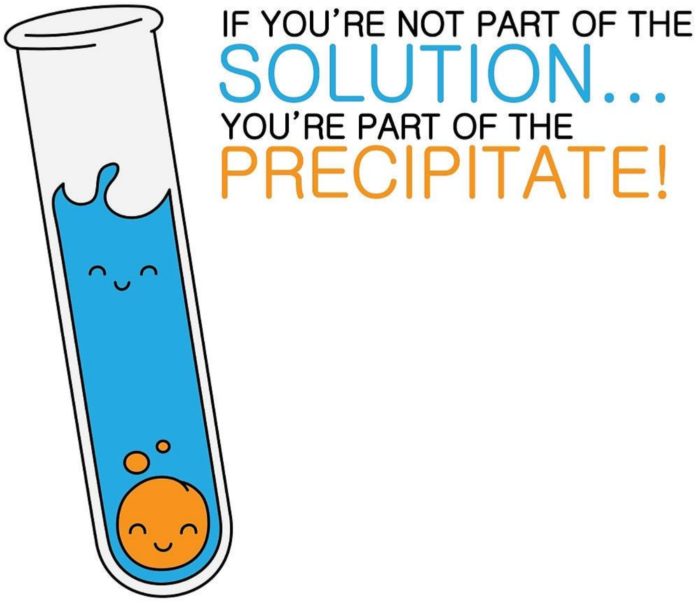
CHEMISTRY 30S

The Alchemist's Cookbook

UNIT 3 – SOLUTION CHEMISTRY



NAME:___________________________________

It is expected that the activities in this book are completed as they are performed in class. This book will be collected at the end of the unit and a mark will be given.

LET'S GET STARTED!

By the end of this unit, you should be able to:

- ✓ Describe the structure of water in terms of the polarity of its chemical bonds.
- ✓ Explain how ionic and covalent compounds dissolve in water using particulate representations and dissociation equations.
- ✓ Differentiate between saturated, unsaturated, and supersaturated solutions.
- ✓ Construct, from experimental data, a solubility curve of a pure substance in water and use it to solve problems.
- ✓ Explain how changes in temperature and pressure affect the solubility of solutes.
- ✓ Quantify concentration by performing various calculations including g/100mL, % concentration, ppm, and molarity.
- ✓ Prepare a solution of a known molarity from mass of solute and volume of water.
- ✓ Solve problems involving the dilution of solutions.
- ✓ Perform stoichiometric calculations on chemical reactions involving solutions using molarity.

This unit will take about **20 lessons** to complete and will make up approximately **20% of your mark**.

ACTIVITY #1 – LAB: STOP BEING SO SALTY!

In this experiment, you will compare the solubility of two white salts in water at room temperature. You'll add 5 g of each salt to 5 mL of water and shake to dissolve as much as possible. Once you're convinced the two solutions are saturated, you'll evaporate some of each solution and determine the mass of salt that had dissolved. From this data, you'll determine the solubility of each salt, expressed as "g/100 mL water".

Procedure:

1. Label a clean test tube with your initials and then add 5.0 mL of water to the tube.

2. Pour in the entire 5.0 g of salt that you obtained.

3. Stopper the test tube and shake it for several minutes to dissolve as much of the salt as possible and create saturated solutions. When it appears that no more salt is dissolving, you may continue to the next step. Before doing so, compare your test tube to that of your partner – does it appear that one salt was more soluble? Record your observations.

4. Place the two test tubes into a test tube rack while you set up the rest of the experiment.

5. Obtain a clean, dry evaporating dish and find its mass. It is VERY important that the dish be dry before massing it!

6. Back at your bench, carefully decant the solution from your test tube into the evaporating dish. Try to get as much of the solution as possible, but do NOT let any solid salt enter the evaporating dish. You will have to leave some solution behind in the test tube.

7. Find the mass of the evaporating dish with the saturated solution in it.

8. Place the dish onto a wire stand and carefully heat the solution with a Bunsen burner until it starts to boil. Watch the dish carefully – if it starts to "splatter", quickly remove the burner and let it settle before continuing to heat. Your objective here is to evaporate all of the water without losing any of the salt!

9. When the water has completely evaporated, let the dish cool back to room temperature. This may take 10 minutes or so. While the dish is cooling, put away the Bunsen burner, thoroughly rinse out your test tube with lots of water, and put it away along with the graduated cylinder you used.

10. When the dish is cooled completely, find its mass again. This is the mass of the dish with the salt that had dissolved.

11. Rinse out the dish thoroughly and put it away.

Data: Record the data for both you and your partner!

	Sodium Chloride	Sodium Nitrate
Mass of Empty Evaporating Dish (g)		
Mass of Evaporating Dish & Saturated Solution (g)		
Mass of Evaporating Dish with Salt After Heating (g)		

Results:

	Sodium Chloride	Sodium Nitrate
Mass of Saturated Solution (g)		
Mass of Salt in the Solution (g)		
Mass of Water in the Solution (g)		
Volume of Water in the Solution (use density) (mL)		
Concentration of Saturated Solution (g/mL)		
Concentration of Saturated Solution (g/100 mL)		

Sample Calculations:

Conclusions: (how close were your values to the true values AND what could have caused your results to be different from the true values)

ACTIVITY #2 – LAB: IT'S GETTING HOT IN HERE!

BACKGROUND

In this experiment, you will study the effect of changing temperature on the amount of solute that will dissolve in a given amount of water. In this experiment, we will completely dissolve different quantities of potassium nitrate, KNO_3, in the same volume of water at a high temperature. As each solution cools, you will monitor temperature and observe the precise instant that solid crystals start to form. At this moment, the solution is saturated and contains the maximum amount of solute at that temperature. Thus, each data pair consists of a *solubility* value (g of solute per 100 g H_2O) and a corresponding *temperature*. A graph of the temperature-solubility data, known as a solubility curve, will be plotted using the computer.

PROCEDURE

1. Obtain and wear goggles.

2. Obtain a Labquest and connect a temperature probe to it. Test to make sure it is reading the temperature (hold it under the tap and look for change).

3. Fill a 400 mL beaker three-fourths full of tap water. Place it on a hot plate set to "high". Move on to steps 4-6 while you are waiting for the bath to warm. Heat the water bath to about 90°C and adjust the heat to maintain the water at this temperature.

