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ABSTRACT


Presented is a science activity in which the student investigates methods of calibration of a simple conductivity meter via a hands-on inquiry technique. Conductivity is mathematically compared to salinity using a point slope formula and graphical techniques. Sample solutions of unknown salinity are provided so that the students can sharpen their salinity measuring abilities. Evaluation exercises as well as suggestions for further study are included. (Author/EB)

# Investigations in Marine Chemistry:

## Salinity II

by

Richard M. Schlenker

Abstract

The student investigates methods of calibration of a simple conductivity meter via a hands-on inquiry technique. Conductivity is mathematically compared to salinity using a point slope formula and graphs. Sample solutions of unknown salinity are provided so that the student can sharpen his salinity measuring abilities. Evaluation exercises, as well as suggestions for further study, are included.

Preface

Threre are many aspects of chemistry and electricty which are assumed to be in the instructors repertoire of background knowledge. However, there are a few facts and cautions concerning this unit which should be mentioned.

Pure water will not readily conduct an electric current; however, extremely sensitive meters will detect a current flow even in the purest water. To minimize this effect, distilled water should be used.

In order that investigations achieve the greatest degree of success, the salt water solution should be a homogeneous mixture. To insure that this condition exists, the students should be instructed to mix the salt and the water as throughly as possible.

When the probe is inserted in the salt water and the switch closed, a current flows. When this condition exists, the copper plates react with the solution. While these reactions are beyond the scope of this unit, the reactions do cause buildups on the plates. These buildups effectively increase the resistance between the plates and thus decrease the amount of current flow which can occur between the plates. These buildups increase as the length of time the probe is immersed increases, they are not instantaneous. For this reason the probe should be inserted briefly and the current reading taken as soon as possible after immersion. After a reading has been taken, it is a good idea to rinse the probe in fresh or distilled water. It is also a good idea to periodically clean the probes with steel wool.

As the depth of probe immersion increases, the amount of surface area presented to the water increases. As the area increases, the area avaliable for electron release to and retrieval from the solution increases. It follows that as the depth of penetration increases, the current readings, for a given salinity, will increase. In order to obtain uniform and meaningful results, the depth of penetration should be held constant as one makes a series of measurements. It should also be remembered that the the depth which is used when the salinity charts are made, is the depth at which measurements will have to be made in real life situations. If this scheme is not followed, the calibration chart will be useless.

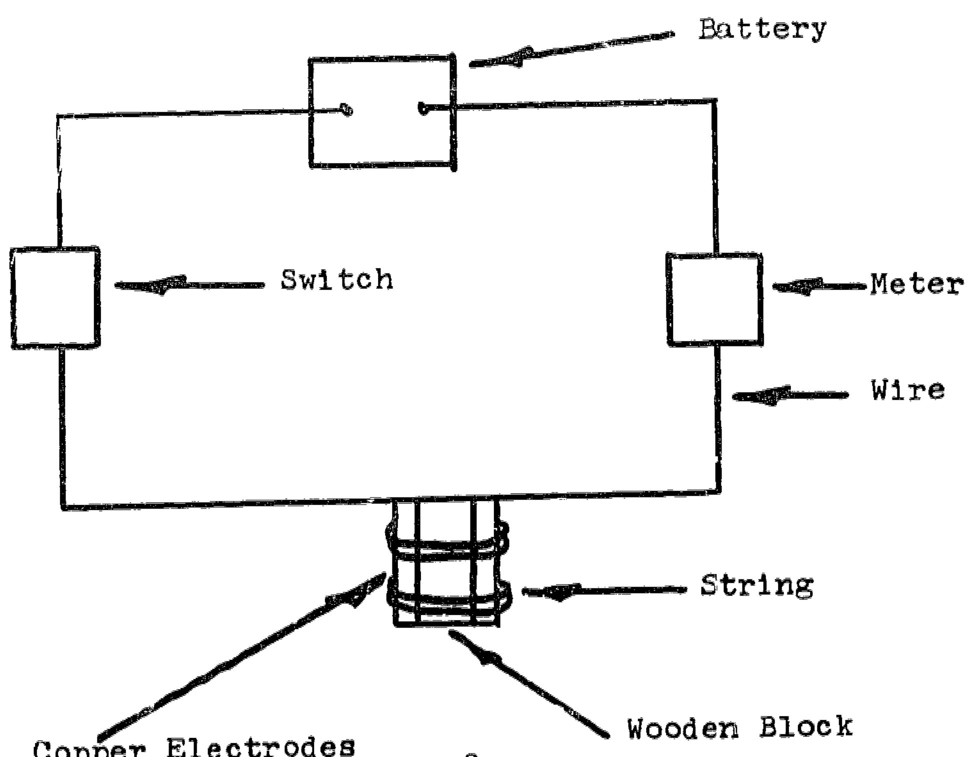
It is hoped that this list of cautions, while not intended to be exhaustive, will produce a more meaningful unit for the student.

