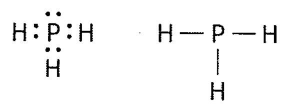
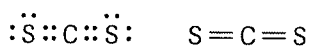
Solutions for Lewis Formulas and Structural Formulas for Molecules, Extra Exercises

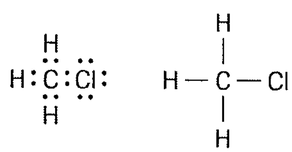
1. Use Lewis formulas and structural formulas to represent molecules of the following compounds:
   (a) $PH_3(g)$ phosphine



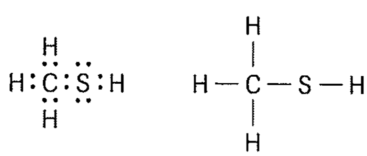
   (b) $CS_2(l)$ carbon disulfide



   (c) $CH_3Cl(g)$, chloromethane



   (d) $CH_3SH(g)$ methanethiol

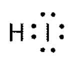


Student Worksheet Solutions LSM 3.3B

Solutions for Predicting Molecular Shapes, Extra Exercises

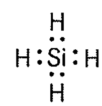
For each of the following molecules, write the chemical formula (if not provided), draw the Lewis formula, and describe the shape around the central atom.

1. hydrogen iodide, HI



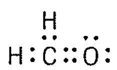
linear

2. silane, SiH_4



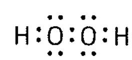
tetrahedral

3. formaldehyde, H_2CO



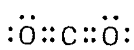
trigonal planar

4. hydrogen peroxide, H_2O_2



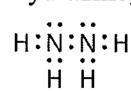
angular around each oxygen atom

5. carbon dioxide, CO_2



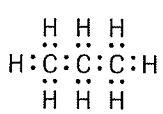
linear

6. hydrazine, N_2H_4



pyramidal around each nitrogen atom

7. propane, C_3H_8



tetrahedral around each carbon atom

Solutions for Gas Laws, Extra Exercises

1. What is the pressure required to compress hydrogen at 1.00 atm from 300 mL to 200 mL at a constant temperature?

$$P_1V_1 = P_2V_2 \qquad P_2 = \frac{P_1V_1}{V_2} = \frac{1.00\text{ atm} \times 300\text{ mL}}{200\text{ mL}} = 1.50\text{ atm}$$

2. A 400 mL sample of a gas at 10 °C is warmed to 25 °C at a constant pressure. Calculate the final volume.

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}, \quad V_2 = \frac{V_1T_2}{T_1} = \frac{400\text{ mL} \times 298\text{ K}}{283\text{ K}} = 421\text{ mL}$$

3. A bicycle tire has a pressure of 450 kPa at 20 °C. Assuming the volume does not change, what is the new pressure at 35 °C?

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}, \quad V_2 = V_1, \quad P_2 = \frac{P_1V_1T_2}{T_1V_2} = \frac{450\text{ kPa} \times 308\text{ K}}{293\text{ K}} = 473\text{ kPa}$$

4. Nitrogen in a 250 mL container at 65.0 kPa is transferred to a container with a volume of 600 mL.

(a) Calculate the new pressure if the temperature is kept constant.

$$P_1V_1 = P_2V_2$$

$$P_2 = \frac{P_1V_1}{V_2} = \frac{65.0\text{ kPa} \times 250\text{ mL}}{600\text{ mL}} = 27.1\text{ kPa}$$

(b) Calculate the new pressure if the temperature changes from 20 °C to 5 °C.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}, \quad P_2 = \frac{P_1V_1T_2}{T_1V_2} = \frac{65.0\text{ kPa} \times 250\text{ mL} \times 288\text{ K}}{293\text{ K} \times 600\text{ mL}} = 26.6\text{ kPa}$$

5. A 450 mL sample of freon gas at 1.50 atm and 15 °C was compressed to 300 mL at a pressure of 2.00 atm. Calculate the final temperature in degrees Celsius.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}, \quad T_2 = \frac{P_2V_2T_1}{P_1V_1} = \frac{2.00\text{ atm} \times 300\text{ mL} \times 288\text{ K}}{1.50\text{ atm} \times 450\text{ mL}} = 256\text{ K or } -17\text{ °C}$$

6. A 2.75 L sample of helium gas at 99.0 kPa was heated from 21.0 °C to 71.0 °C and the pressure changed to 100 kPa. Calculate the final volume.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}, \quad V_2 = \frac{P_1V_1T_2}{P_2T_1} = \frac{99.0\text{ kPa} \times 2.75\text{ L} \times 344\text{ K}}{100\text{ kPa} \times 294\text{ K}} = 3.19\text{ L}$$

Solutions for The Ideal Gas Law, Extra Exercises

Round your answer to three significant digits for each of the following questions.

1. What amount of air, in moles, is present in a house containing 600 m^3 of air at 20 °C and 98 kPa? (1 m^3 = 1 kL)

   PV = nRT

   $$n_{\text{air}} = \frac{PV}{RT} = \frac{98\ \text{kPa} \times 600\ \text{kL} \bullet \text{mol} \bullet \text{K}}{8.31\ \text{kPa} \bullet \text{L} \times 293\ \text{K}} = 24\ \text{kmol}$$

2. Calculate the mass of neon gas in a neon sign with a volume of 50 L at 10 °C and 3.1 kPa.

   $PV = nRT$

   $$n_{\text{Ne}} = \frac{PV}{RT} = \frac{3.1\ \text{kPa} \times 50\ \text{L} \bullet \text{mol} \bullet \text{K}}{8.31\ \text{kPa} \bullet \text{L} \times 283\ \text{K}} = 0.066\ \text{mol}$$

   $$m_{\text{Ne}} = 0.066\ \text{mol} \times \frac{20.18\ \text{g}}{1\ \text{mol}} = 1.3\ \text{g}$$

3. Calculate the volume of 8.4 g of nitrogen at 200 °C and 130 kPa.

   $$n_{N_2} = 8.4\ \text{g} \times \frac{1\ \text{mol}}{28.02\ \text{g}} = 0.30\ \text{mol}$$

   $PV = nRT$

   $$V_{N_2} = \frac{nRT}{P} = \frac{0.30\ \text{mol} \times 8.31\ \text{kPa} \bullet \text{L} \times 473\ \text{K}}{130\ \text{kPa} \times 1\ \text{mol} \bullet \text{K}} = 9.1\ \text{L}$$

4. Hydrogen gas is generated by the decomposition of water to fill a 1.1 kL weather balloon at 20 °C and 100 kPa. What is the mass of hydrogen required?

   PV = nRT

   $$n_{H_2} = \frac{PV}{RT} = \frac{100\ \text{kPa} \times 1.1\ \text{kL} \bullet \text{mol} \bullet \text{K}}{8.31\ \text{kPa} \bullet \text{L} \times 293\ \text{K}} = 0.045\ \text{kmol}$$

   $$m_{H_2} = 0.045\ \text{kmol} \times \frac{2.02\ \text{g}}{1\ \text{mol}} = 91\ \text{g}$$

5. Calculate the volume of 16 g of oxygen at 22 °C and 97.5 kPa.

   $$n_{O_2} = 16\ \text{g} \times \frac{1\ \text{mol}}{32.00\ \text{g}} = 0.50\ \text{mol}$$

   $PV = nRT$

   $$V_{O_2} = \frac{nRT}{P} = \frac{0.50\ \text{mol} \times 8.31\ \text{kPa} \bullet \text{L} \times 295\ \text{K}}{97.5\ \text{kPa} \times 1\ \text{mol} \bullet \text{K}} = 13\ \text{L}$$

Solutions for Properties of Solutions, Extra Exercises

List some properties that could be used to construct diagnostic tests to identify the type of solute in each of the following solutions.

