Dealing with Gases
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When you have completed this powerpoint you should know
• The nature of gases and the kinetic-molecular theory
• What a barometer is
• How gas pressures are expressed
• What is meant by absolute zero
• What the Kelvin temperature scale is
• The mathematical expression for Boyle’s, Charles’, and the ideal gas law
• How to work problems using Boyle’s, Charles’, and the ideal gas law
• What is meant by STP (1 mole of any gas at STP = 22.4 L)
• Calculate a molar volume of gas at STP

The nature of gases and the kinetic-molecular theory
supplemental handout p 154

<table>
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<th>States of Matter</th>
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Know that solids are the most ordered of these states and gases are the most disordered.
List the four points of the Kinetic-Molecular theory

1. A gas consists of particles that are far apart.
2. The gas particles are in continuous, rapid, random, motion.
3. Upon collision there is no net loss of energy; energy may be transferred from one particle to another.
4. The speed (velocity) of particles is directly proportional to the absolute (Kelvin) temperature.
Molecules in motion colliding exert a pressure

Energy of motion, kinetic energy, KE is proportion to temperature

At constant volume,
An increase in temperature leads to an increase in pressure

- What is a barometer?
To measure pressure of a gas, a column of mercury is generally used

This arrangement is called a barometer

Height of mercury, Hg column—a measure of the pressure exerted by the atmosphere or other gases

Force exerted by the atmosphere, or other gases
A standard atmosphere is defined as a pressure sufficient to support a column of mercury 760 mm in height.

1 atm = 760 mm Hg

1 torr = 1 mm Hg

- How gas pressures are expressed
• What is meant by absolute zero

We should realize that there is a temperature so low that nothing can be colder. This **lowest possible temperature is called absolute zero**

The temperature of absolute zero equals **–273.16 °C**

In making calculations using gas law’s, the temperature that must be used is the Kelvin temperature on the absolute scale.

The temperature scale is called the absolute scale or the Kelvin scale

![Image of temperature scales]

• What the Kelvin temperature scale is

\[ K = ^\circ C + 273 \]
• The mathematical expressions for

Boyle's \( P_i V_i = P_f V_f \)

Charles' \( \frac{V_i}{T_i} = \frac{V_f}{T_f} \)

Ideal \( PV = nRT \)  \( R = 0.0821 \frac{\text{L atm}}{\text{K mol}} \)
• How to work problems using Boyle’s Law, supplemental HO 154

Boyle’s Law: Let’s work an example together.

A certain mass of oxygen at 25 °C occupies a volume of 500 mL at 1.50 atm pressure. What pressure must be applied to compress the gas to a volume of 150 mL, assuming that there is no temperature change?

Boyle’s \( P_i V_i = P_f V_f \)

\( P_i = 1.50 \text{ atm} \quad V_i = 500 \text{ mL} \quad V_f = 150 \text{ mL} \quad P_f = \text{? atm} \)

Solving for \( P_f \) and substituting

\[
P_f = \frac{P_i V_i}{V_f} = \frac{(1.50 \text{ atm})(500 \text{ mL})}{(150 \text{ mL})} = 5.0 \text{ atm}
\]

• How to work problems using Boyle’s Law, supplemental HO 155

A certain mass of nitrogen at 20 °C occupies a volume of 625 mL at 488 torr. What will be the volume if the pressure is increased to 779 torr (assume constant temperature)?

Boyle’s \( P_i V_i = P_f V_f \)

\( P_i = 629 \text{ torr} \quad V_i = 4.22 \text{ L} \quad V_f = 9.46 \text{ L} \quad P_f = \text{? torr} \)

Solving for \( V_f \) and substituting

\[
V_f = \frac{P_i V_i}{P_f} = \frac{(488 \text{ torr})(625 \text{ mL})}{(779 \text{ torr})} = 392 \text{ torr}
\]
• How to work problems using Boyle’s Law, supplemental HO 155

A certain mass of nitrogen at 100 °C occupies a volume of 4.22 L at 629 torr. At what pressure will the volume be 9.46 L (assume constant temperature)?

\[ P_i V_i = P_f V_f \]
\[ P_i = 629 \text{ torr} \quad V_i = 4.22 \text{ L} \quad V_f = 9.46 \text{ L} \quad P_f = ? \text{ atm} \]

Solving for \( P_f \) and substituting
\[ P_f = \frac{P_i V_i}{V_f} = \frac{(629 \text{ torr})(4.22 \text{ L})}{(9.46 \text{ L})} = 281 \text{ torr} \]