Introduction

Measuring the salinity of a body of water can be an interesting, enjoyable and fairly inexpensinve task. One problem must be overcome. If you were to build your own salinity or conductivity meter, it would probably need to be calibrated. How might this be accomplished?

In this unit, the student is presented with a simple conductivity meter. The meter is constructed, using a few pieces of wire, a battery, a milliammeter, a switch, two pieces of string, a piece of wood and two copper electrode. His task is to calibrate the meter so that it can be used for measuring the salinities of the worlds oceans, as well as the wide range of salinities found in tide pools.

The construction of the meter is pictured graphically as follows;



Objectives

1. To introduce the student to a functioning conductivity meter.
2. To introduce the student to methods of calibrating a salinity or conductivity meter.
3. To introduce the student to methods of comparing salinity and conductivity.
4. To provide the student with sample situations by which he can gain experience measuring salinity.

Goals

Upon completion of this unit, the student will be able to:

1. Calibrate a simple conductivity meter.
2. Make charts which will allow rapid conversion of current flow to salinity in parts per thousand (o/oo).
3. Use a simple, inexpensive conductivity meter in real situations.

Materials

1. One 6V battery.
2. One DC milliammeter 0-1 amp range.
3. One 1.5V battery.
4. One on/off toggle switch.

5. Two pieces of string.

6. One piece of wood, 1cm x 1cm x 10cm.

7. Two copper electrodes, 1cm x 10cm (other materials may be used, e.g. stainless steel).

8. Several lengths of number 12, 14, of 16 wire with alligator clips on each end.

10. A straight edge, preferably calibrated in cm.

11. A quantity of table salt or a quantity of sea water. Sea water may be prepared with salt compounds obtained from a biological supply house. The mixture one obtains will be identical to that of regular sea water and will support marine life.

12. Several 500ml beakers; other containers may be used.

13. Several 250ml beakers; other containers may be used.

Procedure

In this unit we are concerned with calibrating our instrument. This task shall be accomplished by relating salt water conductivity to salinity in parts per thousand (o/oo).

Current flow is related to resistance in the following formula, $E = IR$ where $E$ = voltage, $I$ = current flow and $R$ = resistance. It follows that $I = E/R$, thus current flow is directly proportional to voltage and inversely proportional to resistance. If voltage is held constant, as it is with the conductivity meter (6V), current flow becomes a function of resistance. Looking at this concept from another perspective, the conductivity of a material is a function of its' resistance.

Saline water has the ability to conduct current flow. This will become rapidly evident if you momentarily dip the probe into a beaker of salt water. Since the voltage is held constant, the milliammeter reading is dependent upon the salinity of the water.

The salinity of the worlds oceans ranges from about 17 o/oo in the dilute northern areas to as much as 300 o/oo in areas such as the Red Sea. There are, of course, a multitude of variations, depending upon the area one finds himself measuring. Much of the local variation is determined by rainfall, river runoff and evaporation. However, the salinity of the standard ocean, by convention, is accepted to be 35 o/oo.

When the conductivity meter is finally calibrated, it must be useful in local areas. This may be accomplished by using a method of calibration which will provide useful readings over a wide range of salinities.

