

Name: \_\_\_\_\_

## The Gas Laws

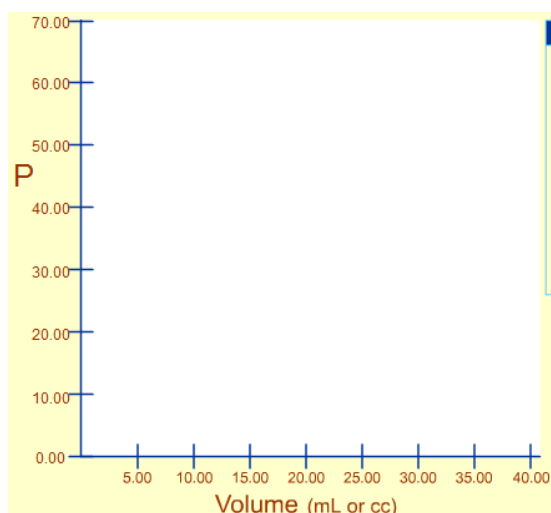
### Boyle's Law

Load the following website:

[http://group.chem.iastate.edu/Greenbowe/sections/projectfolder/flashfiles/gaslaw/boyles\\_law\\_graph.html](http://group.chem.iastate.edu/Greenbowe/sections/projectfolder/flashfiles/gaslaw/boyles_law_graph.html)

#### Pressure and Volume (constant temperature and amount)

- Drag the plunger to change the volume of the gas (in mL). Change it in increments of 5 mL.
- The chart will display the pressure for that volume of gas
- When you have at least ten points with varying volumes, press "Graph" and record your information on the graph below.



What do you notice happens to the pressure as the volume is changed?

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This relationship is known as \_\_\_\_\_

pressure. That is, as the pressure increases the volume \_\_\_\_\_  
increases the pressure \_\_\_\_\_

This relationship can be expressed as:

$$V \propto \frac{1}{P}, \text{ or}$$

$$V = \frac{k}{P}, \text{ where } k \text{ is a constant so}$$

$$PV = k$$

e.g. Consider the following variation of volume with pressure

Pressure (atm)	1	1.5	2	3	4	6	12
Volume (L)	12	8	6	4	3	2	1
k (constant)							

This relationship is very useful as it allows us to determine either the pressure or volume of a **fixed amount of gas at a constant temperature** if either the volume or pressure is changed. This can be expressed by this relationship:

$$P_1V_1 = k = P_2V_2$$

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#### Sample question

An observation balloon is filled with helium gas to a volume of 40L at a pressure of 1 atm. Calculate the volume when the balloon rises to an altitude where the pressure is 0.2 atm, assuming the temperature remains constant.

Complete questions 8-11 on page 430.

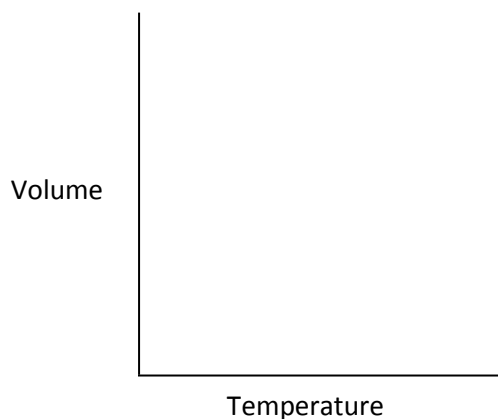
### Charles' Law

Load the following website:

<http://www.grc.nasa.gov/WWW/K-12/airplane/Animation/frglab2.html>

### Volume and Temperature (constant pressure and amount (mole) of gas)

- In the box on the left, freeze mass and pressure
- Choose "Effect of Changing Temperature on Volume"
- Observe the movement of the line graph.
- Record your observation on the graph below.



What do you observe happens to the volume as the temperature changes?

\_\_\_\_\_  
\_\_\_\_\_

This relationship is known as \_\_\_\_\_.

