62 The General Gas Law ♡

Experiments have taught us…

Law	For fixed	In words	Formula
Boyle	Temp.	Halving volume doubles pressure	$pV = k_1$
Pressure	Vol.	Doubling temperature doubles pressure	$p = k_2 T$
Charles	Press.	Doubling temperature doubles volume	$V = k_3 T$

k_1, k_2 and k_3 are constants. The value of k_1, k_2, k_3 would depend on the control variable and the amount of gas in the experiment.

We must use the Kelvin scale so that zero (0 K) is the temperature of absolute zero. Temperature (K) = Temperature (°C) +273.

If you combine the three rules, you get

$$\text{pressure} \times \text{volume} = \text{constant} \times \text{temperature} \qquad pV = \text{const.} \times T$$

$$\Rightarrow \frac{\text{pressure} \times \text{volume}}{\text{temperature}} = \text{constant} \qquad \frac{pV}{T} = \text{const.}$$

Given that the constant must be the same before and after the process (as long as no gas leaks),

$$\frac{p_{\text{after}} V_{\text{after}}}{T_{\text{after}}} = \frac{p_{\text{before}} V_{\text{before}}}{T_{\text{before}}},$$

where T must be in kelvins.

Example – If I start with 10 cm^3 of gas at 20°C at a pressure of 101 kPa and heat it to 100 °C, what will the new pressure be if I let it expand to 12 cm^3?

1st stage: convert the temperatures to kelvins.

$$20\,^\circ\text{C} + 273 = 293\ \text{K} \qquad 100\,^\circ\text{C} + 273 = 373\ \text{K}$$

2nd stage: put the numbers into the equation.

$$\frac{p_{\text{after}} \times 12\ \text{cm}^3}{373\ \text{K}} = \frac{101\ \text{kPa} \times 10\ \text{cm}^3}{293\ \text{K}}$$

3rd stage: rearrange the equation so that the thing you want to know is the subject, and calculate it.

$$p_{\text{after}} = 101\ \text{kPa} \times \frac{10 \times 373}{12 \times 293} = 107\ \text{kPa}$$

4th stage: put the temperatures back in °C if necessary (not needed here).

62.1 I start with 5.0 cm^3 of gas at 30 °C at a pressure of 101 kPa and heat it to 200 °C. What will the new pressure be if I also compress it to 3.0 cm^3?

62.2 Work out the missing measurements from the following table.

p_{before}	V_{before}	T_{before}	p_{after}	V_{after}	T_{after}
101 kPa	200 cm^3	300 K	(a)	300 cm^3	600 K
101 kPa	150 cm^3	−23 °C	505 kPa	(b)	500 °C
10.1 kPa	24 cm^3	(c)	101 kPa	48 cm^3	300 K
5.0 kPa	(d)	−183 °C	50 kPa	2 000 cm^3	23 °C

62.3 I start with 24 L of air at room temperature, 20 °C, and pressure, 101 kPa. Calculate the new volume if:

(a) I raise the temperature to 303 K and compress it to 202 kPa;

(b) I raise the temperature to 600 K and let it expand to 80 kPa;

(c) I cool it to −120 °C and compress it to 303 kPa;

(d) I quarter its pressure and its Kelvin temperature;

(e) I heat it to 1100 K and compress it to 1.50 MPa.

62.4 The gas in a 0.020 m^3 cylinder is stored at 80 bar (1 bar $= 10^5$ Pa). It starts at 290 K. The valve is opened until the gas pressure has equalized with the atmosphere (1.01 bar). Assume that all of the gas is now at 280 K. How much volume does it take up?

62.5 I begin cycling with the air in my tyres at 270 kPa and 285 K. Some time later, the air has warmed to 330 K, and the volume has increased by 3%. What is the new pressure?

62.6 A gas bubble of volume 3.0 cm^3 forms at the bottom of a loch where the pressure is 3.0 atmospheres and the temperature 4.0 °C. What is its volume on reaching the surface where the water temperature is 13 °C?

62.7 The pressure in a flexible plastic flask is $1\,000$ kPa when its volume is 500 cm^3 and its temperature is 10 °C. What would the pressure become if the gas volume was reduced to 400 cm^3 and it was heated to a temperature of 90 °C?

62.8 A syringe contains 100 cm^3 of a gas at 20 °C and its pressure is 1.0 atmosphere. Calculate the volume occupied by the gas if the pressure is increased to 1.5 atmospheres and the temperature becomes 240 °C.

62.9 A gas of volume 500 cm^3 is initially at a pressure of 1.0 Atm and temperature of 17 °C. Its pressure is then increased to 1.5 Atm and its volume decreased to 400 cm^3. What is the resulting temperature of the gas?

62.10 The gas in a spherical balloon is initially at 17 °C. The temperature of the gas increases so that the pressure increases by 2% and the radius of the balloon increases by 4%. What is the new temperature of the gas (in celsius)?