Midway through the exam, Allen pulls out a bigger brain.

How fishermen blow their own minds.

“Mr. Osborne, May I be excused? My brain is full.”

Wendall Zurkowitz: Slave to the waffle light.

STUDENT NUMBER: _____________  HOUR: ____
Unit Objectives:

1. **APPLY** the Kinetic Theory of Matter in the differentiation between solids, liquids and gases. **DESCRIBE** what happens on a particle level at the melting point and the boiling point of a substance.

2. Using the heating curve of water, **LABEL** the melting point, the boiling point, the heat of fusion, the heat of vaporization.

3. **DESIGN, CONDUCT,** and **EVALUATE** experiments that investigate factors affecting the relative rate a solid dissolves in a solvent.

4. **DESCRIBE** the process of solvation in the dissolving process.

5. **MAKE INFERENCES** about the heat of solution and solubility of substances.

6. **DEFINE** solvent, solute, solubility, saturated, super-saturated and unsaturated.

7. **QUANTIFY /CALCULATE** the effects of concentration on the colligative properties (e.g., boiling points, freezing points, vapor pressure) of solutions. **GRAPH** the results.

8. Perform **COMPUTATIONS** involving factor analysis (the picket fence).

9. **INTER-CONVERT / PERFORM CALCULATIONS** involving grams and moles.

10. In a complete sentence, **EXPLAIN** what is meant by the term concentration, as applied to a solution.

11. **CALCULATE** concentration in terms of molarity (M).

12. **CALCULATE** percent concentration in terms of % mass/mass, % mass/volume and % volume/volume.

13. **CALCULATE** concentration in terms of parts per million (PPM, mg/Kg).

14. Accurately **MAKE** a solution of a specified concentration.

15. **USE** analytical techniques to determine the concentration of solutions.

16. **EXPLAIN** the concept of dilution and **INFER** implications for environmental pollution.

17. Using the dilution formula, **CALCULATE** the missing number to make a dilution of a stock solution and **DESCRIBE** how to actually make the specified diluted solution.
Density, Temperature and the Kinetic Theory

The story so far........
1. All matter is made up of small particles in motion.
2. Mass measures the amount of matter in something.
3. Density measures the amount of mass in a specific volume (e.g. cm$^3$).
4. Therefore, density is an indirect measurement of how many particles are in a given volume.
5. Temperature measures the average kinetic energy (related to the speed) of the particles moving in something.

Now for the lab part.....

1. Thoroughly dry the 25 mL graduated cylinder and accurately mass it.  
   Record its mass here: __________ g

2. Fill the graduated cylinder with 25.0 mL of cold water. Use a beral pipette to do this accurately.  
   Do not have any excess water on the outside of the cylinder. Record the temperature of this water:  
   ____°C. Accurately mass the cylinder with the water and calculate the density of the water. Show the 
   setup for your density calculation here:

3. From the data table supplied, what should the density of this water be?  
   Calculate your percent error.  
   Show the setup for your percent error calculation here:

4. Fill the graduated cylinder with 25.0 mL of hot water. Use a beral pipette to do this accurately.  
   Do not have any excess water on the outside of the cylinder. Record the temperature of this water:  
   ____°C. Accurately mass the cylinder with the water and calculate the density of the water. Show the 
   setup for your density calculation here:

5. From the data table supplied, what should the density of this water be?  
   Calculate your percent error.  
   Show the setup for your percent error calculation here:
Now for the mind part.....

1. As temperature increases, what happens to the density of water?

2. As the temperature of the water increases, what happens to the speed of individual water particles?

3. As the temperature of the water increases, what happens to the number of water particles in a mL (cm³)?

4. Make a general statement that relates the number of particles in a given volume to their relative speed. Make an analogy to a stomp with a slow dance and a fast dance and the number of dance partners that can fit in a defined area.

5. Based on your results, complete the table below that generalizes the states of matter. Fill in the relative number of particles/mL, density, and temperature categories with the words “low”, “medium” and “high”. Fill in the space between particles category with “widely spaced”, “medium spaces”, or “closely spaced”. Fill in the speed category with “slow”, “medium” and “fast”.

<table>
<thead>
<tr>
<th></th>
<th>Gas</th>
<th>Liquid</th>
<th>Solid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relative number of particles/mL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative space between particles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative density</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative speed of particles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative Temperature</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. Summarize the properties of a gas, a liquid, and a solid.

GAS          LIQUID          SOLID
1. Describe what happens on a particle level as a substance changes from a liquid to a gas?

2. Why does the temperature of boiling water remain a 100°C (at sea level) until all of the water has been changed to steam? Remember, temperature measures the average kinetic energy of all the particles present.
Factors Controlling the Rate of **Dissolution**

**Problem:** To devise and conduct experiments that demonstrate how the rate of dissolution can be changed.

**Instructions:**
Construct an experimental design box to test the effect each of the factors listed below has on how fast something dissolves (rate of dissolution). In each experiment, the dependent variable will be the time it takes a substance to dissolve. Also, make a numbered list of the procedures you will use to conduct the experiment. After performing the experiment, record your results and make a conclusion.

