Experiment #3
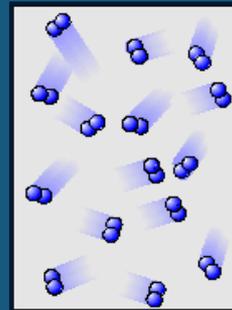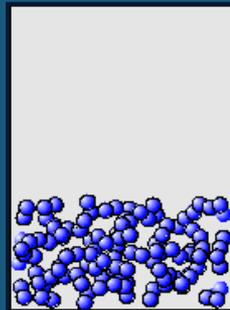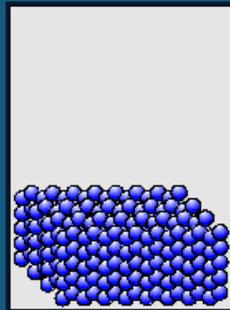
Introduction to Gases

Part A: Characteristics of Gases

ℒ Gases expand to fill any container.
  • random motion, no attraction

ℒ Gases are fluids (like liquids).
  • no attraction

ℒ Gases have very low densities.

# Characteristics of Gases

ℬ Gases have a higher kinetic energy because their particles move a lot more than in a solid or a liquid

ℬ As the temperature increases, the gas particles move faster, and thus kinetic energy increases.
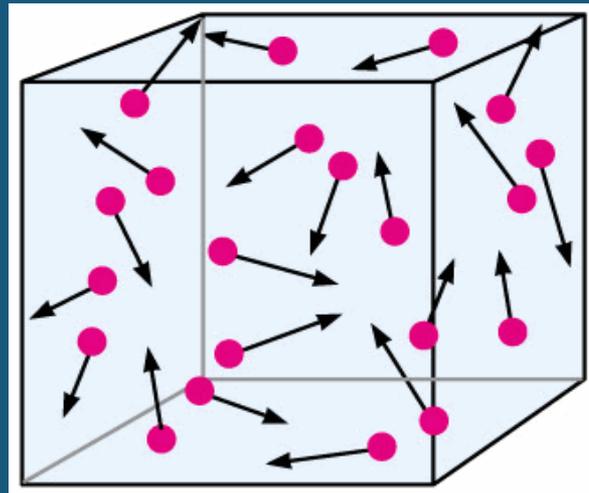
Characteristics of Gases

ℬ Gases can be compressed.
  - no volume = lots of empty space

ℬ Gases undergo diffusion & effusion (across a barrier with small holes).
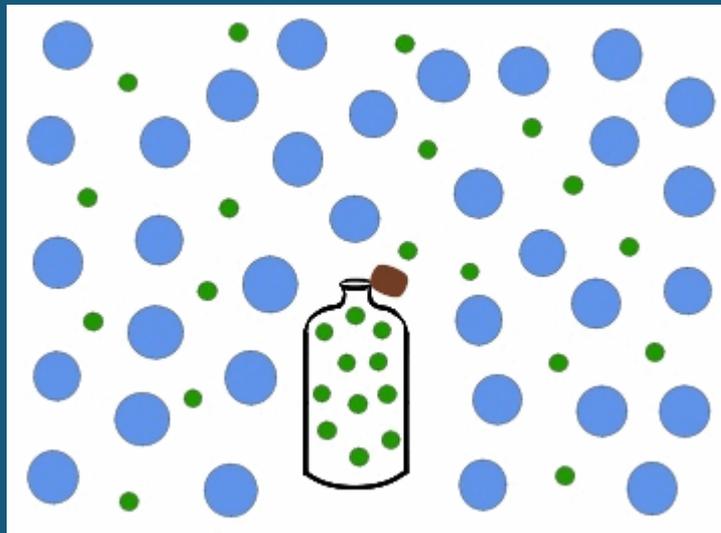
Real Gases

ℬ At <u>STP</u>, molecules of gas are moving fast and are very far apart, making their intermolecular forces and volumes insignificant, so assumptions of an ideal gas are valid under normal temp/pressure conditions. BUT…