4. Mr. Wiebe will assign you one of the test tubes in the chart below. Make note of which one you are assigned. Note: The third column (amount per 100 g of H_2O) is *proportional* to your measured quantity and is the amount you will use to graph your results at the end of the lab.

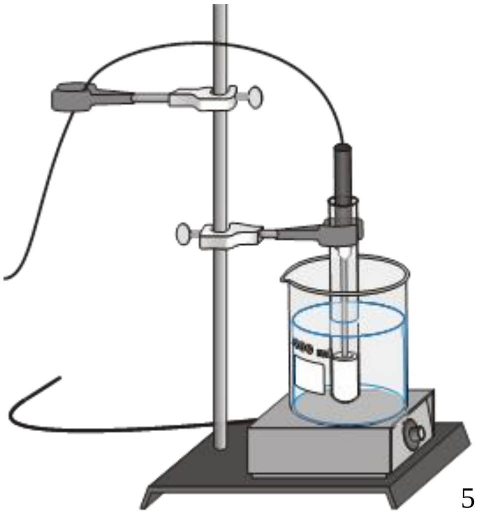
Test tube number	Amount of KNO_3 used per 5 mL H_2O
1	2.0
2	4.0
3	6.0
4	8.0

5. Weigh out your assigned mass of KNO_3 in a cupcake wrapper and place in your test tube.

6. Add exactly 5.0 mL of distilled water to your test tube by weighing out 5.0 g of distilled water. (We are assuming density = 1.0 g/mL for water). Stir the solution to dissolve as much of the solute as possible. You should notice your solution is saturated and that much of your solute remains undissolved.

7. Use a utility clamp to fasten your test tube to the ring stand. Lower the test tube into the water as shown in the picture. Use your stirring rod to stir the mixture until the KNO_3 is *completely* dissolved. Do not leave the test tube in the water bath any longer than is necessary to dissolve the solid.

8. When the KNO_3 is completely dissolved, unfasten the utility clamp and test tube from the ring stand. Use the clamp to hold the test tube up to the light to look for the first sign of crystal formation. At the same time, stir the solution with a slight up and down motion of the Temperature Probe. At the moment crystallization starts to occur, note the temperature of the solution and record.



DATA TABLE

Trial	Amount of KNO_3 used per 5 mL H_2O (weigh in Step 2)	Solubility (g / 100 g H_2O)	Class Average Temp (°C)
1	2.0	40.0	
2	4.0	80.0	
3	6.0	120.0	
4	8.0	160.0	

PROCESSING THE DATA

1. Graph your results by plotting "g/100mL water" on the y-axis and "temperature" on the x-axis. Draw a best fit line through the 4 data points.

2. According to your data, how is solubility of KNO_3 affected by an increase in temperature of the solvent?

3. Using your graph, tell me if each of these solutions would be saturated or unsaturated:
   a. 110 g of KNO_3 in 100 g of water at 40°C

   b. 60 g of KNO_3 in 100 g of water at 70°C

   c. 140 g of KNO_3 in 200 g of water at 60°C

4. According to your graph, will 50 g of KNO_3 completely dissolve in 100 g of water at 50°C? Explain.

5. According to your graph, will 120 g of KNO_3 completely dissolve in 100 g of water at 40°C? Explain.

6. According to your graph, about how many grams of KNO_3 will dissolve in 100 g of water at 30°C?

ACTIVITY #3 – ANALYZING SOLUBILITY CURVES

Use the solubility curves on page 9 to answer the following questions

1. Report the solubility for each substance at the given temperature:
    a. sodium chloride @ 70^{o}C
    b. potassium nitrate @ 10 ^{o}C
    c. sodium nitrate @ 35 ^{o}C
    d. potassium chloride in ice water
    e. sodium bicarbonate @90 ^{o}C
    f. potassium nitrate in boiling water
    g. sodium nitrate @ 75 ^{o}C
    h. ammonia gas at 5 ^{o}C

2. What volume of water is needed to dissolve 35.5 g of potassium chloride at 50 ^{o}C?

3. What volume of water is needed to dissolve 75.0 g of potassium nitrate at 30 ^{o}C?

4. What volume of boiling water is needed to dissolve 3.5 kg of sodium chloride?

5. What mass of sodium bicarbonate can dissolve in 350.0 mL of water at 80 ^{o}C?

6. What mass of sodium nitrate can dissolve in 10.0 mL of water at 25 ^{o}C?

7. What mass of potassium nitrate can dissolve in 15.0 L of boiling water?

8. A student dissolves 45 g of potassium nitrate in 25 mL of boiling water.

    a. Use a calculation to demonstrate that the solution is NOT saturated.

    b. What mass of salt must be added to saturate the solution?

