Properties of Gases

by Ron Clarke

Experiment Overview

This experiment allows students to experience the behaviour of gases. In particular, students discover for themselves via the experiment the basis for the ideal gas law, i.e. that all gases have the same kinetic energy at a given temperature. Students also observe the effect of temperature on gas pressure and discover the effect of aqueous solubility of CO_2 on pH, i.e. the basis for the increasing acidity of the seas due to the buildup of CO_2 emissions in the atmosphere.

Learning Experience

Gases are all around us, but we generally neglect them because, except for noxious or pungent gases, we have little experience of them. The value of this experiment lies in the fact that students can directly experience the behaviour of gases.

Through measurements of the flow velocities of different gases the students discover that all gases have the same kinetic energy at a given temperature. Theoretically this is described by the equation $E_K = 3/2\ kT$, from the kinetic theory of gases due to Maxwell and Boltzmann, which underlies the ideal gas law $PV = nRT$. However, a major strength of the experiment is that it doesn't rely on any prior theoretical knowledge of the students. The students discover ideal gas behaviour directly through experimentation.

A second strength of the experiment is that it introduces the students to the idea of experimental uncertainty and error bars. Students can only conclude that the kinetic energies of all gases are within error the same if they have estimated the errors in their values of kinetic energy for each gas.

Finally, the experiment has an environmental aspect, in that it demonstrates to the students the effect that rising atmospheric CO_2 levels have of the acidity of the seas.

Aims and Objectives

The aims of the experiment are to investigate some of the properties of gases, i.e. how they flow, their phase changes and chemical reactivity.

Level of Experiment

First year undergraduate

Keyword Descriptions of the Experiment

Domain
gases, kinetic energy

Specific Descriptors
flow velocity, phase changes, ideal behaviour, pH, greenhouse effect

Course Context

No prior knowledge or skills necessary

Prerequisite Knowledge and Skills

No prior knowledge or skills necessary

Time Required to Complete

Prior to Lab: zero
In Laboratory: 3 hours
After Laboratory: zero

Experiment History

The experiment was run for the first time as a 1st year undergraduate experiment in 1st semester 2011, i.e. April-June. Prior to that, a previous version of the experiment had been running in the same laboratory for several years. The old version of the experiment was linked to lecture material and was based upon the ideal gas law, PV = nRT. Students had to accept that the ideal gas law was correct and use it in calculations. In 2011 an entire new lab programme was introduced, in which one of the guiding principles was that the experiments should be independent lectures and discovery-based. Therefore, the experiment was redesigned into its current format so that students discover ideal gas behaviour rather than having to accept and apply the ideal gas law.

Comments

It would be desirable to increase the number of gases studied to obtain a broader range of flow velocity values. Currently we use Ar, CO_2 and N_2. The flow velocities of Ar and CO_2 are quite similar because of their similar masses. Measurements could also be made on He, but the flow velocities would be quite fast and the flow times would, therefore, be difficult to accurately resolve. We've investigated the possibility of using a heavier (than Ar or CO_2) gas, but so far we've been unable to find an appropriate gas which fulfils all of the desirable criteria of being nontoxic, non-flammable, not ozone-depleting, not a greenhouse gas and inexpensive.