1. An aqueous solution of a molecular substance:
   - **does not conduct electricity**
   - **has no effect on the colour of litmus paper**
2. An aqueous solution of a neutral ionic compound:
   - **conducts electricity**
   - **has no effect on the colour of litmus paper**
3. An aqueous solution of an acid:
   - **conducts electricity**
   - **turns blue litmus paper red**
4. An aqueous solution of a base:
   - **conducts electricity**
   - **turns red litmus paper blue**
5. Identify, by name, the solute and solvent in each of the following solutions.

   (a) $NaOH(aq)$
   solute: sodium hydroxide
   solvent: water

   (b) $CO_2(aq)$
   solute: carbon dioxide
   solvent: water

   (c) $Br_2(al)$
   solute: bromine
   solvent: alcohol

   (d) $Mg(HCO_3)_2(aq)$
   solute: magnesium hydrogen carbonate
   solvent: water

6. **Problem**

Which of the solutions labelled A, B, C, and D contain $HCl(aq)$, $NaClO_4(aq)$, $NH_2OH(aq)$, and $NaOH(aq)$?

Design

(a) Write an experimental design to answer the question. Identify all variables and controls.
Each solution is tested with a conductivity apparatus and with litmus paper. The independent variable is the solution that is to be tested; the dependent variable is the diagnostic test; and the controlled variables are the concentration and temperature of the solution. Pure water is used as a control.

Materials

(b) List all materials required for this investigation.

lab apron
eye protection
solutions A, B, C, and D
distilled water bottle
well plate or small beaker
conductivity apparatus
red and blue litmus paper

Procedure

(c) Write a list of steps that are necessary to answer the question.

1. **Place about 1 mL of pure water in a clean well.**
2. **Test and record the conductivity of the water, then rinse and clean the leads.**
3. **Test with red and blue litmus, and record any colour change.**
4. **Repeat steps 1 to 4 using the given solutions in place of water.**
5. **Dispose of all solutions in the sink and put litmus paper in the wastebasket.**

Solutions to Explaining Solutions, Extra Exercises

1. The following substances are common chemicals:
2. butane, $C_4H_{10}(g)$ (lighters)
3. ethanol, $C_2H_5OH(l)$ (alcoholic drinks)
4. dichloromethane, $CH_2Cl_2(l)$ (solvent in correction fluid)
   (a) Classify the type(s) of intermolecular forces that are present among molecules of each of these substances.
   butane, London dispersion forces
   ethanol, London dispersion, dipole–dipole, hydrogen-bonding forces
   dichloromethane, London dispersion and dipole–dipole
   (b) Predict the solubility (low, moderate, or high) of each substance in water.
   butane, low
   ethanol, high
   dichloromethane, moderate
2. Why are ionic compounds highly soluble in water, compared with their solubility in any other solvent?
   Ionic compounds contain electrically charged ions. The very polar water molecules are able to form many attractions to both the positive and negative ions.
3. List the three features of a water molecule that make water the best solvent.
   Water molecules have a small size, are highly polar, and have a considerable capacity for hydrogen bonding.
4. For each of the following substances, write the chemical formula including pure state of matter at SATP, predict the solubility (low/high) in water, and if appropriate write a balanced dissociation equation.
   (a) silver sulfide
   $Ag_2S(s)$
   low
   (b) ammonium borate
   $(NH_4)_3BO_3(s)$
   high
   $(NH_4)_3BO_3(s) \rightarrow 3\ NH_4^+(aq) + BO_3^{3-}(aq)$
   (c) copper(II) nitrate trihydrate
   $Cu(NO_3)_2 \cdot 3H_2O(s)$
   high
   $Cu(NO_3)_2 \cdot 3H_2O(s) \rightarrow Cu_2^+(aq) + 2\ NO_3^-(aq) + 3\ H_2O(l)$
   (d) glucose, $C_6H_{12}O_6(s)$
   high

Solutions to Concentration 1, Extra Exercises

Use concentration as a conversion factor to calculate the quantity requested in each question below. Communicate your problem-solving approach, including units and correct certainty.

1. Cow's milk contains 4.5 g of lactose per 100 mL of milk. What mass of lactose is present in 250 mL (one glass) of milk?

$$m_{\text{lactose}} = 250\ \text{mL} \times \frac{4.5\ \text{g}}{100\ \text{mL}} = 11\ \text{g}$$

2. A 10% W/V salt solution is used in making pickles. What mass of salt is present in 750 mL of this solution?

$$m_{\text{NaCl}} = 750\ \text{mL} \times \frac{10\ \text{g}}{100\ \text{mL}} = 75\ \text{g}$$

3. A 250 mL measuring cup of cleaning solution contains 1.2 mol of dissolved ammonia. What is the amount concentration of this solution?

$$c_{\text{NH}_3} = \frac{1.2\ \text{mol}}{0.250\ \text{L}} = 4.8\ \text{mol/L}$$

4. Fish require a concentration of about 4.5 ppm (4.5 mg/L) of dissolved oxygen in water. What volume of water would contain 100 mg of oxygen?

$$V_{\text{H}_2\text{O}} = 100\ \text{mg} \times \frac{1\ \text{L}}{4.5\ \text{mg}} = 22\ \text{L}$$

5. What volume of concentrated 14.6 mol/L phosphoric acid would contain 2.00 mol of solute?

$$V_{\text{H}_3\text{PO}_4} = 2.00\ \text{mol} \times \frac{1\ \text{L}}{14.6\ \text{mol}} = 0.137\ \text{L}$$

6. What mass of table salt is needed to prepare 1.20 L of 5.20 mol/L solution?

$$n_{\text{NaCl}} = 1.20\ \text{L} \times \frac{5.20\ \text{mol}}{1\ \text{L}} = 6.24\ \text{L}$$

$$m_{\text{NaCl}} = 6.24\ \text{L} \times \frac{58.44\ \text{g}}{1\ \text{mol}} = 365\ \text{g}$$

7. What is the amount concentration of zinc nitrate if 94.2 g of solute is dissolved to make 2.00 L of solution?

$$n_{\text{Zn(NO}_3)_2} = 94.2\ \text{g} \times \frac{1\ \text{mol}}{189.40\ \text{g}} = 0.497\ \text{mol}$$

$$c_{\text{Zn(NO}_3)_2} = \frac{0.497\ \text{mol}}{2.00\ \text{L}} = 0.249\ \text{mol/L}$$

Solutions to Concentration 2, Extra Exercises

Modern analytical chemistry uses some sophisticated technology to detect incredibly small quantities of substances. Chemical analysis is approaching one part per trillion concentrations. (See Appendix F.2 for the symbols and values of SI prefixes.)

