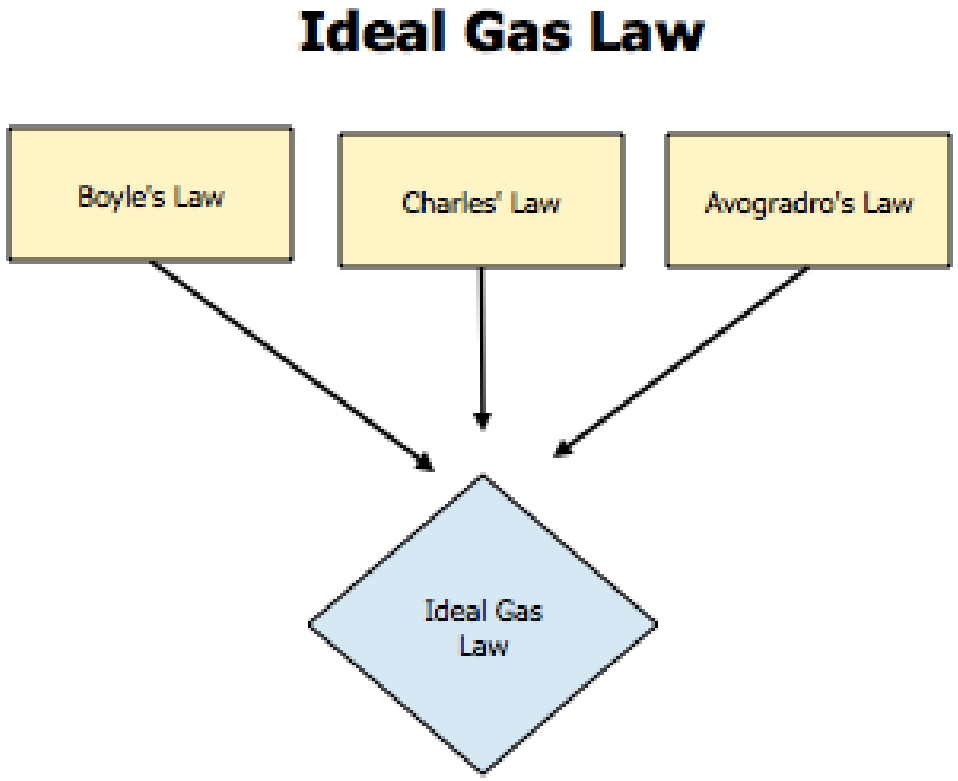
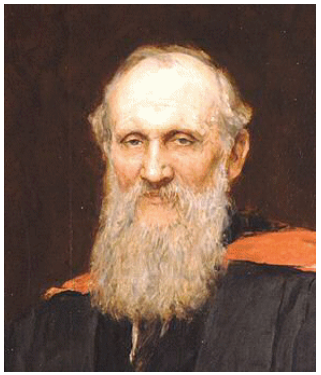
Notes 4 – The Gas Laws



