Chem With Com

Gases

- Chapter 8.1 (Gas Pressure)
- Chapter 8.2 (Relating Pressure, Volume, Amount (Moles), and Temperature: The Ideal Gas Law

Adapted From: Paul Flowers, Edward J. Neth, William R. Robinson, PhD, Klaus Theopold, Richard Langley; Chemistry: Atoms First 2e; OpenStax; Feb 14, 2019; Houston Texas; https://openstax.org/books/chemistry-atoms-first-2e/pages/1-introduction

Gas Pressure

- Chapter 8.1 (Gas Pressure)

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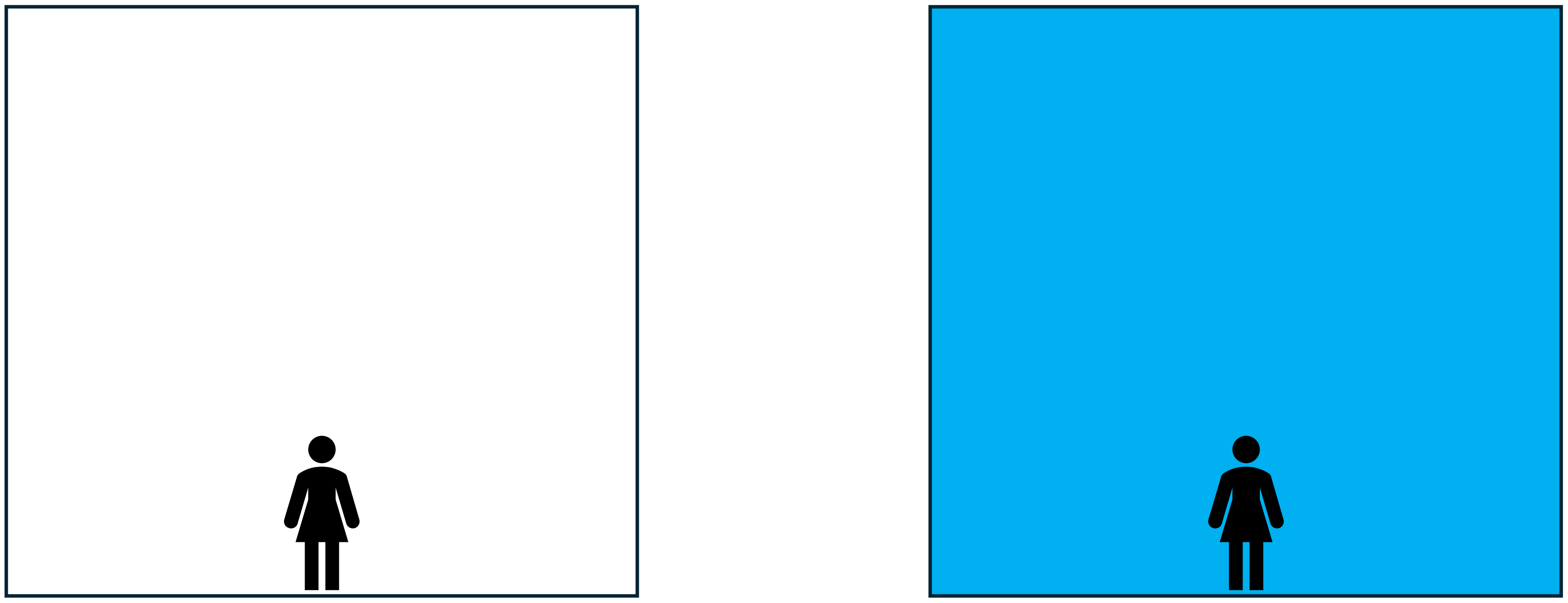
Can you feel water pressure now? What about in water?



What is pressure?

pressure

force exerted per unit area

$$P = \frac{F}{A}$$

F = Force

A = Area

Mass contributes to pressure.

$$\text{pressure per elephant foot} = 14{,}000\,\frac{\text{lb}}{\text{elephant}} \times \frac{1\text{ elephant}}{4\text{ feet}} \times \frac{1\text{ foot}}{250\text{ in}^2} = 14\,\text{lb/in}^2$$

$$\text{pressure per human foot} = 120\,\frac{\text{lb}}{\text{skater}} \times \frac{1\text{ skater}}{2\text{ feet}} \times \frac{1\text{ foot}}{30\text{ in}^2} = 2\,\text{lb/in}^2$$

$$\text{pressure per skate blade} = 120\,\frac{\text{lb}}{\text{skater}} \times \frac{1\text{ skater}}{2\text{ blades}} \times \frac{1\text{ blade}}{2\text{ in}^2} = 30\,\text{lb/in}^2$$

