The International Space Station:
Where Is the Next Glass of Water Coming From?

Katherine M. Puno

INTRODUCTION

This curriculum unit serves a very important purpose in the kind of school in which I teach. As a chemistry teacher in both Advanced Placement (AP) Chemistry and pre-AP Chemistry at Booker T. Washington High School and the High School for Engineering Professions in the Houston Independent School District, I have a student population whose main interest is in the engineering sciences. They are highly analytical students who are good both in mathematics and sciences as well as the manipulative nature of laboratory work. I deal with students who love to design robots that work and move by remote control and computer program. They are highly skillful in making things work. Often in my laboratory experiments, I ask my AP students to make their own procedure given a certain objective and a set of materials. In this way, they will be able to answer their own question by making their own design. Often times, they end up making even more efficient ways of meeting the objecting than I could.

My students are aware of the different engineering courses that have been integrated to natural sciences. For instance, I have students who love to pursue bioengineering or biotechnology. Other than the usual engineering courses offered like mechanical engineering, chemical engineering, metallurgical engineering, other new engineering courses are available like petroleum engineering and now the marriage of engineering, cell biology, molecular biology, and space engineering. This has become a very welcoming advancement in science. Most of my students take AP Biology, AP Chemistry, and AP Physics for their electives. They know that without engineers working in this field, any natural science research will be impossible.

OBJECTIVES

My goal in developing this curriculum unit is to hone my students' skill in designing experiments related to space science. An overview of the life in the International Space Station is given in the introduction part. The students will focus on the utilization, recycling, and conservation of water in the ISS. The end point of this activity is for students to design an efficient way of recycling water in the ISS. They start with a schematic diagram considering the sources of water in space and the condition of microgravity.

When filtering water for drinking, NASA has its own set of standards to meet, set by the Advanced Life Support Program at Johnson Space Center. These standards are cleaner than what is in most people's drinking water at home. Currently, scientists are able to recover approximately 95% of water filtered. The main difference in the ways water is processed in space than on earth is in the amount of water being treated and concentration of contaminates. Water that is treated on earth in water treatment plants is a much larger volume and the contaminants are concentrated. In space, it is more difficult to remove some agents, such as ammonium. Also some processes have to be adapted for the microgravity environment.

It is indeed a challenge to future engineers to be involved in this kind of endeavor. Although most of them may be very much comfortable with the amount of water they use at home and without having to pay for the water bill just yet, they might not know the importance of conserving water. In this unit, the students will be doing four laboratory activities starting with a mimic of how astronauts use a limited amount of water in doing their daily chores in the space station. This will give the students a meaningful experience of conserving water. After that they will be tested on their skill of cleaning water in the simplest way. The third activity will allow them to perform distillation process. In the first three activities, the students will not be given a step-by-step written procedure. Instead they will make their own procedure, provided that they meet the given objective and they use the given materials (Water Filtration lab, Life Science Institute, Space Center Houston).

BACKGROUND

The possibility of life in space has always been a mystery to earth dwellers. Back when we were kids, life outside Earth has always been depicted in caricatures and in cartoon shows proving that imagination actually conceptualized such a possibility of life in space. Only science fiction and imagination led us to enrich the film industry, which I believe helped a lot in sustaining our curiosity about the outer space. I remember the story of Superman. Where did he come from? Where is planet Krypton? Then came Star Trek and Star Wars, and of course the funnier more ridiculous ones like the Jetsons, or even the Planet of the Apes, Mars Attacks, and Men in Black, to mention a few. The deeper, more thought-provoking one of course is the book, *The Little Prince* who came from a very small planet and had the fortune of visiting the earth.

Our idea of life outside Earth is of course the more fanciful one. We create different ugly forms of creatures from head to toes, which for me are really a big insult to whoever finds a habitat in other planets. But then I think about it again and I guess it is indeed possible that they have grown that way (if they exist indeed); some of them have bigger heads and thinner legs, are older looking and walk strangely if they come to earth. This may be because of the microgravity that is outside the earth, which causes all the fluids from their body rise up causing an uneven distribution of fluids in the body. This is the same disorder that our astronauts and cosmonauts have when they come back from space flights. This is called the puffy-head bird-legs syndrome.

