EXPERIMENT 4

Chemical Reactions Involving Changes in States of Matter or Pieces of the Carbon Cycle

INTRODUCTION

There are 3 basic states of matter that we encounter in chemical reactions - solid, liquid and gas. In this laboratory exercise you will experiment with some chemical reactions that produce substances that may be familiar to you.

Adding a substance to water to produce a flammable gas may seem remarkable, but this reaction was the sole source of acetylene prior to 1955, and was the source of valuable organic chemicals from 1940 to 1965.[1] Calcium carbide was used to generate gas for lights in homes as well as vehicles (horse-drawn and horseless carriages) before electric lights became common. Carbide lamps can still be found in flea markets and antique fairs. The chemical reaction can be written as:

$$CaC_2\ (s)\ +\ 2\ H_2O\ (l)\ \rightarrow\ C_2H_2\ (g)\ +\ Ca(OH)_2\ (aq)$$

Acetylene is used commercially for welding and cutting steel and for glass blowing because it burns with a very hot flame when mixed with oxygen. The combustion of acetylene is written as:

$$2\ C_2H_2\ (g)\ +\ 5\ O_2\ (g)\ \rightarrow\ 4\ CO_2\ (g)\ +\ 2\ H_2O\ (g)$$

The calcium hydroxide, or lime water, produced in the first reaction combines with the carbon dioxide in your breath to produce insoluble calcium carbonate:

$$Ca(OH)_2\ (aq)\ +\ CO_2\ (g)\ \rightarrow\ CaCO_3\ (s)\ +\ H_2O\ (l)$$

Acidifying the calcium carbonate causes it to fizz. The acid converts calcium carbonate to carbonic acid, releasing carbon dioxide into the atmosphere. This is the same reaction that occurs when marble or limestone (other forms of calcium carbonate) are exposed to acid rain.

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[1] *Kirk-Othmer Encyclopedia of Chemical Technology*; John Wiley and Sons: New York, 1978; Vol. 4, pp 505-519.

The acid rain will gradually erode statues, buildings, and other materials that contain carbonate minerals. A similar reaction occurs when you open a container of soda or carbonated beverage:

$$H_2CO_3\ (aq) \rightleftharpoons CO_2\ (g) + H_2O\ (l)$$

The double arrow ($\rightleftharpoons$) is used to indicate a reversible reaction, meaning the reaction can go forward or backward. Carbonic acid is a weak acid that can ionize in water:

$$H_2CO_3\ (aq) \rightleftharpoons HCO_3^-\ (aq) + H^+\ (aq)$$

These two reversible reactions occur in the bloodstream to carry carbon dioxide from the tissues of your body to your lungs.

MATERIALS NEEDED

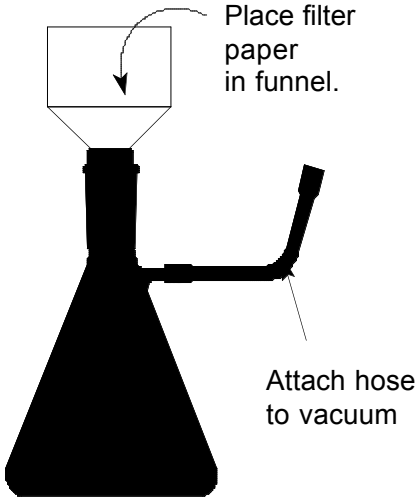
Calcium carbide (CaC_2) solid, one holed rubber stopper with glass tubing extending about 1 inch from the top of the stopper, disposable plastic straws (regular beverage straws), 1 M HCl (hydrochloric acid) solution, chalk for writing on blackboard, will be broken up in the lab, vacuum filtration apparatus (500 ml side arm flask, Buchner funnel and filter paper), two 250 mL Erlenmeyer flasks.

PROCEDURE

Caution: Do not touch the glass tube from the acetylene flame, it is very hot!!!

Note: Perform the first part of this experiment in the fume hood. Add about 2 g of calcium carbide to 150 mL of distilled water in a 250 mL Erlenmeyer flask. Immediately after adding the calcium carbide, stopper the flask with the rubber stopper provided that has a short piece of glass tubing extending from it. After 5 seconds, light the gas coming out of the tube with a match, lighter or striker. Take note of the characteristics of the flame (color, soot, etc.) and record them in your notebook. You should also write the chemical reaction, using chemical formulas as above, to represent what is happening inside the flask (in the water) and when the acetylene burns in the air. What accounts for the soot?

After the acetylene has stopped burning, remove the stopper from the flask and filter the remaining solution with filter material provided. The filtrate (the solution that comes through the filter) contains calcium hydroxide in water (lime water). The residue left on the filter paper will contain some insoluble impurities from the calcium carbide. Save the clear solution and discard the filter paper with the residue in the solid waste container (Trash Can).



Take a clean straw and slowly blow into the clear filtrate solution. The purpose is to blow carbon dioxide into the solution, which will form an insoluble calcium carbonate (chalk; the same thing that is used to write on blackboards, except this is not made into sticks with binding agents). Using chemical formulas, write the chemical equation to represent this reaction in your notebook. In order to get lots of carbon dioxide, take a deep breath and slowly exhale through the straw into the solution. You will see a white precipitate slowly form, making the solution cloudy. After the solution has become very cloudy (by blowing several, 10 or more, deep breaths into it), filter it to collect the calcium carbonate (there won't be much). Get as much of the white precipitate as possible out of the flask and onto the filter paper, rinsing with water if necessary. After all the solution has been filtered, place the filter paper with the white powder on it in a large beaker and add several drops of 1M HCl (hydrochloric acid) to the solid, using a dropper. You should see the mixture fizz, meaning a gas is being given off. What do you think this gas is? Try taking some chalk dust or a small piece of chalk and add the hydrochloric acid to it. Do you see the same chemical reaction taking place? What gas do you think is being produced by mixing acid with the chalk? Record your observations and comments in your notebook along with the chemical reactions (equations) that are taking place at each step in the procedure.

Extra reading assignment: Carbon, by Primo Levi from "The Periodic Table".

Questions to answer In your notebook:

1. Trace the carbon atom(s) from the calcium carbide through the experiment, showing the chemical reaction(s) that takes place in each step of the experiment. There should be two

reactions where carbon dioxide escapes as a product and one reaction where carbon dioxide appears as a reactant.

2. Is it likely that the CO_2 produced in one reaction is the same molecule consumed in the other reaction, considering the design of the experiment and having read the essay "Carbon" by Primo Levi?

3. Considering your observation regarding the combination of CO_2 from your breath with the calcium in lime water, what can you say about the possible fate of CO_2 in the atmosphere when it dissolves in water, such as oceans or streams, that contain calcium ions?

4.* In the last step of this experiment, you treated calcium carbonate with dilute acid, causing the solid to fizz. Briefly describe what building or structural materials contain calcium carbonate and indicate what effects acid rain may have on these materials. Would you expect buildings or monuments made from carbonates to "fizz" when exposed to acid rain? Find examples of materials in your neighborhood that may have succumbed to acid rain, indicating what effects acid rain had on the material you are describing, and indicating the chemical reaction(s) that are taking place with that material upon exposure to acid rain.