Title: Concentration Versus Conductivity of $NaCl_{(aq)}$

Brief Overview:

The salinity of seawater is approximately 35 ppt (parts per thousand) or 35 g of salts per kg of salt water. Of the 35 ppt, about 30 ppt is attributed to NaCl. Students will collect data on conductivity versus salinity for several solutions of known concentrations with the TI-83 and CBL. Using the collected data and the TI-83, students will do statistical analyses on the experimental data and pooled class data. A regression curve fit will be done using the TI-83. The standard curve will be used to determine the salinity of several unknowns using interpolation techniques.

Links to NCTM 2000 Standards:

- **Mathematics as Problem Solving**
  Students will learn the appropriate methods involved in, and the uses, of experimentally gathered data, pooled class data, and mathematical models. They will develop strategies to interpret the data collected and will use their observations to generalize solutions, and as an aid in predicting future outcomes. Students will learn various curve fitting techniques and discover a mathematical model for their data using the TI-83.
- **Mathematics as Reasoning and Proof**
  Students will be asked to make conjectures based on their individually data collected. They will used pooled class data and class observations to validate their conjectures. Students will use reasoning to analyze differences and similarities in pooled data.
- **Mathematics as Communication**
  Students will work in teams to collect, organize, pool, and analyze their data. Whole class discussions and data pooling will be an integral part of the lesson. The importance of communicating one's solution processes, both orally and in writing, will be emphasized throughout the unit.
- **Mathematics as Connections**
  Students will explore the relationships between science and mathematics through real-time experimental collection, statistical analyses, and visual representation of scientific data. A variety of mathematical concepts, topics, and techniques will be intertwined throughout the unit.
- **Mathematics as Representation**
  Students will use tabular, graphical, and functional representations of data and examine their connections. They will learn the appropriate uses of each representational method and examine their inherent strengths and weaknesses.
- **Number and Operation**
  Students will understand the importance of significant digits, precision, and estimation. They will learn the appropriate use of paper and pencil calculations as well as calculator use.
- **Patterns, Functions, and Algebra**
  Students will explore the patterns inherent in the data collected, find mathematical functions to mimic these patterns, and learn various curve fitting techniques using the TI-83.
- **Measurement**
  Students will employ a variety of measuring techniques and tools. Proper units and labeling will be stressed.

- **Data Analysis, Statistics, and Probability**
  Students will collect and analyze data using the TI-83 calculator and the Calculator Based Laboratory (CBL). Data can be transferred between the TI-83 and desktop computers for enhanced analyses and printing if desired. Students will be expected to draw conclusions from their analyses and to extrapolate to situations not observed.

Links to Maryland High School Mathematics Core Learning Goals:

Functions and Algebra

- **1.1**
  Students will analyze patterns and functional relationships using the language of mathematics and appropriate technology. **(1.1.1, 1.1.2)**

- **1.2**
  Students will model and interpret real world situations, using the language of mathematics and appropriate technology. **(1.2.1)**

Data Analysis and Probability

- **3.1**
  Students will collect, organize, analyze, and present data.**(3.1.1, 3.1.2, 3.1.3)**

- **3.2**
  Students will apply the basic concepts of statistics and probability to predict possible outcomes of real world situations. **(3.2.1, 3.2.2)**

Links to National Science Education Standards:

- **Unifying Concepts and Processes**
  Students will demonstrate an understanding of chemical systems, procedural order and organization of procedures, and data. Students will gather evidence of a physical process, model the results mathematically, and use both to explain the reaction.
- **Science as Inquiry**
  Students will develop abilities in scientific inquiry to include, data collection, constructing and reading of graphs, statistical analysis, and the care/handling of lab equipment.
- **Physical Science**
  Students will learn about the structure of atoms and the structure and properties of matter.
- **Science and Technology**
  Students will develop an understanding of science and technology and will demonstrate an ability in both.

Links to Maryland High School Science Core Learning Goals:

Concepts of Chemistry

- **4.1**
  Students will explain how the observation of the property of matter forms the basis for understanding its structure and changes in its structure. **(4.1.1, 4.1.2, 4.1.3)**

- **4.2**
  Students will explain that all matter has structure and structure serves as the basis for the properties of, and the changes in, matter. **(4.2.1, 4.2.3, 4.2.4)**
- **4.6**
  Students will show that connections exist both within the various fields of science and among science and other disciplines including mathematics, social studies, language arts, fine arts, and technology. **(4.6.2)**

Grade/Level:

Grades 10(Honors) - 12
Algebra I / Algebra II / Pre-Calculus
Physical Science / Chemistry

Duration/Length:

- This activity will take 2 or 3 days. The time is based on 45 - 50 minute periods.
- Semesterized formats and student ability can affect the duration.
- Appropriate stopping points are noted in the teacher's guide attached.

