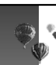
Gases

Dr. Ron Rusay

TED: Gas Properties
https://www.youtube.com/watc?v=EHxdVtygP1g

TED: Gas Laws
https://www.youtube.com/watch?v=BY9VGS2eXas

Gases




- Uniformly fill any container.
- Exert pressure on its surroundings.
- Mix completely with other gases.



Gases:
Pressure, Mass, Volume, Temperature

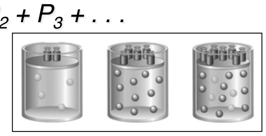
http://chemconnections.org/general/movies/bicycle-gases.MOV

Total Pressure:
Sum of the Partial Pressures

- For a mixture of gases, the total pressure is the sum of the pressures of each gas in the mixture.

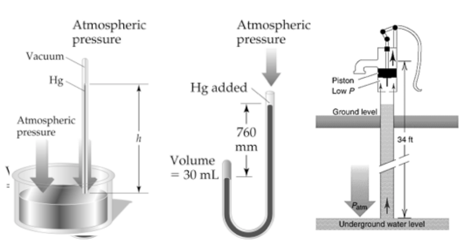
$$P_{Total} = P_1 + P_2 + P_3 + \ldots$$

$$P_{Total} \propto n_{Total}$$

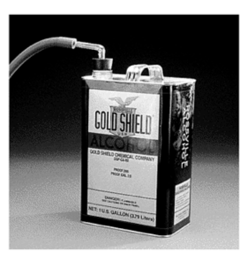


$$n_{Total} = n_1 + n_2 + n_3 + \ldots$$

Toricellian Barometer



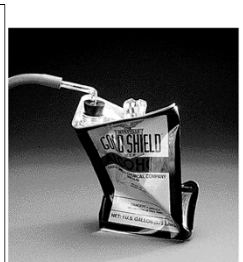
(a) (b)



An empty one gallon can is hooked to a vacuum pump.

What do you expect to happen?

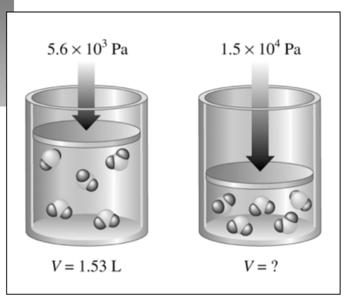
Explain why the can collapsed.



Boyle's Law*

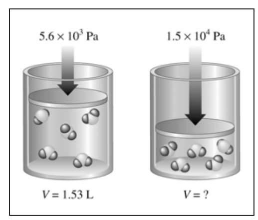
- *Pressure × Volume = Constant*
  (T = constant)
  - $P_1V_1 = P_2V_2$ *(T = constant)*
    - $V \propto 1/P$ *(T = constant)*
- *(*Holds precisely only at very low pressures.)*

QUESTION



A) 4.0 L
B) 0.57 L
C) 5.7 L
D) 0.4 L

ANSWER

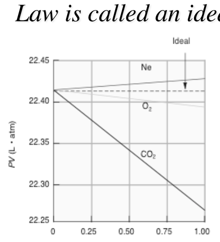


A) 4.0 L
B) 0.57 L
C) 5.7 L
D) 0.4 L

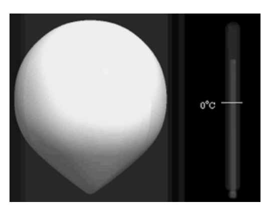
Ideal Gases

Real vs. "Ideal"

Definition: A gas that strictly obeys Boyle's Law is called an ideal gas.

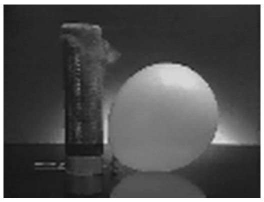


Temperature & Volume



http://chemconnections.org/general/movies/V-and-T.MOV http://chemconnections.org/general/movies/Vol-T-liqN2HMVID10.MOV

Temperature & Volume



$N_{2\,(liq)}$ b.p.= –196 °C (77 K; –321 °F)
A cryogenic fluid which can cause rapid freezing on contact with living tissue, which may lead to frostbite.

