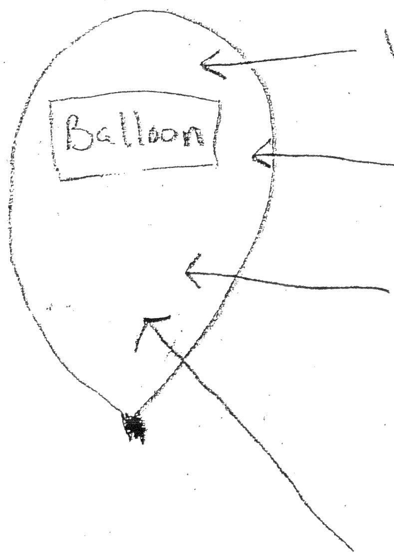
A - packet

Physical properties Gases

particles are far apart.
have more KE than solids or liquids
compressible
no definite volume or shape

So how can we categorize a gas?



V = Volume - they take on the volume of the container

T = particles have KE so they have temperature.

n = composed of particles in terms of moles. 1 mole is 6×10^{23} molecules.

P = pressure - gases exert pressure on the container they occupy.

Summary

A gas can be categorized by knowing:
P, n, T, V

Gases

$R = \frac{0.0821\ L\text{-}atm}{mol \cdot K}$

$R = 8.314\ \frac{J}{K \cdot mole}$

$R = 1.987\ \frac{cal}{K \cdot mole}$

Kinetic Theory of Matter

Particles of all matter are in constant random motion. The energy of moving objects is kinetic Energy (KE).

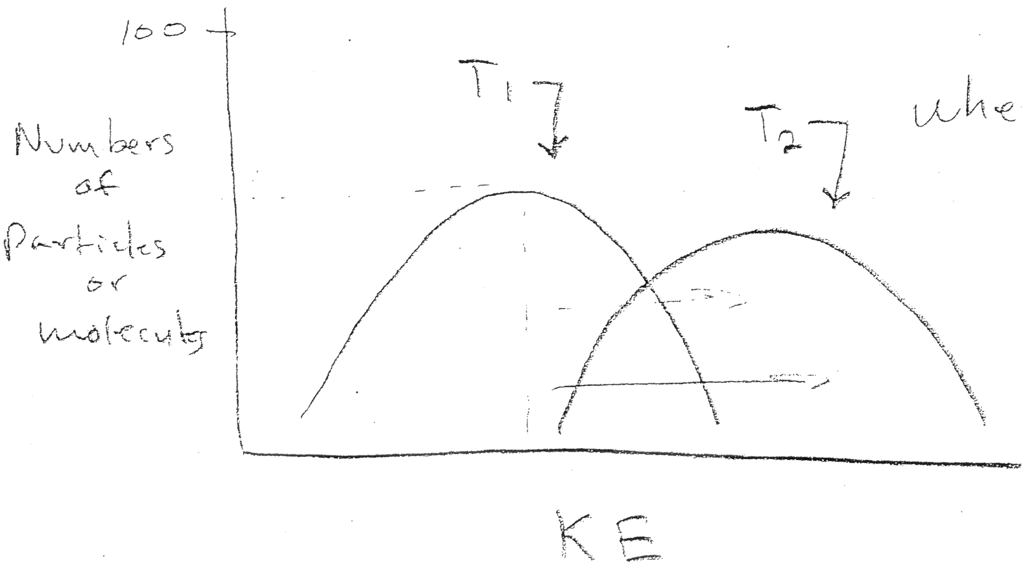
1. Particles are small compared to the distances between them such that the volume of individual particles are negligible.

2. The particles are in constant motion.

3. The particles exert no forces on one another. They do not repel or attract one another. ~~The particles have elastic collisions.~~

4. The average KE of the gas is directly proportional to the temperature of the gas.

The Kinetic Energy of gases:



where $T_2 > T_1$

The average KE is directly proportional to the average temperature.

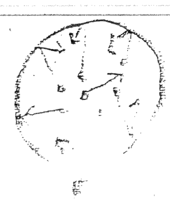
Pressure

Gases exert pressures on the walls of the containers they occupy. They also exert pressure on the surface of the earth.

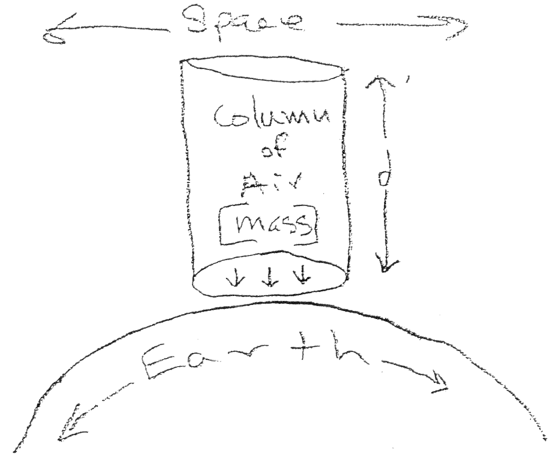
Pressure: pressure is the force exerted by molecules per unit area.

$$P = \frac{F \leftarrow \text{force}}{A \leftarrow \text{area}}$$

All gases that have a detectable temperature have energy. The energy is Kinetic Energy (KE). All gas particles are therefore in motion. when they collide with the container walls they exert force. This is why a balloon has the shape it does.



