

### Experimental Design (1)

The water is tested for oxygen and for organic matter, every 500 m upstream from the fish-kill area to the industrial town.

### Prediction (2)

The fish kill is caused by toxic chemicals or disease organisms in the sewage discharge upstream.

### Experimental Design (2)

The water is tested for chemicals and for organisms causing common diseases in fish, every 500 m upstream from the fish-kill area to the industrial town.

*Note:* This is an example of a correlational study (see Appendix A1, pages 608 – 9). Technically, correlational studies are inductive investigations without a hypothesis and a prediction. Note above that when forced, a hypothesis and a prediction are similar, indicating that the investigation is inductive and that neither a hypothesis nor a prediction should be used.

### Making Connections

- Garbage disposal units decrease the amount of solid bagged waste from a household, which cuts costs and extends the usefulness of landfills. However, the increase of organic matter in the sewage places more demand on the local waste water treatment system. Most of this food waste could be diverted to a composting system.
- Answers will depend on the regulations controlling local hazardous waste facilities. Unless the local area has a tertiary treatment facility, there will automatically be an argument for improvement. The only logical long-term human goal is to eventually have all waste water returned to the cycle in a form that puts no stress on the environment.



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## 7.5 QUALITATIVE CHEMICAL ANALYSIS

### PRACTICE

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#### Understanding Concepts

- colourless
  - blue
  - yellow-brown
  - orange
  - colourless
  - green
- yellow-red
  - blue
  - yellow
  - violet
  - colourless
- yellow-red
  - light blue-grey
  - bright red
  - green

#### Applying Inquiry Skills

- Analysis**  
According to Table 2, Colours of Flames:  
solution A contains  $K^+$  ions,  
solution B contains  $Cu^{2+}$  ions,  
solution C contains  $Na^+$  ions,  
solution D contains  $Ca^{2+}$  ions, and  
solution E contains  $Li^+$  ions and/or  $Sr^{2+}$  ions.
  - Evaluation**  
The design of this experiment is too limited. It only identifies those positive ions (cations) in the solutions that

happen to produce coloured flames. Other possible cations, not to mention the anions in each of these solutions, cannot be identified this way. As well, solution E may contain either or both of two cations, since they both produce the same result.

## PRACTICE

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### Understanding Concepts

- Qualitative analysis determines *what* is in a sample, and quantitative analysis determines *how much* is present.
- A diagnostic test statement always includes procedure, evidence, and analysis steps. For example: *If* a gas is bubbled through limewater, *and* a white precipitate forms, *then* the gas is likely to contain carbon dioxide.
- Precipitates could be formed with the listed ions by adding:
  - $\text{OH}^-$ ,  $\text{CO}_3^{2-}$ ,  $\text{PO}_4^{3-}$ , or  $\text{SO}_3^{2-}$  aqueous ions.
  - $\text{SO}_4^{2-}$ ,  $\text{CO}_3^{2-}$ ,  $\text{PO}_4^{3-}$ , or  $\text{SO}_3^{2-}$  aqueous ions.
  - $\text{Ag}^+$ ,  $\text{Pb}^{2+}$ ,  $\text{Tl}^+$ ,  $\text{Hg}_2^{2+}$ , or  $\text{Cu}^+$  aqueous ions.
  - $\text{Ag}^+$ ,  $\text{Pb}^{2+}$ ,  $\text{Ca}^{2+}$ ,  $\text{Ba}^{2+}$ ,  $\text{Sr}^{2+}$ , or  $\text{Ra}^{2+}$  aqueous ions.

### Applying Inquiry Skills

- To precipitate carbonate ions from a sample, without at the same time precipitating sulfide ions, add a compound that supplies any Group II cation, and an anion that is always soluble in combination (e.g., calcium nitrate, barium nitrate, or magnesium nitrate).
  - One example:  $\text{Ca}_{(\text{aq})}^{2+} + \text{CO}_{3(\text{aq})}^{2-} \rightarrow \text{CaCO}_{3(\text{s})}$
- Experimental Design**  
Calcium nitrate solution is added to the test solution sample. If a precipitate forms it is filtered, and silver nitrate solution is added to the filtrate (or to the original sample, if no precipitate formed in the initial test).