The National Aeronautics and Space Administration (NASA) has conducted several space launches and studies that have helped us understand life and human behavior in less gravity. Although aliens are not the main purpose of these space flights, the International Space Station (ISS) has been built to conduct several researches in microgravity.

The ISS is the largest and most complex international scientific project in history. Led by the United States, the ISS draws upon the scientific and technological resources of 16 nations: Canada, Japan, Russia, 11 nations of the European Space Agency and Brazil (www.shuttlepresskit.com/ISS_OUR).

Research on the International Space Station

The International Space Station has established an unprecedented state-of-the-art laboratory complex in orbit, more than four times the size and with almost 60 times the electrical power for experiments – critical for research capability – of Russia's Mir. Research in the station's six laboratories has lead to discoveries in medicine, materials, and fundamental science that will benefit people all over the world. Through its research and technology, the station also will serve as an indispensable step in preparation for future human space exploration (www.shuttlepresskit.com/ISS_OUR).

Some of the researches currently being conducted in the ISS include the following (taken from www.shuttlepresskit.com/ISS_OUR):

1. **Protein crystal studies**: More pure protein crystals may be grown in space than on Earth. Analysis of these crystals helps scientists better understand the nature of proteins, enzymes and viruses, perhaps leading to the development of new drugs and a better understanding of the fundamental building blocks of life. This type of research could lead to the study of possible treatments for cancer, diabetes, emphysema and immune system disorders among other researches.

2. **Tissue culture**: Living cells can be grown in a laboratory environment in space where they are not distorted by gravity. NASA already has developed a Bioreactor device that is used on Earth to simulate, for such cultures, the effect of reduced gravity. Still, these devices are limited by gravity. Growing cultures for long periods aboard the station will further advance this research. Such cultures can be used to test new treatments for cancer without risking harm to patients, among other uses.

3. **Life in low gravity**: The effects of long-term exposure to reduced gravity on humans – weakening muscles; changes in how the heart, arteries and veins work; and the loss of bone density, among others – are being studied aboard the station. Studies of these effects may lead to a better understanding of the

body's systems and similar ailments on Earth. A thorough understanding of such effects and possible methods of counteracting them is needed to prepare for future long-term human exploration of the solar system.)

4. **Flames, fluids and metal in space**: Fluids, flames, molten metal and other materials will be the subject of basic research on the station. Even flames burn differently without gravity. Reduced gravity reduces convection currents; the currents that cause warm air or fluid to rise and cool air or fluid to sink on Earth. This absence of convection alters the flame shape in orbit and allows studies of the combustion process that are impossible on Earth, a research field called Combustion Science. The absence of convection allows molten metals or other materials to be mixed more thoroughly in orbit than on Earth. Scientists plan to study this field, called Materials Science, to create better metal alloys and more perfect materials for applications such as computer chips.

5. **The nature of space**: Some experiments aboard the station will take place on the exterior of the station modules. Such exterior experiments can study the space environment and how long-term exposure to space, the vacuum and the debris, affects materials. This research can provide future spacecraft designers and scientists a better understanding of the nature of space and enhance spacecraft design. Some experiments will study the basic forces of nature, a field called Fundamental Physics, where experiments take advantage of weightlessness to study forces that are weak and difficult to study when subject to gravity on Earth. Experiments in this field may help explain how the universe developed. Investigations that use lasers to cool atoms to near absolute zero may help us understand gravity itself.

6. **Watching the Earth**: Observations of the Earth from orbit help the study of large-scale, long-term changes in the environment. Studies in this field can increase understanding of the forests, oceans and mountains. The effects of volcanoes, ancient meteorite impacts, hurricanes and typhoons can be studied. In addition, changes to the Earth that are caused by the human race can be observed. The effects of air pollution, such as smog over cities; of deforestation, the cutting and burning of forests; and of water pollution, such as oil spills, are visible from space and can be captured in images that provide a global perspective unavailable from the ground.

7. **Commercialization**: As part of the Commercialization of space research on the station, industries will participate in research by conducting experiments and studies aimed at developing new products and services. The results may benefit those on Earth not only by providing innovative new products as a result, but also by creating new jobs to make the products.

Looking at all these very important researches, we may think, how long would it take for the researchers finish all these tasks? The answer is indefinite. The more discoveries are made, the more questions and areas of research come in and so the International Space Station is indeed indispensable. From researches to making the astronauts' lives more convenient in space, the researches are endless. That is why NASA space centers in the U.S. as well as the space centers in the contributing countries are in constant work, twenty-four hours a day, seven days a week.

