6.2 The pH Scale and Indicators

Key Terms
pH scale
pH indicator

In May 2001, 49 people who attended a dance festival in Dauphin, Manitoba, became sick within a week. The evidence suggests that the source of the illness was the hotel pool. In Chapter 5, the use of chlorinating agents in pools was discussed as a method to help keep pools safe by killing organisms that could cause illness. Sodium hypochlorite, NaClO(s), is often added to pools to form hypochlorous acid, HClO(aq) in the water.

If the water contains too much acid, it might sting your eyes and it will react with substances in the concrete walls of the pool and in the mortar between the tiles. Therefore, a proper balance must be achieved. To maintain the proper acidity in the pool, the pool manager must regularly check the pH of the water, as shown in **Figure 6.7**. How acidic or basic a solution is can be described in terms of the pH. As you learned in the previous section, acids produce hydrogen ions when they dissolve in water. Hypochlorous acid is no different, and ions form according to the chemical equation

$$HClO(aq) \rightarrow H^+(aq) + ClO^-(aq)$$

Figure 6.7 This is a simple test kit to determine the pH of the water in the pool. A pH of 7.2 to 7.6 is ideal to keep the pool clean. Notice that this test kit also checks for proper levels of chlorine, which you have learned is also a common chemical used in pool maintenance.

The pH Scale

pH scale a numerical scale ranging from 0 to 14 that is used to classify aqueous solutions as acidic, basic, or neutral

Most common acids and bases form colourless solutions. Determining the pH of a solution can help you tell whether an unknown solution contains an acid, a base, or neither. The **pH scale** is a scale that typically ranges from 0 to 14, which is used to classify solutions as acidic, basic, or neutral. **Figure 6.8** shows the pH values of some common substances.

Acidic Solutions: pH < 7

Notice that acids have pH values below pH 7. This means there are many more hydrogen ions in the solution than hydroxide ions. The lower the pH, the more acidic the solution is. So, a lemon at pH 2 is more acidic than milk at pH 6. The pH of gastric fluids in the stomach is between 1 and 2.

Basic Solutions: pH > 7

On the other end of the scale, bases have pH values above pH 7. This means there are many more hydroxide ions in the solution than hydrogen ions. The higher the pH, the more basic the solution is. So, oven cleaner at pH 13 is more basic than eggs at pH 8.

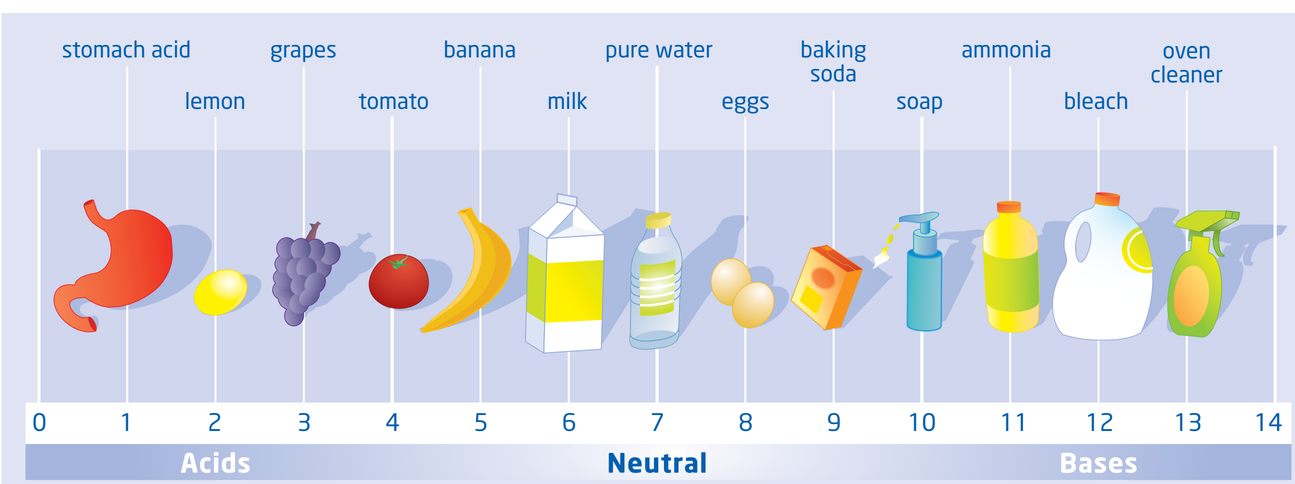
Neutral Solutions: pH = 7

A solution that is neither acidic nor basic is neutral and falls in the middle of the pH scale at pH 7. This means there is the same number of hydrogen ions and hydroxide ions in the solution. Pure water has a pH of 7, as do solutions of some compounds, such as sodium chloride.

