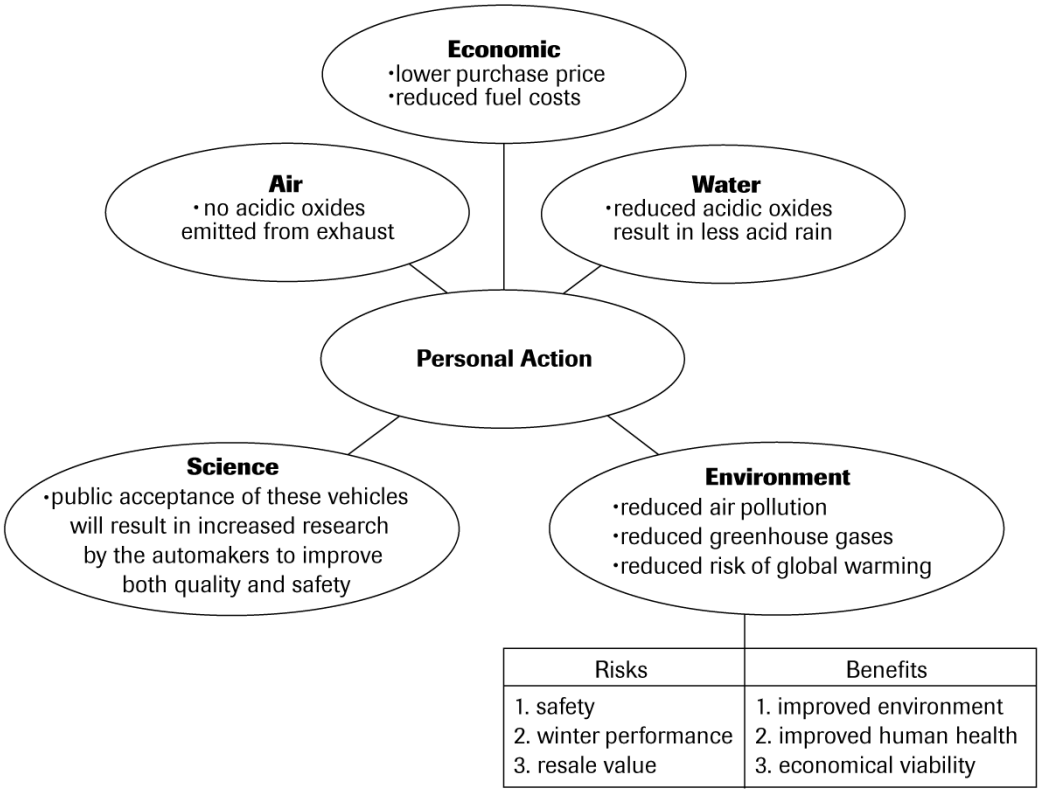
(b)–(c)



Risks	Benefits
1. safety	1. improved environment
2. winter performance	2. improved human health
3. resale value	3. economical viability

UNIT 4 PERFORMANCE TASK: A MICROSCALE ANALYSIS OF HARD WATER

(Pages 361–362)

The following is a sample Perfomance Task report.

DETERMINING THE HARDNESS OF WATER

Purpose

The purpose of this investigation is to test water samples for hardness using a titration procedure.

Question

Which water sample, from a variety of sources, is the hardest?

Experimental Design

Different water samples, including distilled water, were titrated with a 0.01-mol/L solution of EDTA to determine their relative hardness. The water samples were treated with pH 10 buffer solution, and Erichrome Black T indicator. The volume of EDTA solution required for titration to the end point for each sample was recorded. The concentration of hard water ions in each sample was calculated based on the volumes of EDTA required to reach the end point. The independent variable is the number of hard water ions in the water samples being tested; the dependent variable is the volume of EDTA added to each sample; the control is the sample of distilled water. The temperature and the pH of the water samples are also controlled.

Materials

eye protection	lab apron
Erichrome Black T indicator	pH 10 buffer
well plate	microdropper
150-mL beakers	0.01-mol/L EDTA
water samples	distilled or deionized water

Procedure

Part A: Testing the Indicator

1. To separate wells in the well spot plate,
   (a) 2 drops of pH buffer 10 and 10 drops of a known hard water sample, and
   (b) 2 drops of pH buffer 10 and 10 drops of de-ionized water were added.
2. One drop of Erichrome Black T indicator was added to each well. The colour of the indicator with no hard water ions present (in the de-ionized water) and with hard water ions present (in the hard water sample) was noted.

Part B: Titration

3. A burette was filled with 0.01-mol/L EDTA solution. The initial volume was recorded.
4. A graduated cylinder was used to measure 20 mL of a water sample, which was added to a clean, dry 150-mL beaker. To the beaker was added 5 mL of pH 10 buffer and 2–4 drops of Erichrome Black T indicator.
5. The beaker and its contents were place under the burette. EDTA was dispensed until a colour change was observed. The volume of EDTA solution was recorded.
6. Steps 2 and 3 were repeated until three consistent results (similar values of titrant added) were obtained.