**Part I. Particle Size**
Using small equal masses of rock salt (NaCl) and table salt; develop and conduct an experiment that demonstrates the effect of particle size on the rate of dissolution.

Complete the experimental design box below:

<table>
<thead>
<tr>
<th>Problem:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothesis:</td>
</tr>
<tr>
<td>IV:</td>
</tr>
<tr>
<td>Units: None</td>
</tr>
<tr>
<td>DV:</td>
</tr>
<tr>
<td>Units:</td>
</tr>
<tr>
<td>Constants</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

**Procedures:**

1.  
2.  
3.  
4.  
5.  

**Results:**

<table>
<thead>
<tr>
<th>Conclusion:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
</tbody>
</table>
**Part II. Agitation/Shaking**
Using one type of salt, develop and conduct an experiment that demonstrates the effects of agitation/shaking on the rate of dissolution.

Complete the experimental design box below:

<table>
<thead>
<tr>
<th>Problem:</th>
<th>Hypothesis:</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV:</td>
<td>Units: None</td>
</tr>
<tr>
<td>DV:</td>
<td>Units:</td>
</tr>
</tbody>
</table>

**Constants**

<table>
<thead>
<tr>
<th>Procedures:</th>
<th>Results:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Conclusion:</td>
</tr>
<tr>
<td>5.</td>
<td></td>
</tr>
</tbody>
</table>

**Part III. Temperature**
Using table salt, develop and conduct an experiment that demonstrates the effects of temperature on the rate of dissolution.

Complete the experimental design box below:

<table>
<thead>
<tr>
<th>Problem:</th>
<th>Hypothesis:</th>
</tr>
</thead>
<tbody>
<tr>
<td>IV:</td>
<td>Units: None</td>
</tr>
<tr>
<td>DV:</td>
<td>Units:</td>
</tr>
</tbody>
</table>

**Constants**
Solutions

Substances _______________ in water are aqueous solutions.

Nature of solutions
1. ______________ and stable.
2. Both ____________ and ____________ particles pass through ___________ paper and do __________ settle with time.
3. Solvents and solutes may be gases, liquids or solids.
4. Substances that ____________ most readily in water are __________ compounds and __________ covalent molecules forming ionic solutions.
5. ____________ covalent molecules do not dissolve in water.

The Golden Rule of Solutions: **Like Dissolves Like!!**
- Miscible - When __________ liquids can __________ in each other.
- Immiscible - When two __________ can’t __________ in each other.

The Process of Dissolving (Solvation)

Components
1. __________ - the __________ medium, frequently water.
2. __________ - the __________ particles.

The Mechanisms
1. The process of dissolving is ___________. The process is based on the __________ energy of matter.
2. Solute particles are ____________
from the solid, because of the ________ of the solute and solvent particles. This action ________ energy.

3. ________ particles are moved ________ to allow solute particles to enter the ________ environment. This action takes up energy.

4. ________ particles are ________ to solvent particles. This ________ energy.

5. The first two steps are ________ processes and the third step is ________.

6. If the temperature of the solution ________ as the dissolving process occurs, the ________ process is greater than the two endothermic processes. (Negative heat of solution). The solubility of the substance ________ with rising temperature.

7. If the temperature of the solution ________ as the dissolving process occurs, the ________ processes are greater than the exothermic process (Positive heat of solution). The solubility of the substance ________ with rising temperature.

**Applications:**

1. If KClO₃ were dissolved in water, would the temperature of the solution increase or decrease?

2. If NaOH is dissolved in water, how would you expect the temperature of the solution to change?

3. Name the three best substances on the chart to the right, which could be used to make athletic hot packs?

4. Name the best three best substances on the chart to the right, which could be used to make athletic cold packs?

<table>
<thead>
<tr>
<th>Substance</th>
<th>Heat of solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>AgNO₃(s)</td>
<td>+5.44</td>
</tr>
<tr>
<td>CO₂(g)</td>
<td>-4.76</td>
</tr>
<tr>
<td>CuSO₄</td>
<td>-16.20</td>
</tr>
<tr>
<td>HC₂H₃O₂(l)</td>
<td>-0.38</td>
</tr>
<tr>
<td>HCl(g)</td>
<td>-17.74</td>
</tr>
<tr>
<td>HI(g)</td>
<td>-7.02</td>
</tr>
<tr>
<td>KCl(s)</td>
<td>+4.20</td>
</tr>
<tr>
<td>KClO₃(s)</td>
<td>+10.04</td>
</tr>
<tr>
<td>KI(s)</td>
<td>+5.11</td>
</tr>
<tr>
<td>KNO₃(s)</td>
<td>+8.52</td>
</tr>
<tr>
<td>KOH(s)</td>
<td>-13.04</td>
</tr>
<tr>
<td>LiCl(s)</td>
<td>-8.37</td>
</tr>
<tr>
<td>Li₂CO₃(s)</td>
<td>-3.06</td>
</tr>
<tr>
<td>MgSO₄ . 7H₂O(s)</td>
<td>+3.80</td>
</tr>
<tr>
<td>NaCl(s)</td>
<td>+1.02</td>
</tr>
<tr>
<td>NaNO₃(s)</td>
<td>+5.03</td>
</tr>
<tr>
<td>NaOH(s)</td>
<td>-9.94</td>
</tr>
<tr>
<td>Na₂SO₄ . 10H₂O(s)</td>
<td>+18.76</td>
</tr>
<tr>
<td>NH₃(g)</td>
<td>-8.28</td>
</tr>
<tr>
<td>NH₄Cl(s)</td>
<td>+3.88</td>
</tr>
<tr>
<td>NH₄NO₃(s)</td>
<td>+6.08</td>
</tr>
</tbody>
</table>
Solubility of Solids

