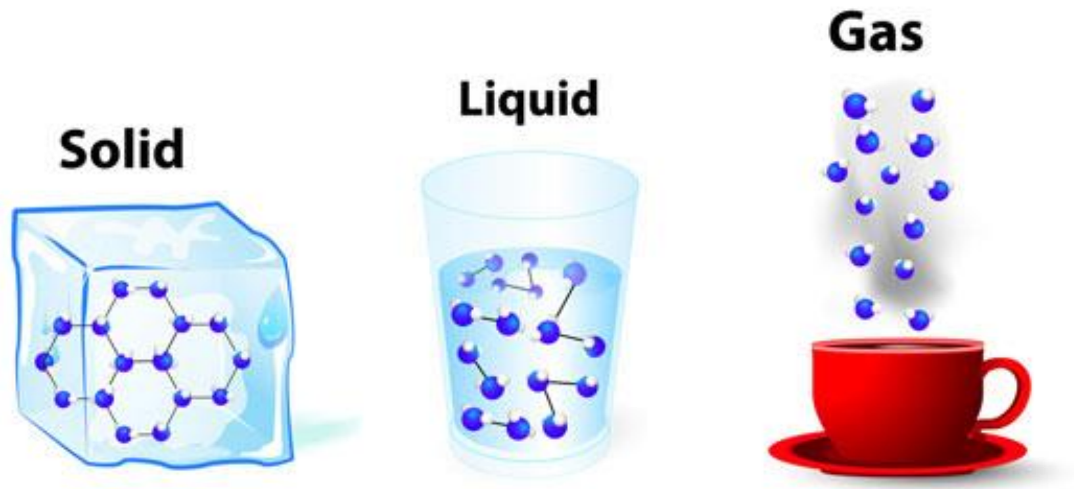
Lecture 4

GASES



https://www.tes.com/lessons/V2VhvEsZ-szNuw/solids-liquids-and-gases

Program in General Science, Faculty of Education,
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Semester 2, Academic year 2022

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OUTLINE

- Properties and types of gases
- Gas pressure
- GAS Law; Boy's, Charles's and Gay–Lussac's Law
- Combined Gas Law, Avogado's Law
- IDEAL GAS LAW (PV = nRT)
- DALTON'S LAW AND PARTIAL PRESSURES
- Solving Stoichiometry Problems Involving Gas Volumes
- Graham's Law of Effusion

สมบัติของแก๊ส

- have weak intermolecular force between gas molecules.
- The shape depend on the container.
- Density lower than liquid
- It can be easily compressed.
- The volume depends on the temperature, pressure and number of moles.

ประเภทของแก๊ส

- **Ideal gas**

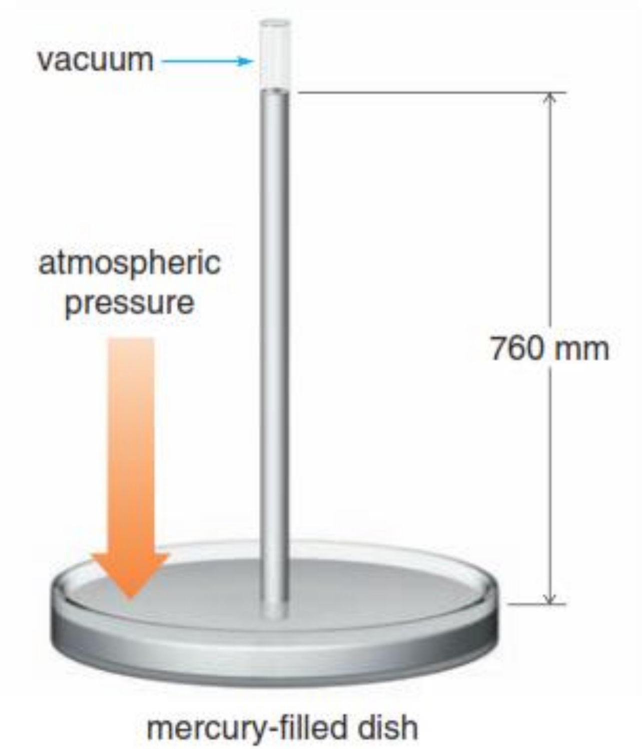
 i.e. a gas that, regardless of its state, behaves and properties in accordance with the rules and kinetic theory of gases.

- **แก๊สจริง(Real gas)**

 i.e. gases whose behavior does not follow the rules and theories of gas in normal conditions.

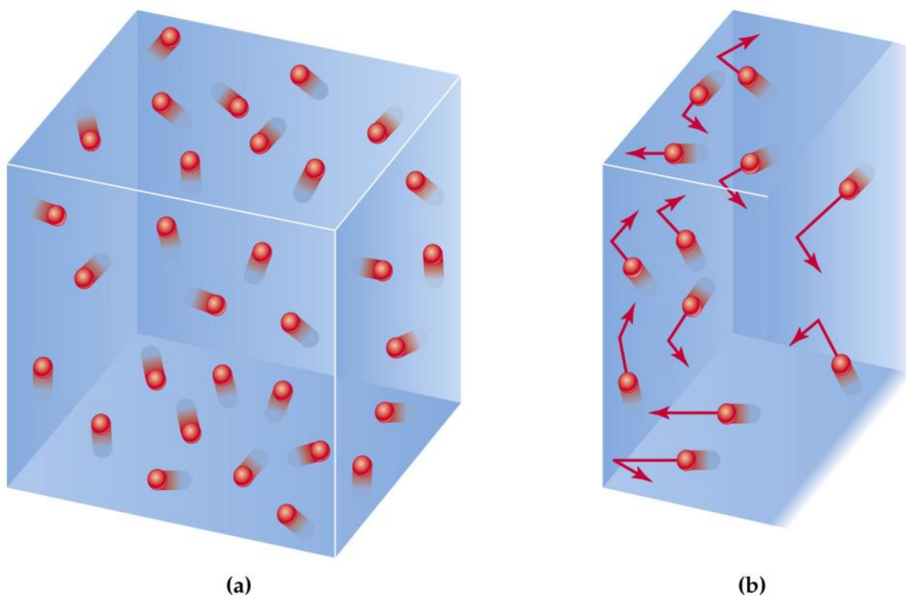
GAS PRESSURE

Pressure (*P*) *is the* force (*F*) *exerted per unit area (A).*



A barometer measures atmospheric pressure. Air pressure on the Hg in the dish pushes Hg up a sealed glass tube to a height that equals the atmospheric pressure.

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{F}{A}$$



GAS PRESSURE

The two most common units are the **atmosphere (atm), and millimeters of mercury (mm Hg), where 1 atm = 760. mm Hg.**

One millimeter of mercury is also called one **torr.**

$$
\begin{aligned}
1\ \text{atm} &= 760\ \text{mmHg} \\
&= 760\ \text{torr} \\
&= 14.7\ \text{psi} \\
&= 101{,}325\ \text{Pa}
\end{aligned}
$$

GAS LAWS THAT RELATE PRESSURE (*P*), VOLUME (*V*), and TEMPERATURE (*T*)

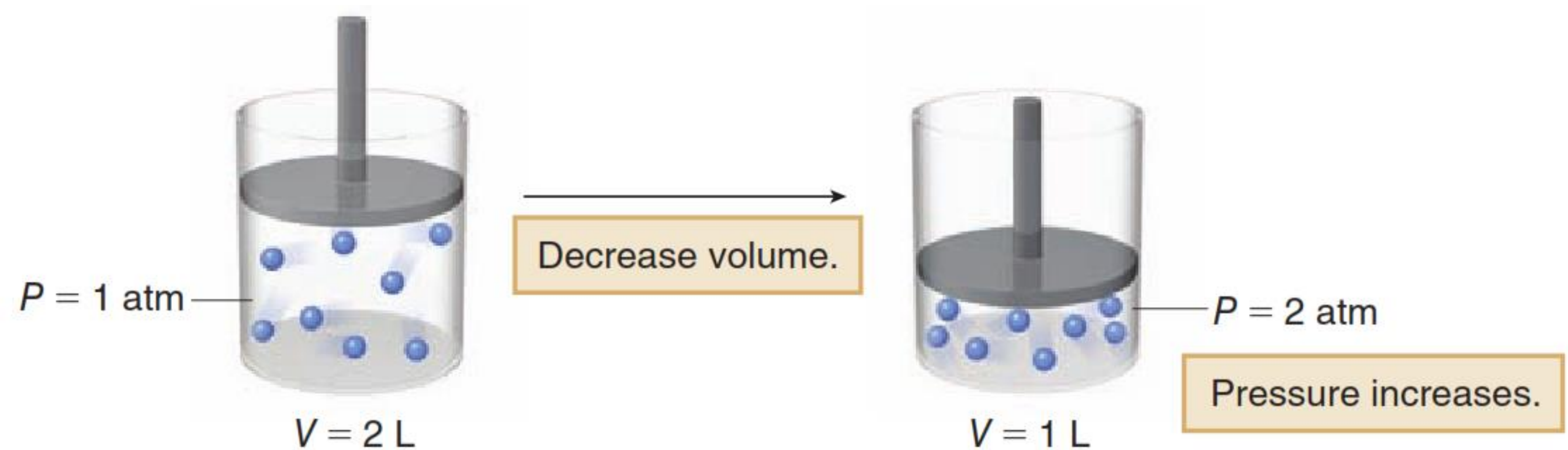
The relationship of these variables is described by equations called **gas laws**

- ❑ Boyle's law relates pressure and volume.
- ❑ Charles's law relates volume and temperature.
- ❑ Gay–Lussac's law relates pressure and temperature.