Differences in pH Values

The pH scale was suggested in 1909 by the Danish chemist Søren Sørenson as a more accurate way to describe acid concentrations in solutions. The concentration of hydrogen ions associated with a value on the pH scale differs from the value above it or below it by a power of 10. For example, a solution that is pH 4 has a concentration of hydrogen ions that is 10 times greater than in a solution that is pH 5, but is only one tenth as great as in a solution that is pH 3. So, a solution that is pH 3 has a concentration of hydrogen ions that is 100 times greater than in a solution that is pH 5.

Figure 6.8 pH values of common substances have a wide range.



Learning Check

1. A solution has a pH of 4. Is it acidic, basic, or neutral?
2. Summarize the pH values associated with acids, with bases, and with neutral solutions using a graphic organizer of your choice.
3. How much more concentrated are the hydrogen ions in a solution that is pH 7 than the hydrogen ions in a solution that is pH 10?
4. Why is it important that the pH of a swimming pool be carefully monitored?

Sense of Value

Litmus is derived from lichens, which are an important component of ecosystems in Canada. Lichens are the largest part of the winter diet of barren-ground caribou, and many Aboriginal peoples depend on lichens to see their herds through the winter. Some lichens are sensitive to certain air pollutants and can serve as early indicators of pollution problems.

Determining the pH of a Solution

There are several methods that can be used to determine the pH of a solution. The method chosen will depend on several factors, such as availability of equipment and how accurate the pH determination needs to be.

pH Meter

One way to determine the pH of a solution is to use an electronic pH meter or pH probe, as shown in **Figure 6.9**. These meters use the electrical properties of a solution to determine pH. By connecting a pH probe to a computer, changes of pH can be analyzed in real time.

Figure 6.9 The pH meter shows that this solution has a pH of 5.47 and is acidic.

Litmus Paper

Another way to determine pH is the use of indicators. A **pH indicator** is a chemical that is added in small amounts to a solution to visually show the acidity or basicity of the solution by changing colour at a particular pH or range of pH values.

An indicator that you might have used is litmus. Litmus solution is often dried onto thin paper strips and comes in red and blue. Using a strip of red litmus paper and a strip of blue litmus paper, you can determine whether a solution is acidic, basic, or neutral. Blue litmus paper turns red in an acidic solution and red litmus paper turns blue in a basic solution, as shown in **Figure 6.10**. In a neutral solution, neither type of litmus paper changes colour. However, using only litmus paper is not sufficient to precisely determine the pH of a solution.

pH indicator a substance that changes colour to show the concentration of hydrogen ions (H^+) and hydroxide ions (OH^-) in a solution

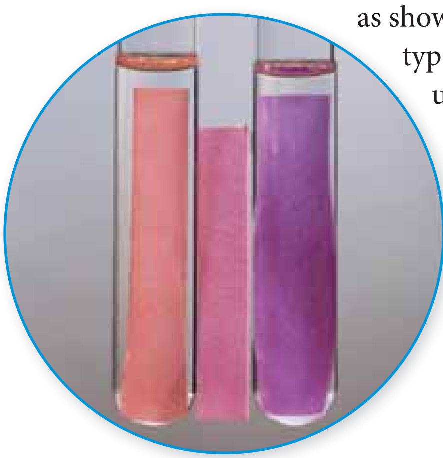


Figure 6.10 This red litmus paper (centre) appears pink in an acidic solution (left) and blue to purple in a basic solution (right).

Figure 6.11 The colour of universal indicator changes through the colours of the spectrum from red to blue as pH increases. The changes in colour help to quickly identify the pH of a solution.

