CHARLES' LAW

Unit Learning Goal

Throughout this unit we will be working on **ALL** of our overall learning goals for this course.

Remember our unit goal with respect to **<u>understanding concepts</u>** is:

We are learning about the laws that explain the behavior of gases and how to solve problems related to these laws.

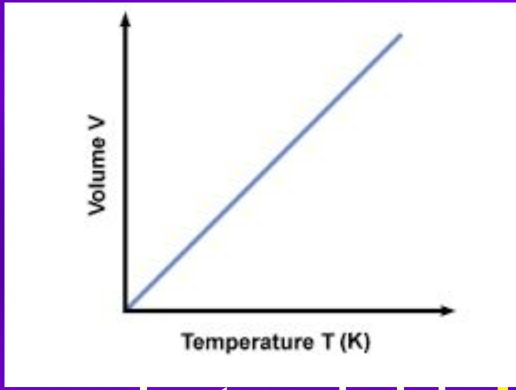
We are learning about the applications of these laws as they pertain to the world around us.

To support this learning goal today's learning goal is…

- We are learning about Charles' Law.

Charles' Law

The **volume** of a fixed mass of gas is ***proportional*** to its **temperature** when the pressure is kept constant.



V α T

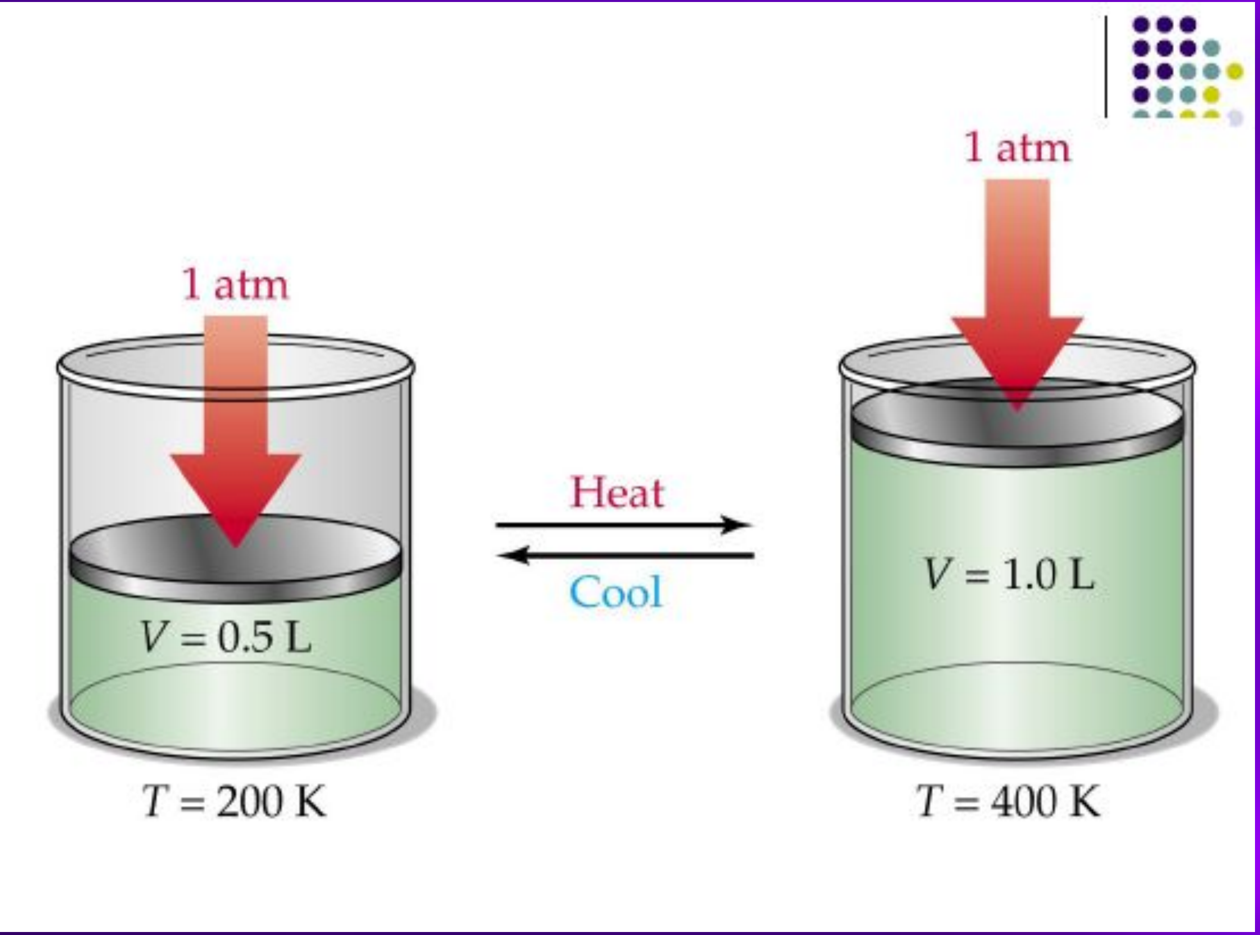
Thus **V = kT**

- We can rearrange this formula to yield **k = V/T**
- Since k is a constant, it is true for a gas at any temperature!
- Thus, for case 1 (initial conditions) and case 2 (final conditions)

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

Charles' Law

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



Charles' Law

There is a catch!

