Problem 2: A little gas

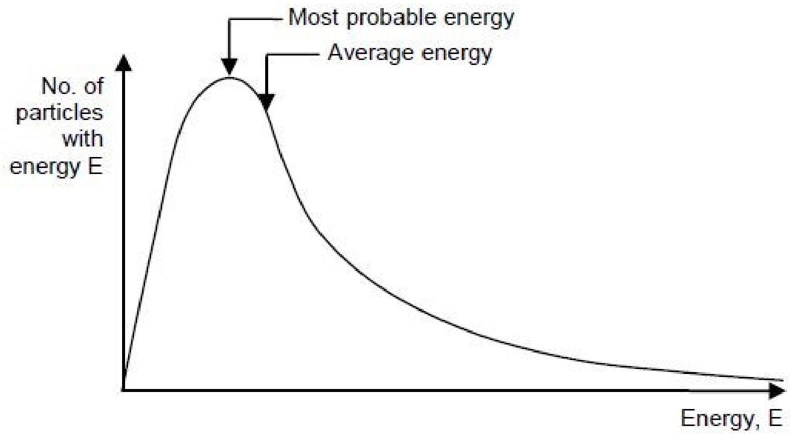
Teacher and technician pack

Pre-Lab answers

1. In an ideal gas, the following assumptions must be true;
   - The volume occupied by the particles is neglible relative to the volume of the container
   - The forces between the gas particles are neglible

In addition, in an ideal gas it is assumed that;
   - The particles behave as rigid spheres
   - Gases are made up of particles which are in constant random motion in straight lines
   - All collisions (particle-particle and particle-container) are perfectly elastic (there is no loss of kinetic energy during the collision)
   - The pressure of the system is a result of collisions between the particles and the walls of the container
   - The temperature of the gas is proportional to the average kinetic energy of the particles

2. a)



b) i.

Average speed, $\upsilon = \sqrt{\frac{8\,RT}{\pi\,M}}$

υ = Average speed, m s^{-1}
R = Ideal gas constant, 8.314 J K^{-1} mol^{-1}
T = Temperature, K
M = molar mass, **kg** mol^{-1}

ii.

Most probable speed, $\upsilon_p = \sqrt{\frac{2\,RT}{M}}$

υ_p = Most probable speed, m s^{-1}
R = Ideal gas constant, 8.314 J K^{-1} mol^{-1}
T = Temperature, K
M = molar mass, kg mol^{-1}

3.

$$\upsilon = \sqrt{\frac{8\,R}{\pi\,M}} \times \sqrt{T}$$

$\therefore$ A plot of υ (y-axis) against $\sqrt{T}$ (x-axis) would give a straight line with gradient $\sqrt{\frac{8\,R}{\pi\,M}}$. Using this gradient a value for the molar mass of the gas, *M* can be calculated.

Equipment list

Each group will need;
Access to the internet
Or
Access to a computer on which the Gas Properties simulation has been downloaded and saved

At the time of going to print, the URL for the PhET Gas Properties Simulation is;

http://phet.colorado.edu/en/simulation/gas-properties

Proposed method

Click on <Species Information> within Measurement tools for Ave. Speed data

Tools & Options

Measurement Tools >>

Advanced Options >>

Reset

Theory

Using the pre-lab questions, students identify that a graph of Average Velocity *vs* √Temperature will give a straight line with gradient $\sqrt{\frac{8R}{\pi M}}$ from which the molar mass of each gas can be determined.

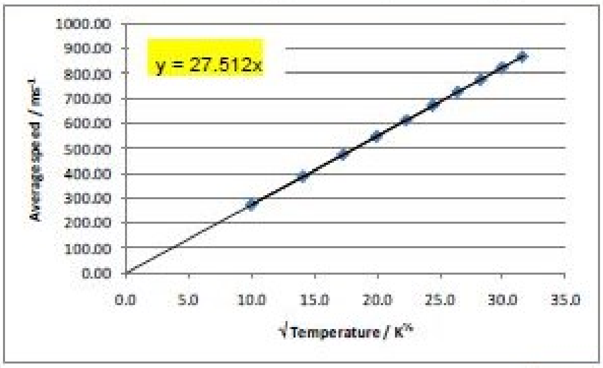
Gas in Chamber — Heavy Species: 1, Light Species: 0 *

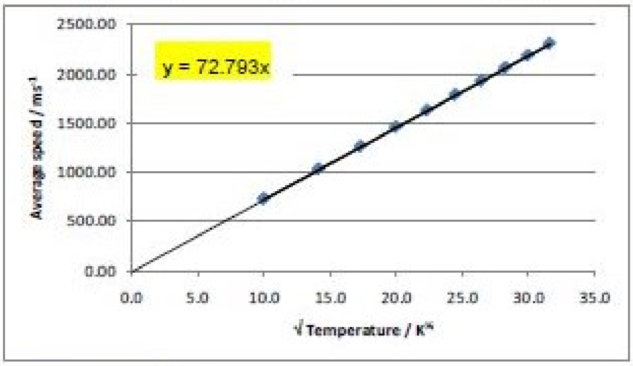
Constant Parameter: ○ Volume ○ Pressure ○ Temperature ⦿ None

Gas in Chamber — Heavy Species: 0, Light Species: 1

Temperature / K	√ Temperature / K½	Average speed / ms⁻¹
100	10.0	274.85
200	14.1	389.53
300	17.3	476.48
400	20.0	549.92
500	22.4	615.23
600	24.5	674.08
700	26.5	727.79
800	28.3	778.20
900	30.0	825.33
1000	31.6	869.97

Temperature / K	√ Temperature / K½	Average speed / ms⁻¹
100	10.0	727.43
200	14.1	1030.09
300	17.3	1260.64
400	20.0	1456.30
500	22.4	1626.97
600	24.5	1782.69
700	26.5	1925.87
800	28.3	2059.07
900	30.0	2183.93
1000	31.6	2302.17





Results

For the heavy gas;

$y = 27.5\,x$

$\therefore 27.5 = \sqrt{\frac{8R}{\pi M}} \quad \therefore 757 = \frac{8R}{\pi M}$

$\therefore M = 0.0279$ kg mol^{-1} or 27.9 g mol^{-1}

∴ The heavy gas is nitrogen, N_2

For the light gas;

$y = 72.8\,x$

$\therefore 72.8 = \sqrt{\frac{8R}{\pi M}} \quad \therefore 5298 = \frac{8R}{\pi M}$

$\therefore M = 3.99 \times 10^{-3}$ kg mol^{-1} or 3.99 g mol^{-1}

∴ The light gas is helium, He

The students may choose to investigate the speed of the gas particles when there is more than one particle in the system. If this is the case, a distribution of gas speeds is given and the gas behaviour is not ideal. The students will need to decide how best to record the distribution and interpret it.