Reflection

2. Student answers will vary depending on each student's evaluation of personal water use in section 4.1. Although the decision-making model may be a new concept, it is expected that many students would have intuitively used certain components of the model when making decisions regarding water use. After a more thorough analysis of personal water use by using the decision-making model, students may re-evaluate earlier resolutions.

4.9 INVESTIGATION: DILUTION AND PH

(Pages 308–311)

Prediction

(a) The pH of a solution is defined in terms of the concentration of hydrogen ions in solution. Therefore, a change of one pH unit is equivalent to a 10-fold difference in hydrogen ion concentration. For example, an acidic solution must be diluted by a factor of 10 to raise the pH by one unit.

Part 1: Dilution

Observations

Table 1 pH Values of Dilute Acid Solutions

Solution	1	2	3	4	5	unknown*
(b) pH from meter	1.85	3.25	4.01	4.93	6.05	5.10
(c) Universal indicator colour	dark red	orange red	orange	pale orange	yellow	pale orange
pH from indicator	2	3	4	5	6	5
Concentration of H^+ (mol/L)	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-5}

Analysis

(d) Student answers will depend on the pH values. The concentration of HCl in each flask for the sample data is shown in **Table 1**.

(e) Refer to the $[H^+]$ values in **Table 1**. The concentration of H^+ ions was obtained from the pH value from the universal indicator.

(f) By diluting an acidic solution by a factor of 10, the pH of the solution increases by one pH unit.

(g) Student answers may vary depending on results. Ideally, the pH value obtained using the pH meter should be very similar to the value determined using the pH indicator scale. The pH meter will give a more reliable value than the pH indicator scale.

(h) The 40 mL of distilled water was added to the flask before the hydrochloric acid to reduce the likelihood of excessive heating or splattering as the acid combined with water.

(i) In step 3, 100 mL of water was not put into the flask because doing so would not produce the correct final volume of solution after the acid was added. The final volume of the solution was to be 100 mL. Therefore, by beginning with 100 mL of water, there would be no room to add hydrochloric acid to the flask without exceeding the required final volume.

Evaluation

(j) Student answers will vary. Sources of error for Part 1 include uncertainty of the initial concentration of acid, measurement error for pipette and flask, cross-contamination of solutions from pipettes, and incorrectly interpreting the pH indicator. Using a pH indicator and colorimetric analyses is subject to error during interpretation.

To obtain more accurate results, a new, clean pipette could be used at each step of the investigation to ensure that cross-contamination could not affect the accuracy of the results. Also, more precise evidence may be gathered using a pH meter instead of a pH indicator to determine the final pH value of each solution.

(k) Student answers will vary depending on the depth of the students' initial prediction and the accuracy of results obtained in the investigation.

(l) The pH meter gives the best value because it is the most accurate and precise method of measuring pH.

Synthesis

(m) Based on this investigation, acidic solutions must be diluted by a very large amount to change the pH value. If a solution is diluted by a factor of ten, the pH changes by one unit. Thus, acid waste should not be dumped into rivers and lakes. A small amount of acidic waste could have a significant impact on the pH of surrounding water.

(n) If 0.1-mol/L sodium hydroxide solution, $NaOH_{(aq)}$, had been used in this investigation, the results would be similar in that, as the solution is diluted by a factor of ten, the pH changes by one unit. However, the pH value would start high, such as 13, and decrease by one pH unit for each dilution.

(o) The dilution of concentrated solutions is commonly performed to adjust the strength of the active ingredient for practical use. For example, floor cleaners are commonly diluted prior to use.

Part 2: pH of a Water Sample

(p) Results will vary depending on the pH of the unknown sample. A sample pH value is given in **Table 1**.

Analysis

(q) The calculated $[H^+]$ in the water sample will depend on the pH of the unknown solution. The $[H^+]$ of the sample is given in **Table 1**.

Evaluation

(r) Student answers will vary depending on students' analyses of their experimental design and procedure. One source of error is incorrectly interpreting the pH indicator. Using a pH indicator and colorimetric analyses are subject to error during interpretation. Evidence that is more precise may be gathered using a pH meter instead of a pH indicator to determine the final pH value of the sample.

Synthesis

(s) A colorimeter measures the absorption of different wavelengths of light by a sample. Many colorimeters contain light-emitting diodes that produce lights of four different colours (**Table 2**). The colorimeter also has a photodiode that measures the quantity of light that passes through a sample. This quantity is the quantity of transmitted light, or percent transmission. Most colorimeters are interfaced to a computer, which displays the quantity of transmitted light.

Table 2 Colour and Wavelength

Colour	Blue	Green	Orange	Red
Wavelength (nm)	460	565	630	697

Data from a colorimeter can be used to create a graph of the percent-transmitted light versus the sample concentration, and the optical density versus the sample concentration. Using these graphs, you can estimate the concentration of a coloured component in an unknown sample.

A colorimeter may improve the accuracy of results obtained in this investigation by providing a sensitive method of measuring colour changes of the pH indicator.

The results obtained using a colorimeter would be very similar to values measured with a pH meter. Both techniques provide a precise, accurate way to determine the pH of a solution. To obtain the most reliable measurements, pH values can be determined using both methods.

4.10 INVESTIGATION: ACID–BASE REACTIONS

(Pages 312–315)

Prediction

(a) **Part 1**

$Zn_{(s)} + 2\ HCl_{(aq)} \rightarrow H_{2(g)} + ZnCl_{2(aq)}$

$NaHCO_{3(s)} + HCl_{(aq)} \rightarrow H_2O_{(l)} + CO_{2(g)} + NaCl_{(aq)}$

$CaCO_{3(s)} + 2\ HCl_{(aq)} \rightarrow H_2O_{(l)} + CO_{2(g)} + CaCl_{2(aq)}$

$2\ Al_{(s)} + 6\ NaOH_{(aq)} \rightarrow 2\ Na_3AlO_{3(aq)} + 3\ H_{2(g)}$