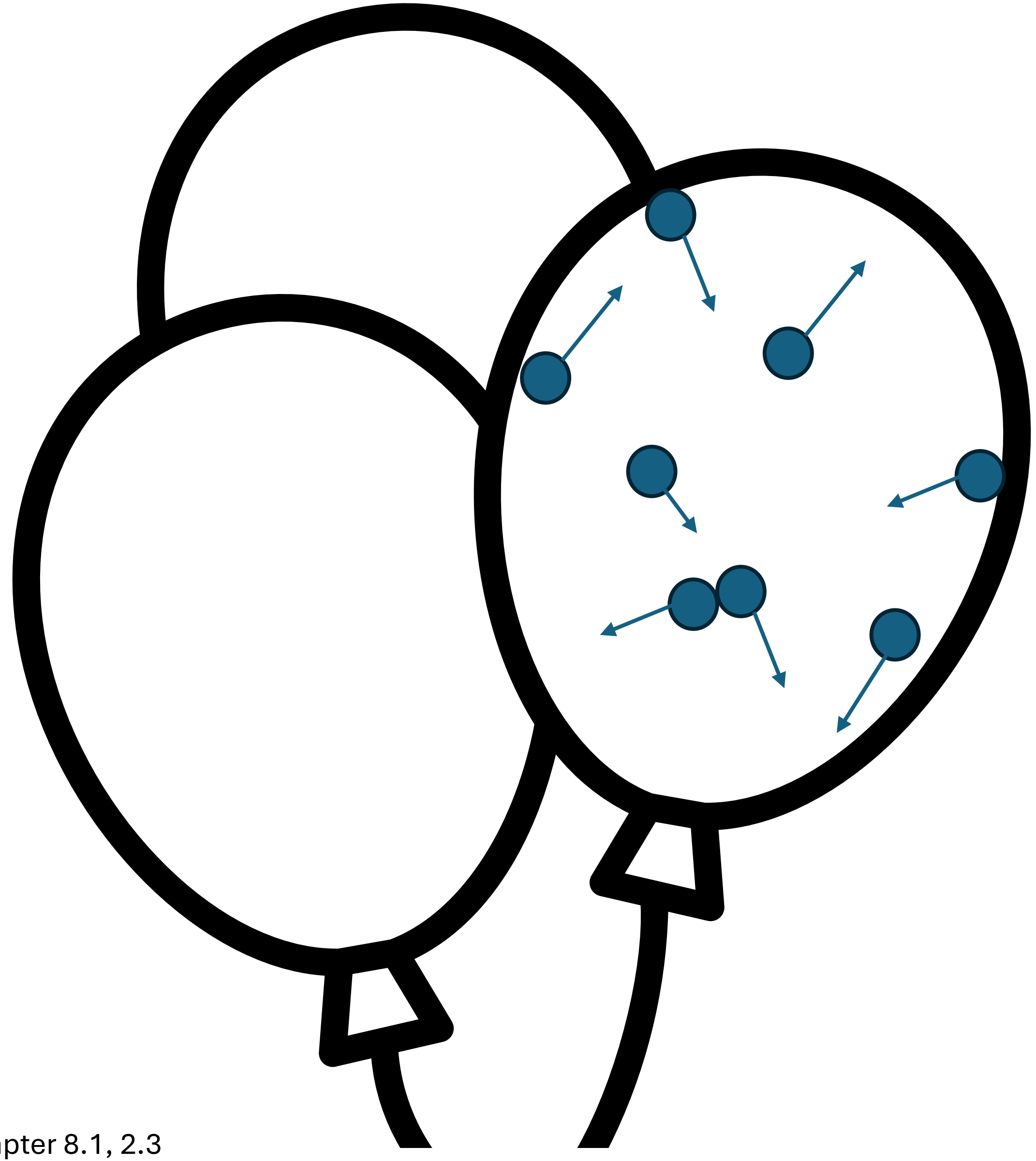
$$F = \mathbf{ma}$$

F = Force

m = mass

a = acceleration

Moving atoms have mass and can exert pressure.

