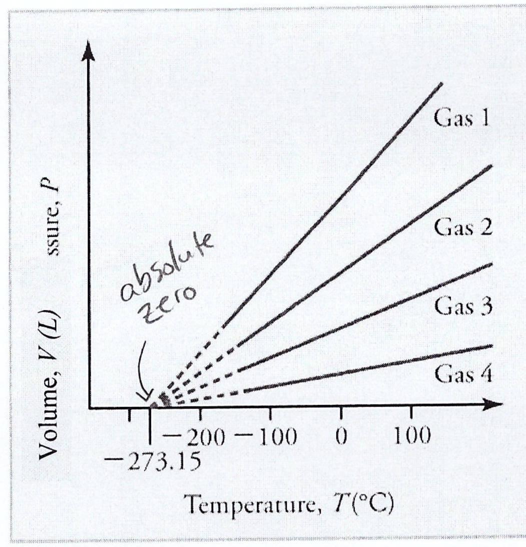
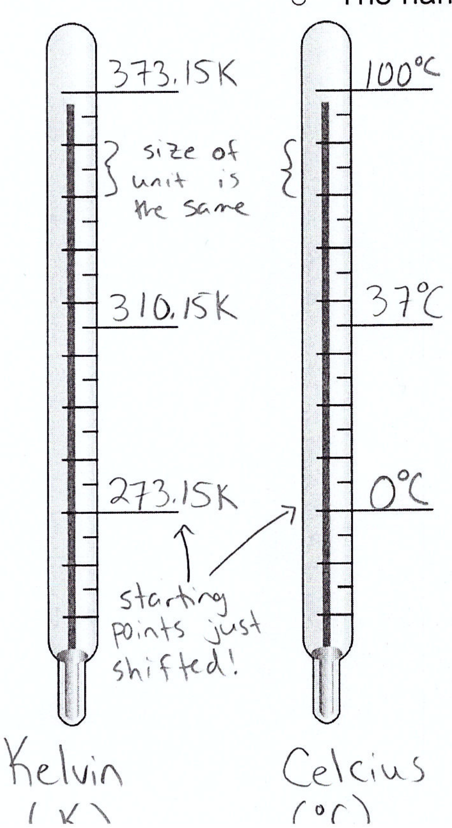
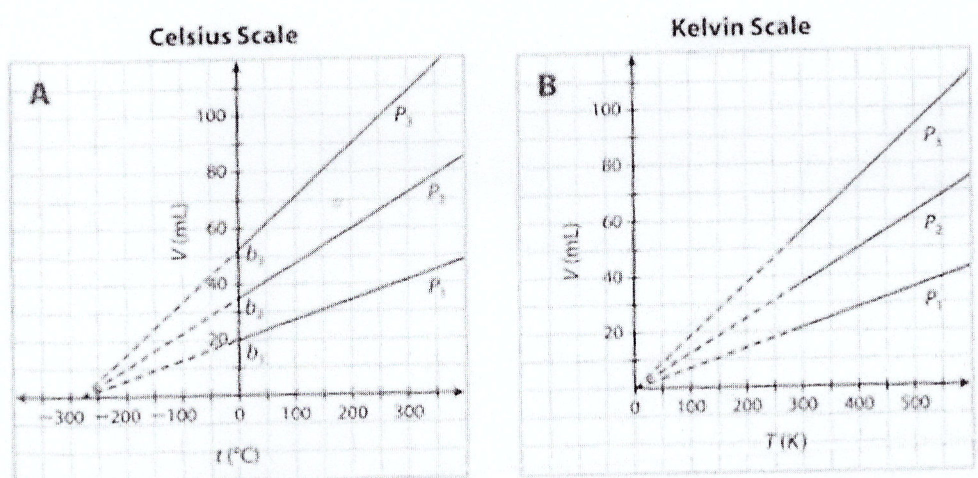
Charles's Law

- Boyle's Law explained the relationship between the pressure and volume of a gas at constant temperature
  - Charles's law explains the relationship between the temperature and volume of a gas at a constant pressure



- When volume and temperature of a gas were plotted on a graph, a linear graph was observed (as long as the amount of gas and pressure was kept constant)
  - It was also observed that when the linear graphs of different gases were extrapolated/extend down to zero volume, all the lines converged at one point
  - The single point of convergence was at a temperature of -273.15°C
  - Lord Kelvin interpreted the significance of this temperature of -273.15°C and suggested it was theoretically the lowest possible temperature; called **absolute zero**
- Kelvin then developed a new temperature scale based on absolute zero as the starting point
  - * The size of a unit of temperature on the Kelvin scale is the same as the size of a degree on the Celsius scale
  - Only the starting points for the temperature scales are different
  - The name of a unit in the Kelvin scale is a kelvin (K)





* slopes are the same, converging point is just shifted!