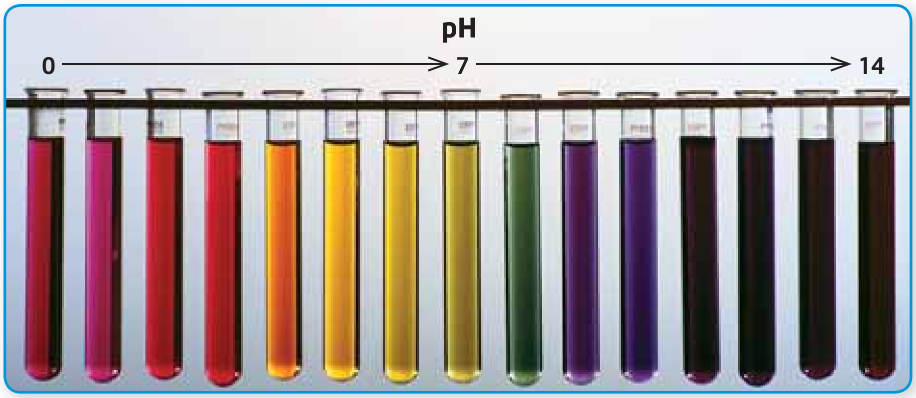


Figure 6.12 pH paper comes with a colour scale to compare colour changes and determine the pH.

Universal Indicator and pH Paper

To more accurately determine the pH of a solution, several indicators that cover the pH range between pH 0 and pH 14 must be used. Universal indicator is a mixture of several indicators that produce a different colour at different pH values, as shown in **Figure 6.11**. The pH paper shown in **Figure 6.12** is prepared by soaking strips of paper in universal indicator and then allowing them to dry. A drop of solution to be tested is placed on the pH paper. The resulting colour is compared against a colour chart to determine the pH of the solution.

Activity 6-3

A Universal Rainbow

When an acidic solution is combined with a basic solution, a reaction occurs that can be shown using an indicator. What identifies that a reaction is taking place?

Safety Precautions

- Wear safety goggles and a lab apron at all times.

Materials

- 2 test tubes
- test-tube rack
- marker or wax pencil
- 20 mL of 0.1 mol/L hydrochloric acid
- 20 mL of 0.1 mol/L sodium carbonate
- universal indicator
- plastic pipette

Procedure

1. Label two test tubes A and B. Put 10 mL of hydrochloric acid solution into test tube A, and 10 mL of sodium carbonate solution into test tube B. Both test tubes will be less than half full.
2. Add several drops of universal indicator to each of the test tubes.
3. Use the plastic pipette to gently transfer solution from test tube B into test tube A. Do not shake or stir the test tubes. Continue until all of the liquid has been transferred. Allow the test tube to sit for one minute, and then draw a diagram of the test tube.
4. If there is enough time, repeat this experiment, this time transferring liquid from test tube A to test tube B.

Questions

1. What signs of chemical change did you observe?
2. List the colours in order from top to bottom.
   a. How does the pH change from the top of the solution to the bottom?
   b. Classify the colours observed according to whether they represent an acidic or basic solution.

Other pH Indicators

Specific indicators can also be used, which change colour within a small range of pH values. A few common indicators and their colour changes are summarized in **Table 6.4** and shown in **Figure 6.13**. By testing a solution with several different indicators, you can more accurately determine the pH of a solution. For example, if a solution turns methyl orange to a yellow colour and causes methyl red to remain a red colour, then the solution must have a pH between 4.4 and 4.8.

Suggested Investigation

Plan Your Own Investigation 6-A, What Is Your Exposure to Acids and Bases?, on page 247

Table 6.4 Acid-Base Indicators

Indicator	pH Range in Which Colour Change Occurs	Colour Change as pH Increases
Methyl orange	3.2-4.4	red to yellow
Methyl red	4.8-6.0	red to yellow
Bromothymol blue	6.0-7.6	yellow to blue
Phenolphthalein	8.2-10.0	colourless to pink
Indigo carmine	11.2-13.0	blue to yellow

Go to **scienceontario** to find out more

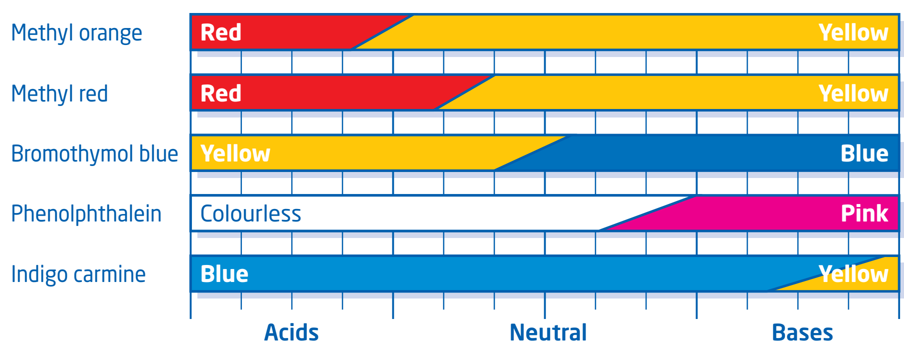


Figure 6.13 Various acid-base indicators change colour in different ranges of pH values.