In General:

A. When an excess amount of ________ is added to a given ________ of solvent at a given ________, the dissolving ________ will take place until ________ more solute can dissolve in the solvent.

- the ________ of substance that ________ in a given quantity of ________ at a given temperature to produce a ________ solution.

B. Condition of ________ will be reached.

1. There is _____ net ________ in the overall system.

2. Particles of ________ move from the ________ to the ________ state and back to the solid state.

3. This ________<------>__________ process happens at the ________ rate producing a dynamic equilibrium.

C. Definitions

__________ solution-

holds the ________ amount of ________ for a given amount of ________ at a constant ________.

__________ solution-

holds ________ solute than a ________ solution.

__________ solution -

holds ________ solute than it ________ hold at a given ________. This is accomplished by ________ the temperature of a ________ solution, having the ________ solid dissolve and then letting the system slowly ________ undisturbed.
Solubility of Gases

A. The solubility of gases behaves ____________ of solids.

B. ____________ and ____________ temperature decreases the solubility of a ____________.

C. ____________ law - at a given temperature the ____________ of a gas in a liquid is ____________ proportional to the ____________ of the gas ____________ the liquid.

Colligative Properties of Solutions

The ____________ properties of a solution are ____________ from those of the ____________ solvent.

Colligative properties are ____________ properties that depend on the ____________ of ____________ in a given mass of solvent.

- ____________ point is ____________, it is higher than the boiling point of the pure solvent.
- Freezing point is ____________, it is lower than the freezing point of the pure solvent.

The magnitude of the change is ____________ proportional to the ____________ of the solutes.

\[ \Delta T = k m \]

A ____________ that dissociates into ____________ particles, like sodium chloride, has an even ____________ effect on colligative properties.

TITLE: Heating Curve for Water with NaCl added:

How does this curve compare to the curve for pure water above?
User Friendly Units

PROBLEM: How many drops from a beral pipette are in one cup of water?

SOLUTION: Show all of your work for solving this problem.

Proportions are _______________ between things, so at when one number changes the other changes as ___________ of the first. It does not matter if proportions are flipped, for example, 3 tsp/1Tbsp says the ___________ as 1 Tbsp/3tsp.

Units are the _______________ that identify what a number is _______________ about. For example, you are about 5.0 x 10^{8} old. What?! Yes, you are about 5.0 x 10^{8} seconds old.

PRACTICE WITH UNITS

Directions: Convert the following phrases to proportions.

1. There are 8 oz. in a cup.
3. For 12 ears of sweet corn, I have to pay $1.32.
4. We hiked for 8 hours and only covered 15 miles.
5. Candy bars are on sale five for two dollars.
6. Rabbits can have up to 16 bunnies in three years.

Directions: For these questions what are the units in the answers?

1. How many cookies can be made from one bag of flour?
2. How many kernels of corn are in a bushel?
3. How many cups of milk are in a gallon?
4. How many songs are on a CD?
5. How many leaves are on a maple tree?
6. How many feet are in one kilometer?
The Picket Fence

When solving problems that use proportions, it is ________________ to make sure that all units ________________, except for those units in the answer.

The picket fence is a _______________ used to make sure that the units cancel.

When a number is on the _________________ of the picket fence, it means the number is used to _________________ others numbers by it.

When a number is on the _________________ of the picket fence, it means the number is sued to _________________ other numbers by it.

STEPS FOR USING THE PICKET FENCE:

Step 1. Write out any _______________ given in the problem and any others that may be of use.

Step 2. Identify what ______________ are needed to satisfy what the problem is asking.

Step 3. Start the picket fence in the __________ hand corner by filling it in with the number and the units that are not part of any proportion and is given to you in the problem.

Step 4. Fill in the picket fence from left to right, making sure to _________________ the units as you go along. Remember, only when the same units are on the top and bottom of a picket fence do they cancel each other.

EXAMPLE:

You have 23 marbles, which cost $1.79. How much do 567 marbles cost?

Step 1:

Step 2:

Step 3 & 4:
PROPORTIONS AND THE PICKET FENCE

Solve the following challenges using the picket fence format. Make sure to show ALL of your work and label and cancel ALL of the units!!

