65 Experiment

Preparation of carbon dioxide

Duration

80 minutes

Materials

- magnesium carbonate or zinc carbonate
- sodium hydrogen carbonate
- 5 mL 0.1 M hydrochloric acid (HCl)
- 50 mL limewater ($Ca(OH)_2(aq)$)
- 25 mL 10% glucose solution
- yeast
- de-ionised water
- 8 test-tubes
- test-tube rack
- 4 stoppers for test-tubes
- drinking straw
- 10 mL measuring cylinder
- 100 mL measuring cylinder
- 100 mL conical flask
- 100 mL beaker
- one-hole stopper (fitted with short glass tube) to fit conical flask
- hard glass (or Pyrex) test-tube
- one-hole stopper (fitted with short glass delivery tube) to fit hard glass test-tube
- 30 cm length rubber tubing
- 15 cm length rubber tubing
- glass delivery tube (approx. 15 cm long)
- spatula
- tongs
- small beaker
- Bunsen burner
- bench mat

Safety

- Wear safety glasses and a laboratory coat.
- Limewater ($Ca(OH)_2$) can cause burns to the skin and eyes.

Purpose

To prepare carbon dioxide using a number of different methods.

Procedure

1. Wearing safety glasses, add approximately 3 mL limewater to a test-tube. Use a drinking straw to blow air gently from your lungs through the solution until it becomes cloudy.
2. Place about 25 mL 10% glucose solution into a 100 mL conical flask. Add about as much yeast as can be piled onto a 10-cent piece. Stopper the flask with a single-holed stopper fitted with a short length of glass tubing. To this attach 30 cm of rubber tubing and then a glass delivery tube about 15 cm in length.
3. Add about 10 mL limewater to a test-tube and stand the tube in a test-tube rack near the flask of fermenting liquid. Insert the delivery tube from the flask into the limewater in the test-tube. Set the apparatus aside for 1–2 days. Yeast contains the enzyme zymase, which catalyses the fermentation of glucose. Note the odour of the fermenting liquid. Record your observations.
4. Add solid magnesium carbonate or zinc carbonate to a clean, dry, hard glass (or Pyrex) test-tube to a depth of about 1 cm. Attach a one-hole stopper fitted with a short glass delivery tube, to which is attached a 15 cm length of rubber tubing. Add 5 mL limewater to a second test-tube.
5. Hold the tube containing the carbonate nearly horizontally and heat it strongly, allowing the gas evolved to fall onto the limewater via the delivery tube. Do not immerse the delivery tube in the limewater. (The limewater may be drawn back into the hot test-tube, causing it to crack.) Shake the limewater to mix it with the gas. Note any changes to the limewater and in the appearance of the solid residue.
6. Add about 1 mL 0.1 M hydrochloric acid to a small amount of solid sodium carbonate in a test-tube. Test the evolved gas with limewater.
7. Light a Bunsen burner and keep the flame yellow by closing the air hole. The major hydrocarbon present in the natural gas is methane (CH_4). Using a test-tube holder or a pair of tongs, hold an empty test-tube in the flame for 10 seconds. Describe what happens to the bottom of the test-tube. After a few minutes, open the air hole of the Bunsen burner and continue heating the test-tube in the blue flame. Describe what now happens to the outside of the test-tube.
8. Observe the operation of a Kipp's apparatus that has been charged with marble chips (calcium carbonate) and hydrochloric acid. Use this apparatus to produce carbon dioxide and to bubble it through a little limewater in a test-tube until the suspension of white calcium carbonate which first forms dissolves. Boil the clear solution for a few minutes and record your observations.

Theory

Carbon dioxide is a product of respiration in living things, and is also produced during the fermentation of glucose and from the decomposition of certain carbonates by heating.

When hydrochloric acid is reacted with calcium carbonate, carbon dioxide is produced. The Kipp's apparatus uses this reaction to produce carbon dioxide. When the tap is opened, the carbon dioxide flows out, reducing the gas pressure in the middle chamber. This allows acid to rise from the bottom chamber and react with the marble chips. When the tap is closed, the carbon dioxide forces the acid back down to the bottom chamber thus stopping the reaction.

The preparation and properties of carbon dioxide and its roles in living systems are discussed in *Heinemann Chemistry 1*, Chapter 20.