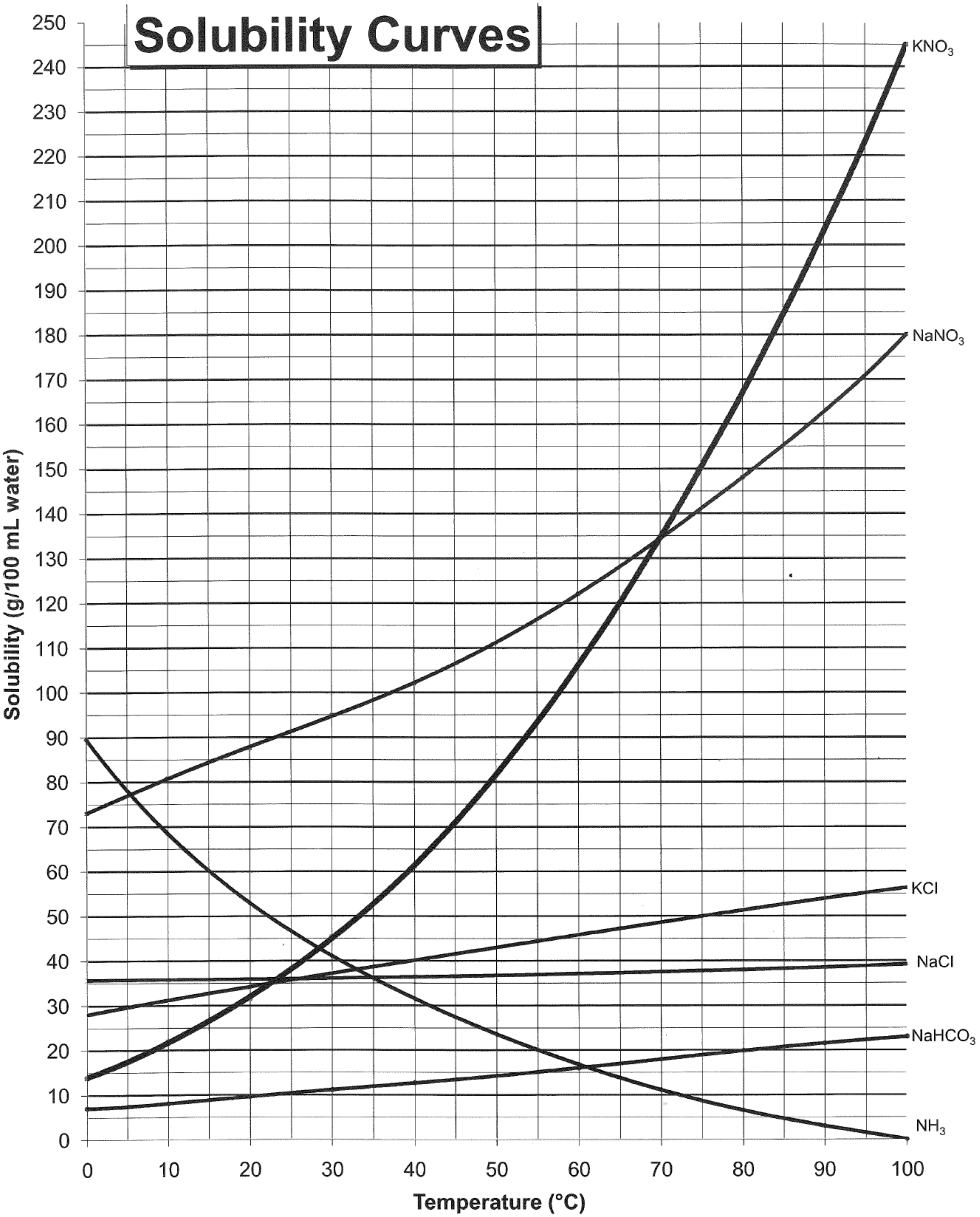
    c. Another way to saturate the solution would be to evaporate away some of the water. What volume of water would need to be removed to saturate the solution?

9. A student dissolves 500 g of sodium nitrate in 400 mL of boiling water.

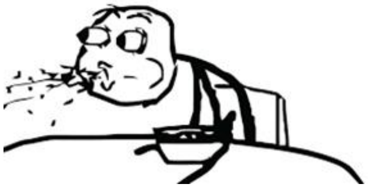
    a. Use a calculation to demonstrate that the solution is NOT saturated.

    b. What mass of salt must be added to saturate the solution?

    c. Another way to saturate the solution would be to evaporate away some of the water. What volume of water would need to be removed to saturate the solution?


Solubility Curves
Solubility (g/100 mL water)
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
70
80
90
100
Temperature (°C)
KNO_3
$NaNO_3$
KCl
NaCl
$NaHCO_3$
NH_3

ACTIVITY #4 – THE DOSE MAKES THE POISON (OPTIONAL)



1. Make jot notes in the following table while watching "The Poisoner's Handbook" in class. We will discuss your notes upon completion of the documentary, whenever that is!

POISON	SYMPTOMS	TEST FOR POISON
Cyanide		
Arsenic		
Methanol		
Lead		

2. On the next page, there is a chart of LD50 values. These values represent the concentration of a chemical that causes death in 50% of treated animals within 14 days of exposure. They are expressed in terms of milligrams of substance per kilogram of body weight, resulting in units of mg/kg. Use this chart, as well as the extra information provided below, to answer the following three questions.

   Additional Information:

   - An average cup of coffee (250mL) contains on average 90 mg of caffeine.
   - One extra strength aspirin contains 500 mg of acetylsalicylic acid or A.S.A.
   - A single cherry pit contains on average about 170 mg of cyanide.

   For each of the following, determine the quantity that would be considered lethal for you to ingest. Use your own body weight for your calculations.

      1. Standard cups of coffee

      2. Tablets of extra-strength aspirin

      3. Cherry pits

      4. Botulin from food poisoning

Substance	Comments	LD50* (mg/kg)
Botulin	An extremely toxic compound formed by bacteria in improperly canned foods; causes botulism, a sometimes fatal form of food poisoning	0.00001
Aflatoxin	A cancer-causing chemical created by mold on grains and nuts; can be found in some peanut butter and other nut and grain products	0.003
Cyanide	A highly poisonous substance found in apricot and cherry pits and used in industrial processes such as making plastics, electroplating, and producing chemicals	10
Vitamin D	An essential part of the human diet but toxic in doses higher than those found in normal human diets	10
Nicotine	The addictive agent that occurs naturally in tobacco and is added to some cigarettes to make them moreaddictive	50
Caffeine	A compound that occurs naturally in cocoa and coffee beans and is a common food additive	200
Acetylsalicylic acid	The active ingredient in aspirin	1,000
Sodium chloride	Table salt	3,000
Ethanol	Alcohol in beer, wine, and other intoxicating beverages	7,000
Trichloroethylene	A solvent and a common contaminant in groundwater and surface water supplies	7,200
Citric acid	An ingredient in citrus fruits such as oranges, grapefruits, and lemons	12,000
Sucrose	Sugar, refined from sugar cane or sugar beets	30,000

ACTIVITY #5 – WORKING WITH CONSUMER CONCENTRATION VALUES

Calculating Percent and PPM/PPB Concentrations

1. Gasohol, which is a solution of ethanol and gasoline, is considered a cleaner fuel than just gasoline alone. A typical gasohol mixture available at gas stations contains 4.1 L of ethanol in a 55.0 L tank of fuel. Calculate the percent by volume (%V/V) concentration of ethanol in gasohol.

(7.5% V/V)

2. Soldering irons are used to connect small electrical circuits. Solder flux, the material used by soldering irons, contains 16.0 g of zinc chloride in 50.0 mL of solution (the solvent being hydrochloric acid). What is the percent weight by volume (%W/V) concentration of zinc chloride in the solution?