- at <u>high pressures</u>: gas molecules are pushed closer together, and their interactions with each other become more significant due to *volume*

- at <u>low temperatures</u>: gas molecules move slower due to KE and *intermolecular forces* are no longer negligible

Standard Temperature & Pressure

STP

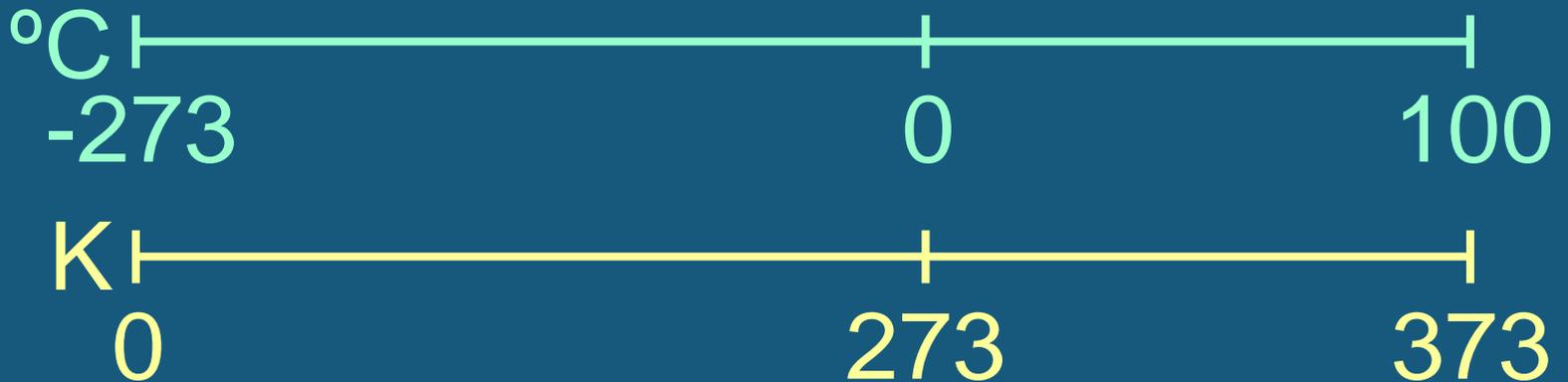Standard Temperature & Pressure

0°C   273 K

-OR-

1 atm   101.325 kPa

Temperature: The Kelvin Scale

ℬ Always use absolute temperature (Kelvin) when working with gases.