Charles's Law

- *The volume of a gas is directly proportional to temperature, and extrapolates to zero at zero Kelvin.*
  - *$V = \alpha T$ (P = constant)*

α = a proportionality constant

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \qquad (P = \text{constant})$$

Molecular Motion / Theory

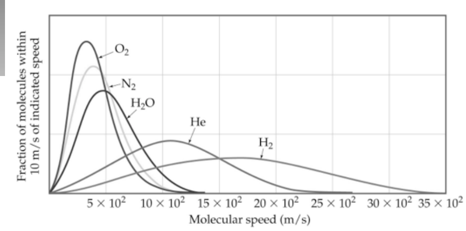
The Meaning of Temperature

Temperature (Kelvin) is an index of the random motions of gas particles (higher T means greater motion.)

$$(\mathrm{KE})_{\mathrm{avg}} = \frac{3}{2} RT$$

http://chemconnections.org/general/movies/KE%20-gas.MOV

Velocity & Temperature



QUESTION

As the temperature of a gas increases, which statement best correlates to information about molecular velocity?

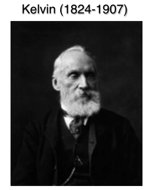
A) The average molecular velocity will increase, but the distribution of molecular velocities will stay the same.
B) The average molecular velocity will stay the same, but the molecular velocity distribution will spread.
C) The average molecular velocity will increase, and the distribution of the molecular velocities will spread.
D) The average molecular velocity will stay the same, and the distribution of the molecular velocities will stay the same.

ANSWER

C) accurately reflects the connection between molecular velocity and an increase in temperature. Kelvin temperature is directly related to molecular velocity - with greater temperature the distribution of available velocities also increases.

K.E. = ½ × mass × velocity^2 = 3/2 RT (T must be in K).

Boyle (1627-1691) ⟶ Kelvin (1824-1907)



Pressure, Volume & Temperature

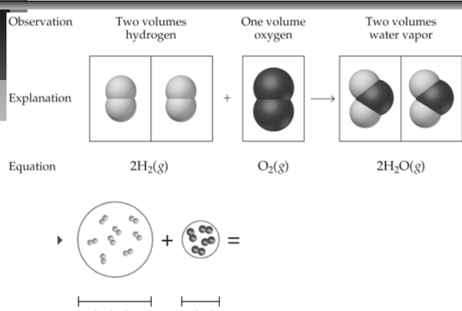
http://chemconnections.org/general/movies/Press-Vol-Temp-can.MOV

Avogadro's Law

- For a gas at constant temperature and pressure, the volume is directly proportional to the number of moles of gas (at low pressures).
- $V = \alpha n$
- α = proportionality constant
- V = volume of the gas
- n = number of moles of gas

http://chemconnections.org/general/movies/Gases-n-vs-V.mov

Volume vs. n (moles of a gas)



Isobaric process: pressure constant
Isochoric process: volume constant
Isothermal process: temperature constant

IDEAL GAS LAW
$PV=nRT$
or
$V=\frac{nRT}{P}$

Boyle's law (fixed n and T) $V=\frac{\text{constant}}{P}$

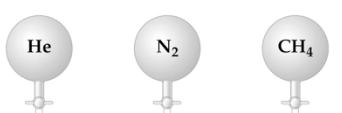
Avagadro's law (fixed P and T) V= constant x n

Charles's law (fixed n and P) V= constant x T

$P_1 V_1 = P_2 V_2$
$P\uparrow \quad V\downarrow$

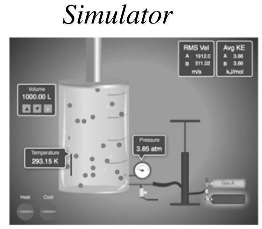
$V_1 / n_1 = V_2 / n_2$
$V\uparrow \quad n\uparrow$

$V_1 / T_1 = V_2 / T_2$
$V\uparrow \quad T\uparrow$



	He	N_2	CH_4
Volume	22.4 L	22.4 L	22.4 L
Pressure	1 atm	1 atm	1 atm
Temperature	0°C	0°C	0°C
Mass of gas	4.00 g	28.0 g	16.0 g
Number of gas molecules	6.02×10^{23}	6.02×10^{23}	6.02×10^{23}

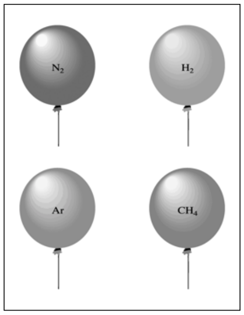
Ideal Gas Law Simulator



http://ch301.cm.utexas.edu/simulations/gas-laws/GasLawSimulator.swf

QUESTION

Each of the balloons hold 1.0 L of different gases. All four are at 25°C and each contains the same number of molecules. Of the following which would also have to be the same for each balloon? (obviously not their color)



A) Their density
B) Their mass
C) Their atomic numbers
D) Their pressure
E) Their number of moles

ANSWER

D)
or
E)
The temperature, pressure, number of moles, and volume are all related for a sample of trapped gas.