1. Katie can earn $9.00 for working two hours. How much would she earn for working 5.5 hours?

2. William can go 985 miles on 11 gallons of gasoline. How many gallons of gasoline will he burn on a trip of 595 miles?

3. Mr. Sanchez paid $345.00 taxes for his lot, which was valued at $65,000.00. At the same rate, what is the value of Mr. Gomez’s lot who paid $468.75 in taxes?

4. An inch is 2.54 centimeters. How tall are you in centimeters?

5. A silk material for a dress costs $14.75 a square meter, how much material could you buy for $18.00?

6. You are a donut addict. Store ‘A’ offers donuts for $1.75 a dozen. How many donuts can you buy with $5.00
The warm and Fuzzy MOLE

Chemists have devised a means of keeping track of the amount of ________ involved in chemical reactions. This method uses the gram formula mass better known as the molar mass - ________ for short.

In each element box on the periodic table are two numbers - the molar mass of an element is the ____________ of these two numbers. For example:

The molar mass of carbon is ________ grams/mole
(rounded off)

What is the molar mass of each of the following elements? Be sure to include the units!

1. Co  4. copper
2. Cr  5. strontium
3. Mn  6. krypton

To find out what the mass of a molecule is (remember a molecule is more than one atom joined together), you must first count up the different ____________ and ____________ of atoms. For example.

\[\text{CuSO}_4 \rightarrow \_ \text{ copper atom} + \_ \text{sulfur atom} + \_ \text{oxygen atoms}\]

Count up the number and types of atoms in the following molecules:

1. H\textsubscript{2}--->
2. AlCl\textsubscript{3}--->
3. C\textsubscript{6}H\textsubscript{12}O\textsubscript{6}--->
4. Ca(NO\textsubscript{3})\textsubscript{2}--->

Next, ____________ the number of each type of atom by the molar mass of that element. For example:

\[\text{CuSO}_4 \rightarrow (1 \times \_ \text{ g/mole}) + (1 \times \_ \text{ g/mole}) + (4 \times \_ \text{ g/mole})\]
Calculate the molar mass, or gram formula mass (gfm), for each of the following molecules:

1. H₂
2. AlCl₃
3. C₆H₁₂O₆
4. Ca(NO₃)₂

You now know how to construct a ______________ for the molar mass of a substance:

\[
\text{Molar Mass} = \frac{\text{grams}}{\text{mole}}
\]

We can use this proportion with the ______________ to calculate the number of moles or the number of grams in a quantity of a substance. For example:

1. How many moles are in 26 g of H₂?

Solution:

\[
\frac{1 \text{ Molar mass of H₂}}{2 \text{ grams}} = \frac{26 \text{ g}}{2 \text{ g}} = \underline{13} \text{ moles of H₂}
\]

2. How many grams are in 2.1 moles of AlCl₃?

Solution:

\[
\frac{1 \text{ Molar mass of AlCl₃}}{133.5 \text{ grams}} = \frac{2.1 \text{ moles}}{1 \text{ mole}} = 280.4 \text{ g of AlCl₃}
\]
3. How many moles are in 107 grams of C$_6$H$_{12}$O$_6$?

4. How many grams are in 8.3 moles of Ca(NO$_3$)$_2$?

5. How many moles are in 127 grams of PCl$_3$?

6. How many grams are in 1.89 moles of Hg$_2$O?

How Concentrated Is It?

**Concentration** - the amount of ______________ dissolved in a given quantity of solvent at a given temperature.

There are two main methods of stating concentration:

A. Qualitative - based on judgment, described with words
   1. Dilute - the solution contains a relatively __________ amount of solute.
   2. Concentrated - the solution contains a __________ amount of solute.

B. Quantitative - involves quantities, described with ______________
   1. Molarity (M)
   2. Percent concentration (%)
   3. Parts per million (ppm)
I. Molarity

**Molarity** - the number of ___________ of a solute dissolved in one liter (L) of solution, not solvent.

\[
\text{Molarity (M)} = \frac{\text{number of moles of solute}}{\text{number of Liters of solution}}
\]

Example: Enough water is added to 2 moles of glucose to make 5 L of solution, what is it’s molarity?

\[
\frac{2 \text{ moles of glucose}}{5 \text{ L of ______}} = \quad \text{____ moles/L (M)}
\]

1. What is the concentration (M) of a 2.5 L solution containing 1.3 moles of ethylene glycol (anti-freeze)?

2. What is the molarity of 800 mL of a solution containing 0.25 moles of salt?

Because molarity is a ____________________, it can be used in the picket fence to solve more complex problems. Review the steps for using the picket fence!