Prerequisite Knowledge:

Students should have a working knowledge of:

- Data collection
- Constructing and reading of a graph
- Basic statistics (e.g. mean, median, mode)
- Care and handling of lab equipment
- Concentration units in g of solute per kg of solution
- Converting volume in mL of 1.00 M NaCl to g of NaCl per kg of solution
- Ionic compounds and their electrolytic properties
- Pipetting techniques

Student Outcomes:

Students will:

- brainstorm methods for data collection and analysis.
- work cooperatively in groups to collect and organize data using the TI-83, CBL, and conductivity probe.
- produce graphs of collected data using the TI-83.
- analyze data with the TI-83.
- perform basic curve fitting with the TI-83.
- use standard curves to predict concentrations.
- participate in a discussion on observed results.
- process data to synthesize answers to related questions.
- relate experimental results to real world situations.

Overview:

Students will collect data on conductivity versus salinity for several solutions of known concentrations of NaCl using the TI-83 and CBL. Students will do statistical analyses on the experimental data and pooled class data. A regression curve fit will be done using the TI-83. The standard curve will be used to determine the salinity of several unknowns using interpolation techniques.

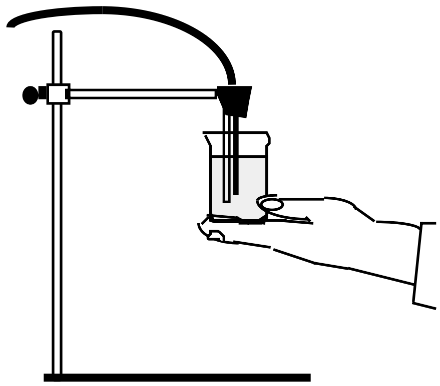

Figure 1

Materials/Resources/Printed Materials:

- TI-83 Calculator with link cable
- Calculator Based Laboratory (CBL)
- Conductivity probe with DIN adapter
- 1-M NaCl
- Unknown solution
- Vernier Chemistry with CBL™ software
- TI Graph-Link™ software (optional)
- Eight 100 mL specimen cups
- 250 mL beaker
- 100 mL beaker
- Ring stand with utility clamp
- Distilled water
- Wash bottle containing dist. H_20
- Vernier Graphical Analysis™ software (optional)

Development/Procedures:

1. Wear goggles.
2. Obtain six specimen cups and one 250 mL beaker. Label the cups (1 - 6).
3. Fill cup #1 to the 50 mL mark with distilled water.
4. Obtain 20 mL of 1-M NaCl solution in a 100 mL beaker. Pipet 0.5 mL of 1-M NaCl solution into cup #2. Add distilled water to the 50 mL mark. (Total volume in cup will be 50 mL) Repeat this process in 0.5 mL increments of NaCl solution for each of the remaining cups. Be sure to bring the **total** volume to 50 mL in each.
5. Calculate the concentration of NaCl in g NaCl per kg of solution. Show your work on the calculation page. Record the concentrations in Table 1. SHOW your teacher.
6. Connect the conductivity probe to channel 1 of the CBL using the DIN adapter. Connect the CBL to the TI-83 via the link cable. Be sure both ends of the link cable are pressed firmly into each piece.
7. Turn on both the CBL and the TI-83.
8. Prepare the data collection system for use with the conductivity probe
   - Press PRGM on the TI-83 and select CHEMBIO from the menu.
   - Press ENTER twice to reach the MAIN MENU.
   - Select 1: SET UP PROBES (The CBL screen should now show - - -)
   - Enter “1” for number of probes, Select 6: CONDUCTIVITY, enter “1” for channel number
   - At the calibration menu choose 3: USE STORED
   - Back at the main menu select 2: COLLECT DATA then 1: MONITOR DATA
   - The CBL should now show a reading in volts.

9. Rinse the probe with distilled water from the wash bottle. Use an empty 250 ml beaker to catch the water. Dump waste water in the sink.

10. Raise cup #1, containing distilled water, until the electrodes of the probe are at least half submersed, but not touching the beaker. (Figure 1). Wait for the CBL readings to settle, then record the conductivity value in Table 1 Individual Data.

