CHAPTER 7 REVIEW

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Understanding Concepts

1. Combinations (a), (b), (c), (d), and (f) will react, but only (a), (c), (d), and (f) will form precipitates. The reaction equations are:
   (a) $Cu^{2+}_{(aq)} + 2\ OH^-_{(aq)} \rightarrow Cu(OH)_{2(s)}$
   (b) $H^+_{(aq)} + H^-_{(aq)} \rightarrow H_2O_{(l)}$
   (c) $3\ Ca^{2+}_{(aq)} + 2\ PO^{3-}_{4(aq)} \rightarrow Ca_3(PO_4)_{2(s)}$
   (d) $Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$
   (f) $Cu^+_{(aq)} + Cl^-_{(aq)} \rightarrow CuCl_{(s)}$
2. (a) $Zn^{2+}_{(aq)} + CO^{2-}_{3(aq)} \rightarrow ZnCO_{3(s)}$
   (b) $Pb^{2+}_{(aq)} + CO^{2-}_{3(aq)} \rightarrow PbCO_{3(s)}$
   (c) $2\ Fe^{3+}_{(aq)} + 3\ CO^{2-}_{3(aq)} \rightarrow Fe_2(CO_3)_{3(s)}$
   (d) $Cu^{2+}_{(aq)} + CO^{2-}_{3(aq)} \rightarrow CuCO_{3(s)}$
   (e) $Ag^+_{(aq)} + CO^{2-}_{3(aq)} \rightarrow Ag_2CO_{3(s)}$
   (f) $Ni^{2+}_{(aq)} + CO^{2-}_{3(aq)} \rightarrow NiCO_{3(s)}$
   (g) The choice of sodium carbonate is good because carbonate ions form low soluble compounds with most metallic ions and the compound is soluble, common, and inexpensive.
3. (a) $Al^{3+}_{(aq)} + 3\ OH^-_{(aq)} \rightarrow Al(OH)_{3(s)}$
   and $Ca^{2+}_{(aq)} + SO^{2-}_{4(aq)} \rightarrow CaSO_{4(s)}$
   or $2\ Al^{3+}_{(aq)} + 3\ SO^{2-}_{4(aq)} + 3\ Ca^{2+}_{(aq)} + 6\ OH^-_{(aq)} \rightarrow 2\ Al(OH)_{3(s)} + 3\ CaSO_{4(s)}$
   Note: The effective precipitate for clarifying the water is the flocculent precipitate, $Al(OH)_{3(s)}$.
   (b) $3\ Ca^{2+}_{(aq)} + 2\ PO^{3-}_{4(aq)} \rightarrow Ca_3(PO_4)_{2(s)}$
   (c) $Mg^{2+}_{(aq)} + 2\ OH^-_{(aq)} \rightarrow Mg(OH)_{2(s)}$
   (d) $Fe^{3+}_{(aq)} + 3\ OH^-_{(aq)} \rightarrow Fe(OH)_{3(s)}$
4. $Cu^{2+}_{(aq)}$
5. Ions of alkali metals, as well as hydrogen, ammonium, and nitrate ions, form compounds with high solubility.
6. A violet flame indicates potassium ions. A precipitate with $Hg^+_{(aq)}$ could indicate any anion on the solubility chart except sulfate, nitrate, or acetate. The compound in solution might be KCl, KBr, K_2S, K_2SO_4, KOH, K_3PO_4, or ...
7. In aqueous solution:
   (a) Cu^+ is green, Cu^{2+} is blue.
   (b) Fe^{2+} is pale green, Fe^{3+} is yellow-brown.
   (c) CrO_4^{2-} is yellow, $Cr_2O_7^{2-}$ is orange.
8. $Ca^{2+}_{(aq)}$ and $Mg^{2+}_{(aq)}$
9. (a) $Na_2CO_{3(aq)} + CuSO_{4(aq)} \rightarrow Na_2SO_{4(aq)} + CuCO_{3(s)}$
   v 4.54 L
   1.25 mol/L 0.0875 mol/L

$$n_{CuSO_4} = 4.54\ \cancel{L} \times \frac{0.0875\ \text{mol}}{1\ \cancel{L}} = 0.397\ \text{mol}$$

$$n_{Na_2CO_3} = 0.397 \text{ mol} \times \frac{1}{1} = 0.397 \text{ mol}$$

$$v_{Na_2CO_3} = 0.397 \cancel{\text{mol}} \times \frac{1 \text{ L}}{1.25 \cancel{\text{mol}}}$$

