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Unit 4 – Moles and Solutions

Progress Tracker

Test Date:

Webassign Due *Score*

Packet Progress Checks

Test Readiness Checks:

- ☐ My webassign scores indicate I am ready for the test.
- ☐ I went to ASP for Webassign help when needed.
- ☐ I have completed the unit review AND checked my answers.
- ☐ I am aware that I cannot retake the test unless my webaassign and packet progress checks are all above 80%.

Learning Objectives

4.1 Mole concepts and calculations
4.2 Lewis Structures

4.1 Mole concepts and calculations

- Demonstrate a conceptual understanding of the magnitude of the mole and why chemists count using the mole.

  1 mole = 6.022 x 10^{23} atoms, molecules, or ions

- Demonstrate an understanding of the concept of counting by mass.
- Calculate the molar mass of a compound.
- Determine the number of moles or number of particles in a specified mass of a substance. (or vice versa)
- Solve "Part of a whole" problems: (e.g. Determine the number of ions in a specific mass of an ionic compound.)

4.2 Solution concepts and calculations

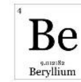
- Define common solutions terminology:
    - Solute
    - Solvent
    - Solution
    - Saturated
    - Unsaturated
    - Concentrated
    - Dilute
    - Soluble
    - Insoluble
    - Stock solution

- Calculate the molarity of a solution given grams or moles of the solute and a volume of the solution.

$$M = \frac{mole\ of\ solute}{Liters\ of\ solution}$$

- Calculate the number of grams needed to make up a solution to a desire concentration.
- Produce a solution in lab doing proper calculations, writing a reproducible procedure, and using appropriate technique and glassware.
- Understand or produce particulate representations of solutions that show relative concentrations or solubilities.
- Use an aliquot of a stock solution to produce a dilute that has a desired concentration.

$$M_1V_1 = M_2V_2$$



Prior Knowledge Check

We will need two skills we learned at the beginning of the year to solve problems in Unit 4. Discuss each of these questions with your neighbor to check your understanding:

Unit Conversions:

1. We need to remember how to use our conversion chart to write metric conversion factors. Find a conversion factor to interconvert these two units:

   _______________mL = _________________ kL (Which side will be "1"?)

2. How many centigrams are in 0.0016 hectograms? (set up a train track and find a conversion factor)

3. How many liters are in 28 quarts? (set up a train track and find a conversion factor)

Scientific Notation

1. Which of these numbers is larger 4×10^{-4} or 5×10^{-5}

2. Use your calculator to find the answer to 6×10^{16} / 2×10^{10}

Mole Notes

Number	Name
12	
2	
	touchdown

1. In your group, think of at least 3 more examples of numbers that have been given names:

   Number **Name**

   ______ ____________________

   ______ ____________________

   ______ ____________________

In Chemistry, we need to count in groups as well.

Number **Name**

602,000,000,000,000,000,000,000

2. As far as we know, no baker has ever packaged up a mole of donuts. Bakers do not use the mole. Can you think of an occupation that could use the mole in their workplace other than chemists?

3. Why do you think chemists don't package (or count) atoms in dozens like bakers do? Why does the mole have to be such a large number?

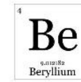
4. Bill Gates is one of the richest people in the world. About how much money do you think Bill Gates has?_________________________ Does he have more or less money than a mole of money?

5. In each of the following pairs, circle the number that is larger. If they are the same, write "same" next to them.

a. 10	or	1 dozen
b. 30	or	1 decade
c. 12	or	2 touchdowns
d. 602,000,000,000,000,000,000,000	or	7.4×10^{28}
e. 6×10^{5}	or	1 mole
f. 2 moles	or	6×10^{46}
g. 1 mole of chlorine atoms	or	1 mole of fluorine atoms

