Global Experiment for the International Year of Chemistry

Salty Waters

This document contains a description for the **Salty Waters Activity** that is part of the Global Experiment being conducted during the International Year of Chemistry, 2011.

Almost all of the water on Earth is in the form of a solution containing dissolved salts. In this activity students are invited to measure the salinity of a sample of salt water. While carrying out the analysis they will learn about the nature of solutions, including the composition of sea water. The results of their analysis will be reported to the Global Experiment Database to contribute to a global survey of salinity.

The activity can be completed as part of the set of four activities that make up the Global Experiment, or it can be completed as an individual activity to allow students to participate in the International Year of Chemistry.

Contents

Submitting Results to the Global Database

The following information should be submitted to the database. If the details of the school and location have already been submitted in association with one of the other activities, these results should be linked to previous submission.

Date sampled: ___________________________

Nature of the water: ___________________________ (sea, estuary, bore, lake etc.)

Salinity of the water: ___________________________ (g/kg)

Location sampled ___________________________ (describe the location)

Number of students involved ______________

School/class registration number ______________

Investigating Salty Waters

Water has a special place in all our lives! There is lots of it (it covers about 70% of the Earth) and more than half of your weight is water. The focus for this activity is a property of water that makes it vitally important, namely the ability to dissolve a wide range of substances. Many substances, such as sugar or salt apparently disappear when they dissolve in water, but appearances are deceptive and the sugar and salt can be recovered from solution by evaporating the water.

This activity makes use of this property to measure the amount of salt in some natural waters. Chemists measure the amounts of many of the substances that are present in water samples and we use the information to both understand how the world works and to keep us safe and healthy.

Method – Measuring Salinity by Mass

1. Collect a sample, (at least 100 mL) of seawater or other water with a significant salt content.
   (If appropriate, this can be the same sample as used for the pH of the Planet activity.)
2. Weigh the dish as accurately as possible and record the result on the Results Sheet, m_D.
3. Measure the volume of about 100 mL of water as precisely as possible and place it in the dish, V_W
4. Weight the dish and water together, m_{D+W}.

Equipment

- Shallow glass or plastic dish or Petri dish (preferably clear to make it easy to see the salt).
- Cover for the dish that allows air circulation.
- Graduated measuring cylinder or jug.
- Balance that can weigh to 0.1 g with the capacity to weigh the dish and water (see method).

Evaporate the water by one of two methods:

5. EITHER - **Solar evaporation**: place the dish in full sunlight and, if necessary to prevent dust, cover it with a transparent cover that allows the air to circulate. It may take a day or more to evaporate so monitor it periodically.
6. OR – **Hotplate evaporation**: Heat a hotplate to about 80^{o}C and place the dish on it. Monitor the process periodically, making sure the water does not boil and splatter

Dryness check – carry out this check to ensure the sample is dry. This process is called drying to constant weight.

7. Weigh the dish with the salt and record the result on the Results Sheet.
8. Return the dish to the sunlight, or the hotplate, and leave it for 15-30 minutes.

9. Allow it to cool and reweigh it, recording the result.
10. If the second weight is less than the first, repeat the process once more and record the results.
11. Continue the process until the weight does not change.
12. The final weight is the mass of the dish and salt, m_{D+S}.

Calculating salinity

13. First calculate the amount of salt by taking the final mass of the dish with the salt and subtracting the initial mass of the dish using the formula:

mass of salt $$m_S = m_{D+S} + m_D \quad \text{(g)}$$

14. Now calculate the mass of saltwater in the experiment:

mass of saltwater $$m_{SW} = m_{D+SW} - m_D \quad \text{(g)}$$

15. Finally calculate the salinity using the formula for the salinity:

absolute salinity $$S = \frac{m_S}{m_{SW}} \times 1000 \quad \text{(g/kg)}$$

This is the value that you should give to your teacher to contribute to the class average which will be entered in the Global Database!

Optional Activity – Measuring the salinity of other samples

If other samples of water are available for testing, repeat the salinity measurement procedure for one of the other samples.