For example:

1. A salt solution contains 0.90 g of NaCl per 100 mL of solution.
   What is its molarity?

   Solution:

   **Step 1**: proportions given and needed

   \[
   \frac{0.90 \text{ g NaCl (given in problem)}}{1000 \text{ mL}} \quad \frac{58.5 \text{ g NaCl}}{L}
   \]

   **Step 2**: The answer needs the units expressed in ___________ (___)

   **Step 3 & 4**: Because only a proportion is given in the problem, start the picket fence with it.

   \[
   \frac{0.90 \text{ g NaCl}}{100 \text{ ___}} \quad \frac{1000 \text{ mole}}{58.5 \text{ g NaCl}} = 0.15 \text{ moles (M)}
   \]
2. An aqueous solution has a volume of 1.8 L and contains 46.0 grams of glucose. If the gram formula mass of glucose is 180 grams / mole, what is the molarity of the solution?

3. 800 mL of a solution contain 32.4 g of NaC₂H₃O₂. What is its molarity?

4. How many grams of LiOH are needed to make 25 mL of a .125 M solution?

Solution:

**Step 1:** proportions given and needed

\[
\frac{0.125 \text{ moles}}{\text{L}} \quad (\text{given in problem}) \quad \frac{24 \text{ g LiOH}}{\text{mole}} \quad \frac{1000 \text{ mL}}{\text{L}}
\]

**Step 2:** the units for the answer are __________

**Step 3 & 4:**

\[
\frac{25 \text{ mL}}{1000 \text{ mL}} \quad 0.125 \text{ moles} \quad \frac{24 \text{ g LiOH}}{\text{mole}} = 0.075 \text{ grams}
\]

5. How many grams of CaCO₃ are needed to make 4.5 L of a 2.1 molar solution?

6. How many grams of H₂SO₄ are needed to make 500 mL of a 3 M solution?
How Many Moles Spell Pain Relief?

DATA TABLE:

Brand Name ______________________
Mass of Aspirin Tablet ___________ grams
Molarity of NaOH _____________ moles/liter

Volume of NaOH Required to Neutralize All Acid Material:

Final buret reading ___________ mL
Beginning buret reading ___________ mL
Volume of NaOH used ___________ mL

Assuming that the only acid present is acetylsalicylic acid, calculate the number of moles and grams present in the aspirin tablet.

1. Use the following formula to find the molarity:
   
   Volume of Base X Molarity of Base = Volume of Acid X Molarity of Acid

2. Use a picket fence to find the number of milligrams of aspirin in the tablet:
   (the molar mass of acetylsalicylic acid is 180 grams/mole)
   
   _____ mL | _____ L | __________ | __________ | __________ = _____ mg

3. Find the % aspirin in the tablet:

4. If the label on the bottle says each tablet contains 325 mg of aspirin. What is the percent error in your laboratory analyses.
Now For Some Hands-On

Problem: To make a 100 mL of a ______M CuSO₄·5H₂O and water solution.

Solution:

1. Graph the % transmittance vs. molarity of the standard CuSO₄·5H₂O solutions on the supplied graph. Make sure to accurately label the axis of your graph!

2. Show your calculations of how many grams of CuSO₄·5H₂O are needed to make 100 mL of your solution.

\[ \text{____mL} \quad \text{________} \quad \text{________} \quad \text{_______} \quad = \quad \text{_______ g} \]

3. Write the procedures you would use to mix up the solution.

4. Accurately make 100 mL of your assigned solution.

5. Filter the solution to remove any cloudiness.

6. Predict what % transmittance your solution should have based on a reading from your graph. The predicted value is _______% transmittance

7. Record the actual % transmittance of your solution _______%

8. Calculate the % error between your prediction and the actual reading.

Title:

Conclusions:
1. Did a chemical reaction occur when you mixed the copper sulfate in the water? How do you know?

2. Why does the mixture need to be filtered? Use the words suspension and solution in your answer.

II. Percent Concentration

__________ concentrations can be used in the following ways:

A. % mass / mass ( % m/m ) - is the number of grams of solute per gram of __________, expressed as a percent.

\[
\frac{\text{grams of solute}}{\text{grams of _______}} \times 100 = \% \text{ m/m concentration}
\]

B. % mass / volume ( % m/v ) - is the number of _________ of solute per milliliter of solution, expressed as a percent.

\[
\frac{\text{grams of solute}}{\text{_____ of solution}} \times 100 = \% \text{ m/v concentration}
\]

C. % volume / volume ( % _____ ) - is the number of milliliters of solute per milliliter of solution, expressed as a percent.

\[
\frac{\text{mL of solute}}{\text{mL of solution}} \times _____ = \% \text{ v/v concentration}
\]

Useful conversions for WATER only!

\[
1 \text{ g} = 1 \text{ mL} = 1 \text{ cm}^3 = 0.001 \text{ Kg} = 0.0001 \text{ L} \quad 1 \text{ L} = 1 \text{ Kg} = 1,000 \text{ g} = 1,000 \text{ mL}
\]

Examples:

1. Calculate the percent concentration (m/m) of a solution of 25 g CuSO₄ in 975 mL of water (Remember to add the masses together to find the total mass of the solution).

2. Calculate the percent concentration (m/m) of a solution of 2.5 g CuSO₄ in 247.5 mL of water (remember to add the masses together to find the total mass of the solution).
3. Calculate the percent concentration (m/v) of a solution 48 g NaCl to make 250 mL of a NaCl/water solution.