Questions

1 **a** Write an equation for the production of carbon dioxide by respiration.
   b What is the precipitate formed when carbon dioxide reacts with limewater?
   c Write an equation for this reaction.
2 Write an equation for the production of carbon dioxide from fermenting glucose.
3 Write an equation for the production of carbon dioxide from the decomposition of magnesium carbonate by heat.
4 Write an equation for the production of carbon dioxide from the addition of hydrochloric acid to sodium hydrogen carbonate.
5 Write chemical equations for the combustions of natural gas when the air hole of the Bunsen burner is:
   a closed (assume only carbon and water form)
   b open.
6 **a** Write an equation for the production of carbon dioxide in the Kipp's apparatus.
   b Why is the carbon dioxide first bubbled through water?
   c What does this tell you about the solubility of carbon dioxide in water?
7 Classify the reactions you carried out to produce carbon dioxide as acid/base, redox or neither.
8 In this experiment you produced carbon dioxide by several different methods: fermentation of glucose, heating a carbonate, and reacting a hydrogen carbonate and a carbonate with an acid. Evaluate these three methods in terms of the 12 principles of green chemistry discussed in *Heinemann Chemistry 1*, Chapter 17.
9 Fruit salines, effervescent glucose powders and soluble aspirin all fizz vigorously when added to water. Examine the ingredients of one of these products. Note its chemical composition and account for the fizz that occurs when the solid is mixed with water.

66 Experiment

Properties of carbon dioxide

Duration

25 minutes

Materials

- 3 small birthday candles
- 2 × 100 mL beakers
- 2 × 250 mL beakers
- electronic top-loading balance (or triple beam balance)
- a source of CO_2 (e.g. dry ice or Kipp's apparatus containing $CaCO_3$ and HCl)
- bottle of universal indicator
- 2 test-tubes
- test-tube rack
- de-ionised water

Safety

- Wear safety glasses and a laboratory coat.
- Limewater ($Ca(OH)_2$) can cause burns to the skin and eyes.

Purpose

To demonstrate that CO_2 is denser than air, does not support combustion and has acidic properties in water.

Procedure

Part A—Mass measurements

1 Measure the mass of a 100 mL beaker.
2 Place some CO_2 in a second 100 mL beaker and, while the first beaker is still on the balance, hold the container of CO_2 above the beaker on the balance and pour the gas into it.
3 Record the increase in mass of the beaker as the gas is added.

Part B—Fire extinguishing properties

4 Cut a 3 cm length of candle and place it in a 100 mL beaker. Light the candle.
5 Fill a 100 mL beaker with CO_2. Pour the gas from this beaker over the candle to show the fire-extinguishing property of the gas.
6 Place three candles of different heights in a 250 mL beaker. The heights of the candles should be less than the height of the beaker. Light the candles.
7 Fill a second 250 mL beaker with CO_2. Pour the gas into the side of the other beaker near the shortest candle. The candles go out in turn.

Part C—Acid base properties

8 Add about 2 mL de-ionised water to a test-tube, shake the mixture and add two drops of universal indicator solution. Record your observations.

Theory

Because CO_2 (M_r = 44) is denser than air (M_r of N_2 = 28), a beaker containing CO_2 has a greater mass than the same beaker of air. As a result, when CO_2 gas is poured down the inside of the beaker it flows under the air in the beaker.

CO_2 does not support combustion. Hence candles are extinguished as they become enveloped in the gas. CO_2 is an acidic oxide. It dissolves slightly in water to produce carbonic acid, a weak acid.

Questions

1 What properties of CO_2 make this gas particularly effective for fighting fires?
2 Suggest why CO_2 extinguishers might not be suitable for all types of fires.
3 Write an equation to show the acidic nature of carbon dioxide.

69 Demonstration

Soda water: Acidity and effect of heating

A beaker containing soda water and universal indicator is heated. The indicator changes colour.

Duration

10 minutes

Materials

- 2 × 250 mL beakers
- hotplate (or Bunsen burner, bench mat, tripod and gauze mat)
- 300 mL soda water (from a recently opened container)
- universal indicator (or phenol red)

Safety

- Wear safety glasses.

Purpose

- To show that soda water is acidic.
- To show that the solubility of CO_2 decreases with an increase in temperature.

Procedure

1. Pour about 150 mL soda water into each of two beakers.
2. Add a few drops of indicator to each beaker, and note the acidity of the solution.
3. Place one beaker on a hotplate and keep the other as a control, to compare indicator colours.

Theory

The CO_2 present in soda water is responsible for the fizz. CO_2 reacts with water to form weak carbonic acid, H_2CO_3:

$$H_2O(l) + CO_2\ (g) \rightarrow H_2CO_3\ (aq)$$

$$H_2CO_3(aq) + H_2O(l) \rightarrow H_3O{+}(aq) + HCO_3^-(aq)$$

As the temperature rises, the solubility of CO_2 in the water decreases. The solution therefore becomes less acidic and the colour of the indicator changes.

Questions

1. Why is soda water acidic?
2. Why is soda water less acidic at higher temperatures?
3. Will the indicator colour return to the original colour as the soda water cools? Explain.