Learn Chemistry

Problem Based Practical Activities

Problem 2: A little gas

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Problem 2:
A little gas

Curriculum links;
ideal gases, Maxwell-Boltzmann distribution, $y = mx + c$

Practical skills;
using computer simulations, graph plotting and interpretation

The students are contacted to write a review on the use of computer simulations in sixth form chemistry for the student chemistry magazine "The Mole". They are directed to a simulation on gas properties produced by PhET (University of Colorado at Boulder) and asked to use the simulation to determine the identity of the "light" and "heavy" gas used in the simulation.

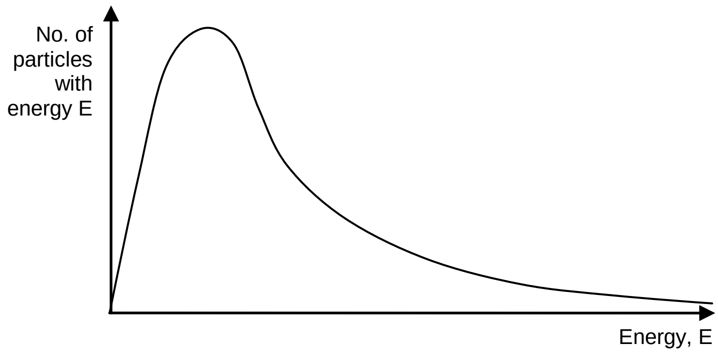
Problem 2: A little gas

Pre-Lab questions

(Remember to give full references for any information beyond A-level that you find out)

1. The Maxwell-Boltzmann distribution is used to describe the energies of particles in a gas at a certain point in time. It applies only to ideal gases. Describe the key assumptions that distinguish an ideal gas from a real gas.

2. The diagram opposite represents a Maxwell-Boltzmann distribution curve for the particles in a sample of gas at a certain temperature, T;



a) Indicate on the curve above an approximate value for;
   i. the most probable energy of a gas particle
   ii. the average energy of a gas particle in this system

b) The Kinetic Theory of Gases describes equations for calculating particle speeds based on their energies. Since there is a distribution of particle speeds in the system, scientists use different measures for the particle speed. Two such measures are the **average speed** of a gas particle and the **most probable speed** of a gas particle.

The **average speed** of a gas particle in a system is given by the equation;

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

   i. Define all the symbols in this equation including UNITS
   ii. A similar equation allows the **most probable speed** of a gas particle to be calculated. Define this equation.

3. In chemistry, many functions can be represented by a straight line graph of the type $y = mx + c$ where;
'x' and 'y' are the coordinates of the points that satisfy the function
'm' is the gradient of the straight line graph, and
'c' is the 'y intercept' of the straight line graph

In the equation for the **average speed** of a gas particle given in question 2 b), if you plotted a graph of $\sqrt{T}$ (x-axis) against the average speed, υ (y-axis), what value would the gradient of your graph be equal to?

Problem 2: A little gas

Introduction

The Mole

... FOR ANYONE INSPIRED TO DIG DEEPER INTO CHEMISTRY

RSC Publishing, Thomas Graham House, Cambridge

Dear sixth form student,

A large amount of experimental chemistry is performed using computer simulations. As part of an article on this topic for the Royal Society of Chemistry student magazine "*The Mole,*" I would like you to review an excellent simulation package on Gas Properties produced by PhET from the University of Colorado at Boulder. A quick internet search of <PhET simulation properties of gases> will take you to the simulation which can either be downloaded or run online.

When you first open the simulation I suggest you have a play and investigate the interactivity available. You will notice that you can either add a *light gas* or a *heavy gas* to the chamber. For the review, I would specifically like you to use the simulation to determine the identity of the light gas and the heavy gas by calculating their molecular masses. By doing this and showing your method and working, I hope that the review will give students a starting point for how the simulation can be used. This will help to draw the reader in. A few ideas following on from this for alternative investigations the reader can carry out will add depth to the article and turn it into an excellent review for either students or teachers.

