Using bubbles to measure a rate of a reaction

Technician and teacher sheet

Apparatus

- Drop counter (set to bubble range)
- Retort stand and clamps.
- Reagent reservoir filled with water.
- 20 ml measuring cylinder.
- 200 ml conical flask.
- Bung to fit conical flask, with a single hole fitted with a glass or hard plastic delivery tube.
- Stopcock fitted to the tube from the conical flask's bung.
- Plastic delivery tubing (to fit glass or hard plastic tube).
- Calcium carbonate ($CaCO_3$) (Marble chips in 3 different grades).
- 1 mol dm^{-3} Hydrochloric acid.
- Balance.
- Syringe to test your set up.

Data recording setup.

Default setting

Select start to begin recording.

Select stop to end recording.

Introduction

When marble chips (calcium carbonate) react with an acid, they produce carbon dioxide gas, calcium chloride and water. The rate at which the carbon dioxide is produced provides a way of measuring the rate of the reaction.

In this experiment the carbon dioxide produced is bubbled though water, the bubbles are then counted electronically by a Bubble counter.

The equation for the reaction is,

$$CaCO_{3(s)} + 2HCl_{(aq)} \quad CaCl_{2(aq)} + H_2O_{(l)} + CO_{2(g)}$$

This is a classic experiment used to demonstrate rates of reaction. Normally the time taken for the chips to disappear is used or the students are asked to quantify the rate by awarding "stars" to indicate speed and vigour of the reaction.

The use of the Bubble counter allows a more quantitative approach to be taken and it becomes simple to relate particle size and temperature to rate. The production of the graph of the rate of reaction in real time enable the students to make (and see) the comparisons easily.

Practical notes

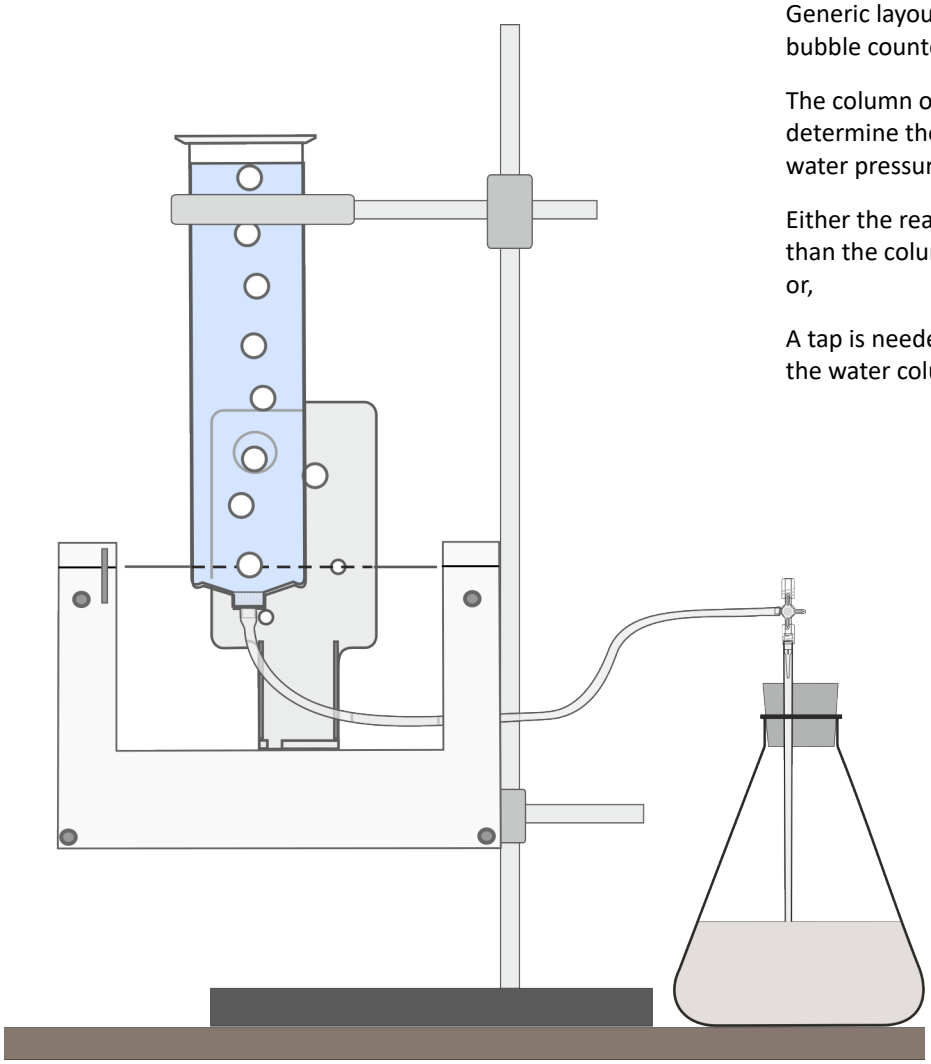
Marble is a metamorphic rock composed of calcium carbonate. Acid will react with the carbonate to form carbon dioxide gas, water and a salt.