6. The conversion factor that we will use most in this unit is:

=



Moles to Atoms or Molecules Practice

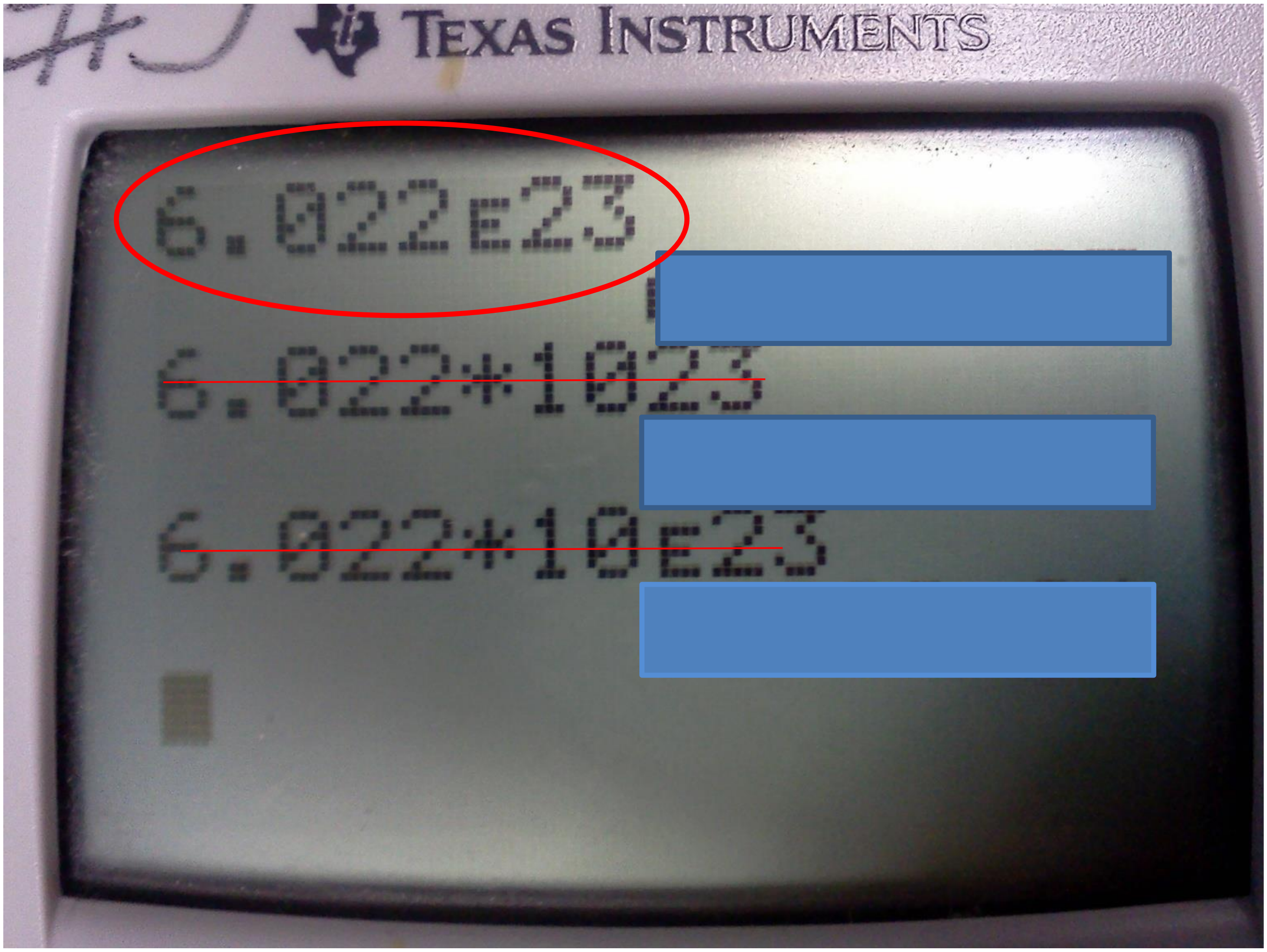
1 mole = 6.022×10^{23} atoms or molecules or ions

Example 1: How many atoms are in 12 moles of copper?

Example 2: How many moles are in 7.1×10^{22} molecules of water?

Practice 1: How many moles are in 5.5×10^{24} atoms of Ni?

Practice 2: How many molecules are in 4 moles of NH_3 molecules?



Counting By Weight

Measurements:

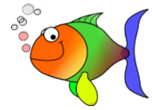
1 **mole** of Cu = 602,000,000,000,000,000,000,000 atoms of Cu = ___________ g Cu

1 **mole** of Sn = 602,000,000,000,000,000,000,000 atoms of Sn = _____________ g Sn

1 **mole** of Zn = 602,000,000,000,000,000,000,000 atoms of Zn = _____________ g Zn

What mass of Aluminum would you need to weigh out to have 6.02×10^{23} atoms of Aluminum? ___________ g

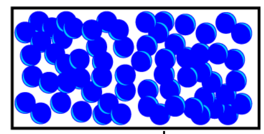
Understanding Molar Mass



Skill: Defining Molar Mass

We have seen that if we want to measure out 1 mole of Cu atoms, we would weigh out 63.5 g of Cu. If we wanted to weigh 1 mole of Sn atoms, we would need 118 g of Sn. **The number of grams in 1 mole of a substance is the *molar mass* of that substance.** Scientists decided that a mole should have 6.02 x 10^{23} atoms because they wanted the following relationship to be true:

Examples:

1 **atom** of Cu weighs 63.5 **a.m.u.** 	1 **mole** of Cu atoms weighs 63.5 **grams**  **(**Remember: this is a whole big pile of atoms)
1 **atom** of N weighs 14.0 **a.m.u.**	1 **mole** of N atoms weighs 14.0 **grams**
1 **atom** of Mg weighs 24.3 **a.m.u.**	1 **mole** of Mg atoms weighs 24.3 **grams**

Practice:

1. Based on the examples above, a **mole** of carbon atoms would weigh 12.0 __________(fill in the units)
2. Based on the example above, a **single atom** of chlorine would weigh 35.5__________(fill in the units)
3. A mole of sodium atoms would weigh ________________________ (fill in the number and units)
4. A mole of bromine atoms would weigh _______________________(fill in the number and units)

Skill: Calculating the Molar Mass of <u>Compounds</u>

We now know that to find the molar mass of an atom, we just look it up on the periodic table. Most substances are compounds however. Here is how we would calculate the molar mass of H_2O:

Example: Calculating the molar mass of H_2O

First list all of the elements in the compound:	H = 1.01 g
Then put the mass of each element.	H = 1.01 g
Then add up the masses.	<u>O = 15.99 g</u>
	1 mole H_2O = 18.01 g

Practice: Following the example above, calculate the molar mass of each of these compounds. Make a list of atoms like was done in the example.

5. What is the molar mass of NH_3?

N =

H =

H =

H = __________

1 mole of NH_3 = g

6. What is the molar mass of CaF_2?(Make an atom list like above)

1 mole of CaF_2 = ___________ g

7. What is the molar mass of $Mg(NO_3)_2$? (remember: you should have 6 oxygens in your list)

1 mole of $Mg(NO_3)_2$ = ___________ g

8. How would the answer change if you wanted to know the mass of **one single** $Mg(NO_3)_2$ molecule?

9. What is the molar mass of ammonium sulfide? (Calculate the answer, then answer the question, "why do we need to be careful when given a chemical in its name format?")

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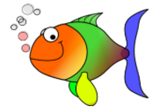
Gram to Mole Conversions



Skill: Using Molar Mass as a Conversion Factor

Molar mass is a conversion factor. It allows us to convert **grams** to **moles**, or the other way around. When calculating molar mass, it is very important to write the molar mass in this exact format:

1 mole H_2O = 18.01 g

We need to avoid forgetting the units, because they guide us when solving problems.

~~1 mole H_2O = 18.01~~

~~1 H_2O = 18.01 g~~

Let's see how to use the molar mass as a conversion factor

Example:

How many **grams** of H_2O are in 1.6 **moles** of H_2O? (Notice the units in this problem! We can use molar mass to convert between these two.)

Solution:

1.6 ~~moles~~ H_2O	*18.01 g*
	1 ~~mole~~

= 28.8 g

Molar Mass Conversion Factor:

1 mole H_2O = *18.01 g*

Practice:

1. How many moles of NH_3 are in 18 grams of NH_3? (set-up the train tracks below.)
   Here is your conversion factor: **1 mole NH_3** = *17.0 g*

= (Confirm that the answer is 1.059 moles)

2. How many grams are in 0.45 moles of NaCl? (set-up the train tracks below.)
   What is the conversion factor?: **1 mole NaCl** = ________ *g*

=

Skill: Identify When to Use Molar Mass

It is not appropriate to use molar mass as a conversion factor in all problems. For instance, we can't use molar mass in this problem:

"How many **atoms** are in 4 **moles** of NH_3?"

3. Why can you not use the molar mass conversion (1 mole NH_3 = 17.0 g) in this problem. Explain.
   ____
   ____
   ____
   ____
   ____

4. One of these problems **cannot** be solved with a molar mass conversion factor. Circle the one that can't be solved with molar mass.
   a. How many grams of $CaCl_2$ are in 2 moles of $CaCl_2$?
   b. How many atoms of N_2O_5 are in 3 moles of N_2O_5?
   c. How many moles of K are in 8 grams of K?
   d. How many moles of $NaNO_3$ are in 1.1 grams of $NaNO_3$?