### Making Connections

- There are innumerable examples of qualitative analysis in society. Common examples include environmental tests for lead (or other heavy metals) in water supply systems; continuous monitoring by household detectors (carbon monoxide or natural gas in houses, propane in trailers); simple swimming pool or aquarium water-testing kits (including quantitative analysis); or even home pregnancy tests. There are also hundreds of industrial and commercial examples of qualitative analysis. There are many career opportunities as an analyst.

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## SECTION 7.5 QUESTIONS

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### Understanding Concepts

- The precipitation reactions are:
  - $\text{Pb}_{(\text{aq})}^{2+} + 2 \text{Cl}_{(\text{aq})}^- \rightarrow \text{PbCl}_{2(\text{s})}$
  - $\text{Zn}_{(\text{aq})}^{2+} + \text{S}_{(\text{aq})}^{2-} \rightarrow \text{ZnS}_{(\text{s})}$
  - $\text{Ag}_{(\text{aq})}^+ + \text{C}_2\text{H}_3\text{O}_{2(\text{aq})}^- \rightarrow \text{AgC}_2\text{H}_3\text{O}_{2(\text{s})}$
  - $3 \text{Ba}_{(\text{aq})}^{2+} + 2 \text{PO}_{4(\text{aq})}^{3-} \rightarrow \text{Ba}_3(\text{PO}_4)_{2(\text{s})}$
  - $\text{Ca}_{(\text{aq})}^{2+} + 2 \text{OH}_{(\text{aq})}^- \rightarrow \text{Ca}(\text{OH})_{2(\text{s})}$
- yellow-brown
  - colourless
  - blue
  - green
  - colourless
- Calcium (yellow-red flame test) can be distinguished from the other ions by a flame test, but lithium and strontium both give bright red flame tests, and so cannot be distinguished from each other in this way.

- (b) Adding sulfate (or carbonate, phosphate, or sulfite) ions to the two unidentified test solutions (aqueous sodium sulfate, for instance) would precipitate the strontium ions, but not the lithium ions.

### Applying Inquiry Skills

4. (a) **Experimental Design**

The solution is flame tested.

(b) **Evaluation**

The experimental design is seriously flawed, because both ions produce coloured flames. If the initial flame test is bright red, there is no way to know whether potassium ions are present, because the violet colour will be hidden by the strontium ion colour.

Alternative answer:

(a) **Experimental Design**

Sodium sulfate is added to the solution. Any precipitate is filtered and then the filtrate or original solution is flame tested.

(b) **Evaluation**

The experimental design is not valid. Although you will know with certainty whether strontium ions are present or not, based upon whether a precipitate forms or not, you will not be able to determine whether potassium ions are present, due to the masking of the potassium flame colour by the sodium flame colour. If cobalt-blue glass is employed in the materials and the procedure, then the design would be valid. (The cobalt-blue glass filters the yellow sodium colour from the flame and allows one to determine whether potassium is present or not.) Alternately, the cation for the sodium solution must be chosen to have a colourless flame test, e.g., hydrogen. (Unfortunately, a list of colourless flame-test ions is not provided in the text and would have to be researched.)

5. **Experimental Design**

Sodium chloride solution is added to the sample. If a precipitate forms, it is filtered. Sodium hydroxide solution is added to the filtrate (or sample, if no precipitate forms). If a precipitate forms, it is filtered. Sodium carbonate (or sulfate) solution is added to the filtrate (or sample, if no precipitate forms).

*Note:* A precipitate in the initial step (when you use any soluble halide ion compound) indicates that thallium ions are present. A precipitate in the second step (when you use any soluble hydroxide compound) indicates that calcium ions are present. A precipitate in the third step (when you use any soluble sulfate, carbonate, phosphate, or sulfite compound) indicates that barium ions are present. The *sequence* of steps is very important: sodium carbonate cannot be added first, for example.

6. (a) The Experimental Design is satisfactory. The solution colour test can confirm the presence of copper(II) ions, but not calcium ions; and any red in the flame test will confirm the presence of calcium ions.

(b) **Alternative Experimental Design**

Sodium sulfate solution is added to the sample solution. If a precipitate forms, it is filtered. Sodium carbonate solution is added to the filtrate (or sample, if no precipitate forms).

*Note:* A precipitate in the initial step (when you use any soluble sulfate compound) indicates that calcium ions are present. A precipitate in the second step (when you use any soluble sulfide, carbonate, phosphate, or sulfite compound) indicates that copper(II) ions are present.