1. An ICP (inductively coupled plasma technology) vaporizes a small sample, which is then analyzed by a mass spectrometer. The detection limit for lead using this method is 0.05 ng/mL.
   (a) What is the detection limit for lead in ppb?
   For dilute aqueous solutions, 1 mL is equivalent to 1 g.
   $$\frac{\mathbf{0.05\ ng}}{\mathbf{1\ g}} = \mathbf{0.05 \times 10^{-9}} = \frac{\mathbf{0.05}}{\mathbf{10^{9}}} = \mathbf{0.05\ ppb}$$
   (b) What volume of solution would contain 1.0 g of lead?
   $$v_{\mathrm{Pb}} = \mathbf{1.0\ g} \times \frac{\mathbf{1\ mL}}{\mathbf{0.05\ ng}} = \mathbf{20\ ML}$$
2. A laser-based microchemical analysis has a detection limit of 9×10^{-10} mol/L using a sample volume of 0.2 pL. How many molecules are present in this sample?
   $$n = \mathbf{0.2\ pL} \times \frac{\mathbf{9 \times 10^{-10}\ mol}}{\mathbf{1\ L}} = \mathbf{2 \times 10^{-22}\ mol}$$
   number of molecules = $\mathbf{2 \times 10^{-22}}$ mol × $\mathbf{6.02 \times 10^{-23}}$ /mol = $\mathbf{1 \times 10^{2}}$
3. Using a sample volume of 0.2 pL, what amount concentration of solute corresponds to the presence of one molecule?
   $$n = \frac{\mathbf{1\ mol}}{\mathbf{6.02 \times 10^{23}\ entities}} = \mathbf{1.66 \times 10^{-24}\ mol}$$
   $$c = \frac{\mathbf{1.66 \times 10^{-24}\ L}}{\mathbf{0.2 \times 10^{-12}\ L}} = \mathbf{8 \times 10^{-12}\ mol/L}$$
4. The detection limit for 2,4-dinitrophenylhydrazones using capillary liquid chromatography is 15 ag in a sample volume of 0.20 pL. (1 ag (attogram) equals 10^{-18} g.) Convert this limit into a concentration in ppb.
   $$c = \frac{\mathbf{15\ ag}}{\mathbf{0.20\ pL}} = \frac{\mathbf{15 \times 10^{-9}\ ng}}{\mathbf{0.20 \times 10^{-9}\ mL}} = \mathbf{75\ ng/g = 75\ ppb}$$

Solutions to Dilution, Extra Exercises

1. An ammonia solution is made by diluting 150 mL of the concentrated commercial reagent until the final volume reaches 1000 mL. What is the final amount concentration?
   $V_i c_i = V_f c_f$
   150 mL × 14.8 mol/L = 1000 mL × c_f
   c_f **= 2.22 mol/L**
2. What volume of a 500 ppm reagent solution is required to prepare a 2.5 L solution with a 100 ppm concentration?
   $V_i c_i = V_f c_f$
   V_i **× 500 ppm = 2.5 L × 100 ppm**
   V_i **= 0.50 L**
3. A 500 mL bottle of concentrated acetic acid is diluted to make a 5.0% solution. Find the volume of diluted solution that is prepared.
   $V_i c_i = V_f c_f$
   500 mL × 99.5% = V_f **× 5.0%**
   V_f **= 10 L**
4. In a chemical analysis, a 25.0 mL sample was diluted to 500.0 mL and analyzed. If the diluted solution had an amount concentration of 0.108 mol/L, what was the amount concentration of the original sample?
   $V_i c_i = V_f c_f$
   25.0 mL × c_i **= 500.0 mL × 0.108 mol/L**
   c_i **= 2.16 mol/L**
5. If a 355 mL can of soda pop is diluted to a final volume of 1.00 L, what can be said quantitatively about the concentration of the diluted solution as compared with the original solution?
   $V_i c_i = V_f c_f$
   0.355 L × c_i **= 1.00 L ×** c_f
   c_f **= 0.355**c_i

Solutions to Solution Preparation, Extra Exercises

Communicate your problem-solving approach when answering the following questions.

1. Calculate the amount concentration of a solution made by dissolving 20.0 g of sodium hydroxide to make 300 mL of solution.

$$n_{NaOH} = 20.0\ \text{g} \times \frac{1\ \text{mol}}{40.00\ \text{g}} = 0.500\ \text{mL}$$

$$c_{NaOH} = \frac{0.500\ \text{mol}}{0.300\ \text{L}} = 1.67\ \text{mol/L}$$

2. Pure sodium thiosulfate–water (1/5), $Na_2S_2O_3•5H_2O(s)$, is used to make 250 mL of 20.0 mmol/L solution. Find the mass of solute required.

$$n_{Na_2S_2O_3g5H_2O} = 0.250\ \text{L} \times \frac{20.0\ \text{mmol}}{1\ \text{L}} = 5.00\ \text{mmol}$$

$$m_{Na_2S_2O_3g5H_2O} = 5.00\ \text{mmol} \times \frac{248.20\ \text{g}}{1\ \text{mol}} = 1.24\ \text{g}$$

3. What mass of copper(II) nitrate is required to prepare 10.0 L of 0.100 mol/L solution?

$$n_{Cu(NO_3)_2} = 10.0\ \text{L} \times \frac{0.100\ \text{mol}}{1\ \text{L}} = 1.00\ \text{mol}$$

$$m_{Cu(NO_3)_2} = 1.00\ \text{mol} \times \frac{187.57\ \text{g}}{1\ \text{mol}} = 188\ \text{g}$$

4. What volume of 75 mmol/L solution can be prepared from 10 g of sodium carbonate?

$$n_{Na_2CO_3} = 10\ \text{g} \times \frac{1\ \text{mol}}{105.99\ \text{g}} = 94\ \text{mmol}$$

$$V_{Na_2CO_3} = 94\ \text{mmol} \times \frac{1\ \text{L}}{75\ \text{mmol}} = 1.3\ \text{L}$$

5. Determine the volume of concentrated hydrochloric acid required to prepare 10.0 L of a 0.200 mol/L solution.

$$V_i c_i = V_f c_f$$

$$V_i \times \frac{11.6\ \text{mol}}{1\ \text{L}} = 10.0\ \text{L} \times \frac{0.200\ \text{mol}}{1\ \text{L}}$$

$$V_i = 0.172\ \text{L}$$

6. What volume of concentrated ammonia is required to prepare 2.0 L of a 1.0 mol/L solution?

$$V_i c_i = V_f c_f$$

$$V_i \times \frac{14.8\ \text{mol}}{1\ \text{L}} = 2.0\ \text{L} \times \frac{1.0\ \text{mol}}{1\ \text{L}}$$

$$V_i = 0.14\ \text{L}$$

Solutions to Solubility, Extra Exercises

1. Classify the following liquids as miscible or immiscible with water: gasoline, vinegar, ethanol, and cooking oil.
   miscible: vinegar, ethanol
   immiscible: gasoline, cooking oil
2. A glass of cold water left sitting on a counter at room temperature usually develops many small gas bubbles on the inside of the glass. Describe what is likely happening.
   Water contains dissolved air. As the temperature of the water increases, the solubility of air in water decreases. Therefore, air bubbles form in the water.
3. Which group of monatomic ions forms compounds that are all highly soluble in water?
   Group 1 compounds all have high solubility in water.
4. Which positive polyatomic ion forms compounds that are all highly soluble in water?
   Ammonium compounds all have high solubility in water.
5. Use the solubility chart (inside back cover of the textbook) to predict the solubility of the following ionic compounds. Write the chemical formula and indicate that the chemical is highly soluble by writing "(aq)" (e.g., NaCl(aq)) or that it is only slightly soluble by writing "(s)" (e.g., $CaCO_3$(s)).

