Chem 111 – Experiment 5 – Simulation – Stoichiometry of a Gas-Forming Reaction

Background

Gas-Forming Reactions

Chemical reactions between solids or liquids can sometimes generate a gas or multiple gases as products. One common example is the reaction of sodium bicarbonate or baking soda with vinegar. Baking soda acts as a leavening agent in baking because when it reacts with acid, CO_2 gas is released, causing expansion of the batter. Carefully measuring the gas produced by a series of reactions that use different amounts of reactant allows the stoichiometry of the reaction to be determined such that the amount of gas produced in future reactions can be predicted based on the amount of reactants.
In this experiment we will be reacting sodium bicarbonate (not its correct IUPAC name) with hydrochloric acid:-

$$NaHCO_3(s) + HCl(aq) = CO_2(g) + NaCl(aq) + H_2O(l)$$

Its common name often leads to confusion due to its assortment of names. The name baking soda is commonly used in the USA while another name for it, bicarbonate of soda, is used in Australia and Britain. There are other common names it also goes by – no wonder the confusion. Thus in a chemistry lab its official IUPAC name – something I will leave for you to find – is used to avoid any confusion.
Primarily sodium bicarbonate is used as a leavening agent in baking but because of its odor eating properties an open box of it can be found in many fridges.
However, I digress, so let me get back on point ☺.

Stoichiometry – A Final Review

Chem 111 labs – both in person, and now simulated – are primarily designed to teach you the basics of stoichiometry, and with this experiment we get to the last type. What you ask am I talking about? Well in a laboratory setting when doing reactions, you are dealing with reagents that come in one of three forms: -

a) Pure solids or liquids

b) Solutions – primarily aqueous solution at this stage of your exposure to chemistry.

c) Gases. This final one is the toughest of all to actually use in a laboratory.

So lets simplify the whole process – because in truth it is just that when you get used to it. The crux to the whole process is that we are always dealing with having to convert, the above mentioned three, to moles.

Pure Solids (or Liquids)

This is probably the easiest.

$$\textbf{\# moles} = \frac{\textbf{\# g}}{\textbf{Molar Mass}}$$

A simple rearrangement of this formula allows you to go from moles to grams if you need to.

$$\textbf{\# g} = \frac{\textbf{Molar Mass}}{\textbf{\# moles}}$$

In this experiment you will be using this as one of the reactants is solid sodium bicarbonate.

Solutions

Next in complexity but not by much. Take again this experiment in which you will be taking 0.5mL increments of 1M hydrochloric acid. How do we determine the number of moles of hydrochloric acids in a 0.5mL sample of a 1M solution? The key here is Molarity.

$$M = \frac{\#\ \text{moles}}{V(L)}$$

Once again a simple rearrangement of this equation gives us:

$$\#\ \text{moles} = M \times V(L)$$

Gases

Not much more complicated, its just difficult to use in a laboratory environment without the proper equipment. Again take this experiment in which we are generating CO_2(g). How do we convert this to moles.
Here we make use of the Ideal Gas Equation:

$$PV = nRT$$

Where:

P:	Pressure – measured in atmospheres
V:	Volume – measured in liters
n:	# moles
R:	Ideal Gas Constant – for this experiment = 0.08205 $L.atm.mol^{-1}.K^{-1}$
T:	Temperature – measured in K

Again let's manipulate the Ideal Gas Equation:

$$n\ (\#\ \text{moles}) = \frac{PV}{RT}$$

So why did I say it's the most complicated? Not from a mathematical perspective as you can see above but from an experimental point of view. In order to determine the # moles you need to have a method to measure the Pressure, Volume and Temperature of the gas.

It goes without saying that everything I have shown above is absolutely useless without a Balanced Chemical Equation!

About This Lab

In this lab, you will determine the stoichiometry of the reaction between sodium bicarbonate and hydrochloric acid. To do this, you will measure the increase in pressure caused by the carbon dioxide formed in the reaction. After taking into account the volume of air that was initially trapped in the closed flask, you will use the change in pressure to determine the moles of carbon dioxide produced by the reaction between the sodium bicarbonate and hydrochloric acid using the balanced chemical equation for the reaction.

Open the simulation by clicking on the virtual lab icon shown on the left on the Hayden-McNeil Web Site. The simulation will launch in a new window.

You may need to move or resize the window in order to view both the Procedure and the simulation at the same time.

Follow the instructions in the Procedure to complete each part of the simulation. When instructed to record your observations, record data, or complete calculations, record them for your own records in order to use them later to complete the post-lab assignment.

Procedure

*Go to the **General Chemistry web site** and **download the Report file**, this when completed is what you should send to your TA.*

1. Take a clean **250 mL Erlenmeyer flask** from the **Containers shelf** and place it on the workbench.

2. Take a **balance** from the **Instruments shelf**. Place the **flask on the balance and zero the mass of the flask**. Then, **add 0.25g sodium bicarbonate** from the **Materials shelf**. **Record** the **mass of sodium bicarbonate** from the balance display.

3. Take a **thermometer** from the **Instruments shelf** and **attach it to the Erlenmeyer flask**.

4. Take a **50 mL graduated cylinder** from the **Containers shelf**. **Add 50 mL water** from the **Materials shelf** to the **graduated cylinder**. Double-click the graduated cylinder to read the liquid volume at the meniscus. **Transfer** the **water** to the **Erlenmeyer flask** to dissolve the sodium bicarbonate. **Repeat this to bring the volume of solution to 100 mL**.

5. **Dissolving solid sodium bicarbonate in water** is an **endothermic process**. You should see the **temperature of the solution decrease after the first addition of water**. **Wait** for the **temperature to return to room temperature (21.5 °C)** and **remove the thermometer from the flask**.

6. **Double-click** on the **Erlenmeyer flask** and **select the option to close the flask**.

7. The **maximum volume** of a **250 mL flask is 314 mL**. *Record the gas volume as the initial volume for this experiment*. Find the **gas volume** by **subtracting the solution's volume** from **the total flask volume** of 314.0 mL.
   Note: the volume is larger than 250 mL due to the space above the top volume marking.

8. Take a **thermometer** and a **pressure gauge** from the **Instruments shelf** and **attach them** to the **Erlenmeyer flask**.

9. If the **pressure gauge** is not already set to measure pressure **in units of atm**, change its units of measurement to atm.

10. **Record** the **initial pressure and temperature in the Erlenmeyer flask** to reference later.

11. Take a **10 mL graduated cylinde**r from the **Containers shelf**. Measure **0.5 mL 1.0 M HCl** from the **Materials shelf** into the **graduated cylinder**. *Double-click the graduated cylinder to read and record the volume at the meniscus*, then **transfer the HCl to the Erlenmeyer flask**. *Observe and record the reaction that takes place*.
    Note: Though it is not visible, the liquid is added as if by a syringe poked through the stopper without opening the flask.

12. **Record the pressure and temperature in the Erlenmeyer flask**. **Calculate and record the new volume of the gas**. **Assume** that the **total solution volume** in the flask **is equal to the initial volume of the water plus the volume of all added HCl**.

13. **Continue to add 0.5 mL increments** of hydrochloric acid solution **up to a total of 8mL**. **After each addition**, **check** to see **whether a reaction has occurred**.

14. **Record** the **pressure, temperature, and volume of gas**.

15. **Identify** the **first hydrochloric acid increment at which no reaction occurs**.

16. Clear the bench of all materials, containers, and instruments, then use the **Report File** that you downloaded from the **General Chemistry web site**. When completed **send it to your TA.**