

CHEMISTRY 111 LECTURE  
**Unit 2a Gases and Liquids**

GASES, LIQUIDS, AND SOLIDS

**I. PROPERTIES OF GASES**

- A. Gas particles are far apart from each other - there is no attraction between particles
- B. Gases have an indefinite shape.
- C. Gases have a low density
- D. Gases are very compressible
- E. Gases exert pressure equally in all directions on the walls of a container.
- F. Gases have a high flow rate. Gases mix spontaneously and completely with one or more other gases.

**II. PROPERTIES OF SOLIDS**

- A. A Solid contain particles which are very close to each other-there are very large attractive forces between particles
- B. Solids have a definite shape. Solids maintain its shape regardless of the container they are in.
- C. Solids in general have a high density
- D. Solids are not compressible (or negligibility)
- E. Solids do not flow

**III. PROPERTIES OF LIQUIDS**

- A. Liquids contain particles which are (somewhat) close to each other - there are attractive forces between particles
- B. Liquids have a definite shape. Liquids maintain the shape of the bottom of the container.
- C. Liquids in general have a medium density
- D. Liquids are not compressible (or negligibility)
- E. Liquids have a medium flow rate

## Part I GASES

### I. Properties of gases

#### II. Measurements

A. Pressure =  $\frac{\text{force}}{\text{Unit area}}$

1. Conversions:

1 atm = 760 mm Hg = 760 torr (exactly)

$1.013 \times 10^5 \text{ Pa} = 1 \text{ atm} = 14.68 \text{ psi}$

2. Barometer

B. Temperature - Kelvin

$$K = ^\circ\text{C} + 273$$

C. Volume

1. The volume of a gas is the volume of the container it occupies.

2. Units: liters or milliliters

#### III. KINETIC MOLECULAR THEORY

A. Gases are composed of such extremely tiny atoms or molecules that are widely separated by empty space.

B. Gas particles move in a random, rapid, and continuous motion, thus has kinetic energy.

C. Gas particles moves so rapidly and are so far apart the there is essentially no force of attraction between the particles.

D. Particles collide frequently with each other and with the walls of the container, the collisions are perfectly "elastic" - (No net loss of energy as a result of a collision)

#### IV. AVERAGE KINETIC ENERGY

The average kinetic energy (energy of motion) of the gas particles are directly proportional to its absolute  $T^\circ$  (Kelvin)

## V. RELATIONSHIP BETWEEN °T, VOLUME, AND PRESSURE.

### A. Boyle's law P & V

As the pressure increases the volume decreases in the same proportion.

### B. Charles's law °T & V

As the temperature (Kelvin) is increased the volume is increased proportionally.

### C. Gay-Lussac's Law

When temperature (K) increases pressure increases proportionally.

### D. COMBINED GAS LAW

P,V, and °T varying. Assume that the mass is constant.

A certain mass of gas occupies 5.50 L at 34°C and 655 mm Hg. What will its volume in liters be if it is cooled to 10.0°C and its pressure remains the same.

### E. GAY-LUSSAC'S LAW OF COMBINING VOLUMES

At the same °T and Pressure, the volumes of gases that combine in a chemical reaction are in the ratio of small whole numbers.

### F. MOLAR GAS VOLUME; AVOGARDO'S HYPOTHESIS

At the same temperature and pressure the same number of moles of different gases have the same volume. The *Molar Volume* is the volume of one mole of any gas at a given °T & P. [STP]

Standard Temperature and Pressure = [STP]:

$$\frac{22.4 \text{ L}}{1 \text{ mole of gas}}$$

At: 273 K and 1 atm (760 torr)

The density of an unknown gas is 1.43 g/L at 0°C and 760 torr. What is the molar mass of the unknown gas?

### G. IDEAL GAS EQUATION:

Derivation:

KNOW:  $PV=nRT$       Where:

n = moles of gas     $R = \frac{0.0821 \text{ L-atm}}{\text{mole-K}}$

1. What volume in liters will be occupied by 6.00 mol carbon dioxide gas at 105 mm Hg and 28°C?

### WHEN TO USE:

1.  $PV = nRT$
2.  $\frac{22.4 \text{ L}}{\text{mole}}$  at STP
3.  $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

### H. DALTON'S LAW OF PARTIAL PRESSURES; Mixtures of gases

The total pressure of a mixture of gases is equal to the sum of the partial pressures exerted by each gas.

$$P_{\text{total}} = P_1 + P_2 + P_3 + \dots$$

Example: The total pressure in a 1.00 liter container is 725 mm Hg. The container contains water vapor and nitrogen gas.