11. Repeat steps 9 and 10 for each of the remaining five cups containing the various NaCl concentrations. Be certain to rinse the electrodes well after each reading.

12. When data collection is complete, press ENTER on the TI-83, then Select 6: QUIT

13. Transfer concentration and conductivity data from Table 1 to the TI-83.
    - Press STAT on the TI-83 and select EDIT from the menu. A data table will appear.
        - **To clear a list of previous data:**
            - Using arrow keys place the curser in the heading of the list, press CLEAR ENTER
            - Repeat for each list with data.
    - Using arrow keys, position the curser in column L1. Begin entering concentration values pressing ENTER or the down arrow after each value.
    - Repeat with column L2 entering conductivity values.
    - Press 2ND Y = on the TI-83 (STAT PLOTS screen appears) then select 1: Plot 1, then press ENTER
    - From the Plot 1 screen, select the following by highlighting and pressing ENTER , Plot 1 = On, Type = scatter plot, Xlist = L1, Ylist = L2, and Mark = your choice
    - To plot the graph of conductivity versus concentration, press ZOOM then 9:Zoom Stat. Copy this graph in #1 of the Analysis and Interpretations Sheet. **LABEL.**
    - OPTIONAL: Use the TI Graph-Link or Graphical Analysis software to transfer the graph to a computer, **LABEL**, and obtain a printout.

14. Have your teacher verify and initial your data table and graph before proceeding.

15. Collect the other groups' conductivity values in Table 2. Using the TI-83, calculate the mean conductivity for each of the six concentrations from **pooled class data.**
    - Press STAT on the TI-83 and select EDIT from the menu. Remove previous data from the lists. (see step 13)
    - Enter each groups conductivity value for the distilled water into column L1
    - Press STAT then select CALC, then 1: 1-Var Stats. On main screen type 2ND 1 to indicate L1, then press ENTER. A list of 1-Var Stats will appear. $\bar{x}$ is the mean conductivity value and Sx is the standard deviation. Record the mean conductivity value and standard deviation in Table 2.
    - Repeat with conductivity of cup #2 in column L2, cup #3 in L3, etc. Record each new mean conductivity and standard deviation in Table 2.

16. Plot mean conductivity values versus concentration.
    - Clear all data from lists L1 through L6.
    - Enter concentrations from Table 1 into L1 and mean conductivities from Table 2 into L2
    - Press 2ND Y = on the TI-83 (STAT PLOTS screen appears) then select 1: Plot1, press ENTER
    - From the Plot 1 screen, select the following by highlighting and pressing ENTER, Plot 1 = On, Type = scatter plot, Xlist = L1, Y = L2, and Mark = your choice
    - To plot the graph of mean conductivity versus concentration press ZOOM , then select 9: ZoomStat. Copy this graph in #2 of the Analysis and Interpretations Sheet. **Label.**
    - OPTIONAL: Use the TI Graph-Link or Graphical Analysis software to transfer the graph to a computer, **LABEL**, and obtain a printout.

17. Calculate and graph a linear regression fit using the TI-83.
    - Press STAT then select CALC, then 4: LinReg(ax+b). On the main screen type 2ND 1 to indicate L1, a comma , then 2ND 2 to indicate L2 then ENTER. The linear regression statistics for the two lists will appear on the main screen. Value **a** is the rate of change (i.e. slope) and **b** is the y intercept of the line. Value **r** is the correlation coefficient (i.e. confidence level where 1.00 is a near perfect fit). **NOTE:** If the **r** value does not appear, type 2ND 0 (CATALOG), scroll down to DIAGNOSTICSON, press ENTER then retry.

    - To graph this line:
        - Press Y = . Position the cursor at the beginning of the Y1 equation and press This will erase any previous functions. Repeat for each Y until all are cleared.
        - Press VARS . Select 5: Statistics. Arrow to EQ. Select 1: RegEQ. Press ENTER . The equation will appear in the "Y = " screen . Record this equation in Table 3.
        - Press GRAPH . The fitted curve will appear along with the mean conductivity data. Add the regression curve to graph in #2 of the Analysis and Interpretations Sheet.
        - OPTIONAL: Use the TI Graph-Link or Graphical Analysis software to transfer the graph to a computer, do a linear regression there and obtain a printed copy.

