Combined Gas Law

- Everyday applications with gases usually involve changes in temperature, pressure and volume all taking place at the same time
  - Recall that Boyle's Law explains the relationship between pressure and volume at constant temperature and that Charles's law explains the relationship between temperature and volume at constant pressure.

$P_1V_1 = P_2V_2$ Boyle's Law & $\frac{V_1}{T_1} = \frac{V_2}{T_2}$ Charles's Law

  - If Boyle's and Charles's Law are combined, we get a new equation that relates all three variables (temperature, pressure and volume) at the same time. This equation is call the **combined gas law**.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$ * memorize!

where P_1 and P_2 are pressures

V_1 and V_2 are volumes

* T_1 and T_2 are temperatures (needs to be in ***Kelvins***)

Pressure and volume can be in any units as long as they are consistent.
↳ the same!

EXAMPLES:

1. A weather balloon is filled with hydrogen gas at 20°C and 100kPa. It has a volume of 7.50L. It rises to an altitude where the air temperature is -36°C and the pressure is 28kPa. What is the new volume of the balloon?

$T_1 = 20°C + 273.15$

$T_1 = 293.15K$

$P_1 = 100kPa$

$V_1 = 7.50L$

$T_2 = -36°C + 273.15$

$T_2 = 237.15K$

$P_2 = 28kPa$

$V_2 = ?$

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

$$\frac{P_1V_1T_2}{T_1P_2} = V_2$$

$$\frac{(100\cancel{kPa})(7.50L)(237.15\cancel{K})}{(293.15\cancel{K})(28\cancel{kPa})} = V_2$$

$$21.6688...L = V_2$$

$$\boxed{22L = V_2}$$

2. A large syringe was filled with 50.0mL of ammonia gas at 700mmHg and 0°C. If the gas was compressed to 25.0mL with a pressure of 109kPa, what was the final temperature in °C?

$V_1 = 50.0\,mL$

$P_1 = 700\,mmHg$

$T_1 = 0°C + 273.15$

$T_1 = 273.15\,K$

$V_2 = 25.0\,mL$

$P_2 = 109\,kPa \times \left(\frac{760\,mmHg}{101.325\,kPa}\right)$

$P_2 = 817.56723...\,mmHg$

$T_2 = ?$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \longrightarrow T_2 = \frac{P_2V_2T_1}{P_1V_1}$$

$$T_2 = \frac{(817.56723...\,mmHg)(25.0\,mL)(273.15\,K)}{(700\,mmHg)(50.0\,mL)}$$

$T_2 = 159.51320...\,K$

$T_2 = 159.51320...\,K - 273.15$

$T_2 = -113.6367...\,°C$

$$\boxed{T_2 = -114°C}$$

3. A sample of gas is initially at 25.0°C. If the volume of gas is tripled and the pressure decreases to 2/3, what is the new temperature of the gas?

$T_1 = 25°C + 273.15$

$T_1 = 298.15\,K$

V_1

P_1

$V_2 = 3V_1$

$P_2 = \frac{2}{3}P_1$

$T_2 = ?$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \longrightarrow T_2 = \frac{P_2V_2T_1}{P_1V_1}$$

$$T_2 = \frac{(\frac{2}{3}P_1)(3V_1)\,298.15\,K}{P_1V_1}$$

$T_2 = (\frac{2}{3})(3)(298.15\,K) = 596.3\,K$

$$\boxed{T_2 = 596\,K}$$

Now try Practice Problems

Practice Problems

1. A sample of gas has a volume of 525mL at 300K and 746mmHg. Find the volume if the temperature increases to 350K and the pressure increase to 780mmHg.

2. A 2.7L sample of nitrogen gas is collected at a temperature of 45.0°C and a pressure of 0.92atm. What pressure would have to be applied to the gas to reduce its volume to 2.0L at a temperature of 25.0°C?

3. A cylinder filled with helium gas is at a pressure of 66.6kPa. If the helium gas is transferred to a new tank that is ¾ the size of the original cylinder and the temperature triples, what will be the new pressure in the new tank?

4. A 2.5L balloon is completely filled with helium indoors at a temperature of 24.2°C. The balloon is taken out on a cold winter day. If the final volume of the balloon is 2.0L, what is the Celsius temperature outdoors?

5. A sample of argon gas occupies a volume of 2.0L at -35°C and 101.325kPa. What is the resulting temperature in Celsius if the volume is decreased to 1.5L and the pressure changed to 2.0atm?

6. Methane gas can be condensed by cooling and increasing the pressure. A 600L sample of methane gas at 25°C and 100kPa is cooled to -20°C at a constant pressure. In a second step, the gas is compressed at a constant temperature until the pressure is quadrupled. What will the final volume be?

7. A small balloon contains 275mL of helium gas at a temperature of 25.0°C and a pressure of 3.454atm. What volume would this gas occupy at 10.0°C and 101kPa?

8. A 500mL sample of oxygen is kept at 950mmHg and 21.5°C. The oxygen is expanded to a volume of 0.700L and the temperature is adjusted until the pressure is 101.325kPa. What is the final temperature of the oxygen gas?

Answers:

1. 586 mL
2. 1.2 atm
3. 266 kPa
4. -35°C
5. 84 °C
6. 1.3×10^2 L
7. 905 mL
8. 56.9°C