If the partial pressure of the water vapor is 225 mm Hg, what is the partial pressure of the nitrogen gas.

$$P_{\text{total}} = P_{\text{N}_2} + P_{\text{H}_2\text{O}}$$

## I. MOLE FRACTIONS; Mixtures of gases

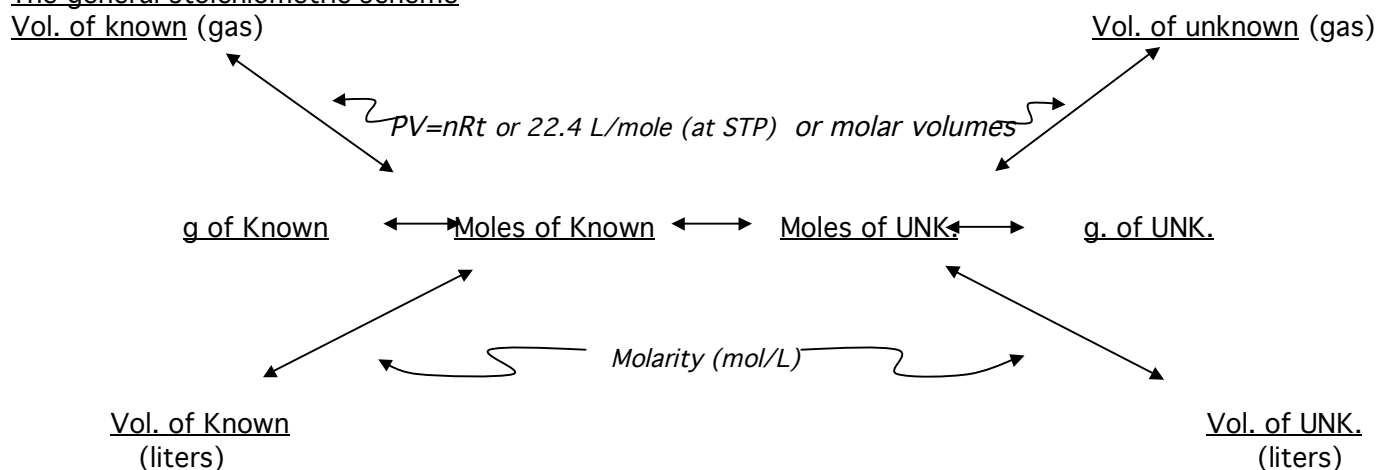
The mole fraction of a component is the fraction of moles of that component of the total moles of the gas mixture.

## VI GAS STOICHIOMETRY

Certain chemical reactions involve gas as a reactant or product. For these types of reactions, the stoichiometric calculations involve the use of:

- 1)  $PV=nRT$
- 2)  $22.4 \frac{L}{mole}$  at STP
- 3) Molar volumes

The general stoichiometric scheme



## VII GAS PROBLEMS

1. How many liters of ammonia gas can be produced by the reaction of 735 ml hydrogen gas with an excess nitrogen gas at 425 °C and 135 atm? Nitrogen + hydrogen --> ammonia

2. How many liters of carbon dioxide gas at 0 °C and 1 atm are produced by the complete combustion of 60.0 mol of liquid glucose,  $C_6H_{12}O_6$ ?

3. How many liters of the air pollutant  $\text{NO}(\text{g})$  could be produced at  $985\text{ }^\circ\text{C}$  and a pressure of  $30.0\text{ atm}$  by the reaction of oxygen gas with  $455\text{ g}$  of nitrogen gas.

4. A  $655\text{ ml}$  gas cylinder filled with oxygen gas at a pressure of  $95\text{ atm}$  and at  $26.0\text{ }^\circ\text{C}$  was used by a scuba diver. The pressure after it was used was  $85\text{ atm}$ . How many moles of oxygen gas were used by the diver?

