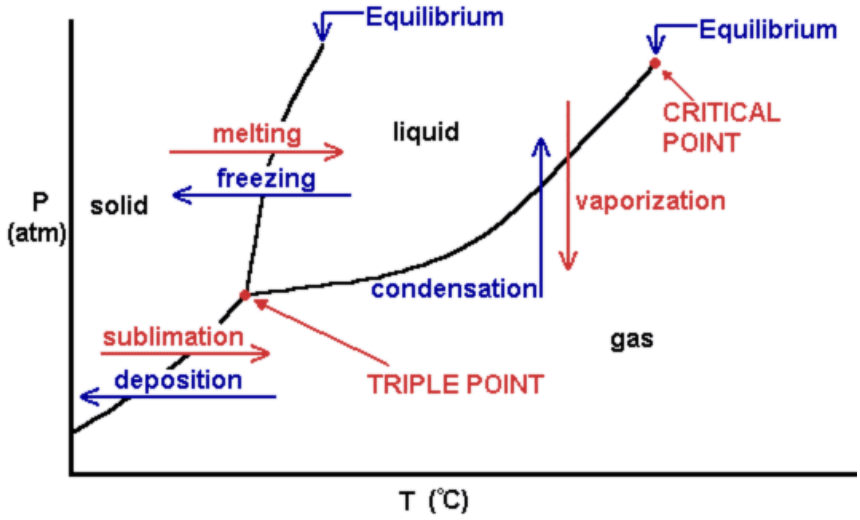
Name KEY Period _____ Date _____

Chemistry - **Changes of State, Vapor Pressure, & Phase Diagrams**

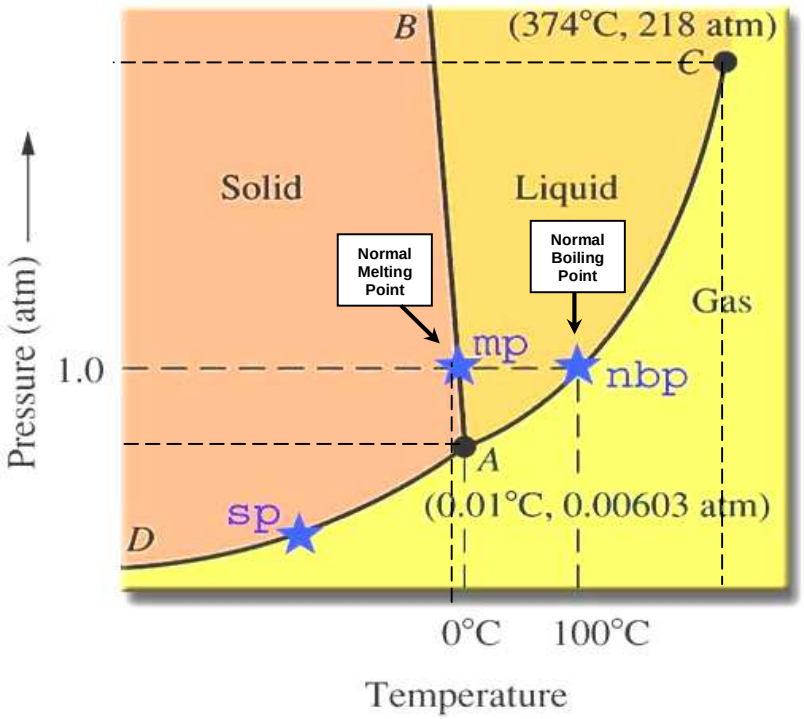
# Generic Phase Diagram




- **Sublimation** is the phase change as a substance changes from a solid to a gas without passing through the intermediate state of a liquid.
- **Deposition** is the phase change as a substance changes from a gas to a solid without passing through the intermediate state of a liquid.
- **TRIPLE POINT** - The temperature and pressure at which the solid, liquid, and gas phases exist simultaneously.
- **CRITICAL POINT** - The temperature above which a substance will always be a gas regardless of the pressure.
- **NOTE:**
  - The solid phase is more dense than the liquid phase.
  - The line between the solid and gas phases is the equilibrium of solid and gas phases at that specific pressure and temperature, i.e. a curve of all the deposition/sublimation points.
  - The line between the solid and liquid phases is the equilibrium of solid and liquid phases at that specific pressure and temperature, i.e. a curve of all the freezing/melting points.
  - The line between the liquid and gas phases is the equilibrium of liquid and gas phases at that specific pressure and temperature, i.e. a curve of all the vaporization/condensation points.
- **Melting Point** (**Freezing Point**) - The temperature at which the solid and liquid phases of a substance are in equilibrium at atmospheric pressure.
  - **Normal Melting Point** (**Freezing Point**) - The temperature at which the solid changes to a liquid at **S**tandard **P**ressure (1.00 atm = 760 mmHg = 760 torr = 101.325 kPa)
- **Boiling Point** (**Condensation Point**) - The temperature at which the vapor pressure of a liquid is equal to the pressure on the liquid.
  - **Normal Boiling Point** (**Condensation Point**) - The temperature at which the vapor pressure of a liquid is equal to **S**tandard **P**ressure (1.00 atm = 760 mmHg = 760 torr = 101.325 kPa)

