Investigation 28

Taking the fizz out of soft drinks

MATERIALS

As selected by student, may include:

- soft drink
- standard 0.1 M sodium hydroxide solution (NaOH)
- phenolphthalein indicator
- measuring cylinders
- beakers
- conical flasks
- burette
- delivery tubes and stoppers
- balance
- thermometer (0–100°C)

Introduction

When carbon dioxide gas (CO_2) reacts with water at low temperatures and elevated pressure, the gas establishes equilibrium with water to create a slightly acidic solution. Soft drinks are usually supersaturated with carbon dioxide.

In this investigation you will design your own investigation to decarbonate soft drink and measure the mass changes when gas is released.

On completion of this investigation, you will be able to:

- identify data sources that enabled you to choose an appropriate procedure for your investigation
- plan the investigation and justify the use of a control
- choose and set up the appropriate equipment
- identify the chemical equations involved in your investigation
- solve problems involving masses and volumes of gases at STP and SLC conditions.

Syllabus

Identify data, plan and perform a first-hand investigation to decarbonate soft drink, gather data to measure the mass changes involved and calculate the volume of gas released at 25°C and 101.3 kPa.

Procedure

1. Identify data sources that will enable you to choose an appropriate procedure for your investigation.
2. Plan and design an investigation that will allow you to:
   - **a** decarbonate a soft drink and quantitatively establish the amount of carbon dioxide in your sample
   - **b** monitor the mass changes involved and calculate the volume of gas released at room temperature (25°C) and 101.3 kPa pressure.
3. Choose and set up the appropriate equipment.
4. Test your plan and set up a control, if necessary. Modify your chosen set-up as required.
5. Before beginning the investigation, carry out a full risk assessment by completing a pre-lab safety table and a risk assessment record.
6. Present a written report that includes:
   - **a** the acknowledgment of data sources and references you have used
   - **b** step-by-step outline of your procedure
   - **c** diagram of the set-up you used
   - **d** justification for a control, or modification of your equipment or procedure
   - **e** results table of gathered data
   - **f** calculations and conclusion with reference to the reliability and accuracy of your results
   - **g** answers to the Discussion and Follow-up questions.

Discussion

1. Explain what may be different in your investigation if you used a cola drink instead of colourless soda water or plain mineral water.
2. Write the chemical equation that accounts for the acidic properties of soda water.
3. Explain in terms of Le Chatelier's Principle why soft drink fizzes up and spills over when opening a bottle at room temperature, but does not fizz as much if the bottle is very cold.
4. A student decided to decarbonate a soft drink by titrating 50 mL soda water with 0.1 M sodium hydroxide solution. The student recorded that 23.5 mL sodium hydroxide was needed to cause a faint pink colour change of an indicator.
   - **a** Write a balanced chemical equation for the reaction of CO_2 with sodium hydroxide.
   - **b** Write a balanced chemical equation that would show how CO_2 establishes equilibrium with water.
   - **c** In terms of Le Chatelier's Principle, explain how the reaction with sodium hydroxide can remove all carbon dioxide from soda water.
   - **d** Calculate the number of moles of CO_2 present in a sample.
   - **e** Calculate the mass and volume (at 25°C and 101.3 kPa) of CO_2 in the sample.
5. The same student carried out another investigation using another 50 mL sample of soda water from the same bottle, which was refrigerated at 0°C. The student monitored the mass changes and calculated the volume of CO_2. At the end of the investigation, the student calculated that 50 mL soda water lost 0.215 g due to evolution of CO_2 gas, while standing open at room temperature (25°C).
   - **a** Calculate the number of moles of CO_2 (assuming that the loss was due only to the evolution of gas).
   - **b** Calculate the volume of gas at 0°C and 101.3 kPa present in the original sample.
   - **c** Compare this amount of gas with the titration procedure and account for any difference.

FOLLOW-UP

1 Consider the following equilibrium established in a soft drink bottle:
$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$
  a Is this reaction exothermic or endothermic? Give your reasons.
  b Using Le Chatelier's Principle, explain what will happen to the equilibrium if:
    i more water is added at the same temperature
    ii more carbon dioxide gas is pumped in, while keeping the temperature constant
    iii pressure inside the container is increased by adding inert gas, while keeping the temperature constant
    iv the temperature is raised.

2 Explain why it is dangerous to put a bottle of soft drink in the freezer.

3 In the final stage of smelting, purified copper sulfide ore is converted into copper and sulfur dioxide gas:
$Cu_2S(l) + O_2(g) \rightarrow 2Cu(l) + SO_2(g)$
  a If a manufacturer is processing about 1 tonne of pure copper sulfide, how many tonnes of sulfur dioxide are released?
  b What volume (in litres) does this mass of sulfur dioxide represent at 25°C and 101.3 kPa?

4 The sulfur dioxide described in question 3 must be removed due to its dangerous environmental effects. This is done in scrubbers containing calcium oxide (CaO), through which sulfur dioxide gas must pass.
  a Write the chemical equation to show how CaO removes SO_2 gas.
  b Calculate the mass (in kg) of CaO needed to absorb all of the SO_2 gas from question 3.

Relative strength of acids

Introduction

Acids occur naturally in many plants, and even in the stomachs of animals and humans. They differ in their strength when dissolved in water.

In this activity you will plan and perform your own investigation to measure the pH of identical concentrations of some naturally occurring acids and manufactured acids in order to compare their relative strengths.

On completion of this investigation, you will be able to:

- relate the measured pH of acids to the concentration of free H^+ ions
- distinguish between strong and weak electrolytes
- recognise the relative strength of acids in terms of the equilibrium established between un-ionised molecules and their ions
- distinguish between the concentration and strength of acids.

Syllabus
Plan and perform a first-hand investigation to measure the pH of identical concentrations of strong and weak acids.

MATERIALS

As selected by student, may include:

- range of 20 mL 0.1 M acid solutions such as:
  - ethanoic acid (CH_3COOH)
  - citric acid ($C_6H_8O_7$)
  - hydrochloric acid (HCl)
  - sulfuric acid (H_2SO_4)
- datalogger or a pH meter
- small beakers

Procedure

1 Carry out a risk assessment of your investigation, with particular emphasis on the disposal of leftover chemicals and safe practices.
2 Choose your equipment and a range of acids of equal concentration, and measure their pH.
3 Calculate the concentrations of H^+ ions of acids.
4 Rank the acids according to their relative strength.
5 Write a written report of your investigation that includes a results table with the data collected, answers to the Discussion and Follow-up questions, as well as an assessment of the reliability and accuracy of your data.

Discussion

1 Account for the difference between the measured pH of ethanoic acid and hydrochloric acid. Write appropriate chemical equations for their respective ionisation.
2 a List the names of your tested acids in decreasing order of electrolyte strength.
  b Give the formulae of the acids you have tested.