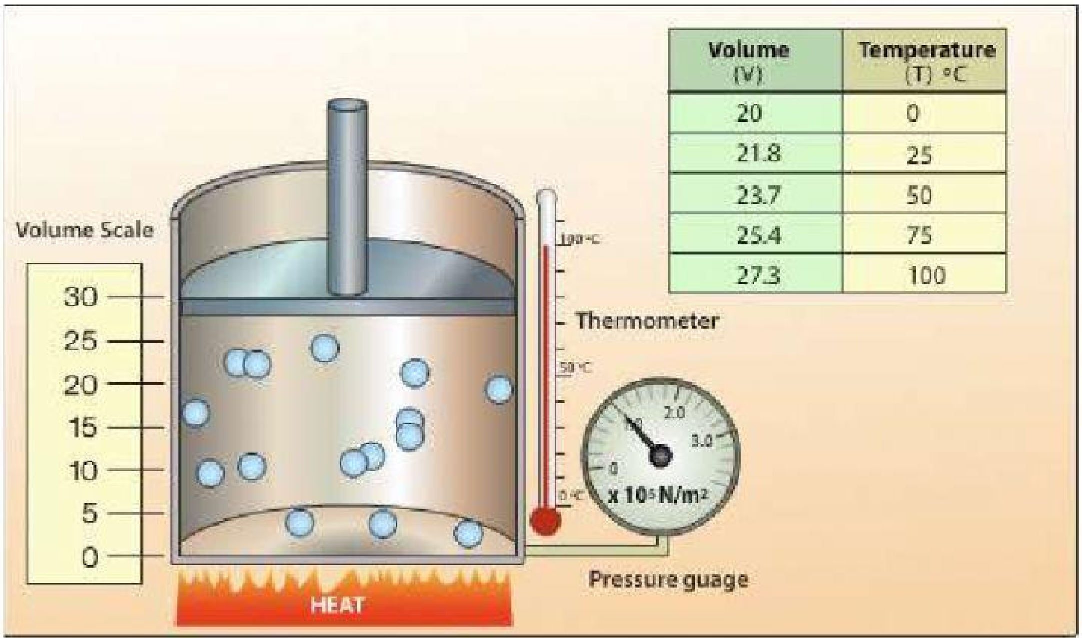
Temperature and volume: Charles' Law

Charles' Law: The temperature of an enclosed gas is directly proportional to the volume it occupies at constant pressure.

4.1 As the temperature of the gaseous deodorant increases, it will expand and the can could explode.



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

The container is then heated.

4.2 As the temperature of the gas increases, the volume of the gas inside will also increase.

4.3 Temperature is thus directly proportional to volume.

4.4 V α T

4.5 Stated above

4.6 The pressure and no of moles of gas are the constant variables.

4.7 The SI unit for volume is m^3 but dm^3 is accepted

4.8

Temp (t) in °C	Temp (T) in Kelvin	V (cm^3)	$\frac{V}{T}$
0	273	20	0,07
25	298	21,8	0,07
50	323	23,7	0,07
75	348	25,4	0,07
100	373	27,3	0,07

4.9 What do you notice about the third column (the ratio of $\frac{V}{T}$):

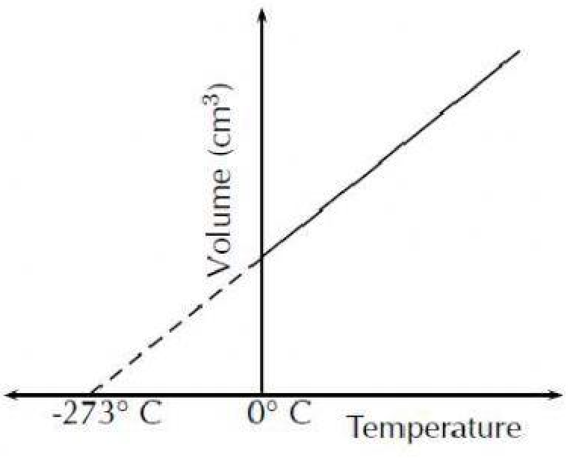
it is a constant value

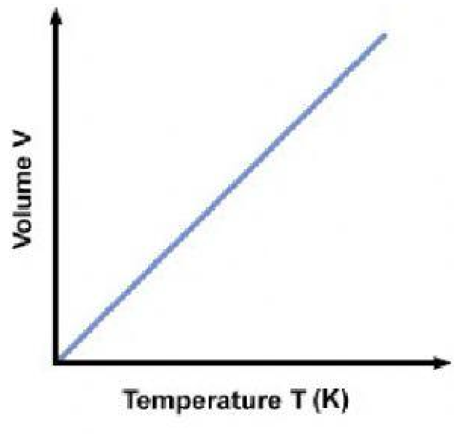
We can thus say that the ratio of $\frac{V}{T}$ stays constant

