Designing a Model Air Bag

# Introduction

In this experiment you will design a model air bag that will be based on the reaction of sodium bicarbonate and hydrochloric acid to produce carbon dioxide gas. The balanced equation for this reaction is:

NaHCO3(*s*) + HCl(*aq*) → CO2(*g*) + H2O(*l*) + NaCl(*aq*)

In the reaction shown above the CO2 gas produced obeys the Ideal Gas Law. In fact, at everyday temperatures and pressures, all gases obey the Ideal Gas Law. This gas law combines together all the major properties of a gas: pressure, volume, temperature and amount (moles) of gas:

PV = nRT

where P is the pressure of the gas in atmospheres (atm), V is the volume in liters (L), n is the moles of gas, R is the Ideal Gas Constant and has a value of 0.0821 atm·L/mole·K and T is the temperature of the gas in Kelvins (K). With this algebraic equation and the measurement of any three properties of a gas, the fourth property can be calculated. For example, if P, V and T are measured, then the moles of gas can be found by substituting these measured values into the Ideal Gas Law equation, along with the value for R and solving for the moles of gas.

In most laboratories the properties of P, V and T are often measured in units different from those used in the Ideal Gas Law. In the lab, pressure is typically measured in mm Hg or torr, volume is typically measured in milliliters (mL) and temperature is typically measured in degrees Celsius (°C). Properties of a gas measured with the these units must be converted to those in the Ideal Gas Constant before being used in the Ideal Gas Law. To do this you can use the following conversion factors: 760 torr (or mm Hg) = 1 atm, 1 L = 1000 mL and K = 273 + °C.

Once the number of moles of gas needed to fill the bag has been calculated, the exact mass of NaHCO3 solid and the volume of 6 M HCl solution needed to make just that amount of gas can be calculated. Let's suppose that we need one mole of CO2 gas to fill the air bag *(NOTE: one mole of CO2 gas is just for this example. Your air bag will contain a different amount of CO2).*

The balanced reaction equation above shows us that 1 mole of CO2 gas can be produced from 1 mole of NaHCO3 and 1 mole of HCl. To find the mass of solid NaHCO3 that is required, you must multiply the moles of NaHCO3 by its molar mass in grams/mole. This is obtained by adding up the molar masses of the elements in the formula using the relative atomic weights on the periodic table. The volume of HCl required is calculated differently since it is a solution instead of a solid. The quantity 6 M indicates a solution that has a concentration of 6 moles/Liter. Therefore, to find the volume you must divide the moles needed, in this case one, by the molarity.

# Materials and Methods

plastic zip-lock bag

ruler or caliper

6 M HCl

baking soda (NaHCO3)

stopwatch

# Procedure

**Safety: 6 M hydrochloric acid (HCl) is caustic. Wear gloves and eye protection.**

The main objective is to design a model automobile airbag which expands to the largest possible volume without breaking the seal on the bag. To simulate the airbag, we will use a zip-lock bag.

You may need other items to complete the design of the air bag. First look at the equipment and supplies available. You should ask your instructor if there are other items you need, but you should be ready to explain why you need them.

Next, your group needs to decide how to measure the pressure, temperature and the volume of gas that fills the air bag. Once you have agreed on how this can be accomplished, make these initial measurements and record the values in the report.

**Part II: Design of the Air Bag**

The specifics of the design are up to you, but we suggest the following:

You should calculate the exact amounts of **solid NaHCO3 (in grams)** and **6 M HCl solution (in mL)** that are needed to produce just enough gas to create a cushion of the largest possible volume without breaking the seal on the bag. Record the amounts you use in the data sheet.

The trigger and deployment system should require minimal external parts or assistance.

You should have the acid and the NaHCO3 inside the model air bag in a stable configuration that would allow it to be attached to a vehicle without deploying until triggered. You will also want to measure the thickness of the bag and how fast it inflates.

You should describe or sketch on your data sheet the design of your airbag, including the mechanism that you are using to trigger the reaction and deploy the bag. **Deploy your airbags in a sink.** After each test of the air bag, empty all the chemical waste into a large waste beaker. The bags may be rinsed in the sink and wiped out with a paper towel to dry them for the next trial.

**Part III: Optimization of Air Bag Design**

Once you have a successful air bag design and you can operate it, use your model air bag to determine whether doubling the amount of one or the other of the reactants changes the speed of inflation of the bag or creates a better or poorer cushion.

# Data and Results

Be ready to share with your instructions your airbag design (Part II) and all calculations of the mass of baking soda and volume of hydrochloric acid. *You may not begin the experiment until after your design and calculations have been approved*.

In the same way, decide how you will write up the results of your trials (Part III). Be sure to answer the questions, did your airbag design succeed?