Solubility of a Salt
Minneapolis Community and Technical College
C1152 v.5.10

Solutions are **homogeneous mixtures** made up of one or more **solutes** dissolved in a **solvent**. The solvent is the component present in the greatest amount. Solutions are **unsaturated** when more solute will dissolve. **Saturated solutions** contain as much dissolved solute as is possible at that temperature. **Supersaturated solutions** have more solute dissolved than should be possible and are quite unstable.

**Solubility** is defined to be the maximum amount of solute that will dissolve in a given amount of solvent at a specific temperature. The solubility of a salt is one of many physical properties that depend on temperature. The graph above illustrates how for many salts, solubility increases at higher temperatures.

Typically, solubility is recorded as grams of solute per 100g of solvent (Y Axis). For example, the solubility of NaCl in water at 20°C is 36 grams per 100 g water. If you attempt to dissolve 40 grams of NaCl in 100 mL of water, 36 grams will dissolve to form a saturated solution and the remaining 4 grams will settle to the bottom of the container.

However, all is not as it seems. The solid NaCl at the bottom of the container is continuously dissolving while at the same time ions from the solution are combining to reform the solid salt. This equilibrium process can be written as follows:

\[
\text{NaCl}_\text{(s)} \rightarrow \text{NaCl}_\text{(aq)}
\]

The mass of the salt observed at the bottom of the beaker never changes because salt that dissolves is immediately replaced by salt that reforms the solid.

For many solutes, increasing the temperature increases the solubility of the solute and thus the graph of solubility vs. temperature has an upward slope. In this experiment, you will determine the temperature dependence of potassium nitrate's solubility in water. To do this you will prepare four different solutions, each containing a different amount of KNO₃ dissolved in 5 mL of water. Each vial is then stirred and heated to dissolve all of the salt.

After the solid completely dissolves, the stirred solution is allowed to slowly cool. At some point, the temperature will be low enough for the solution to become saturated. This point is identified by the formation of small solid crystals floating freely within the solution that resembles a snow flurry. The temperature when crystals are first observed is recorded for each trial solution.

Knowing the temperature when crystals form and the masses of solute and solvent permits us to construct a solubility graph (solubility vs. temperature) with solubility in units of grams solute/100 grams solvent. After plotting the temperature and solubility data, a linear and second order polynomial trend line analysis of the data is performed. The best fit for the data will then be used to determine the concentration of an unknown sample.
II. MSDS: Chemical Information

Potassium Nitrate KNO₃
DANGER! STRONG OXIDIZER.
CONTACT WITH OTHER MATERIAL
MAY CAUSE FIRE. HARMFUL IF
SWALLOWED, INHALED OR
ABSORBED THROUGH SKIN.
CAUSES IRRITATION TO SKIN,
EYES AND RESPIRATORY TRACT.

Health Rating: 1 - Slight
Flammability Rating: 0 - None
Reactivity Rating: 3 - Severe (Oxidizer)
Contact Rating: 1 - Slight
Lab Protective Equip: GOGGLES;
LAB COAT
Storage Color Code: Yellow (Reactive)

Potential Health Effects
Inhalation: Causes irritation to the
respiratory tract. Symptoms may include
coughing, shortness of breath.
Ingestion: Causes irritation to the
gastrointestinal tract. Symptoms may
include nausea, vomiting and diarrhea.
May cause gastroenteritis and abdominal
pains. Purging and diuresis can be
expected. Rare cases of nitrates being
converted to the more toxic nitrites have
been reported, mostly with infants.
Skin Contact: Causes irritation to skin.
Symptoms include redness, itching, and
pain.
Eye Contact: Causes irritation, redness,
and pain.
Chronic Exposure: Under some
circumstances methemoglobinemia
occurs in individuals when the nitrate is
converted by bacteria in the stomach to
nitrite. Nausea, vomiting, dizziness, rapid
heart beat, irregular breathing,
convulsions, coma, and death can occur
should this conversion take place.
Chronic exposure to nitrates may cause
anemia and adverse effects to kidney.
Aggravation of Pre-existing
Conditions: No information found.

III. Procedure

You will be working in pairs as
you do today's experiment.

Construct the ringstand apparatus shown
below. The vial and temperature probe
should be securely clamped so that the
entire apparatus can be moved as a whole.
Two stir plates are required. Only one is
equipped with a hot water bath (50 mL
beaker) for heating purposes. The other
hotplate is used only to stir the vial while it
cools slowly. Move the ringstand apparatus
as a unit between the two stir plates as
needed.

Obtain four vials and label each appropriately.
Weigh each vial (cap on) and record the mass of
each in your notebook.

On a piece of creased weighing paper, measure
out the amount of KNO₃ given by the table
below.
Transfer the solid to the appropriate vial and
reweigh to accurately determine the amount of
solid. Repeat this procedure for all five vials.

