61 Charles' Law ♡

In this situation, the pressure is fixed (we use a container with a free-running piston). The gas is heated, and the volume increases.

As the temperature of the gas goes up, the average speed and kinetic energy of the molecules increases. This means that each time a molecule strikes the wall, its velocity change is larger, so the force on the wall is bigger.

However if the container expands, each molecule strikes the wall less often, leading to the same pressure as before.

The equation is

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

where T must be in kelvins.

Example – If I start with 30.0 cm^3 gas at $20.0\,^\circ$C and heat it up to $100\,^\circ$C, what will the new volume be if I don't let the pressure build up?

1st stage: convert the temperatures to kelvins.

$$20.0\,^\circ\text{C} + 273 = 293\text{ K} \qquad 100\,^\circ\text{C} + 273 = 373\text{ K}$$

2nd stage: put the numbers into the equation.

$$\frac{V_{\text{after}}}{373\text{ K}} = \frac{30.0\text{ cm}^3}{293\text{ K}}$$

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

$$V_{\text{after}} = 30.0\text{ cm}^3 \times \frac{373}{293} = 38.2\text{ cm}^3$$

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

61.1 I start with 20 cm^3 gas at 30 °C and heat it to 200 °C. What will the new volume be if I don't let the pressure build up?

61.2 I start with 50 cm^3 gas at −20 °C and heat it until the volume is 100 cm^3 without letting the pressure build up. What will the new temperature be?

61.3 You want to store 150 litres of gas in a cylinder which only has room for 100 litres. You can do this by reducing the temperature. The 150 litres was measured at 15.0 °C. How cold will you have to make it in order that it will fit in the cylinder at the same pressure?

61.4 Work out the missing measurements from the following table, where each row is a separate question.

V_{before}	T_{before}	V_{after}	T_{after}
200 cm^3	300 K	(a)	600 K
200 cm^3	−23.0 °C	1000 cm^3	(b)
20.0 cm^3	(c)	200 cm^3	300 K
(d)	−183 °C	10.0 cm^3	23.0 °C

61.5 A gas thermometer is made of a narrow cylinder closed at one end, with a fixed mass of gas inside, and a tight-fitting yet low-friction piston at the other end. The piston moves to ensure that the contained gas is always at atmospheric pressure. The cylinder contains helium gas, occupying a length of 134.6 cm when at 22.4 °C.

(a) How long is the gas column when the temperature is −20.0 °C?

(b) How long is the gas column at −183 °C (oxygen boiling point)?

(c) How long is the gas column at 77 K (nitrogen boiling point)?

(d) How far will the piston move when the temperature changes by 1.00 °C?

(e) How far will the piston move if the temperature rises from 22.4 °C to 41.7 °C?