(a) KCl (fertilizer)	**KCl(aq)**
(b) $Ca(NO_3)_2$ (fireworks)	**$Ca(NO_3)_2$(aq)**
(c) Na_2SO_4 (Glauber's salt)	**Na_2SO_4(aq)**
(d) $AgCH_3COO$ (oxidizing agent)	**$AgCH_3COO$(s)**
(e) ammonium bromide (fireproofing)	**NH_4Br(aq)**
(f) barium sufide (vulcanizing)	**BaS(s)**
(g) lead(II) iodide (photography)	**PbI_2(s)**
(h) calcium hydroxide (slaked lime)	**$Ca(OH)_2$(s)**
(i) iron(III) hydroxide (rust)	**$Fe(OH)_3$(s)**
(j) lead(II) sulfate (component of car batteries)	**$PbSO_4$(s)**
(k) calcium phosphate (rock phosphorus)	**$Ca_3(PO_4)_2$**
(l) potassium permanganate (fungicide)	**$KMnO_4$(aq)**
(m) sodium tripolyphosphate (detergent)	**$Na_5P_3O_{10}$(aq)**
(n) ammonium nitrate (fertilizer)	**NH_4NO_3(aq)**
(o) cobalt(II) chloride (humidistat)	**$CoCl_2$(aq)**
(p) calcium carbonate (limestone)	**$CaCO_3$(s)**

6. Predict the solubility of the following chemicals in water. Use the ionic solubility table (inside back cover), the generalization that all elements (except chlorine) are only slightly soluble in water, and the molecular solubility in Table 2 (Section 5.2). Write the chemical formula with (aq) to show high solubility or (s), (l), or (g) to show low solubility.

(a) Zn (in a dry cell)	**$Zn(s)$**
(b) P_4 (white phosphorus)	**$P_4(s)$**
(c) $C_{12}H_{22}O_{11}$ (sugar)	**$C_{12}H_{22}O_{11}(aq)$**
(d) methanol (antifreeze)	**$CH_3OH(aq)$**
(e) methane (natural gas)	**$CH_4(g)$**
(f) octane (in gasoline)	**$C_8H_{18}(l)$**
(g) barium sulfate (ingested for gastric X-ray diagnostics)	**$BaSO_4(s)$**
(h) sodium hydroxide (drain cleaner)	**$Na(OH)(aq)$**
(i) ammonia (cleaner)	**$NH_3(aq)$**
(j) hydrogen fluoride (glass etcher)	**$HF(aq)$**
(k) iodine (disinfectant)	**$I_2(s)$**
(l) iron (metal)	**$Fe(s)$**

7. Use examples to answer the question: Does slightly soluble mean insoluble?
No; slightly soluble does not mean insoluble. For example, oxygen is only slightly soluble in water, but there is enough oxygen dissolved in the water that fish can live in it. Oxygen is also soluble in low, but significant, amounts in blood and plant fluids.

Solutions to Properties of Acids and Bases, Extra Exercises

1. Describe how each of the following tests is used to distinguish acidic, basic, and neutral solutions:
   (a) litmus paper
   If blue litmus paper turns red, the solution is acidic. If red litmus paper turns blue, the solution is basic. If no colour change occurs in either colour of litmus paper, the substance is neutral.
   (b) pH
   If the pH value of a solution is less than 7, the solution is acidic. If the pH value is greater than 7, the solution is basic. If the pH value is 7, the solution is neutral.

2. What methods are used to determine pH? State some advantages and disadvantages of each method.

Table 1 Methods Used to Determine pH

Methods	Advantages	Disadvantages
digital pH meter	much more accurate reading	relatively expensive
pH test strips	relatively inexpensive	less accurate

3. Once empirical definitions of compounds are established, what kind of knowledge about compounds is likely to follow?
   Theoretical knowledge explaining the empirical evidence is likely to follow.

4. Use the evidence in the table below to classify each of the following compounds as ionic, molecular, an acid, or a base.

Table 2 Properties of Compounds

SATP state	Solution conductivity	Litmus test	Classification of compound
s	yes	red to blue	**a base**
l	no	no change	**molecular**
g	yes	blue to red	**an acid**
s	yes	no change	**ionic**
s	no	no change	**molecular**

5. Complete the Analysis of the following investigation report and evaluate the Design.

Purpose

The scientific purpose of this investigation is to use the properties of compounds to identify unlabelled solutions.

Problem

Which of the 0.1 mol/L solutions, labelled 1, 2, 3, 4, and 5, is $KCl(aq)$, $CaBr_2(aq)$, $HCl(aq)$, $CH_3OH(aq)$, and $NaOH(aq)$?

Design

The solutions are prepared so that they all have the same concentration and temperature. Each solution is observed and tested for its effect on litmus paper, conductivity, and pH.

Evidence

Table 3 Evidence from Tests on Five Solutions

Solution	Colour	Litmus	Conductivity	pH
1	none	red to blue	high	13
2	none	no change	high	7
3	none	no change	very high	7
4	none	no change	none	7
5	none	blue to red	high	1

Analysis

According to the evidence obtained, solution 1 is $NaOH(aq)$; 2 is $KCl(aq)$; 3 is $CaBr_2(aq)$; 4 is $CH_3OH(aq)$; 5 is $HCl(aq)$.

Evaluation

The experimental design is adequate since the problem was answered. There were no obvious flaws in the design, but it can be made more efficient by eliminating the observation for colour, since it is not required.
Overall, I am quite confident in the design and in the answer. Sources of uncertainty may include measurement errors in the preparation of the solutions and in the instruments used. These sources of uncertainty would not be a major factor in affecting the outcome and the level of certainty of the answer is high.

Solutions to Properties of Acids and Bases, Extra Exercises

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2	none	no change	high	7
3	none	no change	very high	7
4	none	no change	none	7
5	none	blue to red	high	1

Analysis

According to the evidence obtained, solution 1 is NaOH(aq); 2 is KCl(aq); 3 is $CaBr_2$(aq); 4 is CH_3OH(aq); 5 is HCl(aq).

Evaluation

The experimental design is adequate since the problem was answered. There were no obvious flaws in the design, but it can be made more efficient by eliminating the observation for colour, since it is not required.

Overall, I am quite confident in the design and in the answer. Sources of uncertainty may include measurement errors in the preparation of the solutions and in the instruments used. These sources of uncertainty would not be a major factor in affecting the outcome and the level of certainty of the answer is high.

