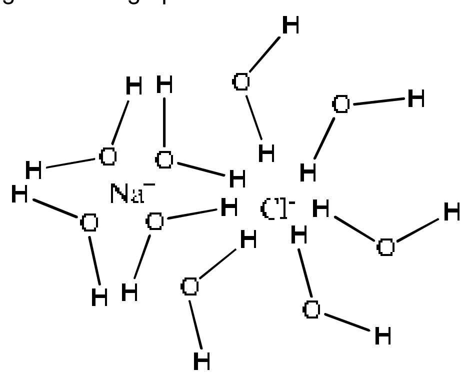
SOLUBILITY OF A SALT IN WATER AT VARIOUS TEMPERATURES LAB

Purpose: Most ionic compounds are considered by chemists to be salts and many of these are water soluble. In this lab, you will determine the solubility, that is, how much of a salt can dissolve in water, of $KClO_3$ (potassium chlorate). In particular, we will be determining solubility at different temperatures.

Background: We learned in class about intermolecular forces; the forces that hold molecules together as solids and liquids. We learned that hydrogen bonding gives water its extraordinary properties, and that salts dissolve in water because their charges line up with the partial charges on water. Water molecules surround an ion, resulting in a "solvent cage" around the charged particle (Figure 1).

Figure 1: Depiction of solvent cage breaking apart the ionic bond in sodium chloride.



To understand this lab, we need to look at a few definitions regarding solubility. Some of these are new and others are review:

- Solution—when one substance (not necessarily a solid) is dissolved in a liquid, a solution forms. Salt water, for example, is a solution of salt (a solid) in water (a liquid). Rubbing alcohol is also a solution, where water is dissolved in isopropyl alcohol (a liquid).
- Solute—the material that is dissolved in a solution. This is the chemical that is in lesser quantity. In salt water and rubbing alcohol, the salt and water are the solutes, respectively.
- Solvent—the liquid that dissolves the solute to form a solution. This is the chemical that is in abundance in a solution. In salt water and rubbing alcohol, the solvents are water and isopropyl alcohol, respectively.
- Unsaturated solutions—in an unsaturated solution, all particles of the solute are dissolved in the solvent. In fact, there is room in the solvent to dissolve more of the solute. There will be no visible solid salt in an unsaturated solution.
- Saturated solutions—in a saturated solution, as much salt as possible will be in solution. That is, the solution is saturated with as much solute as possible. To saturate the solution, we have to heat the solution. In a saturated solution, you will see crystals of the solid salt at the bottom of the solution.

- Supersaturated solutions—A supersaturated solution has more salt dissolved in it than theoretically possible. The formation of crystals is not always easy for the salt and requires certain conditions. When a saturated solution is really hot and starts to cool down, the crystals may not form immediately. This leads to more solute being dissolved in the solvent than is stable at that temperature. It doesn't take much to get crystals to form in a supersaturated solution. An example is in hot packs, where you have to bend the metal piece to get the liquid to turn solid and it turns hot. This is an example of a supersaturated sodium acetate solution that crystallizes and releases heat in the process. All it takes is a little snap of the metal piece to initiate the process.

Each salt acts differently when dissolved in water, and this is due to the physical properties of the atoms in each salt. Polyatomic ions, ions that are made of multiple atoms, will act much differently than a monoatomic ion like chloride. We can ask the question, what is the solubility of solute A in solvent B? The answer to this question is usually answered in grams of A per 100 mL of water.

There is also an important factor in solubility that we have not yet mentioned, temperature. Imagine trying to dissolve sugar in your cold iced tea compared to dissolving sugar in hot tea. The hot tea dissolves sugar much easier. This is also the case with salts. Hot water dissolves salt faster than cold water, and it also will dissolve *more* salt than the cold water will. This is because heat is a form of energy and energy is required to dissolve a substance. The more energy applied, the faster something will dissolve, and in greater quantity. We can report the solubility of a chemical at various temperatures. For example, the solubility of KBr in water at 25 ^{o}C is 64 g/100 g water. At 100 ^{o}C, the solubility increases to about 100 g KBr/100 g water. In this lab, you will be taking a solution of potassium chlorate and heating it until it dissolves. You can watch the test tube as the temperature falls to determine the temperature of crystallization; that is, the temperature that the salt loses its solubility. You will be adding water to the test tube over several trials, making more dilute solutions, and determining the solubility for those as well. From there, you can graph the results to predict potassium chlorate solubility at different temperatures.