<table>
<thead>
<tr>
<th>Vial #</th>
<th>Approximate KNO₃ mass (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>~8 g</td>
</tr>
<tr>
<td>2</td>
<td>~6 g</td>
</tr>
<tr>
<td>3</td>
<td>~4 g</td>
</tr>
<tr>
<td>4</td>
<td>~2 g</td>
</tr>
</tbody>
</table>

Pipette 5.00 mL of distilled water into each vial.
Re-weigh each vial to determine the amount of
water actually transferred to the vial.
LoggerPro File: MCTC Solubility of a Salt

**IMPORTANT:** Keep wires away from the hot plate or they may melt and be damaged!!!

Remove the cap from vial #1 and insert the magnetic stir bar. Use clamps to support the vial in the hot water bath (50 mL beaker). Note that the bottom of the vial must be centered on the stir plate and close (1-2 cm) to the bottom of the water bath for the magnetic stirrer to work.

* Do not let the water from the hot water bath get into your vial!!

* Be sure the vial is centered over the stir plate for best results. If the stir bar appears to be only vibrating, move the control to a slower stir setting to let the stir bar catch up.

* For the more concentrated solutions, it may be necessary to first stir with the temperature probe since the stir rod will be imbedded in solid KNO₃.

Continue heating the solution until the solid has dissolved. Do not leave the vial in the water bath any longer than what is required to completely dissolve the solid. Why?

When the KNO₃ has dissolved, lift the entire ring stand apparatus and repositioning it over the cold stir plate. Continue stirring. Allow the vial to cool slowly

* A small piece of ice held at the bottom of the vial will accelerate the cooling process. Don’t cool too quickly or you may overshoot the crystallization temperature.

Crystals will suddenly form and build in intensity as the solution cools (snow flurry). Record the temperature at the first sign of crystals. 

Reheat the vial/solution and repeat the cooling process (always stirring) a second time and average your results. Report the average value in your data table.

Repeat this process for the remaining vials. Empty each vial in the appropriate "KNO₃ student waste" container and don’t forget to rinse and dry the temperature probe in between experiments to minimize solution cross contamination.

* Use the magnet picker to retrieve the stir bar from the waste solution container.

Lastly, obtain an unknown KNO₃ solution. Remember to record the unknown number in your lab notebook and on your report. Heat the solution until the solid completely dissolves. Cool the solution and record the temperature when crystals form. Repeat a second time and determine the average temperature for the unknown.
**IV. Data Analysis**

1. Use Excel to construct a data table containing mass KNO₃, mass H₂O, T (°C), Solubility (g₄sat/100 gₜsolvent) for all trials. Include an entry for the unknown solution's identification number, its characteristic temperature and solubility determined from the trendline analysis.

2. Construct a solubility graph using the temperature and solubility information for the first four trials. (Use the scatter plot option but do not connect the dots.)

3. Perform a linear and second order polynomial trendline analysis on the data. Display the equation and R squared value for each trendline on the graph. The equation that best fits the data will have a correlation coefficient closest to 1.

4. Use the best equation from step 3 to calculate the solubility of your unknown solution. Clearly label the unknown's location on the graph.

**V. Team Report (1 page)**

All must be word processed, clearly worded and on one page.

- **Upper right corner:** Student Names, lab section number and date of experiment

- **Data table:** Obtain a copy of the data table from the lab-handout web site and fill in your values using MS Word. Include the number and concentration of your unknown. Results will be graded on accuracy.

- **Graph:** Copy and paste your Excel Graph onto the same page.
  
  Note: Do all graph editing in Excel before pasting into MS Word. Include:
  - Both trend line results including equations and R² values
  - Identify the regions on the graph corresponding to saturated, unsaturated and supersaturated solutions
  - Clearly label the unknown’s position on the graph (include temp. and solubility numbers)

- **Answers to the following questions:**
  a. Use your graph to determine if the following solutions are unsaturated, saturated, or super-saturated:
     i. 110 g of KNO₃ in 100 g of water at 40°C
     ii. 80 g of KNO₃ in 100 g of water at 70°C
     iii. 140 g of KNO₃ in 200 g of water at 60°C
     iv. 50 g of KNO₃ 50 g of water at 50°C
  
  b. According to your trendline analysis, how many grams of KNO₃ will dissolve in 250. g of water at 45°C?
**Data Table:** Cut and paste this data table into your lab notebook using glue and transparent tape. The instructor must sign this table before you leave the lab.

<table>
<thead>
<tr>
<th>Vial #</th>
<th>Approx. Mass of KNO₃ (g)</th>
<th>Mass of Empty Vial w/cap (g)</th>
<th>Mass of vial w/cap after adding KNO₃ (g)</th>
<th>Mass of vial with cap +KNO₃ +water (g)</th>
<th>Mass of KNO₃ (g)</th>
<th>Mass of H₂O (g)</th>
<th>Solubility (g)salt/100g solvent</th>
<th>Average Temp. of crystallization(°C )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>~8 g</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>~6 g</td>
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</tr>
<tr>
<td>3</td>
<td>~4 g</td>
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</tr>
<tr>
<td>4</td>
<td>~2 g</td>
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<tr>
<td>Unknown sample</td>
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<td></td>
</tr>
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