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Number of Ions in a Compound Practice

For each of these problems:

- Put a “t” above the chemical that represents the “tires” and a “c” above the chemical that represents the car.
- Determine if you need to do a conversion. Remember that you need to get the “car” into “number of things” first.

1. How many aluminum ions are in a 0.00233 mol sample of aluminum chloride.

2. How many lithium ions are in 2.2 x 10^{26} molecules of lithium carbonate?

3. How many fluorine atoms are in a 20 g sample of carbon tetrafluoride?

4. How many nitrate ions are in a 4 mol sample of magnesium nitrate?

5. How many potassium ions are in 6.0×10^{12} molecule of potassium phosphate?

6. A 1 gram sample of dinitrogen pentoxide will contain __________ nitrogen atoms and ___________ oxygen atoms.

7. How many electrons are in 6 moles of lithium atoms?

Molar Mass Practice #1

1. How many moles are in 16 g of zinc?

    1 mole = _____________ g

2. How many grams will 2.5 moles of copper(II) nitrate weigh?

    1 mole = _____________ g

3. How many moles are in 42 grams of carbon tetrachloride?

    1 mole = _____________ g

4. What is the mass of 0.4 moles of sodium carbonate?

    1 mole = _____________ g

Molar Mass Practice #2

Atoms or molecules ⟷ moles ⟷ grams

1. How many atoms are in 4 g of aluminum?

1 mole	= ______________ g
1 mole	= 6.02×10^{23} atoms or molecules

2. How many grams will 2.5×10^{22} molecules of sulfur dioxide weigh?

1 mole	= ______________ g
1 mole	= 6.02×10^{23} atoms or molecules

3. How many moles are in 2 grams of calcium hydroxide?

1 mole	= ______________ g
1 mole	= 6.02×10^{23} atoms or molecules

4. What is the mass of 3.2×10^{23} atoms of sodium?

1 mole	= ______________ g
1 mole	= 6.02×10^{23} atoms or molecules

5. How many molecules are in of 4.5 moles of aluminum cyanide?

1 mole	= _____________ g
1 mole	= 6.02×10^{23} atoms or molecules

6. Make a prediction: Would you expect 100,000 atoms of sodium to weight more or less than one gram? (1 gram is about the mass of a paper clip.) Explain your thinking.
____
____
____
____
____

7. Now time to calculate: How many grams does 100,000 atoms of sodium actually weigh?

1 mole	= _____________ g
1 mole	= 6.02×10^{23} atoms or molecules

1 mole = 6.02 x 10^{23} atoms or molecules 1 mole =_______ g

Atoms or molecules $\longleftrightarrow$ moles $\longleftrightarrow$ grams

1. How many moles are in 4 g of H_2O?

1 mole = 6.02 x 10^{23} atoms or molecules 1 mole =_______ g

Atoms or molecules $\longleftrightarrow$ moles $\longleftrightarrow$ grams

2. How many molecules of NH_3 are in 3 g of NH_3?

1 mole = 6.02 x 10^{23} atoms or molecules 1 mole =_______ g

Atoms or molecules ⟷ moles ⟷ grams

3. How many moles are in 2 grams of lithium sulfate?

1 mole = 6.02 x 10^{23} atoms or molecules 1 mole =_______ g

Atoms or molecules ⟷ moles ⟷ grams

4. What is the mass of 3.2 x 10^{23} magnesium phosphate molecules?

1 mole = 6.02 x 10^{23} atoms or molecules 1 mole =_______ g

Atoms or molecules ⟷ moles ⟷ grams

5. How many grams are in 2 moles of carbon tetrahydride?

6. How many grams does $1.8x10^{22}$ molecules of lithium nitride weigh?

7. How many moles are in 14 grams of $CaCO_3$?

8. What is the mass of 9.1×10^{22} $Al_2(CO_3)_3$ molecules?

Aluminum Lab

Determine the number of atoms of aluminum are in your sample. Write down a procedure describing what you did. Make a table showing any measurements that you made. Show all calculations.

Chalk Lab

Write your name on a piece of paper using chalk. Determine how many chalk molecules where used in the writing of your name. (Hint: chalk = $CaCO_3$). Record a procedure, table of measurements, and show your calculations.

Solutions Notes

Solute

Solvent

Solution

Molarity

Saturated

Unsaturated

Supersaturated

Basic Molarity Practice

What is the molarity of each solution? (Show your work)

1. 3.2 moles of powdered KBr is dissolved in 18 liters of water.

2. 2 g of solid CaO is added to 0.6 liters of water. The solution is then stirred.