Atmospheric Pressure:



Mass of Column exerts force on surface.

$P = 1\ atm = 760\ mmHg =$
$= 760\ torr = 14.7\ psi =$
$= 101.3\ kPa$

Boyle's Law

The relationship between Pressure and Volume $P \frac{1}{V}$

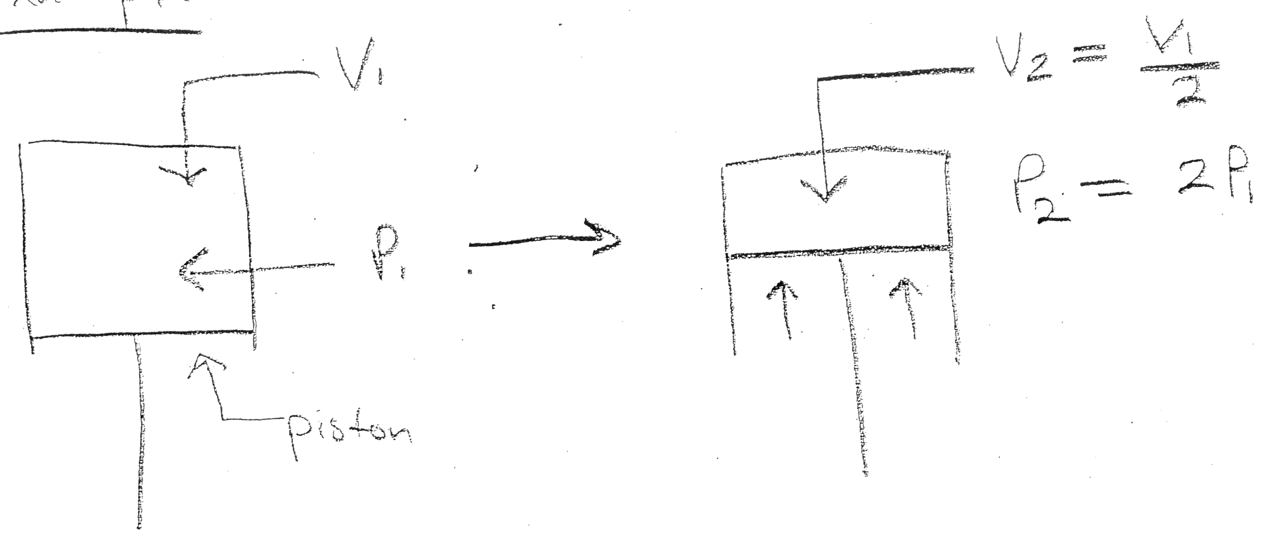
Boyles Law States $P_1V_1 = P_2V_2$

For a gas at constant temperature (T) and constant moles (n) the pressure (P) is inversely related to the volume (V).

$$P \sim \frac{1}{V} \qquad P_1V_1 = P_2V_2$$

1. Pressure goes up, volume goes down
2. Pressure goes down, volume goes up

Example



In the example, the gas starts at V_1 and P_1. The piston moves up cutting the volume in half compressing the gas. Since the volume was made smaller the pressure increases. The product $P_1V_1 = P_2V_2$

Calculations with Units of Pressure and Boyle's Law $P_1V_1 = P_2V_2$ Problems

Unit multipliers

1 atm = 760 mmHg = 760 torr = 14.7 Psi = 101.3 kPa

1. Convert 29.4 Psi to mmHg.

$$29.4 \text{ Psi} \times \frac{760 \text{ mmHg}}{14.7 \text{ Psi}} = 1520 \text{ mmHg}$$

2. Convert 730 mmHg to atms.

$$730 \text{ mmHg} \times \frac{1 \text{ atm}}{760 \text{ mmHg}} = 0.961 \text{ atm}$$

3. 19 psi to kPa

$$19 \text{ psi} \times \frac{101.3 \text{ kPa}}{14.7 \text{ psi}} = 130.9 \text{ kPa}$$

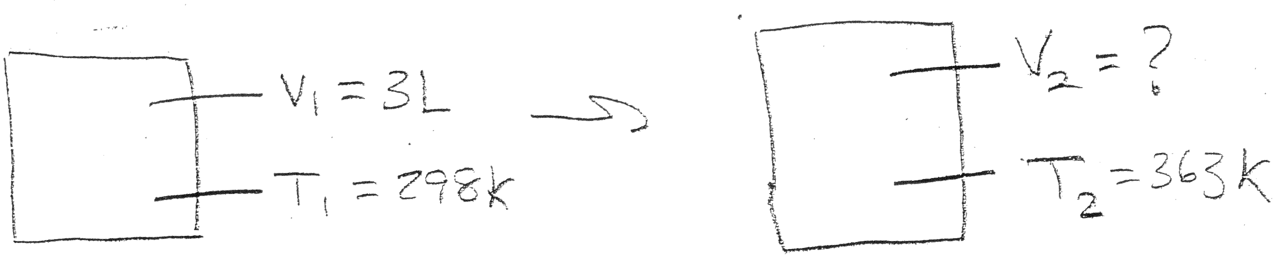
Charles Law

The volume (V), of a gas is directly proportional to temperature (T) at constant (P) and (n).

