Tutorial – Combining the Gas Laws and the Universal Gas Law (Ideal Gas Law) (Std 4c & 4h)

Read through this tutorial very carefully. It has almost everything that needs to be done in the most difficult of problems and goes through the logic of why each step needs to be done in detail. I hope this helps !!!!

Up until Ch 12.5, you used separate laws to do each type of problem as follows:

Boyle's $P_1V_1 = P_2V_2$ meaning **V**olume varies **inversely** with **P**ressure

Charles' Law $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ meaning **V**olume varies **directly** with **T**emperature

Avogadro's Law

$\frac{V_1}{n_1} = \frac{V_2}{n_2}$ meaning **V**olume varies **directly** with **n** (number of moles)

If we combine Boyle's Law, Charles' Law and Avogadro's Law formulas, we come up with a **Combined Gas Law** that can be used to solve any one of the three !!! Here's what it looks like:

$$\frac{P_1V_1}{T_1n_1} = \frac{P_2V_2}{T_2n_2}$$

Now lets see how to do the examples I gave you before (Boyle & Charles) using this new tool:

Example (Boyle's Law):

If you have P_1 = 235 kPa and P_2 = 9,500 Torr and V_1 = 925 ml, what will V_2 be?

Solution:

You must first change **235 kPa** to **Torr** (P_1) so that P_1 and P_2 are in the same units of measure **and** we have to change **kPa** to **Pa** before we can change to **atm**.

. 1000 Pa = 1 kPa **and** 101,325 Pa = 1 atm **and** 1 atm = 760 Torr

So, converting would go like this:

$$\frac{235\ \text{kPa}}{1} \times \frac{1000\ \text{Pa}}{\text{kPa}} \times \frac{1\ \text{atm}}{101{,}325\ \text{Pa}} \times \frac{760\ \text{Torr}}{1\ \text{atm}} = 1763\ \text{Torr} = \mathbf{P_1}$$

Now we have everything we need to use the new formula to solve this Boyle's Law problem:

$$\frac{P_1V_1}{T_1n_1} = \frac{P_2V_2}{T_2n_2}$$

First we look for the variables that **<u>do not change</u>**. In this case temperature (T) does not change. So we remove it from the formula and this is left:

$$\frac{P_1V_1}{n_1} = \frac{P_2V_2}{n_2}$$

The next thing that does not change is the moles of the gas (n). Now the formula looks like (and is) the Boyle's law formula, which allows us to proceed as before:

$$P_1\ V_1 = P_2\ V_2$$

1,763 Torr x 925 ml = 9,500 Torr x V_2

Divide both sides by 1 Torr to get rid of that unit of measure and also divide both sides by 9,500 to get that number to the left side of the equation. Now the equation looks like this:

$$\frac{1{,}763 \times 925\ \text{ml}}{9{,}500} = V_2$$

Answer $V_2 = 171.7$ **ml**

Compare this logic to what we did before in the Boyle's Law tutorial.

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Example (<u>Charles Law</u>):

We start with temperature at 25 °C and an end with a temperature of 58 °C. The volume starts at 75 ml. What is the final volume?

Solution:

T_1 = 25 °C T_2 = 58 °C V_1 = 75 ml   and V_2 = unknown

We cannot use Charles Law until the temperatures at changed to Kelvin. So, be sure you know how to use p. 44 of the textbook. It tells you how to convert any temperature unit of measure to any other temperature unit of measure. Using the first formula in the chart, we can do the following conversions before we use Charles Law:

25 °C + 273 °C = 298 °K = T_1
58 °C + 273 °C = 331 °K = T_2

We use the Combined Gas Law as follows:

$$\frac{P_1V_1}{T_1n_1} = \frac{P_2V_2}{T_2n_2}$$

What are the two variables that do not change? The first is number of moles (n). So we remove n from the formula, which leaves:

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

The other variable that does not change is pressure. Taking that out leaves the familiar Charles Law formula:

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

Now we can proceed as we did in the last tutorial on Charles Law, plug in the numbers:

$$\frac{75 \text{ ml}}{298\ °K} = \frac{T_2}{331\ °K}$$

The unit of measure °K crosses out on both side of the = sign. The unit of measure left is ml. To finish off the math, multiply 75 ml x 331 and then divide your answer by 298: **Answer** **83.3 ml = T_2**

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<u>Now let's look the the new type of problem</u>, where only one variable is unknown, and no other variables change, we neec the **Universal Gas Law**:

$$\mathbf{PV = nRT}$$

$$R = \frac{0.08206 \text{ atm L}}{\text{Moles } °K}$$

Example:

What mass of helium gas is needed to pressurize a 100.0 L tank to 255 atm at 25 °C ?

Solution:

First, we know that we can use PV = nRT because we are being asked to find one out of the 4 variables – n (moles of Helium). Note they didn't ask for moles, but grams. That means we have to find moles first and then convert to grams. If you are having trouble with that type of conversion, see my tutorial: Converting grams to moles to atoms or PDF **Std 3**

What are we given?

V = 100.0 L – which is already in the correct unit of measure
P = 255 atm – which is already in the correct unit of measure
T = 25 °C - which must be converted to Kelvin
25 + 273 = 298 °K

Now we can put the numbers into the formula:

(225 atm)(100.0 L) = n (0.08206)(298 °K)

$$\frac{(225 \text{ atm})(100.0 \text{ L})}{(0.08206)(298\ °K)} = n \qquad n = \frac{22{,}500}{24.45} = \mathbf{920 \text{ mol He}}$$

The problem wants to know the mass of the He. So, we must convert to grams as follows:

1 mol He = 4.0 grams

$$\frac{920 \text{ mol He}}{1} \times \frac{4.0 \text{ grams}}{1 \text{ mol He}} = \mathbf{3{,}680 \text{ grams}}$$

This is the answer you were asked to find.