THE MOST EFFICIENT HOME-MADE FIRE EXTINGUISHER

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. If we know how to obtain this gas quickly, we can make a good home-made fire extinguisher.

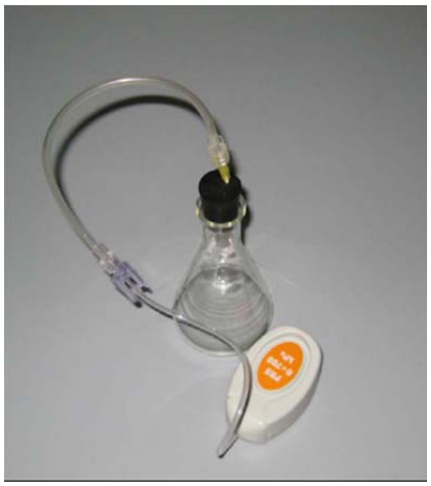
To address this situation we need to know the answer to next question:

Under which conditions will we obtain carbon dioxide at the fastest rate to be used as a fire extinguisher?

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.
- Learn or remember which variables that can modify the speed of a reaction and why.
- Design and perform experiments to modify the speed of a reaction.
- Work collaboratively to find the best answer to the problem.

PART 1 Preliminary measure: Observation of an experiment (Optional, warming up)



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

Cite this work as:
Tortosa, Montserrat (2014). A home-made fire extinguisherpp. 1-7.Available at http://comblab.uab.cat

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein Project N. 517587-LLP-2011-ES-COMENIUS-CMP

- period of time divided by this time period $\mathbf{v} = \frac{\Delta[\mathbf{c}]}{\Delta \mathbf{t}}$. As in our case the product of the reaction is a gaseous 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 $\Delta \mathbf{p}$ is the variation of pressure in the flask due to the formation of CO_2.

<u>Equivalences between pressure units</u>

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

> 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.

<u>Hands on</u>

a) Adjust the pressure sensor to the extension tube and this to a stopper with just one piercing. This operation is very important to avoid gas leaks.

b) Pour 20 mL of HCl 0,2 M in the Erlenmeyer flask

c) Prepare apart 0,2 g of $CaCO_3$

d) Configure the MBL equipment so that registers data of the pressure in the flask and ambient temperature in function of time.

e) 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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f) Explain and discuss your predictions with the other members of your group

The next operations have to be made quickly in order to avoid gas leakages.

g) Put on the software so that the measures start and simultaneously

h) Add the solid into the flask and put the stopper.

i) Observe and write the evolution of the reaction

j) Once the reaction has finished, stop the MBL equipment.

k) Save the graph obtained and the tables of data (e.g. In an excel file)

OBS: Lack of experience can lead to gas leaks. If this is the case, you should repeat it carefully.

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					
5					
6					

h) Write your **conclusions** on the experiment .....
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Part 2: Modeling the situation in the laboratory

The objective of this part is to design and to perform experiments to answer the question:

"Under which conditions will we obtain carbon dioxide at the fastest rate to be used as a fire extinguisher? "

Theoretical model: collision theory

To obtain carbon dioxide at a higher rate, the speed of the reaction has to be higher; one of the theories that explains this how does it work is the “collisions theory”

How do you think that the number of efficient collisions can be increased? That is, how do you think that the reactants or the conditions under the reaction is developed should be, so that the frequency of efficient collisions is higher?

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It is accepted that a chemical reaction happens when there are efficient collisions among the reactants’ particles (atoms, molecules or ions). Due to the impacts some of the existing bonds break and new bonds are formed, this process allows the products of the reaction be formed from the reactants. That is chemical reactions can occur only if reacting particles collide. Nevertheless not all collisions produce chemical change, some of them do not have enough energy, they are not efficient and do not yield products. Collisions with enough energy to break the existing bonds and to form new ones are called efficient collisions. Only efficient collisions produce chemical change. The number of efficient collisions determines the speed of the reaction.

Write and explain which factors or variables do you think that can increase (or diminish) the speed of the reaction between calcium carbonate and hydrochloric acid.

- ……
- ……
- ……
- ……
- ……
- ……
- ……

Now you will design an experiment (choosing the laboratory glassware and equipment that you consider) to investigate how these variables intervene in the speed of reaction. You will choose one variable, design and perform the experiment and explain your conclusions to the other groups. A common solution will be proposed.

The experiment

Choose a factor that affects the speed of the reaction	
Experiments you will perform (draw and write a short description of them)	
What experimental data do you need? Which evidences will you use?	
What will you do so the other variables considered before don't affect your experiment?	
Prediction of the results	
Prepare a table (or the axes for the graph) to write the results obtained.	

Evaluating results

a) Evaluate the data that you have obtained and compare them with your predictions: In what are they similar?

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How do you explain these similarities?

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How do they differ? Why?

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b) Conclusions of your experiment: ……
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Share your results with the other groups, discuss in a plenary session to agree on a suitable answer to the main question, write it:

Under which conditions will we obtain carbon dioxide at the fastest rate to be used as a fire extinguisher?

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Questions

a) How does the speed of the reaction between hydrochloric acid and calcium carbonate evolve along the time? ……
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b) It was easy for our group to design our own experiment.
1, 2, 3, 4, 5 (1: strongly agree 5: strongly disagree)
Please explain your answer……
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In-depth activities

a) Do you think that the studied chemical reaction can be done at home with everyday materials? ……
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b) Write at least one other reaction in which you can obtain carbon dioxide using household ingredient ……
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c) Design a household fire extinguisher taking into account what you have learned
d) Test your fire extinguisher, how does it work? Attach a picture or a video document of it

References

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