V is proportional to T

constant P, n

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



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

$$\frac{(V_1)(T_2)}{T_1} = V_2 = \frac{(3L)(363K)}{298K} = 3.65L$$

Avogadro's Law

The volume of a gas is directly proportional to the number of particles at constant pressure and temperature.

$$V \propto n \quad \text{at constant } P + T$$

(V = volume; n = moles)

$$\frac{V_1}{n_1} = \frac{V_2}{n_2}$$

↑V n↑

↓V n↓

Example

2 L of a gas contains 2 mole. The volume is increased to 3.5 L. Calculate the new moles. Assume constant P + T.

State 1: $V_1 = 2L$, $n_1 = 2\text{mole}$

State 2: $V_2 = 3.5L$, $n_2 = ?$

$$\frac{V_1}{n_1} = \frac{V_2}{n_2} \quad \text{so} \quad \frac{n_1}{V_1} = \frac{n_2}{V_2} \qquad n_2 = \frac{V_2 n_1}{V_1}$$

$$n_2 = \frac{(3.5L)(2\text{mole})}{2L} = 3.5\text{mole}$$

Gay-Lussac: The pressure of a gas is directly proportional to temperature at constant volume and moles.

$$P \propto T$$

So if the absolute kelvin temperature <u>increases</u>, the pressure <u>goes up</u>.

$$\uparrow P \quad T \uparrow$$

$$\downarrow P \quad T \downarrow$$

where $$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

<u>Example</u>

1 mole of a gas is in a fixed volume at 1atm and 25°c. The Temp is increased to 300°c. Calculate the new pressure.

State 1: $P_1 = 1atm$, $T_1 = 298K$

State 2: $P_2 = ?$, $T_2 = 573K$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \qquad P_2 = \frac{T_2 P_1}{T_1} = \frac{(573K)(1atm)}{298K} = 1.9atm$$

Ideal Gas Law

Ideal gas law combines P, V, T and n into one equation where:

$$PV = nRT$$

R is the gas constant whose value and units are: $\frac{0.0821\ L \cdot atm}{mole \cdot K}$

Example

Find the moles of a gas, n, if P is 1atm, V is 5 L, and T = 25°C.

$$n = \frac{PV}{RT} = \frac{(1atm)(5L)}{\left(\frac{0.0821\ L \cdot atm}{mole \cdot K}\right)(298K)}$$

n = 0.2044 moles gas

Standard Temperature and Pressure

STP

STP is a unique condition for a gas where $T = 0°C = 273K$ and $P = 1atm$.

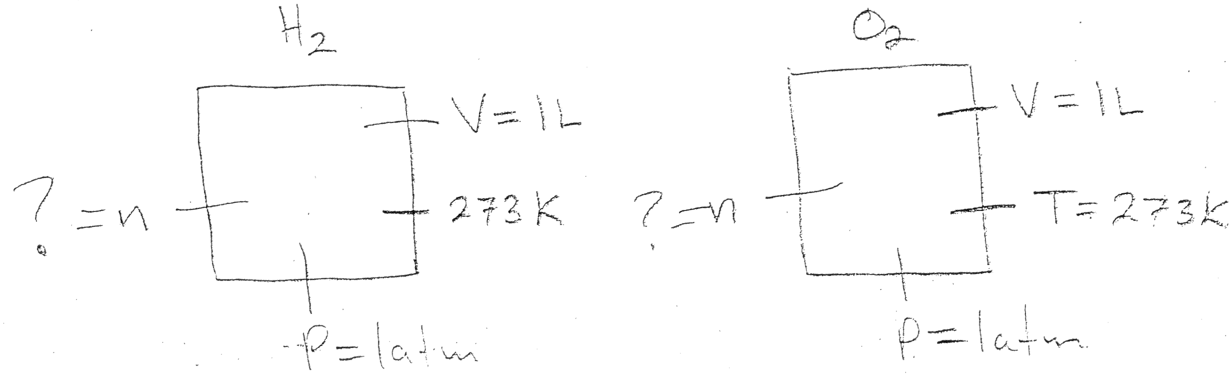
If a gas at STP also is composed of exactly $\underline{1 mole = n}$, then the volume is also unique:

$$V = \frac{\overset{1mole}{n}\,R\,\overset{273K}{T}}{\underset{1atm}{P}} = \frac{(1mole)(R)(273K)}{1atm}$$

$V = 22.41\,L$ for any ideal gas.