BOYLE'S LAW

HOW THE PRESSURE AND VOLUME OF A GAS ARE RELATED

Boyle's law: For a fixed amount of gas at constant temperature, the pressure and volume of a gas are inversely related.



if the volume of a cylinder of gas is halved, the pressure of the gas inside the cylinder doubles. **The same number of gas particles occupies half the volume and exerts two times the pressure.**

BOYLE’S LAW

HOW THE PRESSURE AND VOLUME OF A GAS ARE RELATED

When two quantities are *inversely related, one quantity increases as the other decreases.* ***The* product of the two quantities, however, is a *constant, symbolized by k.***

When pressure increases...

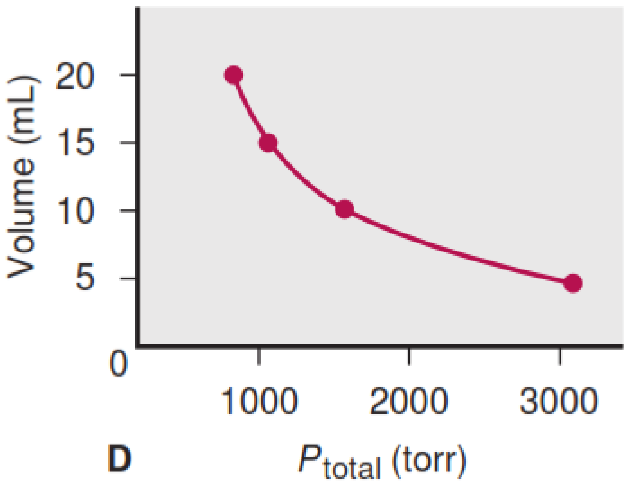
Pressure × Volume = constant

...volume decreases.

$$PV = k$$

BOYLE'S LAW

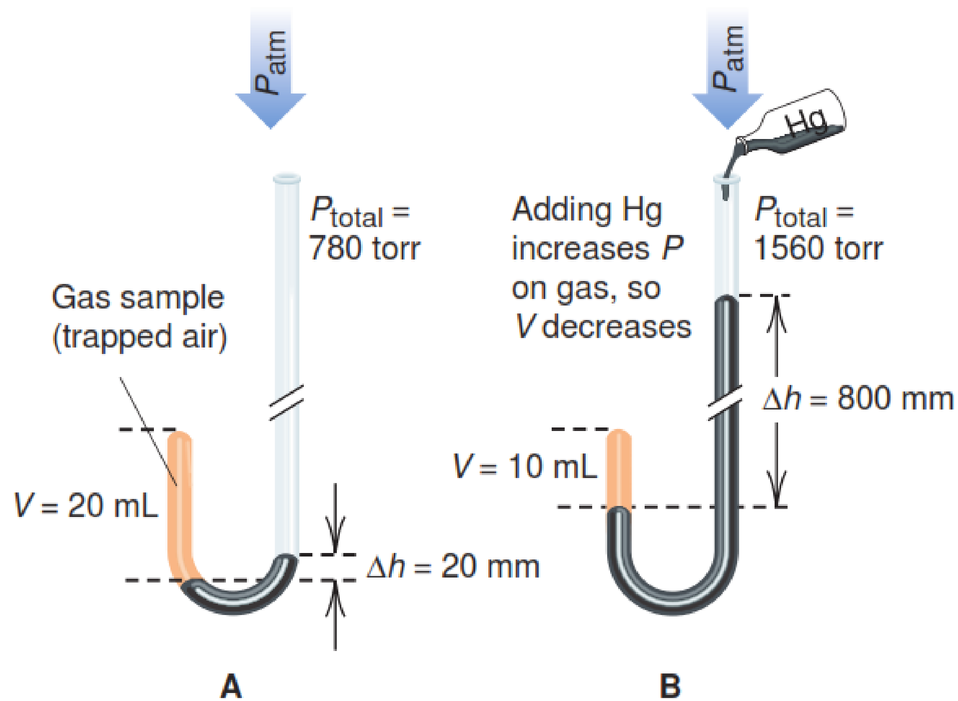
HOW THE PRESSURE AND VOLUME OF A GAS ARE RELATED



V (mL)	P (torr)			$\frac{1}{P_{total}}$	PV (torr•mL)
	Δh +	P_{atm} =	P_{total}		
20.0	20.0	760	780	0.00128	1.56×10^4
15.0	278	760	1038	0.000963	1.56×10^4
10.0	800	760	1560	0.000641	1.56×10^4
5.0	2352	760	3112	0.000321	1.56×10^4

T and mol fixed

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



Silberberg, M. *Chemistry: The Molecular Nature of Matter and Change; McGraw-Hill Education, 2011.*

BOYLE'S LAW

HOW THE PRESSURE AND VOLUME OF A GAS ARE RELATED

If we know the pressure and volume under an initial set of conditions (P_1V_1), we can calculate the pressure or volume under a different set of conditions (P_2V_2), since the product of pressure and volume is a constant.

$$P_1V_1 = P_2V_2$$

initial conditions		new conditions

HOW TO Use Boyle's Law to Calculate a New Gas Volume or Pressure

EXAMPLE If a 4.0-L container of helium gas has a pressure of 10.0 atm, what pressure does the gas exert if the volume is increased to 6.0 L?

Step 1 Identify the known quantities and the desired quantity.

In this case, P1, V1, and V2 are known and the final pressure, P_2, must be determined.

P_1 = 10.0 atm

V_1 = 4.0 L V_2 = 6.0 L

known quantities

P_2 = ?

desired quantity

HOW TO Use Boyle's Law to Calculate a New Gas Volume or Pressure

EXAMPLE **If a 4.0-L container of helium gas has a pressure of 10.0 atm, what pressure does the gas exert if the volume is increased to 6.0 L?**

Step 2 **Write the equation and rearrange it to isolate the desired quantity on one side.**

Rearrange the equation for Boyle's law so that the unknown quantity, $\boldsymbol{P_2}$ is presented alone one side

$$P_1V_1 = P_2V_2$$

Solve for P_2 by dividing both sides by V_2

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

HOW TO Use Boyle's Law to Calculate a New Gas Volume or Pressure

EXAMPLE If a 4.0-L container of helium gas has a pressure of 10.0 atm, what pressure does the gas exert if the volume is increased to 6.0 L?

Step 3 **Solve the problem.**

Substitute the known quantities into the equation and solve for P_2

$$P_2 = \frac{P_1V_1}{V_2} = \frac{(10.0\ \text{atm})(4.0\ \cancel{\text{L}})}{6.0\ \cancel{\text{L}}} = 6.7\ \text{atm}$$

Liters cancel.

Answer

In this example, the volume increased so the pressure decreased.

QUESTION Boyle's Law

A tank of compressed air for scuba diving contains 8.5 L of gas at 204 atm pressure. What volume of air does this gas occupy at 1.0 atm?