• How to work problems using Boyle’s Law, supplemental HO 155

A certain mass of nitrogen at 25 °C occupies a volume of 3.03 L at 682 torr. What will be the volume if the pressure is changed to 1.18 atm (assume constant temperature)?

\[ P_i V_i = P_f V_f \]
\[ P_i = 1.18 \text{ atm} \quad V_i = 3.03 \text{ L} \quad P_f = 682 \text{ torr} \quad V_f = ? \]

Solving for \( V_f \) and substituting
\[ V_f = \frac{P_i V_i}{P_f} = \frac{(1.18 \text{ atm})(760 \text{ torr})(3.03 \text{ L})}{(1 \text{ atm})(682 \text{ torr})} = 2.30 \text{ L} \]
• How to work problems using Charle’s Law, supplemental HO 156

**Charle’s Law**  Let’s work an example together.

A balloon filled with helium has a volume of 4.0 L at 25 °C. What would be the balloon’s volume at 50 °C if the pressure surrounding the balloon remained constant?

Remember the temperature must be converted to Kelvin when working with gases.

\[
\frac{V_i}{T_i} = \frac{V_f}{T_f}
\]

\[T_i = 25 \, ^\circ \text{C} + 273 = 298 \, \text{K}\]

\[V_i = 150 \, \text{L}\]

\[V_f = ?\]

\[T_f = 50 \, ^\circ \text{C} + 273 = 323 \, \text{K}\]

Solving for \(V_f\) and substituting:

\[V_f = \frac{V_i T_f}{T_i} = \frac{(4.0 \, \text{L})(323 \, \text{K})}{298 \, \text{K}} = 4.3 \, \text{L}\]

• How to work problems using Charle’s Law, supplemental HO 156

A sample of nitrogen has a volume of 474 mL at 39 °C. What will be its volume at 131 °C (assume constant pressure)?

\[
\frac{V_i}{T_i} = \frac{V_f}{T_f}
\]

Remember the temperature must be converted to Kelvin.

\[T_i = 39 \, ^\circ \text{C} + 273 = 312 \, \text{K}\]

\[V_i = 474 \, \text{mL}\]

\[V_f = ?\]

\[T_f = 131 \, ^\circ \text{C} + 273 = 404 \, \text{K}\]

Solving for \(V_f\) and substituting:

\[V_f = \frac{V_i T_f}{T_i} = \frac{(474 \, \text{mL})(404 \, \text{K})}{312 \, \text{K}} = 614 \, \text{mL}\]
• How to work problems using Charle’s Law, supplemental HO 156

A sample of nitrogen has a volume of 3.19 L at -15 °C. At what temperature (°C) will the volume be 4.44 L (assume constant pressure)?

Charles' \( \frac{V_i}{T_i} = \frac{V_f}{T_f} \)

Remember the temperature must be converted to Kelvin when

\[ T_i = -15 \, ^\circ C + 273 = 258 \, K \quad V_i = 3.19 \, L \quad V_f = 4.44 \, L \]
\[ T_f = ? \]

Solving for \( V_f \) and substituting

\[ T_f = \frac{V_f T_i}{V_i} = \frac{(4.44 \, L)(258 \, K)}{(3.19 \, L)} = 359 \, K \]

• How to work problems using Charle’s Law, supplemental HO 156

A sample of nitrogen has a volume of 572 mL at 56 °C. What will be its volume at 38 °F (assume constant pressure)?

Charles' \( \frac{V_i}{T_i} = \frac{V_f}{T_f} \)

Remember the temperature must be converted to Kelvin

\[ T_i = 56 \, ^\circ C + 273 = 329 \, K \quad V_i = 572 \, mL \quad V_f = ? \]
\[ T_f = 3.33 \, ^\circ C + 273 = 276 \, K \]

Solving for \( V_f \) and substituting

\[ V_f = \frac{V_i T_f}{T_i} = \frac{(474 \, mL)(276 \, K)}{(329 \, K)} = 480. \, mL \]
• How to work problems using the ideal gas law, supplemental HO 157

Calculate the number of moles of $N_2$ in a 3.17 L balloon at 39 °C and a pressure of 0.952 atm. How many grams of $N_2$ is this?