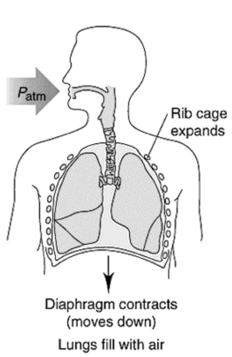
QUESTION

If a 10.0 L sample of a gas at 25°C suddenly had its volume doubled, without changing its temperature what would happen to its pressure? What could be done to keep the pressure constant without changing the temperature?

A) The pressure would double; nothing else could be done to prevent this.
B) The pressure would double; the moles of gas could be doubled.
C) The pressure would decrease by a factor of two; the moles of gas could be halved.
D) The pressure would decrease by a factor of two; the moles could be doubled.

ANSWER

D) describes two opposing changes. When the volume increases, the pressure of a trapped gas will decrease (at constant temperature and constant moles of gas). However, if the pressure drops, more collisions could be restored by adding more particles of gas in the same ratio as the pressure decline.



Do you have enough oxygen to climb Mt. Everest?
http://chemconnections.org/chemwiki/everest/everest.htm

QUESTION

Typical total volume for human lungs is approximately 5,800 mL. At a temperature of 37°C (average body temperature) and pressure of 0.98 atm, how many theoretical number of moles of air can we carry inside our lungs? (R = 0.08206 L atm/ K mol)

A) 1.9 mol
B) 0.22 mol
C) 230 mol
D) 2.20 mol
E) 0 mol: Moles can harm a person's lungs.

ANSWER

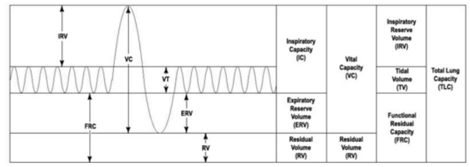
B)

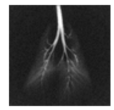
The units for temperature must be in K, pressure in atm, and volume in L. Then using the universal constant 0.08206 L atm/ K mol :

$n_{air} = PV / RT$

$n_{air} = 0.98 \text{ atm} \times 5.800 \text{ L} / (37 + 273) \text{ K} \times 0.08206 \text{ L} * \text{atm/ K mol}$

$n_{air} = 0.22 \text{ mol}$





An average pair of human lungs actually contains only about 3.5 L of air after inhalation and about 3.0 L after exhalation. Assuming that air in your lungs is at 37°C and 1.0 atm and there is 20.9% oxygen in air. (R = 0.08206 L atm/ K mol)

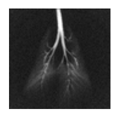
1) *How many moles of O_2* are actually *in a typical breath?*.
2) *What is the mass of O_2 in a typical breath?*.
3) *How much of the O_2 is essential biochemically?*

QUESTION

An average pair of human lungs actually contains only about 3.5 L of air after inhalation and about 3.0 L after exhalation. Assuming that air in your lungs is at 37°C and 1.0 atm and there is 20.9% oxygen in air. (R = 0.08206 L atm/ K mol)

How many moles of oxygen are actually *in a typical breath?*

A) 0.0020 mol
B) 0.020 mol
C) 0.030 mol
D) 0.025 mol
E) 0.0041 mol



An average pair of human lungs actually contains only about 3.5 L of air after inhalation and about 3.0 L after exhalation. Assuming that air in your lungs is at 37°C and 1.0 atm and there is 20.9% oxygen in air.

How many moles of O_2 are actually *in a typical breath?*.

