Chapter 11

Properties of Gases

Section 11.2 Gases and Pressure Changes

Solutions for Practice Problems

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Note: Assume that the temperature and amount of gas are constant in all of the following problems.

1. Practice Problem (page 514)

1.00 L of a gas at 1.00 atm pressure is compressed to 0.437 L. What is the new pressure of the gas?

What Is Required?

You need to calculate the final pressure, P_2, on a sample of gas.

What Is Given?

You know the pressure and volume of the gas for the initial set of conditions and the volume for the final set of conditions:

$P_1 = 1.00$ atm

$V_1 = 1.00$ L

$V_2 = 0.437$ L

Plan Your Strategy

The pressure and volume are changing at constant temperature. Use the equation for Boyle's law: $P_1V_1 = P_2V_2$

Divide each side of the equation by V_2 to isolate the variable P_2.

Substitute the numbers and units for the known variables in the formula and solve for P_2.

Act on Your Strategy

Isolation of the variable P_2:

$$P_1V_1 = P_2V_2$$

$$\frac{P_1V_1}{V_2} = \frac{P_2\cancel{V_2}}{\cancel{V_2}}$$

$$P_2 = \frac{P_1V_1}{V_2}$$

Substitution to solve for P_2:

$$P_2 = \frac{P_1 V_1}{V_2}$$

$$= \frac{(1.00 \text{ atm})(1.00 \cancel{\text{L}})}{0.437 \cancel{\text{L}}}$$

$$= 2.2883 \text{ atm}$$

$$= 2.29 \text{ atm}$$

The final pressure on the sample of gas is 2.29 atm.

Alternative Solution

Plan Your Strategy

According to Boyle's law, at constant temperature, a decrease in volume will cause an increase in pressure. Therefore, the final pressure must be greater than the initial pressure.

Determine the ratio of the initial volume and the final volume that is greater than 1.

Multiply the initial pressure by the volume ratio determined to obtain the final pressure.

Act on Your Strategy

Volume ratio:

$V_1 = 1.00$ L

$V_2 = 0.437$ L

volume ratio > 1 is $\frac{1.00 \text{ L}}{0.437 \text{ L}}$

Substitution to solve for P_2:

$$P_2 = P_1 \times \text{volume ratio}$$

$$= 1.00 \text{ atm} \times \frac{1.00 \cancel{\text{L}}}{0.437 \cancel{\text{L}}}$$

$$= 2.22883 \text{ atm}$$

$$= 2.29 \text{ atm}$$

The final pressure on the sample of gas is 2.29 atm.

Check Your Solution

The initial volume is greater than the final volume and the initial pressure is less than the final pressure. This inverse relationship between volume and pressure is consistent with Boyle's law. The units are correct and the answer shows three significant digits.

Alternative Solution

Plan Your Strategy
According to Boyle's law, at constant temperature, a decrease in volume will cause an increase in pressure. Therefore, the final pressure must be greater than the initial pressure.
Determine a ratio of initial volume and final volume that is greater than 1.
Multiply the initial pressure by the volume ratio to obtain the final pressure.

Act on Your Strategy
Volume ratio:
$V_1 = 60$ mL
$V_2 = 15$ mL

volume ratio > 1 is $\frac{60 \text{ mL}}{15 \text{ mL}}$

Substitution to solve for P_2:

$$P_2 = P_1 \times \text{volume ratio}$$

$$= 99.5 \text{ kPa} \times \frac{60 \cancel{\text{mL}}}{15 \cancel{\text{mL}}}$$

$$= 3.98 \times 10^2 \text{ kPa}$$

The final pressure on the sample of gas is 3.98×10^2 kPa.

Check Your Solution
The initial volume is greater than the final volume and the initial pressure is less than the final pressure. This inverse relationship between volume and pressure is consistent with Boyle's law. The units are correct and the answer correctly shows three significant digits.

3. Practice Problem (page 514)

Atmospheric pressure on the peak of Mount Everest can be as low as 0.20 atm. If the volume of an oxygen tank is 10.0 L, at what pressure must the tank be filled so that the gas inside would occupy a volume of 1.2×10^3 L at this pressure?

What Is Required?
You need to find the initial pressure inside an oxygen tank.

