Boyle's Law

Boyle's Law, a principle that describes the relationship between the pressure and volume of a gas. According to this law, the pressure exerted by a gas held at a constant temperature varies inversely with the volume of the gas. For example, if the volume is halved, the pressure is doubled; and if the volume is doubled, the pressure is halved. The reason for this effect is that a gas is made up of loosely spaced molecules moving at random. If a gas is compressed in a container, these molecules are pushed together; thus, the gas occupies less volume. The molecules, having less space in which to move, hit the walls of the container more frequently and thus exert an increased pressure.

Boyle's Law actually applies only to an ideal, theoretical gas. When real gases are compressed at a constant temperature, changes in the relationship between pressure and volume occur. However, the law is accurate enough to be useful in a number of practical applications. It is used, for example, in calculating the volume and pressure of internal-combustion engines and steam engines.

The law was first stated in 1662 by Robert Boyle. In 1676, Edme Mariotte of France independently stated the same law, and it is sometimes called Mariotte's Law.

Stated as a formula, Boyle's Law reads:

V1/V2=P2/P1 (at constant temperature)

where V1 equals the original volume, V2 equals the new volume, P1 the original pressure, and P2 the new pressure.

1.) A certain mass of carbon dioxide occupies a volume of 480 liters at 1 atmosphere pressure. What pressure must be applied to confine it to a cylinder of 12 liter capacity, temperature remaining constant?

Given:
P_1=1atm
P_2 =?
V_1= 480 L
V_2 =12 L

Solution:
$P_1V_1= P_2V_2$
(1atm)(480L)= (P_2)(12L)

$$P_2=\frac{(1atm)(480L)}{12L}$$

P_2= 40atm

2.) A certain mass of ammonia occupies 600 ml at a certain pressure. When the pressure is changed to 4 atmospheres it occupies a volume of 2.4 liters, temperature remaining constant. What was the initial pressure?

Given:
P_1=?
P_2 =4atm
V_1= 600mL
V_2 =2.4L

Solution:
$P_1V_1= P_2V_2$
P_1(0.6L)=(4atm)(2.4L)

$$P_1=\frac{(4atm)(2.4L)}{0.6L}$$

P_1= 16atm

3.) If a gas at 25.0 °C occupies 3.60 liters at a pressure of 1.00 atm, what will be its volume at a pressure of 2.50 atm?

Given:
P_1=1atm
P_2 =2.5atm
V_1= 3.6L
V_2 =?

Solution:
$P_1V_1= P_2V_2$
(1atm)(3.6L)=(2.5atm)(V_2)

$$V_2=\frac{(1atm)(3.6L)}{2.5atm}$$

V_2 = 1.44L

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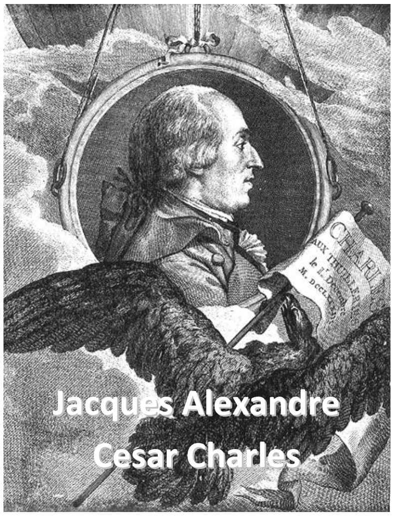
Charles' Law



Charles' Law, in physics, a principle that deals with the effect of heat on the expansion of gases.

The law states:

If the pressure of a gas remains constant, the volume of the gas will increase as the temperature increases.

Thus if the temperature increases, the gas takes up more space. If the temperature decreases, the gas takes up less space. The principle was first formulated by the French physicist Jacques Alexandre Cesar Charles in 1787.

Charles' law is stated this way in formula form:

where V1 equals the original volume, V2 equals the new volume, T1 equals the original temperature, and T2 equals the new temperature.

In using Charles' law, temperatures must be converted to the Kelvin scale, in which the zero point is absolute zero (-273.15° C.).

1.) A container contains 5 L of nitrogen gas at 25° C. What will be its volume if the temperature increases by 35° C keeping the pressure constant?