4. Calculate the percent concentration (m/v) of a solution of 56 g NaCl to make 2 L of a NaCl/water solution.

5. Calculate the percent concentration (v/v) of a solution of 1.5 mL ethanol in 550 mL of an ethanol/water solution.

6. Calculate the percent concentration (v/v) of a solution of 32 mL ethanol in 0.75 L of an ethanol/water solution.

**III. Parts Per Million (ppm, mg/Kg)**

Parts per million is a concentration expression that relates ________________ of solute to kilograms of solution (mg/Kg)

\[
\frac{\text{mg of solute}}{\text{mg of solution}} = \text{ppm (mg/Kg)}
\]

**Useful Conversions**

1g = 1,000 mg; 0.0001g = 1mg; 1Kg = 1,000g = 1,000,000mg

Examples:

1. Calculate the concentration of a solution in ppm when 33.4 mg of naphthalene are mixed with benzene to make 1.5 Kg of solution.

2. Calculate the concentration of a solution in ppm when 145 mg of naphthalene are mixed with benzene to make 550 g of solution.

3. Calculate the concentration of a solution in ppm when 2.3 g of naphthalene are mixed with benzene to make 2,550 g of solution.
Dilutions

A useful laboratory technique is to make concentrated solutions and then __________ them with water to make less concentrated solutions that you need. The more concentrated solution is called a ______________ solution.

To make a solution by dilution, you use the following equation:

\[
\text{Volume}_{\text{concen.}} \times \text{Concentration}_{\text{concen.}} = \text{Volume}_{\text{dilute}} \times \text{Concentration}_{\text{dilute}}
\]

Example:

What volume of 1.5 M sodium nitrate solution would you use to make 200 mL of a .5 M solution?

\[
\text{Volume}_{\text{concen.}} \times 1.5 \text{ M} = 200 \text{ mL} \times .5 \text{ M}
\]

\[
\text{Volume}_{\text{concen.}} = \frac{200 \text{ mL} \times .5 \text{ M}}{1.5 \text{ M}}
\]

\[
\text{Volume}_{\text{concen.}} = 66.6 \text{ mL}
\]

1. What volume of water should be added to 10.19 mL of an 8.0 M acetic acid solution in order to obtain a final solution that is 1.50 M?

2. What volume of a 8.75 M formic acid solution should be used to prepare 2.0 L of a .15 M formic acid solution?

3. What is the molarity of a solution of ammonium chloride prepared by diluting 50.0 mL of a 5.70 M ammonium chloride solution to 2.0 L?
Is dilution the Solution for Pollution?

Introduction:
Copper chloride is a byproduct from such industrial processes such as copper smelting. Copper chloride is toxic to human health and must be treated before being released into the environment. Is dilution a solution?

<table>
<thead>
<tr>
<th>Microwell</th>
<th>After Water Dilution</th>
<th>After Ammonia is Added</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>50,000 ppm</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Aluminum Clean-up

<table>
<thead>
<tr>
<th>Appearance</th>
<th>Copper Chloride Solution</th>
<th>Aluminum Foil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before Reaction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>After Reaction</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Record any observations you made:
DILUTION OF COPPER WASTE

Prepare a dilution of the copper waste

SPECTOPHOTOMETER READING ____________

1. What would lead you to believe a chemical reaction occurred when you added ammonia to the copper solution?

2. What is the lowest concentration of a copper solution that can be visually detected with the ammonia test? Was a blue color visible in that concentration before adding the ammonia? How could this test be useful in finding harmful levels of copper in water in the environment?

3. How much water must be added to one liter of 50,000 ppm copper chloride waste solution to dilute it to 5 ppm?

4. What is the % (m/m) in a 50,000 ppm copper chloride solution. Show all of your work.

5. After adding the ammonia to the decanted liquid and comparing it to the previous diluted microwells, what is the concentration of copper in the liquid?

6. After decanting the liquid, describe the solid material. What do you think it is? Why?

7. Is the decanted liquid now safe for human consumption? Why or why not? Account for what happened to the aluminum foil as the copper deposited.

8. As an environmental engineer for Kennecott copper mine, you are in charge of disposing a 50,000 ppm CuCl₂ waste stream into a nearby creek. The EPA mandates only a 1 ppm waste stream can enter the creek. What will you do? Discuss dilution and/or treatment in your answer.
CONCENTRATE ON THIS SKILL PRACTICE

1. Using the concepts in the Kinetic Theory of matter and the following phrases to describe a solid, a liquid, and a gas. PHRASES: Relative density, Number of particles/mL, Relative space between particles, Relative speed of particles, Relative temperature

   A solid has...

   A liquid has ...

   A gas has .......

2. Draw in the space to the right a graph of a solid changing into a liquid. Label solid, liquid, melting point, freezing point and the axes of the graph

3. Why does each of the following factors speed up the rate of dissolution?
   Particle size...
   Agitation...
   Temperature...