°C ⊢——————————|——————————⊣

-273   0   100

K ⊢——————————|——————————⊣

0   273   373

$$°\text{C} = K - 273 \qquad K = °\text{C} + 273$$

Kelvin Scale vs Celsius Scale
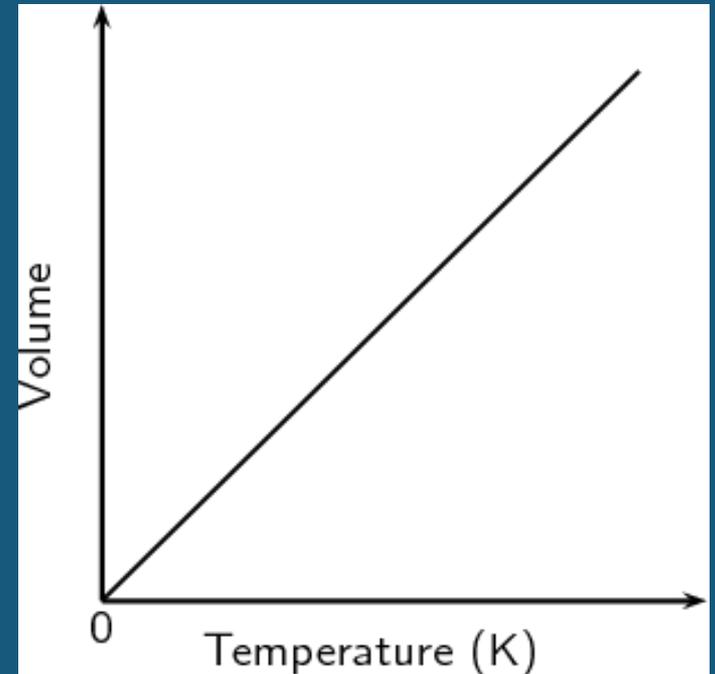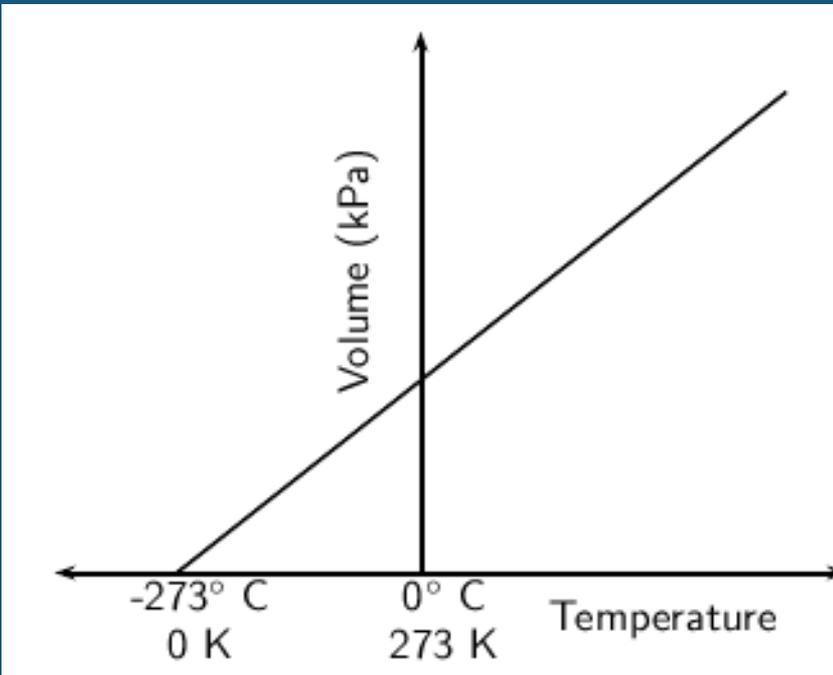
Kinetic Molecular Theory of 'Ideal' Gases

Ϩ Particles in an ideal gas…

- have no volume.

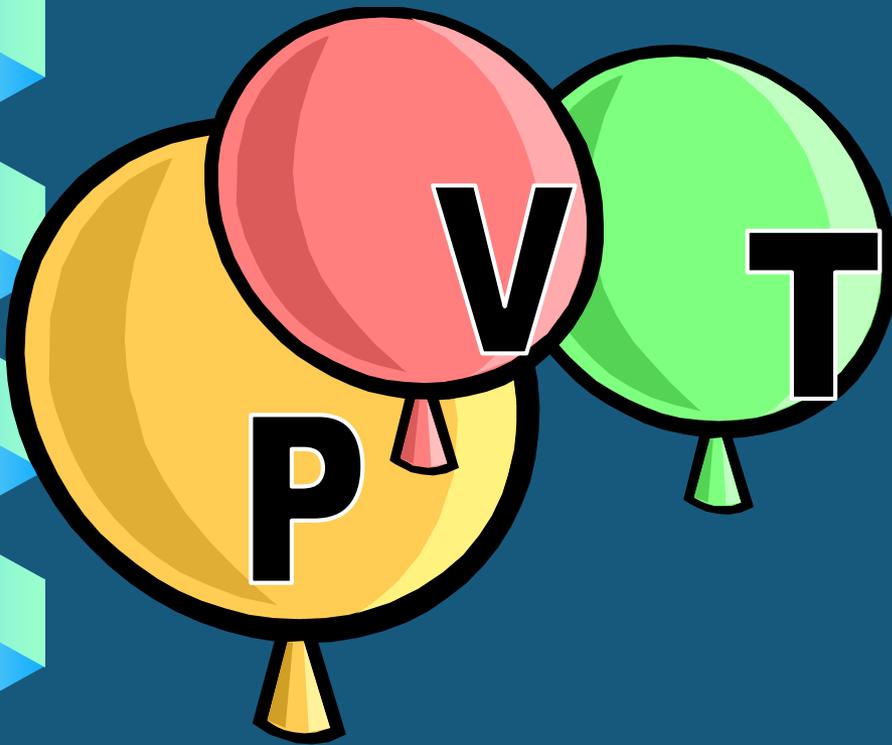- have elastic collisions : particles exchange energy with each other, but total KE is conserved