Avogadro's Principle

Equal volumes of gases at the same temperature and pressure have equal numbers of particles.



$$PV = nRT$$

$$n = \frac{PV}{RT}$$

$$n_{H_2} = \frac{(1\,atm)(1\,L)}{\left(\frac{0.0821\,L\cdot atm}{mole\cdot K}\right)(273\,K)}$$

$$n_{O_2} = \frac{(1\,atm)(1\,L)}{\left(\frac{0.0821\,L\cdot atm}{mole\cdot K}\right)(273\,K)}$$

$n_{H_2} = 0.045$ mole

$n_{O_2} = 0.045$ mole

Equal numbers of particles in equal volumes at constant T and P.

(B) The molar volume of any gas at STP (standard temp. and pressure) is 22.4 L.

Where P = 1 atm, n = 1, T = 273 K

and $V = \frac{nRT}{P} = \frac{(1\text{ mole})\left(\frac{0.0821\text{ L}\cdot\text{atm}}{\text{mole}\cdot\text{K}}\right)(273\text{ K})}{1\text{ atm}}$

$V = 22.4\text{ L}$

1 mole of any gas at STP, where T = 273 K, P = 1 atm, the volume is 22.4 L.

(C) Avogadro's Principle has implications for chemical reactions with components in the gas form. Remember that 1 L of H_2 has the same number of particles as 1 L of O_2.

$$2H_2(g) + O_2(g) \xrightarrow{298K,\ 1atm} 2H_2O(g)$$

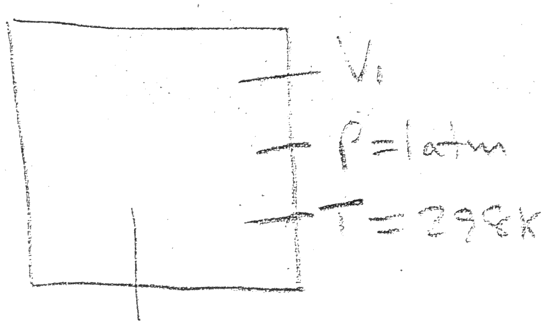
in volume: 2L 1L 2L

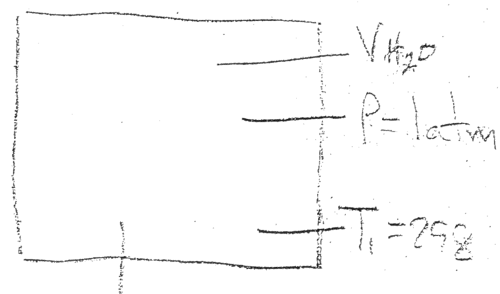
3L 2L

Thus, the volume of H_2O (g) produced will be $\frac{2}{3}$ of the ~~total~~ starting volume for the reaction.

We will prove this: A reaction is set up with 2 mole H_2 and 1 mole O_2 at $P = 1atm$ and $T = 298K$. Find V_{react}:

V_{react}





$n_{tot} = 2 + 1$

$n_{tot} = 3$

$n_{H_2O} = 2$

$$V_{react} = \frac{nRT}{P} =$$

$$= \frac{(3\,mole)\left(0.0821\,\frac{L \cdot atm}{mole \cdot K}\right)(298K)}{1atm}$$

$$V_{react} = 73.4\,L$$

$$V_{H_2O} = \frac{(2\,mole)\left(0.0821\,\frac{L \cdot atm}{mole \cdot K}\right)(298K)}{1atm}$$

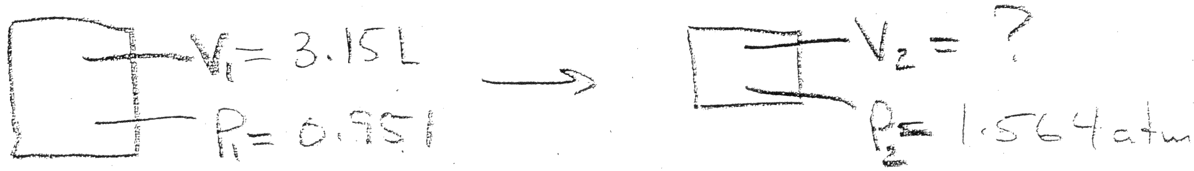
$$V_{H_2O} = 48.93$$

Take the ratio of $\frac{V_{H_2O}}{}$ →

$$\rightarrow \frac{48.93}{73.4} = 0.66 \doteq \frac{2}{3}$$

Boyle's Gas Problems

3.15L of gas is kept at 21°C and a pressure of 0.951 atm. If the pressure is increased to 1.564 atm, find the new volume. T is constant.



$$P_1V_1 = P_2V_2$$

$$V_2 = \frac{P_1V_1}{P_2} = \frac{(0.951\,\text{atm})(3.15\,\text{L})}{1.564\,\text{atm}}$$

$$V_2 = 1.92\,\text{L}$$

Qualitative aspects gleaned from reading the problem. The T is constant and P is increasing so V must go down.

BOYLE'S LAW

Name ____________

Boyle's Law states that the volume of a gas varies inversely with its pressure if temperature is held constant. (If one goes up, the other goes down.) We use the formula:

$$P_1 \times V_1 = P_2 \times V_2$$

Solve the following problems (assuming constant temperature).