What Is Given?
You know volume of the oxygen tank for the initial set of conditions and the volume and pressure for the final set of conditions:
$V_1 = 10.0$ L
$V_2 = 1.2 \times 10^3$ L
$P_2 = 0.20$ atm

Plan Your Strategy
The pressure and volume are changing at constant temperature. Use the equation for Boyle's law: $P_1V_1 = P_2V_2$
Divide each side of the equation by V_1 to isolate the variable P_1.
Substitute the numbers and units for the known variables in the formula and solve for P_1.

Act on Your Strategy
Isolation of the variable P_1:

$$P_1V_1 = P_2V_2$$

$$\frac{P_1\cancel{V_1}}{\cancel{V_1}} = \frac{P_2V_2}{V_1}$$

$$P_1 = \frac{P_2V_2}{V_1}$$

Substitution to solve for P_1:

$$P_1 = \frac{P_2V_2}{V_1}$$

$$= \frac{(0.20 \text{ atm})\ (1.2 \times 10^3\ \cancel{\text{L}})}{10.0\ \cancel{\text{L}}}$$

$$= 24 \text{ atm}$$

The tank must be filled at a pressure of 24 atm.

Alternative Solution

Plan Your Strategy
According to Boyle's law, at constant temperature, an increase in volume will cause a decrease in pressure. Therefore, the initial pressure must be greater than the final pressure.
Determine the ratio of the initial volume and the final volume that is greater than 1.
Multiply the final pressure by the volume ratio determined to obtain the initial pressure.

Act on Your Strategy
Volume ratio:
$V_1 = 10.0$ L
$V_2 = 1.2 \times 10^3$ L

volume ratio > 1 is $\frac{1.2 \times 10^3 \text{ L}}{10.0 \text{ L}}$

Substitution to solve for P_1:
$P_1 = P_2 \times$ volume ratio

$$= 0.2 \text{ atm} \times \frac{1.2 \times 10^3 \text{ L}}{10.0 \text{ L}}$$

$$= 24 \text{ atm}$$

The tank must be filled at a pressure of 24 atm.

Check Your Solution
The initial volume is less than the final volume and the initial pressure is greater than the final pressure. This inverse relationship between volume and pressure is consistent with Boyle's law. The units are correct and the answer shows two significant digits.

4. Practice Problem (page 514)
If a person has 2.0×10^2 mL of trapped intestinal gas at an atmospheric pressure of 0.98 atm, what would the volume of gas be (in litres) at a higher altitude that has an atmospheric pressure of 0.72 atm?

What Is Required?
You need to calculate the final volume (in litres) of a sample of gas after the pressure decreases.

What Is Given?
You know the volume and pressure of the sample of gas for the initial conditions and the pressure of the gas for the final set of conditions:
$P_1 = 0.98$ atm
$V_1 = 2.0 \times 10^2$ mL
$P_2 = 0.72$ atm

Plan Your Strategy
The pressure and volume are changing at constant temperature. Use the equation for Boyle's law: $P_1V_1 = P_2V_2$
Divide each side of the equation by P_2 to isolate the variable V_2.

Act on Your Strategy
Pressure ratio:
$P_1 = 0.98$ atm
$P_2 = 0.72$ atm

pressure ratio > 1 is $\frac{0.98 \text{ atm}}{0.72 \text{ atm}}$

Substitution to solve for V_2:
$V_2 = V_1 \times$ pressure ratio

$$= 2.0 \times 10^2 \text{ mL} \times \frac{0.98 \cancel{\text{atm}}}{0.72 \cancel{\text{atm}}}$$

$$= 2.722 \times 10^2 \text{ mL}$$

Volume conversion:

$$V_2 = 2.722 \times 10^2 \cancel{\text{mL}} \times \frac{1 \times 10^{-3} \text{ L}}{1 \cancel{\text{mL}}}$$

$$= 2.722 \text{ L}$$

$$= 2.7 \text{ L}$$

The final volume (in litres) of the gas is 0.27 L.

Check Your Solution
The initial pressure is greater than the final pressure and the initial volume is less than the final volume. This inverse relationship between volume and pressure is consistent with Boyle's law. The units are correct and the answer correctly shows two significant digits.