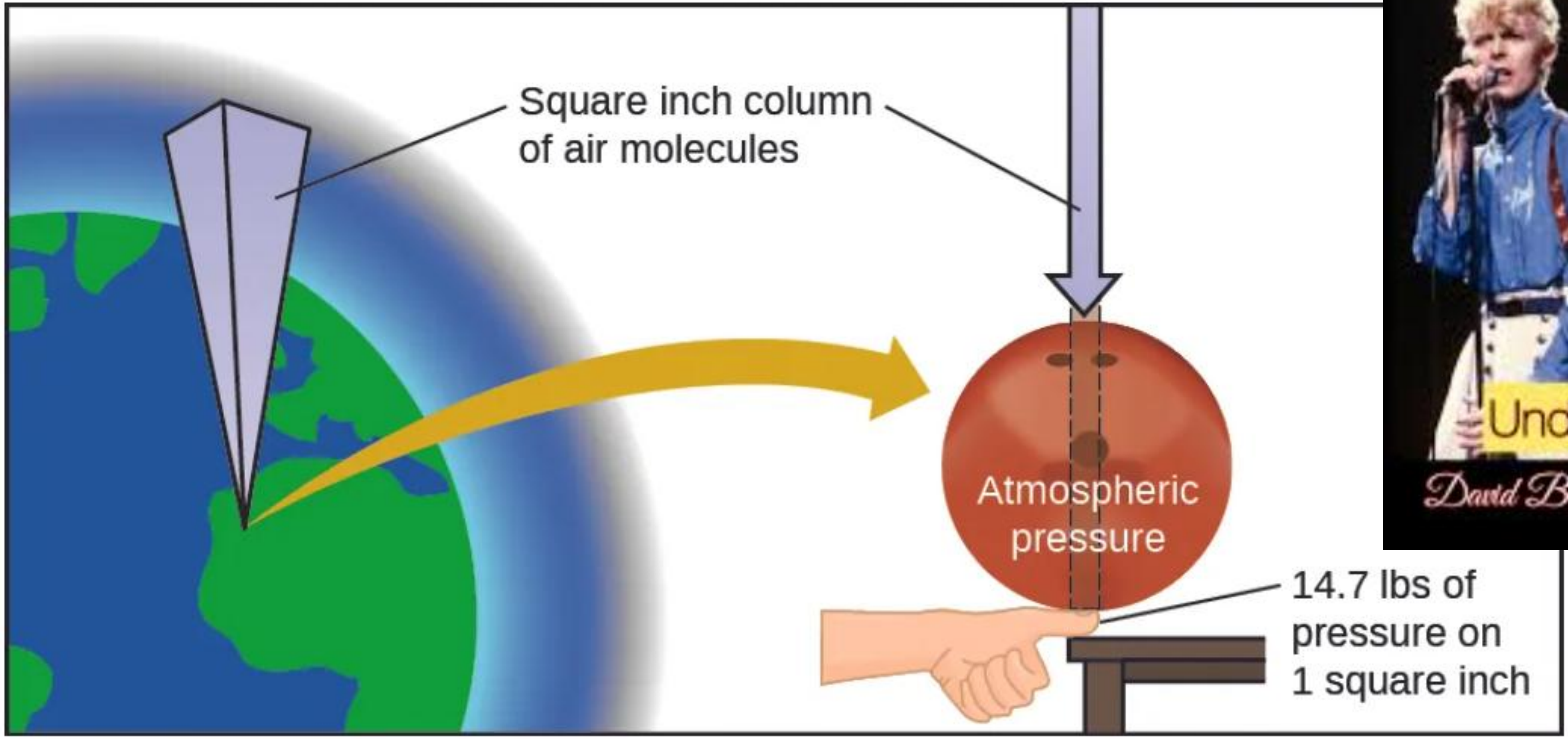


Properties of Subatomic Particles

Name	Location	Charge (C)	Unit Charge	Mass (amu)	Mass (g)
electron	outside nucleus	-1.602×10^{-19}	1−	0.00055	0.00091×10^{-24}
proton	nucleus	1.602×10^{-19}	1+	1.00727	1.67262×10^{-24}
neutron	nucleus	0	0	1.00866	1.67493×10^{-24}

Table 2.2

We’re all under pressure!



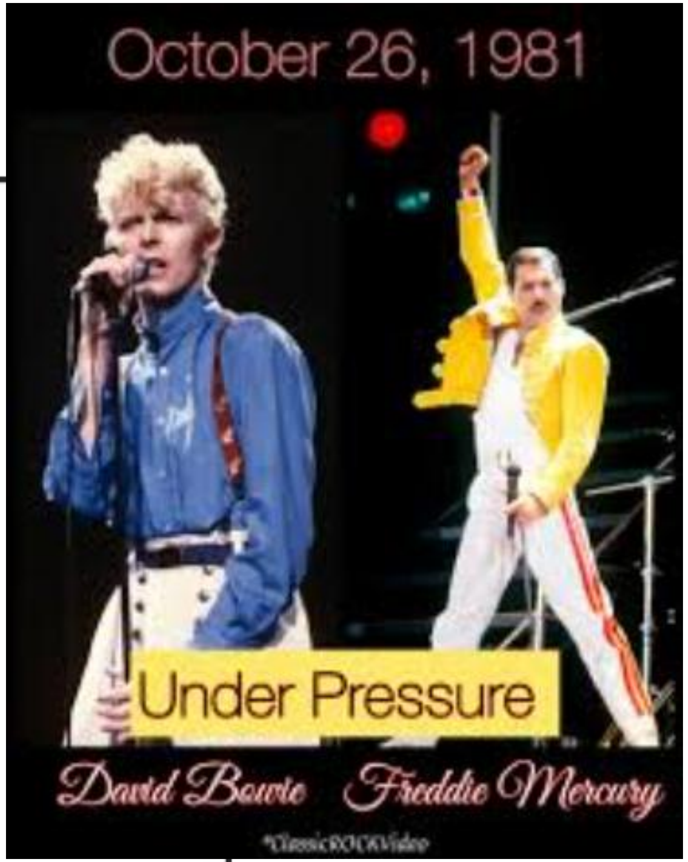


Figure 8.2 The atmosphere above us exerts a large pressure on objects at the surface of the earth, roughly equal to the weight of a bowling ball pressing on an area the size of a human thumbnail.

Pressure has many different units.

Pressure Units

Unit Name and Abbreviation	Definition or Relation to Other Unit
pascal (Pa)	1 Pa = 1 N/m^2 recommended IUPAC unit
kilopascal (kPa)	1 kPa = 1000 Pa
pounds per square inch (psi)	air pressure at sea level is ~14.7 psi
atmosphere (atm)	1 atm = 101,325 Pa = 760 torr air pressure at sea level is ~1 atm
bar (bar, or b)	1 bar = 100,000 Pa (exactly) commonly used in meteorology
millibar (mbar, or mb)	1000 mbar = 1 bar
inches of mercury (in. Hg)	1 in. Hg = 3386 Pa used by aviation industry, also some weather reports
torr	$1 \text{ torr} = \frac{1}{760} \text{ atm}$ named after Evangelista Torricelli, inventor of the barometer
millimeters of mercury (mm Hg)	1 mm Hg ~1 torr

Remember conversions! (Topic 6: Dimensional Analysis)

How to Convert Anything in the World in 3 Steps:

Problem: convert 327 g to kg

Step 1: Find the conversion rates.