1. Have the student mix two salt solutions. Each solution should be made using 400ml of fresh or distilled water. In 400ml volume, dissolve 5g NaCl and in the other, dissolve 2.5g.
2. The student should now build the meter as shown in the previous diagram.

3. Immerse the probe (review the precautions in the preface) in each beaker momentarily, close the switch and record the readings.
4. Compute the resistance of the water for the different salt contents, using the formula $E = IR$.

At this point the student has investigated and is aware of the conductivity-salt relationship. If a sample of sea water of known salinity is available, it may be used. If not, it is necessary to mix a solution which can be used as a standard. Since salinity is measured in parts per thousand, we realize that for every so many parts of sea water there is a part of salt. The standard ocean is 35 o/oo. It follows that if we desire to mix a solution of 35 o/oo, 35g NaCl must be added to every 1000g of distilled water. Should a 300 o/oo solution be desired, 300g NaCl must be dissolved in 1000g of water.

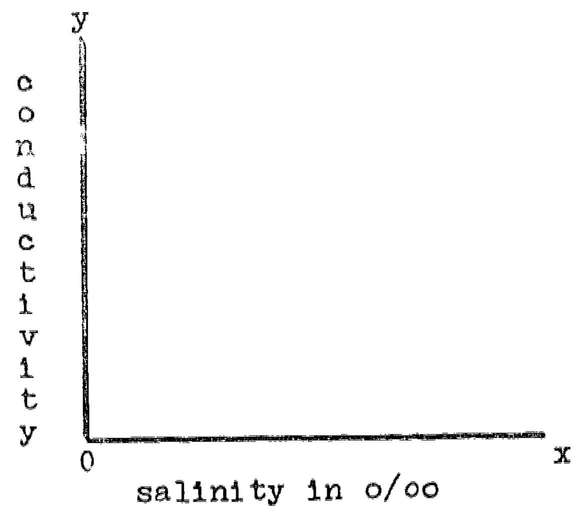
5. The class should mix several different solutions; for example, 42 o/oo, 40 o/oo, 35 o/oo, 22 o/oo, 18 o/oo.
6. Using the salinity meter, measure the conductivity of each solution and record the data. The following scheme works well.

| salinity in o/oo | 42 | 40 | 35 | 22 | 18 |
|---|---|---|---|---|---|
| conductivity in milliamps | ? | ? | ? | ? | ? |

7. An alternative method is to mix one solution of high salinity, say 70 o/oo, and take a current reading. Caution should be observed here. Your meter may not have a sufficient range to handle the current flow which is produced. If this is the case, the meter will peg and be internally damaged. There are two possibilities which you may use. You may use a meter of greater current measuring capacity or you may decrease the size of your battery to say 1.5V. Following the first measurement, the solution can be diluted and a second reading taken. This procedure can be followed for several measurements. The student following this course gains some experience in dilution. Once a series of readings have been obtained they somehow be stored for future use.

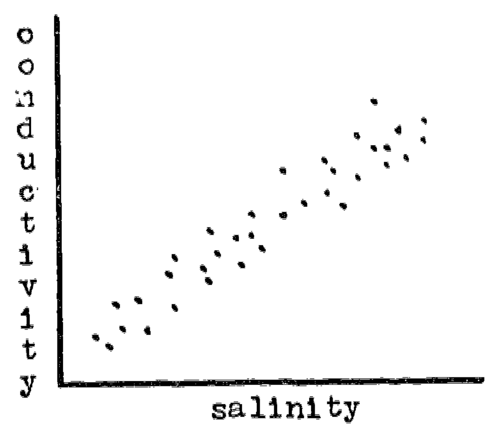
8. Have the student investigate the following method.
   A. The student makes a chart or extends the chart he started in step #6, as he takes many more readings. Once this task is complete, baseline data will be available for future reference. This method is cumbersome; perhaps the student will notice this.

9. Have the student plot his data on a Cartesian coordinate system (x and y coordinates).

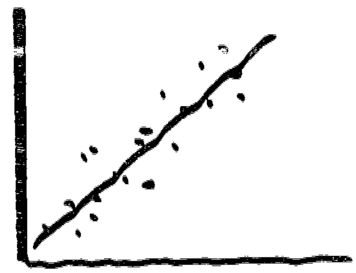



Remember that since conductivity is dependent upon salinity, its' values are plotted along the "y" axis. The student should use the values obtained in step #6 to complete this step. The question now is how can plotting data in this manner be useful at a later date?