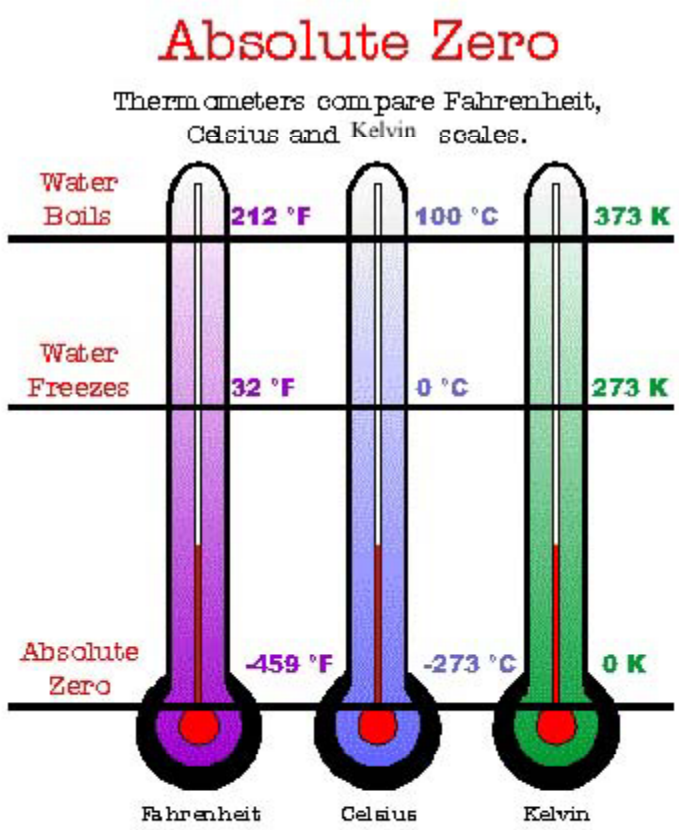
Factors that affect a GAS



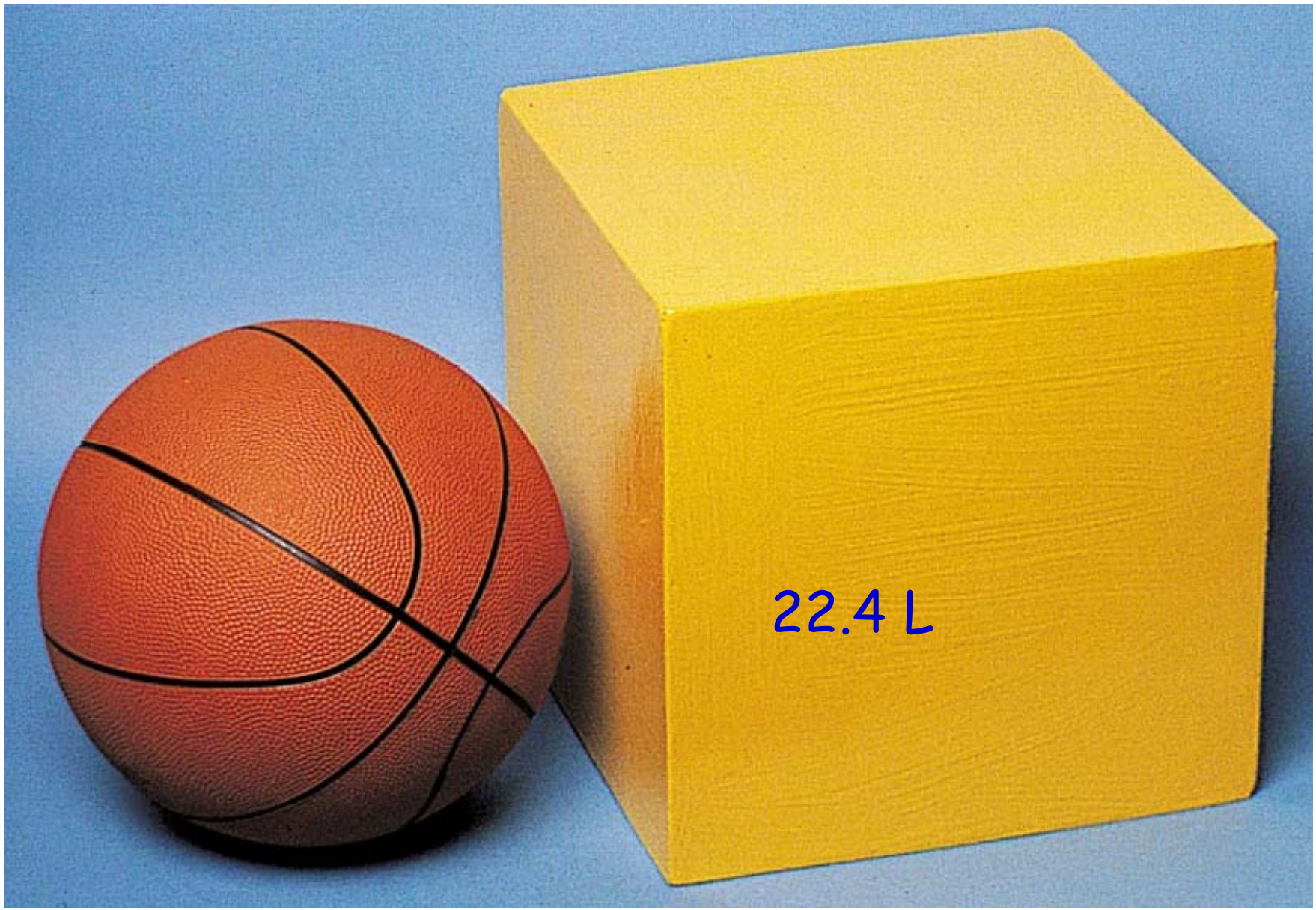
1. The **quantity** of a gas, ***n***, in moles
2. The **temperature** of a gas, ***T***, in Kelvin (Celsius degrees + 273)
3. The **pressure** of a gas, ***P***, in pascals (Pa), atmospheres (atm), or millimeters of mercury (mmHg)
4. The **volume** of a gas, ***V***, in cubic meters or Liters