Almost any two values with units with an equals sign between them can be a conversion rate or conversion factor (same thing, different name). You can find conversion rates in this tutorial, in your book, on the internet, on food menus, etc. Directly below is a generic version of a conversion rate

$value1unit1 = value2unit2$

1000 g = 1 kg

Step 2: Write the conversion rate as a fractions

Any of the conversion rates above can be written in different forms which include fractions.

$$\frac{1kg}{1000g} \qquad \frac{1000g}{1kg}$$

Step 3: Multiply what you are trying to convert by the fraction.

Use the conversion rate above to multiply by the value you are trying to convert. Use the fraction that has the same unit as the original value on the bottom of the fraction. Cancel out anything that is the same on top of the fraction line and the bottom of the fraction line.

Original Value (what you are trying to convert)	Conversion Rate	Problem	Work (see the units cancelling out)	Answer (any units that don't cancel carry over to the answer)
327 grams	$\frac{1kg}{1000g}$	$327\cancel{g} \times \frac{1kg}{1000\cancel{g}}$	$327 \times \frac{1kg}{1000}$	0.327 kg

Check Your Learning

A typical barometric pressure in Kansas City is 740 torr. What is this pressure in atmospheres, in millimeters of mercury, in kilopascals, and in bar?

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Unit Name and Abbreviation	Definition or Relation to Other Unit
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torr	$1\ \text{torr} = \frac{1}{760}\ \text{atm}$ named after Evangelista Torricelli, inventor of the barometer
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Gas Laws

- Chapter 8.2 (Relating Pressure, Volume, Amount (Moles), and Temperature: The Ideal Gas Law

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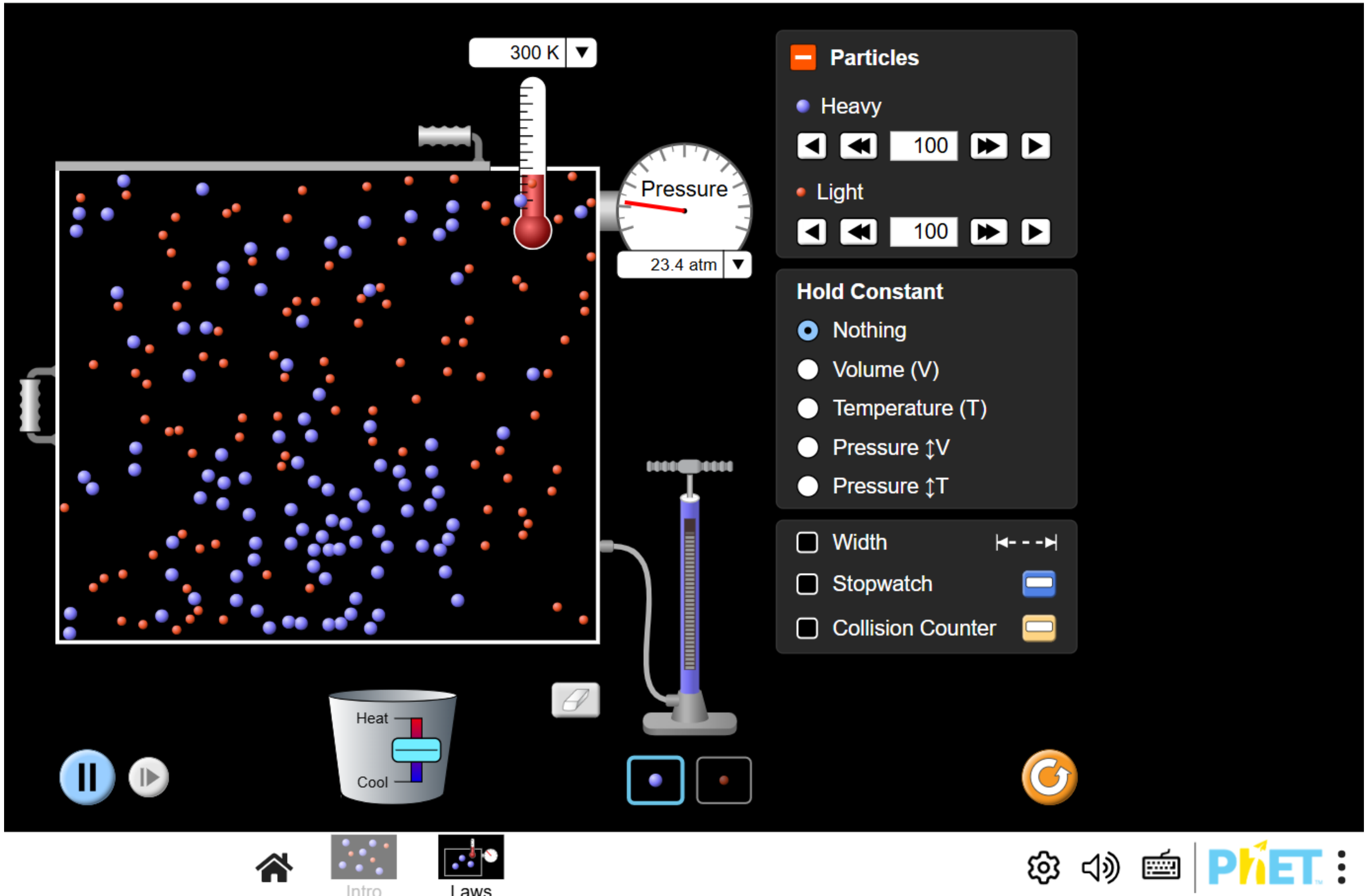
Gas Simulation

