**Answer Key: Investigating the Self-Inflating Balloon**

**Background**
In this lab, you will investigate the reaction that occurs within the self-inflating balloon. This is a reaction that occurs between citric acid and sodium bicarbonate, to produce carbon dioxide gas as one of the products.

**Prelab Questions**
1. What is the equation for the ideal gas law?
   \[ \text{PV} = \text{nRT} \]

2. What is the conversion between °C and K?
   \[ \text{Kelvin} = °C + 273.15 \]

3. Balance the equation that will occur:
   \[ \text{1C}_6\text{H}_8\text{O}_7\text{(aq)} + 3\text{NaHCO}_3\text{(s)} \rightarrow \text{1Na}_3\text{C}_6\text{H}_5\text{O}_7\text{(aq)} + 3\text{H}_2\text{O}\text{(l)} + 3\text{CO}_2\text{(g)} \]

4. What are some common uses of citric acid (C_6H_8O_7) and sodium bicarbonate (NaHCO_3)?
   **Examples:**
   - Citric acid: natural preservative, used to add sour taste to food and soda
   - Sodium bicarbonate: it is baking soda, baking, antacids

**Objective**
Determine the mass of sodium bicarbonate and citric acid used to inflate the balloon.

**Materials:**
- Self-inflating balloon
- 1000 ml beaker
- Thermometer
- Electronic Scale

**Safety**
- Always wear safety goggles when handling chemicals in the lab.
- Wash your hands thoroughly before leaving the lab.
- Follow the teacher’s instructions for cleanup of materials and disposal of chemicals.
- Do not consume lab solutions, even if they’re otherwise edible products.
- Food in the lab should be considered a chemical not for consumption.

**Procedure**
1. Your teacher will demonstrate the proper technique for inflating the balloon.
2. When you inflate a balloon with your group you should hear some evidence that the reaction is making a gas and you should notice a temperature change (it is safe to hold the balloon in your hand once it has inflated) that will tell you something about the nature of the reaction.
3. When the balloon has fully inflated you need to measure the volume of the balloon. Use the beaker, room temperature tap water and the water displacement method to find the volume of your balloon.
4. Pay close attention to the markings on the beaker as they will guide you in knowing to what level of precision you should record the volume. (Example: if the lines are placed every 1ml, I should estimate to the nearest 0.1ml).
5. Record the volume of the balloon in the data table.
6. Using room temperature water, you can assume the water temperature and room temperature are the same. Record the temperature value in the data table.
7. Determine (look it up, or provided by teacher) the atmospheric pressure in the classroom (convert the value if necessary to an appropriate unit such as mmHg, kPa or atm). We will assume that the pressures inside and outside the balloon are equal. Record this value, as well as any conversions you completed, in the data table.

Data (Sample data provided)

<table>
<thead>
<tr>
<th>Observations:</th>
<th>Cold</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature of balloon during reaction (was it hot or cold to the touch?)</td>
<td>Cold</td>
</tr>
<tr>
<td>Volume of Balloon: Show calculation from displacement</td>
<td>250 ml (range should be 200-300ml)</td>
</tr>
<tr>
<td>Temperature (°C): Also record temperature value in Kelvin</td>
<td>23°C (range should be 20-25°C)</td>
</tr>
<tr>
<td>Pressure: Locate value from weather site or teacher</td>
<td>757 mmHg (will vary based on location)</td>
</tr>
<tr>
<td>Mass of NaHCO$_3$ in “dissected” balloon: Value provided from teacher</td>
<td>1.10 grams</td>
</tr>
</tbody>
</table>

Calculations
Record all work clearly. Pay attention to units and significant figures.
1. Convert your temperature value to Kelvin. 
   
   $23°C = 296.15K$

2. If needed, convert your pressure value to an appropriate unit, as instructed by your teacher.
   
   $757 \text{ mmHg} \times \frac{1 \text{ atm}}{760 \text{ mmHg}} = 0.996 \text{ atm}$

3. Convert the volume of your balloon to L.
   
   $250\text{ ml} = 0.250\text{ L}$

4. Calculate the number of moles of CO$_2$ gas in the balloon.
   
   $PV = nRT$
   
   $(0.996\text{ atm})(0.250\text{ L}) = n (0.0821 \text{ L} \cdot \text{atm/mol} \cdot \text{K})(296.15\text{ K})$