Solutions to pH of a Solution, Extra Exercises

1. (a) What is the pH of a solution with a hydronium ion concentration of 1×10^{-7} mol/L?
   pH = –log [H_3O^+(aq)] = –log (1×10^{-7}) = 7.0
   (b) What is the pH of a solution with a hydronium ion concentration of 1×10^{-5} mol/L?
   pH = –log [H_3O^+(aq)] = –log (1×10^{-5}) = 5.0
   (c) Compare the hydronium ion concentrations and pH's in (a) and (b).
   The hydrogen ion concentrations differ by a factor of 100 (10^2) and the pHs differ by 2 units.
2. What happens to the pH of a solution when
   (a) the hydronium ion concentration increases?
   The pH decreases.
   (b) the hydronium ion concentration decreases?
   The pH increases.
   (c) a strong acid is diluted?
   The pH increases because the hydronium ion concentration decreases upon dilution.
3. Some hydrochloric acid is completely neutralized with a sodium hydroxide solution. Describe the pHs of the reactants and final solution.
   The pH of the acid is less than 7; the pH of the base is greater than 7; and the pH of the final solution is 7.
4. A vinegar solution has a pH of 2.82. Calculate the hydronium ion concentration of this solution.
   [H_3O^+(aq)] = 10^{-pH} = $10^{-2.82}$ mol/L = 1.5×10^{-3} mol/L

Complete the following table.

Table 1 pH of Common Liquids

Substance		[H_3O^+(aq)] (mol/L)	pH	Acidic, basic, or neutral
5.	milk	3.1×10^{-8}	**6.51**	**acidic**
6.	pure water	**1×10^{-7}**	7.0	**neutral**
7.	blood	4.0×10^{-8}	**7.40**	**basic**
8.	drain cleaner	**1×10^{-15}**	15.0	**basic**

Solutions for Net Ionic Equations, Extra Exercises

1. A zinc strip is dipped into an aqueous solution of silver nitrate.
   $Zn(s) + 2\ AgNO_3(aq) \rightarrow 2\ Ag(s) + Zn(NO_3)_2(aq)$
   $Zn(s) + 2\ Ag^+(aq) + 2\ NO_3^-(aq) \rightarrow 2\ Ag(s) + Zn^{2+}(aq) + 2\ NO_3^-(aq)$
   $Zn(s) + 2\ Ag^+ \rightarrow 2\ Ag(s) + Zn^{2+}(aq)$

2. Solutions of lead(II) nitrate and potassium chloride are mixed.
   $Pb(NO_3)_2(aq) + 2\ KCl(aq) \rightarrow 2\ KNO_3(aq) + PbCl_2(s)$
   $Pb^{2+}(aq) + 2\ NO_3^-(aq) + 2\ K^+(aq) + 2\ Cl^-(aq) \rightarrow 2\ K^+(aq) + 2\ NO_3^-(aq) + PbCl_2(s)$
   $Pb^{2+}(aq) + 2\ Cl^-(aq) \rightarrow PbCl_2(s)$

3. Barium hydroxide is used to neutralize sulfuric acid.
   $Ba(OH)_2(aq) + H_2SO_4(aq) \rightarrow 2\ HOH(l) + BaSO_4(s)$
   $Ba^{2+}(aq) + 2\ OH^-(aq) + 2\ H^+(aq) + 2\ SO_4^{2-}(aq) \rightarrow 2\ HOH(aq) + BaSO_4(s)$

4. Chlorine gas is bubbled through an aqueous solution of sodium iodide.
   $2\ NaI(aq) + Cl_2(g) \rightarrow 2\ NaCl(aq) + I_2(s)$
   $2\ Na^+(aq) + 2\ I^-(aq) + Cl_2(g) \rightarrow 2\ Na^+(aq) + 2\ Cl^-(aq) + I_2(s)$
   $2\ I^-(aq) + Cl_2(g) \rightarrow 2\ Cl^-(aq) + I_2(s)$

5. Aqueous solutions of aluminium sulfate and calcium hydroxide are mixed.
   $Al_2(SO_4)_3(aq) + 3\ Ca(OH)_2(aq) \rightarrow 3\ CaSO_4(s) + 2\ Al(OH)_3(s)$
   $2\ Al^{3+}(aq) + 3\ SO_4^{2-}(aq) + 3\ Ca^{2+}(aq) + 6\ OH^-(aq) \rightarrow 3\ CaSO_4(s) + 2\ Al(OH)_3(s)$

6. An iron nail is dropped into a beaker of sulfuric acid.
   $2\ Fe(s) + 3\ H_2SO_4(aq) \rightarrow Fe_2(SO_4)_3(aq) + 3\ H_2(g)$
   $2\ Fe(s) + 6\ H^+(aq) + 3\ SO_4^{2-}(aq) \rightarrow 3\ Fe^{2+}(aq) + 3\ SO_4^{2-}(aq) + 3\ H_2(g)$
   $2\ Fe(s) + 6\ H^+(aq) \rightarrow 3\ Fe^{2+}(aq) + 3\ H_2(g)$

Solutions to Gravimetric Stoichiometry, Extra Exercises

1. Calculate the mass of iron(III) oxide (rust) produced by the reaction of 500 g of iron with oxygen from the air.

$4\ Fe(s) + 3\ O_2(g) \rightarrow\ 2\ Fe_2O_3(s)$
500 g — ***m***
55.85 g/mol — 159.70 g/mol

$$n_{Fe} = 500\ g \times \frac{1\ mol}{55.85\ g} = 8.95\ mol$$

$$n_{Fe_2O_3} = 8.95\ mol \times \frac{2}{4} = 4.48\ mol$$

$$m_{Fe_2O_3} = 4.48\ mol \times \frac{159.70\ g}{1\ mol} = 715\ g$$

or

$$m_{Fe_2O_3} = 500\ g\ Fe \times \frac{1\ mol}{55.85\ g} \times \frac{2\ mol\ Fe_2O_3}{4\ mol\ Fe} \times \frac{159.70\ g\ Fe_2O_3}{1\ mol\ Fe_2O_3} = 715\ g$$

2. What mass of precipitate should form if 2.00 g of silver nitrate in solution is reacted with excess sodium sulfide solution?

$2\ AgNO_3(aq) + Na_2S(aq) \rightarrow\ Ag_2S(s) + 2\ NaNO_3(aq)$
2.00 g — ***m***
55.85 g/mol — 159.70 g/mol

$$n_{AgNO_3} = 2.00\ g \times \frac{1\ mol}{169.88\ g} = 0.0118\ mol$$

$$n_{Ag_2S} = 0.0118\ mol \times \frac{1}{2} = 0.00589\ mol$$

$$m_{Ag_2S} = 0.00589\ mol \times \frac{247.80\ g}{1\ mol} = 1.46\ g$$

or

$$m_{Ag_2S} = 2.00\ g\ AgNO_3 \times \frac{1\ mol\ AgNO_3}{169.88\ g\ AgNO_3} \times \frac{1\ mol\ Ag_2S}{2\ mol\ AgNO_3} \times \frac{247.80\ g\ Ag_2S}{1\ mol\ Ag_2S} = 1.46\ g$$

3. Determine the mass of water vapour formed when 1.00 g of butane, $C_4H_{10}(g)$, is burned in a lighter.

$2\ C_4H_{10}(g) + 13\ O_2(g) \rightarrow\ 8\ CO_2(g) + 10\ H_2O(g)$
1.00 g — ***m***
58.14 g/mol — 18.02 g/mol

$$n_{C_4H_{10}} = 1.00\ g \times \frac{1\ mol}{58.14\ g} = 0.0172\ mol$$

$$n_{H_2O} = 0.0172\ mol \times \frac{10}{2} = 0.0860\ mol$$

$$m_{H_2O} = 0.0860\ mol \times \frac{18.02\ g}{1\ mol} = 1.55\ g$$

or

$$m_{H_2O} = 1.00\ g\ C_4H_{10} \times \frac{1\ mol\ C_4H_{10}}{58.14\ g\ C_4H_{10}} \times \frac{10\ mol\ H_2O}{2\ mol\ C_4H_{10}} \times \frac{18.02\ g\ H_2O}{1\ mol\ H_2O} = 1.55\ g$$

4. Silver metal can be recovered from waste silver nitrate solutions by reaction with copper metal. What mass of silver can be obtained using 50 g of copper?

