(b) **Evaluation**

A percentage yield of 80% is very low for a precipitation reaction. This would probably indicate that the precipitate remained at least partly dissolved in the original solution, or dissolved to some extent in the wash water. Obviously, a different process must be tried to improve the yield.

Making Connections

4. There are many "green" projects for students to research — one example might be the work on fuel cells to allow cars to run on hydrogen, thus reducing pollutant levels significantly.

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5. Student reports will be specific to the educational institution they choose and especially to the person they choose to interview. The report should concentrate on educational requirements, and the nature of the workday.

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5.7 CHEMISTRY IN TECHNOLOGY

PRACTICE

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Understanding Concepts

1. Inspection of the reaction equations shows that all mole ratios in each step are 1:1, so two moles (in total) of hydrochloric acid are produced for each one mole of sodium carbonate produced.
2. The LeBlanc process was expensive because it required using a large amount of fuel for heat.
3. Air pollutants were a matter of personal concern to people affected directly by them in these centuries, but no government had, as yet, considered that controlling pollutants was its responsibility. People in general were not aware of long-term health hazards or, indeed, of specific pollution hazards, other than odours and skin or lung irritation. Also, because industries were smaller and relatively few in number, pollutant effects tended to be local rather than widespread.

PRACTICE

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Understanding Concepts

4. (a) $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$

   (b) $CO_{2(g)} + NH_{3(aq)} + H_2O_{(l)} \rightarrow NH_4HCO_{3(aq)}$

   (c) $NH_4HCO_{3(aq)} + NaCl_{(aq)} \rightarrow NH_4Cl_{(aq)} + NaHCO_{3(s)}$

   (d) $2\ NaHCO_{3(s)} \rightarrow Na_2CO_{3(s)} + H_2O_{(g)} + CO_{2(g)}$

   (e) $CaO_{(s)} + H_2O_{(l)} \rightarrow Ca(OH)_{2(s)}$

   (f) $Ca(OH)_{2(s)} + 2\ NH_4Cl_{(aq)} \rightarrow 2\ NH_{3(g)} + CaCl_{2(aq)} + 2\ H_2O_{(l)}$

   (g) $CaCO_{3(s)} + 2\ NaCl_{(aq)} \rightarrow Na_2CO_{3(s)} + CaCl_{2(aq)}$ (from text, p. 247)

5. (i) $CaCO_{3(s)} \rightarrow \cancel{CaO}_{(s)} + \cancel{CO}_{2(g)}$

   (ii) $\cancel{CO}_{2(g)} + \cancel{NH}_{3(aq)} + \cancel{H_2O}_{(l)} \rightarrow NH_{\cancel{4}}\cancel{HCO}_{3\,(aq)}$

   (iii) $NH_{\cancel{4}}\cancel{HCO}_{3(aq)} + NaCl_{(aq)} \rightarrow NH_{\cancel{4}}Cl_{\,(aq)} + Na\cancel{HCO}_{3(s)}$

   (iv) $2\ Na\cancel{HCO}_{3(s)} \rightarrow Na_2CO_{3(s)} + \cancel{H_2O}_{(g)} + \cancel{CO}_{2(g)}$

   (v) $\cancel{CaO}_{(s)} + \cancel{H_2O}_{(l)} \rightarrow Ca(\cancel{OH})_{2\,(s)}$

(vi) $Ca(OH)_{2\,(s)} + 2\ NH_4Cl_{\,(aq)} \rightarrow 2\ NH_{3(g)} + CaCl_{2(aq)} + 2\ H_2O_{(l)}$

Totalling the above, we get:

$CaCO_{3(s)} + 2\ NaCl_{(aq)} \rightarrow Na_2CO_{3(s)} + CaCl_{2(aq)}$

6. The raw materials are $CaCO_{3(s)}$ and $NaCl_{(s)}$, both of which are mined easily in large quantity.
7. The primary product is sodium carbonate (washing soda), $Na_2CO_{3(s)}$. The byproduct is calcium chloride, $CaCl_{2(s)}$.
8. Sodium hydrogen carbonate (sodium bicarbonate or baking soda), $NaHCO_{3(s)}$, is a marketable intermediate. Removing this intermediate from the reaction sequence means less sodium carbonate, $Na_2CO_{3(s)}$, will be produced, and some water and carbon dioxide must be added back into the reaction sequence.
9. Water and energy will also be required for this process.
10. Larger reaction scale is more efficient, and thus more economic. It does not cost twice as much to build a reaction vessel twice as large, nor are twice as many employees required to operate it, but it will produce twice as much product, and therefore, twice the value.

PRACTICE

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Making Connections

11. Industries may resist changing processes because of high restructuring costs (new manufacturing plants, new delivery methods, perhaps a need for new resources) and employee change/training/dislocation costs. The risk is loss of profitability; the benefit may not be sufficient, or may not be sufficiently well defined.
12. Consumers have input through consumer action groups, by personal complaints, and through government, but their primary input is the effect they have on the profitability of the process, through their decision to purchase or refuse to purchase the product.
13. Student discussion should include examples of percentage composition, stoichiometric reaction quantities, and percentage yield for the industrial chemical process chosen.

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SECTION 5.7 QUESTIONS

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Understanding Concepts

1. Science is the study of the natural world to describe, predict, and explain changes and substances; technology encompasses the skills, processes, and equipment required to make useful products or to perform useful tasks.
2. (a) Technological question.
   (b) Scientific question.
   (c) Scientific question.
   (d) Technological question.
   (e) Scientific question.
   (f) Technological question.
3. The LeBlanc process produced sodium carbonate (washing soda), which was in demand for glassmaking, among other things.
4. The LeBlanc process required a great quantity of costly fuel for energy, and produced a large quantity of undesirable pollutants.
5. Some (only a few) of the uses of Solvay products and a byproduct:
   (a) $Na_2CO_{3(s)}$ — cleaning compounds, pH control, food additive, glassmaking, chemical analysis.
   (b) $NaHCO_{3(s)}$ — baking powder, pharmaceuticals, sponge rubber, gold and platinum plating, fire extinguishers, cleaners, and antacids.
   (c) $CaCl_{2(s)}$ — de-icing, dust control on roads, fungicides, use in the paper industry, drying agent, and pharmaceuticals.