1. A sample of oxygen gas occupies a volume of 250. mL at 740. torr pressure. What volume will it occupy at 800. torr pressure?

   ____

2. A sample of carbon dioxide occupies a volume of 3.50 liters at 125 kPa pressure. What pressure would the gas exert if the volume was decreased to 2.00 liters?

   ____

3. A 2.0 liter container of nitrogen had a pressure of 3.2 atm. What volume would be necessary to decrease the pressure to 1.0 atm?

   ____

4. Ammonia gas occupies a volume of 450. mL at a pressure of 720. mm Hg. What volume will it occupy at standard pressure?

   ____

5. A 175 mL sample of neon had its pressure changed from 75 kPa to 150 kPa. What is its new volume?

   ____

6. A sample of hydrogen at 1.5 atm had its pressure decreased to 0.50 atm producing a new volume of 750 mL. What was its original volume?

   ____

7. Chlorine gas occupies a volume of 1.2 liters at 720 torr pressure. What volume will it occupy at 1 atm pressure?

   ____

8. Fluorine gas exerts a pressure of 900. torr. When the pressure is changed to 1.50 atm, its volume is 250. mL. What was the original volume?

   ____

HARLES' LAW

Name ______________________

...les' Law states that the volume of a gas varies directly with the Kelvin temperature, ...ning that pressure is constant. We use the following formulas:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad \text{or} \quad V_1 \times T_2 = V_2 \times T_1$$

$$K = °C + 273$$

...lve the following problems assuming a constant pressure.

1. A sample of nitrogen occupies a volume of 250 mL at 25° C. What volume will it occupy at 95° C?

   ____

2. Oxygen gas is at a temperature of 40° C when it occupies a volume of 2.3 liters. To what temperature should it be raised to occupy a volume of 6.5 liters?

   ____

3. Hydrogen gas was cooled from 15$\bar{0}$° C to 5$\bar{0}$° C. Its new volume is 75 mL. What was its original volume?

   ____

4. Chlorine gas occupies a volume of 25 mL at 3$\bar{0}$0 K. What volume will it occupy at 600 K?

   ____

5. A sample of neon gas at 5$\bar{0}$° C and a volume of 2.5 liters is cooled to 25° C. What is the new volume?

   ____

6. Fluorine gas at 30$\bar{0}$ K occupies a volume of 50$\bar{0}$ mL. To what temperature should it be lowered to bring the volume to 30$\bar{0}$ mL?

   ____

7. Helium occupies a volume of 3.8 liters at -45° C. What volume will it occupy at 45° C?

   ____

8. A sample of argon gas is cooled and its volume went from 38$\bar{0}$ mL to 25$\bar{0}$ mL. If its final temperature was -55° C, what was its original temperature?

   ____

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Period ___ Date ___/___/___

12 • The Gas Laws

BOYLE'S LAW

Boyle's Law states that the volume of a gas varies inversely with its pressure if temperature is held constant. (If one goes up, the other goes down.) We use the formula:

$$P_1 \times V_1 = P_2 \times V_2$$

Solve the following problems (assuming constant temperature). Assume all number are 3 significant figures.

1. A sample of oxygen gas occupies a volume of 250 mL at 740 torr pressure. What volume will it occupy at 800 torr pressure?

   $P_1V_1 = P_2V_2$

   $V_2 = \frac{P_1V_1}{P_2} = \frac{(740\ torr)(250\ mL)}{(800\ torr)} = 231\ mL$

2. A sample of carbon dioxide occupies a volume of 3.50 Liters at 125 kPa pressure. What pressure would the gas exert if the volume was decreased to 2.00 liters?

   $P_2 = \frac{P_1V_1}{V_2} = \frac{(125\ kPa)(3.50\ L)}{(2.00\ L)} = 219\ kPa$

3. A 2.00-Liter container of nitrogen had a pressure of 3.20 atm. What volume would be necessary to decrease the pressure to 1.00 atm?

   $P_1 = 3.20\ atm$ $V_1 = 2.00\ L$ $P_2 = 1.00\ atm$

   $V_2 = \frac{P_1V_1}{P_2} = \frac{(3.20\ atm)(2.00\ L)}{(1.00\ atm)} = 6.40\ L$

4. Ammonia gas occupies a volume of 450 mL as a pressure of 720 mmHg. What volume will it occupy at standard pressure (760 mmHg)?

   $P_1 = 720\ mmHg$ $V_1 = 450\ mL$ $P_2 = 760\ mmHg$

   $V_2 = \frac{P_1V_1}{P_2} = \frac{(720\ mmHg)(450\ mL)}{(760\ mmHg)} = 426\ mL$

5. A 175 mL sample of neon had its pressure changed from 75.0 kPa to 150 kPa. What is its new volume?

   $V_2 = \frac{P_1V_1}{P_2} = \frac{(75.0\ kPa)(175\ mL)}{150\ kPa} = 87.5\ mL$

6. A sample of hydrogen at 1.50 atm had its pressure decreased to 0.50 atm producing a new volume of 750 mL. What was the sample's original volume?