4. Describe the mechanisms (steps) of dissolution, as a sugar cube dissolves in water.

Refer to the chart below to answer the following questions.

5. What substance in the table below would release the most heat when dissolving in water?

6. What substance would take in the most heat when dissolving in water?

7. If NaNO₃ is added to hot water rather than cold water would its solubility increase?

8. Because NaOH has a negative heat of solution, are the exothermic or the endothermic processes greater in the dissolving process?

9. What would happen to the solubility of KI as the temperature of water increased?

10. If H₂SO₄ is dissolved in water, what would the temperature of the solution do?

11. Given the equation: Heat + KClO₃(s) \rightarrow K^+(aq) + ClO₃⁻(aq) and the information in the chart, KClO₃ would be used to make __________ packs for athletic injuries.
HEATS OF SOLUTION
(Kcal/mole solute in 200 moles H₂O)
[(s) = solid, (l) = liquid, (g) = gas at STP]

<table>
<thead>
<tr>
<th>Substance</th>
<th>Heat of solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>CuSO₄(s)</td>
<td>-16.20</td>
</tr>
<tr>
<td>CuSO₄ · 5H₂O(s)</td>
<td>+ 2.75</td>
</tr>
<tr>
<td>H₂SO₄(l)</td>
<td>-17.75</td>
</tr>
<tr>
<td>KClO₃(s)</td>
<td>+10.04</td>
</tr>
<tr>
<td>KI(s)</td>
<td>+ 5.11</td>
</tr>
<tr>
<td>KOH(s)</td>
<td>-13.04</td>
</tr>
<tr>
<td>NaCl(s)</td>
<td>+ 1.02</td>
</tr>
<tr>
<td>NaNO₃(s)</td>
<td>+ 5.03</td>
</tr>
<tr>
<td>NaOH(s)</td>
<td>- 9.94</td>
</tr>
<tr>
<td>Na₂SO₄ · 10H₂O(s)</td>
<td>+18.76</td>
</tr>
</tbody>
</table>

Refer to the graph on the right to answer the following questions.

12. What substances' solubility is least affected by changes of temperature?
13. What substances show a decrease in solubility with increasing temperature?
14. What substances' solubility is most affected by changes of temperature?
15. What is the concentration of KCl at 50°C?
16. At what temperature does the solubility of KNO₃ begin to exceed that of KCl?
17. How many grams of NaNO₃ will dissolve in 400 grams of H₂O at 10°C?
18. As the temperature of a solution is decreased from 70°C to 20°C, what happens to the amount of KNO₃ that can dissolve in 100 grams of H₂O?
19. If 30 grams of KNO₃ is dissolved in 100 grams of water at 60°C would the solution be saturated, supersaturated or unsaturated?
20. As a pond warms its temperature during the summer what effect would this have on the amount of dissolved oxygen in the water?

Define the following:
21. Immiscible
22. Solvent
23. Solute
24. Solution
25. Saturated solution
26. Supersaturated solution
27. Unsaturated solution

The dissolution rate is a measure of how fast a substance dissolves in water or acid/water solutions (such as rainwater). Geologists study the dissolution rates of different minerals because the dissolution rate influences how minerals and rock weather (break down).

Experiment 1
The masses of 8 pieces of Mineral A, all of equal size and shape, were measured with a balance. Each piece was then placed in a separate beaker of a prepared hydrochloric acid solution of known pH (a measure of acidity with lower values corresponding with higher acidity) and stirred at a constant rate and temperature for a known time. After being removed from the beaker, each piece was rinsed, dried and re-measured. To determine how much of the piece dissolved. The dissolution rate for each piece was then calculated in milligrams per second (mg/sec). The results are in Table 1.

Experiment 2
Four pieces of Mineral B were analyzed using the procedure from Experiment 1. The results are in Table 2.

Experiment 3
Using the same procedure as in Experiment 1, ten pieces of Mineral A were analyzed with rainwater samples (collected from various locations) instead of prepared acid solutions. The pH of rainwater varies from 3.5 to 5.5. It was determined that the lower the pH of the rainwater, the higher the dissolution rate.

28. Which of the following factors was varied in Experiment 2?
   a. The length of time in the beaker of acid solution
   b. The initial pH of the acid solution
   c. The temperature of the acid solution
   d. The temperature of the rainwater

29. Which of the following explanations best describes why the mineral pieces were dried after being removed from the acid and rinsed?
a. So that all of the mineral pieces would have the same mass
b. To properly measure the mass of the liquid absorbed by each piece
c. To remove any liquid that might affect the measurement of the final mass of each piece
d. Because mineral pieces experience alternating wet and dry periods in nature

30. In which of the following ways, if any, did the experimental conditions for Pieces 1-4 differ from those for Pieces 5-8 in Experiment 1?
   a. The time in the beaker was varied for Pieces 1-4, while the initial pH was varied for Pieces 5-8.
   b. Rainwater was used for Pieces 1-4, while acid solutions were used for Pieces 5-8.
   c. Pieces 1-4 were composed of Mineral A, while Pieces 5-8 were composed of Mineral B.
   d. The experimental conditions were the same for Pieces 1-4 as they were for Pieces 5-8.