Optional Activity – Measuring the salinity using a conductivity meter

If a conductivity meter is available it can be used to provide a complementary measurement of the salinity. Check with your teacher.

Results Worksheet

Record the results of your salinity analysis in the following table and then answer the questions below:

			Saltwater sample	Other sample (optional)
Mass of dish	m_D	(g)		
Volume of saltwater	V_{SW}	(mL)		
Mass of dish and water sample	m_{D+SW}	(g)		
Drying to constant weight				
Mass of dish and salts – 1st test		(g)		
Mass of dish and salts – 2nd test		(g)		
Mass of dish and salts – 3rd test		(g)		
Final mass of dish + salts	m_{D+S}	(g)		
Calculations				
Mass of salt	$m_S = m_{D+S} - m_D$	(g)		
Mass of saltwater	$m_{SW} = m_{D+SW} - m_D$	(g)		
Absolute salinity	$S = \frac{m_S}{m_{SW}} \times 1000$	(g/kg)		
Density	$\sigma = \frac{m_{SW}}{V_{SW}}$	(g/mL)		
Optional - Conductivity Test				
Salinity from conductivity		(psu)		

Question 1

Examine the dish containing the salt and see if you can see signs of crystals. Crystals glint in the light because they have flat faces that reflect light when they are big enough. You can often see the crystals better with a hand lens of simple microscope.

Describe the appearance of the salt in your dish.

Question 2

Compare the value of the salinity of your sample with the class average. Can you explain any factors that may have contributed to the difference in values?

Question 3

If you have been studying a seawater sample, compare your class average value to the common value for seawater of 3.5% salt by weight. Identify any possible reasons why the class value might differ from the average.

(If you have been investigating a different type of water, look up common values and comment of the relationship to your measurement.)

Question 4

When you swim in salt water how can you tell that it is more dense than pure water which is slightly less than 1 g/mL at 20^oC.

Class Results Sheet

Record students' average absolute salinity values for the saltwater sample being tested for the Global Experiment (and other water samples if appropriate - see teacher notes). Record the ancillary data ready for submission to the Global Experiment Database.

		(Optional) Other samples tested by class				
Group	**Saltwater sample**	A	B	C	D	E
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
Average						

- Location of water sampling: ___________________________
- Nature of water: ___________________________
- Date sampled: ___________________________
- Temperature: ___________________________
- Number of students involved: ___________________________

Teacher's Notes

Instructions for the Activity

The following notes have been written to assist teachers implement the Salty Waters activity with their classes. It is hoped that the activity will be used together with the other Global Experiment activities and in conjunction with local resources that help students understand water, its chemistry and its vital role in our lives and its importance on Earth. But the activity will be equally useful if carried out on it own to provide students with the experience of collaborating with their colleagues around the world.

In the activity students are invited to explore the nature of solutions and focus on dissolved substances, the solutes. In both this activity and the Solar Still Challenge, they use the process of evaporation to separate components of the solution. In this case, wherever possible, they will use marine or other naturally salty waters and will measure the amount of salt in the water, its salinity.

Learning Outcomes

During the activity students will:

- Explore the properties of water solutions containing salts.
- Use the process of evaporation to extract the salts from solution.
- Measure the concentration of salts in a water sample and use the a class average to estimate the quality of the measurement.
- (Optional) Explore other methods of measuring salinity and the process of crystalisation.

Planning the Activity

A strategy using students working in pairs is often a successful way of carrying out this type of activity as it halves the amount of equipment required while students support each other. The activity can be carried out in a single 1-2 hour period if the a source of heating such as a hotplate is used, or, if the water is allowed to evaporate in the sun, it is best completed on over two days.

When selecting the dishes for the evaporation, dishes with a large diameter will allow the water to evaporate quickest. 15 cm diameter Petri dishes work well as do plates with a comparable diameter. Check that the weight of a dish plus water can be measured successfully on the balance. The greater the mass of water used, the more precise the measurement will be, but also the longer the evaporation time.