1,734 rounded to 1,700 L

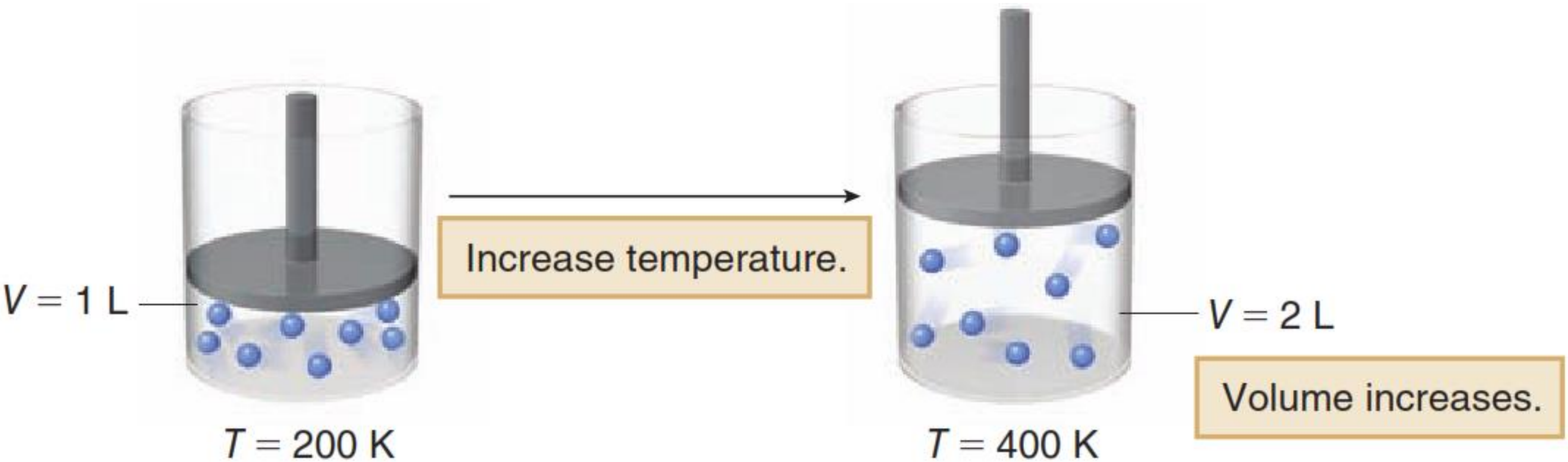
Answer

CHARLES'S LAW

HOW THE VOLUME AND TEMPERATURE OF A GAS ARE RELATED

Charles's law: For a fixed amount of gas at constant pressure, the volume of a gas is proportional to its Kelvin temperature.

All gases expand when they are heated and contract when they are cooled.



Increasing the temperature increases the kinetic energy of the gas particles, and they move faster and spread out, thus occupying a larger volume.

CHARLES’S LAW

HOW THE VOLUME AND TEMPERATURE OF A GAS ARE RELATED

Volume and temperature are *proportional; that is, as one quantity increases, the other increases* as well. Thus, **dividing volume by temperature is a constant (*k*).**

When temperature increases...

$$V \propto T$$

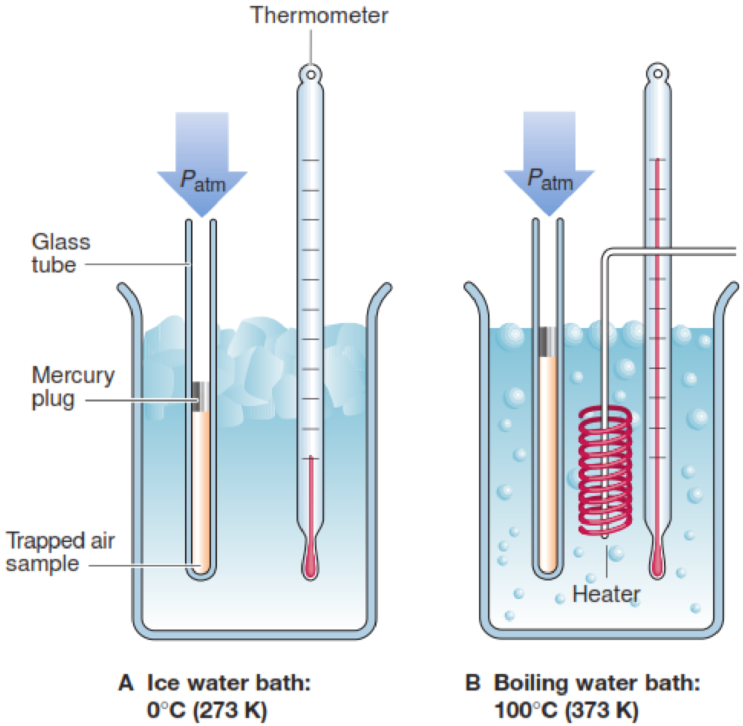
...volume increases.

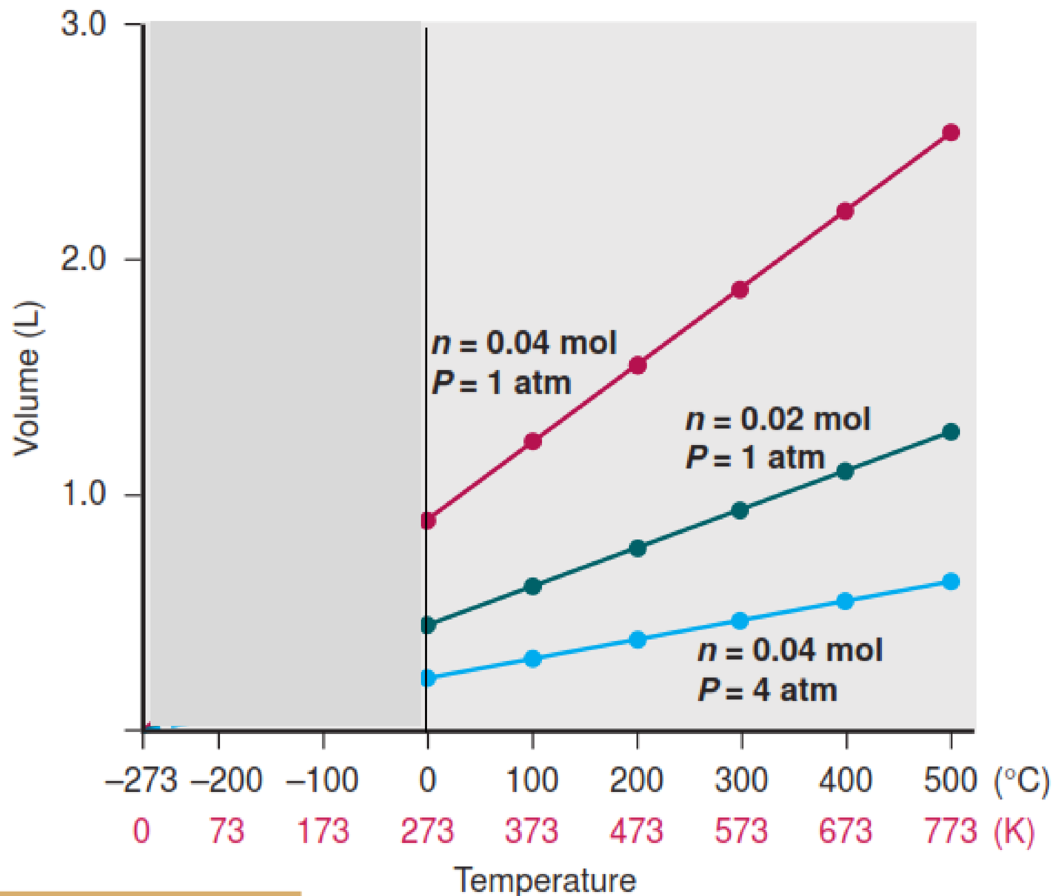
[The symbol ∝ means *is proportional to.*]

$$\frac{V}{T} = k$$

CHARLES'S LAW

HOW THE VOLUME AND TEMPERATURE OF A GAS ARE RELATED





V (L)	T (°C)	T (K)	$\frac{V}{T}$ (L/K)
0.8965	0	273	3.28×10^{-3}
0.9786	25	298	3.28×10^{-3}
1.061	50	323	3.28×10^{-3}
1.143	75	348	3.28×10^{-3}
1.225	100	373	3.28×10^{-3}

$$\frac{V}{T} = k$$

Silberberg, M. *Chemistry: The Molecular Nature of Matter and Change; McGraw-Hill Education, 2011.*

CHARLES'S LAW

HOW THE VOLUME AND TEMPERATURE OF A GAS ARE RELATED

Since dividing the volume of a gas by the temperature gives a constant, knowing the volume and temperature under an initial set of conditions (V_1T_1) means we can calculate the volume or temperature under another set of conditions (V_2T_2) when either volume or temperature is changed.

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

initial conditions new conditions

Note that **Kelvin temperature must be used in** calculations involving gas laws.

Example

A balloon that contains 0.50 L of air at 25 °C is cooled to –196 °C. What volume does the balloon now occupy?

Step 1 **Identify the known quantities and the desired quantity.**

known quantities		desired quantity
$V_1 = 0.50$ L		
$T_1 = 25$ °C	$T_2 = -196$ °C	$V_2 = ?$

- Both temperatures must be converted to Kelvin temperatures using the equation **K = °C + 273.**
- $T_1 = 25\ °C + 273 = 298$ K
- $T_2 = -196\ °C + 273 = 77$ K

Example

A balloon that contains 0.50 L of air at 25 °C is cooled to –196 °C. What volume does the balloon now occupy?