18. Obtain an unknown sodium chloride solution and record the number in Table 3.
    - Repeat steps 6 - 10 using the unknown instead of the distilled water.
    - Record the conductivity reading in your data table.
    - Press Y = . Position the cursor at the beginning of the Y2 equation and enter the conductivity value of the unknown.
    - Press 2ND TRACE (CALC) then select 5: intersect. Press ENTER three times.
    - An x and a y value will appear at the bottom of the graph screen. The x value is the concentration for the unknown. Record this value in Table 3.

19. Turn in completed Data Tables 1 - 3, calculations sheet, and any printouts. **Clean up**.

Assessment:

In the development/procedures there are references as to appropriate places to implement the unit. These would also be appropriate places for periodic assessment. Before data collection, students need to calculate concentrations, and record the results. The teacher may wish to informally assess progress at this point. After the data collection, students are asked to record the conductivity data in Table 1 and then to graph concentration vs. conductivity on the calculator. This graph is then transferred to their worksheet. The teacher should check this graph for accuracy, appropriate labeling, and a linear pattern. During the second portion of the unit, students collect pooled data and construct a scatter plot, again transferring from the calculator to the worksheet. This time a regression curve is calculated and added to the graph. Here is your next assessment opportunity. The teacher should again assess the accuracy, appropriate labeling, and a linear pattern. Look for differentiation between observed data points and the regression curve (i.e., X's representing data points not necessarily "on" the regression curve). The student also records the regression equation on the worksheet (Table 3). Assess the students understanding of the use of this equation (i.e., x = concentration, y = conductivity). Finally, the students will calculate the concentration of an unknown from it's conductivity.

Extension/Follow Up:

1. Distillation of a saline solution can be demonstrated. The distillate can be tested for conductivity. A discussion on desalinization as one solution to the world wide freshwater shortage could follow.
2. The experiment could be repeated using different salts, (i.e., $CaCl_2$).
3. A more detailed discussion on the significance of multiple trials versus pooled group data. Statistical analyses including measures of central tendency and dispersion could be included.
4. Data could be provided for nonlinear modeling using the TI-83's regression capabilities.

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NOTE: Worksheets/resources are on the following pages; please use them as appropriate.

Concentration Calculations

Calculate the concentrations of NaCl in g/kg for each of the standard solutions prepared in step four. Pay attention to units and significant figures. Record results in Table 1.

EX: if the volume of saline solution is **0.5** mL perform the following calculation

0.001(**0.5**) L • (1.00 mol/L • 58.5 g NaCl/mol) ≈ 0.0292 g NaCl

1.00 g/mL • 50.0 mL ÷ 1000 g/kg = 0.0500 kg solution

$$\frac{.0292\text{ g NaCl}}{.0500\text{ kg solution}} = 0.584\,\frac{\text{g NaCl}}{\text{kg solution}}$$

Table 1: Individual Data

	Vol. 1-M NaCl (mL)	Volume of H_2O (mL)	Concentration of NaCl (g NaCl / kg solution)	Conductivity (volts)
Cup 1	0.0	50.0		
Cup 2	0.5	49.5		
Cup 3	1.0	49.0		
Cup 4	1.5	48.5		
Cup 5	2.0	48.0		
Cup 6	2.5	47.5		

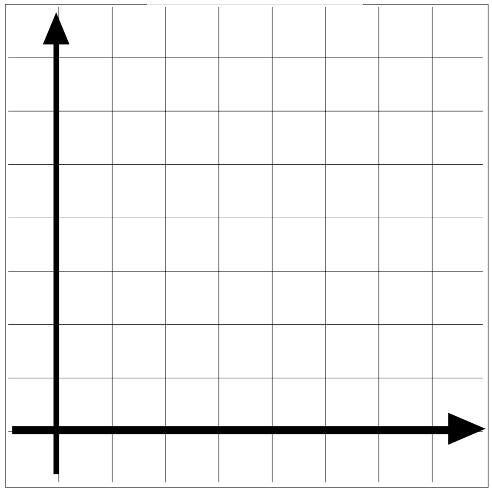
Table 2: NaCl Conductivity Pooled Data

Group #	Cup 1	Cup 2	Cup 3	Cup 4	Cup 5	Cup 6

Analysis and Interpretation

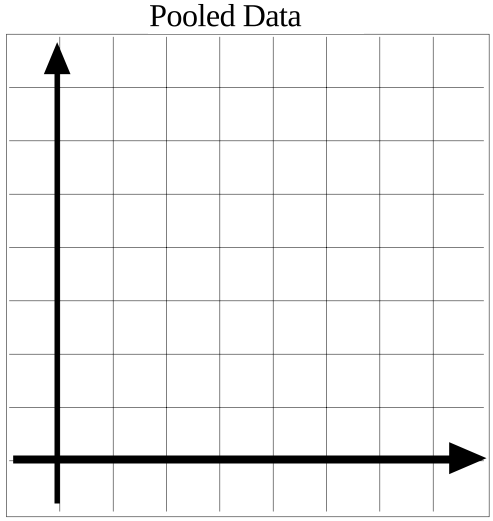
1. Copy the TI-83 graph for **your** concentration versus conductivity data. Be sure the x-axis is the concentration and the y-axis is the conductivity. **<u>LABEL!</u>**

