Gas laws

You have already covered the basics of gases in your research project

The aim of this worksheet is to, once again, reinforce the basics, build on that foundation and to look at the more complex questions in this section

The first part of every law are the questions that were done in the research project – with all working shown

To stay on track: The gases worksheets should take you one week to complete.

At the end of the week the memo's to the exam question given on the last worksheet will be sent.

Instructions

Round off all values to 2 decimal places, unless otherwise stated

Don't leave any spaces between answer values and units

Pressure and volume

DEFINITION: *Boyle's Law*

The pressure of a fixed quantity of gas is inversely proportional to the volume it occupies so long as the temperature remains constant.

2. Boyle's law explains the relationship between the pressure and volume for a fixed amount of gas.

In the diagram above a fixed amount (mol) of gas is trapped in a gas syringe.

The syringe is then pulled out and the volume inside increases.

- As the volume of the syringe increases the pressure on the gas will decrease.
- Write the mathematical relationship between volume and pressure.
- $p \propto \frac{1}{V}$
- The SI unit for volume is cm^3 but dm^3 is accepted
- The SI unit for pressure is Pa

The volume of the syringe is now decreased and the volume and pressure readings are recorded.

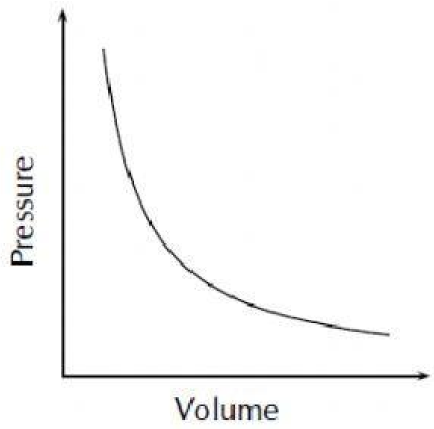
Volume(V) of syringe cm^3	pressure(p) in kPa	p x V (rounded off to the nearest integer)	$\frac{1}{p}$
35	128,5	4500	$\frac{1}{128,5} = 7,8 \times 10^{-3}$
25	180	4500	$5,56 \times 10^{-3}$
20,5	220	4510	$4,55 \times 10^{-3}$
15,0	300	4500	$3,33 \times 10^{-3}$

2.8 What do you notice about the third column (the product of p and v)?

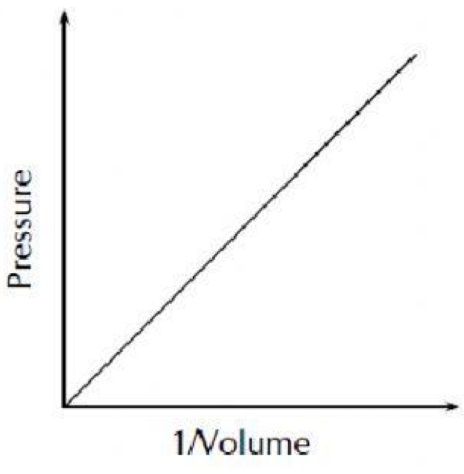
We can thus say that the relationship between p and V is a constant.

Thus $p_1.V_1 = p_2.V_2$

Draw the following graphs using the values in the table below



Thus V is inversely proportional to p.



Thus V is directly proportional to $\frac{1}{p}$.

The two constant variables in the experiment are:

Temperature and mol of gas

This practical was originally performed by Robert Boyle using the following apparatus, now referred to as Boyle's apparatus.

A sample of dry air is confined in a tall, wide glass tube by a piston of oil. The volume is found from the length of the air column, which should be clearly visible at the back of the class.

The pressure is read from a Bourdon gauge connected to the air over the oil reservoir. This is calibrated to read absolute pressure and is also visible from the back of the class.

The foot pump is attached to the oil reservoir and is used to change the pressure. The gauge reads up to 3×10^5 N m^{-2} and the pressure can safely be taken up to this value but must not be taken beyond.

Useful links:

http://scienceprimer.com/boyles-law

https://phet.colorado.edu/en/simulation/legacy/gas-properties

Calculations using boyle's law:

Examples:

300 cm^3 of Helium gas under a pressure of 200 kPa is compressed to occupy 10 cm^3. Calculate at what pressure this will be (assuming the temperature remains constant).