Carrying out the Activity

The activity has been designed in three parts:

- Initially students set up the experiment, measuring the mass of the dish they are using, the volume of the salty water they are adding and the combined mass of the water and the dish. Students can increase the precision of their measurements if they measure each value several times and practice the transfer processes to minimise losses.

- The length of time required for the evaporation part of the activity depends critically on the local conditions. Pre-testing the length of time required for the equipment that students will use will ensure the experiment goes smoothly.

  One of the biggest sources of error in the measurement occurs if the sample is not completely dry, even when it appears dry. For this reason the standard analytical method of drying to constant weight is recommended. Carrying out this procedure is useful to students appreciate the care needed to get good results. However, younger students particularly may be confused by the procedure and it can be avoided if the time to get to get the sample completely dry is pre-tested.

- The third part involves carrying out the calculation. The method described has been written for upper primary and lower secondary school students and should be adapted for use by other groups. Normally repetition of measurements would be recommended to check the quality of the results, but in this case the length of time for the measurement would make this arduous and the repetition is achieved through the averaging of all the individual results in the class. At the same time this means that all students contribute to the result that is posted to the Global Experiment Database.

Water Samples

Seawater samples are particularly good for this activity because the amount of salt in seawater is readily measurable, usually around 3.5% which means that students using 100 mL water samples are measuring masses of salt between 3 and 4 g. Samples collected from the sea, or from estuaries will work well.

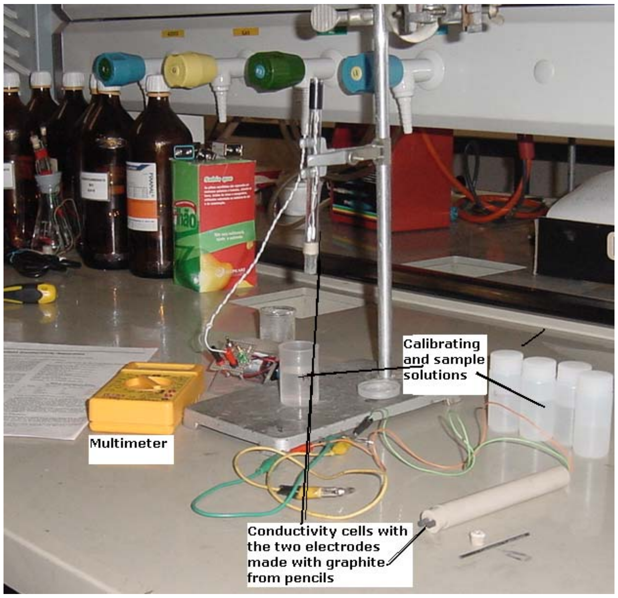
Samples from sources that are usually regarded as fresh water and likely to have much smaller salt contents. In these cases it may be appropriate to make up a “synthetic” seawater with 35 g of table salt (sodium chloride) per litre of water. Students can then test the method on the synthetic seawater before they attempt to measure their local water source.

Filtration: In the case of waters with visible suspended matter, filtration is recommended before evaporation

Optional Activities

Other Water Samples

Students can explore the salinity of other water samples to get an understanding of how much salinity changes in different common liquids such as the normal saline solutions used in medicine. Students can be invited to bring samples of everyday solutions to test in which case students can each test different samples so that the class gets the results for a range of solutions to discuss. (However care has to be taken to check whether the samples contain significant amounts of dissolves substances that are not salts.)



Measuring the Salinity using a Electrical Conductivity Meter

If your school has conductivity meters students can get a second source of salinity data to compare with the evaporation experiment.

Simple qualitative conductivity meters can be readily made from general laboratory equipment to demonstrate that salt solutions conduct electricity and that the current is proportional to the salt concentration.

Calibration has to be performed with seawater of known salinity or an equivalent potassium chloride solution. The assessed value is thus relative and salinity is expressed in dimensionless Practical Salinity Units, PSU.

Levels of Explanation

Primary School

In primary schools the activity provides an excellent opportunity for students to use simple equipment and develop useful skills of recording observations. The calculations need to be presented in an appropriate way to suit the class.

The topic of water quality and availability is one of the important chemical ideas that should be firmly embedded in students' experiences of drinking water and waterborne diseases.