5. Practice Problem (page 514)
Decaying vegetation at the bottom of a pond contains trapped methane gas. 5.5×10^2 mL of gas are released. When the gas rises to the surface, it now occupies 7.0×10^2 mL. If the surface pressure is 101 kPa, what was the pressure at the bottom of the pond?

What Is Required?
You need to find the initial pressure at the bottom of a pond.

What Is Given?
You know the volume of the gas for the initial set of conditions and the volume and pressure for the final set of conditions:
$V_1 = 5.5 \times 10^2$ mL
$V_2 = 7.0 \times 10^2$ mL
$P_2 = 101$ kPa

Plan Your Strategy
The pressure and volume are changing at constant temperature. Use the equation for Boyle's law: $P_1V_1 = P_2V_2$
Divide each side of the equation by V_1 to isolate the variable P_1.
Substitute the numbers and units for the known variables in the formula and solve for P_1.

Act on Your Strategy
Isolation of the variable P_1:

$$P_1V_1 = P_2V_2$$

$$\frac{P_1\cancel{V_1}}{\cancel{V_1}} = \frac{P_2V_2}{V_1}$$

$$P_1 = \frac{P_2V_2}{V_1}$$

Substitution to solve for P_1:

$$P_1 = \frac{P_2V_2}{V_1}$$

$$= \frac{(101 \text{ kPa})\,(7.0 \times 10^2 \cancel{\text{mL}})}{5.5 \times 10^2 \cancel{\text{mL}}}$$

$$= 1.285 \times 10^2 \text{ kPa}$$

$$= 1.3 \times 10^2 \text{ kPa}$$

The pressure at the bottom of the pond is 1.3×10^2 kPa.

Alternative Solution

Plan Your Strategy
According to Boyle's law, at constant temperature, an increase in volume will cause a decrease in pressure. Therefore, the initial pressure must be greater than the final pressure.
Determine the ratio of the initial volume and the final volume that is greater than 1.
Multiply the final pressure by the volume ratio determined to obtain the initial pressure.

Act on Your Strategy
Volume ratio:
$V_1 = 5.5 \times 10^2$ mL
$V_2 = 7.0 \times 10^2$ mL

volume ratio > 1 is $\frac{7.0 \times 10^2 \text{ mL}}{5.5 \times 10^2 \text{ mL}}$

Substitution to solve for P_1:

$P_1 = P_2 \times$ volume ratio

$$= 101 \text{ kPa} \times \frac{7.0 \times 10^2 \cancel{\text{mL}}}{5.5 \times 10^2 \cancel{\text{mL}}}$$

$$= 1.2854 \times 10^2 \text{ kPa}$$

$$= 1.3 \times 10^2 \text{ kPa}$$

The pressure at the bottom of the pond is 1.3×10^2 kPa.

Check Your Solution

The initial volume is less than the final volume and the initial pressure is greater than the final pressure. This inverse relationship between volume and pressure is consistent with Boyle's law. The units are correct and the answer shows the correct number of significant digits.

6. Practice Problem (page 514)

The volume of carbon dioxide in a fire extinguisher is 25.5 L. The pressure of the gas in this can is 260 psi. What is the volume of carbon dioxide released when sprayed if the room pressure is 15 psi?

What Is Required?

You need to calculate the final volume, V_2, of a sample of gas.

What Is Given?

You know the pressure and volume of the gas for the initial set of conditions and the pressure for the final set of conditions:

$P_1 = 260$ psi

$V_1 = 25.5$ L

$P_2 = 15$ psi

Plan Your Strategy

The pressure and volume are changing at constant temperature. Use the equation for Boyle's law: $P_1V_1 = P_2V_2$

Divide each side of the equation by P_2 to isolate the variable V_2.

Substitute the numbers and units for the known variables in the formula and solve for V_2.

Substitution to solve for V_2:

$V_2 = V_1 \times$ pressure ratio

$$= 25.5 \text{ L} \times \frac{260 \cancel{\text{ psi}}}{15 \cancel{\text{ psi}}}$$

$$= 442 \text{ L}$$

$$= 4.4 \times 10^2 \text{ L}$$

The volume of carbon dioxide released is 4.4×10^2 L.

Check Your Solution

The initial pressure is greater than the final pressure and the initial volume is less than the final volume. This inverse relationship between volume and pressure is consistent with Boyle's law. The units are correct and the answer shows two significant digits.