https://phet.colorado.edu/sims/html/gases-intro/latest/gases-intro_all.html

Or web search: PHET gases



Pressure and Temperature: Amontons's Law

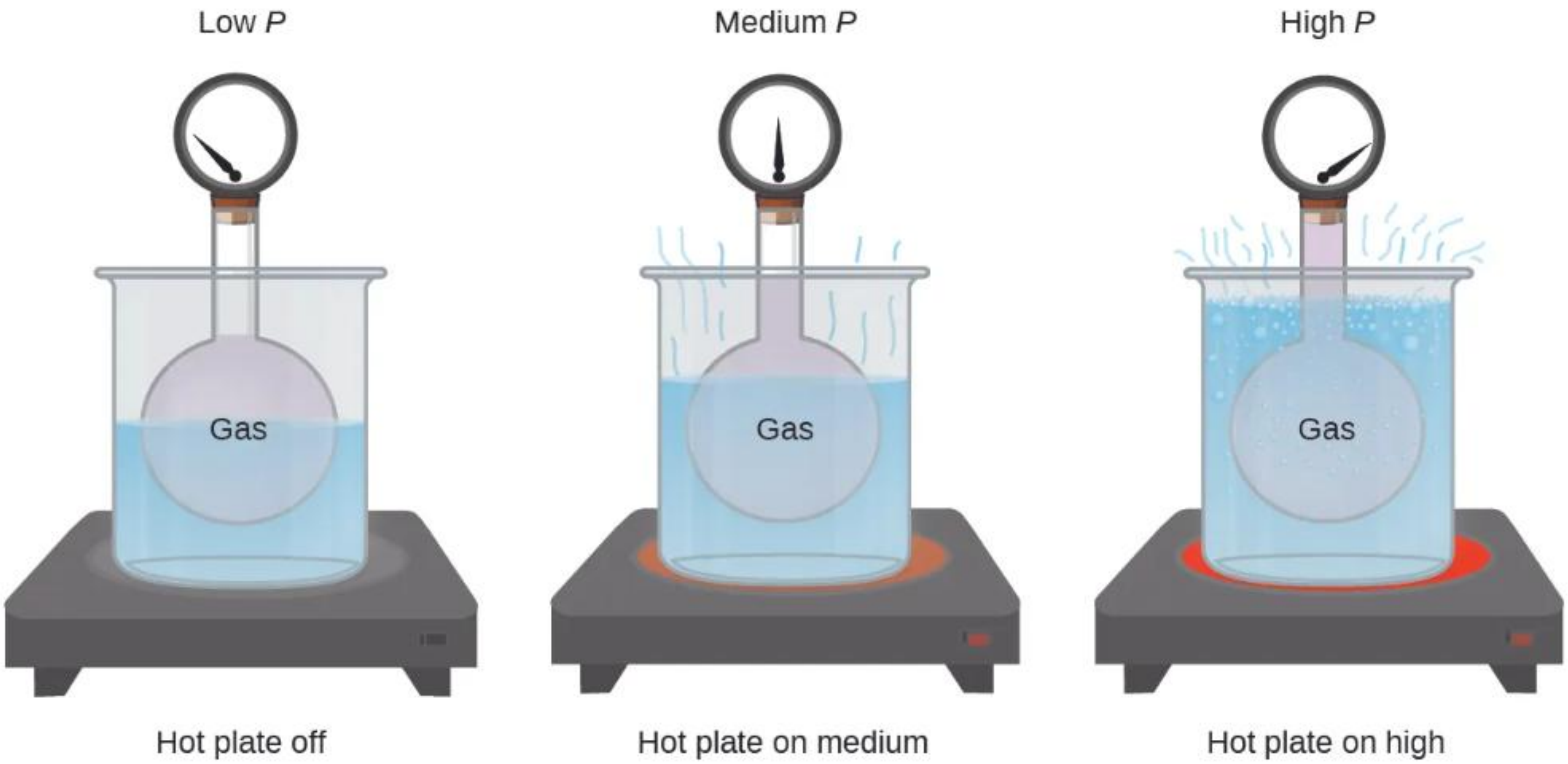


Figure 8.10 The effect of temperature on gas pressure: When the hot plate is off, the pressure of the gas in the sphere is relatively low. As the gas is heated, the pressure of the gas in the sphere increases.