- are in constant, random, straight-line motion.

- don't attract or repel each other.

- have an avg. KE directly related to temperature (↑temp= ↑motion= ↑ KE)

1. Intro to Boyle's Law

ℬ Imagine that you hold the tip of a syringe on the tip of your finger so no gas can escape. Now push down on the plunger of the syringe.

- What happens to the volume in the syringe?

- What happens to the pressure the gas is exerting in the syringe?

1. Boyle's Law

Decreasing volume increases collisions and increases pressure.
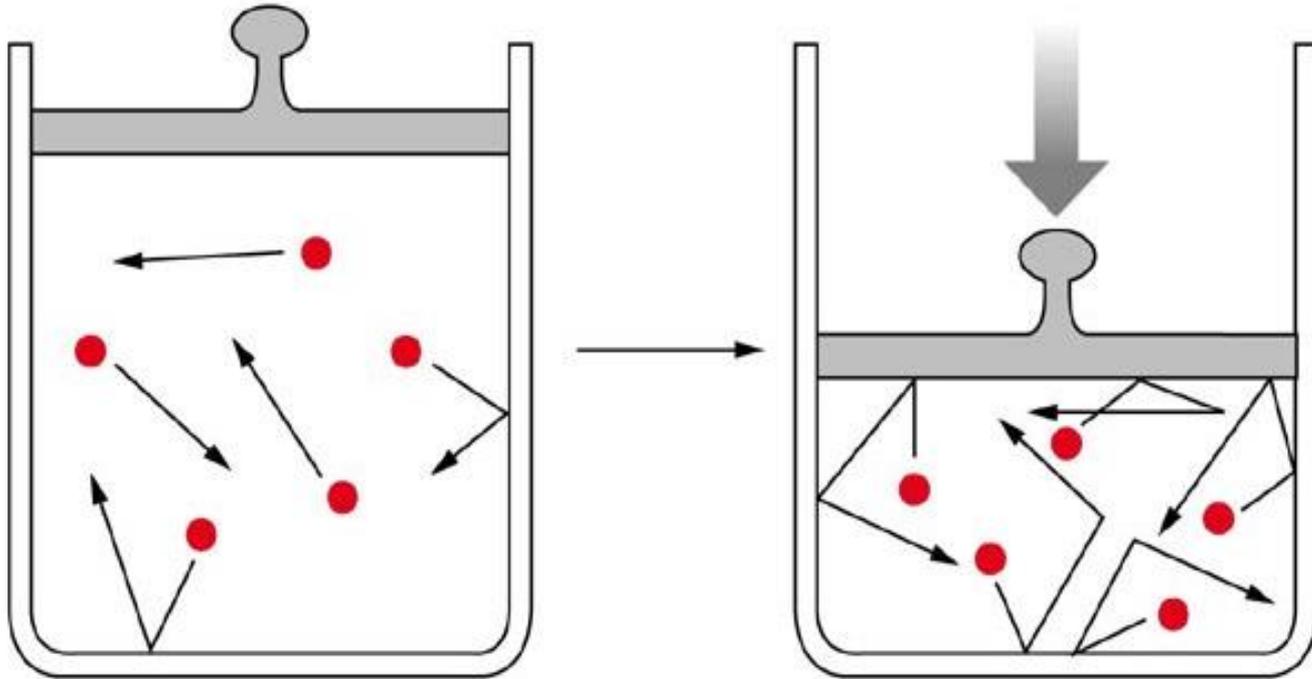
$V_1 = 1.0 \, L$
$P_1 = 100 \, mm \, Hg$
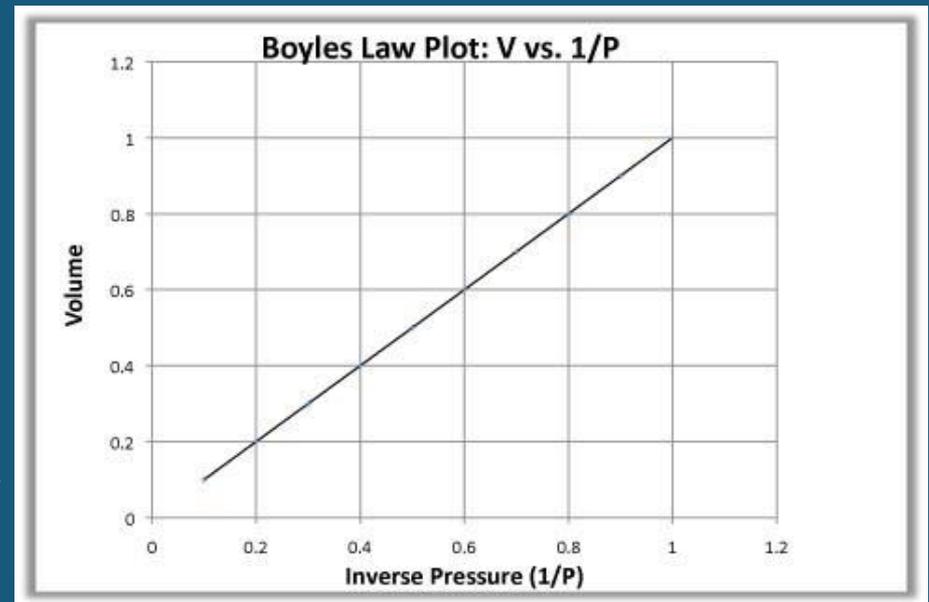
$V_2 = 0.5 \, L$
$P_2 = 200 \, mm \, Hg$