Learning Check

5. What is a pH indicator?
6. A solution caused red litmus paper to turn blue. Was the solution acidic, neutral, or basic?
7. You suspect that a solution is slightly basic, and you want to perform one additional test to confirm your conclusion. Which indicators in **Figure 6.13** would be best to use? Why?
8. Write a proposal to persuade your school to buy universal indicator for use in science investigations instead of several individual indicators.

pH Indicators in Nature

In Activity 6-1, you noticed that the colour of the red cabbage juice changed when you added lemon juice or soap. The cabbage juice was an acid-base indicator that changed colour as you added acid (lemon juice) or base (soap). Additional substances that contain natural acid-base indicators are listed in **Table 6.5**. These include the pomegranate, shown in **Figure 6.14**.

Figure 6.14 Extracts of some fruits, such as pomegranate, can act as pH indicators.

Table 6.5 Acid-Base Indicators Extracted from Common Plants

Plant	Colour of Indicator		
	Acid	Neutral	Base
Apple	red	grey-purple	green
Blackberry	red	purple	blue-green
Blueberry	red	purple	blue
Cherry	red	red-purple	blue-green
Mountain cranberry	red	pale purple	pale green
Grape	red	purple	blue-green
Plum	red	pale purple	pale green
Pomegranate	red	purple	blue-green
Raspberry	red	red purple	pale green

Acids and Bases: Similarities and Differences

In this chapter, you have learned several important properties about acids and bases. These are summarized in **Table 6.6**.

Study Toolkit

Interpreting Tables

For **Table 6.6**, use the strategy outlined on page 218 for interpreting data in tables. What does the title of the table tell you about the content? What do the headings tell you about the information in each cell?

Learning how to efficiently interpret tables will help you obtain as much information from them as possible.

Table 6.6 Properties of Acids and Bases

Property	Acid	Base
Taste CAUTION: Never taste chemicals in the laboratory.	Acids taste sour.	Bases taste bitter.
Touch CAUTION: Never touch chemicals in the laboratory with your bare skin.	Many acids will burn your skin.	Bases feel slippery and many bases will burn your skin.
Indicator tests	Acids turn blue litmus paper red.	Bases turn red litmus paper blue.
Electrical conductivity	Solutions of acids conduct electricity.	Solutions of bases conduct electricity.
pH	The pH of acidic solutions is less than 7.	The pH of basic solutions is greater than 7.
Production of ions	Acids form hydrogen ions, H^+ (aq), when dissolved in water.	Bases form hydroxide ions, OH^- (aq), when dissolved in water.

Section 6.2 Review

Section Summary

- The pH scale ranges from 0 to 14 and is used to classify an aqueous solution as acidic, basic, or neutral. Neutral solutions are pH 7. Acidic solutions have a pH less than 7. Basic solutions have a pH greater than 7.
- A change of 1 on the pH scale represents a change in the concentration of hydrogen ions in a solution by a factor of 10. The pH of a solution can be determined using pH indicators or an electronic pH probe.
- A pH indicator is a chemical that is added in small amounts to a solution to visually show the acidity or basicity of the solution by changing colours within a small range of pH values.
- Universal pH indicator and pH paper contain several indicators and can be used to determine the pH of a solution.

Review Questions

K/U **1.** Is the mixture shown on the right acidic, basic, or neutral? Explain.

K/U **2.** What are two methods that you can use to determine the pH of a solution?

C **3.** Use a diagram to show how the concentration of hydrogen ions changes as pH increases.

K/U **4.** Explain why both red and blue litmus paper must be used to determine that a solution is neutral.

A **5.** Search your home for commonly used household products. In a table, record the product's name, describe its use, and identify it as an acidic or basic solution. What evidence can you provide to support your conclusions?

K/U **6.** Name three examples of acid-base indicators found in nature.

T/I **7.** Based on the information in **Table 6.4**, what indicator would you use to monitor the pH of a solution that you were changing from pH 7 to 9?

T/I **8.** The data in the table below were recorded using different indicators to determine the pH of a solution. Based on these data, what is the best estimate for the pH of the solution? Explain your reasoning.

Colours of the Solution

Indicator	Colour
Bromothymol blue	blue
Phenolphthalein	colourless
Indigo carmine	blue

An electronic meter can be used to determine pH.