Global Experiment for the International Year of Chemistry

Solar Still Challenge

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

In this activity students will make a solar still and measure its efficiency. They will develop their understanding of water in liquid and gaseous states and how distillation can be used to purify water. They will be challenged to design and make a more efficient still. A diagram and photograph of the most efficient solar still made in their class will be reported to the Global Experiment Database together with the efficiency data.

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 water: ____________________________ (tap, river sea, etc.)

File Name of diagram: ____________________________

File Name of Photograph: ____________________________

Efficiency of the still: ____________________________

Number of students involved ______________

School/class registration number ______________

The Global Experiment activities have been designed by the Global Chemistry Experiment Team of the International Year of Chemistry.

Solar Still Challenge

The Challenge

In this activity you will build a solar still and find out how it can purify water. You will be challenged to use your knowledge to build a more efficient solar still.

Water covers most of the Earth (about 70%), but almost all of it is in the oceans and is salty. Much of the water on land or in the ground is also salty or otherwise unsuitable for human use. The challenge of finding ways to purify water is increasing with human population.

The solar still is a device that that uses solar energy to purify water. Different versions of a still are used to desalinate seawater, in desert survival kits and for home water purification.

(*An alternative method for Part A for classes with access to laboratory equipment is included at the end of the document*.)

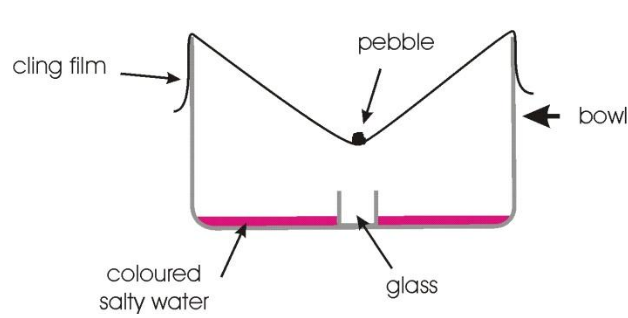
Method - Part A – Building a Solar Still

1. Add a measured volume of hot water (about 1 cm) to the bowl.
2. Add some food colouring and about a teaspoonful of salt to the water in the bowl.
3. Take all the equipment out to a sunny, level place.
4. Place the glass or cup in the middle of the bowl making sure no water splashes into it.
5. Cover the bowl loosely with cling film, sealing the film to the rim of the bowl. (Use tape or string if necessary.)
6. Place the stone in the middle of the film above the cup.
7. Leave the still for at least an hour (the longer the better) and then check that there is some water in the cup.
8. Take the still back indoors, remove the cling film and take out the cup without splashing any water into or out of the cup.
9. Measure the amount of water in the cup.
10. Observe the colour of the water in the cup and test it for salt.

Equipment

- Large metal or plastic bowl
- Small, shallow glass or cup (clean)
- Measuring jug or cylinder
- Cling film (wider than the bowl)
- Small stone (pebble)
- Hot water
- Food dye and salt

The Solar Still



11. Calculate the percentage of the water that was purified:

$$\%\ \text{water purified} = \frac{\text{volume collected}}{\text{volume added to still}} \times 100$$

12. Look at your results and see if you can explain what happened to the water. Why is it called "purified water"? Write your suggestions on the Results Sheet under Question One.

Part B – The Design Challenge

Your challenge is to modify or make a more efficient solar still than the one that you made in Part A.

13. Write down some ideas about how you might improve the still. For example you might try using different coloured containers to find out which absorbs the sunlight most efficiently.
14. Discuss your ideas with your teacher and get his/her permission to carry out the experiment.
15. Carry out the experiment recording the volume of water you start with and the volume you purify.
16. Calculate the % water purified and record it on the Results Table.
17. If you have time, you can develop your design further. Make sure you get permission from your teacher for each experiment you carry out.
18. Draw a diagram of your most efficient still showing why it is more efficient than your first still. Take a photo of your still if you can.
19. Complete the other questions on the Results Sheet.
20. Hand in your results to your teacher so that the most efficient still can be selected and uploaded to the Global Experiment Database.

