Investigation 29

# 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.

3 Which of the tested acids have equilibrium established in solution?

4 a Write the structural formula of citric acid (2-hydroxypropane-1,2,3-tricarboxylic acid).

b How many hydrogen ions can citric acid theoretically release?

c The pH of 0.1 M citric acid solution was found to be 2.7, while the pH of 0.1 M hydrochloric acid solution is close to 1. Account for this difference.

5 Several acids have been tested for their relative conductivity and pH (see Table 1).

**TABLE 1**

| Acid tested | Relative conductivity | pH |
|---|---|---|
| concentrated $CH_3COOH$ (glacial acetic acid) | low | 7 |
| concentrated $H_2SO_4$ containing dissolved $SO_3$ (oleum) | low | 7 |
| 0.1 M HCl solution | high | 1.2 |
| 0.1 M $CH_3COOH$ solution | moderate | 3.3 |
| 0.1 M $H_2SO_4$ solution | high | 0.7 |

a Use appropriate models to explain these results in terms of strong and weak electrolytes, and dilute and concentrated solutions.

b Explain why sulfuric acid of the same concentration as HCl has a pH of less than 1.

c Predict the concentration of a sulfuric acid solution ($H_2SO_4$) with a pH of 2.

## FOLLOW-UP

*1 Phosphoric acid ($H_3PO_4$) is a manufactured acid that ionises in water solution in three stages. A 0.1 M solution of phosphoric acid has a pH of 3.3.*

*a Write chemical equations for its ionisation.*

*b In terms of the above ionisations and the measured pH, is phosphoric acid a weak or a strong acid? Explain.*

*2 Calculate the pH of a standard 0.1107 M HCl solution.*

*3 An unknown solution has a pH of 8.9.*

*a Is this solution acidic or basic?*

*b Calculate the concentration of $H^+$ ions in the solution.*

*4 Sodium hydrogen carbonate ($NaHCO_3$) can be used to neutralise acids or bases.*

*a Write the equation for its dissolution in water.*

*b Show that the $HCO_3^-$ ion is a Bronsted–Lowry acid, and name its conjugate base.*

*c Show by means of an equation that $HCO_3^-$ is also a Bronsted–Lowry base, and name its conjugate acid.*

*d What is the name given to a species that can act as an acid and a base?*