Step 2 **Write the equation and rearrange it to isolate the desired quantity, V_2 on one side.**

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

Solve for V_2 by multiplying both sides by T_2

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

Example

A balloon that contains 0.50 L of air at 25 °C is cooled to –196 °C. What volume does the balloon now occupy?

Step 3 **Solve the problem**

Substitute the three known quantities into the equation and solve for V_2.

$$V_2 = \frac{V_1 T_2}{T_1} = \frac{(0.50\ \text{L})(77\ \cancel{\text{K}})}{298\ \cancel{\text{K}}} = 0.13\ \text{L}$$

Kelvins cancel.

Answer

Since the temperature has decreased,
the volume of gas must decrease as well

QUESTION

Calculate the Kelvin temperature to which 10.0 L of a gas at 27 °C would have to be heated to change the volume to 12.0 L.

GAY–LUSSAC'S LAW

HOW THE PRESSURE AND TEMPERATURE OF A GAS ARE RELATED

Gay–Lussac's law: For a fixed amount of gas at constant volume, the pressure of a gas is proportional to its Kelvin temperature.

Pressure and temperature are ***proportional; that is, as one quantity increases, the other*** *increases. Thus,* ***dividing the pressure by the temperature is a constant (k).***

When temperature increases...

$$P \propto T$$

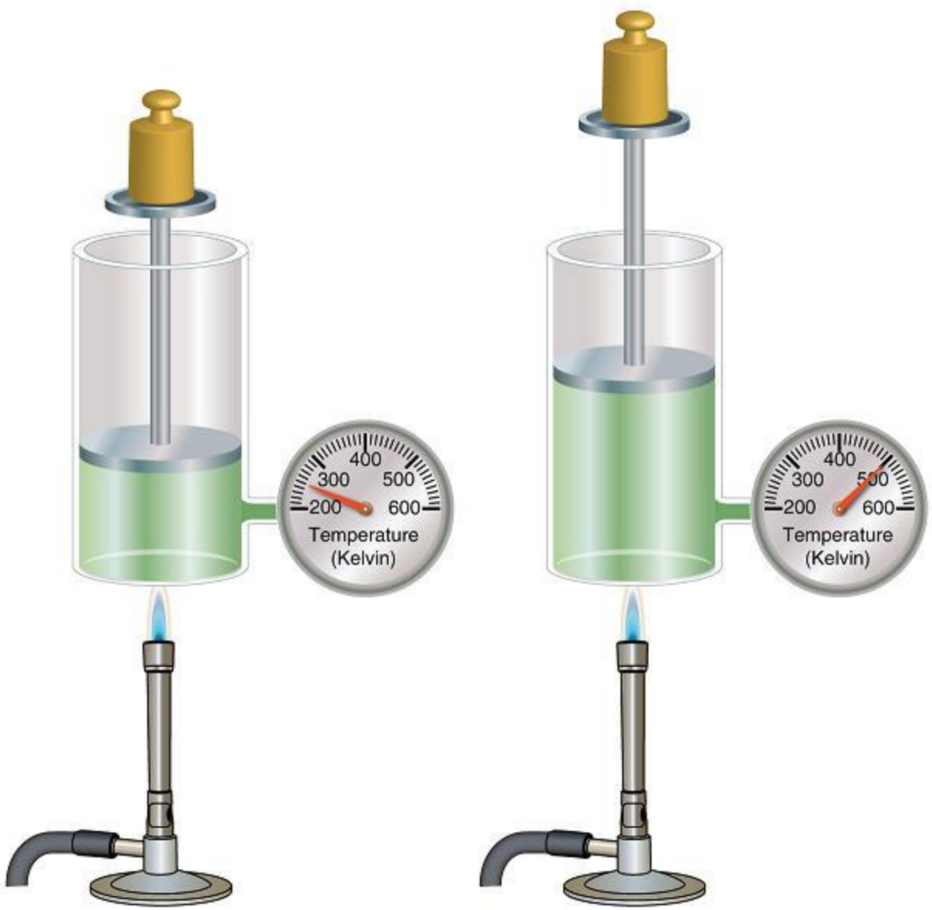
...pressure increases.

$$\frac{P}{T} = k$$

GAY–LUSSAC'S LAW

HOW THE PRESSURE AND TEMPERATURE OF A GAS ARE RELATED

Gay–Lussac's law: For a fixed amount of gas at constant volume, the pressure of a gas is proportional to its Kelvin temperature.



GAY–LUSSAC'S LAW

HOW THE PRESSURE AND TEMPERATURE OF A GAS ARE RELATED

Increasing the temperature increases the kinetic energy of the gas particles, and if the volume is kept constant, the pressure exerted by the particles increases.

Since dividing the pressure of a gas by the temperature gives a constant, knowing the pressure and Kelvin temperature under an initial set of conditions (P_1T_1) means we can calculate the pressure or temperature under another set of conditions (P_2T_2) when either pressure or temperature is changed.

$$\underset{\text{initial conditions}}{\frac{P_1}{T_1}} = \underset{\text{new conditions}}{\frac{P_2}{T_2}}$$

QUESTION

HOW THE PRESSURE AND TEMPERATURE OF A GAS ARE RELATED

A pressure cooker is used to cook food in a closed pot. By heating the contents of a pressure cooker at constant volume, the pressure increases. If the steam inside the pressure cooker is initially at 100. °C and 1.00 atm, what is the final temperature of the steam if the pressure is increased to 1.05 atm?

THE COMBINED GAS LAW

All three gas laws—Boyle's, and Charles's law can be combined in a single equation, the **combined gas law, that relates pressure, volume, and temperature.**

Boyle's law: $\mathbf{V \propto 1/P}$

Charles's law $\mathbf{V \propto T}$

$$V \propto T/P$$
$$V = k\,T/P$$
$$PV = k_3 T$$

$$PV/T = k_3$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

initial conditions new conditions

QUESTION

A weather balloon contains 222 L of helium at 20 °C and 760 mm Hg. What is the volume of the balloon when it ascends to an altitude where the temperature is –40 °C and 540 mm Hg?

248.5 L rounded to 250 L

Answer

TABLE 7.2 Summary of the Gas Laws That Relate Pressure, Volume, and Temperature

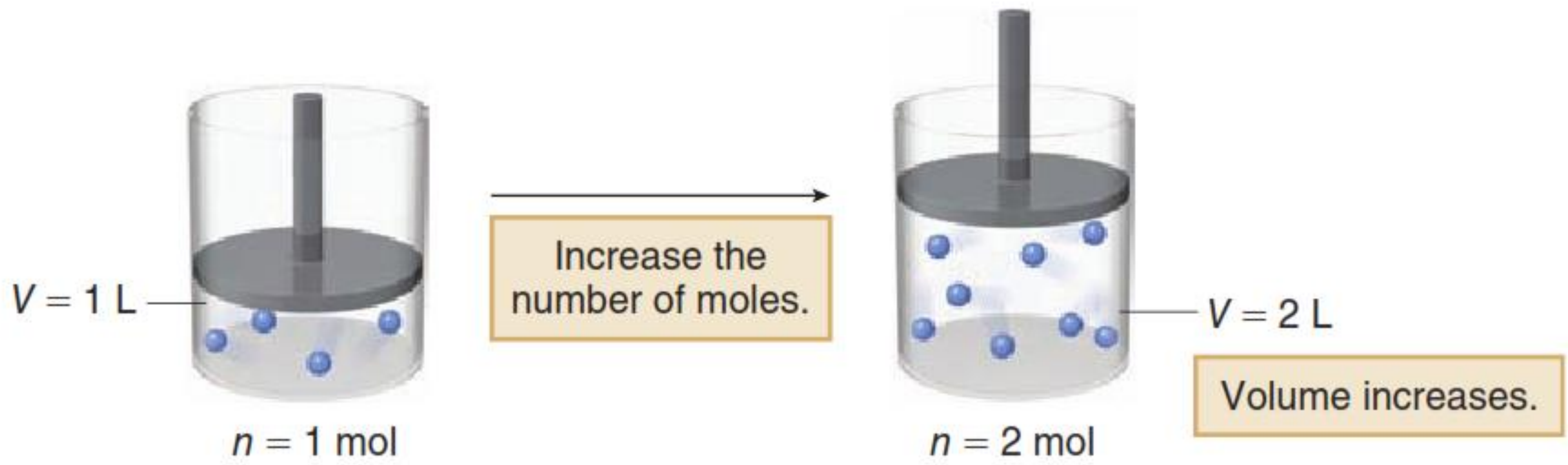
Law	Equation	Relationship
Boyle's law	$P_1V_1 = P_2V_2$	As P increases, V decreases for constant T and n.
Charles's law	$\frac{V_1}{T_1} = \frac{V_2}{T_2}$	As T increases, V increases for constant P and n.
Gay–Lussac's law	$\frac{P_1}{T_1} = \frac{P_2}{T_2}$	As T increases, P increases for constant V and n.
Combined gas law	$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$	The combined gas law shows the relationship of P, V, and T when two quantities are changed.