5. A flask contained 1.017 mol of carbon dioxide. The gas exerted a pressure of 925 mm Hg at a temperature of 28 °C. When an additional 0.250 mole of Carbon dioxide was added to the flask the temperature increased to 35°C. What is the new pressure in the flask?

6. A sample of an unknown gaseous hydrocarbon had a density of 1.56 g/L at 25.0 °C AND 1.33 atm. Calculate the molar mass of the gas.

8. A container with only He had a pressure of 544 torr at a temperature of 35 °C. When 0.810 g of Ne is added to this container, the pressure increases to 959 torr. Calculate the grams of He in the container.

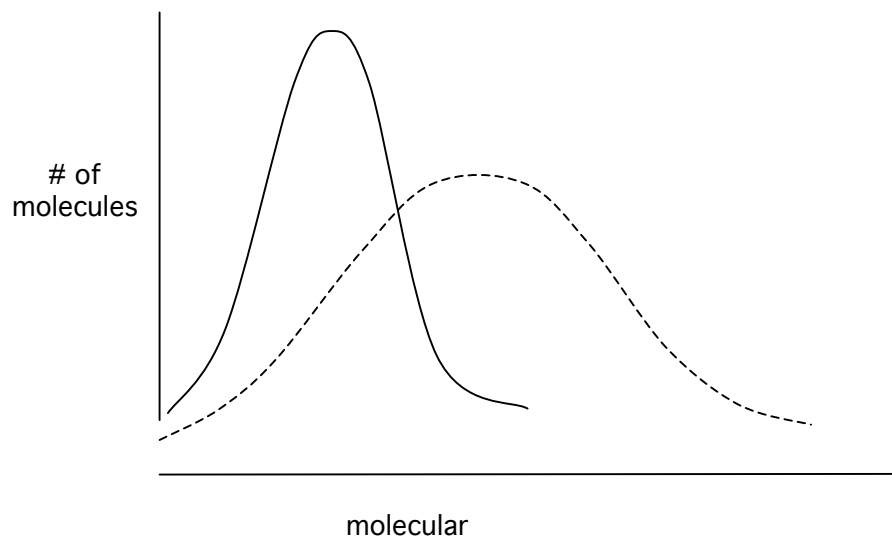
9.  $6.53 \times 10^{28}$  molecules of Oxygen occupy 15.00 liters. What is the volume occupied by 66.5 g of carbon dioxide under the same conditions?

10. A mixture containing 1.22 g Xe and 0.675 g NO<sub>2</sub> exerts a pressure of 1.44 atm. What is the partial pressure of NO<sub>2</sub>?

11. The complete combustion of 0.500 g of hydrocarbon, containing only C and H, produced 0.771 L of  $\text{CO}_2$  at STP and 0.755 g of water. In another experiment, 0.218 g of sample occupied 185 ml at 23 °C and 374 mm Hg. What is the molecular formula of the compound?

## VIII MOLECULAR SPEEDS; DIFFUSION AND EFFUSION

### A. MOLECULAR SPEEDS



### B. DIFFUSION AND EFFUSION

**Diffusion** is the ability of two or more gases to spontaneously mix until it becomes a uniform, homogeneous mixture.

**Effusion** is the process by which gas particles flows thru a very small hole from a container of high pressure to a lower pressure.

**Graham's Law of Effusion** - The rate of effusion of a gas is inversely proportional to it's size [ $\sqrt{\text{Molar Mass}}$ ] at constant temperature and pressure.

$$\frac{r_A}{r_B} = \sqrt{\frac{M_B}{M_A}}$$

Problem #1: What is the rate of effusion for H<sub>2</sub> if 15.00 ml carbon dioxide of CO<sub>2</sub> takes 4.55 sec to effuse out of a container?

Problem #2: What is the molar mass of gas X if it effuses 0.876 times as rapidly as N<sub>2</sub>(g)?

## IX REAL GASES

Gas laws describe the behavior of an ideal or "perfect" gas - a gas described by the kinetic molecular theory. Under normal conditions of typical pressure and temperature, gases follow the ideal gas laws fairly closely. At low temperature and/or high pressures gases deviate from the ideal gas laws.