$p_1.V_1 = p_2.V_2$ $(300)(200) = 10.P_2$ $P_2 = 6000$ kPa $= 6000000$ Pa	Or $p_1.V_1 = p_2.V_2$ $(0{,}3)(200\,000) = 0{,}01.P_2$ $P_2 = 60000000$ Pa *you do not have to convert each unit, however the final answer will be in the unit of your initial value. For example if you leave pressure in kilopascal, then your answer will be in kilopascal.

The video below demonstrates how to use the Boyle's Law apparatus

Ensure that you watch this as the experiment itself is examinable

Your questions from the research project (working shown):

1. 250 cm^3 of Nitrogen gas under a pressure of 100 kPa is compressed to occupy 17 cm^3. Calculate at what pressure this will be (assuming the temperature remains constant)

$p_1.V_1 = p_2.V_2$

$(100\ 000)(250) = p_2(17)$

$\frac{(100\ 000)(250)}{17} = \frac{p2(17)}{17}$

P_2 = 1,47 x 106 Pa or 1470588,24 Pa

2. The pressure in a system is increased from 2000 Pa to 4000 Pa. If the original volume was 400 cm^3, calculate the volume at the new pressure.

$p_1.V_1 = p_2.V_2$

$(2000)(400) = (4000)(V_2)$

$\frac{(2000)(400)}{4000} = \frac{(4000)(V2)}{4000}$

V_2 = 200 cm^3 or 0,2 dm^3

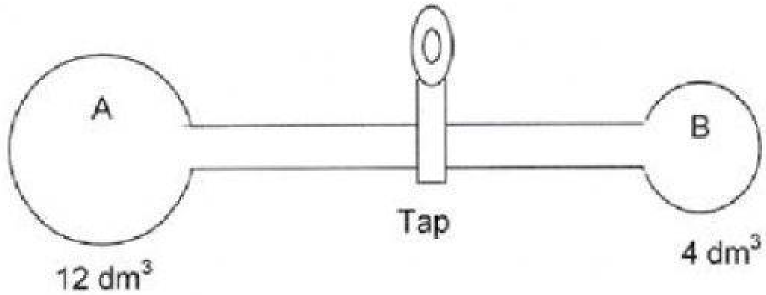
For the final answers use the following units as the SI units

(and type them as they are given below)

Formula used	Variable	SI unit
$p_1.V_1 = p_2.V_2$ $\frac{p1}{T1} = \frac{p2}{T2}$ $\frac{V1}{T1} = \frac{V2}{T2}$ $\frac{P1.V1}{T1} = \frac{P2.V2}{T2}$	Pressure Volume Temperature	Pa dm^3 K
pV = nRT	Pressure Volume Mol Gas constant Temperature	Pa m^3 mol 8,31 K
m = n.M	Mass Moles Molar mass	g mol g.mol-1

Exam questions

Two gas spheres, A and B, of volumes $12dm^3$ and $4\ dm^3$ respectively, are connected by a glass tube and a closed tap.



The pressure in A is recorded as 250 kPa, whilst B does not contain any gas. Both spheres are maintained at 27 °C.
The tap is now opened. (Ignore the volume of the connecting tube)

1.1 Calculate the new pressure of the gas at 27 °C.

Choose the appropriate formula to use

1.1 $p_1.V_1 = p_2.V_2$

$$\frac{p1}{T1} = \frac{p2}{T2}$$

$$\frac{V1}{T1} = \frac{V2}{T2}$$

$$\frac{P1.V1}{T1} = \frac{P2.V2}{T2}$$

pV = nRT

Then type the final answer = {in the correct SI unit and using decimal notation)