AVOGADRO'S LAW

HOW VOLUME AND MOLES ARE RELATED

Each equation in previous Section was written for a constant amount of gas; that is, the number of moles (*n) did not change.*

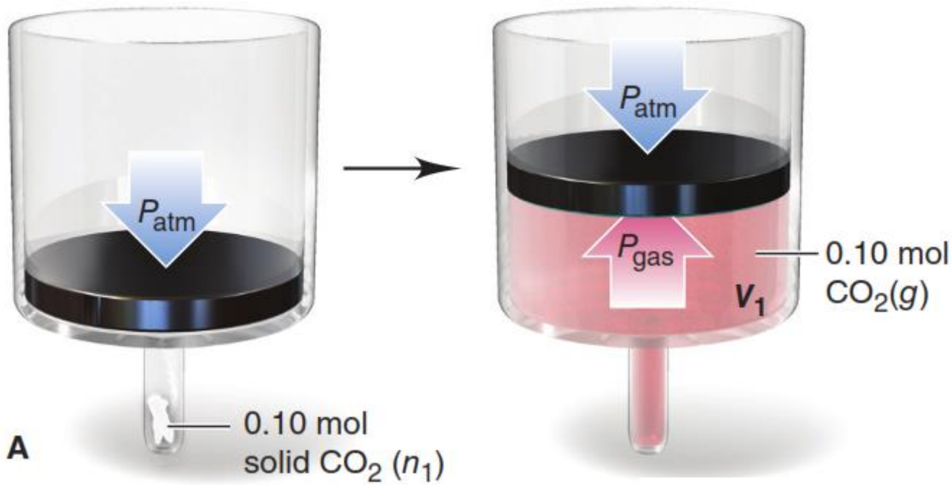
Avogadro's law: When the pressure and temperature are held constant, the volume of a gas is proportional to the number of moles present.

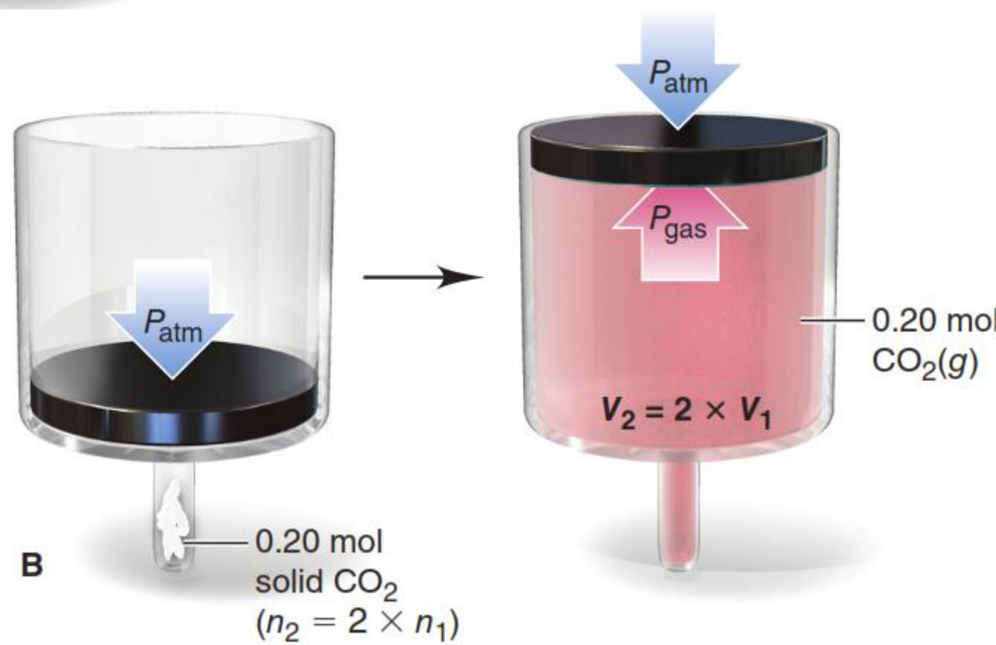


Thus, if the pressure and temperature of a system are held constant, **increasing the number of moles increases the volume of a gas.**

AVOGADRO’S LAW

Avogadro’s law, the relationship between the volume and amount of a gas.





Silberberg, M. *Chemistry: The Molecular Nature of Matter and Change; McGraw-Hill Education, 2011.*

AVOGADRO'S LAW

HOW VOLUME AND MOLES ARE RELATED

As the number of moles of a gas *increases, its volume increases as well. Thus, dividing the* volume by the number of moles is a constant (*k*)*.* ***The value of k is the same regardless of the*** **identity of the gas.**

When the number of moles increases...

$$V \propto n$$

...the volume increases.

$$\frac{V}{n} = k$$

AVOGADRO'S LAW

HOW VOLUME AND MOLES ARE RELATED

Since dividing the volume of a gas by the number of moles is a constant, knowing the volume and number of moles initially (V_1 and n1) means we can calculate a new volume or number of moles (V_2 and n_2) when one of these quantities is changed.

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

initial conditions new conditions

QUESTION

HOW VOLUME AND MOLES ARE RELATED

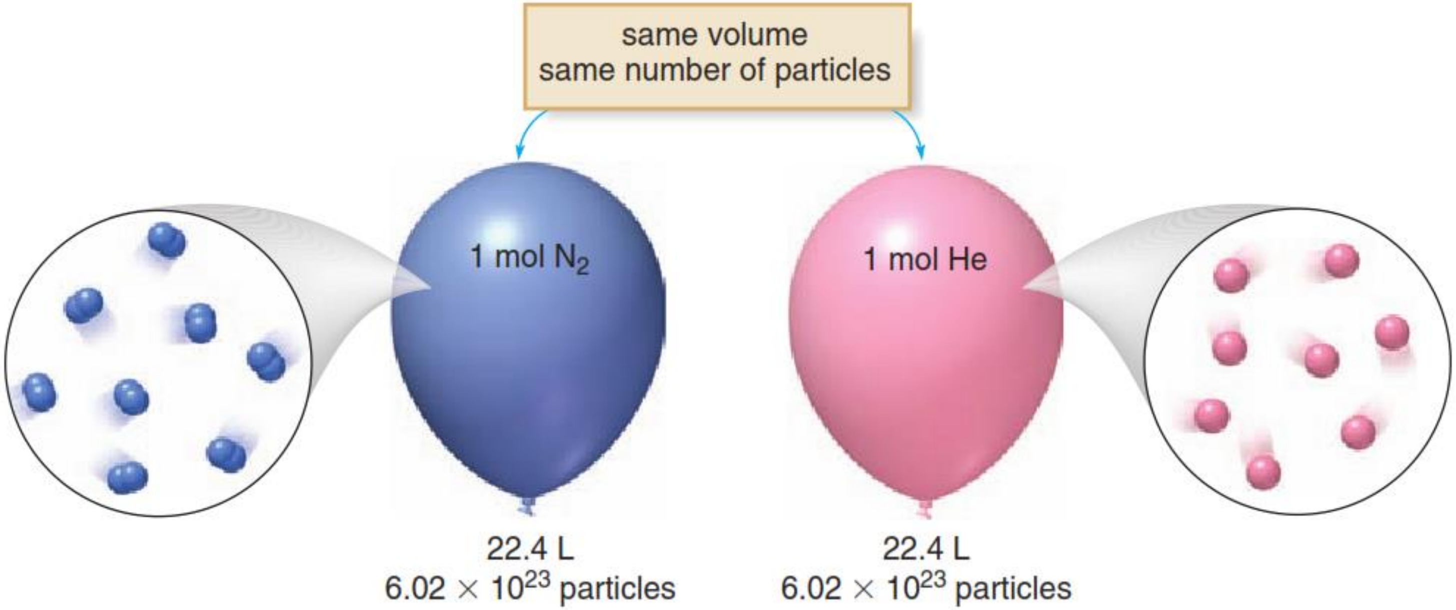
The lungs of an average male hold 0.25 mol of air in a volume of 5.8 L. How many moles of air do the lungs of an average female hold if the volume is 4.6 L?