$2\ AgNO_3(aq) + Cu(s) \rightarrow$		$2\ Ag(s) + Cu(NO_3)_2(aq)$
	50 g	*m*
	63.55 g/mol	107.87 g/mol

$$n_{Cu} = 50\ g \times \frac{1\ mol}{63.55\ g} = 0.79\ mol$$

$$n_{Ag} = 0.79\ mol \times \frac{2}{1} = 1.6\ mol$$

$$m_{Ag} = 1.6\ mol \times \frac{107.87\ g}{1\ mol} = 0.17\ kg$$

or

$$m_{Ag} = 50\ g\ Cu \times \frac{1\ mol\ Cu}{63.55\ g\ Cu} \times \frac{2\ mol\ Ag}{1\ mol\ Cu} \times \frac{107.87\ g\ Ag}{1\ mol\ Ag} = 0.17\ kg$$

Solutions to Gas Stoichiometry, Extra Exercises

Complete the following stoichiometric problems. Communicate your problem-solving approach using internationally accepted symbols for elements, quantities, numbers, and units.

1. The first step in the industrial manufacture of sulfuric acid is the complete combustion of octasulfur, $S_8(s)$. What mass of octasulfur is required to produce 112 L of sulfur dioxide at STP?

$S_8(s) + 8\ O_2(g) \rightarrow\ 8\ SO_2(g)$
m 112 L
256.48 g/mol 22.4 L/mol

$$n_{SO_2} = 112\ \text{L}\ SO_2 \times \frac{1\ \text{mol}}{22.4\ \text{L}} = 5.00\ \text{mol}$$

$$n_{S_8} = 5.00\ \text{mol} \times \frac{1}{8} = 0.625\ \text{mol}$$

$$m_{S_8} = 0.625\ \text{mol} \times \frac{256.48\ \text{g}}{1\ \text{mol}} = 160\ \text{g}$$

or

$$m_{Ag} = 112\ \text{L} \times \frac{1\ \text{mol}\ SO_2}{22.4\ \text{L}\ SO_2} \times \frac{1\ \text{mol}\ S_8}{8\ \text{mol}\ SO_2} \times \frac{256.48\ \text{g}\ S_8}{1\ \text{mol}\ S_8} = 160\ \text{g}$$

2. Coal can undergo an incomplete combustion in the absence of a plentiful supply of air to produce deadly carbon monoxide gas. What volume of carbon monoxide is produced at SATP by the incomplete combustion of 150 kg of coal?

$2\ C(s) + O_2(g) \rightarrow\ 2\ CO(g)$
150 kg V
12.01 g/mol 24.8 L/mol

$$n_C = 150\ \text{kg} \times \frac{1\ \text{mol}}{12.01\ \text{g}} = 12.5\ \text{kmol}$$

$$n_{CO} = 12.5\ \text{kmol} \times \frac{2}{2} = 12.5\ \text{kmol}$$

$$V_{CO} = 12.5\ \text{kmol} \times \frac{24.8\ \text{L}}{1\ \text{mol}} = 310\ \text{kL}$$

or

$$V_{CO} = 150\ \text{kg C} \times \frac{1\ \text{mol C}}{12.01\ \text{g C}} \times \frac{2\ \text{mol CO}}{2\ \text{mol C}} \times \frac{24.8\ \text{L CO}}{1\ \text{mol CO}} = 310\ \text{kL}$$

3. The first recorded observation of hydrogen gas was made by the famous alchemist Paracelsus when he added iron to sulfuric acid. Calculate the volume of hydrogen gas at STP produced by adding 10.0 g of iron to an excess of sulfuric acid.

$2\ Fe(s) + 3\ H_2SO_4(aq) \rightarrow\ 3\ H_2(g) + Fe_2(SO_4)_3(aq)$
10.0 g V
55.85 g/mol 22.4 L/mol

$$n_{Fe} = 10.0\ g \times \frac{1\ mol}{55.85\ g} = 0.179\ mol$$

$$n_{H_2} = 0.179\ mol \times \frac{3}{2} = 0.269\ mol$$

$$V_{H_2} = 0.269\ mol \times \frac{22.4\ L}{1\ mol} = 6.02\ L$$

or

$$V_{H_2} = 10.0\ g\ Fe \times \frac{1\ mol\ Fe}{55.85\ g} \times \frac{3\ mol\ H_2}{2\ mol\ Fe} \times \frac{22.4\ L\ H_2}{1\ mol\ H_2} = 6.02\ L$$

4. Ammonia reacts with sulfuric acid to form the important fertilizer, ammonium sulfate. What mass of ammonium sulfate can be produced from 75.0 kL of ammonia at 10 °C and 110 kPa?

2 NH_3(g) + H_2SO_4(aq) → $(NH_4)_2SO_4$(aq)
75.0 kL — ***m***
10 °C, 110 kPa — **132.16 g/mol**

$$n_{NH_3} = \frac{PV}{RT} = \frac{110\ kPa \times 75.0\ kL \bullet mol \bullet K}{8.31\ kPa \bullet L \times 283\ K} = 3.51\ kmol$$

$$n_{(NH_4)_2SO_4} = 3.51\ kmol \times \frac{1}{2} = 1.75\ kmol$$

$$m_{(NH_4)_2SO_4} = 1.75\ kmol \times \frac{132.16\ g}{1\ mol} = 232\ kg$$

or

$$m_{(NH_4)_2SO_4} = 75.0\ kL \times \frac{1\ mol \bullet K}{8.31\ kPa \bullet L} \times \frac{110\ kPa}{283\ K} \times \frac{1\ mol\ (NH_4)_2SO_4}{2\ mol\ NH_3} \times \frac{132.16\ g\ (NH_4)_2SO_4}{1\ mol\ (NH_4)_2SO_4} = 232\ kg$$

Solutions to Mixed Stoichiometry, Extra Exercises

Complete the following stoichiometric problems. Communicate your problem-solving approach using internationally accepted symbols for elements, quantities, numbers, and units.

1. A 6.72 g sample of zinc was placed in 100.0 mL of 1.50 mol/L hydrochloric acid. After all reaction stops, how much zinc should remain?