(32% W/V)

3. Brass is an alloy of copper and zinc. If the concentration of zinc is relatively low, the brass has a golden colour and is often used for inexpensive jewelry. If a 35.0 g pendant contains 1.7 g of zinc, what is the percent weight by weight (%W/W) concentration of zinc in this brass? What is the percent weight by weight of copper in the brass?

(4.9% W/W zinc, 95.1% W/W copper)

4. Fish require dissolved oxygen in their water to breath. In a typical 40.0 L fish tank, there need to be at least 320 mg of dissolved O_2 in the water for a fish to survive. What is the part per million (ppm) concentration of dissolved oxygen in this fish tank?

(8 ppm)

5. Formaldehyde (CH_2O) was once used as embalming fluid in funeral homes. It is now most commonly found in cigarette smoke. Formaldehyde is a probable carcinogen (cancer causing molecule), which is why breathing second hand smoke is considered harmful. If a sample of air with a mass of 0.59 kg contained 3.2 mg of formaldehyde, this would be considered a dangerous level. What would be the parts per million (ppm) concentration of formaldehyde in this air?

(5.4 ppm)

Performing Calculations with Percent and PPM/PPB Values

6. Copper is a trace element that is essential for animal life. An average adult requires the equivalent of 1.0 L of water containing 30 ppb of copper a day. What mass of copper does this equate to?

(3×10^{-5} g or 30 µg)

7. Nurses regularly administer solutions intravenously to patients. These concentrations of these solutions are usually communicated a percentages. Suppose, as a nurse, you administered a 1000.0 mL bag of D5W (a solution of 5% W/V dextrose in water) to a patient via IV. What mass of dextrose was administered?

(50.0 g)

8. Rubbing alcohol, C_3H_7OH, is sold as a 70.0% V/V solution for external use only. What volume of pure C_3H_7OH is present in a 500.0 mL bottle of rubbing alcohol?

(350. mL)

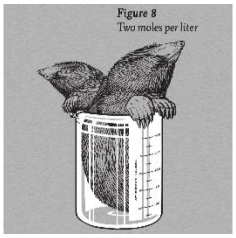
9. Suppose your company made generic hydrogen peroxide, H_2O_2, for the local Selkirk drug store. What mass of pure H_2O_2 would be required to make 1000 bottles each containing 250.0 mL of 3.0% V/V H_2O_2 solution?

(7500 g or 7.5 kg)

10. Municipalities add fluoride ions to local water supplies to help residents fight tooth decay. The maximum acceptable concentration of fluoride ions in water supplies is 1.5 ppm. What is the maximum mass of fluoride ions you would expect to find in a standard cup of water (250.0 mL)?

(3.8×10^{-4} g or 0.38 mg)

ACTIVITY #6 – WORKING WITH CHEMISTRY LAB CONCENTRATION VALUES



$$\text{Molarity} = \frac{\text{moles of solute}}{\text{volume of solution in liters}}$$

	Variables	Work	Answer
1.	solute = 0.22 mol NaBr solution = 1.40 L M = ?		
2.	solute = ? mol $MgCl_2$ solution = 0.80 L M = 0.65 *mol/L*		
3.	solute = 0.050 mol Na_2O solution = ? M = 0.18 *mol/L*		
4.	solute = ? mol KI solution = 300 mL M = 1.15 *mol/L*		
5.	solute = 1.05 mol $Ca(NO_3)_2$ solution = 800 mL M = ?		

6. What is the molarity of a 600 mL solution if 30.0 g of NaF is used?

Molar Mass =

7. What is the molarity when 75.0 g of LiBr is used to prepare a 1.4 L solution?

Molar Mass =

8. How many moles of Li_2SO_4 is required to prepare 300 mL of a 0.25 M solution?

9. What is the molar concentration when 0.018 mol of $MgSO_4$ is used to prepare a 600 mL solution?

10. What mass of $MgCl_2$ is required to prepare a 120 mL of a 0.040 *M* solution?

Molar Mass =

ACTIVITY #7 – PREPARING A STOCK SOLUTION OF A KNOWN MOLARITY

Steps for Preparing 100.0 mL of 0.500 mol/L aqueous calcium chloride

How many grams of calcium chloride are needed to make this solution?

Dissolve ___________ g $CaCl_2$ in approximately 40 mL of distilled water in a volumetric flask. Swirl to dissolve. Add enough water to make the total volume of __________ mL of solution. Transfer stock solution into a clean, dry beaker and label.

Steps for Preparing 100.0 mL of 0.700 mol/L aqueous sodium carbonate

How many grams of sodium carbonate are needed to make this solution?

Dissolve ___________ g Na_2CO_3 in approximately 40 mL of distilled water in a volumetric flask. Swirl to dissolve. Add enough water to make the total volume of __________ mL of solution. Transfer stock solution into a clean, dry beaker and label.

ACTIVITY #8 – DILUTIONS

Many chemicals (mostly acids) are acquired from chemical supply houses in concentrated form. These chemicals are diluted to the desired concentration by adding water. Since moles of chemical before dilution = moles of chemical after dilution, then we can use the following algebraic expression when diluting chemicals:

$$M_1V_1 = M_2V_2$$

VARIABLES		WORK	ANSWER
1.	M_1 =18 M V_1 = ? M_2 = 6.0 M V_2 = 250 mL		
2.	M_1 =15 M V_1 = 25 mL M_2 = 3.0 M V_2 = ?		
3.	M_1 =12 M V_1 = 400 mL M_2 = ? V_2 = 1500 mL		
4.	M_1 = ? V_1 = 125 mL M_2 = 0.50 M V_2 = 500 mL		
5.	M_1 =18 M V_1 = 750 mL M_2 = ? V_2 = 1.75 L		

INFORMATION & WORK	ANSWER
Find the volume in liters of a 1.80 *M* solution of potassium chloride that is required to prepare 0.100 L of a 0.600 *M* solution?	
Find the concentration of the new solution when 20.0 mL of a 2.5 *M* solution of hydrochloric acid is used to prepare a 1.20 L solution.	
15 mL of a 3.0 *M* solution of nitric acid is used to prepare a final solution with a concentration of 0.60 *M*. Find the volume of the final solution.	
12.0 mL of a concentrated solution of sodium hydroxide is required to prepare 150 mL of a 0.60 *M* solution. Find the concentration of the original solution.	

ACTIVITY #9 – STOICHIOMETRY…THE RETURN!