$n_{O_2(g)} = (20.9\%) * PV / RT$

$n_{O_2(g)} = (0.209 \text{ mol } O_{2(g)} / \text{mol air}) \times 1.0 \text{ atm} \times (3.5 \text{ L} - 3.0 \text{ L}) / 0.08206 \text{ L} * \text{atm} \times 310 \text{ K})$

$n_{O_2(g)} = 0.0041 \text{ mol}$

ANSWER

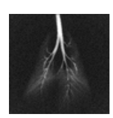
An average pair of human lungs actually contains only about 3.5 L of air after inhalation and about 3.0 L after exhalation. Assuming that air in your lungs is at 37°C and 1.0 atm. (R = 0.08206 L atm/ K mol)

How many moles of air are actually *in a typical breath?*

A) 0.0020 mol
B) 0.020 mol air
C) 0.030 mol
D) 0.025 mol
E) 0.0041 mol oxygen

$n_{air\,(g)} = PV / RT$

$n_{O_2(g)} = (20.9\%) * PV / RT$



QUESTION

An average pair of human lungs actually contains only about 3.5 L of air after inhalation and about 3.0 L after exhalation. Assuming that air in your lungs is at 37°C and 1.0 atm and there is 20.9% oxygen in air:

What is the mass of O_2 in a typical breath?

A) 0.0041 mol x 16 g/mol
B) 0.020 mol x 16 g/mol
C) 0.0041 mol x 32 g/mol
D) 0.020 mol x 32 g/mol

An average pair of human lungs actually contains only about 3.5 L of air after inhalation and about 3.0 L after exhalation. Assuming that air in your lungs is at 37°C and 1.0 atm and there is 20.9% oxygen in air.

What is the mass of O_2 in a typical breath?.

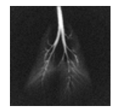
$n_{O_2(g)} = (20.9\%) * PV / RT$

$n_{O_2(g)}$ = (0.209 mol $O_{2(g)}$ / mol air) (1.0 atm x (3.5 L-3.0 L) x mol air * K / 0.0821 L * atm x 300 K)

$n_{O_2(g)}$ = 0.0041 mol

$g_{O_2(g)}$ = 0.0041 mol x 32.0 g/mol

$g_{O_2(g)}$ = 0.13 g



An average pair of human lungs actually contains only about 3.5 L of air after inhalation and about 3.0 L after exhalation. Assuming that air in your lungs is at 37°C and 1.0 atm

How much of the O_2 is essential biochemically?

Two estimates for a person with normal physical activity range from **0.67 - 0.84 kg of O_2 being used per day** (NASA provided the higher value). How many breaths do you take in one day? ~ 5 mol % of the O_2 is actually used per breath.

Hard exercise increases this oxygen demand (intake) about 10 fold.

QUESTION

The primary source of exhaled CO_2 is from the combustion of glucose, $C_6H_{12}O_6$ (molar mass = 180. g/mol.). The balanced equation is shown here:

$$C_6H_{12}O_6\,(aq) + 6\,O_2\,(g) \rightarrow 6\,CO_2\,(g) + 6\,H_2O\,(l)$$

If you oxidized 5.42 grams of $C_6H_{12}O_6$ while tying your boots to climb Mt. Everest, how many liters of O_2 @ STP conditions did you use? (R = 0.08206 L atm/ K mol)

A) 0.737 L
B) 0.672 L
C) 4.05 L
D) 22.4 L

ANSWER

C) 4.05 L

$C_6H_{12}O_6\,(aq) + \mathbf{6}\,O_2\,(g) \rightarrow 6\,CO_2\,(g) + 6\,H_2O\,(l)$

The number of moles of glucose must first be determined (5.42 g /180. g/mol = 0.0301 moles), then this is multiplied by 6 to account for the stoichiometric ratio between glucose and oxygen.

From this, $V = nRT/P$ is used with the appropriate substitutions. (R = 0.08206 L atm/ K mol)

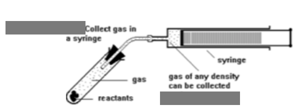
= **6 x** 0.0301 mol **O_2(g)** x 0.08206 L * atm mol^{-1} x 273 K/ 1 atm)

Molar Mass of a Gas

- *PV = n RT*
- *n = g of gas/ MM_{gas} [MM_{gas} = g/mol]*
- *PV = (g of gas/ MM_{gas})RT*
- *MM_{gas} = g of gas/V (RT/P)*

Density of gas = g of gas/V [experimental]

- *MM_{gas} = density of gas (RT/P)*

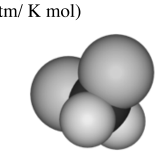


QUESTION

Freon-12, CF_2Cl_2, a "safe" compressible gas, was widely used from 1935-1994 as a refrigerant in refrigerators, freezers, and air conditioning systems. However, it had been shown to be a greenhouse gas and to catalytically destroy the ozone layer. It was phased out and banned.

