Exploration Brief

O_2—How Much?

Context

A typical extravehicular activity (EVA) lasts about 7 hours. During that time, an astronaut performs a number of activities, some of which are very strenuous. To make it possible to accomplish the mission, the spacesuit has to provide a steady and reliable oxygen supply for breathing and suit pressurization. The oxygen supply in the primary life-support system (PLSS) is contained in four oxygen tanks. Two of the tanks are used as the primary oxygen supply and two for an emergency secondary supply. The two primary tanks each have a volume of 3,980 cm^3. They contain a total of 0.55 kilograms of oxygen at a pressure of 5,860.5 kilopascals. As this oxygen circulates through the suit, it passes through a recycling system that removes carbon dioxide, odors, and humidity. The two secondary oxygen tanks have a volume of 1,460 cm3 and contain a total of 1.19 kilograms of oxygen at a pressure of 41,368.5 kilopascals. This supplies only enough oxygen for about 30 minutes because this oxygen is not conserved and recycled.

Although the Shuttle spacesuit is used in Earth orbit where the suit is in effect, weightless, the oxygen tanks still have to be constructed from lightweight materials. Weight is not a problem in orbit, but it is a problem for Shuttle liftoff. The Space Shuttle can carry only so much mass to orbit. Lighter tanks means that additional payload can be carried.

To reduce their weight tanks are made from thin-wall metal shells that are wrapped with Kevlar® filaments and resin for strength.

Objective

- To measure the quantity of oxygen a person will need under varying levels of activity

Materials and Tools Checklist

- ☐ Two-liter soft drink bottle
- ☐ 1 meter of flexible plastic tubing (from a hardware or aquarium store)
- ☐ Permanent marker
- ☐ Paper strips
- ☐ Cellophane tape
- ☐ Water
- ☐ Large pot or aquarium

Procedure

Step 1. Obtain the materials in the material list and begin by calibrating the 2 liter soft drink bottle. Stand the bottle upright and pour measured amounts of water into the bottle with a beaker. Add 100 ml and mark the side of the bottle at the top surface of the water. Repeat this procedure until the bottle is filled.

Step 2. Make paper mouthpieces by rolling a strip of paper around one end of the tube. Use a small strip of tape to hold the mouthpiece together. Make a new mouthpiece each time a different person uses the apparatus.

Step 3. Partially fill a large pot or aquarium with water. Fill the bottle with water and invert it in the aquarium. Support the bottle by holding it with one hand around the neck. Insert the air hose into the bottle neck. Attach a mouthpiece to the other end of the tube and have a student fully exhale a normal breath of air through the tube. Water will be driven out of the bottle. Read the volume of air trapped inside the bottle from the calibration marks placed on the bottle's side in step 1.

Activity

Step 4. Measure the air quantity required in normal breathing by several volunteer students. Begin with the students at rest. With a fresh mouthpiece on the tubing, have a student inhale a normal breath of air and exhale the air through the tube. The student should do this several times. Measure the amount of air in the bottle and divide this quantity by the number of breaths.Record the quantity for "at rest" on a data table or computer spread sheet. Also measure and record how long it took for the test.

Step 5. After recording "at rest" breathing requirements, refill the bottle with water and have each student perform a moderate amount of activity such as lifting small barbells for a minute or two. After exercising, repeat the air quantity requirement measurements and record the numbers in the data table for "moderate work."

Step 6. Repeat the procedure a third time, but have the students run in place for a minute or two before taking the measurements. Record the results under "strenuous exercise."

Step 7. Discuss possible ways to determine how much air an average "student astronaut" will need on a 7-hour spacewalk in which the work level will range from moderate to strenuous and calculate an answer from the data collected. Make sure the students realize that not only will the quantity of air taken in with each breath changes but the breathing rate will change with exercise. Determine what the quantity would be if, instead of a normal air mixture, pure oxygen would be used. (Normal air contains 20 percent oxygen.)

Extensions

- Determine the actual volume of oxygen carried in the Shuttle spacesuit primary and secondary oxygen supplies. Oxygen, under standard conditions, has a mass of 1.327 kilograms per cubic meter. (The primary and secondary oxygen systems contain a total of 1.74 kilograms of oxygen. Divide that number by 1.327 to get the volume of oxygen in cubit meters. Although the volume may seem small, remember that oxygen is recycled.)