THE IDEAL GAS LAW

PV = nRT

Ideal gas is a gas whose pressure P,volume V, and temperature T are related by the **ideal gas law**

Real gas exhibit properties that cannot be explained entirely using the ideal gas law. At high temperature and low pressure, this gas will exhibit properties liked ideal gas



THE IDEAL GAS LAW

PV = nRT

$$\text{Boyle's law:} \quad V \propto \frac{1}{P} \quad (\text{at constant } n \text{ and } T)$$

$$\text{Charles's law:} \quad V \propto T \quad (\text{at constant } n \text{ and } P)$$

$$\text{Avogadro's law:} \quad V \propto n \quad (\text{at constant } P \text{ and } T)$$

We can combine all three expressions to form a single master equation for the behavior of gases:

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

$$V = R\frac{nT}{P}$$

or $$PV = \mathrm{nRT}$$

THE IDEAL GAS LAW

$$PV = nRT$$

$$PV = \frac{g}{MW} RT$$

The product of pressure and volume divided by the product of moles and Kelvin temperature is a constant, called the **universal gas constant** and symbolized by ***R.***

P = pressure
V = volume (L)
n = number of moles
R = universal gas constant (0.0821 L·atm·mol^{-1}·K^{-1})
T = temperature (K)
g = mass (in gram)
MW = molecular weight

THE IDEAL GAS LAW

$$PV = \text{nRT}$$

$$d = \frac{P(MW)}{RT}$$

$$PV = \frac{g}{MW}\,\text{RT}$$

$$P = \text{MRT}$$

P = pressure
V = volume (L)
n = number of moles
R = universal gas constant (0.0821 L·atm·mol^{-1}·K^{-1})
T = temperature (K)
g = mass (in gram)
MW = molecular weight
D = density (g/L)
M = Molarity (mol/L)

How to carry out calculation with ideal gas law

Ex) How many moles of gas are contained in a typical human breath that takes in 0.50 L of air at 1.0 atm pressure and 37 °C?

P = 1.0 atm

V = 0.5 L

T = 273 + 37 = 310

R = 0.082 atm L / mol K

$$PV = nRT$$

$$(1\ atm)\ (0.5\ L) = n(0.082\ atm \cdot L\ mol^{-1} \cdot K^{-1})(310\ K)$$

$$n = 0.0196\ mol$$

0.0196 rounded to 0.020 mol

Answer

QUESTION

1) If a person exhales 25.0 g of CO_2 in an hour, what volume does this amount occupy at 1.00 atm and 37 °C?

14.5 L

Answer

QUESTION

2) Determine the volume of 8.50 g of He gas at 25 °C and 750 mm Hg.

3) How many moles of oxygen (O_2) are contained in a 5.0-L cylinder that has a pressure of 175 atm and a temperature of 20 °C?

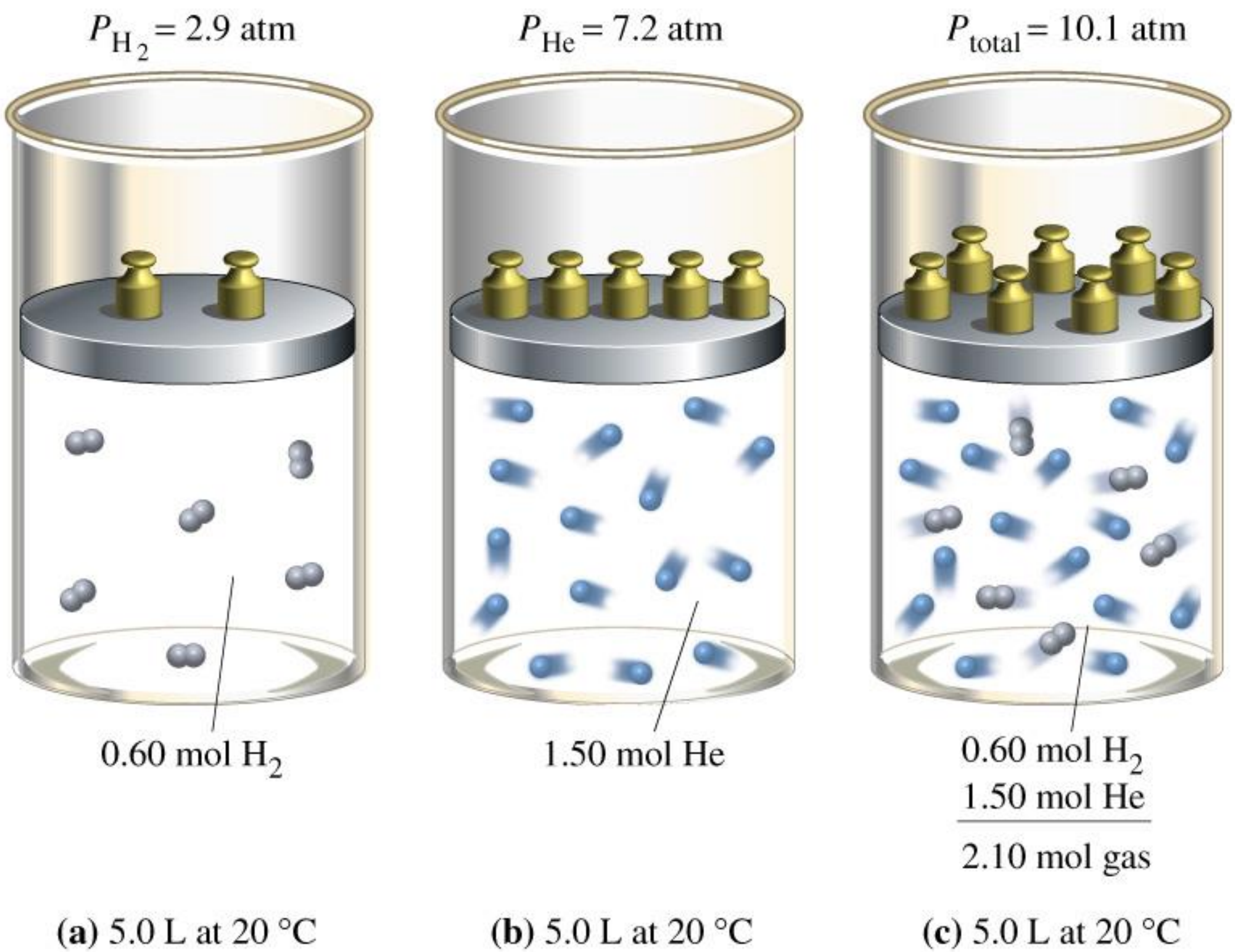
QUESTION

4) What is the density of oxygen, O_2, in grams per liter at 25 °C and 0.850 atm?.

QUESTION

5) a 200.0-mL flask at 99 °C and a pressure of 733 mm Hg is filled with the vapor of a volatile (easily vaporized)liquid. The mass of the substance in the flask is 0.970 g. What is the molecular weight of the liquid?

DALTON'S LAW AND PARTIAL PRESSURES



DALTON'S LAW AND PARTIAL PRESSURES

Dalton's law describes the relationship between the *partial pressures* of the components and the *total pressure* of a gas mixture.

Dalton's law: The total pressure (P) of a gas mixture is the sum of the partial pressures of its component gases total

Thus, if a mixture has three gases (**A, B, and C) with partial pressures** P_A, P_B, P_c, respectively. The total pressure of the system (P_{total}) is the sum of the three partial pressures.

$$P_{\text{total}} = P_A + P_B + P_C$$

total pressure — partial pressures of **A, B,** and **C**

Example

A sample of exhaled air from the lungs contains four gases with the following partial pressures: N_2 (563 mm Hg), O_2(118 mm Hg), CO_2 (30 mm Hg), and H_2O (50 mm Hg). What is the total pressure of the sample?

QUESTION

1) CO_2 was added to a cylinder containing 2.5 atm of O_2 to give a total pressure of 4.0 atm of gas. What is the partial pressure of CO_2 in the final mixture?

QUESTION

2) Air is a mixture of 21% O_2, 78% N_2, and 1% argon by volume. What is the partial pressure of each gas at sea level, where the total pressure is 760 mm Hg?