Remember the temperature must be converted to Kelvin when working with gases.

$$T = 39 \, ^\circ\text{C} + 273 = 312 \, \text{K}$$

$$P = 0.952 \, \text{atm} \quad V = 3.17 \, \text{L} \quad T = 300 \, \text{K} \quad R = 0.0821 \, \frac{\text{L} \cdot \text{atm}}{\text{K} \cdot \text{mol}}$$

$$PV = nRT$$

Solving for $n$ and substituting

$$n = \frac{PV}{RT} = \frac{(1.00 \, \text{atm}) \cdot (1.00 \, \text{L})}{(0.0821 \, \text{L} \cdot \text{atm} / \text{K} \cdot \text{mol}) \cdot (300 \, \text{K})} = 0.0406 \, \text{mol} \, N_2$$

$$\times \frac{28.0 \, \text{g} \, N_2}{1 \, \text{mol} \, N_2} = 3.30 \, \text{g} \, N_2$$


• How to work problems using the ideal gas law, supplemental HO 157

How many grams of $O_2$ are there in a 47.5 L cylinder, if the gas is a 14 °C and a pressure of 54416 torr?

Remember the temperature must be converted to Kelvin when working with gases.

$$T = 14 \, ^\circ\text{C} + 273 = 287 \, \text{K}$$

$$P = 54416 \, \text{torr} \quad V = 47.5 \, \text{L} \quad T = 287 \, \text{K} \quad R = 0.0821 \, \frac{\text{L} \cdot \text{atm}}{\text{K} \cdot \text{mol}}$$

$$PV = nRT$$

Solving for $n$ and substituting

$$n = \frac{PV}{RT} = \frac{(71.6 \, \text{atm}) \cdot (47.5 \, \text{L})}{(0.0821 \, \text{L} \cdot \text{atm} / \text{K} \cdot \text{mol}) \cdot (287 \, \text{K})} = 144 \, \text{mol} \, O_2$$

$$\times \frac{32.0 \, \text{g} \, O_2}{1 \, \text{mol} \, O_2} = 4610 \, \text{g} \, O_2$$

$$(54416 \, \text{torr}) \times \frac{(1 \, \text{atm})}{(760 \, \text{torr})} = 71.6 \, \text{atm}$$
• How to work problems using the ideal gas law, supplemental HO 157

What is the pressure of a 35.0 L cylinder containing 1660 g of N₂ at 39 °C?

Remember the temperature must be converted to Kelvin when working with gases.

\[ T = 39°C + 273 = 312 \text{ K} \]

\[ n = \frac{1660 \text{ g N}_2}{28.0 \text{ g N}_2 \text{ per mole N}_2} = 59.3 \text{ mol N}_2 \]

\[ V = 35.0 \text{ L} \]

\[ R = 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{K} \cdot \text{mol}} \]

\[ PV = nRT \]

\[ P = \frac{nRT}{V} = \frac{(59.3 \text{ mol N}_2) (0.0821 \frac{\text{L} \cdot \text{atm}}{\text{K} \cdot \text{mol}}) (312 \text{ K})}{35.0 \text{ L}} = 43.4 \text{ atm} \]

• How to work problems using the ideal gas law, supplemental HO 157

What is the volume of a cylinder containing 28.0 g of N₂ at 0 °C and 1 atm?

Remember the temperature must be converted to Kelvin when working with gases.

\[ T = 0°C + 273 = 273 \text{ K} \]

\[ n = \frac{28.0 \text{ g N}_2}{28.0 \text{ g N}_2 \text{ per mol N}_2} = 1.00 \text{ mol N}_2 \]

\[ P = 0.952 \text{ atm} \]

\[ R = 0.0821 \frac{\text{L} \cdot \text{atm}}{\text{K} \cdot \text{mol}} \]

\[ PV = nRT \]

\[ V = \frac{nRT}{P} = \frac{(1.00 \text{ mol N}_2) (0.0821 \frac{\text{L} \cdot \text{atm}}{\text{K} \cdot \text{mol}}) (298 \text{ K})}{1.00 \text{ atm}} = 22.4 \text{ L} \]
• What is meant by STP (1 mole of any gas at STP = 22.4 L)

One mole of any gas at 0°C and 1atm will occupy a volume of 22.4 L

• Calculate a molar volume of gas at STP ; 1 mol = 22.4 L @ standard temperature and pressure 0°C and 1atm

Calculate the molar volume of carbon dioxide at STP that will be produced when 2.0 grams of calcium carbonate is reacted in excess hydrochloric acid.

(0.020 moles CaCO₃ reacted) x (1 CO₂) = 0.020 mol of CO₂ produced (1 CaCO₃)

(0.020 moles CO₂ produced) x (22.4L) = 0.45L of CO₂ at STP (1 mol)