1. Boyle's Law

℘ The pressure and volume of a gas are inversely proportional (as one increases, the other decreases, and vice versa

- at constant mass & temp

P

V

Boyles Law Plot: V vs. 1/P

Volume

Inverse Pressure (1/P)
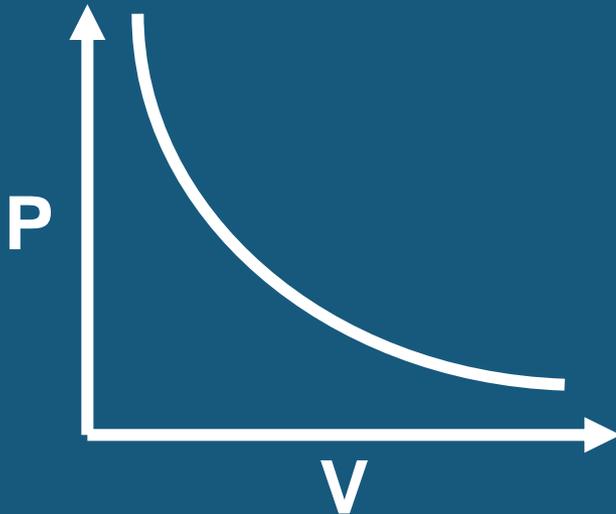
1. Boyle's Law

Boyle's Law leads to the mathematical expression: *Assuming temp is constant

$$P_1V_1=P_2V_2$$

Where P_1 represents the initial pressure

V_1 represents the initial volume

P_2 represents the final pressure

V_2 represents the final volume

Boyle's Law Example

A gas' volume at 9.9 atm is 300.0 mL. If pressure decreases to 3.4 atm, what is the new volume?

$$P_1V_1 = P_2V_2$$

Data:

$P_1 = 9.9\,atm$

$V_1 = 300.0\,mL$

$P_2 = 3.4\,atm$

$V_2 = ?$

$$V_2 = \frac{P_1 \cdot V_1}{P_2} = \frac{9.9\,atm \cdot 300.0\,ml}{3.4\,atm}$$

$$= 874\,ml$$

Problems : try to solve ?