Given:

V_1 = 5 L

V_2 =?

T_1 = (25°C + 273) K = 298 K

T_2 = (25°C + 35°C + 273) K = 333 K

Solution:

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

$$\frac{5L}{298K} = \frac{V_2}{333K}$$

V_2 =5.59 L

2.) A sample of gas occupies 3 L at 300 K. What volume will it occupy at 200 K?

Given:

V_1 = 3 L

V_2 = ?

T_1 = 300 K

T_2 = 200 K

Solution:

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

$$\frac{3L}{300K} = \frac{V_2}{200K}$$

V_2 = 2L

3.) A sample of hydrogen has an initial temperature of 50°C. When the temperature is lowered to 10°C, the volume of hydrogen becomes 2 L. What was the initial volume of the hydrogen?

Given:

V_1 = ?

V_2 = 2L

T_1 = 50°C+273= 323K

T_2 = 50°C-10°C+273= 313K

Solution:

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

$$\frac{V_1}{323K} = \frac{2L}{313K}$$

V_2 = 2L

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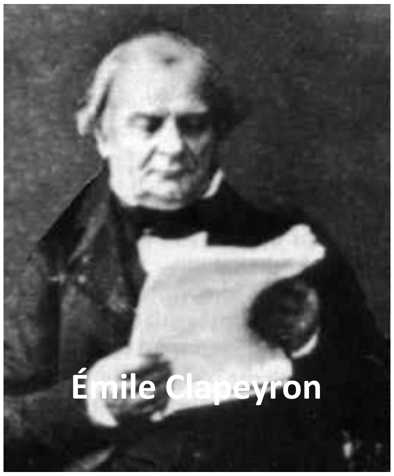
Ideal Gas Law



An equation that chemists call the **Ideal Gas Law**, shown below, relates the volume, temperature, and pressure of a gas, considering the amount of gas present.

$$PV = nRT$$

Where:
P=pressure in atm
T=temperature in Kelvins
R is the *molar gas constant*, where R=0.082058 L atm mol^{-1} K^{-1}.

The Ideal Gas Law assumes several factors about the molecules of gas. The volume of the molecules is considered negligible compared to the volume of the container in which they are held. We also assume that gas molecules move randomly, and collide in completely elastic collisions. Attractive and repulsive forces between the molecules are therefore considered negligible.

1.) 2.50 g of XeF_4 gas is placed into an evacuated 3.00 liter container at 80°C. What is the pressure in the container?

Given:
P=?
V = 3L
n = 2.5g XeF_4 x 1 mol/207.3g XeF_4 = 0.0121mol
R = 0.0821L•atm/(mol•K)
T = 80 + 273 = 353 K

Solution:
PV=nRT
(P)(3L) = (0.0121 mol) (0.0821 L•atm/(mol•K) (353 K)
P= [(0.0121 mol) (0.0821 L•atm/(mol•K) (353 K)] / (3L)
P = 0.12 atm

2.) What is the volume of 4.5 of moles of nitrogen gas at 1.2atm and 70°C

Given:
P= 1.2atm
V = ?
n = 4.5mol
R = 0.0821L•atm/(mol•K)
T = 70 + 273 = 343 K

Solution:
PV=nRT
(1.2atm)(V)= (4.5mol)(0.0821L•atm/(mol•K))(343K)
V=[(4.5mol)(0.0821L atm/(mol K))(343K)]/ (1.2atm)
V=105.6L

3.) 0.105 moles of an ideal gas occupy 5.00 L at a pressure of 0.975 atm. What is the temperature of the gas?

Given:
P= 0.975atm
V = 5L
n = 0.105mol
R = 0.0821L•atm/(mol•K)
T = ?