Equipment:

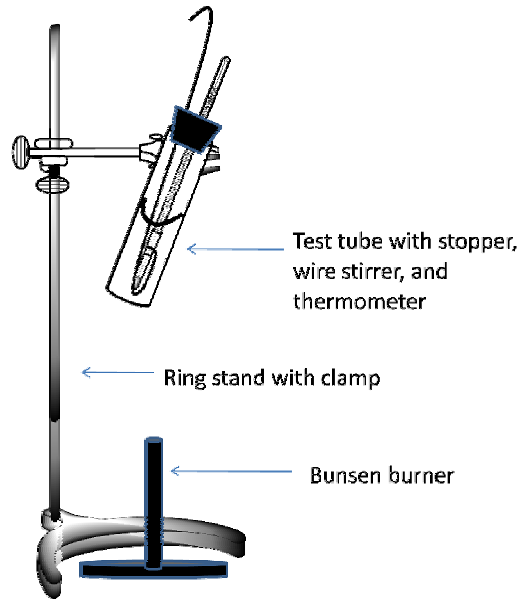
Large test tube and clamp	split rubber stopper	110 ^{o}C thermometer
10-mL graduated cylinder	ring stand	Bunsen burner
Wire stirrer	distilled water	10 g salt

Procedure:

A graph must be prepared showing the grams of salt dissolved in 100 g water on the y-axis and temperature on the x-axis.

I. Assemble the apparatus as shown in Figure 2. You will need to make sure the wire stirrer is around the thermometer so you can easily stir the solution as it heats. Use a 20 cm test tube with the stopper, stirring wire, and thermometer as your apparatus, and attached it to a ring stand with a clamp. Add a Bunsen burner underneath. You may want to keep out a beaker to rest your test tube in while you work.

Figure 2: Scheme of apparatus



II. Weigh somewhere between 4.5-5.0 grams of salt on a balance and record the mass on the data sheet.

III. Using a graduated cylinder, measure out about 10 mL of water and add it to the salt in the apparatus. Record the *mass* of water on your data sheet (remember than 1 g of water is 1 mL).

IV. Clamp the apparatus to the ring stand and heat it, stirring it continuously as it heats by moving the stirrer up and down until the solid salt dissolves. You will want to use a cool flame—don't use an interior blue cone to heat because it will crack your test tube.* Turn off the burner and stir continuously and vigorously as the apparatus cools down by moving the stir wire up and down the test tube. Record the exact temperature when you see crystals of salt forming (in ^{o}C).

V. Cool down the test tube until it is warm to the touch. You can put it under the water tap to speed this up. Measure about 4 mL of water and add to the previous 10 mL in the test tube. DON'T dump out what is already in the test tube. You are simply adding 4 mL of water to what is already there. Record the mass of how much water you add. Repeat step IV and record your data.

VI. Add 4 mL of water to the previous 14 mL. Repeat step IV and record the data.

VII. Add 4 mL of water to the previous 18. Repeat step IV and record the data.

VIII. Add 4 mL of water to the previous 22. Repeat step IV and record the data.

IX. Pour your salt water solution to a waste beaker.

*If you crack a test tube, you will need to use a new test tube, measuring a new quantity of salt. Indicate on your data sheet when the test tube cracks and record the new quantity of salt. You will need to start where you left off with the volume of water, so add enough water to make up the amount in your tube when it cracked.

Calculations:

Fill in the prepared table attached to your data sheet. The mass of the salt does not change, only the mass of the water. Remember to use the total amount of water in the test tube at any given measurement, not just the water you added for that particular step.

To calculate the solubility, you will need to use the formula:

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Solving for *x*, the solubility of salt, we get the formula:

$$x = \frac{mass\ salt\ (g) \times 100\ g\ water}{mass\ water\ (g)}$$

Where x is the solubility of salt (in g) in 100 g water.

Prepare a graph of solubility (y axis) vs. temperature of crystallization(x axis) in Celsius. Use a line to connect the points in the best possible manner. It may not be a straight line. Use the graph to answer the post-lab questions.

SOLUBILITY OF A SALT IN WATER AT VARIOUS TEMPERATURES PRE-LAB

Name:____

1. Many liquids you use are actually solutions made of a solute dissolved in a solvent. What is an example of a solution in your kitchen? ________________________________

2. What is an example of a solution in your bathroom? ______________________________

3. Sodium bicarbonate, or baking soda, is a common salt found in your home. Sodium bicarbonate is only partially soluble in water at room temperature. How could you increase the solubility of sodium bicarbonate in water?