7. Any carbonated beverage is a home solution with a gaseous solute. A diagnostic test is: If a gas is bubbled through limewater, and a white precipitate forms, then the gas contains carbon dioxide.

Another example would be household ammonia, or any of several spray window cleaners containing ammonia. The diagnostic test would be the characteristic odour of ammonia.

8. Sodium carbonate is a typical home solution with a solid solute; e.g., as a water softener (washing soda) in laundry detergents. Diagnostic tests for this example would be flame testing for sodium ions, and precipitation using calcium chloride solution, for carbonate ions.

9. **Experimental Design**

Oxalic acid is added to sample solutions of nitrate or chloride compounds of as many metal cations as can be found in the school laboratory supplies. Any precipitate formation is recorded.

10. **Experimental Design**

A solution of the product is first flame tested; then a solution of calcium chloride is added.

*Note:* A yellow flame test indicates sodium; a precipitate indicates carbonate ions.

## Making Connections

11. Forensic chemists analyze tissue for many things. A typical test would be for the presence and amount of arsenic. Quantity must be measured precisely to determine if a substance is present in a natural amount, or in an amount much greater, which could perhaps indicate foul play.

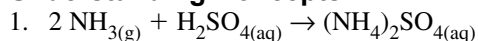
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## 7.6 QUANTITATIVE ANALYSIS

### PRACTICE

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#### Understanding Concepts



24.4 mL      50.0 mL

2.20 mol/L    C

$$n_{\text{NH}_3} = 0.0244 \text{ L} \times \frac{2.20 \text{ mol}}{1 \text{ L}} = 0.0537 \text{ mol}$$

$$n_{\text{H}_2\text{SO}_4} = 0.0537 \text{ mol} \times \frac{1}{2} = 0.0268 \text{ mol}$$

$$n_{\text{H}_2\text{SO}_4} = 0.0268 \text{ mol}$$

$$C_{\text{H}_2\text{SO}_4} = \frac{0.0268 \text{ mol}}{0.0500 \text{ L}}$$

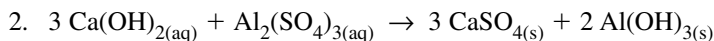
$$C_{\text{H}_2\text{SO}_4} = 0.537 \text{ mol/L}$$

or

$$C_{\text{H}_2\text{SO}_4} = 0.0244 \text{ L NH}_3 \times \frac{2.20 \text{ mol NH}_3}{1 \text{ L NH}_3} \times \frac{1 \text{ mol H}_2\text{SO}_4}{2 \text{ mol NH}_3} \times \frac{1}{0.0500 \text{ L}}$$

$$C_{\text{H}_2\text{SO}_4} = 0.537 \text{ mol/L}$$

The concentration of sulfuric acid at this stage is 0.537 mol/L.



v                      25.0 mL

0.0250 mol/L      0.125 mol/L

$$n_{\text{Al}_2(\text{SO}_4)_3} = 25.0 \text{ mL} \times \frac{0.125 \text{ mol}}{1 \text{ L}} = 3.13 \text{ mmol}$$

$$n_{\text{Ca}(\text{OH})_2} = 3.13 \text{ mmol} \times \frac{3}{1} = 9.38 \text{ mmol}$$

$$v_{\text{Ca}(\text{OH})_2} = 9.38 \text{ mmol} \times \frac{1 \text{ L}}{0.0250 \text{ mol}}$$

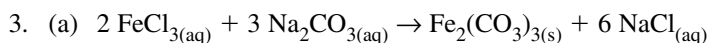
$$v_{\text{Ca}(\text{OH})_2} = 375 \text{ mL}$$

or

$$v_{\text{Ca}(\text{OH})_2} = 25.0 \text{ mL Al}_2(\text{SO}_4)_3 \times \frac{0.125 \text{ mol Al}_2(\text{SO}_4)_3}{1 \text{ mol Al}_2(\text{SO}_4)_3} \times \frac{3 \text{ mol Ca}(\text{OH})_2}{1 \text{ mol Al}_2(\text{SO}_4)_3} \times \frac{1 \text{ L Ca}(\text{OH})_2}{0.0250 \text{ mol}}$$

$$v_{\text{Ca}(\text{OH})_2} = 375 \text{ mL}$$

The volume of calcium hydroxide solution reacted is 375 mL.



75.0 mL                      v