# Phase Diagram for Water

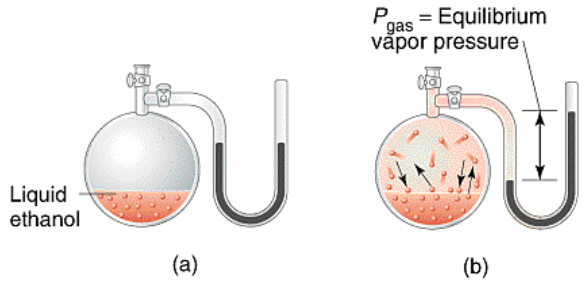
**For water, the liquid phase is more dense than the solid phase due to hydrogen bonding.**

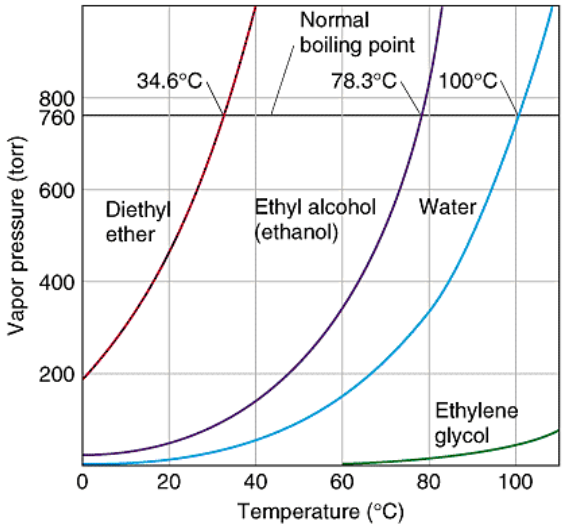


## Vapor Pressure

If you put any liquid in a sealed vessel and wait long enough, (b) the liquid will come into equilibrium with its vapor, and a constant (steady; dependent only of the temperature) equilibrium vapor pressure will be established.

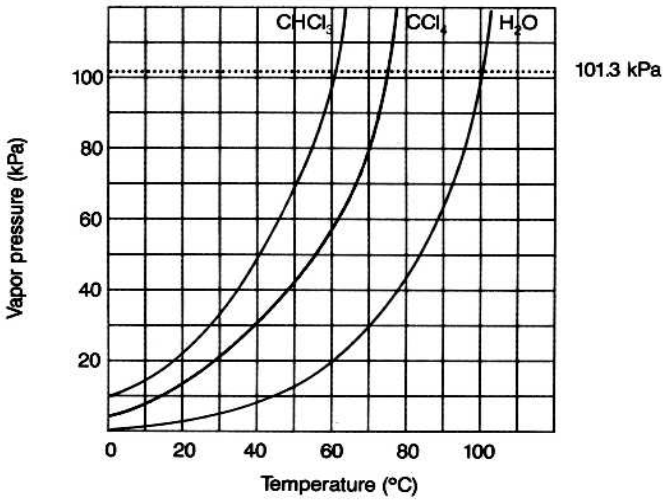
**Normal Boiling Point** - The temperature at which the vapor pressure of a liquid is equal to **S**tandard **P**ressure (1.00 atm = 760 mmHg = 760 torr = 101.325 kPa)




### PART B – VAPOR PRESSURE GRAPH

Use the graph at right to answer the following questions:




1. What is the vapor pressure of $CHCl_3$ at 50°C?

   69 kPa

2. What is the boiling point of $H_2O$ when the external pressure is 30 kPa?

   70°C

3. What is the normal boiling point of $CCl_4$?

   75°C

4. Which substance has the weakest IMF?

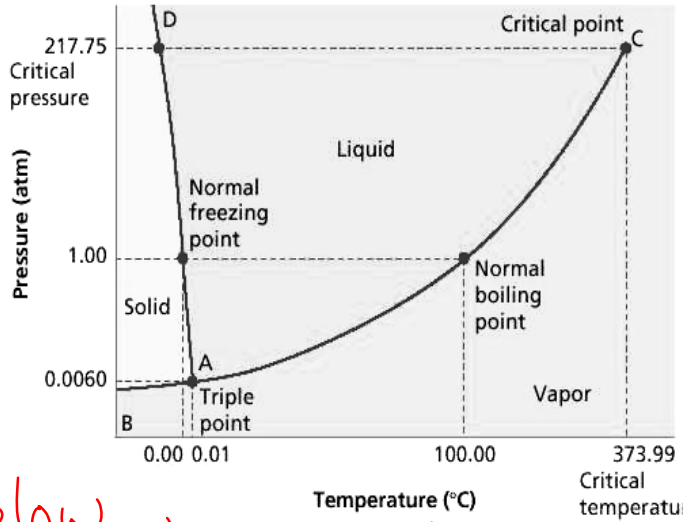
   $CHCl_3$

5. What does each VP curve represent?

   Liquid - gas equilibrium

### Phase Diagram 1

Use the phase diagram for water at right to answer the following questions:




1. What is the state of water at 2 atm and 50°

   liquid

2. What phase change will occur if the temperature is lowered from 80°C to -5°C at 1 atm?

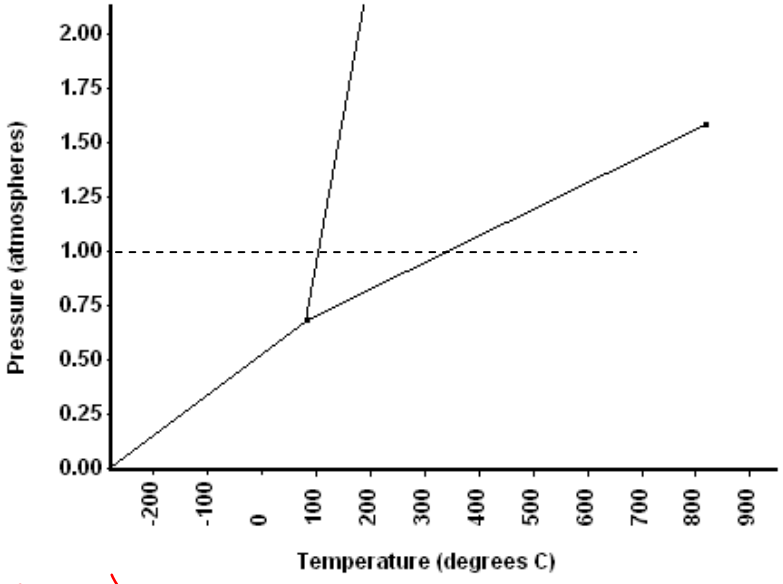
   Freezing (l → s)

3. You have ice at -10°C and 1 atm. What could you do in order cause the ice to sublime?

   decrease pressure below 0.0060 atm

**Phase Diagram 2**

Refer to the phase diagram at right when answering the questions on this worksheet:




1. What is the normal freezing point of this substance? ≃ 100°C

2. What is the normal boiling point of this substance? ≃ 360°C

3. What is the normal melting point of this substance? ≃ 100°C

4. If I had a quantity of this substance at a pressure of 1.25 atm and a temperature of $300^0$ C and lowered the pressure to 0.25 atm, what phase transition(s) would occur? evaporation (l → g)

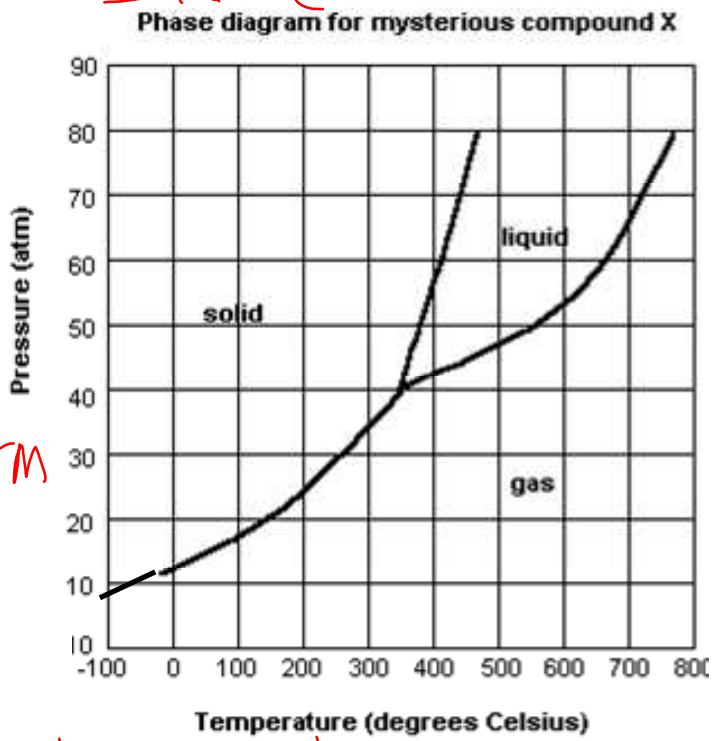
5 At what temperature do the gas and liquid phases become indistinguishable from each other? ≃ 830°C

6. If I had a quantity of this substance at a pressure of 0.75 atm and a temperature of $-100^0$ C, what phase change(s) would occur if I increased the temperature to $600^0$ C? At what temperature(s) would they occur?