Observations

Erichrome Black T Colours in Hard and Soft Water

Indicator	Soft water	Hard water
Erichrome Black T	blue	red

Hard Water Determination

Water type	Volume of sample	Trial #	Initial burette reading	Final burette reading	Volume of EDTA used	Hardness of water (ppm)
Tap	150 mL	1	8.0 mL	8.3 mL	0.3 mL	0.813
		2	8.3 mL	8.7 mL	0.4 mL	1.069
		3	8.7 mL	9.0 mL	0.3 mL	0.813
		4	9.0 mL	9.3 mL	0.3 mL	0.813
Stream	150 mL	1	1.8 mL	2.4 mL	0.6 mL	1.603
		2	2.4 mL	2.8 mL	0.4 mL	1.069
		3	2.8 mL	3.3 mL	0.5 mL	1.336
		4	3.3 mL	3.9 mL	0.6 mL	1.603
		5	3.9 mL	4.4 mL	0.6 mL	1.603
Lake	150 mL	1	11.5 mL	12.0 mL	0.5 mL	1.336
		2	12.0 mL	12.3 mL	0.3 mL	0.813
		3	12.3 mL	12.6 mL	0.3 mL	0.813
		4	12.6 mL	12.9 mL	0.3 mL	0.813
Well (ground)	150 mL	1	9.6 mL	20.0 mL	10.4 mL	27.80
		2	20.0 mL	30.5 mL	10.5 mL	28.06
		3	30.5 mL	41.0 mL	10.5 mL	28.06
		4	0.2 mL	10.7 mL	10.5 mL	28.06

Sample Calculation

Tap Water Trial 1

$$0.3 \text{ mL of } 0.01\text{-mol/L EDTA} = 0.3 \text{ mL} \times \frac{1 \cancel{\text{L}}}{1000 \text{ mL}} \times \frac{0.01 \text{ mol EDTA}}{1 \cancel{\text{L}}} = 0.000003 \text{ mol EDTA}$$

1 mol EDTA removes 1 mol of Ca^{2+} ions from solution.
0.000 003 mol EDTA removes 0.000 003 mol Ca^{2+} ions from solution.

$$0.000\,003 \text{ mol } Ca^{2+} \text{ ions} = 0.000\,003 \text{ mol} \times 40.08 \text{ g/mol} = 0.000\,120\,2 \text{ g } Ca^{2+} \text{ ions}$$

0.000 120 2 g Ca^{2+} ions is present in 150 mL of water.

$$\frac{0.000\,120\,2 \text{ g } Ca^{2+} \text{ ions}}{150 \text{ mL}} \times 1000 \text{ mL} = 0.000\,801\,3 \text{ g } Ca^{2+} \text{ ions}$$

0.000 801 3 g Ca^{2+} ions is present in 1000 mL of water.
0.8013 mg of Ca^{2+} ions is present in 1 L of water (0.8013 ppm).

Analysis

Analysis of the data clearly shows that the groundwater sample taken from a well has the highest level of hardness. On the hardness scale, this water would be ranked as "very hard." It is also interesting to note from the data that the hardness of the lake water and the hardness of the tap water are virtually the same. One could conclude that the lake may be the source of the tap water. If so, then the water treatment process would not have to incorporate any water softening processes.

The softest water appears to be the sample of lake water, followed by the tap water and the stream water. The groundwater is clearly the hardest.

Evaluation

The experimental design appears to be sound. By adding Erichrome Black T indicator to buffered solutions (pH = 10) of both hard and soft water, we were able to see both colours of the indicator. The titration procedure had been used before in neutralizing acids and bases. One thing we noted was the time delay between the addition of EDTA from the burette and a colour appearing in the beaker. Once we observed this time delay, we allowed time for a slight change in colour to occur before adding any more of the titrant. The only source of error that may have influenced our results was the small quantities of EDTA that were required for each titration. The amount required for each soft water sample was less than 1 mL. Dispensing the titrant form a calibrated graduated pipette might have improved the accuracy of the volume of titrant required.

I am confident that our techniques and measurements resulted in acceptable evidence, notwithstanding the point made in the previous paragraph about the small volumes of titrant required for each sample. Three of the four water samples required only four trials to achieve three consistent results, with the fourth sample requiring five trials.

The only change in experimental design would be to improve the accuracy of the volume of quantities measured in this investigation. For example, using a 150-mL pipette to dispense the water samples into the beaker instead of measuring the same quantity into a graduated cylinder would improve the accuracy of the water sample volumes and ensure that this variable is controlled. Similarly, the volumes of the pH 10 solution added each time could be more accurately measured using a graduated pipette.

Synthesis

In an acid–base titration, an acidic solution, for example, is added from a burette to a basic solution. The indicator is the base colour until the last $OH^-_{(aq)}$ ion has been neutralized by $H^+_{(aq)}$ ions from the titrant. The next drop of titrant results in surplus $H^+_{(aq)}$ ions, which cause the indicator to change to its acid colour.

In this titration, the initial colour of the indicator is caused by the chemical bonds between the indicator and the hard water ions in solution. As EDTA is added, it first bonds with the hard water ions in solution, and then displaces the hard water ions that are bonded to the indicator. As more unbonded indicator ions are formed in the solution, the solution changes colour. This colour change occurs more slowly than the colour change in an acid–base titration.