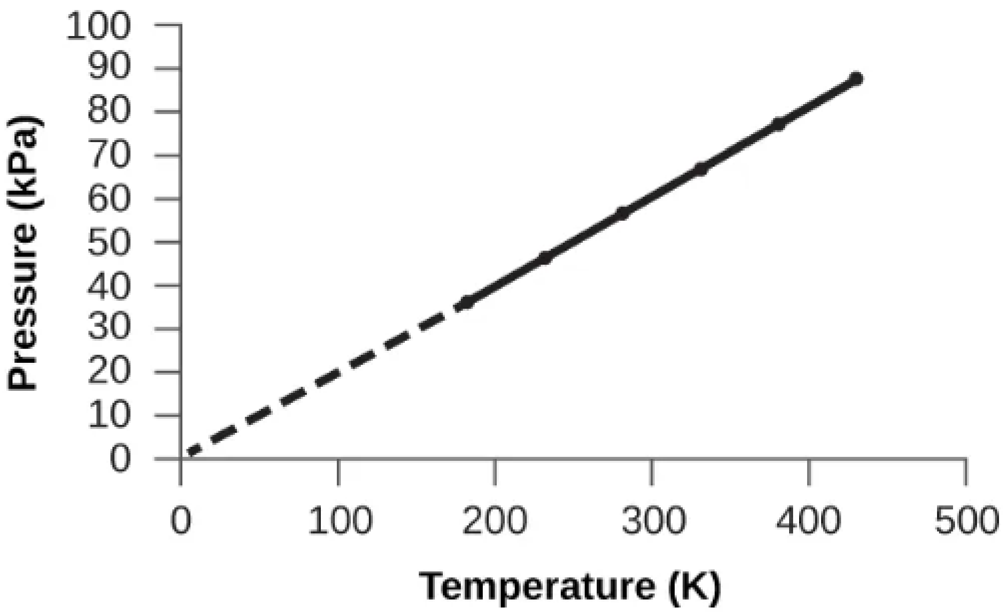
Pressure is proportional to temperature

$$P \propto T$$

$\uparrow P \quad T \uparrow$

$\downarrow P \quad T \downarrow$

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



All temperatures for gas problems should be converted to K → K = °C + 273.15

Check Your Learning

A sample of nitrogen, N_2, occupies 45.0 mL at 27 °C and 600 torr. What pressure will it have if cooled to –73 °C while the volume remains constant?

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

All temperatures for gas problems should be converted to K → K = °C + 273.15

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

All temperatures for gas problems should be converted to K → K = °C + 273.15

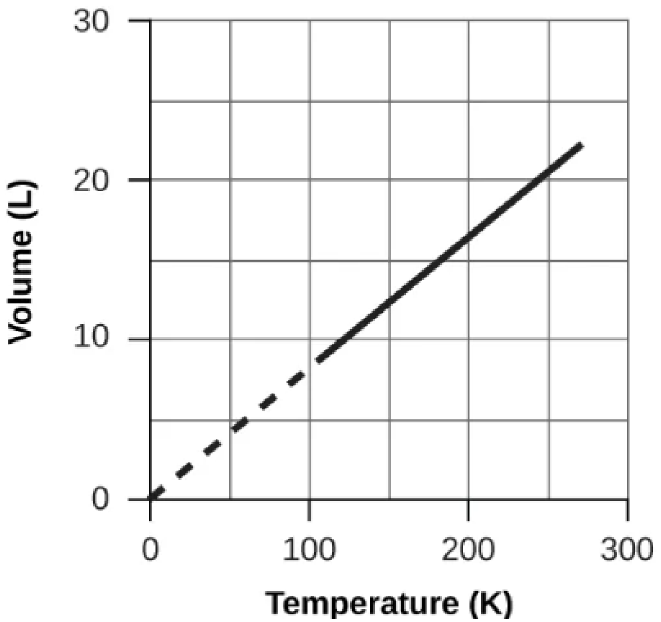
Volume is proportional to temperature: Charles's Law

$$V \propto T$$

⇧ V T ⇧

⇩ V T ⇩

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



All temperatures for gas problems should be converted to K → K = ^{o}C + 273.15

Check Your Learning

A sample of oxygen, O_2, occupies 32.2 mL at 30 °C and 452 torr. What volume will it occupy at –70 °C and the same pressure?

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

All temperatures for gas problems should be converted to K → K = ^{o}C + 273.15

Check Your Learning

What is the volume of a sample of ethane at 467 K and 1.1 atm if it occupies 405 mL at 298 K and 1.1 atm?

