Key

ChemQuest 51

Mixing Acids and Bases

Name: _____

Date: _____

Hour: _____

Information: Dilutions

When water is added to a solution, the concentration decreases. It is often desirable to be able to calculate the concentration of solutions that have been diluted. For doing this, keep in mind that molarity is equal to the moles of solute divided by the total liters of solution. Therefore, the following equations are valid where M is molarity, $L_{solution}$ is liters of solution and mol_{solute} is the moles of solute:

Equation #1: $$M = \frac{mol_{solute}}{L_{solution}}$$

Equation #2: $$mol_{solute} = (M)(L_{solution})$$

Critical Thinking Questions

For the following questions, assume that liquid volumes are additive.

1. A certain solution is prepared by dissolving 4.0 moles of salt (NaCl) in enough water to make 400 mL of solution. Later, the solution was diluted with enough water so that the volume of the solution was 650 mL. Calculate the molarity of the solution before and after dilution.
   M_{before} = 4.0mol ÷ 0.400L = 10.0 M
   M_{after} = 4.0mol ÷ 0.650L = 6.15 M

2. A 6.0 M solution of salt has a volume of 500 mL. Later, 275 mL of water is added. Confirm that the molarity of the resulting is approximately 3.87 M. (Hint: first find the moles of salt present before the additional 275 mL of water was added by using equation #2 and then find the new molarity using equation #1.)
   moles of salt = 6.0M x 0.5L = 3.0mol
   M = 3.0mol ÷ (0.500 + 0.275)L = 3.87 M

3. Calculate the molarity of the solution formed by taking 350 mL of 2.25 M HCl and adding 420 mL of water.
   mol solute = 2.25M x 0.350L = 0.788 mol
   M = 0.788mol ÷ (0.350 + 0.420) = 1.02 M

4. Imagine that you have 300 mL of a stock solution of 2.8 M HCl solution. Describe how I could prepare 50 mL of 1.2 M HCl solution by using some of stock solution and diluting it with water. Be specific.
   mol HCl needed = 1.2M x 0.050L = 0.060 mol
   (2.8M)(xL) = 0.060 → x = 0.0214 L = 21.4 mL
   Take 21.4 mL of the stock solution and dilute it to 50 mL.

Information: Mixing Strong Acids and Strong Bases

Usually when we speak of "salt" we mean table salt, which is sodium chloride (NaCl). A salt is a general term for an ionic compound formed when an acid and a base mix. Whenever an acid and a base react, water and a salt are formed. For example consider the following reactions in which nitric acid (HNO_3) and hydrochloric acid (HCl) react with the base sodium hydroxide (NaOH):

$$HCl + NaOH \rightarrow NaCl + H_2O$$
$$HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$$

Notice that in each reaction water and a salt (sodium chloride one reaction and sodium nitrate in another) were formed.

If equal moles of strong acid and strong base react, then they neutralize each other and form a solution of salt water. If there are more moles of acid than base then the resulting solution will be acidic. If there are more moles of base than acid, then the resulting solution will be basic.

Critical Thinking Questions

5. Consider the reaction of 2.5 moles of hydrochloric acid with 1.9 moles of sodium hydroxide.
   a) If this reaction took place in 2.0 L of solution, what is the concentration of leftover hydrochloric acid after the reaction?

      mol leftover = 2.5 – 1.9 = 0.6 mol ÷ 2.0L = 0.3 M

   b) From your answer to part a, verify that the pH of the solution after the reaction is approximately 0.52.

      pH = -log(0.3) = 0.52

6. Question 5 could be rewritten like this: *Consider the reaction of 1.0 L of _2.5_ M hydrochloric acid with 1.0 L of _1.9_ M sodium hydroxide.* Fill in the blanks with the appropriate numbers indicating the molarity.

7. 320 mL of 3.1 M HCl is mixed with 240 mL of 4.1 M NaOH. Use the following steps to find the pH of the resulting solution.
   a) Calculate the moles of HCl and the moles of NaOH that are reacting using Equation #2.
   mol HCl = (3.1M)(0.320L) = 0.992 mol
   mol NaOH = (4.1M)(0.240L) = 0.984 mol

   b) Find out which substance is left over and find out how many moles of this substance is left over.
   mol HCl leftover = 0.992 – 0.984 = 0.008 mol

   c) Divide the moles left over by the total volume in liters to get the concentration of the left over substance.
   0.008 mol ÷ (0.320+0.240) = 0.014 M

   d) Your answer to part c is also the concentration of H^+ (if the acid is left over) or the concentration of OH^- (if the base is left over). From this information calculate the pH of the solution. You should get approximately 1.85 for your answer.
   $[H^+] = [HCl] = 0.014M$
   pH = -log(0.014) = 1.85

8. Calculate the pH of a solution formed by mixing 450 mL of 0.79 M HCl with 430 mL of 1.2 M NaOH. Hint: this is very similar to question 7.
   13.26
   mol HCl = (0.79M)(0.450L) = 0.356mol; mol NaOH = (1.2M)(0.430L) = 0.516mol
   mol NaOH leftover = 0.516 – 0.356 = 0.16 mol ÷ (0.45+0.43) = 0.182 M = $[OH^-]$
   pOH = -log(0.182) = 0.74 → pH = 14 – 0.74 = 13.26

9. Calculate the pH of a solution formed by mixing 820 mL of 1.2 M HNO_3 with 700 mL of 0.9 M NaOH.
   0.633
   mol HNO_3 = (1.2)(0.820) = 0.984 mol; mol NaOH = (0.9)(0.700) = 0.630 mol
   mol HNO_3 leftover = 0.984 – 0.630 = 0.354 mol ÷ (0.700+0.820) = 0.233 M = $[H^+]$
   pH = -log(.233) = 0.633

10. Consider 400 mL of a 2.5 M HCl solution. How many milliliters of 1.25 M NaOH will be needed to neutralize the HCl?
   800 mL
   mol NaOH must equal mol HCl = (2.5M)(0.400L) = 1.00 mol
   L = mol ÷ M = 1.00 ÷ 1.25 = 0.800 L → 800 mL

Skill Practice 51

Mixing Practice

Name: _____

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1. What is the pH of a solution formed by diluting 245 mL of 0.024 M HCl with 200 mL of water? (Assume volumes of liquids are additive.)

   1.88

2. What is the pH of a solution made by mixing 1.5 L of 0.35 M HCl with 2.0 L of 0.10 M NaOH?

   1.03

3. In titration, the equivalence point is when the moles of an acid equals the moles of a base. Consider 245 mL of 0.25 M NaOH being titrated with 0.40 M HCl.

   a) How many mL of HCl will need to be added to reach the equivalence point?

      153 mL

   b) What is the pH at the equivalence point?

      7

4. What is the pH of a solution formed by mixing 1.27 L of 0.035 M NaOH with 1.65 L of 0.025 M HCl?

   11.51

5. Find the pH of a solution that is formed by diluting 450 mL of 0.045 M NaOH with 300 mL of water. (Assume volumes of liquids are additive.)

   12.43