Determining the molar mass of carbon dioxide

Determining the value of molar mass of chosen compound Marta Durrigl 1mmA Chemical reaction: b.)$CaCO_3$ (s) + 2HCl (aq) ----------- $CaCl_2$ (aq) + CO_2 (g) + H_2O(l) AIM: The aim of this investigation is to experimentally determine the molar mass of carbon dioxide (CO_2) by measuring its volume and calculating its mass. CO_2 which we will measure will arise as a product of a chemical reaction between Calcium Carbonate ($CaCO_3$) and Hydrochloric acid (HCl) as it is shown in the chemical equation above.

Once we find out the volume of the compound which molar mass we want to determine, it will be easy to calculate the number of moles by using the following formula; pV= nRT * p is pressure in Pa, * V is volume in m^3, * n is molar quantity in mol, * R is gas constant of 8. 314 J/Kmol * T is temperature in K. In addition we need to find out the mass of CO_2 to be able to calculate its molar mass using the second formula M= m/n * M is a molar mass with the measuring unit grams per mole (g/mol) * m is a mass of a compound in grams (g) * n is a number of moles(mol)

HYPOTHESIS (1): By measuring the volume and calculating the mass of CO_2 we will be able to determine its molar mass. We can predict that the molar mass of CO_2 is going to be 44. 01 g/mol because the molar mass (M)as a number equals the relative molecular mass (Mr) which is a sum of relative atomic masses (Ar) of all the elements in the compound. Relative atomic mass values we can find in periodic system. (Ar)of C is 12. 01 and the (Ar) of O is 16. This molar mass is theoretically stated and we do not expect it to change. HYPOTHESIS (2):

Molar mass is the ratio between mass of a compound and its number of moles. Number of moles of a gaseous compound can be determined by measuring its temperature, pressure and volume and calculated by the following expression: pV= nRT which means that n= pV/RT In this experiment we will use the chemical reaction between $CaCO_3$ and HCl to produce CO_2. When mixing $CaCO_3$ in a solid state with a solution of HCl in the beaker a solution of $CaCl_2$ in water will stay in the beaker while CO_2 will move through a pipe in a measuring cylinder placed in another beaker filled with water.

This measuring cylinder will be turned upside down and thus completely filled with water. When CO_2 enters the cylinder since it has a lower density then the water it will move to the top of the cylinder displacing the water. The volume of the displaced water is equal to the volume of the gas produced in the reaction. To find out the mass of CO_2 we will use the idea of conservation of mass which says that mass can be neither created nor destroyed so that a chemical reaction that changes a properties of substances leave their total mass unchanged.

In other words knowing the chemical equation $CaCO_3$(s) + 2HCl (aq) ----------- $CaCl_2$ (aq) + CO_2 (g) + H_2O (l) we can expect that the total mass of substances entering the reaction equals the total mass of products of this reaction. So we will measure the mass of $CaCO_3$ and HCl before the reaction and the mass of the substance in the beaker after the reaction ($CaCl_2$ (aq) + H_2O (l)) assuming that the difference will be a mass of CO_2 which will have passed through the pipe to the measuring cylinder. Knowing the mass of CO_2 and number of moles we can easily determine its molar mass.

MATERIALS: Materials and chemicals that we're going to use in this experiment * beaker of 400 mL * thermometer * barometer * measuring cylinder of 100mL * glass pipes * Erlenmeyer flask of 250 mL * Rubber stopper for Erlenmeyer flask with two holes in the middle * analytical balance * 50 g of $CaCO_3$ * 225 mL of about 6 mol/ L HCl* *obtained by dilution of concentrated HCl with deionized water in 1: 1 ratio METHOD (1): First step in our method is to measure the mass of substances entering the chemical reaction.

For the measurement we will use the analytical balance to the precision of 0. 001 g. First we will measure the mass of the Erlenmeyer flask filled with predefined volume of HCl. We will start with 50 mL of HCl. Now we put the flask onto the balance to measure the mass of flask and the HCl in it. Then we will weigh out 10 g of $CaCO_3$ on the same balance to the nearest 0. 001 g. We will sum these two masses to get the mass of substances entering the reaction. $CaCO_3$ will be added to the flask through the second pipe that goes through the stopper.