1. Combining solutions of sodium carbonate and calcium chloride produces a calcium carbonate precipitate:

$$Na_2CO_3(aq) + CaCl_2(aq) \rightarrow CaCO_3(s) + 2\ NaCl(aq)$$

   a. During an investigation, 15.2 g of calcium carbonate was collected by filtration when 200.0 mL of sodium carbonate solution was reacted with an excess of calcium chloride solution. What was the molarity of the sodium carbonate solution?

   b. What volume of a 0.500 mol/L calcium chloride solution would produce 15.2 g of calcium carbonate precipitate?

2. The steel industry uses large volumes of concentrated hydrochloric acid to remove rust (Fe2O3) from the surface of steel. This process is called “pickling”.

$$Fe_2O_3(s) + 6\ HCl(aq) \rightarrow 2\ FeCl_3(aq) + 3\ H_2O(l)$$

   What volume of 12.0 mol/L HCl(aq) is required to remove 224 g of iron(III) oxide?

3. When aluminum metal is placed in copper(II) sulphate solution, the aluminum ions displace the copper(II) ions in a single replacement reaction.

   a. Write the balanced chemical equation for the reaction above.

   b. What mass of aluminum is required to remove all the copper(II) ions from 150 mL of a 0.100 mol/L solution of copper(II) sulphate?

4. Sodium hydroxide (NaOH) is used in the production of paper, textiles, cleaners, and detergents. Sodium hydroxide is produced industrially by passing electricity through a concentrated sodium hydroxide solution. The chemical equation for this reaction is:

$$2\ NaCl(aq) + 2\ H_2O(l) \rightarrow 2\ NaOH(aq) + Cl_2(g) + H_2(g)$$

As much as 4.5×10^{10} kg of sodium hydroxide is produced around the world each year. What volume of a 6.0 mol/L sodium chloride solution is required to produce this mass of sodium hydroxide?

5. Nickel(II) sulphate solution reacts with aqueous sodium hydroxide in a double replacement reaction to form a precipitate.

   a. Write the balanced chemical equation for this reaction.

   b. Predict the mass of precipitate expected to form when 50.0 mL of 0.45 mol/L nickel(II) sulphate reacts with 25.0 mL of 1.00 mol/L sodium hydroxide solution.

ACTIVITY #10 – "CHALK IT UP" TO STOICHIOMETRY

One example of a double replacement reaction is the mixing of two solutions resulting in the formation of a precipitate. In solution chemistry, the term *precipitate* is used to describe a solid that forms when a positive ion (cation) and a negative ion (anion) are strongly attracted to one another. In this experiment, a precipitation reaction will be studied. Stoichiometry will then be used to investigate the amounts of reactants and products that are involved. The word *stoichiometry* is derived from two Greek words: *stoicheion* (meaning "element") and *metron* (meaning "measure"). Stoichiometry is an important field of chemistry that uses calculations to determine the quantities (masses, volumes) of reactants and products involved in chemical reactions. It is a very mathematical part of chemistry.

In this experiment, you will react a known amount of sodium carbonate solution with a known amount of calcium chloride solution. The skeletal (unbalanced) equation for the resulting double replacement reaction is:

$$Na_2CO_3(aq) + CaCl_2(aq) \rightarrow NaCl(aq) + CaCO_3(s)\ .$$

Note that three of the chemicals have their states or phases designated as (*aq*) and one is designated as (*s*). The (*aq*) represents the term *aqueous* which means that the substance is soluble and dissolved in water. The (*s*) means that the substance is a *solid* (in this case, it is a precipitate). Precipitate formation is easily observed as the mixed solutions turn cloudy and, if desired, the precipitate can be easily separated from the solution by filtering. Since your precipitate will be separated and weighed, this experiment will require a second lab period to allow time for the precipitate to dry. Stoichiometry will then be used to determine the amount of precipitate that should be formed in the reaction.

It is often difficult as well as impractical to combine just the right amount of each reactant that is required for a particular reaction to occur. Given this fact, this experiment is designed so that only one of the reactants will be completely used up. This is called the *limiting reactant* because it limits the amount of products formed. Since the other reactant will have a quantity remaining, it is called the *excess reactant*. One of your tasks will be to determine which of your reactants is limiting and which is in excess.

The two chemical reactants in this experiment have common uses in our lives. In one solid form, sodium carbonate is known as "washing soda" and is used to enhance the effectiveness of laundry soap. Calcium chloride solid can act as a *desiccant* (drying agent) and is used by recreational vehicle owners to remove moisture from the air in the vehicle during winter storage.

OBJECTIVES

1. to observe the reaction between solutions of sodium carbonate and calcium chloride
2. to determine which of the reactants is the limiting reactant and which is the excess reactant
3. to determine the theoretical mass of precipitate that should form
4. to compare the actual mass with the theoretical mass of precipitate and calculate the percent yield

SUPPLIES

Equipment

centigram balance
2 graduated cylinders (25 mL)
beaker (250 mL)
wash bottle
filtering apparatus (ring with stand, Erlenmeyer flask (250 mL) + funnel)
filter paper
lab apron
safety goggles

Chemical Reagents

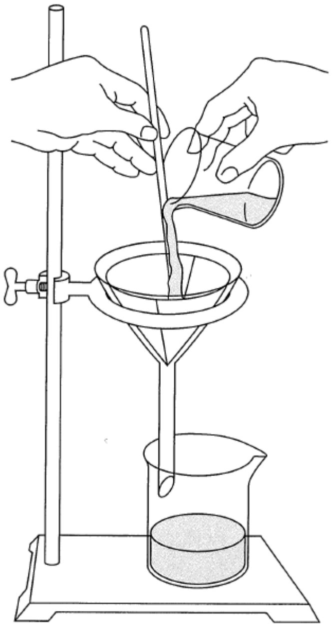
0.70*M* sodium carbonate solution, Na_2CO_3
0.50*M* calcium chloride solution, $CaCl_2$

PROCEDURE

Part I: The Precipitation Reaction (Day 1)

1. Put on your lab apron and safety goggles.
2. Obtain two clean, dry 25 mL graduated cylinders and one 250 mL beaker.
3. In one of the graduated cylinders measure 25 mL of the Na_2CO_3 solution. In the other graduated cylinder measure 25 mL of the $CaCl_2$ solution. Record these volumes in your copy of Experimental Results in your notebook.
4. Pour the contents of both graduated cylinders into the 250 mL beaker and observe the results. Record these qualitative observations in your notebook. Allow the contents of the beaker to sit undisturbed for 5 min to see what happens to the suspended solid particles. Meanwhile, proceed to Step 5.
5. Obtain a piece of filter paper and put your name on it using a pencil. Weigh and record the mass of the filter paper, then use it to set up a filtering apparatus as shown in Figure 6D-1.
6. Use the wash bottle to lightly wet the filter paper in the funnel to keep the filter paper in place. Swirl the beaker and its contents to suspend the precipitate in the solution, then pour it carefully and slowly into the filter funnel. It takes time to complete the filtering process so plan to do it in stages. Use the wash bottle to rinse the remaining precipitate from the beaker.