   $V_1 = \frac{P_2V_2}{P_1} = \frac{(.50\ atm)(750\ mL)}{(1.50\ atm)} = 250.\ mL$

7. Chlorine gas occupies a volume of 1.20 liters at 720 torr pressure. What volume will it occupy at 1 atm pressure?

   $V_2 = \frac{P_1V_1}{P_2} = \frac{(720\ torr)(1.20\ L)}{(1\ atm \times \frac{760\ torr}{1\ atm})} = 1.14\ L$

8. Fluorine gas exerts a pressure of 900 torr. When the pressure is changed to 1.50 atm, its volume is 250 mL. What was the original volume?

   $V_1 = \frac{P_2V_2}{P_1} = \frac{(1.50\ atm)(250\ mL)}{(900\ torr \times \frac{1\ atm}{760\ torr})} = 317\ mL$

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8 • Why Do Hot Air Balloons Float?

CHARLES'S LAW

Charles' Law states the volume of a gas varies directly with the Kelvin temperature, assuming the pressure is constant. We use the following formulas:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \quad \text{or} \quad V_1 \times T_2 = V_2 \times T_1$$

$$K = {}^\circ C + 273$$

Solve the following problems assuming a constant pressure. Assume all numbers are 3 significant figures.

1. A sample of nitrogen occupies a volume of 250 mL at 25 °C. What volume will it occupy at 95 °C?

   $\frac{250\ mL}{298\ K} = \frac{x}{368\ K}$ $x = 309\ mL$

2. Oxygen gas is at a temperature of 40 °C when it occupies a volume of 2.30 Liters. To what temperature should it be raised to occupy a volume of 6.50 Liters?

   $\frac{2.30\ L}{313\ K} = \frac{6.50\ L}{x}$ $x = 885\ K = 612\ {}^\circ C$

3. Hydrogen gas was cooled from 150 °C to 50 °C. Its new volume is 75.0 mL. What was its original volume?

   $\frac{x}{423} = \frac{75.0\ mL}{323}$ $x = 98.2\ mL$

4. Chlorine gas occupies a volume of 25.0 mL at 300 K. What volume will it occupy at 600 K?

   $\frac{25.0\ mL}{300\ K} = \frac{x}{600\ K}$ $x = 50.0\ mL$

5. A sample of neon gas at 50 °C and a volume of 2.50 Liters is cooled to 25 °C. What is the new volume?

   $\frac{2.50\ L}{323\ K} = \frac{x}{298\ K}$ $x = 2.31\ L$

6. Fluorine gas at 300 K occupies a volume of 500 mL. To what temperature should it be lowered to bring the volume to 300 mL?

   $\frac{500\ mL}{300\ K} = \frac{300\ mL}{x}$ $x = 180\ K = -93\ {}^\circ C$

7. Helium occupies a volume of 3.80 Liters at -45 °C. What volume will it occupy at 45 °C?

   $\frac{3.80\ L}{228\ K} = \frac{x}{318\ K}$ $x = 5.30\ L$

8. A sample of argon gas is cooled and its volume went from 380 mL to 250 mL. If its final temperature was -55 °C, what was its original temperature?

   218 K = T_2

   $\frac{380\ mL}{x} = \frac{250\ mL}{218\ K}$ $x = 331\ K = 58.4\ {}^\circ C$

Ebbing

5.30 Three 25.0-L flasks are placed next to each other on a shelf in a chemistry stockroom. The first flask contains He at a pressure of 1.0 atm, the second contains Xe at 1.50 atm, and the third contains F_2 and has a label that says 2.0 mol F_2. Consider the following questions about these flasks.

(a) Which flask has the greatest number of moles of gas?
(b) If you wanted each of the flasks to be at the same pressure as the He flask, what general things could you do to the other two containers to make this happen?

PRACTICE PROBLEMS

Note: In these problems, the final zeros given in temperatures and pressures (for example, 20°C, 760 mmHg) are significant figures.

Answers in classroom solutions manual

UNITS OF PRESSURE

5.31 A gas in a closed-tube manometer (Figure 5.4) has a measured pressure of 0.047 atm. Calculate the pressure in mmHg.

5.32 The barometric pressure measured outside an airplane at 9 km (30,000 ft) was 259 mmHg. Calculate the pressure in kPa.

EMPIRICAL GAS LAWS

5.33 Suppose you had a 3.15-L sample of neon gas at 21°C and a pressure of 0.951 atm. What would be the volume of this gas if the pressure were increased to 1.292 atm while the temperature remained constant?

5.34 You fill a balloon with helium gas to a volume of 2.68 L at 23°C and 789 mmHg. Now you release the balloon. What would be the volume of helium if its pressure changes to 543 mmHg but the temperature is unchanged?

5.35 You have a tank of argon gas at 19.8 atm pressure at 19°C. The volume of argon in the tank is 50.0 L. What would be the volume of this gas if you allowed it to expand to the pressure of the surrounding air (0.974 atm)? Assume the temperature remains constant.