$Zn(s)$ +	**2 $HCl(aq)$ →**	**$H_2(g)$ + $ZnCl_2(aq)$**
6.72 g	**100.0 mL**	
65.38 g/mol	**1.50 mol/L**	

$$n_{HCl} = 100.0\ mL \times \frac{1.50\ mol}{1\ L} = 150\ mmol$$

$$n_{Zn} = 150\ mmol \times \frac{1}{2} = 75.0\ mmol$$

$$m_{Zn} = 75.0\ mmol \times \frac{65.38\ g}{1\ mol} = 4.90\ g\ (reacted)$$

or

$$m_{Zn} = 100.0\ mL\ HCl \times \frac{1.50\ mol\ HCl}{1\ L\ HCl} \times \frac{1\ mol\ Zn}{2\ mol\ HCl} \times \frac{65.38\ g\ Zn}{1\ mol\ Zn} = 4.90\ g$$

mass of zinc remaining = 6.72 g - 4.90 g = 1.82 g

2. An unlabelled white solid acid, $H_2X(s)$, is known to react in a 1:2 mole ratio with sodium hydroxide. In an attempt to identify the acid, a titration provides evidence that 12.5 mL of 0.300 mol/L $NaOH(aq)$ reacts with 0.169 g of the acid. What is the molar mass of the acid?

$H_2X(aq)$ +	**2 $NaOH(aq)$ →**	**2 $H_2O(l)$ + $Na_2X(aq)$**
0.169 g	**12.5 mL**	
M	**0.300 mol/L**	

$$n_{NaOH} = 12.5\ mL \times \frac{0.300\ mol}{1\ L} = 3.75\ mmol$$

$$n_{H_2X} = 3.75\ mmol \times \frac{1}{2} = 1.88\ mmol$$

or

$$m_{H_2X} = 12.5\ mL\ NaOH \times \frac{0.300\ mol\ NaOH}{1\ L\ NaOH} = \frac{1\ mol\ H_2X}{2\ mol\ NaOH} = 1.88\ mmol$$

$$M_{H_2X} = \frac{0.169\ g}{1.88\ mmol} = 90.1\ g/mol$$

3. What volume of hydrogen gas at STP will be produced when 1000 g of aluminium is added to 4.00 L of 1.40 mol/L sulfuric acid?

3 $H_2SO_4(aq)$ +	**2 $Al(s)$ →**	**2 $H_2O(l)$ + $Na_2X(aq)$**
4.00 L	**100 g**	***V***
1.40 mol/L	**26.98 g/mol**	**22.4 L/mol**

$$n_{Al} = 100.0\ g \times \frac{1\ mol}{26.98\ g} = 3.71\ mol$$

$$n_{H_2SO_4} = 4.00\ L \times \frac{1.40\ mol}{1\ L} = 5.60\ mol\ (available)$$

If all of this aluminium reacts, then the chemical amount of sulfuric acid required is :

$$n_{H_2SO_4} = 3.71\ mol \times \frac{3}{2} = 5.56\ mol$$

Therefore, excess sulfuric acid is available, and aluminium is the limiting reagent.

$$n_{H_2} = 3.71\ mol \times \frac{3}{2} = 5.56\ mol$$

$$V_{H_2} = 5.56\ mol \times \frac{22.4\ L}{1\ mol} = 125\ L$$

or

$$V_{H_2} = 3.71\ mol\ Al \times \frac{3\ mol\ H_2}{2\ mol\ Al} \times \frac{22.4\ L\ H_2}{1\ mol\ H_2} = 125\ L$$

Solutions for Solution Stoichiometry, Extra Exercises

Complete the following stoichiometric problems. Communicate your problem-solving approach using internationally accepted symbols for elements, quantities, numbers, and units.

1. What is the amount concentration of a KOH(aq) solution if 12.8 mL of this solution is required to react with 25.0 mL of 0.110 mol/L H_2SO_4(aq)?

2 KOH(aq) + H_2SO_4(aq) → K_2SO_4(aq) + H_2O(l)
12.8 mL 25.0 mL
C **0.110 mol/L**

$$n_{H_2SO_4} = 25.0\ \text{mL} \times \frac{0.110\ \text{mol}}{1\ \text{L}} = 2.75\ \text{mmol}$$

$$n_{KOH} = 2.75\ \text{mmol} \times \frac{2}{1} = 5.50\ \text{mmol}$$

$$C_{KOH} = \frac{5.50\ \text{mmol}}{12.8\ \text{mL}} = 0.430\ \text{mol/L}$$

or

$$C_{KOH} = 25.0\ \text{mL H}_2\text{SO}_4 \times \frac{0.110\ \text{mol H}_2\text{SO}_4}{1\ \text{L H}_2\text{SO}_4} \times \frac{2\ \text{mol KOH}}{1\ \text{mol H}_2\text{SO}_4} \times \frac{1}{12.8\ \text{mL}} = 0.430\ \text{mol}$$

2. What volume of 0.125 mol/L NaOH(aq) is required to react completely with 15.0 mL of 0.100 mol/L $Al_2(SO_4)_3$(aq)?

6 NaOH(aq) + $Al_2(SO_4)_3$(aq) → 2 $Al(OH)_3$(s) + 3 Na_2SO_4(aq)
V **15.0 mL**
0.125 mol/L 0.110 mol/L

$$n_{Al_2(SO_4)_3} = 15.0\ \text{mL} \times \frac{0.100\ \text{mol}}{1\ \text{L}} = 1.50\ \text{mmol}$$

$$n_{NaOH} = 1.50\ \text{mmol} \times \frac{6}{1} = 9.00\ \text{mmol}$$

$$V_{NaOH} = 9.00\ \text{mmol} \times \frac{1\ \text{L}}{0.125\ \text{mol}} = 72.0\ \text{mL}$$

or

$$V_{NaOH} = 15.0\ \text{mL Al}_2(\text{SO}_4)_2 \times \frac{0.100\ \text{mol Al}_2(\text{SO}_4)_2}{1\ \text{L Al}_2(\text{SO}_4)_2} \times \frac{6\ \text{mol NaOH}}{1\ \text{mol Al}_2(\text{SO}_4)_2} \times \frac{1\ \text{L NaOH}}{0.125\ \text{mol NaOH}}$$

$$= 72.0\ \text{mL}$$

3. In a chemical analysis, a 10.0 mL sample of $H_3PO_4(aq)$ was reacted with 18.2 mL of 0.259 mol/L NaOH(aq). Calculate the amount concentration of the phosphoric acid.

$$H_3PO_4(aq) + 3\ NaOH(aq) \rightarrow Na_3PO_4(aq) + 3\ H_2O(l)$$

10.0 mL **18.2 mL**

C **0.259 mol/L**

$$n_{NaOH} = 18.2\ mL \times \frac{0.259\ mol}{1\ L} = 4.71\ mmol$$

$$n_{H_3PO_4} = 4.71\ mmol \times \frac{1}{3} = 1.57\ mmol$$

$$C_{H_3PO_4} = \frac{1.57\ mmol}{10.0\ mL} = 0.157\ mol/L$$

or

$$C_{H_3PO_4} = 18.2\ mL\ NaOH \times \frac{0.259\ mol\ NaOH}{1\ L\ NaOH} \times \frac{1\ mol\ H_3PO_4}{3\ mol\ NaOH} \times \frac{1}{10.0\ mL} = 0.157\ mol/L$$