3. <u>Before</u> the solution in the previous problem is stirred, do you believe the concentration of CaO in the water is higher or lower than the answer that you eventually calculated. Explain in words and by making a drawing in this beaker. (The water is already drawn for you.)

4. A stream of NH_3 gas is bubbled into a solution. 0.68 g ends up dissolving in the 2 liters of water.

5. 2 moles of solid sulfur are dissolved in 180 mL of water.

6. 0.12 moles of sodium sulfate are dissolved in 20 mL of liquid methanol.

Molarity to Gram Conversions 

Show your work for each problem.

1. How many grams of KBr would you need to make 18L of a 3.2 M solution in water?

2. How many grams of lithium carbonate would be required to make 2mL of a 2M solution in liquid methanol?

3. How many mL of water would be required to make a 1.4M solution of calcium hydroxide if you had 28 g to work with?

4. How many mg would be required to make a 3.0M solution of carbon dioxide in 2 mL of water?

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Dilution Problems

$M_1V_1 = M_2V_2$

In each problem, label M_1V_1 and either M_2 or V_2 (depending on what is being asked for). SHOW ALL OF YOUR WORK. Provide Units for the answer.

1. 1.6 L of a 2.4M sugar solution needs to be converted to a 0.6M solution. What will the final volume of the solution be?

2. 28 mL of a 2.4M sugar solution needs to be diluted to a 1.1M solution. What will the final volume of the solution be?

3. What volume of a 3.7M stock solution would be required to make 15 mL of a 0.2M sample of that solution?

4. 18 mL of a NH_3 solution (0.25M in MeOH) is diluted with 5 mL of MeOH. What is its new molarity (M)?

5. What would the final volume be if you start with 1.4M solution (0.3 L) of a stock solution and make 1.1M solution?

The Salt Lab

Procedure:

1. Use approximately 30 mL of water and between 3 – 4 grams of salt to make a solution. (Record the amounts that you used exactly.)

_________ g _________mL

DO NOT THROW AWAY YOUR SOLUTION!!!

2. Calculate the molarity of the solution you have made. (Show your calculation)

$$M = \frac{\text{moles}}{L}$$

Write your name and the concentration of your solution on a piece of tape and put the tape on your graduated cylinder.

Questions to consider:

- Why is it important to add the salt to the graduated cylinder first. (Try the other way and find out!) Record your answer here:

- You had to do two things to the numbers that you recorded in step 1 to figure out the molarity. Describe how you changed those numbers before doing the molarity calculation.:

Part 2:

3. Concentration of the solution that you were given: _________________ (include units!)

4. Calculate how many **moles** of NaCl should be in the solution that you were given:

$$M = \frac{\text{moles}}{L}$$

Hints:

- Plug the numbers that you know into this equation.
- You know "M" because it is written on the tape.
- You know "L" by looking at the graduated cylinder.
- Find "moles" by solving the equation.

5. Calculate how many **grams** of NaCl should be in the solution: (convert moles to grams):

6. Time to see if you were right about how many grams are in that liquid! Tare a large beaker. Pour the solution into it and boil off the water. Safety: Remove the flame if the liquid starts to "bump". Pull the Bunsen burner by its base and let the solution cool down if necessary. Watch your solution so that the salt does not burn once it is dry.

7. Mass of NaCl recovered: _________________________ g

The Salt Lab version 2!!!

Procedure:

1. Make 250 mL of a 0.74M NaCl solution. (Show your calculations and how you determined the number of grams that you need to weigh out.)

2. Record the number of grams of NaCl that you **actually** weighed out.

_________ g

3. Label your graduated cylinder with a piece of tape that indicates its molarity (which should be 0.74M) This is your "<u>stock solution</u>".

4. Pour **10 mL** of your stock solution into a graduated cylinder. We are going to dilute it. Before we start: What is M_1 and V_1? Plug them in below.

$$M_1 \quad V_1 \quad = \quad M_2 \quad V_2$$

$$(\qquad)(\qquad) = (\qquad)(\qquad)$$

5. Add enough water so that you have diluted the solution to a concentration of **0.30 M**. In the space above, <u>show how you determined</u> how much water to add.