A plot of many readings will probably look something like this.



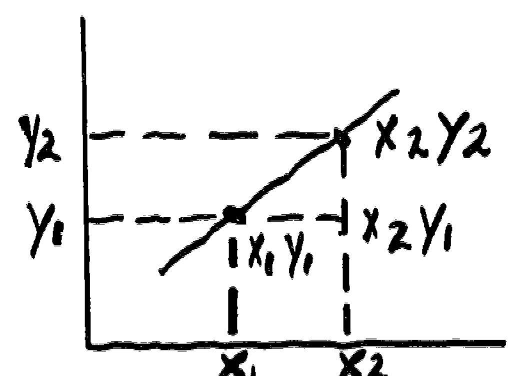

There is a definite relationship here which can be better identified by drawing a best fit line through the center of the data plot.



This line has the formula, $y = mx + b$, where $b$ = the "y" intercept or that point on the "y" axis where the best fit line crosses it. The slope = $m$ = rise/run, $x$ = a value along the "x" axis and $y$ = a value along the "y" axis. The slope or value of "m" is the amount of rise there is for each unit of run.

10. Have the student examine his best fit line. Does it pass through more than one data point? The answer is probably yes.

11. The student should label the point which it goes through closest to the "y" axis, $x_1$ and the second point $x_2$. These points can also be labeled $y_1$ and $y_2$ respectively.




$(x_2 - x_1)$ = run and $(y_2 - y_1)$ = the rise. It follows that:

$$m = (y_2 - y_1)/(x_2 - x_1) = \text{rise/run}$$

12. Have the student extend the best fit line so that it intercepts the "y" axis. This point is labeled "b" in the formula. The student now has sufficient information to substitute in the equation, $y = mx + b$ and arrive at a formula which identifies the true relationship between salinity and conductivity.