Grade is the size of the marble chips; often the supplier will have given an average size of the chips within the grade. The average size could be used as the controlled variable when plotting size vs. rate

A preliminary experiment could be carried out to show that the gas produced is carbon dioxide. Collect the gas and test with limewater.

The bubbles are counted but there is no calibration of the bubble to volume.

Make sure the students understand the need to reset the Bubble counter to zero before each new run or the count becomes a cumulative count.



Generic layout for drop counter in use as a bubble counter.

The column of water in the reservoir will determine the size of the bubbles due to the water pressure.

Either the reaction vessel should be higher than the column of water to prevent back flow or,

A tap is needed in the delivery tube to isolate the water column from the reaction vessel.

Analysis

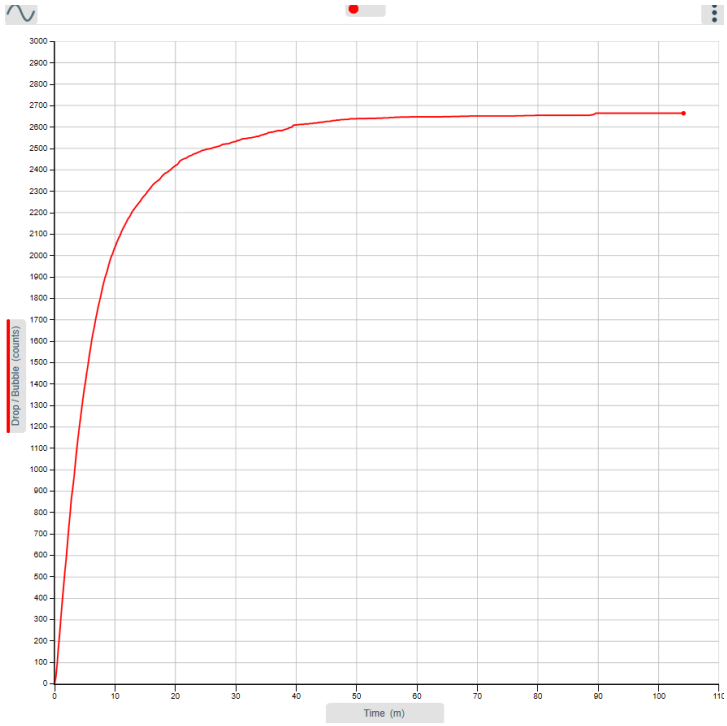
If the purpose of the data is to find the volume (and therefore concentration, molar quantities) the values tool will give pH and Volume data without any further treatment of the data.

If the data is to be presented as a pH vs. Volume graph, this can be done within ES2 by changing the axis label of the axis and selecting the sensor to be displayed.

If you wish to consider the “first derivative” approach where the peak of the rate of change of pH is used to pin point the equivalence point and volume, this can also be conducted in ES2. Use the calculation dx/dy, use pH as the data series for the calculation. This will give a sharp peak at the “point”, the values tool can then be used to find the volume.

A further application of the dx/dy calculation on the 1st derivative data will give a more accurate (sic) point, the 2nd derivative plot will create a line that crosses the x axis at equivalence.

Example data



Typical set of data for marble chips and hydrochloric acid.

You collect the number of bubbles against time. There is no volume of gas available.

You can record for as long or as short a time as you require, this example was over 110 minutes.

To software has tools to select data, use a gradient to find a rate and superimpose sets of data for the same experiment with different grades of chips to show effect of surface area on rate.

The same apparatus can be used for Biology to monitor the production of gas from a yeast fermentation.

The bubble counter cannot measure the bubbles from Photosynthesis, the volume and size are too small for the technology.

Software knowledge required.

1. Connecting the sensor(s) to the software.
2. Change the range of the sensors to correct bubble count range
3. Use set up to change the intersample period
4. Change axis limits.
5. Use values, difference and interval to find times between areas of interest
6. Use the runs manager to show individual or multiple runs on the same chart.
7. Use gradient tool to find rate number.