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

All temperatures for gas problems should be converted to K → K = ^{o}C + 273.15

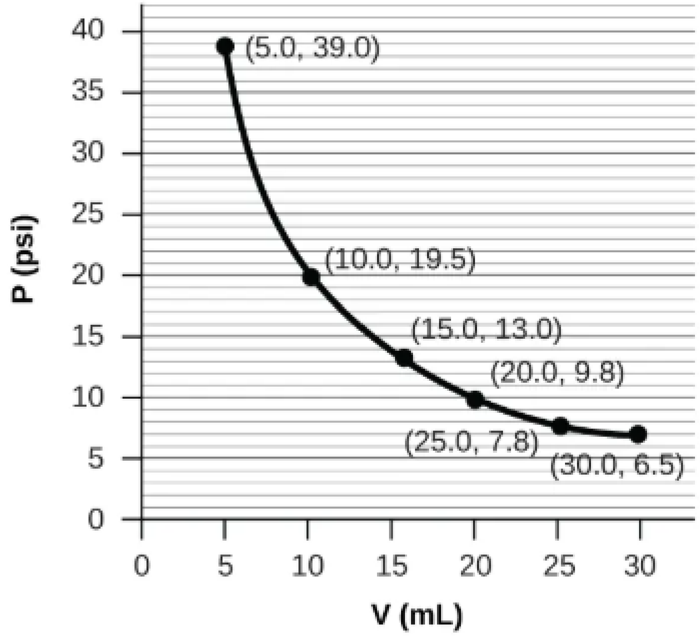
Volume is inversely proportional to pressure: Boyle's Law

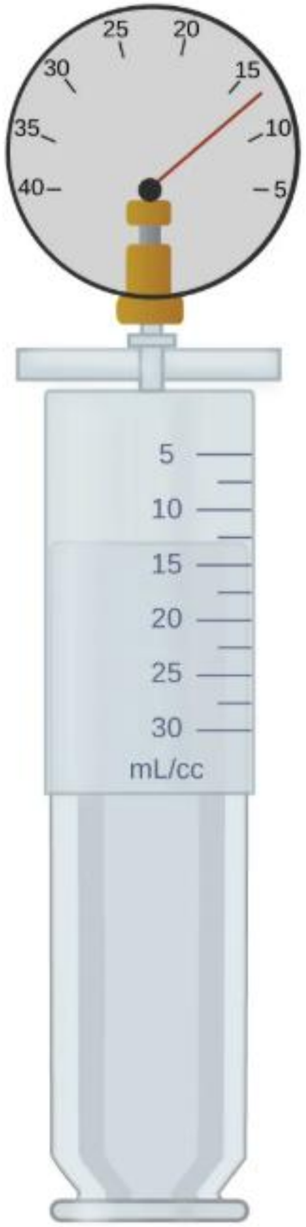
$$P \propto \frac{1}{V}$$

$$P_1V_1 = P_2V_2$$

↑P V↓

↓P V↑





Check Your Learning

The sample of gas in Figure 8.13 has a volume of 30.0 mL at a pressure of 6.5 psi. Determine the volume of the gas at a pressure of 11.0 psi, using:

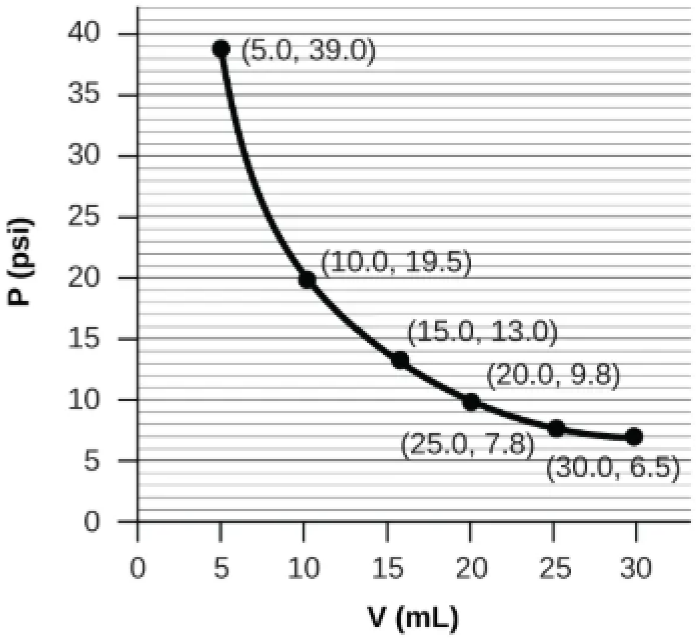
(a) the *P-V* graph in Figure 8.13

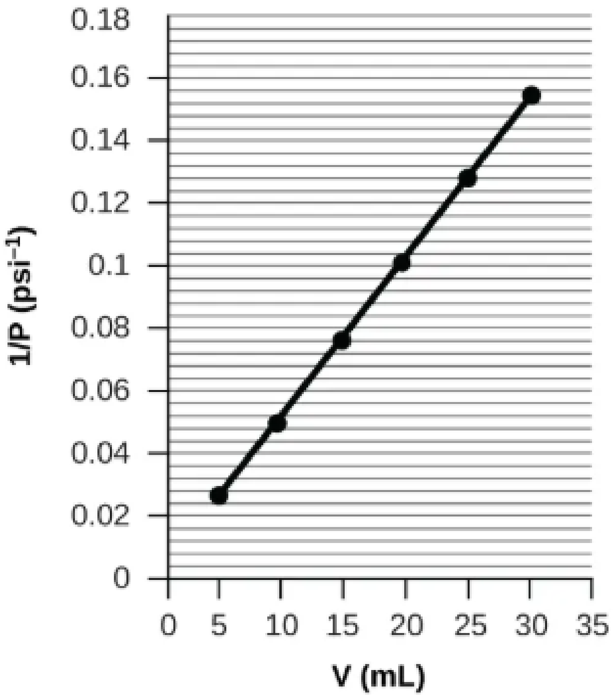
(b) the $\frac{1}{P}$ vs. *V* graph in Figure 8.13