Figure 6D-1 *Filtering the solid from the liquid*



CAUTION

Wash spills off your skin and clothes with plenty of water.

7. Use the wash bottle one last time to rinse the precipitate in the filter paper. This will remove any residual $NaCl(aq)$ that remains with the precipitate.
8. After the filtering is complete, remove the wet filter paper containing $CaCO_3$ precipitate and place it on a folded paper towel. Put your filter paper in the assigned location to dry.
9. Clean up all your apparatus.
10. Wash your hands thoroughly with soap and water before leaving the laboratory

Part II: Weighing the Dried Precipitate (Day 2)

1. Weigh and record the mass of the dry filter paper containing the $CaCO_3$ precipitate.

REAGENT DISPOSAL

Rinse all solutions down the sink with copious amounts of water. Any solids should go into the designated containers.

POST LAB CONSIDERATIONS

The double replacement reaction in this experiment formed two chemicals which are commonly known to you. The $NaCl(aq)$ is salt water and the $CaCO_3(s)$ is a component of some classroom chalks.

Using the data collected, you will be able to calculate the moles of each of the chemicals that are added together to react. Then using the principles of stoichiometry you will be able to determine which chemical is the limiting reactant and thereby predict how much precipitate should form. This stoichiometric determination will then be compared to the actual mass of $CaCO_3(s)$ formed.

Chemists are often concerned with optimal yields in manufacturing a certain chemical. One way of measuring this is to calculate the percent yield of that particular chemical by using this formula:

$$\text{Percent yield} = \frac{\text{actual mass produced (grams)}}{\text{theoretical mass produced (grams)}} \times 100\%$$

Data Table:

Volume $CaCl_2$ (mL)	Volume Na_2CO_3 (mL)	Mass of Filter Paper (g)	Mass of Filter Paper and Precipitate (g)	Mass of Precipitate (g)

Analysis:

1. Write the balanced formula equation for this double replacement reaction.
2. Use your solubility table to identify the product that is insoluble in water and therefor the precipitate.
3. How many moles of calcium chloride did you initially add to the reaction?
4. How many moles of sodium carbonate did you initially add to the reaction?
5. Create an ICE table for this reaction and fill it in. Identify the limiting reagent.

6. What was the theoretical yield in grams? How does it compare to your actual yield? Determine the percent yield.

Follow-Up Questions

1. What substances are present in the filtered solution? Explain why you think this.

2. What volume of Na_2CO_3 solution used in this experiment would result in no excess reagent?

3. A reaction occurs when 50.0 mL of 0.50M $BaCl_2(aq)$ is mixed with 75.0 mL of 0.75M $Na_2CO_3(aq)$. The only precipitate that forms is $BaCO_3(s)$.
    a. Write the balanced formula equation for this reaction.
    b. Using an ICE table, determine the limiting reactant and calculate the theoretical mass of $BaCO_3(s)$ that should form in this reaction.
    c. This experiment was conducted and the percent yield was found to be 82%. What was the actual mass of $BaCO_3(s)$ that formed?

ACTIVITY #11 – UNIT TEST REVIEW

1. Draw a simple picture of a water molecule and label it. Explain how its structure allows it to dissolve ionic compounds.

2. Draw a simple picture of water molecules dissolving an ionic solute and explain how and why this happens.

3. Fill in the blanks or circle the correct answer for each of the following statements:

   a. When solute dissolves readily in a solvent, it is considered _______________.

   b. When solute doesn't dissolve readily in a solvent, it is considered ________________.

   c. You can dissolve (more/less) solid solute in a colder solvent compared to a warm solvent.

   d. You can dissolve (more/less) gaseous solute in a colder solvent compared to a warm solvent.

   e. When a solution cannot accept any more solute at a specific temperature, it is considered _____________________.

   f. When a solution contains a relatively high solute to solvent ratio, it is considered ___________________.

   g. When a solution contains a relatively low solute to solvent ratio, it is considered ___________________.

4. Use your solubility table to determine if the following ionic compounds are soluble or low solubility in water. Write dissociation equations for each of the soluble solutes.

   a. sodium chloride

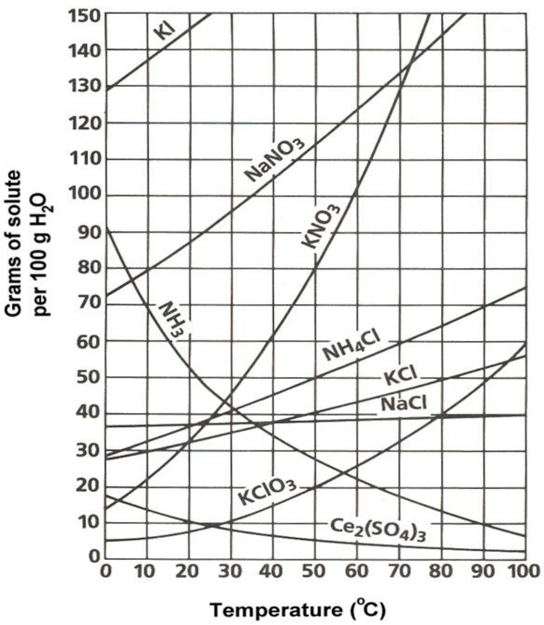
   b. lead(II) iodide

   c. lithium sulphate

   d. calcium carbonate

   e. ammonium phosphate

5. Use the solubility curves below to answer all the questions of this page.



a) What is the solubility of potassium nitrate at 44^{o}C?

b) 40 g of potassium nitrate is dissolved in 100g of water at 30^{o}C. Determine whether this solution is saturated. If yes, explain why.

c) What mass of sodium nitrate can dissolve in 10.0 mL of water at 25 ^{o}C?

d) What volume of water is needed to dissolve 75.0 g of potassium nitrate at 30 ^{o}C?

e) A student dissolves 500 g of sodium nitrate in 400 mL of 80^{o}C water. What mass of salt must be added to saturate the solution?