   $n = 0.0102 \text{ moles of CO}_2 \text{ gas}$
5. Calculate the number of moles of NaHCO$_3$ that reacted in the balloon.

\[ \text{1C}_6\text{H}_8\text{O}_7\text{(aq)} + 3\text{NaHCO}_3\text{(s)} \rightarrow \text{1Na}_3\text{C}_6\text{H}_5\text{O}_7\text{(aq)} + 3\text{H}_2\text{O}\text{(l)} + 3\text{CO}_2\text{(g)} \]

0.0102 moles of CO$_2$ gas $ \times $ 3NaHCO$_3$ = 0.0102 moles of NaHCO$_3$

6. Calculate the mass of NaHCO$_3$ that was used to inflate the balloon.

0.0102 moles of NaHCO$_3$ $ \times $ 86.1 g/mole = 0.878 grams of NaHCO$_3$

**Analysis**

Calculate your percent error between the actual mass of NaHCO$_3$ in the balloon (as measured by your teacher or your group) and the calculated mass determined in question 6. Show work.

\[
\frac{|0.878\text{ g} - 1.10\text{ g}| \times 100}{1.10\text{ g}} = 20.2\% \text{ (low)}
\]

**Extension Questions**

Answer the following questions related to this lab:

1. Suppose you took your balloon with you to a variety of environments:
   a. You go to Denver, where the temperature is -4°C and the air pressure is 0.91 atm. What volume will your balloon have there?

*Answers will vary; calculation uses values shown in lab examples previously.*

\[ PV = nRT \]

\[ (0.91\text{ atm})(V) = (0.0102)(0.0821 \text{ L} \cdot \text{atm/mol} \cdot \text{K})(269.15\text{ K}) \]

\[ V = 0.248\text{ L} \text{ or } 248\text{ mL} \]

b. You go the Death Valley where the air pressure is 791 mm Hg and the temperature is 43°C. What volume will your balloon have there?

*Answers will vary; calculation uses values shown in lab examples previously.*

\( 791\text{ mmHg} = 1.041\text{ atm} \)

\[ PV = nRT \]

\[ (1.041\text{ atm})(V) = (0.0102)(0.0821 \text{ L} \cdot \text{atm/mol} \cdot \text{K})(316.15\text{ K}) \]

\[ V = 0.254\text{ L} \text{ or } 254\text{ mL} \]

c. If you took your balloon up in a hot air balloon where the temperature was 5°C and the air pressure was 95 kPa, what volume would your balloon have there?

*Answers will vary; calculation uses values shown in lab examples previously.*

\( 95\text{ kPa} = 0.938\text{ atm} \)

\[ PV = nRT \]

\[ (0.938\text{ atm})(V) = (0.0102)(0.0821 \text{ L} \cdot \text{atm/mol} \cdot \text{K})(278.15\text{ K}) \]

\[ V = 0.248\text{ L} \text{ or } 248\text{ mL} \]
2. Calculate the mass of citric acid that was in the balloon (we can’t weigh that as it was dissolved in water.) Show all work.

\[ \text{1C}_6\text{H}_8\text{O}_7(\text{aq}) + 3\text{NaHCO}_3(\text{s}) \rightarrow \text{1Na}_3\text{C}_6\text{H}_5\text{O}_7(\text{aq}) + 3\text{H}_2\text{O}(\text{l}) + 3\text{CO}_2(\text{g}) \]

*Answers will vary; calculation uses values shown in lab examples previously.

0.0102 moles of CO₂ gas × \( \frac{\text{1C}_6\text{H}_8\text{O}_7}{3\text{CO}_2} \) = 0.0034 moles of C₆H₈O₇

0.0034 moles of C₆H₈O₇ × 192.124 g/mole = 0.653 grams of C₆H₈O₇

3. Describe at least two ways to provide evidence that the solution in the little plastic pouch is in fact an acid.

pH paper, indicator

4. If your balloon was filled with the same number of moles of a gas such as Helium, would the volume be the same, more, or less? Explain.

The same. The variable are not dependent on the type of gas.

5. Was the reaction endothermic or exothermic? What evidence do you have to support this?

This was an endothermic reaction because the temperature decreased.

**Conclusion**

Based on your data, summarize the mass of each reactant needed to inflate the balloon to the volume you obtained. Could you have dissolved the NaHCO₃ in water in the “pouch” and had the citric acid as a powder? Why or why not?

Answers may vary.