Melting (s → l) ≃ 90°C & evaporating (l → g) ≃ 160°C

**Phase Diagram 3**

For each of the questions on this worksheet, refer to the phase diagram for mysterious compound X:




1. What is the critical temperature of compound X? 770°C

2. If you were to have a bottle containing compound in your closet, what phase would it most likely be in? Gas

3. At what temperature and pressure will all three phases coexist? ≃ 350°C & 40 atm

4. If I have a bottle of compound X at a pressure of 45 atm and temperature of $100^0$ C, what will happen if I raise the temperature to $400^0$ C? Melting (s → l)

5. Why can't compound X be boiled at a temperature of $200^0$ C? Only solid + gas phases at 200°C

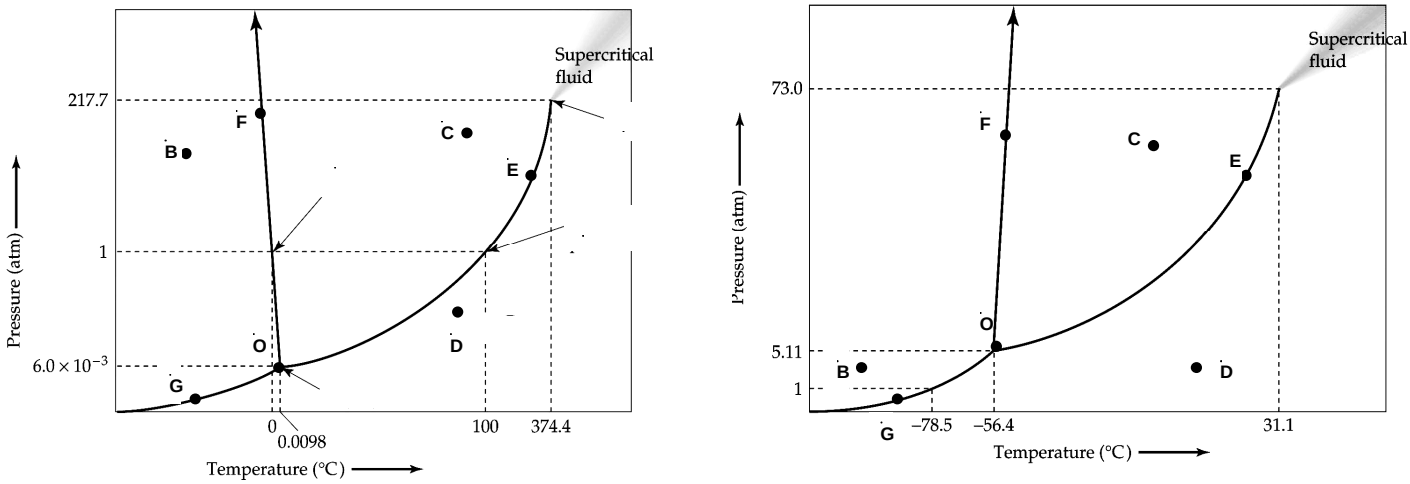
6. If I wanted to, could I drink compound X? No

Name:_____Period____Date_____

Chemistry I - Phase Diagrams Water & $CO_2$

Use the diagrams below to answer the following questions:

**Phase Diagram for Water** (Not to Scale) **Phase Diagram for Carbon Dioxide**




1. What does Point O in both diagrams above represents? And what can you tell me about the phase or phases of matter at those pressures and temperatures?
Triple point: s, l, g coexist (equilibrium)

2. What is the significance of line OF?
liquid solid equilibrium (both states exist)

3. What is the significance of line OG?
Solid gas equilibrium (s + g exist)

4. What is the significance of line OE?
liquid gas equilibrium (l + g exist)

5. Using the diagrams above indicate the proper temperature or pressure for the following points.
   a. Normal melting point °C for water 0°C
   g. Normal boiling point for °C for water 100°C
   b. Triple point temp for water 0.0098°C
   h. triple point pressure for water $6 \times 10^{-3}$ atm
   c. Triple point temp for $CO_2$ -56.4°C
   i. triple point pressure for $CO_2$ 5.11 atm
   d. Critical pressure for water 217.7 atm
   j. critical temp for water 374.4°C
   e. Critical pressure for $CO_2$ 73 atm
   k. critical temp for $CO_2$ 31.1°C
   f. Normal sublimation temperature for $CO_2$ -78.5°C

6. Refer to the phase diagram for water. What changes in temperature, pressure, and physical state would be necessary to go from point D to point C?
pressure increases, temp stays fairly steady, gas condenses to a liquid.

7. Refer to the phase diagram for $CO_2$. What changes in temperature, pressure, and physical state would be necessary to go from point B to point D?
pressure is steady, temp increases, solid sublimes to a gas