Important Definitions

- **Absolute Zero** – The temperature at which the kinetic energy of matter is zero. Equal to 0 K or -273.15 ^{o}C
- **Standard Temperature and Pressure (STP)** – 0 ^{o}C (273.15 K) and 1 atm (100 kPa)
- **Molar Volume** – 22.4 L at STP



The molar volume of a gas.



Converting from Celsius to Kelvin

K = ^{o}C + 273.15

What is 20 ^{o}C in K?

20 ^{o}C + 273.15 = 293.15 K

What is 20 K in Celsius?

^{o}C + 273.15 = 20 K

^{o}C = 20 K - 273.15 = -253.15 ^{o}C

Gas Law #1 – Boyles' Law

"The pressure of a gas is inversely related to the volume"

- *Moles and Temperature are constant*

$$P \alpha \frac{1}{V} \rightarrow P = \frac{k}{V}$$

$k = \text{constant of proportionality}$

$$P_1 V_1 = k$$

$$P_2 V_2 = k$$

$$\boxed{P_1 V_1 = P_2 V_2}$$

Gas Law #2 – Charles' Law

"The volume of a gas is directly related to the temperature"

- *Pressure and Moles are constant*

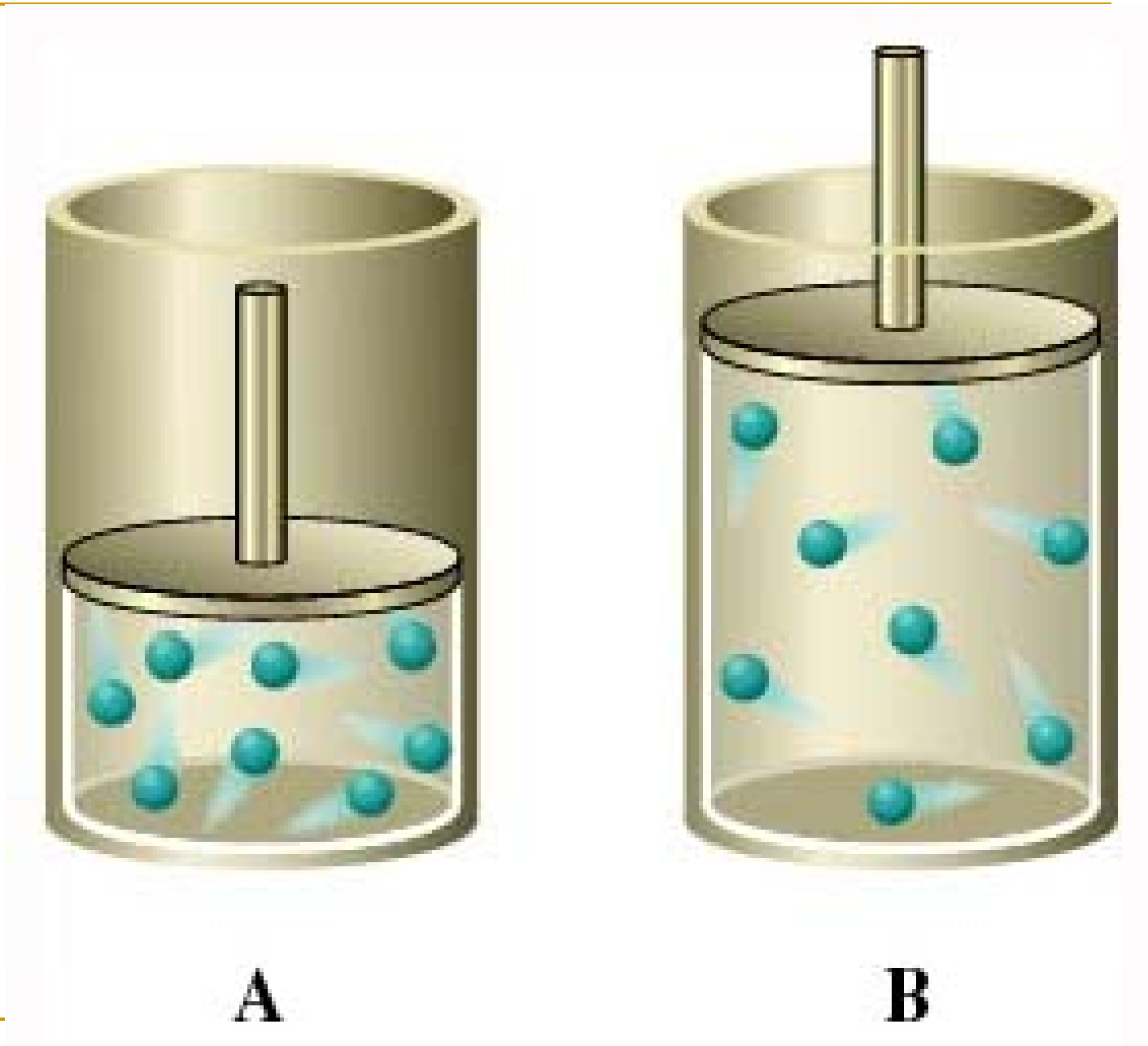
$$V_1 \alpha\, T_1 \rightarrow V_1 = kT_1$$