1- A weather balloon with a volume of 2000L at a pressure of 96.3 kPa rises to an altitude of 1000m, where the atmospheric pressure is measured to be 60.8kPa. Assuming there is no change in the temperature or the amount of gas, calculate the weather balloon's final volume.

2- Atmospheric pressure on the peak of Kilimanjaro can be as low as 0.20 atm. If the volume of an oxygen tank is 10.0L, at what pressure must the tank be filled so the gas inside would occupy a volume of 1.2×10^3L at this pressure?
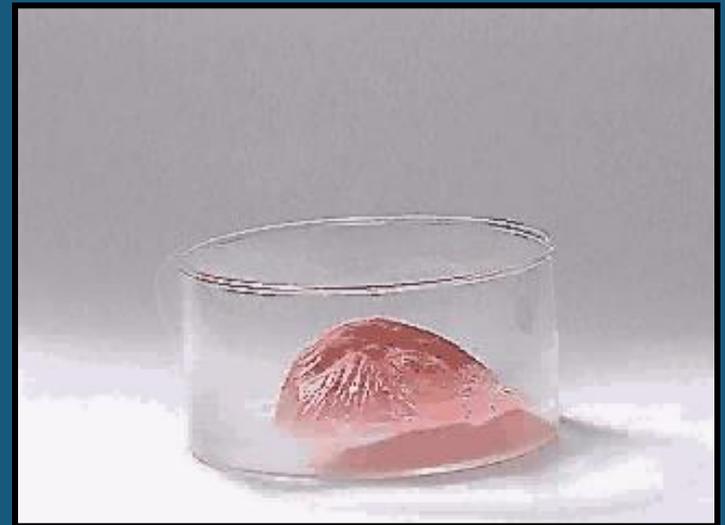
2. Intro to Charles' Law
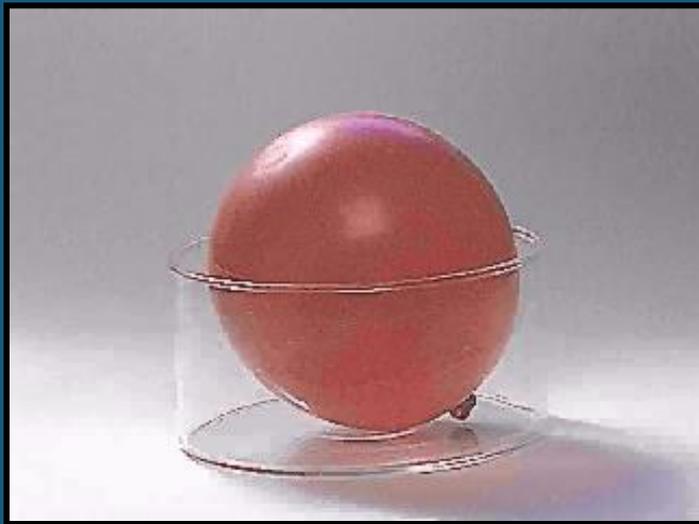
❧Imagine that you put a balloon filled with gas in liquid nitrogen

What is happening to the temperature of the gas in the balloon?