Where Is the International Space Station?

No, it is not in any state in the U.S. It is of course in space. In the figure below, you will see a location map of the ISS relative to its position outside the earth. This will lead you to a website that will tell you the exact current location of the ISS as it orbits the earth.

Imagine how the crew that conducts these studies lives in such an environment. Floating in microgravity, stuck in a shuttle like a ship in a bottle. Whatever they need must all be in the station. Otherwise, they would have to go back to Earth, or send someone to the shuttle to bring in what they need. This will cost a lot of money if shuttles come and go to bring the crew in the ISS whatever the need. Therefore, it is pertinent that they have all they need packed inside the station.

Tracking					Sighting		Other		
J-Track	J-Track 3D	Station	Shuttle	Mir	J-Pass	J-Pass E-Mail	J-Sky	FAQ	Links

19 Jun 2002 17:41 UTC

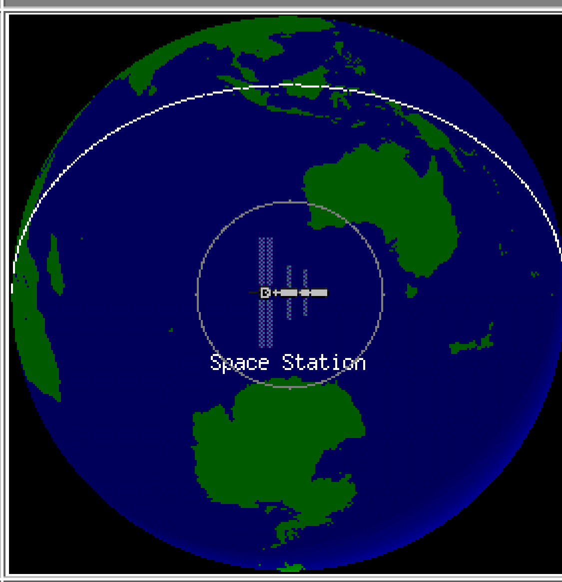
Latitude (Degrees)	Longitude (Degrees)	Altitude (Kilometers)
-47.2	105.2	403.6

Explorer's Update

STS-111 - Mission to the Space Station - 6/7/2002

- Learning About Clouds - 5/24/2002
- The Planets Line Up - 4/26/2002
- Water on Mars - 4/19/2002

Current Station Location



Write Us   Join Explorers

Before the ISS was built, on the Skylab, the first NASA space station, crews of three men stayed in space for a shorter period, say 84 days and then they went back to earth. The shorter the mission, the less basic materials are brought with them to space (http://www.flatoday.com/space/explore/stories/2000b/102900g.htm).

The following section tells about the general condition and routine for the crew members in space. This was taken from www.howstuffworks.com/space-station4.htm.

Living and Working aboard the ISS

The first space station crew members will spend a lot of their time setting up the station, building its components and conducting various scientific experiments and Earth observations. The crew will live in the service module at first. This module has spartan living quarters, but provides everything the crew needs – personal sleeping quarters, a toilet, hygiene facilities, a kitchen with a table, a treadmill and a stationary bicycle. Astronauts will have to exercise frequently to keep from losing bone and muscle mass, which happens with prolonged weightlessness.

Sleeping

Sleeping in space is quite different from sleeping on Earth. Instead of a bed, you have a wall-mounted sleeping bag that you slip into and zip up. The bag is also equipped with arm restraints to prevent your arms from floating above your head while you sleep.

Bathing

While stations such as Skylab and Mir have been equipped with a shower, most astronauts take sponge baths using washcloths or moistened towelettes. This reduces the amount of water consumed. Each astronaut will also have a personal hygiene kit with a toothbrush, toothpaste, shampoo, razor and other basic toiletries.

Eating

The food on the ISS will be mainly frozen, dehydrated or heat-stabilized, and drinks will be dehydrated. Astronauts will collect food trays and utensils, locate their individually-packaged meal from a storage compartment, prepare the items (rehydrate if necessary), heat the items (microwave, forced air convection oven), place them in the tray and eat. After the meal, they will place the used items in a trash compactor, and clean and stow the utensils and trays. Interestingly, astronauts get to select their menus approximately five months before their flight.