Solution:
PV=nRT
(0.975atm)(5L) = (0.105mol) (0.0821 L•atm/(mol•K) (T)
T= [(0.975atm)(5L)] / [(0.105mol) (0.0821 L•atm/(mol•K)]
T= 566K

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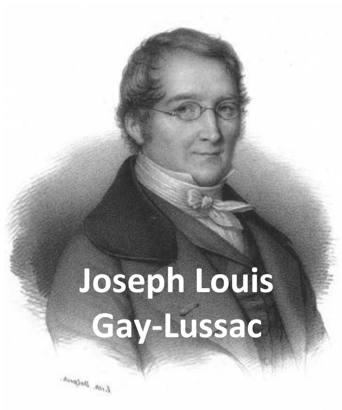
Gay-Lussac's Law



Gay-Lussac's law is a statement that the volume occupied by a fixed amount of gas is directly proportional to its absolute temperature, if the pressure remains constant. This empirical relation was first suggested by the French physicist J.-A.-C. Charles about 1787 and was later placed on a sound empirical footing by the chemist Joseph-Louis Gay-Lussac. It is a special case of the general gas law and can be derived from the kinetic theory of gases under the assumption of a perfect (ideal) gas. Measurements show that at constant pressure the thermal expansion of real gases, at sufficiently low pressure and high temperature, conforms closely to Charles's law.

1.) A gas cylinder is at 55 kPa and 300 K. What would be the pressure if the cylinder was heated to 350K.

Given:

P_1=55kPa

P_2= ?

T_1=300K

T_2=350K

Solution:

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

(55kPa)/(300K)=(P_2)/(350K)

P_2= [(55kPa) (350K)] / (300K)

P_2= 64.17kPa

2.) A cylinder contain a gas which has a pressure of 125kPa at a temperature of 200 K. Find the temperature of the gas which has a pressure of 100 kPa.

Given:

P_1=125kPa

P_2= 100kPa

T_1=200K

T_2=?

Solution:

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

(125kPa)/(200K)=(100K)/(T_2)

T_2=[(200K)(100kPa)] / 125kPa

T_2=160K

3.) Find the final pressure of gas at 150 K, if the pressure of gas is 210 kPa at 120 K.

Given:

P_1=210kPa

P_2=?

T_1=120K

T_2=150K

Solution:

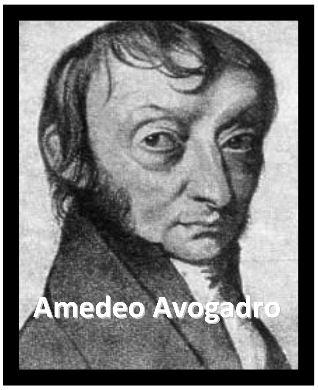
$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

(210kPa)/(120K)=(P_2)/(150K)

P_2= [(210kPa)(150K)] / (120K)

P_2=262.5kPa

Avogadro's Law



Avogadro's Law states that for a gas at constant temperature and pressure the volume is directly proportional to the number of moles of gas.

According to Avogadro's Law:

V_1 / n_1 = constant

After the change involume and mole number,

V_2 / n_2 = constant

Combine the two:

$V_1 / n_1 = V_2 / n_2$

When any three of the four quantities in the equation are known, the fourth can be calculated. For example, if n_1, V_1 and V_2 are known, the n_2 can be solved by the following equation: $n_2 = V_2 \times (n_1/V_1)$

1.) A sample containing 1.50 moles neon gas has a volume of 8.00L. What is the new volume when 3.50 moles O2 is added to the gas already in the container?

Given:	Solution:
V_1= 8.00L	$V_1 / n_1 = V_2 / n_2$
n_1 = 1.50mol	8L/1.5mol=V_2/5mol
V_2=?	V_2=[(8L)(5mol)] / 1.5mol
n_2=1.50mol + 3.50mol= 5mol	**V_2=26.67L**

2.) 5.00 L of a gas is known to contain 0.965 mol. If the amount of gas is increased to 1.80 mol, what new volume will result (at an unchanged temperature and pressure)?

Given:	Solution:
V_1= 5.00L	$V_1 / n_1 = V_2 / n_2$
n_1 = 0.965mol	5L/0.965mol = V_2/1.8mol
V_2=?	V_2=[(5L)(1.8mol)] / 0.965mol
n_2=1.80mol	**V_2=9.33L**

3.) Find the volume for 6 mole of gas, if the 4 mole of gas contains 85 L of volume.

Given:	Solution:
V_1= 85L	$V_1 / n_1 = V_2 / n_2$
n_1 = 4mol	85L/4mol = V_2/6mol
V_2=?	V_2=[(85L)(6mol)] / 4mol
n_2=6mol	**V_2=127.**