Individual Data



2. Copy the TI-83 graph for concentration versus the **<u>pooled</u>** conductivity along with the regression curve. Be sure the x-axis is the concentration and the y-axis is the conductivity. **<u>LABEL!</u>**

Pooled Data



3. Use the regression equation obtained in Step 17 to calculate the concentration of your unknown. **Pay attention** to which are the dependent and independent variables. You may wish to isolate the unknown variable before you substitute.

Table 3:

Regression Equation: y = _____ x + _______	**Unknown #**_______
Conductivity: ___________	**Concentration:** ___________ g NaCl / kg solution

4. Identify the ions contributing to the solution's conductivity.

5. Write an equation illustrating the solution of sodium chloride in water.

6. Write an equation for the solution of magnesium chloride in water.

7. Compare and contrast the conductivity of sodium chloride and magnesium chloride.

8. Pair with other groups and compare individual graphs with the class mean conductivity graph.

- What could account for the differences?

- Which graph appears more reliable? **WHY?**

- What is the significance of the standard deviation of the group data?

Extensions:

9. Research the chemical composition of seawater.

- Would the standard curve generated in this lab be an appropriate tool for analyzing the salinity of the oceans?

- **EXPLAIN!**

10. Explain the process by which the TI-83 calculated the mean conductivity values from the pooled data.

11. What does the standard deviation value (Sx) for the mean conductivity of each NaCl tell you? How could you represent this on your graph?

TEACHING GUIDE

Concentration versus Conductivity of $NaCl_{(aq)}$

1. Prelab students on the properties of ionic compounds making sure to discuss electrolytes.

2. Write dissociation equations for a variety of soluble salts.

3. Discuss how to calculate the mean and the concept of dispersion, i.e. standard deviation.

4. Instruct students in proper graphing techniques.

5. Preload the Vernier ChemBio Software files into the TI-83 using TI Graph-Link and a computer.

6. Specimen cups can be obtained from local sources.

7. Sample calculation converting milliliters of 1-M NaCl to grams NaCl per kg of solution for concentration values in Table 1. Students should complete concentration calculations **PRIOR** to beginning the experiment.

   - assume the density of the solution will be 1.00 g/mL (density of water)

   $$\frac{\text{g NaCl}}{\text{kg solution}} = \frac{0.001(\mathbf{X})\text{ L} \cdot (1.00\text{ mol/L} \cdot 58.5\text{ g NaCl/mol})}{1.00\text{ g/mL} \cdot 50.0\text{ mL} \div 1000\text{ g/kg}}$$

   = your concentration where **X** is mL of 1-M NaCl solution

   EX: if the volume of saline solution is **0.5** mL perform the following calculation

   $0.001(\mathbf{0.5})\text{ L} \cdot (1.00\text{ mol/L} \cdot 58.5\text{ g NaCl/mol}) \approx 0.0292\text{ g NaCl}$

   $1.00\text{ g/mL} \cdot 50.0\text{ mL} \div 1000\text{ g/kg} = 0.0500\text{ kg solution}$

   $$\frac{.0292\text{ g NaCl}}{.0500\text{ kg solution}} = 0.584\ \frac{\text{g NaCl}}{\text{kg solution}}$$

8. This lab procedure contains explicit instructions on use of the TI-83 and CBL. It is suggested that the teacher become familiar with these before the lab.

9. Step 14 would be an appropriate place to conclude the first portion of the learning unit. At the beginning of the second portion, gather class data on board or overhead. Allow students to copy data into Table 2.

10. Step 17 would be an appropriate place to conclude the second portion of the learning unit. Prepare unknown NaCl solutions with a concentration range of 0.5 g NaCl/kg solution and 30 g NaCl/kg solution or alternately make unknowns using procedure 4 in lab procedures.

11. If students begin step 18 on a new day, steps 16 and 17 may need to be repeated.