4. The concentration of magnesium ions (assume magnesium chloride) in sea water was analyzed and found to be 50.0 mmol/L. What volume of 0.200 mol/L sodium hydroxide solution would be needed in an industrial process to precipitate all of the magnesium ions from 1.00 ML of sea water?

$$MgCl_2(aq) + 2\ NaOH(aq) \rightarrow Mg(OH)_2(s) + 2\ NaCl(aq)$$

1.00 ML ***V***

50.0 mmol/L **0.200 mol/L**

$$n_{MgCl_2} = 1.00\ ML \times \frac{50.0\ mmol}{1\ L} = 50.0\ kmol$$

$$n_{NaOH} = 50.0\ kmol \times \frac{2}{1} = 100\ kmol$$

$$V_{NaOH} = 100\ kmol \times \frac{1\ L}{0.200\ ml} = 500\ kL$$

or

$$V_{NaOH} = 1.00\ ML\ MgCl_2 \times \frac{50.0\ mmol\ MgCl_2}{1\ L\ MgCl_2} \times \frac{2\ mol\ NaOH}{1\ mol\ MgCl_2} \times \frac{1\ L\ NaOH}{0.200\ mol\ NaOH} = 500\ kL$$

Solutions for Gravimetric Analysis, Extra Exercises

1. In a chemical analysis to test the purity of a bottle of sodium bromide, a solution containing 1.17 g of sodium bromide was reacted with an excess of dimercury(I) acetate solution. The dry precipitate had a mass of 2.73 g. Calculate the percent yield for the precipitate and comment on the purity of sodium bromide.

$2\ NaBr(aq) + Hg_2(CH_3COO)_2(aq) \rightarrow Hg_2Br_2(s) + 2\ NaCH_3COO(aq)$

1.17 g		***m***	
102.89 g/mol		**560.98 g/mol**	

$$n_{NaBr} = 1.17\ g \times \frac{1\ mol}{102.89\ g} = 0.0114\ mol$$

$$n_{Hg_2Br_2} = 0.0114\ mol \times \frac{1}{2} = 0.00569\ mol$$

$$m_{Hg_2Br_2} = 0.00569\ mol \times \frac{560.98\ g}{1\ mol} = 3.19\ g$$

or

$$m_{Hg_2Br_2} = 1.17\ g\ NaBr \times \frac{1\ mol\ NaBr}{102.89\ g\ NaBr} \times \frac{1\ mol\ Hg_2Br_2}{2\ mol\ NaBr} \times \frac{560.98\ g\ Hg_2Br_2}{1\ mol\ Hg_2Br_2} = 3.19\ g$$

$$\%\ yield = \frac{2.73\ g}{3.19\ g} \times 100 = 85.6\%$$

The purity of the sodium bromide is relatively poor and it is likely a technical grade rather than a reagent grade.

2. A solution containing 2.56 g of aluminium nitrate is mixed with a solution containing 1.02 g of ammonium sulfide. Determine the unreacted mass of the excess reagent and the mass of precipitate formed.

$2\ Al(NO_3)_3(aq) + 3\ (NH_4)_2S(aq) \rightarrow Al_2S_3(s) + 6\ NH_4NO_3(aq)$

2.56 g	**1.02 g**	***m***	
213.01 g/mol	**68.16 g/mol**	**150.14 g/mol**	

$$n_{Al(NO_3)_3} = 2.56\ g \times \frac{1\ mol}{213.01\ g} = 0.0120\ mol$$

$$n_{(NH_4)_2S} = 1.02\ g \times \frac{1\ mol}{68.16\ g} = 0.0150\ mol$$

If $Al(NO_3)_3$ is the limiting reagent, the chemical amount of $(NH_4)_2S$ required is:

$$n_{(NH_4)_2S} = 0.0120\ mol \times \frac{3}{2} = 0.0180\ mol$$

Insufficient $(NH_4)_2S$ is present, so $Al(NO_3)_3$ is the excess reagent and $(NH_4)_2S$ is the limiting reagent.

$$n_{Al(NO_3)_3} = 0.0150\ mol \times \frac{2}{3} = 0.00998\ mol\ (required\ amount)$$

$$n_{Al(NO_3)_3} = 0.0120\ mol - 0.00998\ mol = 0.0020\ mol\ (excess\ amount)$$

$$m_{Al(NO_3)_3} = 0.0020\ mol \times \frac{213.01\ g}{1\ mol} = 0.43\ g\ \text{excess (unreacted mass)}$$

$$n_{Al(NO_3)_3} = 0.0150\ mol \times \frac{1}{3} = 0.00499\ mol$$

$$m_{Al_2S_3} = 0.00499\ mol \times \frac{150.14\ g}{1\ mol} = 0.749\ g$$

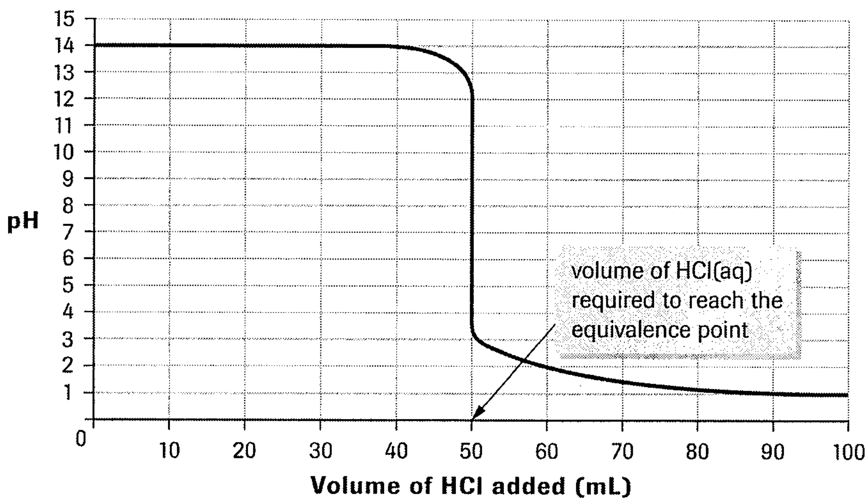
or

$$m_{Al_2S_3} = 0.0150\ mol\ (NH_4)_2S \times \frac{1\ mol\ Al_2S_3}{3\ mol\ (NH_4)_2S} \times \frac{150.14\ g\ Al_2S_3}{1\ mol\ Al_2S_3} = 0.749\ g$$

Solutions for Predicting pH Curves, Extra Exercise

1. (a) Using the axes below, sketch a graph to predict how the pH of a NaOH(aq) sample in Investigation 8.5 will change as HCl(aq) is gradually added, first enough volume to get to the equivalence point (complete reaction), and then more until at least a 100% excess has been added. (Hint: First consider whether the initial and final pH readings will be high or low.)
   (b) What pH do you predict at the equivalence point?
   (c) If litmus is used as an indicator, describe what colours will be observed as the titration proceeds.

   (a) The initial pH is obviously going to be high in a strong base solution (Chapter 6), and the final pH, just as obviously, must be low in an excess of strong acid.



   (b) The equivalence point will be at approximately pH 7.5.

   (c) Initially the solution will be blue, with litmus, but will turn red when 50 mL of acid has been added.

