Skill Sheet 23-A   Making Solutions

Chemists are required to make many of the solutions that they use in experiments. They may be provided with a material in solid form and need to dissolve it in a suitable solvent, or they may be provided with a solution and need to dilute it to make a new solution of a certain concentration. Chemists use basic techniques to calculate the necessary amounts of the solute and solvent. You will practice these calculation techniques in the following exercises.

1. What is molarity?

Making solutions is something you already know how to do! For example, when you add some hot cocoa mix to a cup of hot water, you are making a solution. In a science lab, the ingredients for solutions often include water and a chemical compound. These solutions are described according to their *molarity*. *Molarity* is a scientific measure of concentration. The formula for molarity is:

$$\text{molarity} = M = \frac{\text{moles of solute}}{\text{liters of solution}}$$

Remember that a *mole* is equivalent to the mass of Avogadro's number of atoms or molecules. If I had a mole of carbon atoms, I would have 6.022×10^{23} atoms. A carbon atom has a mass of 12.01 atomic mass units (amu). A mole of carbon has a mass of 12.01 grams. Remember you can derive the mass of one mole of an element by finding the atomic mass on a periodic table.

Likewise, if I had a mole of sodium chloride, I would have 6.022×10^{23} molecules of NaCl. What would be the mass of a mole of NaCl molecules?

2. Making solutions from a solid solute

A scientist needs to prepare one liter of a solution of potassium chloride (KCl) for an experiment. The concentration of the required solution is 3.2 M. How will the scientist prepare this solution from the solid KCl she has in a jar on her lab shelf?

To answer this question, let's first break it down.

The scientist needs 1 liter of a solution. She wants the final concentration to be 3.2 M.

After reading part 1, you know how to figure out how much KCl you would need to make a 1 M solution. The mass of a potassium atom is 39 amu and the mass of a chlorine atom is 35 amu. This means that KCl has a mass of 74 amu and one mole of KCl is 74 grams.

To make a 1 M solution of KCl you would dissolve 74.0 grams in one liter of water.

For 1 liter of a 3.20 M solution, we need 3.20 moles of solute. To find out how many grams of KCl we need to make this solution, use the following calculation.

$$3.20 \text{ moles} \times 74.0 \text{ g/mole} = 237 \text{ g KCl}$$

The scientist would make the solution by dissolving 237 grams of KCl in 1 liter of water.

3. Practice preparing solutions

Practice your skills in making solutions by solving the following problems. The first one is done for you.

1. Two liters of a 0.8 M solution of KNO_3 was prepared from solid KNO_3 and water. How many grams of KNO_3 were used in the preparation of this solution?

    You need 2 liters of a solution. The final concentration of the solution is 0.8 M.
    K = 39 amu; N = 14 amu; O = 16 amu (x 3)
    KNO_3 = 39 amu + 14 amu + 48 amu = 101 amu
    KNO_3 = 101 grams
    1 mole of KNO_3 = 101 grams

    $$2.00 \text{ L} \times 0.80 \text{ moles}/\text{L} \times 101 \text{ g/mole } = 162 \text{ g } KNO_3$$

    To make two liters of a 0.8 M solution of KNO_3, you need 162 grams of KNO_3.

2. A chemist needs 500 ml of a 2.1 M NaOH solution. How many grams of NaOH are required to make this solution?

3. A scientist uses 68 grams of $CaCO_3$ to prepare 1.5 liters of solution. What is the molarity of this solution?

4. An experiment requires 3 liters of a 0.75 M $Mg(OH)_2$ solution. How many grams of $Mg(OH)_2$ are required to prepare this reagent?

5. The density of two solutions—NaCl and $MgCl_2$— was measured. If the concentrations and volumes of the solutions were identical, which solution do you think would be more dense? Explain your answer.

4. Preparing solutions from existing solutions—dilution

Stock solutions of substances are prepared solutions of a given concentration. Stock solutions can be diluted to make a solution of a different concentration. The formula below will help you do this easily.

$$V_i C_i = V_f C_f$$

where V_i and C_i represent the volume and concentration of the stock solution (the initial solution) and V_f and C_f represent the volume and concentration of the final solution. Using this formula, scientists can create any lower concentration solution from a more concentrated stock solution. The concentration of a solution can be represented as molarity or as a percentage.

Example 1:

A scientist needs to prepare 2.5 liters of 0.3 M NaCl solution. Her stock solution is 4.5 M. How will the woman prepare the final solution?

First, we need to use the formula to calculate the volume of stock solution necessary to prepare the final solution. We know that the molarity of the stock solution (C_i) is 4.5 M, the desired molarity of the final solution is 0.3 M, and the final volume required is 2.5 liters. Inserting this information into the formula:

$$V_i C_i = V_f C_f$$

$$(V_i) \times 4.5 \text{ M NaCl} = 2.5 \text{ liters NaCl} \times 0.3 \text{ M NaCl}$$

$$V_i = 0.17 \text{ liters, or 170 ml of 4.5 M NaCl}$$

To prepare the final solution, the scientist would add 170 milliliters of her stock solution and add sufficient solvent to get a final volume of 2.5 liters.

Example 2:

In science laboratories, it is often important to work in a sterile environment. As you might know, alcohol kills bacteria. The least concentrated alcohol solution you need to kill bacteria is 70%. How would you make 500 milliliters of a 70% alcohol solution if you had a 95% alcohol stock solution?

$$V_i C_i = V_f C_f$$

$$(V_i) \times 95\% \text{ ethanol} = 0.5 \text{ L} \times 70\% \text{ ethanol}$$

$$V_i = 0.37 \text{ liters or 370 mL of 95\% ethanol}$$

To prepare the final solution, you would mix 370 milliliters of stock solution with 130 milliliters of water to get a final volume of 0.5 liters.

5. Practice dilution calculations

1. A chemist purchases a 2.0 M stock solution of KNO_3. He would like to prepare 100 milliliters of 0.5 M KNO_3. Describe how he would prepare this solution. Show your work.

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2. How many liters of 3.5 M HCl are required to make 0.75 liters of 1.5 M HCl?

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3. A scientist uses 1.3 liters of 0.65 M $Ca(NO_3)_2$ solution in an experiment. The stock solution from which she prepared this solution was 2.0 M. What volume of the stock solution did she use in the preparation of the solution for the experiment? What volume of solvent was used?

4. 135 ml of a 6.0 M $NaHCO_3$ solution was used in the preparation of 1.5 liters of diluted $NaHCO_3$. What is the molarity of the diluted solution?

5. How many grams of $NaHCO_3$ went into the preparation of one liter of the 6.0 M stock solution in the previous problem?

6. You have a 80% solution of household vinegar. This means that there are 80 milliliters of vinegar in every 100 milliliters of solution. How could you use this stock solution to make up 1 liter of a 20% vinegar solution?

7. If you take 40 milliliters of a 60% solution and add it to 100 milliliters of water. What is the concentration and volume of the final solution?