200 ml of Freon-12 was collected by syringe. It weighed 0.927 grams, had a temperature of 30.0°C, and a pressure of 698.2 mm of Hg. What is the experimental molar mass of Freon-12? (R = 0.08206 L atm/ K mol)

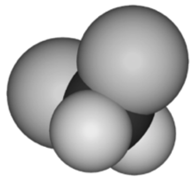
A. 12.1 g/mol
B. 84 g/mol
C. 92.7 g/mol
D. 115 g/mol
E. 121 g/mol



ANSWER

E)

MM $_{gas}$ = density of gas (RT/P)
MM $_{gas}$ = 0.927 g/ 0.200 L x 0.08206 L atm K^{-1} mol^{-1} x 303 K / 698.2 mm Hg / 760 mm Hg/ 1atm



QUESTION

The density of an unknown atmospheric gas pollutant was experimentally determined to be 1.964 g/ L @ 0 °C and 760 torr.

- *What is the molar mass of the gas?*
- *What might the gas be?*

A) CO B) SO_2 C) H_2O D) CO_2

ANSWER

1.964 g/ L @ 0 °C and 760 torr.
R = 0.08206 L atm K^{-1} mol^{-1}
°C → K
torr → atm

MM $_{gas}$ = density of gas (RT/P)
MM $_{gas}$ = 1.964 g/ L x 0.08206 L atm K^{-1} mol^{-1} x 273K/ 760 torr x 760 torr/ 1atm

MM $_{gas}$ = 44.0 g/mol

D) CO_2

QUESTION

0.0820 grams of the volatile, gaseous phase, of a compound, which smells like fresh raspberries, was trapped in a syringe. It had a volume of 12.2 mL at 1.00 atmosphere of pressure and 25.0°C. What is the molar mass of this pleasant smelling compound ?

A) 13.8 g/mol
B) 164 g/mol
C) 40.9 g/mol
D) 224 g/mol

ANSWER

B) 164 g/mol

Using $PV = nRT$:

0.0122 L for *V*, 298 K for *T*, 0.08206 for *R* and solving for *n* the number of moles represented by 0.0820 grams can be obtained.

Then the MOLAR MASS (grams in one mole) can be determined.

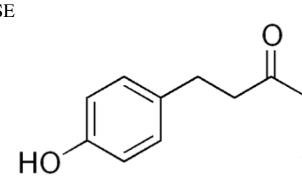
MM $_{gas}$ = density of gas (RT/P)

MM $_{gas}$ = 0.0820 g/ L x 0.00122 L x 0.0821 atm K^{-1} mol^{-1} x 298K/ 1atm

QUESTION

For the compound that smells like fresh raspberries, the following structure, $C_{10}H_{12}O_2$, matches its calculated molar mass.

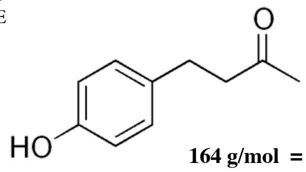
A) TRUE
B) FALSE



ANSWER

Based on your answers for the compound, which smells like fresh raspberries, in the previous two questions, the following structure matches its molecular formula.

A) TRUE
B) FALSE



164 g/mol = $C_{10}H_{12}O_2$

QUESTION

Which sequence represents the gases in order of increasing density at STP?

A) Fluorine < Carbon monoxide < Chlorine < Argon
B) Carbon monoxide < Fluorine < Argon < Chlorine
C) Argon < Carbon monoxide < Chlorine < Fluorine
D) Fluorine < Chlorine < Carbon monoxide < Argon

ANSWER

Which sequence represents the gases in order of increasing density at STP?

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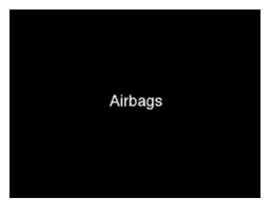
B) Carbon monoxide < Fluorine < Argon < Chlorine
C) Argon < Carbon monoxide < Chlorine < Fluorine
D) Fluorine < Chlorine < Carbon monoxide < Argon

Gases & Airbags

Use of Chemical Reactions and Physical Properties



http://chemconnections.org/public_html/general/movies/airbags.MOV