- You can convert between the two scales by the following formula

$T = t + 273.15$ in data book

where t is the temperature in degrees Celsius (°C)

T is the temperature in Kelvins (K)

- EXAMPLES:

Convert 25.0°C to K

$T = t + 273.15$

$T = 25.0°C + 273.15 = 298.15\ K$

$T = 298.2\ K$

Convert 375K to °C

$T = t + 273.15$

$t = T - 273.15$

$t = 375K - 273.15 = 101.85°C$

$t = 102°C$

- The relationship between the temperature and volume of a gas can be explained by the kinetic molecular theory
  - As the temperature of a gas increases, so does the kinetic energy of the gas molecules
  - As the molecules move faster, they collide more frequently with the walls of their container resulting in more force exerted on the surface area of the container walls (ie. higher pressure)
  - The increase in pressure, causes the volume of the gas in a container to expand until the pressure on the inside of the container equals the pressure on the outside of the container

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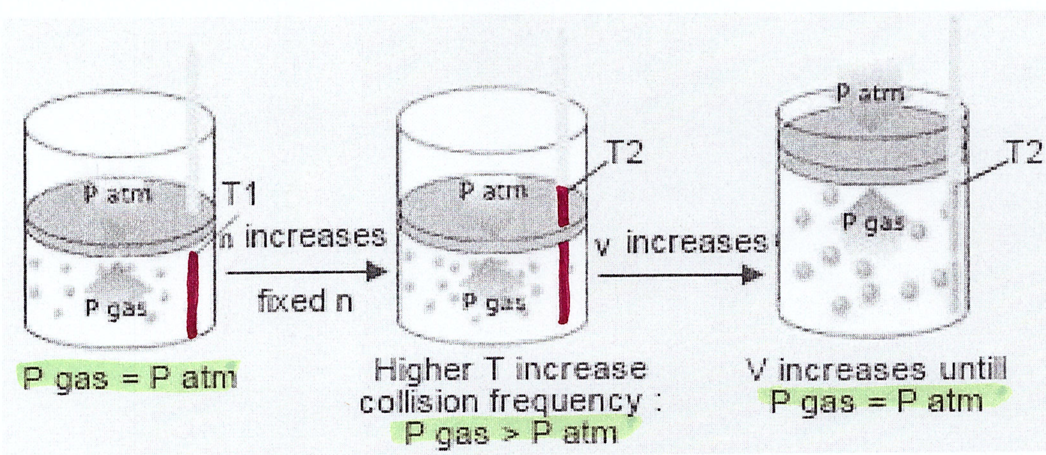

- Charles's Law states that the volume of a gas is <u>*directly proportional*</u> to the temperature of a gas at constant pressure and mass
  - *Proportional* means that as one variable increase, a second variable must also increase and vice versa
  - *Directly proportional* just means that as one variable increase by a certain factor, the other variable must also increase by the same factor (ie. if temperature doubles, then volume must also double)

  *

- The equation to express Charles's Law is as follows

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$ * memorize!

where T_1 and T_2 are temperatures measure in Kelvins (K) ← must!

V_1 and V_2 are volumes (any units as long as they are consistent)

EXAMPLES:

1. A balloon is inflated to a volume of 4.0L at 27°C. If it is heated to 330K, what is the new volume assuming constant pressure?

$V_1 = 4.0\,L$

$T_1 = 27°C + 273.15$

$T_1 = 300.15\,K$

$T_2 = 330\,K$

$V_2 = ?$

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

$$V_2 = \frac{(4.0L)(330K)}{300.15K} = 4.3978\ldots L$$

$$\boxed{V_2 = 4.4L}$$

2. A sample of gas occupies 6.8L at 110°C. What will be the final temperature in Celsius when the volume is decreased to 560mL? Assume constant pressure.

$V_1 = 6.8\,L$

$T_1 = 110°C + 273.15$

$T_1 = 383.15\,K$

$T_2 = ?$

$V_2 = 560\,mL \times \left(\frac{10^{-3}}{1\,m}\right)$

$V_2 = 0.560\,L$

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

$$T_2 = \frac{(0.560L)(383.15K)}{6.8L} = 31.553\ldots K$$

$T_2 = 31.553\ldots K - 273.15 = -241.596\ldots °C$

$$\boxed{T_2 = -2.4 \times 10^2\ °C}$$

*****Now try Practice Problems*****

Practice Problems

1. Butane is a gas that can be used in simple lighters.
   a. If 15 mL of butane gas at 0°C is warmed to 25°C, calculate its final volume.
   b. What assumptions did you make?
   c. Why is it essential to use Kelvins scale in this question?

2. Compressed gases can be condensed when they are cooled. A 500mL sample of carbon dioxide at room temperature (assume 25.0°C) is compressed by a factor of four, and then cooled so that its volume is reduced to 25.0mL. What must the final temperature be in order to maintain a constant pressure?

3. By what factor does the temperature have to be raised to double the volume of a given balloon at constant pressure?

4. A sample of hydrogen has an initial temperature of 50°C. When the temperature is lowered to 10°C, the volume of hydrogen becomes 2.0L. What was the initial volume of the hydrogen?

5. An open, "empty" 2.0L plastic pop bottle, which has an actual inside volume of 2.05L, is removed from a refrigerator at 5.00°C. The "empty" pop bottle is then placed on the kitchen counter were it warms up to 294K. What volume of air, measured at 294K, will leave the container as it warms?

6. A birthday balloon is filled to a volume of 1.50L of helium gas in an air-conditioned room at 21.0°C. The balloon is then taken outdoors on a warm sunny day. The volume of the balloon expands to 1.55L. Assuming the pressure remains constant, what is the temperature outdoors?

Answers:

1.
    a. 16 mL
    b. Pressure and amount of gas remained constant.
    c. If you used Celsius, you would have got an answer of that was undefined, which doesn't make sense.
2. -258°C
3. By a factor of 2
4. 2.3 L
5. 0.117 L
6. 30.8°C