A HOME-MADE FIRE EXTINGUISHER (I)

Introduction

Many fire extinguishers, like the ones in the figure, use carbon dioxide. Although we can find fire extinguishers that work in different manners, in order that a fire extinguisher is efficient it is necessary that the carbon dioxide is released as fast as possible.

CO_2 is a gas that can be obtained in the laboratory or at home as a result of a very simple chemical reaction, using household products. To be able to use this gas, it is useful to know how to measure its rate of production.

We will work in this activity to answer the questions:

How can we measure the rate of production of carbon dioxide? Does it vary over time?

To answer this question you will:

- Learn how to get experimental data to obtain the speed of a reaction in which a gas is released.
- Work collaboratively to find the best answer to the problem.

PART 1 (warming up, optional)

Introductory concepts

- Carbon dioxide can be obtained by the reaction of an acid and a metallic carbonate or bicarbonate. For example

$$CaCO_{3(s)} + 2\ HCl_{(aq)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O$$

- The speed of a reaction is defined as a concentration change (of reactants or products) in a period of time. To determine the reaction speed it is possible to monitor many different physical quantities. It depends on the behaviour of a reaction.
- As mentioned, the reaction speed can be calculated as a ratio between the concentration change of a product (or a reactant) in a period of time divided by this time period. As in our case the product of the reaction is a gaseous

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- compound (CO_2), the concentration change can be monitored by the change of pressure. If the reaction is performed in a closed vessel we will be able to monitor the product formation by means of a pressure sensor. If temperature and volume remain constant, the speed of the reaction in a specific interval of time is proportional to the change of pressure.

- The calculation is based on the equation of state for ideal gas:

$$\mathbf{p \cdot V = n \cdot R \cdot T}$$

- As the **n/V** ratio represents the concentration **c**, we will obtain:

$$\mathbf{p = \frac{n}{V} \cdot R \cdot T}$$

- Concentration **c** can be than expressed

$$\mathbf{c = \frac{p}{R \cdot T}}$$

- With this equation for the speed of CO_2 production can be written:

$$\mathbf{v = \frac{\Delta[CO_2]}{\Delta t} = \frac{\Delta p_{(CO_2)}}{R \cdot T \cdot \Delta t}} \quad \left[\frac{\mathbf{mol}}{\mathbf{L \cdot s}}\right]$$

where Δ **p** is the pressure change in the flask during the CO_2 formation.

Equivalences between pressure units

1 atm = 101.3 KPa = 1.013 Bar

- Having these premises, to obtain the speed of the reaction we will do the reaction in a closed recipient, at a constant temperature (ambient) and measuring the evolution of pressure along the time. We can use the laboratory assembly of the accompanying image

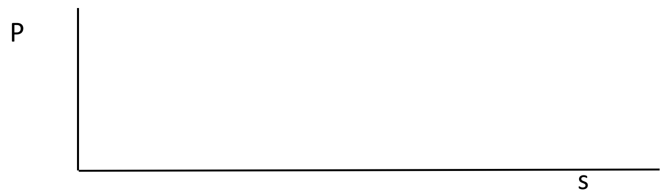
Part 2: Hands on. Design of experiments

I) Your aim here is to design an experiment that allows you to calculate the speed of reaction.
You can use: Pressure sensor, temperature sensor, Erlenmeyer flask, extension and connecting tubes, rubber stopper pierced by a hypodermic needle (or similar), MBL equipment, classical laboratory glassware, calcium carbonate, hydrochloric acid, and other available glassware and products in your laboratory.
Explain the experiment that you will perform, and draw it. Make the calculations of the amounts that you will need (1)

Use security goggles

They protect us from acid spills (like the HCl used in this experiment), stoppers, needles,... or anything that could be harmful for the eyes.

a) Write and draw your individual prediction: How do you think the pressure will vary during the reaction between the acid and the carbonate? Which will be the shape of the graph?



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b) Explain and discuss your predictions with the other members of your group (2)

Analysis of the data obtained

If necessary adjust the axes so that the graph covers the full screen. Observe the shape of the graph obtained and explain:

a) Is the amount of gas produced the same during all the experience?
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b) How long has the reaction been? ....
c) What are the initial values of pressure and of temperature? What is the reason of these values? ……………………………………………………………………………………………

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d) What can you say about the speed of the reaction? (How can you know it from the graph, does it remain constant or not, describe the evolution of the speed of your reaction?

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e) Observe the results of other groups; have they obtained the same speed of reaction? How do you know it?

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f) Compare your results with your predictions (in what they are the same and in what do they differ? Explain it)

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g) Calculate the speed of reaction of several intervals of the reaction and write them down in the table below:

Interval	T_0 (s)	T (s)	P_0 (KPa)	P (KPa)	Speed of reaction (mols/litre·s)
1					
2					
3					
4					

h) Write your conclusions on the experiment answering the initial questions: How can we measure the rate of production of carbon dioxide? Does it vary over time?…………………………

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References

Tortosa M. (2006). Ràpid, hem d'apagar foc. Labsheet used at Revir workshops (2006-2009) http://crecim.uab.cat/revir/ . In Catalan. Unpublished.