Exercising

In weightless conditions, the body loses bone and muscle mass. To counter these losses, astronauts will have to exercise daily. The service module is equipped with a treadmill and a stationary bicycle. Astronauts must strap themselves onto these devices so that they do not float away while exercising.

Working

Work involves maintaining the station (fixing broken equipment, repairing structures, etc.) and conducting scientific experiments and observations. The station will have six scientific laboratories. Closet-sized racks along the walls of the laboratory module will hold the equipment, and the astronauts will use footholds and restraints so they won't float away while working. The experiment racks will also have remote video and data links so that scientists on the ground will be able to monitor the experiments onboard the ISS continuously. The Japanese laboratory module will have a platform open to space, for determining the effects of the space environment on materials.

Moving around on the ISS

Working in weightlessness, or **microgravity**, is very different from what we are used to. For example, as I write this article at my computer, I do not have to worry about floating off of my chair or having the papers on my desk float away. This is not the case in the ISS. As we have mentioned above, many places (experiment racks, kitchen area, crew quarters) will have restraints to keep the astronauts and equipment from floating away. And while I can walk the corridor in my office with no trouble, astronauts on the ISS will have to use handholds mounted on the walls of the station to keep themselves stable as they move around.

With all these unusual conditions they have, a lot of aspects in the development of the International Space Station are under study. Let us focus, for the purpose of this paper, on one very important basic need they have, which is water. The Skylab crew brought with them their own supply of water because they have a shorter term in space. However for the ISS, there are more crew members staying in space for much longer time. Carrying with them gallons of water would definitely cost a lot more. Other than that, it will add mass to the space station thus making use of a larger amount of fuel to bring the station up. It would also be too expensive to send water over there every now and then.

All water on the station has to come from earth. That costs at least $10,000 per pound for the shuttle. A crew needs at least eight gallons of water a day per person. That is a gigantic expense! And don’t forget to think about how many days, if not months or years, these crewmembers stay in space. And of course don’t forget, laboratory animals need water too. One person would be tantamount to 72 laboratory rats, which need

approximately the same amount of water.
(http://www.flatoday.com/space/explore/stories/2000b/102900g.htm)

So having calculated the expenses for this flight, what could be the best way to save water on the ISS? Plumbing in space? Think about this: “Which way does water flow in a weightless environment?” And if there were a leak, where would be the nearest plumber? He would be at least 235 miles away racing at 17,000 miles per hour (http://science.nasa.gov/headlines/y2001/ast03apr_2.htm?list42293).

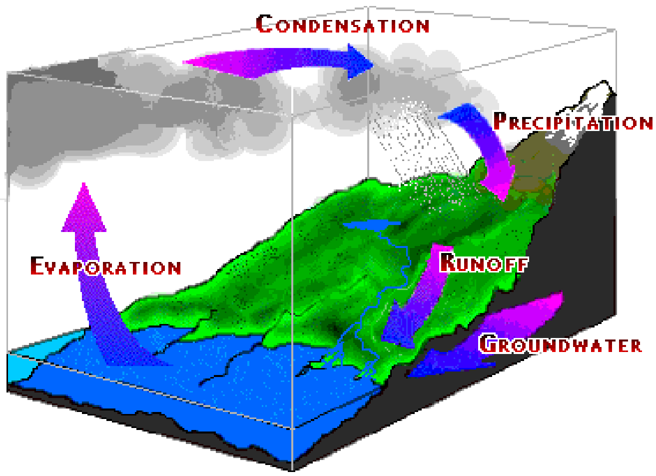
What Is the Plumbing System in the ISS?

Designers of the International Space Station asked these same questions as they laid out a complex network of tubes, pipes and ducts between the stations outer skin and its inner walls. The ISS’s plumbing circulates vital liquids and gases that keep the crew and the ISS in good health (http://science.nasa.gov/headlines/y2001/ast03apr_2.htm?list42293).

Jim Reuter, leader of the of the International Space Station’s Environmental Control and Life Support System (ECLSS) at Marshall Space Flight Center, confirms that it is indeed expensive to ferry water from earth. So the next resort would be to recycle water. Engineering of the water recycling system in space has been very challenging. Even at present there is no 100% efficient process that recycles water from all sources this in the station. These sources of water include wastewater from space shuttles’ fuel cells, from urine, from oral hygiene and hand washing, and by condensing humidly from the air. Otherwise, if recycling were not an option, then around 40,000 pounds of water from earth would be required to resupply a minimum of four crewmembers for the life of the space station (http://science.nasa.gov/headlines/y2000/ast02nov_1.htm).