Thus

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

4.10 Graph:





Examples: The temperature on a fixed amount of gas which occupies a volume of 20 cm^3 is increased from 20 °C to 200 °C. Calculate the new volume which the gas will occupy.

$\frac{V1}{T1} = \frac{V2}{T2}$ $\frac{0,02}{293} = \frac{V2}{473}$ $V_2 =$ 0,03 dm^3

Your questions:

4.11 In a tube containing a bead of mercury trapping a fixed mass of gas, the volume is 0,11 cm^3 at 27°C. To what temperature must the gas be heated at constant pressure so as to have a volume of 0,165 cm^3?

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

$$\frac{0,11}{27+273} = \frac{0,165}{T2}$$

Cross multiply first

0,11(T2) = 49,5

$$\frac{0,11(T2)}{0,11} = \frac{49,5}{0,11}$$

Then divide by the number with T_2 on both sides

T_2 = 450 K

4.12 A balloon, filled with air at 27°C was placed in the sun. Assuming that the pressure remained constant find at what temperature the volume would be 12% greater than the original volume.

When a question like this is asked choose the V1 as 100, then it is very easy to calculate the extra 12% for V2   (100 x12% = 12)   Thus V2 = 112

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

$$\frac{100}{27+273} = \frac{112}{T2}$$

Cross multiply first

100(T2) = 33600

$$\frac{100(T2)}{100} = \frac{33600}{100}$$

Then divide by 100 on both sides

T2 = 336 K

Watch the video example below of **Charles' Law**:

General gas equation

Now put all 3 formulae together :

$p_1.V_1 = p_2.V_2$

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

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

And make one big equation, called the **general gas equation**.

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

Watch the video example below of the general gas equation below

Examples:

250 cm^3 of hydrogen gas is at a temperature of 21°C and at a pressure if 180 kPa. Calculate the volume of hydrogen if the temperature is raised to 67°C and the pressure is decreased to 80 kPa.

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

$$\frac{180\ 000(0{,}25)}{(21+273)} = \frac{80\ 000.V2}{(67+273)}$$

$15300000 = 23520000V_2$

$V_2 = 0{,}65\ dm^3$

Your questions:

5.1 The pressure in a car tyre is 2,1 x 10^5 Pa at 27°C. If the temperature increased to 57°C while the volume of the tyre decreased by 5%, calculate the new pressure of the air in the tyre.

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

When a question like this is asked choose the V1 as 100, then it is very easy to calculate the 5% less for V2

(100 x5% = 5)

Thus V2 = 100 – 5

= 95

$$\frac{2.1x10^5(100)}{(27+27\ \ )} = \frac{P2.(95)}{(57+273)}$$

*cross multiply first

6,93 x 10^9= 2,85 x 10^4(P2)

Then divide by 2,85 x 10^4 on both sides

P2 = 243157,89 Pa or 2,43 x 10^5Pa

5.2 The pressure of a system is doubled. The temperature changes from 21°C to 47°C and the original volume was $10m^3$. Calculate the final volume if the original pressure was 1 atmosphere.

When choosing the volume to use – just choose V1 as $100dm^3$

Then V2 would be double and thus $200dm^3$

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

The SI unit is either cm^3 or dm^3

dm^3 might be easier since that is also the SI unit in the mole

$$\frac{(100)(10)}{(21+273)} = \frac{(200)(v2)}{(47+273)}$$

320000= 58800V2

V2 = 5,44 m^3

V2 = 5,44 x 10^3

= 5440 dm^3

Exam questions

Oxygen gas occupies a volume of 500 cm^3 at a temperature of 27° C and a pressure of 100 kPa. The gas is heated to 70° C and the pressure of the gas increases to 200 kPa.

1.1 Calculate the new volume that the oxygen gas will occupy at a temperature of 70° C.

V_2 =