6. Calculate the following:

0.25 g of acetic acid, CH_3COOH, in enough water to create 2.0 L *of solution*.

%W/V	ppm	molarity

15.0 mL of ethanol, C_2H_5OH, in 500.0 mL *of water*. (1 mL = 0.789 g)

%V/V	ppm	molarity

7. Nurses regularly administer solutions intravenously to patients. These concentrations of these solutions are usually communicated a percentages. Suppose, as a nurse, you administered a 1.0 L bag of D5W (a solution of 5% W/V dextrose in water) to a patient via IV. What mass of dextrose was administered?

8. Municipalities add fluoride ions to local water supplies to help residents fight tooth decay. The maximum acceptable concentration of fluoride ions in water supplies is 1.5 ppm. What is the maximum mass of fluoride ions you would expect to find in a standard cup of water (250.0 mL)?

9. Calculate the mass of sodium nitrate needed to prepare 400. mL of a 0.250 M solution.

10. Calculate the volume of a 0.400 M solution of copper(II) sulphate that contains 120. g of solute.

11. What will the final concentration be when 10.0 ml of a 5.0 mol/L glucose ($C_6H_{12}O_6$) solution is diluted to 250 mL?

12. What volume of a 0.450 mol/L $CuSO_4$ solution must be used to create 250.0 mL of 0.100 mol/L solution.

13. What volume of 0.250 mol/L potassium iodide solution, KI(aq), would be required to react completely with 45 mL of a 0.375 mol/L solution of lead(II) nitrate?

14. What mass of precipitate will be produced from the reaction of 50.0 mL of 2.50 mol/L sodium hydroxide with 100.0 mL of 1.50 mol/L zinc chloride solution?

Solubility of Common Compounds in Water

The term soluble here means > 0.1 mol/L at 25°C.

Negative Ions (Anions)	**Positive Ions (Cations)**	**Solubility of Compounds**
All	Alkali ions: Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+	Soluble
All	Hydrogen ion: H^+	Soluble
All	Ammonium ion: NH_4^+	Soluble
Nitrate, NO_3^-	All	Soluble
Chloride, Cl^- or Bromide, Br^- or Iodide, I^-	All others	Soluble
	Ag^+, Pb^{2+}, Cu^+	Low Solubility
Sulphate, SO_4^{2-}	All others	Soluble
	Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}	Low Solubility
Sulphide, S^{2-}	Alkali ions, H^+, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}	Soluble
	All others	Low Solubility
Hydroxide, OH^-	Alkali ions, H^+, NH_4^+, Sr^{2+}	Soluble
	All others	Low Solubility
Phosphate, PO_4^{3-} or Carbonate, CO_3^{2-} or Sulphite, SO_3^{2-}	Alkali ions, H^+, NH_4^+	Soluble
	All others	Low Solubility

Periodic Chart of Ions

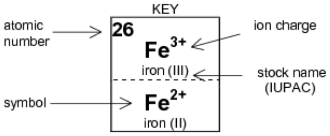
Table of Polyatomic Ions

acetate	CH_3COO^-	dichromate	$Cr_2O_7^{2-}$	dihydrogen phosphate	$H_2PO_4^-$
ammonium	NH_4^+	cyanide	CN^-	silicate	SiO_3^{2-}
benzoate	$C_6H_5COO^-$	hydroxide	OH^-	sulphate	SO_4^{2-}
borate	BO_3^{3-}	iodate	IO_3^-	sulphite	SO_3^{2-}
carbonate	CO_3^{2-}	nitrate	NO_3^-	hydrogen sulphide	HS^-
hydrogen carbonate	HCO_3^-	nitrite	NO_2^-	hydrogen sulphate	HSO_4^-
chlorate	ClO_3^-	oxalate	$OOCCOO^{2-}$	hydrogen sulphite	HSO_3^-
hypochlorite	ClO^-	permanganate	MnO_4^-	thiocyanate	SCN^-
chromate	CrO_4^{2-}	phosphate	PO_4^{3-}	thiosulphate	$S_2O_3^{2-}$
		hydrogen phosphate	HPO_4^{2-}		

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1 H^+ hydrogen																	2 He helium
3 Li^+ lithium	4 Be^{2+} Beryllium											5 B boron	6 C carbon	7 N^{3-} nitride	8 O^{2-} oxide	9 F^- fluoride	10 Ne neon
11 Na^+ sodium	12 Mg^{2+} magnesium											13 Al^{3+} aluminum	14 Si silicon	15 P^{3-} phosphide	16 S^{2-} sulfide	17 Cl^- chloride	18 Ar argon
19 K^+ potassium	20 Ca^{2+} calcium	21 Sc^{3+} scandium	22 Ti^{4+} titanium (IV) Ti^{3+} titanium (III)	23 V^{5+} vanadium (V) V^{4+} vanadium (IV)	24 Cr^{3+} chromium (III) Cr^{2+} chromium (II)	25 Mn^{2+} manganese (II) Mn^{4+} manganese (IV)	26 Fe^{3+} iron (III) Fe^{2+} iron (II)	27 Co^{2+} cobalt (II) Co^{3+} cobalt (III)	28 Ni^{2+} nickel (II) Ni^{3+} nickel (III)	29 Cu^{2+} copper (II) Cu^+ copper (I)	30 Zn^{2+} zinc	31 Ga^{3+} gallium	32 Ge^{4+} germanium	33 As^{3-} arsenide	34 Se^{2-} selenide	35 Br^- bromide	36 Kr krypton
37 Rb^+ rubidium	38 Sr^{2+} strontium	39 Y^{3+} yttrium	40 Zr^{4+} zirconium	41 Nb^{5+} niobium (V) Nb^{3+} niobium (III)	42 Mo^{6+} molybdenum	43 Tc^{7+} technetium	44 Ru^{3+} ruthenium (III) Ru^{4+} ruthenium (IV)	45 Rh^{3+} rhodium	46 Pd^{2+} paladium (II) Pd^{4+} paladium (IV)	47 Ag^+ silver	48 Cd^{2+} cadmium	49 In^{3+} indium	50 Sn^{4+} tin (IV) Sn^{2+} tin (II)	51 Sb^{3+} antimony (III) Sb^{5+} antimony (V)	52 Te^{2-} telluride	53 I^- iodide	54 Xe xenon
55 Cs^+ cesium	56 Ba^{2+} barium	57 La^{3+} lanthanum	72 Hf^{4+} hafnium	73 Ta^{5+} tantalum	74 W^{6+} tungsten	75 Re^{7+} rhenium	76 Os^{4+} osmium	77 Ir^{4+} iridium	78 Pt^{4+} platinum (IV) Pt^{2+} platinum (II)	79 Au^{3+} gold (III) Au^+ gold (I)	80 Hg^{2+} mercury (II) Hg^+ mercury (I)	81 Tl^+ thallium (I) Tl^{3+} thallium (III)	82 Pb^{2+} lead (II) Pb^{4+} lead (IV)	83 Bi^{3+} bismuth (III) Bi^{5+} bismuth (V)	84 Po^{2+} polonium (II) Po^{4+} polonium (IV)	85 At^- astatide	86 Rn radon
87 Fr^+ francium	88 Ra^{2+} radium	89 Ac^{3+} actinium															