### A. Intermolecular forces of attraction

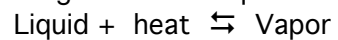
### B. Molecular volume

## Part 2 Liquids

A. Comparison of the three physical states of matter

### B. EVAPORATION OF LIQUIDS

Evaporation is the change from the liquid state to the gaseous or vapor state.

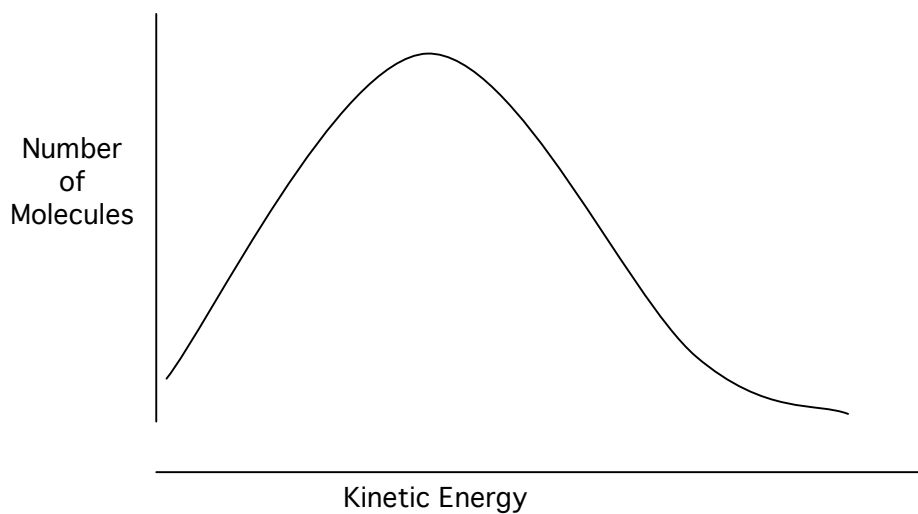


1. Effect of intermolecular forces on evaporation

2. Effect of temperature on evaporation

3. Effect of surface area on surface area

4. Effect of evaporation on the average kinetic energy



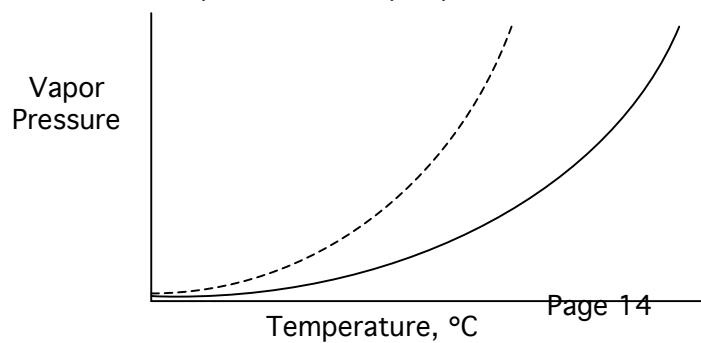
C. VAPOR PRESSURE OF LIQUIDS

The vapor pressure of a liquid is the pressure exerted by the vapor above a liquid.

*Dynamic equilibrium* : rate of evaporation = rate of condensation

1. Effect of intermolecular forces on vapor pressure

2. Effect of temperature on vapor pressure



\*Note: The vapor pressure of a liquid is independent of the volume of the container, provided that there is some liquid present so that equilibrium is established