31. Use the following grid to graph the results of Experiment 2. Plot the initial pH of the acid solution on the X axis and dissolution rate (mg/sec) on the Y axis.

32. The results of Experiment 3 provide a better understanding of how minerals might dissolve in nature than do the results of the other experiments because:
   a. pieces of Mineral A were used instead of pieces of Mineral B
   b. 10 pieces of Mineral A were tested, rather than 8 pieces
   c. samples of rainwater, rather than prepared acid solutions, were tested
   d. lower pH resulted in greater dissolution rates than in the other experiments

33. The scientist repeated the part of Experiment 1 that involved Pieces 5-8, using a different mineral (Mineral C). At the end of the experiment, none of the mineral had dissolved. Based on what was learned from Experiment 1 and 3, the scientist would most likely conclude that Mineral C:
   a. has the same dissolution rate as Mineral B.
   b. has the same dissolution rate as Mineral A.
   c. would probably dissolve in rainwater.
   d. Would probably not dissolve in rainwater.

34. Solutions with pH less than 6 were mostly used in all of the experiments because:
   a. minerals dissolve too quickly in solutions with pH greater than 6.
   b. minerals won’t dissolve in solutions with pH less than 6.
   c. rainwater samples have pH less than 6.
   d. rainwater samples have pH greater than 6.
**Formula Masses:** Determine the formula weight for each of these compounds:

35. NO$_3$
36. MgCl$_2$
37. NaCl
38. Al$_2$SO$_3$
39. Hg$_2$O
40. Be(NO$_3$)$_2$

**Moles:** You are given 27.0 grams of each of the following substances. How many moles of each substance do you have?

41. CaO
42. K$_2$CrO$_4$
43. Na$_2$CO$_3$·10H$_2$O
44. Fe(NO$_3$)$_3$

Give the number of grams in each quantity of substance.

45. 3 moles of boron
46. 5 moles of Hg$_2$O
47. 11.5 moles of oxygen
48. 7.28 moles of N$_2$O$_4$

**Molarity** Calculate the molarity of each of the following solutions, which were prepared by dissolving the solute in enough water to achieve the final volume indicated.

49. 15 g KCl in 2.50 L
50. 43 g MgSO$_4$ in 5.75 L
51. 5 g KBr in 0.5 L
52. .5 g NH$_3$ in 55.0 mL

Calculate the number of grams of solute needed to prepare each of the following solutions.

53. 2.50 L of 0.250 M (NH$_4$)$_2$CO$_3$
54. 725 mL of 2.50 M NH$_4$Cl
55. 37.5 mL of 0.685 M KI
Percent Concentrations

How would you prepare aqueous solutions of each of the following?

56. 168 mL of 14.0% isopropyl alcohol (by volume/volume)

57. 750 mL of 3.0% acetic acid (by volume/volume)

58. 30 g of 25% glucose (by mass/volume)

Parts per Million

<table>
<thead>
<tr>
<th>Substance</th>
<th>Maximum contaminant level (PPM)</th>
<th>Substance</th>
<th>Maximum contaminant level (PPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water Quality</td>
<td></td>
<td>Air Quality</td>
<td></td>
</tr>
<tr>
<td>Arsenic</td>
<td>0.05</td>
<td>Ozone</td>
<td>0.12</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.05</td>
<td>Carbon Monoxide</td>
<td>9</td>
</tr>
<tr>
<td>Lead</td>
<td>0.05</td>
<td>Nitrogen Dioxide</td>
<td>0.05</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.002</td>
<td>Sulfur Dioxide</td>
<td>0.03</td>
</tr>
<tr>
<td>Nitrate</td>
<td>45.0</td>
<td>Hydrocarbons</td>
<td>0.24</td>
</tr>
</tbody>
</table>

59. A 25 Kg sample of water is tested for arsenic and is found to contain 5.1 mg of this toxic element. How many parts per million does this represent? Does this level fall within the allowable limits in the table above?

60. A car is tested for tail pipe emissions. A 8 Kg sample of exhaust was collected. The sample contained 8.5 grams of carbon monoxide and 298 mg of unburned hydrocarbons. How many parts per million of each substance was found in the exhaust. Did the car pass the emission standards test?

Dilutions

How would you prepare each of the following dilute solutions from the concentrated solution indicated?

61. 500 mL of 1 M HCL from 10 M HCL

62. 250 mL of 4.8 M HNO₃ from 15 M HNO₃

63. To what volume should 25 mL of an 2 M citric acid solution be diluted in order to obtain a final solution that is 1.5 M?

64. What volume of a 12 M hydrochloric acid solution should be used to prepare 2.6 L of a 2 M hydrochloric acid solution?

65. What is the molarity of a solution of sodium chloride prepared by diluting 750 mL of a 4 M sodium chloride solution to 1.3 L?