(c) the Boyle's law equation

Comment on the likely accuracy of each method.

$$P_1V_1 = P_2V_2$$





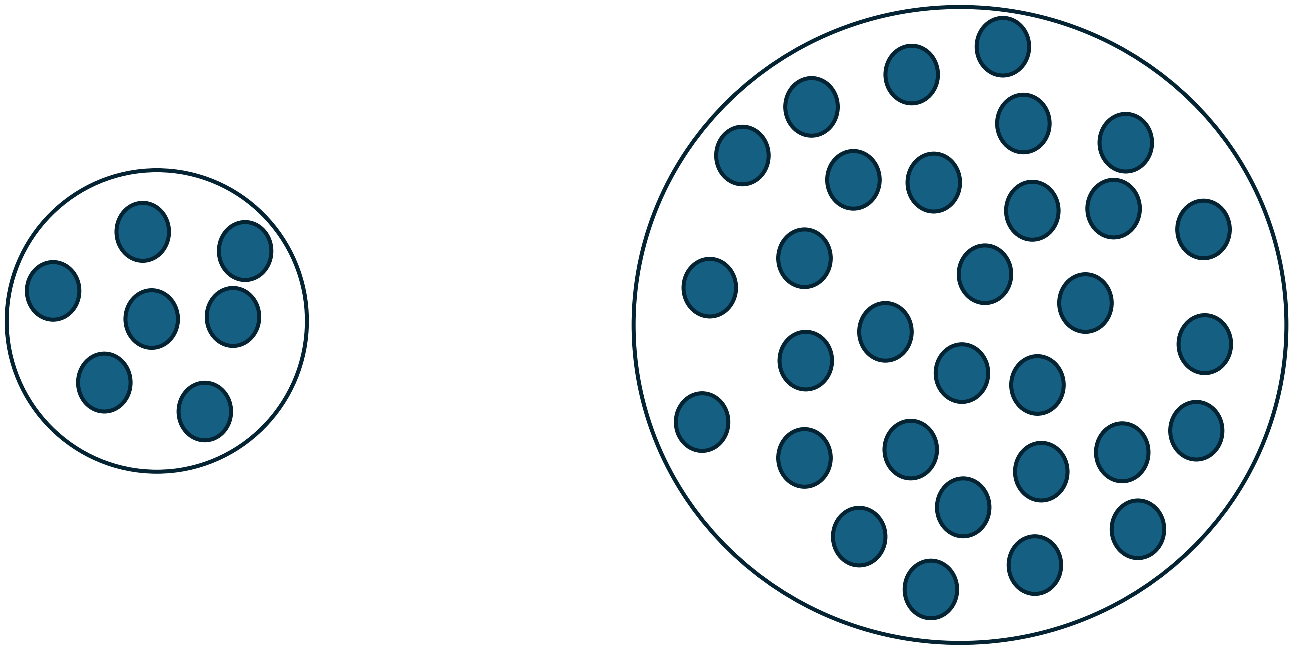
Moles of gas is proportional to volume: Avogadro's Law

$$V \propto n$$

$$\uparrow V \quad n \uparrow$$

$$\downarrow V \quad n \downarrow$$

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



? Exercise 11.7.1

A 12.8 L volume of gas contains .000498 moles of oxygen gas. At constant temperature and pressure, what volume does .0000136 moles of the gas fill?

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

Combined and Ideal Gas Law

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The combined gas law does it all!

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

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

$$P_1V_1 = P_2V_2$$

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

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$$

Check Your Learning

A sample of ammonia is found to occupy 0.250 L under laboratory conditions of 27 °C and 0.850 atm. Find the volume of this sample at 0 °C and 1.00 atm.

$$\frac{P_1 V_1}{n_1 T_1} = \frac{P_2 V_2}{n_2 T_2}$$

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$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$$

The ideal gas law relates pressure, volume, moles, and temp

$$P \propto T$$

$$V \propto n$$

$$V \propto T$$

$$PV \propto nT$$

$$PV = nRT$$

Gas Constant (R)

$$R = 0.08206\,\frac{L \cdot atm}{mol \cdot K}$$

Using the Ideal Gas Law

Methane, CH_4, is being considered for use as an alternative automotive fuel to replace gasoline. One gallon of gasoline could be replaced by 655 g of CH_4. What is the volume of this much methane at 25 °C and 745 torr?

6 C 12.01 carbon	1 H 1.008 hydrogen

760 torr = 1 atm

K = °C + 273.15

PV=nRT

$R = 0.08206 \frac{L \cdot atm}{mol \cdot K}$

Calculate the pressure in bar of 2520 moles of hydrogen gas stored at 27 °C in the 180-L storage tank of a modern hydrogen-powered car.

1
H
1.008
hydrogen

1 atm = 101,325 Pa = 760 torr

K = °C + 273.15

PV=nRT

$$R = 0.08206 \frac{L \cdot atm}{mol \cdot K}$$

1 bar = 100,000 Pa

Important Gas Equations and Conversions

$$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$$

$$PV = nRT$$

$$R = 0.08206\ \frac{L \cdot atm}{mol \cdot K}$$

$$K = {}^{o}C + 273.15$$

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