Dalton's law of partial pressure

1. ใช้สมการของแก๊สสมบูรณ์แบบ PV = nRT

$$P_t = (n_1 + n_2 + n_3 + \ldots)\frac{RT}{V} = n_t\left(\frac{RT}{V}\right)$$

$$P_t V = n_t RT$$

2. ถ้าโจทย์กำหนดความดันรวมมาให้ ให้หาความดันย่อยของ gas ชนิดต่างๆ ใช้สมการ

$$P_1 = \left(\frac{n_1}{n_t}\right)P_t = X_1 P_t$$

$$\chi_1 = \frac{n_1}{n_1 + n_2 + n_3}$$

P_1 คือ ความดันแก๊สที่กำลังพิจารณา

n_1 คือ จำนวนโมลของแก๊สนั้น

P_t คือ ความดันรวม

χ คือ เศษส่วนโมล

ตัวอย่าง แก๊สผสมหนึ่งประกอบไปด้วย แก๊ส Ne จำนวน 4.46 โมล, แก๊ส Ar จำนวน 0.74 โมล และแก๊ส Xe จำนวน 2.15 โมล ถูกบรรจุอยู่ในถังเหล็กปริมาตร 90 L ที่อุณหภูมิ 27 °C จงคำนวณหาความดันรวมและความดัน ย่อยของแก๊สแต่ละชนิด

แบบฝึกหัด

แก๊สตัวอย่างชนิดหนึ่งประกอบไปด้วย แก๊สมีเทน (CH_4) 8.24 mol, อีเทน จำนวน 0.64 mol และแก๊สโพรเพน 0.12 mol. ถ้าแก๊สตัวอย่างนี้มีปริมาตร 55 ลิตร ที่อุณหภูมิ 25 °C จงหาความดันรวมของแก๊สตัวอย่างนี้ และหาความดันย่อยของแก๊สแต่ละชนิดนี้

Solving Stoichiometry Problems Involving Gas Volumes

พิจารณาตัวอย่าง

$$6\ NaN_3\ (s) + Fe_2O_3\ (s) \rightarrow 3Na_2O\ (s) + 2\ Fe\ (s) + 9N_2\ (g)$$

จากปฏิกิริยาด้านบน จะต้องใช้ NaN_3 กี่กรัมจึงจะทำให้เกิดแก๊สไนโตรเจน 75 L ที่ 25 °C ความดัน 748 mmHg (มวลโมเลกุของ NaN_3 : 65)

Solving Stoichiometry Problems Involving Gas Volumes

1) จงคำนวนหาปริมาตรของ CO_2 ที่เกิดขึ้นที่อุณหภูมิ 37 °C ความดัน 1 atm เมื่อใช้กลูโคส 5.60 g มาทำปฏิกิริยาดังต่อไปนี้

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

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2) ถ้าใช้ HCl หนัก 9.41 กรัมทำปฏิกิริยากับ $KMnO_4$ จะได้แก๊ส Cl_2 เป็นสารผลิตภัณฑ์ออกมากี่ลิตร ที่อุณหภูมิ 40 °C ความดัน 787 mmHg

$$2KMnO_4\,(s) + 16HCl(aq) \longrightarrow 8H_2O(l) + 2KCl(aq) + 2MnCl_2\,(aq) + 5Cl_2\,(g)$$

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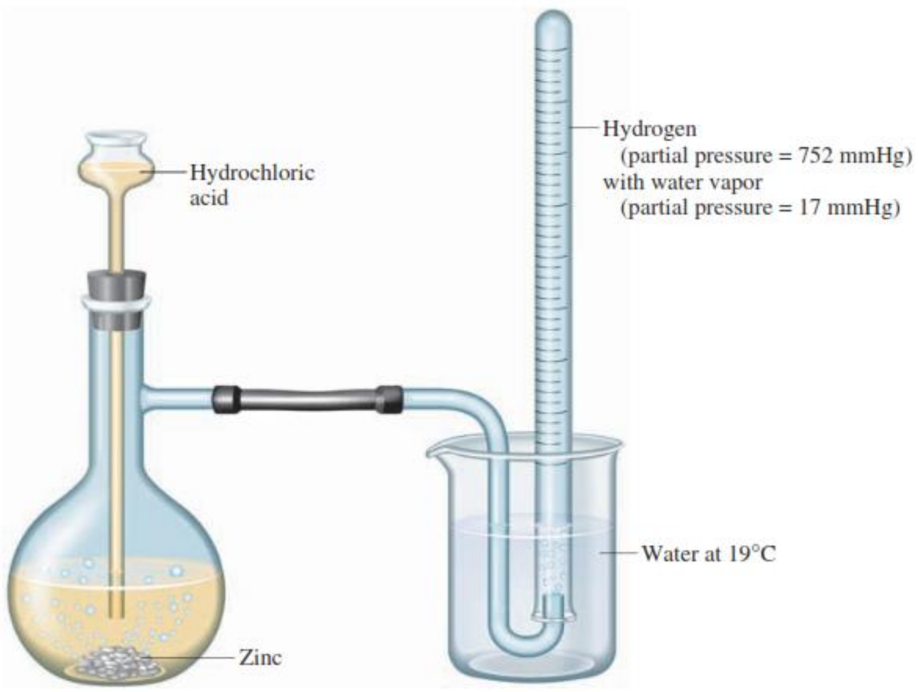
$$2HCl(aq) + Zn(s) \rightarrow ZnCl_2(aq) + H_2(g)$$

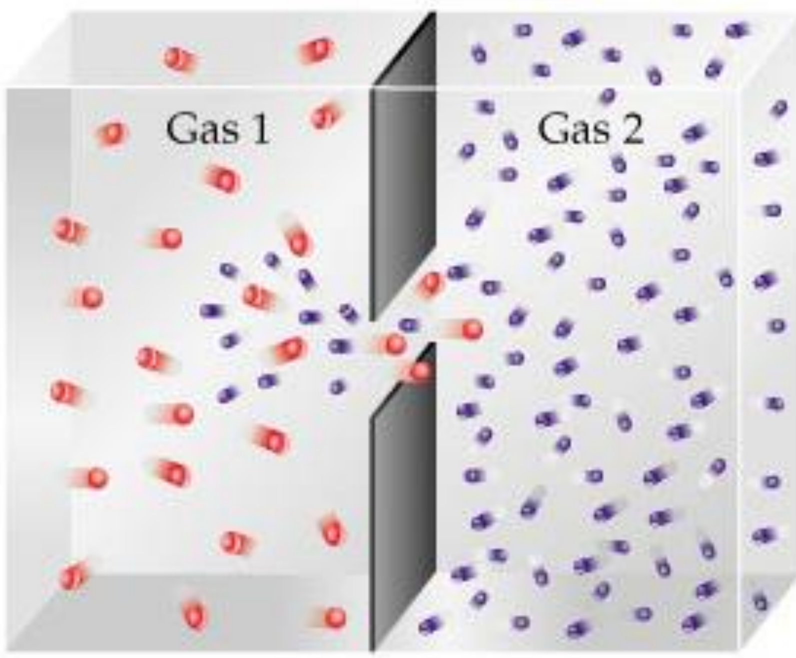
3) จากปฏิกิริยาที่แสดงด้านบนสามารถเก็บแก๊สไฮโดรเจนได้ 156 mL ที่อุณหภูมิ 19 °C วัดความดันรวมได้เท่ากับ 769 mmHg จงหาน้ำหนักของแก๊สไฮโดรเจน กำหนดความดันย่อยของน้ำเท่ากับ 17 mmHg



0.0130 g H_2

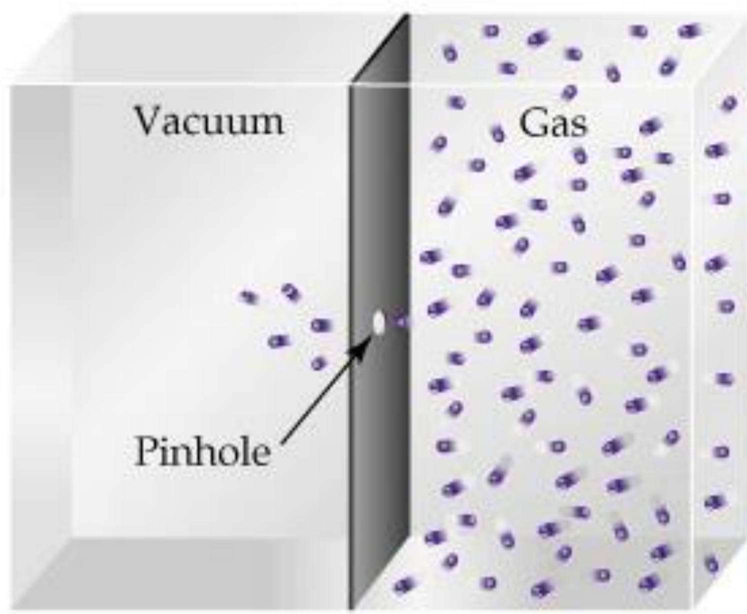
Molecular Effusion and Diffusion

การแพร่ของแก๊ส (Diffusion of gases) เป็นการเคลื่อนที่ของโมเลกุลของแก๊สตั้งแต่ 2 ชนิด ขึ้นไป จากที่มีความดันสูงไปสู่ส่วนที่มีความดันต่ำ โดยที่โมเลกุลของแก๊สแต่ละชนิดสามารถสอดแทรกผสมกลมกลืนกัน หรืออาจชนกันระหว่างโมเลกุลของแก๊สที่เคลื่อนที่ผ่านนั้นได้