$$v_{Na_2CO_3} = 0.318 \text{ L}$$

or

$$v_{Na_2CO_3} = 4.54 \cancel{\text{L}} \cancel{CuSO_4} \times \frac{0.0875 \cancel{\text{mol}} \cancel{CuSO_4}}{1 \cancel{\text{L}} \cancel{CuSO_4}} \times \frac{1 \cancel{\text{mol}} \cancel{Na_2CO_3}}{1 \cancel{\text{mol}} \cancel{CuSO_4}} \times \frac{1 \text{ L } Na_2CO_3}{1.25 \cancel{\text{mol}} \cancel{Na_2CO_3}}$$

$$v_{Na_2CO_3} = 0.318 \text{ L}$$

The minimum volume of sodium carbonate solution required is 0.318 L.

(b) A suitable volume would be about 350 mL. (Assume an excess of > 10%.)

10. The mass of zinc reacted (24.89 g − 21.62 g) = 3.27 g

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

3.27 g   350 mL   350 mL

65.38 g/mol C

$$n_{Zn} = 3.27 \cancel{\text{g}} \times \frac{1 \text{ mol}}{65.38 \cancel{\text{g}}}$$

$$n_{Zn} = 0.0500 \text{ mol}$$

$$n_{ZnCl_2} = 0.0500 \text{ mol} \times \frac{1}{1} = 0.0500 \text{ mol}$$

$$C_{ZnCl_2} = \frac{0.0500 \text{ mol}}{0.350 \text{ L}}$$

$$C_{ZnCl_2} = 0.143 \text{ mol/L}$$

or

$$C_{ZnCl_2} = 3.27 \cancel{\text{g}} \cancel{Zn} \times \frac{1 \cancel{\text{mol}} \cancel{Zn}}{65.38 \cancel{\text{g}} \cancel{Zn}} \times \frac{1 \text{ mol } ZnCl_2}{1 \cancel{\text{mol}} \cancel{Zn}} \times \frac{1}{0.350 \text{ L}}$$

$$C_{ZnCl_2} = 0.143 \text{ mol/L}$$

The molar concentration of zinc chloride solution is 0.143 mol/L.

Applying Inquiry Skills

11. The precipitated anion could be SO_4^{2-}, CO_3^{2-}, PO_4^{3-}, or SO_3^{2-}.
Since most sulfates are soluble, and most sulfites, carbonates, and phosphates are only slightly soluble, the original solution could be tested with $Zn(NO_3)_{2(aq)}$, $Cu(NO_3)_{2(aq)}$, or $Ni(NO_3)_{2(aq)}$, etc. If no precipitate forms, the anion must be SO_4^{2-}.

12. **Experimental Design**
The solution is tested with $TlNO_{3(aq)}$ (or $Hg_2(NO_3)_{2(aq)}$ or $CuNO_{3(aq)}$) for the presence of halide ions. If a precipitate forms it is filtered, and the filtrate (or original solution if no precipitate forms) is tested with $Ca(NO_3)_{2(aq)}$ (or barium, strontium, or radium nitrate) for the presence of sulfate ions.

13. **Experimental Design**
The solutions are tested with litmus to identify the acid and hydroxide (basic) compounds. The remaining solutions are then tested for conductivity (to identify the ionic compound). To confirm that the final solution contains nitrogen gas, it could be heated slightly. The formation of tiny bubbles would confirm the presence of a dissolved gas.
Note: The least confidence is for the nitrogen test. Nitrogen has one-half the solubility of oxygen gas in water — 0.00175 g/100 mL.

14. (a) **Materials**
- deep-seawater sample solution
- 1.00 mol/L $Pb(NO_3)_{2\,(aq)}$ stock solution
- KI $_{(aq)}$ test solution
- medicine dropper
- 50-mL pipet and bulb

- 250-mL beaker
- 400-mL beaker
- filtration apparatus
- filter paper
- wash bottle of pure water
- centigram balance