What will happen to the volume of the balloon?
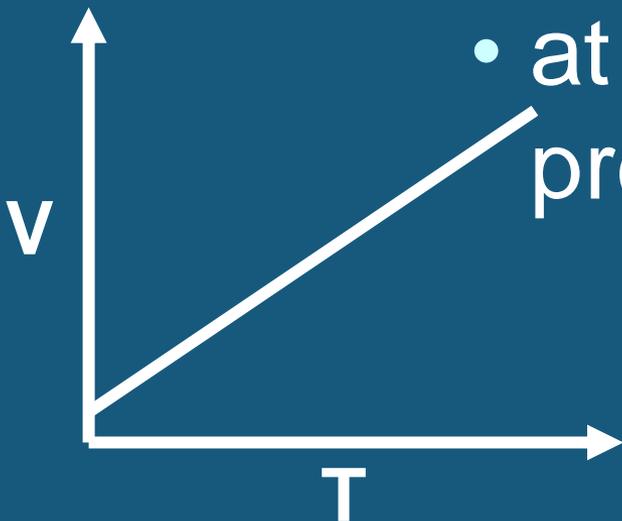
2. Charles' Law

2. Charles' Law

ℒ The volume and absolute temperature (K) of a gas are directly proportional (an increase in temp leads to an increase in volume)

- at constant mass & pressure

V

T

2. Charles' Law

➢ Charles' Law leads to the mathematical expression:

*Assuming pressure remains constant

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

Problems : (try to solve)

1- A birthday balloon is filled to a volume of 1.5L of helium gas in an air-conditioned room at 293K. The balloon is taken outdoors on a warm day where the volume expands to 1.55L. Assuming the pressure and the amount of gas remain constant, what is the air temperature outside in Celsius?

2- A beach ball is inflated to a volume of 25L of air at 15ºC. During the afternoon, the volume increases by 1L. What is the new temperature outside?

3. Intro to Gay-Lussac's Law

ᵇ Imagine you have a balloon inside a container that ensures it has a fixed volume. You heat the balloon.

What is happening to the temp of the gas inside the balloon?
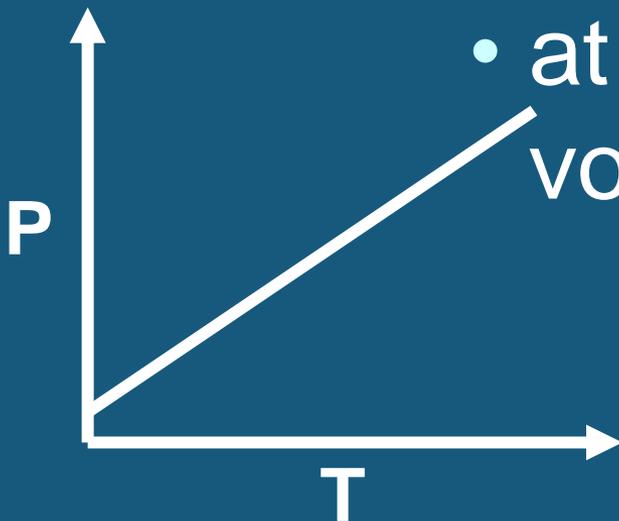
What will happen to the pressure the gas is exerting on the balloon?

3. Gay-Lussac's Law

℘The pressure and absolute temperature (K) of a gas are directly proportional (as temperature rises, so does pressure)

- at constant mass & volume

P

T

3. Gay-Lussac's Law

➢ Gay-Lussac's Law leads to the mathematical expression:

*Assuming volume remains constant

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

Problems : (try to solve)

1- The pressure of the oxygen gas inside a canister with a fixed volume is 5.0atm at 15oC. What is the pressure of the oxygen gas inside the canister if the temperature changes to 263K? Assume the amount of gas remains constant.

2- The pressure of a gas in a sealed canister is 350.0kPa at a room temperature of 15°C. The canister is placed in a refrigerator that drops the temperature of the gas by 20K. What is the new pressure in the canister?

4. Combined Gas Law

By combining Boyle's, Charles' and Gay Lussac's Laws, the following equation is derived:

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

Problem : (try to solve)

A gas occupies 7.84 cm^3 at 71.8 kPa & 25°C. Find its volume at STP.