Molecular Effusion and Diffusion

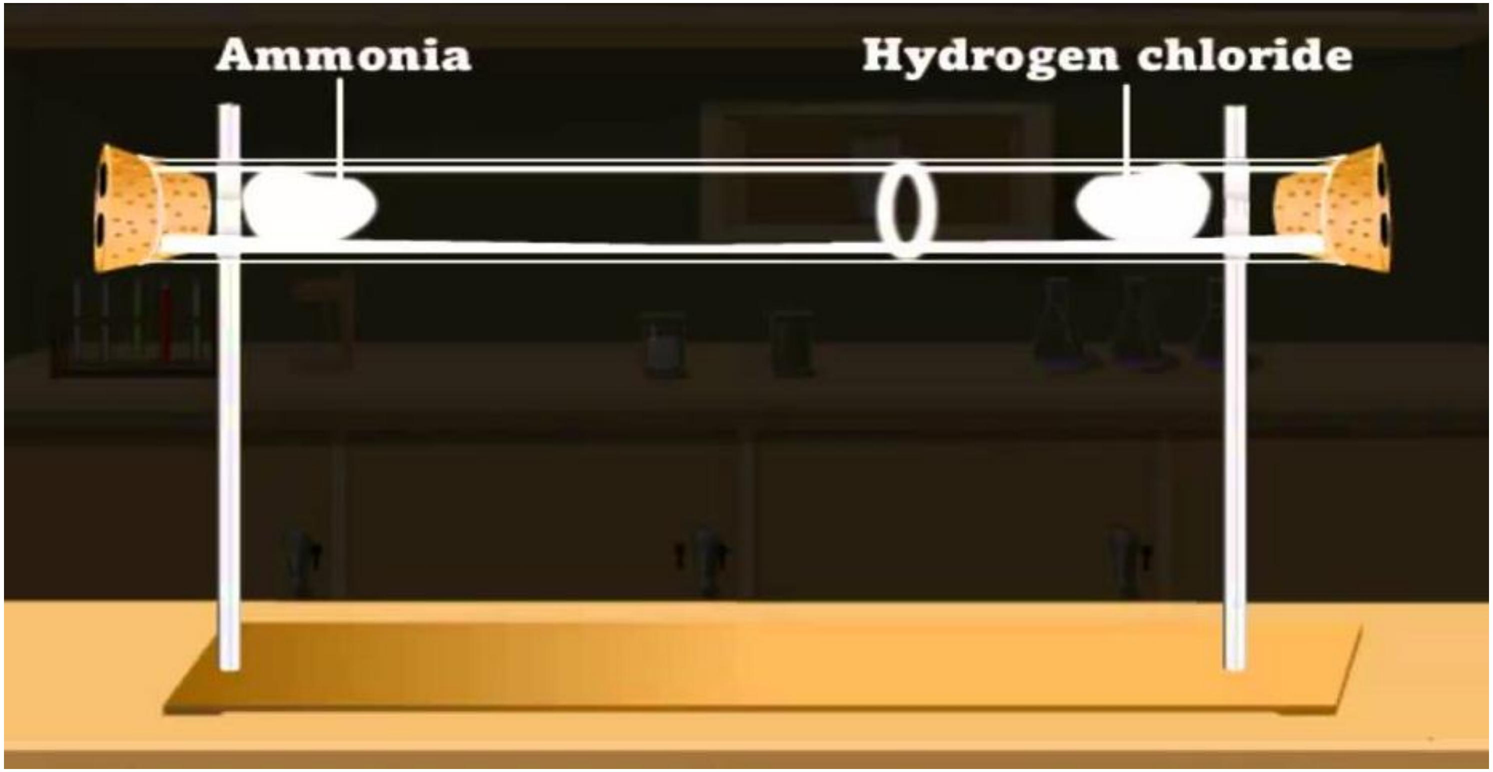
•การแพร่ผ่านของแก๊ส (Effusion of gases) หมายถึงกระบวนการที่แก๊สเคลื่อนที่จากบริเวณที่มีความดันสูงไปสู่ส่วนที่มีความดันต่ำ ผ่านรูที่เล็กมากๆ โดยโมเลกุลไม่ชนกันเอง (ideal flow)



Graham's Law of Effusion

$NH_3(g) + HCl(g) \longrightarrow NH_4Cl(s)$

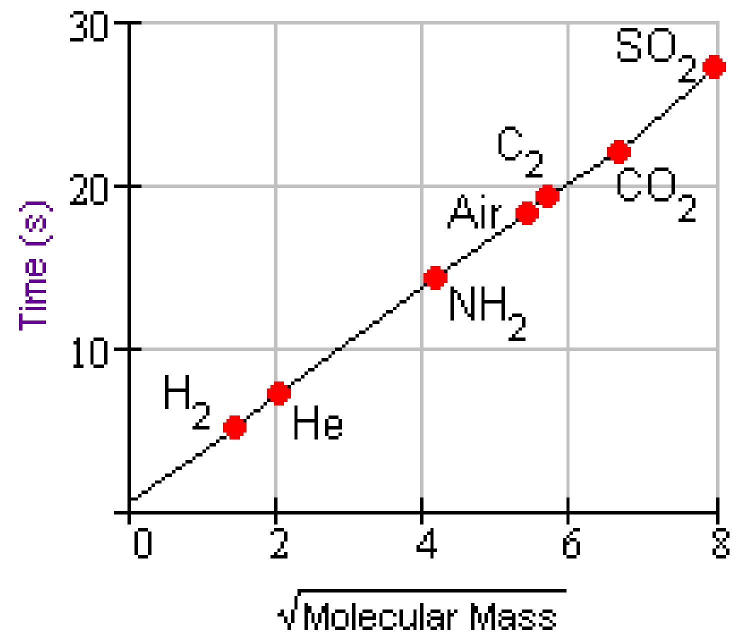
มวลโมเลกุล 17 36.5



Graham's Law of Effusion

- **Graham's law**: “ภายใต้อุณหภูมิและความดันเดียวกัน อัตราการแพร่ผ่านของแก๊สจะเป็นสัดส่วนผกผันกับรากที่สองของมวลโมเลกุลของแก๊ส”

$$r \quad \alpha \frac{1}{\sqrt{M}}$$



เปรียบเทียบการแพร่ผ่านหรือการแพร่ของแก๊สชนิดที่ 1 และ 2 ภายใต้สภาวะเดียวกันจะได้

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$$

เนื่องจากมวลโมเลกุลของแก๊สแปรผันตรงกับความหนาแน่น จะได้

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}} = \sqrt{\frac{d_2}{d_1}}$$

r_1, r_2 คือ อัตราการแพร่ผ่านของแก๊สชนิดที่ 1 และ 2 ตามลำดับ

M_1, M_2 คือ มวลโมเลกุลของแก๊สชนิดที่ 1 และ 2 ตามลำดับ

Ex.1 จงเปรียบเทียบอัตราการแพร่ผ่านของแก๊ส H_2 และ O_2 กำหนดความหนาแน่นของ H_2 = 0.0899 g/L และ O_2 = 1.43 g/L

Ex.2 C_2F_4 แพร่ผ่านช่องเล็ก ๆ ด้วยอัตรา 4.6 x 10^{-6} mol/hr ถ้าแก๊สชนิดหนึ่งแพร่ผ่านช่องเล็ก ๆ นี้ที่สภาวะเดียวกันด้วยอัตรา 6.5 x 10^{-6} mol/hr จงหาน้ำหนักโมเลกุลของแก๊สชนิดนี้ *(มวลโมเลกุลของ C_2F_4 = 100 g/mol)*

Ex 3) แก๊ส X มีมวลโมเลกุลเท่ากับ 64 เคลื่อนที่ได้ระยะทาง 80 เซนติเมตร ภายในเวลา 2 วินาที ในภาชนะใบเดียวกัน ถ้าแก๊ส Y มีมวลโมเลกุลเท่ากับ 16 ภายในเวลา 5 วินาที แก๊ส Y จะเคลื่อนที่ได้ระยะทางเท่าใด

Key = 400 cm

References

1) Chang, R.; Overby, J. S. *General Chemistry: The Essential Concepts; McGraw-Hill, 2011.*
2) Gallagher, R.; Ingram, P. *Complete Science for Cambridge IGCSE Complete Chemistry for Cambridge IGCSE. Per Le Scuole Superiori; Oxford University Press, 2014.*
3) Silberberg, M. *Chemistry: The Molecular Nature of Matter and Change; McGraw-Hill Education, 2011.*
4) Zumdahl, S. S. *World of Chemistry; McDougal Littell, 2001.*
5) Ebbing, D.; Gammon, S. D. *General Chemistry; Cengage Learning, 2007.*