Topic 4: Combined Gas Law

Boyles Law and Charles Law can be combined to give a gas law which takes into account pressure, temperature and volume.

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

When using the combined gas law, variables that don't change can be cancelled from the equaon

Example

A steel cylinder with a fixed volume contains a gas a pressure of 652kPa and a temp of 25°C. If the cylinder is heated to 150°C, use the combined gas law to calculate the new pressure.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \qquad \frac{P_1}{T_1} = \frac{P_2}{T_2}$$

Gay-Lussac's Law

$P_1 =$ 652kPa
~~$V_1 =$~~
$T_1 =$ 298k
$P_2 =$?
~~$V_2 =$~~
$T_2 =$ 423k

$$\frac{652\,kPa}{298\,k} = \frac{P_2}{423\,k}$$

$P_2 = 925.48\ldots\, kPa$

$= 925\, kPa$

Example:

A balloon containing helium gas at 20°C (293k) and a pressure of 100kPa has a volume of 7.50L. Calculate the volume aer is rises 10km into the atmosphere where the temp is -36°C and the pressure is 28kPa. Assume the balloon is free to expand.

$P_1 =$ 100kPa
$V_1 =$ 7.50L
$T_1 =$ 293k
$P_2 =$ 28kPa
$V_2 =$?
$T_2 =$ 237k

$P_1V_1T_2 = P_2V_2T_1$

$[(100\,kPa)(7.50\,L)(237\,k)] = (28\,kPa)V_2(293\,k)$

$V_2 = 21.66\ldots\, L$

$= 22L$

Using the Kinetic Molecular Theory to Explain Gases

Gases are compressible (why?)

- Most of the volume of a gas is empty space, so it is possible to force gas molecules closer together

Gases exert pressure (why?)

- Gas molecules collide with the walls of the container that holds them. Pressure is the total force of these collisions

Boyles Law

- If the volume of a container is reduced, the gas molecules travel a shorter distance before striking the container wall again, exerting more pressure

Charles Law

- The higher the temperature of gas molecules, the faster they move. This results in more collisions with the container walls and if the container can expand, the gas molecules will expand in volume

Summary of what has been learned so far:

STP: ___^{o}C and __________kPa

SATP: ___^{o}C and __________kPa

101.325 kPa = _____atm = ____mm Hg

Absolute zero = ____K or __________ ^{o}C

Boyles Law

Charles Law

Combined Gas Law

Practice Sheet 4

1. A large party balloon has a volume of 5.00 L at 20 °C and 100 kPa. Calculate the pressure for a volume of 6.00 L at 35 °C.

$P_1 = 100\ kPa$

$V_1 = 5.00\ L$

$T_1 = 20°C = 293\ K$

$P_1 V_1 T_2 = P_2 V_2 T_1$

$(100\ kPa)(5.00\ L)(308\ K) = P_2(6.00\ L)(293\ K)$

$P_2 = 87.6\ kPa$

$P_2 = ??$

$V_2 = 6.00\ L$

$T_2 = 35°C = 308\ K$

2. A cylinder of helium gas has a volume of 1.0 L. The gas in the cylinder exerts a pressure of 800 kPa at 30 °C. What volume would this gas occupy at SATP?

$P_1 = 800\ kPa$

$V_1 = 1.0\ L$

$T_1 = 303\ K$

$(800)(1.0)(298) = (100)(V_2)(303)$

$V_2 = 7.867...\ L$

$= 7.9\ L$

$P_2 = 100\ kPa$

$V_2 = ??$

$T_2 = 298\ K$

3. A 2.0 mL bubble of gas is released at the bottom of a lake where the pressure is 6.5 atm and the temperature is 10 °C. Predict the Celsius temperature of the gas bubble at the surface, where the pressure is 0.95 atm and the volume becomes 14.4 mL.

$V_1 = 2.0\ mL$

$P_1 = 6.5\ atm$

$T_1 = 283\ K$

$(2.0\ mL)(6.5\ atm)(T_2) = (14.4\ mL)(0.95\ atm)(283)$

$T_2 = 297.80...\ K$

$= 25°C$

$V_2 = 14.4\ mL$

$P_2 = 0.95\ atm$

$T_2 = ??$

4. Popcorn is a favorite snack food for many people. The corn kernel is heated, and some of the moisture inside the kernel vaporizes, starting a chain of events that leads to the tasty popped corn.

(a) If we assume a constant volume kernel (before popping), what happens to the pressure inside the kernel as the temperature increases? Justify your answer using appropriate mathematical equations or relationships.

(b) The pressure inside the kernel forces some superheated water and steam to penetrate into the starch granules, making them soft and gelatinous. When the hull of the kernel breaks at about 900 kPa, what happens to the volume of water vapour when the pressure quickly drops to about 100 kPa? Justify your answer using appropriate mathematical equations or relationships.

5. A syringe contains 50.0 mL of a gas at a pressure of 96.0 mm Hg. The end is sealed, and the plunger is pushed to compress the gas to 12.5 mL. What is the new pressure of the gas inside the syringe, assuming constant temperature?

6. In a cylinder of a diesel engine, 500 mL of air at 40.0 °C and 1.00 atm is powerfully compressed just before the diesel fuel is injected. The resulting pressure is 35.0 atm. If the final volume is 23.0 mL, what is the final temperature in the cylinder?

7. For a typical geyser, underground water seeps into a deep narrow shaft in the ground and is heated from below. Because of the depth, the pressure on the water is high, so the water at the bottom of the shaft boils at a much higher temperature than normal.

What happens to the volume of a 1.0 L bubble of water vapour at 130 °C and 3.05 atm when it reaches the surface, where the conditions are 100 °C and 1.01 atm?