5.36 A diving bell is a container open at the bottom. As the bell descends, the water level inside changes so that the pressure inside equals the pressure outside. Initially, the volume of air is 8.58 m^3 at 1.020 atm and 20°C. What is the volume at 1.584 atm and 20°C?

5.37 A McLeod gauge measures low gas pressures by compressing a known volume of the gas at constant temperature. If 345 cm^3 of gas is compressed to a volume of 0.0457 cm^3 under a pressure of 2.51 kPa, what was the original gas pressure?

5.38 If 456 dm^3 of krypton at 101 kPa and 21°C is compressed into a 27.0-dm^3 tank at the same temperature, what is the pressure of krypton in the tank?

5.39 A sample of nitrogen gas at 18°C and 760 mmHg has a volume of 2.67 mL. What is the volume at 0°C and 1 atm of pressure?

5.40 A mole of gas at 0°C and 760 mmHg occupies 22.41 L. What is the volume at 20°C and 760 mmHg?

5.41 Helium gas, He, at 22°C and 1.00 atm occupied a vessel whose volume was 2.54 L. What volume would this gas occupy if it were cooled to liquid-nitrogen temperature (−197°C)?

5.42 An experiment called for 5.83 L of sulfur dioxide, SO_2, at 0°C and 1.00 atm. What would be the volume of this gas at 25°C and 1.00 atm?

5.43 A vessel containing 39.5 cm^3 of helium gas at 25°C and 106 kPa was inverted and placed in cold ethanol. As the gas contracted, ethanol was forced into the vessel to maintain the same pressure of helium. If this required 18.8 cm^3 of ethanol, what was the final temperature of the helium?

5.44 A sample of 62.3 cm^3 of argon gas at 18°C was contained at a pressure of 155 kPa in a J-shaped tube with mercury, as in Figure 5.5. Later the temperature changed. When the mercury level was adjusted to give the same pressure of argon, the gas volume changed to 46.7 cm^3. What was the final temperature of the argon?

5.45 A bacterial culture isolated from sewage produced 37.6 mL of methane, CH_4, at 31°C and 753 mmHg. What is the volume of this methane at standard temperature and pressure (0°C, 760 mmHg)?

5.46 Pantothenic acid is a B vitamin. Using the Dumas method, you find that a sample weighing 71.6 mg gives 3.84 mL of nitrogen gas at 23°C and 785 mmHg. What is the volume of nitrogen at STP?

5.29 In order to double the volume you could reduce the pressure by 1/2. You could also increase the temperature, but you cannot determine to what final temperature without knowing the initial temperature.

5.30 a. If you assume that the flasks are at ordinary room temperature, say 25°C, then there would be approximately one mole of He (at 1.0 atm) and 1.5 mol of Xe (at 1.5 atm). Thus, the F_2 flask (with 2.0 mol) would contain the greatest number of moles of gas.

b. You could either decrease the volume, or increase the temperature, or both.

■ Solutions to Practice Problems

Note on significant figures: If the final answer to a solution needs to be rounded off, it is given first with one nonsignificant figure, and the last significant figure is underlined. The final answer is then rounded to the correct number of significant figures. In multiple step problems, intermediate answers are given with at least one nonsignificant figure, however only the final answer has been rounded off.

5.31 Use the conversion factor 1 atm = 760 mmHg.

$$0.047 \text{ atm} \times \frac{760 \text{ mmHg}}{1 \text{ atm}} = 3\underline{5}.7 = 36 \text{ mmHg}$$

5.32 Use the conversion factors 1 atm = 760 mmHg and 1 atm = 101325 Pa, or 101.325 kPa

$$259 \text{ mmHg} \times \frac{1 \text{ atm}}{760 \text{ mmHg}} \times \frac{101.325 \text{ kPa}}{1 \text{ atm}} = 34.\underline{5}3 = 34.5 \text{ kPa}$$

5.33 Using Boyle's law, solve for V_f of the neon gas at 1.292 atm pressure.

$$V_f = V_i \times \frac{P_i}{P_f} = 3.15 \text{ L} \times \frac{0.951 \text{ atm}}{1.292 \text{ atm}} = 2.3\underline{1}8 = 2.32 \text{ L}$$

5.34 Using Boyle's law, solve for V_f of the helium gas at 543 mmHg.

$$V_f = V_i \times \frac{P_i}{P_f} = 2.68 \text{ L} \times \frac{789 \text{ mmHg}}{543 \text{ mmHg}} = 3.8\underline{9}4 = 3.89 \text{ L}$$

5.35 Using Boyle's law, let V_f = volume at 0.974 atm (P_f), V_i = 50.0 L, and P_i = 19.8 atm.

$$V_f = V_i \times \frac{P_i}{P_f} = 50.0\ \text{L} \times \frac{19.8\ \text{atm}}{0.974\ \text{atm}} = 10\underline{1}6.4 = 1.02 \times 10^3\ \text{L}$$