The volume of a fixed amount of gas is directly \_\_\_\_\_ to the **kelvin temperature**, provided the pressure remains constant. That is, as the temperature increases the volume \_\_\_\_\_ or as the temperature decreases the volume \_\_\_\_\_.

\_\_\_\_\_ temperature is another temperature scale like the Fahrenheit scale. However it is a bit different as there can be no negative values, like there are in the Celsius and Fahrenheit scale.

The temperature 0 K (-273°C) is the theoretically lowest value and at this value all molecules have no kinetic energy. 0 K is described as \_\_\_\_\_.

Kelvin temperature (K):  $K = ^\circ C + 273$

The relationship between volume and temperature can be expressed as:

$$V \propto T$$
$$\frac{V}{T} = b, \text{ where } b \text{ is a constant}$$
$$\therefore \frac{V_1}{T_1} = b = \frac{V_2}{T_2}$$
$$=$$

Where  $V_1$  is the volume of a fixed amount of gas at \_\_\_\_\_ temperature of  $T_1$ .

### Sample question

A balloon, inflated outside on a hot day when the temperature is 40°C, has a volume of 5.0 L. What would the volume of the balloon be when it is placed in a cool store at 5°C, assuming the pressure remains constant.

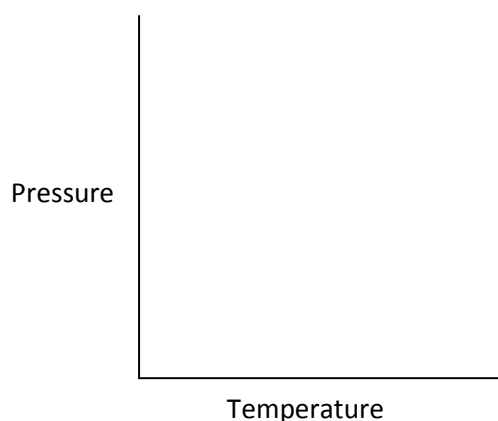
## Pressure – Temperature Changes

Load the following website:

<http://www.grc.nasa.gov/WWW/K-12/airplane/Animation/frglab2.html>

### Pressure and Temperature (constant volume and amount (mole) of gas)

- In the box on the left, freeze mass and volume
- Choose “Effect of Changing Temperature on Pressure
- Observe the movement of the line graph.
- Record your observation on the graph below.



What do you observe happens to the pressure as the temperature changes?

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The pressure of a fixed amount of gas is directly \_\_\_\_\_ to the **kelvin** temperature, provided the volume remains constant. That is, as the temperature increases the pressure \_\_\_\_\_ or as the temperature decreases the pressure \_\_\_\_\_ .

This relation is an adaptation of \_\_\_\_\_ law.

The relationship between volume and pressure can be expressed as:

$$P \propto T$$

$$\frac{P}{T} = c, \text{ where } c \text{ is a constant}$$

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

=

### Sample question

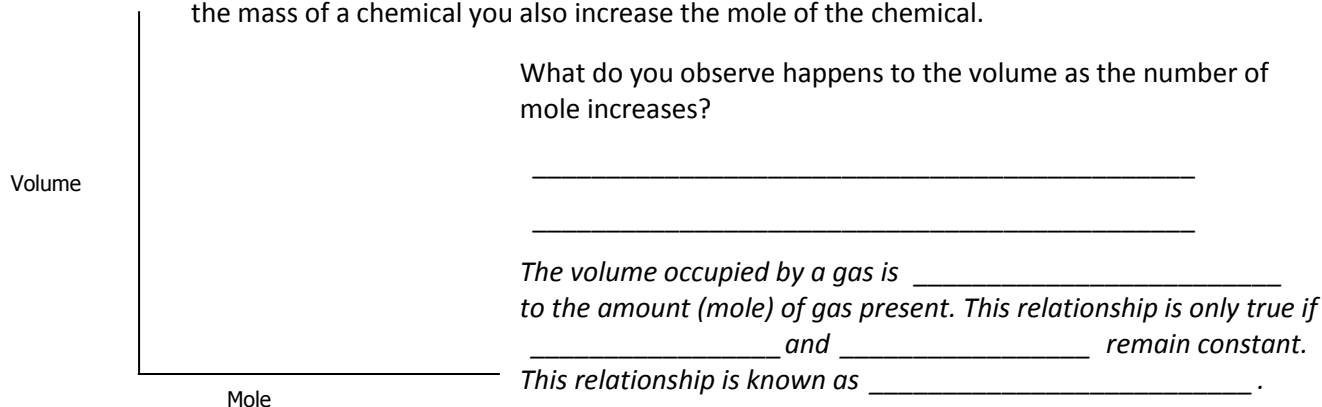
On a 25°C day before leaving for a 180 km ride a cyclist pumps his tyres to a pressure of 30 psi. At the end of the ride the cyclist measure the temperature to be 40°C. Determine the new pressure of the tyre.