1.2 How will the pressure of the gas sphere A compare to that in sphere B (once the valve is opened)?

Greater than

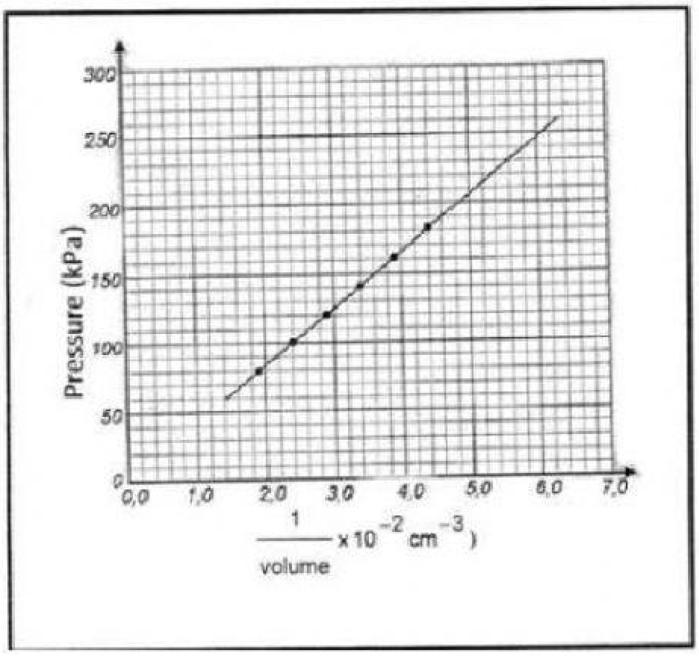
Less than

Equal to

Question 2

An experiment was carried out to investigate the relationship between the pressure exerted by a sample of air and the volume of the air.

The following graph of Pressure (kPa) versus $\frac{1}{\text{Volume}}$ (cm^{-3}) for the air taken at 25 °C was drawn.



2.1 For this investigation, write down the following:

2.1.1 The **TWO** controlled variables

2.1.2 The dependent variable

2.1.3 The conclusion/s that can be drawn from the graph is:

Pressure is directly proportional to volume

Pressure is inversely proportional to volume

Pressure is indirectly proportional to volume

Pressure is directly proportional to $\frac{1}{V}$

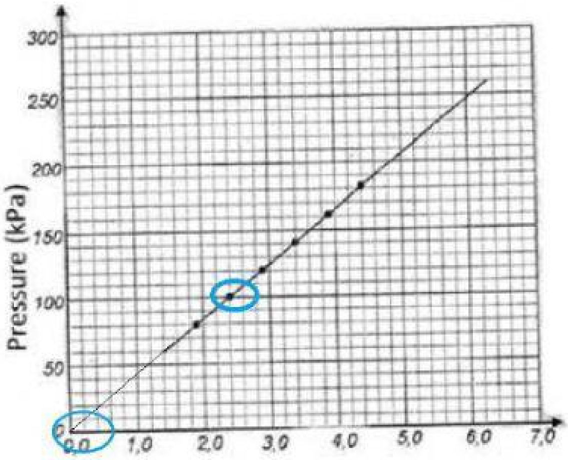
Pressure is inversely proportional to $\frac{1}{V}$

2.1.4 State the gas law that has been verified

2.2 Calculate the gradient of the graph

Gradient =

Choose two points that are clear on the graph



2.3 What does the gradient represent

2.4 Using data from the graph, calculate the number of moles of gas that was used in this investigation.

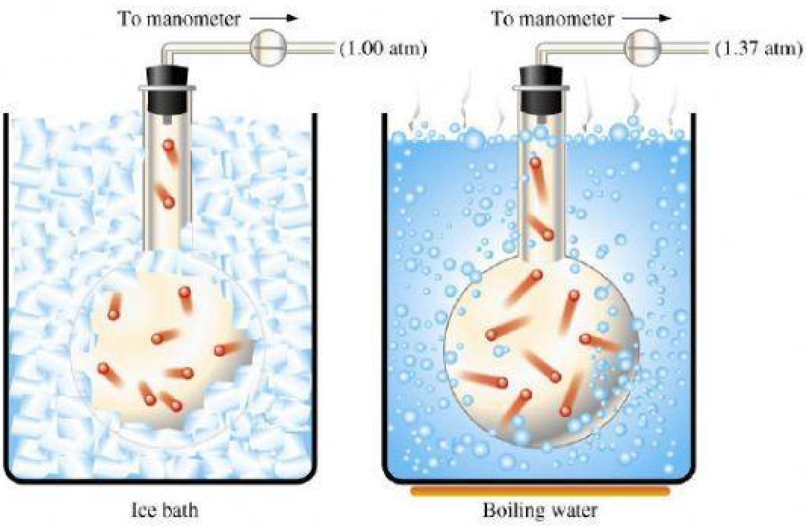
2.5 If this investigation was carried out at a higher temperature, describe what would happen to the gradient of the graph.

The gradient would be steeper

The gradient would be less steep

Temperature and pressure

Gay Lussac's Law: The pressure of a gas is directly proportional to its temperature in kelvin at constant volume.



Watch the video of Gay-Lussac's law below (however remember that we always leave our pressure in Pa at the end ☺)