4/7/20

Combined Gas Law: (use for GASES ONLY when all THREE VARIABLES for a gas are CHANGING – nothing remains constant in this type of problem)

From Reference Table T:

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

P_1 = Initial Presure	V_1 = Initial Volume	T_1 = Initial Kelvin Temperature
P_2 = Final Pressure	V_2 = Final Volume	T_2 = Final Kelvin Temperature

****NOTE:** You MUST use Kelvin (not °C) for the calculation to work!

Sample Problem 1: A gas has a volume of 100. mL at a temperature of 20.0 K and a pressure of 760. mmHg. What will be the new volume if the temperature is changed to 40.0 K and the pressure to 380. mmHg?

V_1 = 100. mL
T_1 = 20.0 K
P_1 = 760. mmHg
V_2 = ?
T_2 = 40.0 K
P_2 = 380. mmHg

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

$$\frac{760. \times 100.}{20.0} = \frac{380. \times V_2}{40.0}$$

$$\frac{3.04 \times 10^6}{7{,}600} = \frac{7{,}600 \times V_2}{7600}$$

$400. = V_2$

400. mL = V_2

Sample Problem 2: An ideally behaving gas occupies 500. mL at (STP.) Look on Table A
What volume does it occupy at 546 K and 980. KPa?

V_1 = 500. mL
T_1 = 273 K
P_1 = 101.3 KPa
V_2 = ?
T_2 = 546 K
P_2 = 980. KPa

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

$$\frac{101.3 \times 500.}{273\text{ K}} = \frac{980. \times V_2}{546}$$

$$\frac{27654900}{267540} = \frac{267540 \times V_2}{267540}$$

103.4 mL = V_2

*Both Avogadro's Law and the Kinetic Molecular Theory can be used to explain the relationship between pressure, temperature, and volume of a gas.

Some Gas Law Problems to Try:

1. A gas has a volume of 75.0 mL at a temperature of 15.0 K and a pressure of 760. mm Hg. What will be the new volume when the temperature is changed to 40.0 K and the pressure is changed to 570. mm Hg?

$V_1 = 75.0 \text{ mL}$
$T_1 = 15.0 \text{ K}$
$P_1 = 760. \text{ mm Hg}$
$V_2 = ?$
$T_2 = 40.0 \text{ K}$
$P_2 = 570. \text{ mm Hg}$

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

$$\frac{760. \times 75.0}{15.0} = \frac{570. \times V_2}{40.0}$$

$$\frac{2280000}{8550} = \frac{8550 \times V_2}{8550}$$

$$266.7 \text{ mL} = V_2$$

2. The volume of a sample of a gas at 273°C is 200.0 L. If the volume is decreased to 100.0 L at constant pressure, what will be the new temperature of the gas? ↑ leave pressure out of formula

$V_1 = 200.0 \text{ L}$
$T_1 = 273 + 273 = 546 \text{ K}$
$V_2 = 100.0 \text{ L}$
$T_2 = ?$

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

$$\frac{200.0}{546 \text{ K}} = \frac{100.0}{T_2}$$

$$\frac{200.0 \times T_2}{200.0} = \frac{54600}{200.0}$$

$$T_2 = 273 \text{ K}$$

3. What will be the new volume of 100. mL of gas if the Kelvin temperature and the pressure are both doubled? (make up values)

$V_1 = 100. \text{ mL}$
$P_1 = 10 \text{ atm}$ $P_2 = 20 \text{ atm}$
$T_1 = 100 \text{ K}$ $T_2 = 200 \text{ K}$
$V_2 = ?$

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

$$\frac{10 \text{ atm} \cdot 100.0 \text{ mL}}{100 \text{ K}} = \frac{20. \text{ atm} \cdot V_2}{200 \text{ K}}$$

$$\frac{200000}{2000} = \frac{2000 \times V_2}{2000}$$

$$100.0 \text{ mL} = V_2$$

4. A gas occupies a volume of 400. mL at a pressure of 330. torr and a temperature of 298 K. At what temperature will the gas occupy a volume of 200. mL and have a pressure of 660. torr?

$V_1 = 400. \text{ mL}$
$P_1 = 330. \text{ torr}$
$T_1 = 298 \text{ K}$
$T_2 = ?$
$V_2 = 200. \text{ mL}$
$P_2 = 660. \text{ torr}$

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

$$\frac{330. \times 400.}{298} = \frac{660. \times 200.}{T_2}$$

$$\frac{39336000}{132000} = \frac{132{,}000 \times T_2}{132000}$$

$$298 \text{ K} = T_2$$

5. At 75.0°C a gas has a volume of 2.20 L and exerts a pressure of 1.30 atm on the walls of the container. If the gas is compressed to a volume of 1.00 L and temperature is reduced to 10.0°C, what is the new pressure on the walls of the container?

$T_1 = 75.0 + 273 = 348K$
$V_1 = 2.20L$
$P_1 = 1.30atm$
$V_2 = 1.00L$
$T_2 = 10.0 + 273 = 283K$
$P_2 = ?$

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

$$\frac{1.30 \times 2.20}{348} = \frac{P_2 \times 1.00}{283}$$

$$\frac{809.4}{348} = \frac{348 \times P_2}{348}$$

$$2.33 \text{ atm} = P_2$$

6. A gas at STP (Table A) occupies a volume of 34.0 liters. What is the temperature of the gas if it is compressed to 20.0 liters by increasing the pressure to 250. kPa?

$V_1 = 34.0L$
$V_2 = 20.0L$
$P_1 = 101.3KPa$
$T_1 = 273K$
$P_2 = 250.0KPa$
$T_2 = ?$

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

$$\frac{101.3 \times 34.0}{273} = \frac{250.0 \times 20.0}{T_2}$$

$$\frac{3444.2 \times T_2}{3444.2} = \frac{1365000}{3444.2}$$

$$T_2 = 396K$$

7. You are given two equally sized containers of Ar and N_2 that both behave as ideal gasses and have equal pressures and temperatures.

   a. Does each container have the same number of particles? Explain.

   Yes, equal volumes of gases have the same number of particles.

   b. Do they have the same number of atoms? Explain.

   No, each molecule of N_2 contains 2 atoms

   c. Do they have the same mass? Explain.

   No, 1 mole of each substance has a different mass.

8. Using the first page of your Reference Tables, convert 2.6 atm to mmHg.

1atm = 760 mmHg

$$\frac{1 \text{atm}}{760 \text{ mmHg}} = \frac{2.6 \text{atm}}{X}$$

$X = 2.6 \times 760$

$X = 1976 \text{ mmHg}$