Complete questions 13 -15 on page 433 and question 17 on page 434

## Avogadro's Law

### Amount (mole) of gas and volume (constant pressure and temperature)

- Reset the conditions in the left-hand side panel.
- Freeze temperature and pressure this time.
- Observe the movement of the line graph.
- Record your observations in the graph below. Replace mass with mole as if you increase the mass of a chemical you also increase the mole of the chemical.



This relationship can be expressed as:

$$V \propto n$$

or  $V = an$ , where  $a$  is a constant

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

### Samples questions

A 0.10 mol sample of oxygen occupies 2.0 L. What volume would be occupied by 0.25 mol of oxygen? Both samples are at the same temperature and pressure.

A balloon contains 0.35 mol of helium and has a volume of 5.3 L at a certain temperature and pressure. A further 0.12 mol of helium is added, the temperature and pressure being kept constant. Calculate the new volume of the balloon.

A cylinder, volume 20 000 L, contains methane. A second cylinder, volume 500 L, contains 40 mol of methane. Both gas samples are at the same temperature and pressure. Calculate:

- the amount of methane in the first cylinder.
- the mass of methane in the first cylinder.

Fill in the chart below with your observations and collected data. Under "Law" record the name of the law. Under "Constant" record what variables are kept constant. Under "Proportionality", record whether the two changing variables are directly or inversely proportional. Under "Graph", sketch the shape of the graph created by these two variables (you do not need to add numbers).

Variables	Law	Constant	Proportionality	Graph
Pressure and Volume				
Volume and Temperature				
Pressure and Temperature				
Amount (mole) of gas and Volume				

### Combined Gas Equation

If we consider all the equations and relationships we have looked at so far:

**Boyle's Law:**  $V_1P_1 = V_2P_2$

**Charles' Law:**  $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

**Pressure-Temperature Change:**  $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

**Avogadro's Law:**  $\frac{V_1}{n_1} = \frac{V_2}{n_2}$

These gas laws can be combined to give:

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

This relationship is useful because in realistic cases variables such as \_\_\_\_\_, \_\_\_\_\_, \_\_\_\_\_ and \_\_\_\_\_ will change.

In this relationship \_\_\_\_\_ is always measured in \_\_\_\_\_ and the \_\_\_\_\_ is always measured in \_\_\_\_\_. The units for volume and pressure can vary as long as they are the same for  $P_1$  and  $P_2$  and  $V_1$  and  $V_2$ .

### Sample questions

A 0.25 mol sample of gas in a 10.0 L cylinder exerts a pressure of 100 kPa at 208°C. A second cylinder, volume 15 L, contains gas at a temperature of 100°C and a pressure of 120 kPa. What is the amount of gas in the second container?

A gas exerts a pressure of 2.0 atm, at 30°C in a 10.0 L container. In what size would the same amount of gas exert a pressure of 4.0 atm at 20°C?

Calculate the molar volume of an ideal gas at -10°C and 90.0 kPa. Molar volume at STC (25°C and 101.1 kPa) is 24.5 L mol<sup>-1</sup>.