This apparatus is assembled of a big 400 mL beaker full filled with water. We place our measuring cylinder upside down into the beaker and make sure that it is completely fulfilled with water. The ending part of the pipe is put into the cylinder. When we mix $CaCO_3$ and HCl the reaction will immediately begin and gaseous CO_2 will enter into the measuring cylinder in form of bubbles displacing the water. When we see that no more bubbles appear in the measuring cylinder the reaction is completed. We read, from the measuring cylinder, the volume of CO_2 produced in reaction.

We disconnect the pipe from the Erlenmeyer flask and measure the mass of the flask and substance in it produced after the reaction. This method has to be repeated two more times using different amounts of substances. Second time we will do this experiment we will use 75 mL of HCl and 15 g of $CaCO_3$. The third time we do the experiment we will use 100 mL of HCl and 20 g of $CaCO_3$. Each time during the experiment, room temperature and pressure has to be measured. Procedure: 1. Put 50 mL HCl to the Erlenmeyer flask and measure the total mass of the flask and the HCl on the analytical balance to the nearest of 0. 01 g. Name this mass as m1 2. Clog the flask with the rubber stopper in which two pipes are already placed 3. Weigh out 10 g of $CaCO_3$. Name this mass as m2 4. Assemble the apparatus so that the pipe from the flask enter the measuring cylinder 5. Add $CaCO_3$ to the flask through the pipe which needs to be dipped into the HCl 6. The reaction will start immediately and will last until there are no more bubbles which can be seen in the measuring cylinder. When the reaction starts measure the temperature and the pressure in the room. 7.

When the reaction is finished measure the volume of displaced water in the cylinder 8. Disconnect the flask and put it on the balance. Name the measured mass as m3. Calculate the mass of CO_2 using the following formula: $(m1+m2)-m3= mCO_2$ 9. Repeat the same procedure 2 more times using different amount of $CaCO_3$ (15g and 20g) and HCl (75 mL and 100 mL) VARIABLES: INDEPENDENT VARIABLE is a variable that we can change during the experiment. In our case this variable is mass of $CaCO_3$. DEPENDENT VARIABLE is a variable that changes due to the independent variable we change.

We can say that this is the volume of CO_2 produced. METHOD (2): controlled variables Controlled variables are variables which we can control to make sure our experiment goes as we have planned. Our first controlled variable in this experiment is temperature that we have to control because the volume of CO_2 depends on the temperature. The higher the temperature is the bigger the volume will be. We can control it with thermometer. The second controlled variable is pressure. Volume of CO_2 also depends on the pressure.

The lower the pressure is the bigger the volume will be. We will easily control it by checking the station in our classroom. METHOD (3): We can predict that this method will be reliable but we need to be very precise in each and every measurement. The flaw of this procedure is primarily the fact that we need to measure the mass of CO_2 by subtracting the masses of substances entering and exiting reaction. Since the mass of CO_2 will be very small, every mistake in measuring the mass can result with a significant error in the end.

The other risk can be that not only CO_2 but also some air and steam will move from Erlenmeyer flask, so again the difference of the masses that we will measure will not be solely the CO_2 mass. We have to use precise apparatus with adequate scales. Our measuring cylinder has to be very precise to determine the volume of CO_2 that displaced water. The scale on the cylinder has to be at maximum 0, 2 mL. We also have to make sure that we have enough chemicals that are stated and that we need for the experiment.

The amount of HCl that we put in the reaction has to excess the amount of $CaCO_3$ to make sure the whole $CaCO_3$ has reacted. To validate the results we can use our hypothesis that the molar mass of CO_2 will be 44. 01 g/mol so any significant discrepancy would mean that either the method is not precise or measurements were not correct. Alternatively, if we know the density of CO_2 at a given temperature and pressure, we can calculate it's mass from the volume we measured thus avoiding potential error in measuring the mass.