- Temperature must be measured in **Kelvin**
- The Kelvin scale is similar to the Celsius scale (in graduations)
- To determine the Kelvin temperature just add 273.15 to the Celsius scale (we will use 273)

$$T_K = T_{°C} + 273$$

- Unlike other temperature scales K has no ° symbol.

B.P. of water	100°C	373 K
Body Temp.	37°C	310 K
F.P. of water	0°C	273 K
Absolute Zero	-273°C	0 K

Gases expand with increasing temperature.
Jacques Charles realised that regardless of gas tested, gas particles STOP moving at -273 °C
Therefore, at -273°C, the volume of the gas is also 0
Lord Kelvin used this reasoning to develop the KELVIN SCALE

- Present and Previous Names for these scales:

Celsius □ Centigrade

Kelvin □ Absolute

Sample Problems:

Using a glass syringe, a scientist draws exactly 25.5 cm^3 of oxygen at 20.0°C from a metal cylinder. After heating the syringe in an oven at 65°C for 30 min, what volume will the oxygen occupy if the atmospheric pressure stays the same.

Given

$V_1 = 25.5\ cm^3$

$T_1 = (20.0^{o}C + 273^{o}C) = 293\ K$

$T_2 = (65.0^{o}C + 273^{o}C) = 338\ K$

Equation

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

$$V_2 = \frac{25.5\ cm^3 \times 338\ K}{293\ K}$$

$$= 29.42\ cm^3$$

Therefore the volume that the oxygen would occupy at 65°C is 29.4 cm^3.

Calculating Temperature using Charles' Law

A balloon is filled with 2.50 L of dry helium at 23.5°C. The balloon is placed in the freezer overnight and its volume is found to be 2.15 L. If the pressure is constant what is the temperature of the freezer.

Given:

$V_1 = 2.5\ \text{L}$

$T_1 = (23.5^{o}\text{C} + 273^{o}\text{C}) = 296.5\ \text{K}$

$V_2 = 2.15\ \text{L}$

Equation:

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

$$T_2 = \frac{2.15\text{L} \times 296.5\ \text{K}}{2.50\ \text{L}}$$

$$= \quad 254.99\ \text{K}$$

Therefore, the temperature of the freezer is 254.99K.

Applications of Charles' Law

Please take a moment and look at a couple of these examples and discover….

- What happens to a helium balloon on a cold day?
- What happens to a hot air balloon on a cold day?
- How does a turkey timer work (a thermometer you place in the turkey)?
- How could you pump up a ping pong ball using Charles' law?
- Tire pressure what happens when its warm outside, when its cold? When is the best time to check your tire pressure?

1. What would be the new volume if the temp on 450 mL of gas is changed from 45°C to - 5°C
2. A sample of gas whose volume at 27°C is 0.127 L, is heated at constant pressure until its volume becomes 317 mL. What is the final temperature of the gas in Celsius and kelvin?
3. To make 300 mL of oxygen at 20.0°C and change its volume to 250 mL, what must be done to the sample if its pressure and mass are to be held constant? To what temperature must an ideal gas at 27°C be cooled to reduce its volume to 1/3?
4. From the data in the following questions calculate the missing quantity.
   a) V1 = 22.4 L; T1 = 0°C; T2 = 91°C; V2 = ? L
   b) V1 = 125 mL; T1 = ? ; T2 = 25oC; V2 = 100 mL
   c) V1 = ? L; T1 = 400 K; T2 = 175 K; V2 = 6.20 L
   d) V1 = 250 mL; T1 = 298 K; T2 = ? K; V2 = 273 mL

5. A 50 cm^3 sample of a gas in a syringe at 15^{o}C is heated to 50^{o}C and the syringe's piston is allowed to move outward against a constant atmospheric pressure. Calculate the new volume of the hot gas.

6. What is the final volume if 3.4 L of nitrogen gas at 400 K is cooled to 200 K and kept at the same pressure?

7. Determine the final volume of 20 L of a gas whose temperature changes from -73^{o}C to 327^{o}C if the pressure remains constant.

8. A partially filled plastic balloon contains 3.4×10^3 m^3 of helium gas at 5^{o}C. The noon day sun heats this gas to 37^{o}C. What is the volume of the balloon if atmospheric pressure remains constant?

Success Criteria

By the end of this lesson…

- ❑ I can explain Charles' Law as it pertains to the world around me.
- ❑ I can solve problems related to Charles' Law.