### Complete questions 18 – 20 on page 435

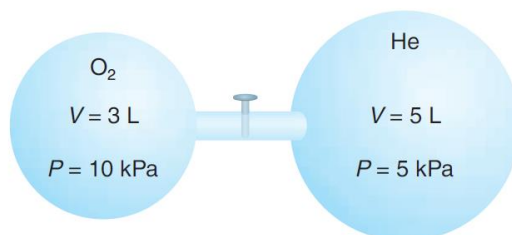
#### Partial Pressures – Dalton's Law

Dalton's Law of partial pressures states that, at constant temperature and volume, the \_\_\_\_\_ pressure exerted by a mixture of gases is \_\_\_\_\_ to the sum of all the \_\_\_\_\_ pressures of the constituent gases.

$$P_{total} = P_1 + P_2 + P_3 + \dots$$

where  $P_1, P_2, P_3$ , etc. represent the partial pressures exerted by the constituent gases.

Dalton's Law of partial pressures holds true because the pressure exerted by each gas is irrespective of the pressure exerted by the other gas particles in the mixture.



#### Sample question

If the valve in the above figure determine the total pressure in the connected spheres.

### Complete questions 21 and 22 on page 437 and questions 23 and 24 on page 438

## Molar Volume of a Gas

If we take **1 mole** of any gas at a given temperature and pressure it will have a set volume, this set volume is defined as the \_\_\_\_\_. This relationship can be expressed as:

$$n = \frac{V}{V_m} \text{ (at a given temperature and pressure)}$$

As there are so many possible variations of temperature and pressure, scientists for convenience sake, have determined the molar volume (the volume occupied by 1 mole of gas) of gases at 2 different conditions. These are the \_\_\_\_\_ and \_\_\_\_\_.

**Standard laboratory conditions (SLC):** the temperature is 25°C (298 K) and 101.3 kPa (this closely mimics the conditions of this room). The molar volume of SLC is \_\_\_\_\_.

**Standard temperature and pressure (STP):** the temperature is 0°C (273 K) and 101.3 kPa. The molar volume of STP is \_\_\_\_\_.

To try and remember these values SLC has the higher value because at a higher temperature the gas molecules have more kinetic energy and therefore will bounce around more causing the volume to expand.

### Sample questions

*Calculate the amount of nitrogen gas in a volume of 6.1 L measured at SLC.*

*Determine the volume occupied by 16.0 g of oxygen gas (O<sub>2</sub>) at SLC.*

**Complete questions 25 – 29 on page 441.**

## General Gas Equation

If we consider Boyle's, Charles' and Avogadro's Law

**Boyle's Law:**  $V = \frac{k}{P}$

**Charles' Law:**  $V = bT$

**Avogadro's Law:**  $V = an$

They can be combined to form the **general gas equation**

$$V = R \left( \frac{nT}{P} \right)$$

where  $R = k \times b \times a$

In the **general gas equation** R is referred to as the \_\_\_\_\_.

This constant as being determined experimentally and has found to be:

$$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$$

Therefore the general gas equation becomes:

$$V = nRT$$

or

$$PV = nRT$$

For the value of  $8.31 \text{ J K}^{-1} \text{ mol}^{-1}$  to be true,

- P is measured in \_\_\_\_\_
- V is measured in \_\_\_\_\_
- n is measured in \_\_\_\_\_
- T is measured on the \_\_\_\_\_

Gases which obey this equation are called \_\_\_\_\_. Generally speaking only gases at \_\_\_\_\_ and \_\_\_\_\_ obey this equation.

### Sample questions

Calculate the amount of oxygen gas ( $O_2$ ) in a cylinder of 30 L, if the pressure is 20 atm at  $30^\circ\text{C}$ .

At what temperature would 3.2 g of helium occupy a volume of 25 L at a pressure of 700 mmHg?

Calculate the mass of helium in a balloon if the volume is 100 L at a pressure of 95 000 Pa and a temperature of  $0^\circ\text{C}$

**Complete questions 30-33 on page 443**