$$k = \frac{V_1}{T_1}$$

$$k = \frac{V_2}{T_2}$$

$$\boxed{\frac{V_1}{T_1} = \frac{V_2}{T_2}}$$

Figure 5.22: Molecular description of Charles's law.



Gas Law #3 – Gay-Lussac's Law

"The pressure of a gas is directly related to the temperature"

- *Moles and Volume are constant*

$$P_1 \alpha\ T_1 \rightarrow P_1 = kT_1$$

$$k = \frac{P_1}{T_1}$$

$$k = \frac{P_2}{T_2}$$

$$\boxed{\frac{P_1}{T_1} = \frac{P_2}{T_2}}$$

Gas Law #4 – Avogadro's Law

"The volume of a gas is directly related to the # of moles of a gas"

- *Pressure and Temperature are constant*

$$V_1 \alpha\ n_1 \rightarrow V_1 = kn_1$$

$$k = \frac{V_1}{n_1}$$

$$k = \frac{V_2}{n_2}$$

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

Gas Law #5 – The Combined Gas Law

You basically take Boyle's Charles' and Gay-Lussac's Law and combine them together.

- *Moles are constant*

$$P_1V_1 \alpha\ T_1 \rightarrow P_1V_1 = kT_1$$

$$k = \frac{P_1V_1}{T_1}$$

$$k = \frac{P_2V_2}{T_2}$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

Example

Pure helium gas is admitted into a leak proof cylinder containing a movable piston. The initial volume, pressure, and temperature of the gas are 15 L, 2.0 atm, and 300 K. If the volume is decreased to 12 L and the pressure increased to 3.5 atm, find the final temperature of the gas.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \rightarrow T_2 = \frac{T_1P_2V_2}{P_1V_1}$$

$$T = \frac{(12)(3.5)(300)}{(15)(2)} = \text{420 K}$$

Ideal Gas Law

- $PV = nRT$
- where R is the ideal gas law constant. If three of the variables are known, the 4th can be determined.
- The units of R depend on the units used for P, T, and V.

Units of R

- Two common values of R:

- 0.08206 $\frac{\text{Liter·Atm}}{\text{Mole·K}}$

- 8.314 $\frac{\text{Liter·KPa}}{\text{Mole ·K}}$

Problem-Solving

- Most commonly used value of R:
- 0.08206 $\frac{\text{Liter·Atm}}{\text{Mole·K}}$
- Note:
- Pressure must be in atm
- Volume must be in liters
- Temperature must be in Kelvins

Ideal Gas Law Problems

- What pressure is exerted by 0.75 moles of a gas at 25°C in a container with a volume of 1.5 L?
- Find the volume of 0.85 moles of gas at a pressure of 520 torr and a temperature of 15°C.
- How many moles of gas are present in a sample at 700 torr, 333°C, and occupying a volume of 452 mL?