Student Results Sheet

Record your results and calculate the percentage of the water purified.

Trial	Volume of water added (mL)	Volume collected (mL)	% water purified
Part A – First still			
Part B –			

Part A

1. Explain in your own words how the still works.

2. Write down one way in which you could make your still work better.

Part B

3. Explain the design for a still that will work more efficiently than the still you made in Part A and then discuss your ideas with your teacher.

4. (After you have finished testing your new still.)
   Draw a diagram to show how your new still works.

5. Paste a photograph of your new still here:

Teacher's Notes

Instructions for the Activity

Two different approaches to the activity are presented in this document. The first is appropriate for all students, uses household items for making the still and is simple to make and use. The second is appropriate for more advanced students who have access to laboratory glassware and resources.

Solar Still Challenge

The activity is most successful if students work in pairs but can be carried out individually.

First, in **Part A**, students make a simple still and use it to purify some water. They are invited to develop their explanation for how the still works.

- A class discussion should used to conclude Part A and to check that students have a scientific explanation for the way the still works (see below).

Then, in **Part B** students are challenged to improve the yield of purified water by modifying the stiill or the way it is used.

Safety

There is very little hazard involved in carrying out the activity. Standard laboratory safety rules suggest that students should not taste or smell the products of activities and so students should be advised not to use taste as a test for salt in the purified water.

- Student proposals should be checked that they are safe and students should be guided to help them develop designs that utilize their understanding of the ways the still works.

After they have carried out their experiments they draw a diagram explaining how their new design has improved the % water purified which is a measure of the efficiency of the still. If possible they should include a photograph of their improved solar still.

- At the completion of the activity collect the work from all the groups that have completed the challenge and select the winning entry for the challenge. If appropriate this can be made into a culminating event for the **Global Experiment** and the class can be involved in the selection.

The diagram (and an accompanying photograph) of the still producing the highest yield in the class should be submitted to the Global Experiment Database.

Learning Outcomes

During the activity students will:

- Learn about the liquid and gaseous state of matter (water) and their inter-conversion (evaporation and condensation).
- Learn about the use of the process of distillation to purify water.
- Develop an appropriate level of scientific explanation for the distillation process.
- Use their knowledge about distillation to carry out a technology process improving the efficiency of a solar still.

Hints for making the solar still work well Part A:

- Carry out the activity on a cloudless day, preferably over the mid-day period.
- Using warm water at the start speeds up the process usefully unless it is a very hot day.
- Help students make sure their still is airtight to avoid water loss.
- The use of coloured salty water is a useful check that the still is operating correctly.
- If sunlight is not available, the activity can be conducted using a suitable container such as a large saucepan warmed gently on a hot plate. In this case the glass or cup should be insulated from the bottom of the saucepan.

Arranging the design challenge Part B:

This is an opportunity for students to use their ingenuity to improve the efficiency of the solar still. At the same time students learn about the relationship of technology to science. The technological process usually requires criteria on which the technological product can be judged.

In this case, the criterion for the design challenge should be clearly explained. The simple criterion of % water purified is a good start for primary school students but should be made more sophisticated for older students. For example the criteria might specify the time length of water collection.

An attractive range of factors can be explored by students including:

- The length of time.
- The type of container.
- The colour of the container.
- The amount of water.
- The shape of the still.
- The collection mechanism.

How the Still Works

Summary

As the water in the still warms, increasing amounts of water evaporate into the air. This water condenses on cool surfaces including the plastic film, turning back into a liquid. As the liquid condenses on the film it collects into droplets that run down the film to the pebble and then fall into the cup.

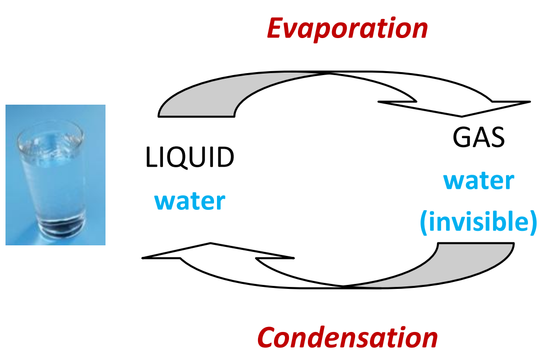
The purification works because both the salt and the food dyes do not evaporate.