5.36 Using Boyle's law, let V_f = volume at 1.584 atm (P_f), V_i = 8.58 m^3, and P_i = 1.020 atm.

$$V_f = V_i \times \frac{P_i}{P_f} = 8.58\ \text{m}^3 \times \frac{1.020\ \text{atm}}{1.584\ \text{atm}} = 5.5\underline{2}5 = 5.53\ \text{L}$$

5.37 Using Boyle's law, let P_i = pressure of 345 cm^3 of gas, and solve for it:

$$P_i = P_f \times \frac{V_f}{V_i} = 2.51\ \text{kPa} \times \frac{0.0457\ \text{cm}^3}{345\ \text{cm}^3} = 3.3\underline{2}4 \times 10^{-4} = 3.32 \times 10^{-4}\ \text{kPa}$$

5.38 Using Boyle's law, let P_f = final pressure of 27.0 dm^3 of gas, and solve for it:

$$P_f = P_i \times \frac{V_i}{V_f} = 101\ \text{kPa} \times \frac{456\ \text{dm}^3}{27.0\ \text{dm}^3} = 17\underline{0}5.7 = 1.71 \times 10^3\ \text{kPa}$$

5.39 Use Charles's law: T_i = 18°C + 273 = 291 K, and T_f = 0°C + 273 = 273 K.

$$V_f = V_i \times \frac{T_f}{T_i} = 2.67\ \text{mL} \times \frac{273\ \text{K}}{291\text{K}} = 2.5\underline{0}48 = 2.50\ \text{mL}$$

5.40 Use Charles's law: T_i = 0°C + 273 = 273 K, and T_f = 20°C + 273 = 293 K.

$$V_f = V_i \times \frac{T_f}{T_i} = 22.41\ \text{L} \times \frac{293\ \text{K}}{273\ \text{K}} = 24.\underline{0}51 = 24.1\ \text{L}$$

5.41 Use Charles's law: T_i = 22°C + 273 = 295 K, and T_f = -197°C + 273 = 76 K.

$$V_f = V_i \times \frac{T_f}{T_i} = 2.54\ \text{L} \times \frac{76\ \text{K}}{295\ \text{K}} = 0.6\underline{5}4 = 0.65\ \text{L}$$

5.42 Use Charles's law: $T_i = 0°C + 273 = 273$ K, and $T_f = 25°C + 273 = 298$ K.

$$V_f = V_i \times \frac{T_f}{T_i} = 5.83 \text{ L} \times \frac{298 \text{ K}}{273 \text{ K}} = 6.3\underline{6}3 = 6.36 \text{ L}$$

5.43 Use Charles's law: $T_i = 25°C + 273 = 298$ K; and V_f is the difference between the vessel's volume of 39.5 cm^3 and the 18.8 cm^3 of ethanol that is forced into the vessel.

$$T_f = T_i \times \frac{V_f}{V_i} = 298 \text{ K} \times \frac{(39.5 - 18.8) \text{ cm}^3}{39.5 \text{ cm}^3} = 15\underline{6}.1 \text{K} (-11\underline{6}.9 \text{ or } -117°\text{C})$$

5.44 Use Charles's law: $T_i = 18°C + 273 = 291$ K, $V_i = 62.3$ cm^3, and $V_f = 46.7$ cm^3.

$$T_f = T_i \times \frac{V_f}{V_i} = 291\text{K} \times \frac{46.7 \text{ cm}^3}{62.3 \text{ cm}^3} = 21\underline{8}.1 = 218 \text{ K} \ (-55.0 \text{ or } -55°\text{C})$$

5.45 Use the combined law: $T_i = 31°C + 273 = 304$ K, and $T_f = 0°C + 273 = 273$ K.

$$V_f = V_i = \times \frac{P_i}{P_f} \times \frac{T_f}{T_i} = 37.6 \text{ mL} \times \frac{753 \text{ mmHg}}{760 \text{ mmHg}} \times \frac{273 \text{ K}}{304 \text{ K}} = 33.\underline{4}54 = 33.5 \text{ mL}$$

5.46 Use the combined law: $T_i = 23°C + 273 = 296$ K, and $T_f = 0°C + 273 = 273$ K.

$$V_f = V_i = \times \frac{P_i}{P_f} \times \frac{T_f}{T_i} = 3.84 \text{ mL} \times \frac{785 \text{ mmHg}}{760 \text{ mmHg}} \times \frac{273 \text{ K}}{296 \text{ K}} = 3.6\underline{5}8 = 3.66 \text{ mL}$$

5.47 The balanced equation is

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$

The ratio of moles of NH_3 to moles of NO = 4 to 4, or 1 to 1, so 1 volume of NH_3 will produce 1 volume of NO at the same temperature and pressure.

5.48 The balanced equation is

$$CO_2 + 3H_2 \rightarrow CH_3OH + H_2O$$

The ratio of moles of H_2 to moles of CO_2 = 3 to 1, so 3 volumes of H_2 are required to react with 1 volume of CO_2 at the same temperature and pressure.