How Is Water Recycling Modeled in the ISS?

Here on earth, water is recycled foremost by the natural water cycle. When water evaporates from the ocean and surface waters, it leaves behind impurities. In the absence of air pollution, nearly pure water falls back to the ground as precipitation.



.

Note: Illustration taken from http://science.nasa.gov/headlines/y2000/ast02nov_1.htm

In space the water recycling system follows the same principle except that they don't use microbes to break down urea and convert it to a form that plants can absorb or use to build new plant tissue. In space they simply rely on machines.

The three-step process of the water purification on the ISS starts with a filter that removes particles and debris. Then the water passes through the "multi-filtration beds," which contain substances that remove organic and inorganic impurities. And finally, the "catalytic oxidation reactor" which removes the volatile organic compounds and kills bacteria and viruses (http://science.nasa.gov/headlines/y2000/ast02nov_1.htm).

Indeed the process of purifying water in space is more complex that the three-step process mentioned above. At present, a better and more efficient process is being engineered until 100% efficiency is achieved and not just a close 97%.

This poses a challenge to the young minds that are interested in working for the space station. Engineers are on call and in demand for such a task.

The following section is a set of laboratory activities for students. Teachers should notice that no particular set of procedure is given in each activity thus providing a chance for students to design their own set up to meet the objectives of the activity.

LESSON PLAN ONE: CONSERVING WATER

Objective

This activity will allow the students to utilize a limited amount of water in doing the following chores: Brushing teeth
Washing face with soap

Washing the arms, legs, and feet
Cleaning dishes

Materials (each group)

2 liters of water
4 toothbrushes
1 toothpaste
1 waste jar (2-liter capacity)
1 bar of soap (Liquid soap would be more difficult to handle in space.)
4 face towels
4 soiled dishes

Procedures

1. Put students in groups of four.
2. Give each group a packet of materials.
3. Ask the students to do the tasks listed above and make sure they keep all their wastewater on the waste jar.
4. Challenge the students to use the least amount of water as possible in accomplishing all these tasks.
5. Ask students to do measure the total amount of water they used and get the percent by volume used:

$$\%\ \text{Volume} = \frac{\text{original volume of water} - \text{volume of water used}}{\text{original volume of water}} \times 100$$

LESSON PLAN TWO: WATER FILTRATION LAB
(Adapted from Life Science Institute, Space Center Houston)

Objective

The purpose of this activity is to test the skills of the students to filter polluted water by making their own filtering system given the materials. The students should come up with the cleanest possible water from the polluted mixture given to them.

Materials

Empty 0.5-liter water bottle/filter to be made
Beakers, at least 500 mL (used to collect water after it has been filtered)
Balance or scale
Stop watch or clock with second hand for each group
Graduated cylinder for each group
Polluted water samples (this can be prepared by teachers beforehand or students can decide on the pollutants and mix on their own):

Organic matter such as leaves and grass
Salt
Sugar
Food coloring
Ammonia
Vinegar
Coffee creamer
Various materials to be used as filtering agents:
Soil
Sand
Gravel
Styrofoam pellets (make sure these are not the water soluble pellets)
Scrap cloth
Cotton balls
Plastic beads
Grass clippings
Activated charcoal

Procedures

1. Students divide into groups and discuss the design of their filters.
2. The groups must pick what materials and how much of each they will use. Students should keep in mind not only water quality, but also how fast the water moves through the filter.
3. Construct the filtering device by first cutting out the bottom of the water bottle leaving half of it to serve as the funnel.
4. Layer the different filtering materials into the funnel (which is half the plastic bottle turned upside down). It is up to the students to organize these filtering materials by layer. They should write down the rationale for the arrangement of there materials.
5. Each group should be given 500 mL of polluted water for them to purify. This sample should be weighed and observed for color, odor, clarity, viscosity, etc.)
6. Pour the polluted sample through the filter constructed and allow the water to collect in the beaker. The rate of flow through the filter should be timed.
7. After the filtering the water, repeat the observations concerning the properties of the polluted water and compare them with those of the filtered one.