The activity helps students learn that clear water may contain various substances, useful or harmful, in different concentrations, and that appropriate means can be used for their separation.

The activity also gives students the opportunity to learn about changes of states that occur in Nature and identify processes such as evaporation and crystallisation. The activity is also an opportunity to create awareness to the mineral resources that may be obtained from aquatic systems.

Junior High School

In addition to the learning outcomes mentioned for primary schools, students can utilize they developing knowledge of algebra in the calculations and explore the proportionality involving volume and mass in the determination of concentrations and densities..

The topic of the units, namely SI, for expressing the various quantities can appropriately be discussed here.

The concepts of soluble and insoluble substances, solutions and solubility should be examined. The process of crystal formation should be discusse. This can be extended to redisolution followed by recrystallization as an optional activity associated with crystal growing.

A more detailed discussion of changes of state can be held, involving particle theory and the concepts of heat, temperature and vapour pressure.

Senior High School

The quantitative approach brings the opportunity for students to explore the significant figures associated with the values of the measured and calculated quantities.

The activity can be expanded to the chemical identification of some of the species in solution, namely sodium chloride, by writing simple chemical reactions.

It is appropriate to introduce the concepts of amount of substance, concentration and stoichiometric coefficients and to practice writing chemical formulae and chemical equations.

The use of electrical conductivity meters is particularly recommended to illustrate different possible approaches to acquiring quantitative data.

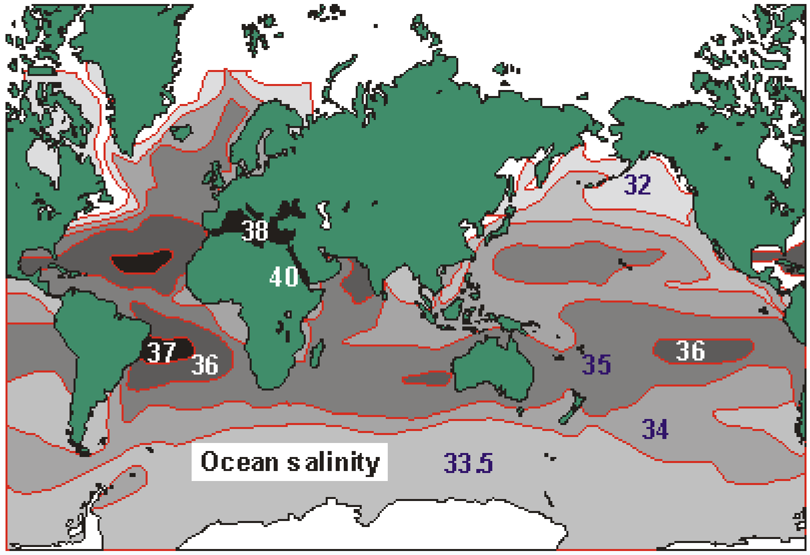
Background Information

The ocean is naturally saline at approximately 3.5% salt. **Salinity** is a measure of the dissolved salts in water, i.e. the amount of salts (in grams) dissolved in 1000 grams (1 kilogram). This is the **absolute salinity, S** (g/kg) of seawater. The symbol ‰ is also used meaning parts per thousand.

The composition of seawater is quite complex and a range of salts exist in significant amounts. All salts are made up of ions such as the sodium and chloride ions in sodium chloride. In water all the ions separate and so the ions exist independently in seawater (Table One).

Table 1 Typical Concentrations of Ions in Seawater

Ion	g/kg
Chloride Cl^{-1}	19.345
Sodium Na^{+1}	10.752
Sulfate SO_4^{-2}	2.701
Magnesium Mg^{+2}	1.295
Calcium Ca^{+2}	0.416
Potassium K^{+1}	0.390
Bicarbonate HCO_3^{-1}	0.145
Bromide Br^{-1}	0.066
Borate BO_3^{-3}	0.027
Strontium Sr^{+2}	0.013
Fluoride F^{-1}	0.001



Methods for measuring salinity

The first method recommended for measuring salinity was the chemical, Knudsen-Mohr, method based on the volumetric analysis of chloride, Cl^- , bromide, Br^- and iodide, I^-. The method involves the precipitation of the ions with silver nitrate, $AgNO_3$ (aq). The mass of the precipitate can then be measured and the concentration of chloride ion calculated.