#### D. BOILING POINT

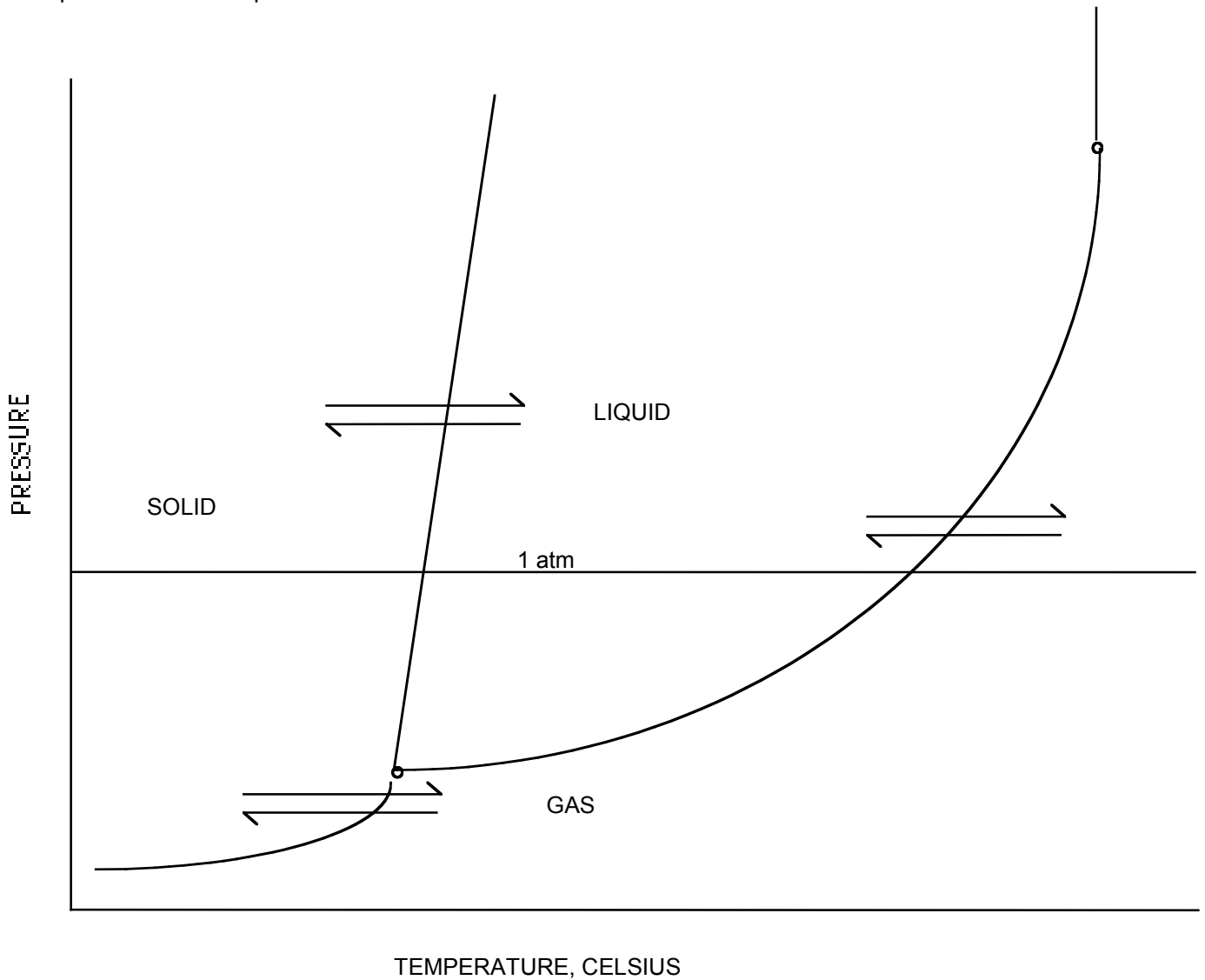
The boiling point of a liquid is the temperature at which a liquid is changed to a gas *within* the liquid (bubbles formed underneath the surface). The **boiling point** is the temperature at which the vapor pressure equals the atmospheric pressure (external pressure)

1. The **normal boiling point** is the temperature at which the vapor pressure equals the atmospheric pressure of 1 atm.
2. Effect of intermolecular forces on the boiling point

## Part 3 Changes of State

### A. PHASE DIAGRAMS

A phase diagram is a graph of pressure versus temperature that shows the region of stability for each of the physical states. The three line segments show the combinations of pressure and temperature at which any two phases exist in equilibrium.



1. The line that separates the gas from the liquid is the vapor pressure curve
2. The **Triple point** is the pressure and temperature at which solid, liquid, and gas all coexist at the same time.
3. The liquid-gas equilibrium line ends at the critical point. Above the critical temperature only a gas exists.