Note to Teachers:

1. Although some filters will work better than the other, the type of filter which will work most effectively will have the filtering agents layered in the following order from top to bottom: gravel, sand, charcoal, cotton.
2. Ask students to draw the model of their group's filter and label all parts and filter agents.

3. Compare the different filtrate of each group and present which one is the clearest and which appears to be cleanest and relatively purified.
4. Ask students to compute for percent mass of the water (filtrate) as compared to the original mass of the polluted mixture.

$$\% \text{ mass} = \frac{\text{(original mass-mass of filtrate)}}{\text{original mass}} \times 100$$

5. Make sure all their data is recorded in tables or charts that the teacher can prepare prior to laboratory activity.

LESSON PLAN THREE: WATER DISTILLATION

This activity may be used as a sequel to Lesson Plan One where they have to recycle their wastewater by distillation. Distillation is one of several methods of water purification. In distillation, water is boiled to produce steam. As the steam separates from the water it leaves behind solids and dissolved gasses are driven off. This steam is then condensed into purified water and collected in a tank and stored for use as needed.

Objective

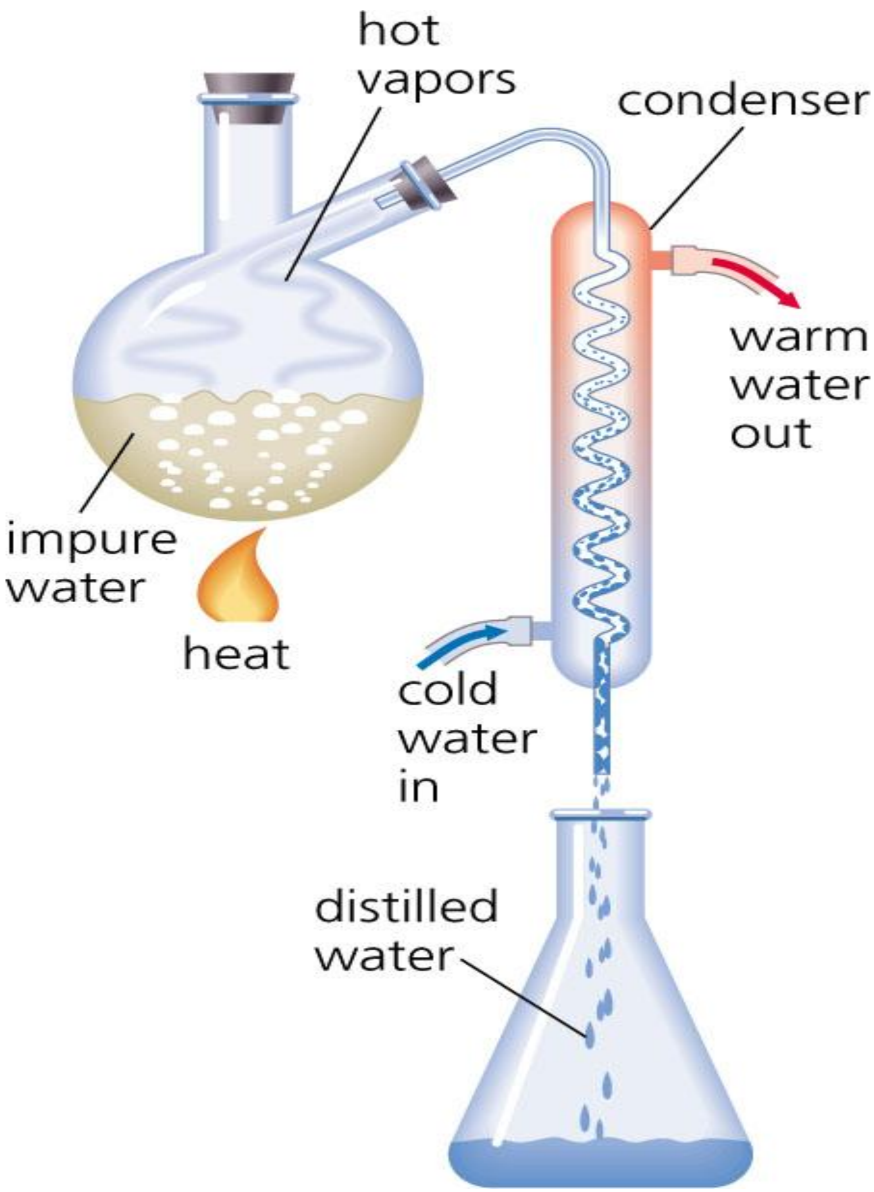
This lesson plan is designed to let students understand the principle of purification of mixture specifically to separate water from other non-volatile components of a mixture.