7. Practice Problem (page 514)

A 50.0 mL sample of hydrogen gas is collected at standard atmospheric pressure. What is the volume of the gas if it is compressed to a pressure of 3.50 atm?

What Is Required?

You need to calculate the final volume of a sample of gas.

What Is Given?

You know the pressure and volume of the gas for the initial set of conditions and the pressure for the final set of conditions:

$P_1 = 1.00$ atm

$V_1 = 50.0$ mL

$P_2 = 3.50$ atm

Plan Your Strategy

The pressure and volume are changing at constant temperature. Use the equation for Boyle's law: $P_1V_1 = P_2V_2$

Divide each side of the equation by P_2 to isolate the variable V_2.

Substitute the numbers and units for the known variables in the formula and solve for V_2.

Act on Your Strategy
Isolation of the variable V_2:

$$P_1V_1 = P_2V_2$$

$$\frac{P_1V_1}{P_2} = \frac{\cancel{P_2}V_2}{\cancel{P_2}}$$

$$V_2 = \frac{P_1V_1}{P_2}$$

Substitution to solve for V_2:

$$V_2 = \frac{P_1V_1}{P_2}$$

$$= \frac{(1.00\ \cancel{\text{atm}})\ (50.0\ \text{mL})}{3.50\ \cancel{\text{atm}}}$$

$$= 14.2857\ \text{mL}$$

$$= 14.3\ \text{mL}$$

The volume of the compressed gas is 14.3 mL.

Alternative Solution

Plan Your Strategy
According to Boyle's law, at constant temperature, an increase in pressure will cause a decrease in volume. Therefore, the final volume will be less than the initial volume.
Determine the ratio of the initial pressure and the final pressure that is less than 1.
Multiply the initial volume by the pressure ratio determined to obtain the final volume.

Act on Your Strategy
Pressure ratio:
$P_1 = 1.00$ atm
$P_2 = 3.50$ atm
pressure ratio < 1 is $\frac{1.00\ \text{atm}}{3.50\ \text{atm}}$

Substitution to solve for V_2:

$V_2 = V_1 \times$ pressure ratio

$$= 50.0 \text{ mL} \times \frac{1.00 \cancel{\text{ atm}}}{3.50 \cancel{\text{ atm}}}$$

$$= 14.2857 \text{ mL}$$

$$= 14.3 \text{ mL}$$

The volume of the compressed gas is 14.3 mL.

Check Your Solution

The initial pressure is less than the final pressure and the initial volume is greater than the final volume. This inverse relationship between volume and pressure is consistent with Boyle's law. The units are correct and the answer correctly shows three significant digits.

8. Practice Problem (page 514)

A portable air compressor has an air capacity of 15.2 L and an interior pressure of 110 psi. If all the air in the tank is released, what volume will that air occupy at an atmospheric pressure of 102 kPa?

What Is Required?

You need to calculate the final volume of a sample of gas.

What Is Given?

You know the pressure and volume of the gas for the initial set of conditions and the pressure for the final set of conditions:

$P_1 = 110$ psi

$V_1 = 15.2$ L

$P_2 = 102$ kPa

Plan Your Strategy

The initial pressure and the final pressure must be expressed in the same units.

Convert the units of the initial pressure from psi to kPa: 14.7 psi = 103.325 kPa

The pressure and volume are changing at constant temperature. Use the equation for Boyle's law: $P_1V_1 = P_2V_2$

Divide each side of the equation by P_2 to isolate the variable V_2.

Substitute the numbers and units for the known variables in the formula and solve for V_2.

Act on Your Strategy
Pressure conversion:

$$P_1 = 110 \text{ psi} \times \frac{103.325 \text{ kPa}}{14.7 \text{ psi}}$$

$$= 7.5821 \times 10^2 \text{ kPa}$$

Pressure ratio:
$P_1 = 7.5821 \times 10^2$ kPa
$P_2 = 102$ kPa

pressure ratio > 1 is $\frac{7.5821 \times 10^2 \text{ kPa}}{102 \text{ kPa}}$

Substitution to solve for V_2:
$V_2 = V_1 \times$ pressure ratio

$$= 15.2 \text{ L} \times \frac{7.5821 \times 10^2 \text{ kPa}}{102 \text{ kPa}}$$

$$= 112.988 \text{ L}$$

$$= 1.1 \times 10^2 \text{ L}$$

The final volume of the sample of gas is 1.1×10^2 L.