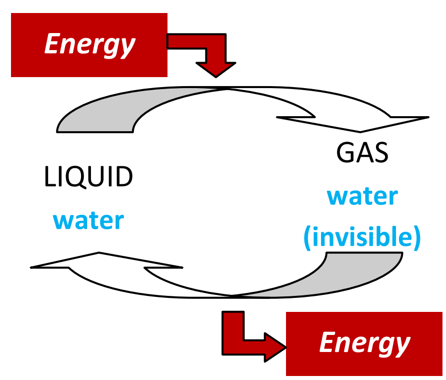
A deeper level of explanation is available if the students have been introduced to the particle nature of matter and the concept of energy:

The sunlight entering the still is absorbed by the water and the container. The result is that the molecules and ions absorb the energy. Some of the water molecules absorb enough energy to break free from the liquid water and become gaseous molecules flying about inside the container. Some of these flying molecules collide with the plastic film, lose energy to the film, and stick to the film. The water molecules lose more energy as they join together forming droplets of pure water which run down into the cup.

Background

While the activity is set in the context of water purification, students should become aware that the process is a general one for liquids and gases. It is a key to understanding a wide variety of everyday events ranging from why we feel cool when standing in the wind to how the household refrigerator works or how the world gets its fresh water from the water cycle.





A central idea to understanding the process involves the role of energy which is required for evaporation and released in condensation. In the case of feeling cool when the wind blows, we can understand the effect by realizing that the wind evaporated moisture from the skin and energy is absorbed from the body making us feel cold. In the case of the solar still, energy is required to evaporate the water in the still and in his case we harness the free light energy that comes from the Sun.

Understanding the process of evaporation and condensation allows students to analyse the design of the solar still and generate ideas about how it might be improved (for the Design Challenge). However it doesn't provide an understanding of how the water purification occurs.

The purification of water in the still occurs because some substances evaporate more easily than others. Salt and food dyes, for example, are almost impossible to evaporate and biological hazards in water such as bacteria and viruses also don't evaporate easily. (However other substances that are often added to water such as alcohol evaporate readily and much more carefully designed stills are needed to separate alcohol from water.)

The term volatility is used to describe ease of evaporation so that salt and food dyes are involatile while alcohol and water are much more volatile. The reason for these different behaviours can be readily understood if the substances are examined at the molecular level.

At the molecular level, salts are made up of ions and very large amounts of energy are needed to separate ions, making evaporation almost impossible. In the case of food dyes, the molecules are large and ionic and so are similarly involatile.

Water is less volatile than alcohol (ethanol), which appears surprising because water molecules are less massive than alcohol molecules. However water molecules stick together particularly strongly. Chemists call this interaction hydrogen bonding and it is responsible for many of the important properties of water. In the case of evaporation, because of the many hydrogen bonding interactions between water molecules more energy is requ

Addressing the Challenge

The challenge arises because the efficiency of the still is dependent on a number of variables. The length of time the still is in the sun is critical, and you may wish to make the length fixed at around 3 or 4 hours to make the final judgment of the most efficient still easier. Other factors are more subtle, but also important. For example, a design feature of most commercial stills is the separation of the evaporation stage and condensation stage so they take place in different parts of the still.

Sample Results - Student Results Sheet

(*Grade 7 student sample*)

Record your results and calculate the percentage of the water purified.

Trial	Volume of water added (mL)	Volume collected (mL)	% water purified
Part A – First still	*100*	*12*	*12*
Part B – *Second trial 1st still*	*50*	*16*	*32*
Third trial 1st still	*50*	*22*	*44*
Second still	*50*	*27*	*54*

Part A

1. Explain in your own words how the still works.

The still works by letting the Sun's rays warm the water. Some of the water goes into the air but you can't see it because it is gas not liquid. The water turns back into liquid when it touches the plastic and you can see the drops turn down to the pebble and fall into the cup.