Materials

Hot plate or Bunsen burner
Iron stand
Iron ring
Clamps
Ice bath
Thermometer
Safety goggles
Distilling flask
Condenser
Florence flask
Rubber tubing
Match
Wastewater

Glass tubing (short) that can fit the rubber tubing for connection purposes
Rubber stoppers that can fit the flasks (Rubber stoppers must have one hole for the thermometer or the glass tubing, if necessary.)

Below is an example of distillation set up. Ideally, students should come up with this illustration. They should be guided in the way they set up their distillation process to avoid accidents. Safety precautions must be observed strictly (www.yhooligan.com/reference/dictionary/illus/distln.html).



LESSON PLAN FOUR: MICRO FILTRATION OF DISTILLED WATER

Objective

This activity allows the students to ensure that small particles of micro size including microorganisms are separated from the distilled water. This activity will give students an idea that purification of water is not simply by distillation and separation of larger impurities but also other contaminates that are not visible to the eyes.

In the international space station they use equipment manufactured and engineered in Japan, which filters. This is called High Efficiency Particulate Assembly (HEPA) Filter, which is a part of the Japanese Experiment Module (JEM) Environmental Control and Life Support System (ECLSS). Its primary function is to provide JEM cabin air filtration of particles and microorganisms. The HEPA filter is comprised of a debris screen, filter, and housing (www.hsssi.com/Applications/SpaceHabitat/).

Another important equipment used is the Bacteria Filter Assembly, which filters the bacteria in the air shared among the crewmembers. The Cabin Air Bacteria Filter Assembly (CABFA) consists of a fiberglass and aluminum housing assembly, which contains a replaceable HEPA Filter Element. It provides air filtration upstream of the Common Cabin Air Assembly (www.hsssi.com/Applications/SpaceHabitat/).

To give the students an idea of how to filter further more their partially purified water, this activity allows them to use more sensitive filters with microspores to eliminate micro size particles.

Materials

Funnel
Filter paper
Erlen Meyer Flask
25-ml sterile syringe
Micro filters (Adtec)
Partially purified water (May come from the distilled water in Lesson Plan Three)
Aluminum foil
Parafilm

Procedures

The students will purify distilled water from micro size materials and probably bacterial contaminates using micro filters. They will use the sterile syringe to draw some distilled water and let the water sample pass through the micro filters. This will be collected in a clean flask and then covered.

Note to Teachers:

Make sure students thoroughly clean their glassware before using them as container for purified water. Otherwise, they would be collecting purified water on dirty containers, which will only make them do the experiments all over again. Emphasize to the students the importance of cleaning all the glassware.

LESSON PLAN FIVE: ELECTROLYSIS

Electrolysis plays a special role in the production of water in the space station, as well as electrolysis provides a way of producing oxygen gas essential for respiration. To show us a general formula, the following reactions come in handy:

Electrolysis:

Electricity + Water → Oxygen and Hydrogen

Reverse Electrolysis:

Hydrogen + Oxygen → Electricity and Water

Most people can survive only a couple of minutes without oxygen, and low concentrations of oxygen can cause fatigue and blackouts. To ensure the safety of the crew, the ISS will have redundant supplies of that essential gas. Most of the station's oxygen will come from a process called "electrolysis," which uses electricity from the ISS solar panels to split water into hydrogen gas and oxygen gas (www.firstscience.com/site/articles/breathe.asp).

Each molecule of water contains two hydrogen atoms and one oxygen atom. Running a current through water causes these atoms to separate and recombine as gaseous hydrogen (H_2) and oxygen (O_2) (www.firstscience.com/site/articles/breathe.asp).

In this activity the students will be exposed to the electrolysis process wherein they will attempt to produce hydrogen and oxygen gas. In this case, careful attention and discussion of procedure must be done prior to the actual work of the students. From this point students will be able to design a set up where in they will do a reverse electrolysis.