58 Ce^{3+} cerium	59 Pr^{3+} praseodymium	60 Nd^{3+} neodymium	61 Pm^{3+} promethium	62 Sm^{3+} samarium (III) Sm^{2+} samium(II)	63 Eu^{3+} europium (III) Eu^{2+} europium(II)	64 Gd^{3+} gadolinium	65 Tb^{3+} terbium	66 Dy^{3+} dysprosium	67 Ho^{3+} holmium	68 Er^{3+} erbium	69 Tm^{3+} thulium	70 Yb^{3+} ytterbium (III) Yb^{2+} ytterbium (II)	71 Lu lutetium
90 Th^{4+} thorium	91 Pa^{5+} protactinium (V) Pa^{4+} protactinium(IV)	92 U^{6+} uranium (VI) U^{4+} uranium (IV)	93 Np^{5+} neptunium	94 Pu^{4+} plutonium (IV) Pu^{6+} plutonium (VI)	95 Am^{3+} americium (III) Am^{4+} americium (IV)	96 Cm^{3+} curium	97 Bk^{3+} berkelium (III) Bk^{4+} berkelium (IV)	98 Cf^{3+} californium	99 Es^{3+} einsteinium	100 Fm^{3+} fermium	101 Md^{2+} mendelevium(II) Md^{3+} mendelevium (III)	102 No^{2+} nobelium (II) No^{3+} nobelium (III)	103 Gd^{3+} lawrencium

KEY



PERIODIC TABLE OF THE ELEMENTS

14 — Atomic Number
Si — Symbol
Silicon — Name
28.1 — Atomic Mass

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** Hydrogen 1.0																	2 **He** Helium 4.0
3 **Li** Lithium 6.9	4 **Be** Beryllium 9.0											5 **B** Boron 10.8	6 **C** Carbon 12.0	7 **N** Nitrogen 14.0	8 **O** Oxygen 16.0	9 **F** Fluorine 19.0	10 **Ne** Neon 20.2
11 **Na** Sodium 23.0	12 **Mg** Magnesium 24.3											13 **Al** Aluminum 27.0	14 **Si** Silicon 28.1	15 **P** Phosphorus 31.0	16 **S** Sulphur 32.1	17 **Cl** Chlorine 35.5	18 **Ar** Argon 39.9
19 **K** Potassium 39.1	20 **Ca** Calcium 40.1	21 **Sc** Scandium 45.0	22 **Ti** Titanium 47.9	23 **V** Vanadium 50.9	24 **Cr** Chromium 52.0	25 **Mn** Manganese 54.9	26 **Fe** Iron 55.8	27 **Co** Cobalt 58.9	28 **Ni** Nickel 58.7	29 **Cu** Copper 63.5	30 **Zn** Zinc 65.4	31 **Ga** Gallium 69.7	32 **Ge** Germanium 72.6	33 **As** Arsenic 74.9	34 **Se** Selenium 79.0	35 **Br** Bromine 79.9	36 **Kr** Krypton 83.8
37 **Rb** Rubidium 85.5	38 **Sr** Strontium 87.6	39 **Y** Yttrium 88.9	40 **Zr** Zirconium 91.2	41 **Nb** Niobium 92.9	42 **Mo** Molybdenum 95.9	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.1	45 **Rh** Rhodium 102.9	46 **Pd** Palladium 106.4	47 **Ag** Silver 107.9	48 **Cd** Cadmium 112.4	49 **In** Indium 114.8	50 **Sn** Tin 118.7	51 **Sb** Antimony 121.8	52 **Te** Tellurium 127.6	53 **I** Iodine 126.9	54 **Xe** Xenon 131.3
55 **Cs** Cesium 132.9	56 **Ba** Barium 137.3	57 **La** Lanthanum 138.9	72 **Hf** Hafnium 178.5	73 **Ta** Tantalum 180.9	74 **W** Tungsten 183.8	75 **Re** Rhenium 186.2	76 **Os** Osmium 190.2	77 **Ir** Iridium 192.2	78 **Pt** Platinum 195.1	79 **Au** Gold 197.0	80 **Hg** Mercury 200.6	81 **Tl** Thallium 204.4	82 **Pb** Lead 207.2	83 **Bi** Bismuth 209.0	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)									

58 **Ce** Cerium 140.1	59 **Pr** Praseodymium 140.9	60 **Nd** Neodymium 144.2	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.4	63 **Eu** Europium 152.0	64 **Gd** Gadolinium 157.3	65 **Tb** Terbium 158.9	66 **Dy** Dysprosium 162.5	67 **Ho** Holmium 164.9	68 **Er** Erbium 167.3	69 **Tm** Thulium 168.9	70 **Yb** Ytterbium 173.0	71 **Lu** Lutetium 175.0
90 **Th** Thorium 232.0	91 **Pa** Protactinium 231.0	92 **U** Uranium 238.0	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

Based on mass of C^{12} at 12.00.

Values in parentheses are the masses of the most stable or best known isotopes for elements which do not occur naturally.