Check Your Solution
The initial pressure is greater than the final pressure and the initial volume is smaller than the final volume. This inverse relationship between volume and pressure is consistent with Boyle's law. The units are correct and the answer correctly shows two significant digits.

9. Practice Problem (page 514)
A scuba tank with a volume of 10.0 L holds air at a pressure of 1.75×10^4 kPa. What volume of air at an atmospheric pressure of 101 kPa was compressed into the tank if the temperature of the air in the tank is the same as the temperature of the air before it was compressed?

What Is Required?
You need to calculate the initial volume of a sample of gas.

What Is Given?
You know the pressure of the gas for the initial set of conditions and the volume and pressure for the final set of conditions:
$P_1 = 101$ kPa
$V_2 = 10.0$ L
$P_2 = 1.75 \times 10^4$ kPa

Plan Your Strategy
The pressure and volume are changing at constant temperature. Use the equation for Boyle's law: $P_1V_1 = P_2V_2$.
Divide each side of the equation by P_1 to isolate the variable V_1.
Substitute the numbers and units for the known variables in the formula and solve for V_1.

Act on Your Strategy
Isolate the variable V_1:

$$P_1V_1 = P_2V_2$$

$$\frac{\cancel{P_1}V_1}{\cancel{P_1}} = \frac{P_2V_2}{P_1}$$

$$V_1 = \frac{P_2V_2}{P_1}$$

Substitute to solve for V_1:

$$V_1 = \frac{P_2V_2}{P_1}$$

$$= \frac{(1.75 \times 10^4 \cancel{\text{kPa}})(10.0\text{ L})}{101\cancel{\text{kPa}}}$$

$$= 1.7326 \times 10^3\text{ L}$$

$$= 1.7 \times 10^3\text{ L}$$

The volume of air compressed was 1.73×10^3 L.

Alternative Solution

Plan Your Strategy
According to Boyle's law, at constant temperature, an increase in pressure will cause a decrease in volume. The initial volume must be greater than the final volume.
Determine the ratio of the initial pressure and the final pressure that is greater than 1.
Multiply the final volume by the pressure ratio determined to obtain the initial volume.

Act on Your Strategy
Pressure ratio:
$P_1 = 101$ kPa
$P_2 = 1.75 \times 10^4$ kPa

pressure ratio > 1 is $\frac{1.75 \times 10^4 \text{ kPa}}{101 \text{ kPa}}$

Substitution to solve for V_1:

$V_1 = V_2 \times$ pressure ratio

$$= 10.0 \text{ L} \times \frac{1.75 \times 10^4 \cancel{\text{kPa}}}{101 \cancel{\text{kPa}}}$$

$$= 1.7326 \times 10^3 \text{ L}$$

$$= 1.73 \times 10^3 \text{ L}$$

The volume of air compressed was 1.73×10^3 L.

Check Your Solution

The initial pressure is less than the final pressure and the initial volume is greater than the final volume. This inverse relationship between volume and pressure is consistent with Boyle's law. The units are correct and the answer correctly shows three significant digits.

10. Practice Problem (page 514)

An oxygen tank has a volume of 45 L and is pressurized to 1200 psi.

a. What volume of gas would be released at 765 torr?

b. If the flow of gas from the tank is 6.5 L per minute, how long would the tank last?

a. volume of gas

What Is Required?

You need to calculate the volume of oxygen released from a 45 L tank.

What Is Given?

You know the pressure and volume of the gas for the initial set of conditions and the pressure for the final set of conditions:

$P_1 = 1200$ psi

$V_1 = 45$ L

$P_2 = 765$ torr

Plan Your Strategy

The initial pressure and the final pressure must be expressed in the same units.

Convert the units of the initial pressure to torr: 760 torr = 14.7 psi

The pressure and volume are changing at constant temperature. Use the equation for Boyle's law: $P_1V_1 = P_2V_2$

Divide each side of the equation by P_2 to isolate the variable V_2.

Substitute the numbers and units for the known variables in the formula and solve for V_2.