Objective

The students will allow water to undergo electrolysis. They should be able to produce hydrogen gas and oxygen gas from this process and explain the process of REDOX reaction.

Materials

Electrolysis flask
Iron stand
Platinum wires
Platinum electrodes
Rubber stoppers
AC current or dry cell
Clamps

Distilled water
Dye
Alligator clips

Set up the materials as seen on the photo below:

Demonstrating the electrolysis of water requires a specialized piece of glassware, and a source of electrical current. Go to the following website to examine this apparatus in more detail: www.chem.uiuc.edu/demos/elec.htm.

Procedure
(Adapted from the website www.chem.uiuc.edu/demos/elec.htm)

1. The outer glass tubes and the middle tube are filled with water and the reservoir half filled. Food coloring is usually added so that it is easier to see the liquid in the tubes.
2. Rectangular platinum electrodes attached to a platinum wire are held in position by the rubber stoppers at the bottom of both glass tubes. The platinum wire passes through holes in the rubber stoppers. The platinum electrodes are flattened into rectangles to expose as much metal as possible to the reactant (water).
3. The platinum wires extending from the rubber stoppers are attached to the power source with alligator clips. Either a dry cell battery or AC current provides enough current to cause the decomposition of water.
4. Once the current is applied, you can see that a reaction is occurring in one of two ways. Bubbles of gas rise from the surface of the electrodes as water decomposes to H_2 and O_2 gas.
5. We can tell that the tube on the right has the cathode, since at the cathode H_2 is produced. In the decomposition reaction, the volume of H_2 produced is twice the volume of O_2.

$$2\,H_2O \rightarrow 2\,H_2 + O_2$$

LESSON PLAN SIX: CONSTRUCTING A MODEL OF A WATER RECYCLING SYSTEM IN SPACE

Objective

To propose a three-dimensional design of a water filtration or recycling system in the International Space Station.

The most challenging part of this unit is for students to learn draw three-dimensional design for a proposed water recycling system for the ISS taking into consideration the following:

Sources of water:

1. Space shuttle's fuel cells. Water is a byproduct of the fuel cells that produce electricity for use in the shuttle, but the production of water takes a lot of time and it only occurs after the solar panel in the cargo doors are activated. The cells produce electricity and the byproduct is about one gallon per hour (Water Filtration Lab, Life Science Institute, Space Center Houston).
2. Urine.
3. Oral hygiene.
4. Hand washing.
5. Condensing humidity from air.
6. The materials used should be lightweight but not expensive in operation requirements.
7. Collection of water is done in microgravity.

Most students are very skillful in using computer-based illustrations to produce a three-dimensional illustration of a system they would like to propose. They should be able to rationalize all the parts and assembly of the system.

This activity will hone their engineering skills in troubleshooting, solving problems, and designing a workable, above 95% efficiency equipment. Considering the different points mentioned above will help them do more research and in depth analysis of how all these factors affect an equipment design.

The students need not make a miniature of their design, but if they can produce one, it would be best. They will then present their project in class and account for every parts of the design as is possible.

BIBLIOGRAPHY

Internet Resources

http://science.nasa.gov/headlines/y2001/ast03apr_2.htm?list42293
http://science.nasa.gov/y2000/ast02nov_1.htm
http://www.bagelhole.org/article.php/Water/101/
http://www.chem.uiuc.edu/demos/elec.htm
http://www.firstscience.com/site/articles/breathe.asp
http://www.flatoday.com/space/explore/stories/2000b/102900g.htm
http://www.hsssi.com/Applications/SpaceHabitat/
http://www.shuttlepresskit.com/ISS_OUR
http://www.tva.apogee.net/res/rekwdis.asp
http://www.yahooligans.com/reference/dictionary/illus/distln.html
http://wwwhpwstuffworks.com/space-station4.htm.

Information Handouts

"Water Filtration Lab," Life Science Institute, Space Center Houston

Additional Information and Links for Teachers

http://spacelink.nasa.gov
http://core.nasa.gov
http://spaceflight.nasa/gov
http://quest.nasa.gov
http://www.spacebio.net
http://science.nasa.gov
http://www.thursdayclassroom.com
http://learningoutpost.jsc.nasa.gov
http://advtech.jsc.nasa.gov/tech_spacelife.shtm