2. Write down one way in which you could make your still work better.

We could make the still work better by starting with less water. It took a long time for the first drops to form because it was a bit cloudy and the Sun wasn't very hot. Smaller amounts of water will heat up quicker.

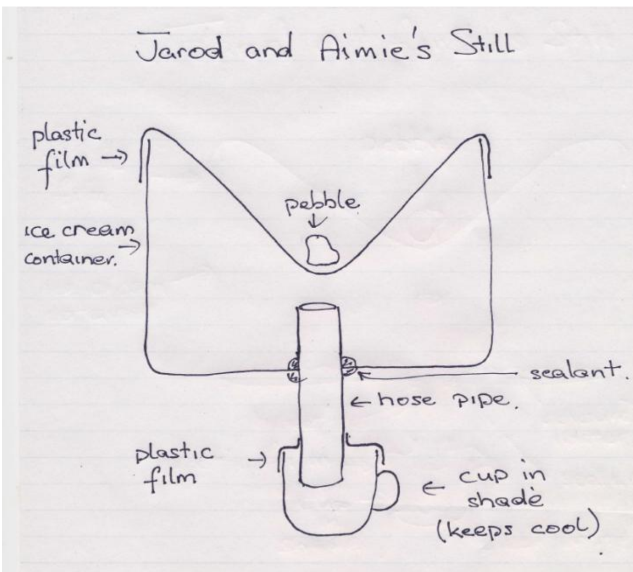
Part B

3. Explain the design for a still that will work more efficiently than the still you made in Part A and then discuss your ideas with your teacher.

First we tried to make the still more efficient by using less water so it heated up quicker and then we made sure that the water was warm before we started. Both changes made the still work more efficiently.

Then we cut a hole in the bottom of the container (an ice cream carton) and put a piece of hosepipe through the hole. We stopped it leaking with sealant, and then collected the water in a cup that was kept cool in the shade of the container. Then we were able to collect more than half of the water we started with.

4. (After you have finished testing your new still.)
   Draw a diagram to show how your new still works.



We used two chairs and put the still on them with the pipe between the chairs. We put the cup on a pile of books.

5. Paste a photograph of your new still here:

   (See below for an example of a still constructed using laboratory glassware.)

An Alternative Design for the Solar Still Using Laboratory Equipment

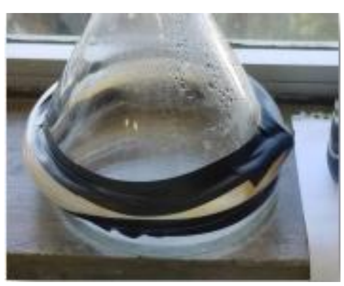
If access to laboratory equipment is available, there is scope for students to make a greater range of designs. For example, the following method describes a design that utilises a large funnel and a Petrie dish.

Method

- Take the glass funnel and close its outlet with the rubber stopper.
- Take the plastic tube and cut it along its 50 cm length.
- Fit the plastic tube around the funnel's edge.
- Add a measured volume of water to the Petrie dish (about 100 mL is suitable).
- Cover the Petri dish with the inverted funnel and seal with adhesive tape.
- Place the Petri dish on the black sheet.
- Place in sunlight until the level of water in the Petrie dish has changed significantly.
- Carefully remove the funnel and take out the tube where the evaporated water has condensed.
- Pour this desalinated water into a beaker or the graduated cylinder and measure the volume.
- Calculate the percentage of the water that was collected.

Equipment

- A large surface dish, e.g. Petri dish, Ø= 15 cm.
- A glass funnel, Ø= 15 cm.
- A rubber stopper to fit the funnel's outlet.
- A plastic tube, Ø= 2 cm, 50 cm long.
- A sheet of black plastic.
- Adhesive tape.
- A measuring cylinder for measuring the water volumes.


Notes

1. This method replaces **Part A - Building a Solar Still** described earlier.
2. This still can also be used for the investigation of salinity outlined in the **Salty Waters Activity**. The activities can either be carried out sequentially, or combined, in which case the **Salty Waters** method should be employed.