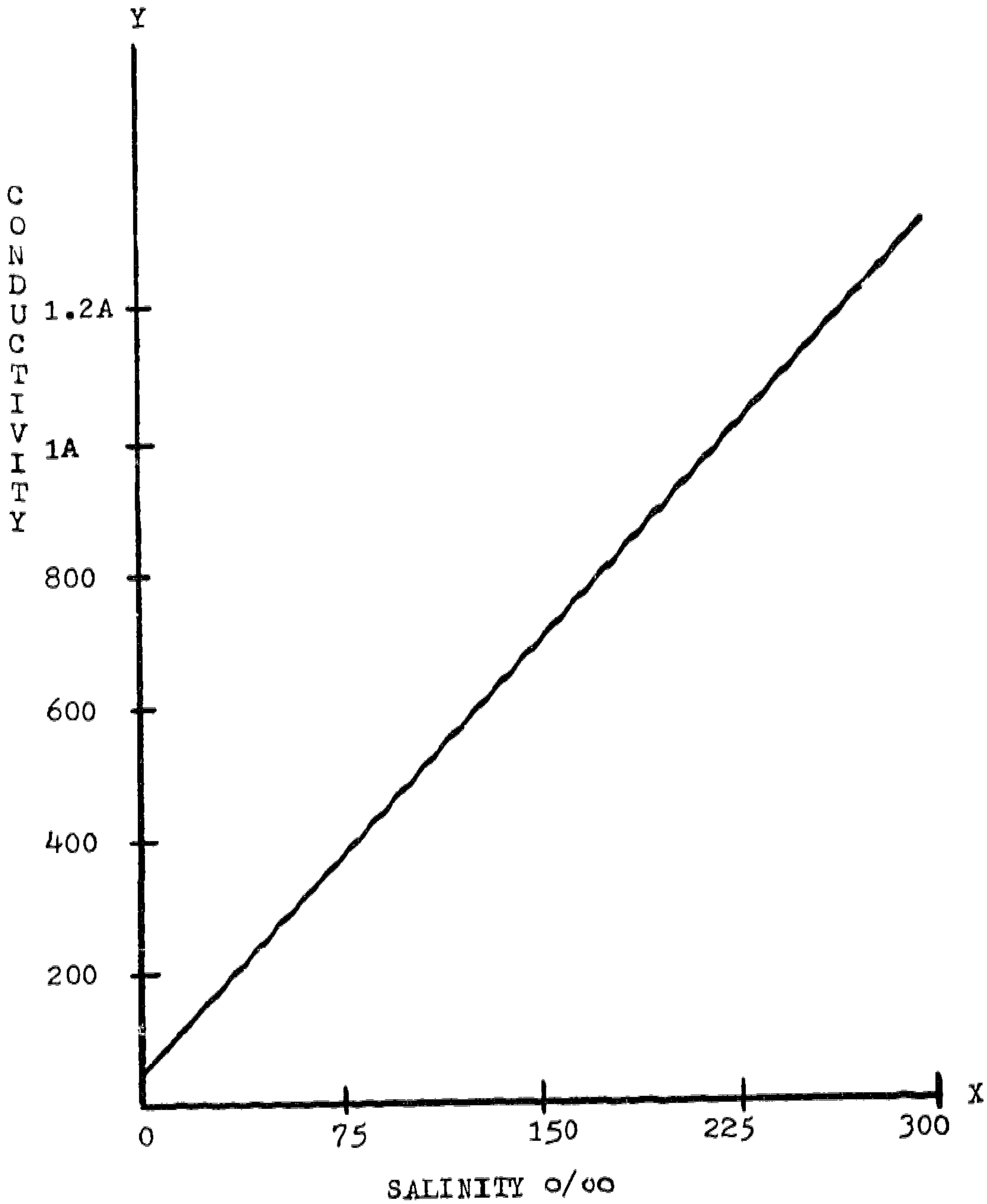
13. The student should make the necessary substitutions. At this point an enterprising student might conclude that in order to obtain the slope, only two points are needed. He might also mention that once a point is ploted (an ordered pair known) and the slope known, the "y" intercept may be arrived at mathematically; the best fit line need not be extended through the "y" axis. If not mentioned, these facts should be pointed out.

14. Have the student make a graph whose "x" axis is divided in a linear manner from 0 to 300 o/oo. This should be accomplished using graph paper.

15. Using the information, which he has previously obtained, each student should plot and should draw a best fit line. The line should begin at the "y" axis and extend to at least 300 o/oo on the "x" axis.

16. The student graduates the "y" axis in a manner consistent with his data. This will be a linear graduation. The product should be similar to the one shown below.

Salinity vs. Conductivity



17. The instructor should make up 10 or more solutions for which only he knows the salinity.

18. The students are now asked to determine the salinity of the unknowns, using only the meter which they have built and their graph.

19. The instructor conducts a group discussion. During the discussion, the group should be led toward the areas which have been investigated in the unit.

Evaluation

1. Using a simple conductivity meter, which incorporates a 1.5V battery as a voltage source, make the following graphs:
   A. A plot of the resistance between the plates vs. salinity.
   B. A plot of current flow vs. salinity.
2. Write a mathematical equation for each relationship listed in question #1.
3. Determine the salinities of several mystery solutions (provided by the instructor).

Suggestions for Further Study

1. Investigate how your meter functions in a real situation.
2. Study the available chemistry books and ascertain what takes place when the probe is inserted in the saline solution and the switch closed.

3. What other materials might be used in place of the copper electrodes? Investigate several materials.

   A. Which materials are better?

   B. Why are some materials better than others?

4. What is the buildup which occurs on the copper plates after the system is energized?

Vocabulary

1. Amp--A unit measure of current flow.
2. Calibrate--To adjust according to some predetermined scheme.
3. Cartesian coordinates--An x, y coordinate system which is named after the mathematician, Decartes.
5. Resistance--The quality of a material which determines the amount of current which can pass through that material.
6. River runoff--Discharge of river water into the ocean.
7. Salinity--The amount of salt contained per unit volume of water.
8. Slope--Rise/run.
9. Voltage--The force which causes current to flow.