For publication, the review will need to be no longer than 500 words in length and follow the Guidelines for Publication as detailed below;

- **Text** — All text is in the Calibri font, left aligned, black. Line spacing is 'exactly' 14 point. The magazine body text is in two columns but tips/did you know/interesting facts can be added in an out-side sidebar on each page
- **Headings** — All **Headings** are in the bold Calibri font, black
  MAIN CHAPTER HEADINGS are in capitals, bold, 13 point italic
  Sub headings are 11 point, lower case, bold
  Image captions are 9 point, lower case, bold, italic
- **Paragraphs** — Paragraphs are 11 point, regular
  Headings and paragraphs are followed by an extra six points

I look forward to receiving your reviews,

Many thanks,

Aysha Bhatti

Teacher and Technician Pack

Pre-Lab answers

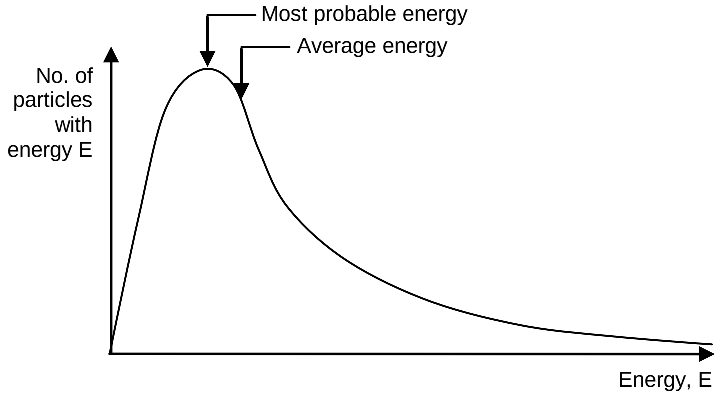
1. In an ideal gas, the following assumptions must be true;

- 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.

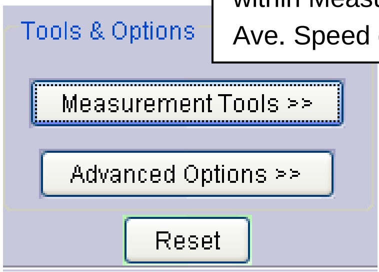
$$\upsilon = \sqrt{\frac{8\,R}{\pi\,M}} \times \sqrt{T}$$

$\therefore$ 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.

Proposed method

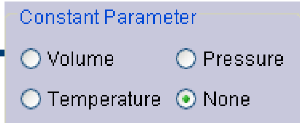
Theory

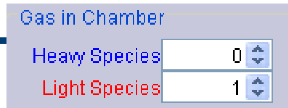
Using the pre-lab questions, students identify that a graph of Average Velocity *vs* √Temperature will give a straight line with gradient $\sqrt{\frac{8R}{\pi M}}$ from which the molar mass of each gas can be determined.



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

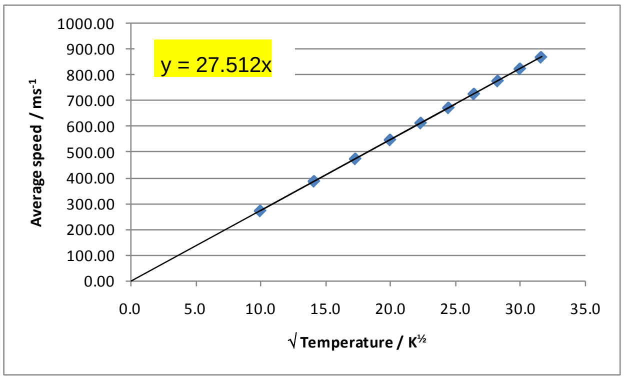
*

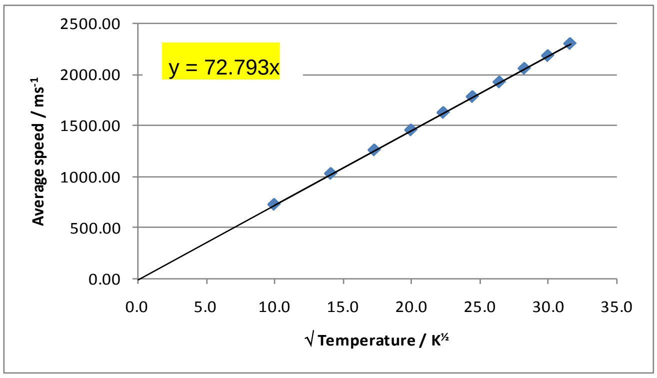




Temperature / K	√ Temperature / K½	Average speed / ms^{-1}
100	10.0	274.85
200	14.1	389.53
300	17.3	476.48
400	20.0	549.92
500	22.4	615.23
600	24.5	674.08
700	26.5	727.79
800	28.3	778.20
900	30.0	825.33
1000	31.6	869.97

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

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

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

∴ The heavy gas is nitrogen, N_2

For the light gas;

y = 72.8 x

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

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

∴ 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.

Teacher and Technician Pack

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

The simulation was created by;

PhET Interactive Simulations
University of Colorado
http://phet.colorado.edu.