   ____

   ____

4. How could you decrease the solubility of baking soda?

   ____

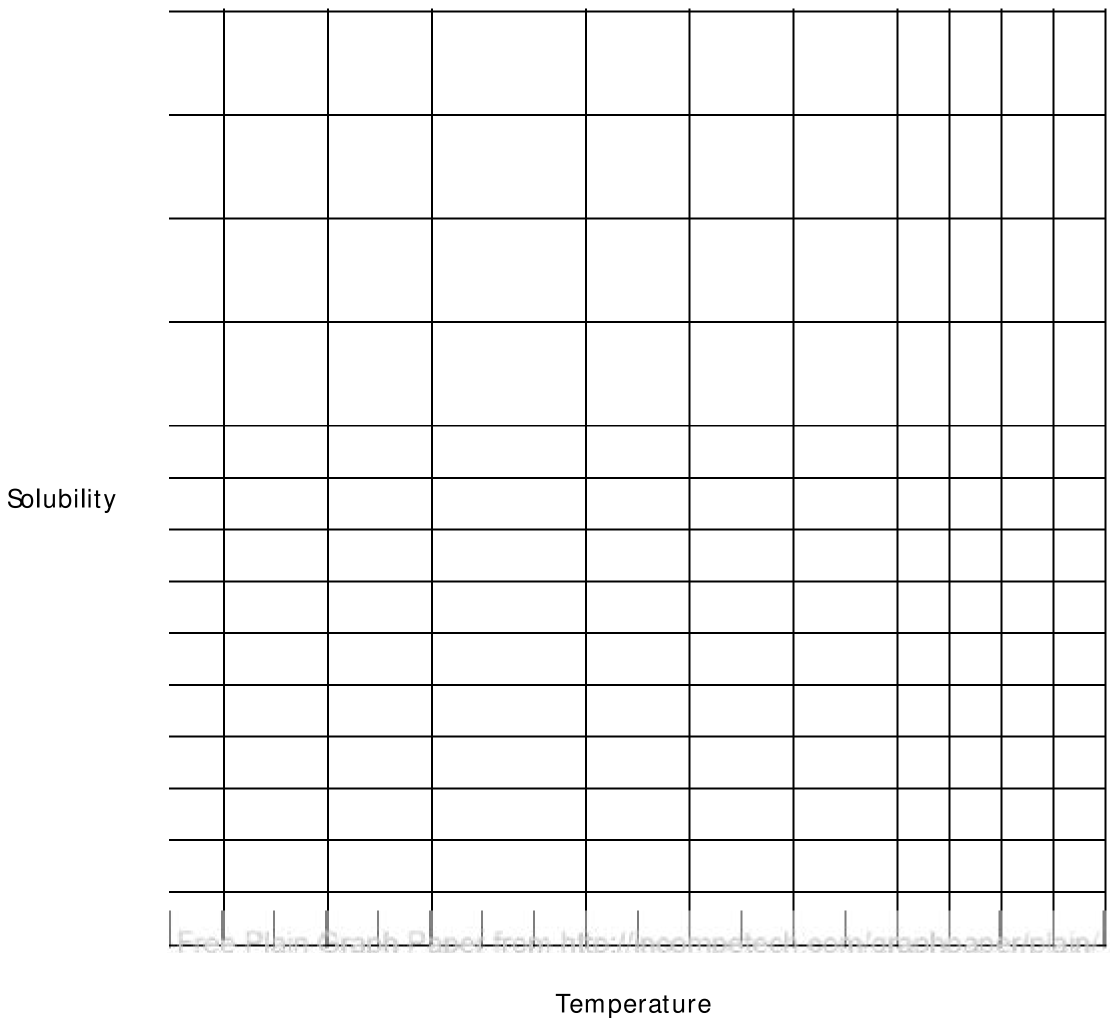
   ____

5. What is the solute in this lab? ____

6. What is the solvent? ____

7. Practice plotting data points: In this lab you will be plotting points to get a graph and answer questions regarding that graph. There are example data plots below for the solubility experiments of lead nitrate. Plot these points and answer the following questions. You will want to extend the line in both directions past the data points to get answers to the questions.

Temperature (^{o}C) x-axis	Solubility (g/100 mL water) y-axis
92.1	115
70.1	91.2
49.6	78.6
31.2	61.4



a. What would the solubility be at 35 °C of lead nitrate? ______________________________

b. What would the solubility be at 25 °C of lead nitrate? ______________________________

c. What would the temperature be if the solubility were 65.0 g/100 mL? ________________

SOLUBILITY OF A SALT IN WATER AT VARIOUS TEMPERATURES POST-LAB

Name:____

Partner(s):____

1. Mass of salt __________________g
2. Mass of water __________________g
3. Temperature of crystallization for IV __________________^{o}C

4. Mass of water added in V __________________g
5. Total mass of water added (6+3) __________________g
6. Temperature of crystallization for V __________________^{o}C

7. Mass of water added in VI __________________g
8. Total mass of water added (5+7) __________________g
9. Temperature of crystallization for VI __________________^{o}C

10. Mass of water added in VII __________________g
11. Total mass of water added (8+10) __________________g
12. Temperature of crystallization for VII __________________^{o}C

13. Mass of water added in VIII __________________g
14. Total mass of water added (11+13) __________________g
15. Temperature of crystallization for VIII __________________^{o}C

Fill in the following data table for each section above. Use the formula in the background section to determine the salt concentration. You will be using this table to make your graph.

Section	Water mass (g)	Salt concentration	Crystallization temperature (°C)
IV			
V			
VI			
VII			
VIII			

Graph your data points below and connect with a line. You will want to extend the line past the points in both directions to answer all of the questions that follow. Label your axis.

Post-lab questions:

1. Predict the solubility of your salt at the following temperatures (watch your units):

   a. 70 °C ______________________

   b. 50 °C ______________________

   c. 30 °C ______________________

2. How would your graph change if you added 1 mL too much water in one step, then added 1 mL less the next step to compensate for it? How would this affect your solubility measurements from the table? This requires a bit of thought so be careful!!!

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3. How could you have gotten better results for this lab? ______________________

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