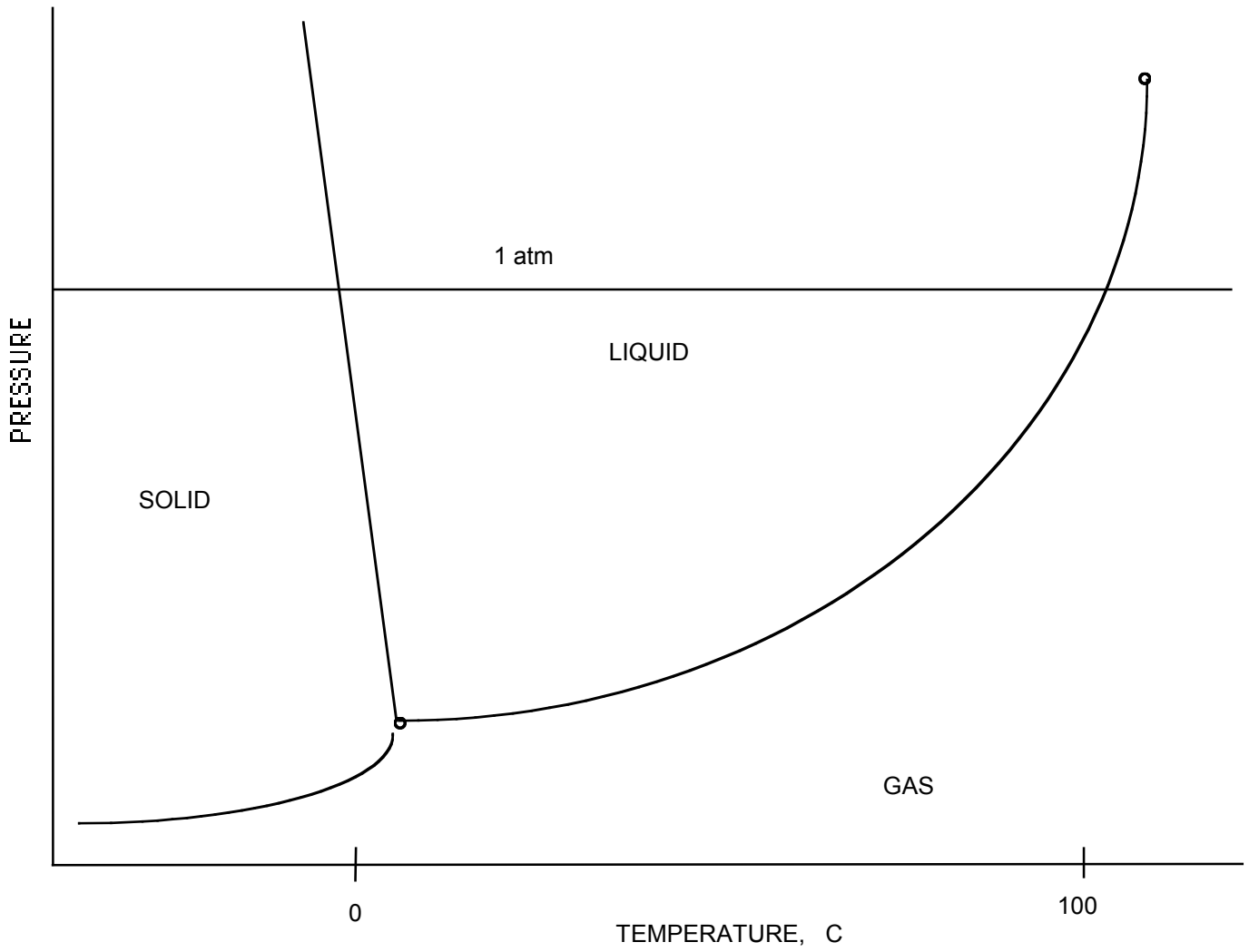
### E. CRITICAL TEMPERATURE, CRITICAL PRESSURE, AND CRITICAL POINT

To convert a gas to a liquid, you must:

- a. Lower the temperature  
and/or
- b. Increase the pressure

1. The **Critical temperature** of a gas is the highest temperature above which a substance can only exist as a gas. Above its critical temperature, no increase in pressure will convert the gas into a liquid.
2. The **Critical pressure** is the minimum vapor pressure at the critical temperature. The minimum pressure required to convert the gas into a liquid is its critical temperature.

PHASE DIAGRAM FOR H<sub>2</sub>O



PHASE DIAGRAM FOR CO<sub>2</sub>