(b) **Analysis**

mass of $PbCl_{2\,(s)}$ precipitate (4.58 g – 0.91 g) = 3.67 g

$$Pb(NO_3)_{2(aq)} + 2\,NaCl_{(aq)} \rightarrow PbCl_{2\,(s)} + 2\,NaNO_{3(aq)}$$

$$\begin{array}{ll} 50.0\text{ mL} & 3.67\text{ g} \\ C & 278.10\text{ g/mol} \end{array}$$

$$n_{PbCl_2} = 3.67\,\cancel{\text{g}} \times \frac{1\text{ mol}}{278.10\,\cancel{\text{g}}} = 0.0132\text{ mol}$$

$$n_{NaCl} = 0.0132\text{ mol} \times \frac{2}{1} = 0.0264\text{ mol}$$

$$C_{NaCl} = \frac{0.0264\text{ mol}}{0.0500\text{ L}}$$

$$C_{NaCl} = 0.528\text{ mol/L}$$

or

$$C_{NaCl} = 3.67\,\cancel{\text{g}}\,\cancel{PbCl_2} \times \frac{1\,\cancel{\text{mol}}\,\cancel{PbCl_2}}{278.10\,\cancel{\text{g}}\,\cancel{PbCl_2}} \times \frac{2\text{ mol NaCl}}{1\,\cancel{\text{mol}}\,\cancel{PbCl_2}} \times \frac{1}{0.0500\text{ L}}$$

$$C_{NaCl} = 0.528\text{ mol/L}$$

According to the evidence and the stoichiometric concept, the concentration of sodium chloride in the seawater sample is 0.528 mol/L.

(c) **Evaluation**

The design of this experiment is judged to be adequate because it allowed the question to be answered easily, and with confidence in the result. There are no apparent flaws and the equipment is simple and easy to use.

15. (a) **Materials**

- $CuSO_{4(aq)}$ sample solution
- 0.750 mol/L $NaOH_{(aq)}$ stock solution
- medicine dropper
- 25-mL pipet and bulb
- 250-mL beaker
- 400-mL beaker
- filtration apparatus
- filter paper
- wash bottle of pure water
- centigram balance

(b) **Analysis**

mass of $Cu(OH)_{2\,(s)}$ precipitate (2.83 g – 0.88 g) = 1.95 g

$$CuSO_{4(aq)} + 2\,NaOH_{(aq)} \rightarrow Cu(OH)_{2\,(s)} + 2\,Na_2SO_{4(aq)}$$

25.0 mL 1.95 g

C 97.57 g/mol

$$n_{Cu(OH)_2} = 1.95\ \cancel{g} \times \frac{1\ mol}{97.57\ \cancel{g}} = 0.0200\ mol$$

$$n_{CuSO_4} = 0.0200\ mol \times \frac{1}{1} = 0.0200\ mol$$

$$C_{CuSO_4} = \frac{0.0200\ mol}{0.02500\ L}$$

$$C_{CuSO_4} = 0.799\ mol/L$$

or

$$C_{CuSO_4} = 1.95\ \cancel{g\ Cu(OH)_2} \times \frac{1\ \cancel{mol\ Cu(OH)_2}}{97.57\ \cancel{g\ Cu(OH)_2}} \times \frac{1\ mol\ CuSO_4}{1\ \cancel{mol\ Cu(OH)_2}}$$

$$C_{CuSO_4} = 0.799\ mol/L$$

According to the evidence and the stoichiometric concept, the concentration of copper(II) sulfate in the sample is 0.799 mol/L.

(c) **Evaluation**

The design of this experiment is judged to be adequate because it allowed the question to be answered easily, and with confidence in the result. There are no apparent flaws and the equipment is simple and easy to use.

Making Connections

16. For example, the hardness may be 250 ppm (250 mg/L). The soda-lime process could be used by adding washing soda, $Na_2CO_{3(aq)}$, and lime, $Ca(OH)_{2(aq)/(s)}$, to the water to precipitate the hard-water ions as carbonates; e.g., $CaCO_{3(s)}$.
    Note: Answers will be specific to school/community location.

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17. Answers will vary, but might express concern about an old septic system at a cottage because of a danger of leakage, which might release disease-causing organisms into ground water.
    Note: Answers will be specific to school/community location. Student discussion should use concepts from this chapter.

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18. (a) Recall that ppm = mg/L

    $O_{2(aq)}$ (maximum) in 50 L is:

    $$50\ \cancel{L} \times \frac{14.7\ mg}{\cancel{L}} = 735\ mg \text{ at } 0°C$$

    and

    $$50\ \cancel{L} \times \frac{8.7\ mg}{\cancel{L}} = 435\ mg \text{ at } 20°C$$

    $$|735 - 435|\ mg = 300\ mg$$

    The difference in mass of oxygen that can be dissolved in 50 L of water at the two temperatures is 300 mg.

    (b) Fish require O_2 for respiration, so they might prefer 0°C water, in which O_2 solubility is higher and obtaining sufficient oxygen would be easier. On the other hand, the temperature of the surrounding water affects the activity level of cold-blooded animals. The fish would not be able to move as fast at the colder temperature.