The first empirical equation converting this measure of chlorinity (Cl ‰) to absolute salinity, S ‰, dates from 1902: S= 0,03 + 1,805 (Cl). For zero chlorinity, the salinity would not be zero, which goes against the Principle of Constant Proportions. To overcome this contradiction, in 1969 UNESCO proposed a new relation: S = 1,80655 (Cl). A salinity of 35 ‰ corresponds to a chlorinity of 19,374 ‰.

The electrical conductivity of water can also be taken as a measure of its ionic composition and, hence of its salinity. The instrumental method is based on the comparison of the conductivities of the water sample and conductivity standards, assuming proportionality between conductivity and salinity. Potassium chloride solutions, KCl (aq), are used as conductivity standards.

In 1978, oceanographers redefined salinity in **Practical Salinity Units** (**psu**) in which the conductivity ratio of a sea water sample to a standard KCl solution is measured. Ratios have no units, so 35, is equivalent to 35 ‰. Standard saline waters of known conductivity have been developed to work as standards in the calibration of salinometers which are specially designed conductivity meters used to assess the salinity of seawater.

Assessment of high quality salinity values has become of particular relevance and is of worldwide concern, due to the main role that salinity takes, in the context of current environmental problems associated with global climate change.

Sample Results - Results Worksheet

Record the results of your salinity analysis in the following table and then answer the questions below:

			Saltwater sample	*Normal saline*
Mass of dish	m_D	(g)	*73.2*	*74.5*
Volume of saltwater	V_{SW}	(mL)	*102*	*97*
Mass of dish and water sample	m_{D+SW}	(g)	*178.5*	*172.1*
Drying to constant weight				
Mass of dish and salts – 1st test		(g)	*78.5*	*75.7*
Mass of dish and salts – 2nd test		(g)	*77.0*	*75.7*
Mass of dish and salts – 3rd test		(g)	*77.0*	
Final mass of dish + salts	m_{D+S}	(g)	*77.0*	*75.7*
Calculations				
Mass of salt	$m_S = m_{D+S} - m_D$	(g)	*3.8*	*1.2*
Mass of saltwater	$m_{SW} = m_{D+SW} - m_D$	(g)	*105.3*	*97.6*
Absolute salinity	$S = \frac{m_S}{m_{SW}} \times 1000$	(g/kg)	*36*	*12*
Density	$\sigma = \frac{m_{SW}}{V_{SW}}$	(g/mL)	*1.03*	*1.01*
Optional - Conductivity Test				
Salinity from conductivity		(psu)		

Question 1

Examine the dish containing the salt and see if you can see signs of crystals. Crystals glint in the light because they have flat faces that reflect light when they are big enough. You can often see the crystals better with a hand lens of simple microscope.

Describe the appearance of the salt in your dish.

Most of the material in the dish was powdery and slightly brown coloured. Some of the material in the middle of the dish had bigger bits that glittered when we shone a torch at them.

Question 2

Compare the value of the salinity of your sample with the class average. Can you explain any factors that may have contributed to the difference in values?

The class average for the saltwater sample 36.7 g/kg which was slightly higher than our value. But a lot of other groups got numbers that were not as close.

Question 3

If you have been studying a seawater sample, compare your class average value to the common value for seawater of 3.5% salt by weight. Identify any possible reasons why the class value might differ from the average.

(If you have been investigating a different type of water, look up common values and comment of the relationship to your measurement.)

Our class value showed that the salinity was very close to the normal value seawater. The slightly high value might be because the sample was taken in a shallow area where the water was very warm so more water may have evaporated.

Question 4

When you swim in salt water can you tell that it is more dense than pure water. (which is slightly less than 1 g/mL at 20^{o}C).

Yes because it is easier to float in the sea than in fresh water.