6. Very good! Now we are ready to check to see if we are making up solutions correctly. In your diluted solution (the one in your graduated cylinder that you just added water to)… what is the molarity now? What is the volume? Plug them into the molarity equation and figure out how many grams of NaCl are in the diluted solution. (show your work)

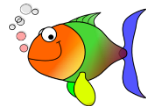
$$M = \frac{moles}{L}$$

7. Time to see if you were right! That salt is dissolved in water…so the only way to check is to boil off the water and weigh the left over salt. Pour your diluted solution into a beaker and use a hot plate to boil off the water. (**It is a good idea to tare your beaker before hand!**)

8. Mass of NaCl recovered ____________ g.

9. % error calculation: (The theoretical amount of grams is your calculation in step 6

Solutions Simulation Lab



Accessing the website:

- Search the internet for “Phet” and “salts and solubility”. It should be the first link in your search results. Alternatively type in the web address for the site:

  http://phet.colorado.edu/new/simulations/sims.php?sim=SaltsandSolubility

- Click “run now” (the green button)

Exercise A: Describing solubility and solutions

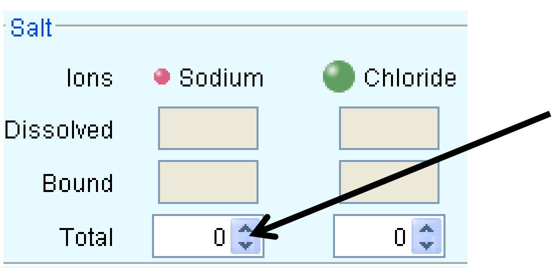
1. Shake the salt shaker 1 time. (If you accidentally shook too many times, just click “reset” to start over) The simulation will show you what happens when a salt dissolves.

Describe what happens to the ions of a salt when it dissolves in water:

____

____

____



2. Click reset all.
3. Now type 300 into this field and hit enter to put some salt in the water. Is the solution saturated or unsaturated? ___________________________
4. The simulation says that the amount of water is 5.00 E-23 L of water. To get all of the salt to dissolve, would you have to add water or take it away? ______________________
5. There are two spouts (a drain on the bottom and a fill spout on top). Change the amount of water so that the solution is just about to turn unsaturated. (Don’t overshoot it! Remember the “bound” number will help guide you.) How much water is in the container now? ______________

Exercise B: Saturated Versus Unsaturated Solutions

6. Click “reset” again. Drain some water so that you have about 3.00E-23 L of water in the tank. Now add enough salt so that you have about 80 total sodium ions in the tank. Is the solution saturated or unsaturated? ____________________.

7. Click “reset” again. Add some water so that you have 7.00 E-23 L of water in the tank. Now add enough salt so that you have about 250 total sodium ions in the tank. Is the solution saturated or unsaturated? _____________________.

8. Click “reset” again. Drain some water so that you have about 4.00E-23 L of water in the tank. Now add enough salt so that you have about 160 total sodium ions in the tank. Is the solution saturated or unsaturated? ______________________.

Exercise C: Dissolving Different Salts (other than NaCl)

At the top of the screen is a tab marked “slightly soluble salts”. Click the tab. This screen will let you choose from 6 different salts by a drop-down menu on the right side of the screen.

Doing one salt at a time, determine how many “shakes” of the salt shaker it takes to just reach the saturation point. Also record the number of total cations that are in solution at the saturation point. Use the table below to record your data.

Type of Salt	**Volume of water**	**Number of shakes to reach saturation**	**Number of cations in solution at saturation**
Silver bromide	1.00 E-16 L		Ag ions:
Thalium sulfide	1.00 E-16 L		Tl ions:
Silver arsenate	1.00 E-16 L		Ag ions:
Copper iodide	1.00 E-16 L		Cu ions:
Mercury bromide	1.00 E-16 L		Hg ions:
Strontium phophate	1.00 E-16 L		Sr ions:

Definitions that you will need for the post lab questions:

- Compounds that easily dissolve in water are considered to be VERY **SOLUBLE**.
- Compounds that precipitate to the bottom with very little salt added are considered to be VERY **INSOLUBLE**.

Post Lab Questions:

1. What was the most soluble salt that you discovered in your table? (Explain how your data in the table supports your answer.)

2. What was the most insoluble salt that you discovered in you table? (Explain how your data in the table supports your answer.)

3. What would happen if you added more salt to an unsaturated solution?

4. What would happen if you added more salt to a saturated solution?

5. When one formula unit of NaCl splits into its ions in water, it produces 2 ions. (One Na^{+1} ion and one Cl^{-1} ion). When $Ca(NO_2)_2$ dissociates in water, it produces 3 ions. (One Ca^{+2} ion and two NO_2^- ions).

   How many ions would be released into water by each of these compounds?

   a. $MgCl_2$ ________
   b. Na_2SO_4 ________
   c. $Al_2(CO_3)_3$ ________