MATH AND SCIENCE @ WORK

AP* CHEMISTRY Student Edition

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FUEL CELL GENERATION

Background

Since its conception in 1981, NASA has used the space shuttle for human transport, the construction of the International Space Station (ISS), and to research the effects of space on the human body. One of the keys to the success of the Space Shuttle Program is the Space Shuttle Mission Control Center (MCC). The Space Shuttle MCC at NASA Johnson Space Center uses some of the most sophisticated technology and communication equipment in the world to monitor and control the space shuttle flights.

Within the Space Shuttle MCC, teams of highly qualified engineers, scientists, doctors, and technicians, known as flight controllers, monitor the systems and activities aboard the space shuttle. They work together as a powerful team, spending many hours performing critical simulations as they prepare to support preflight, ascent, flight, and reentry of the space shuttle and the crew. The flight controllers provide the knowledge and expertise needed to support normal operations and any unexpected events.

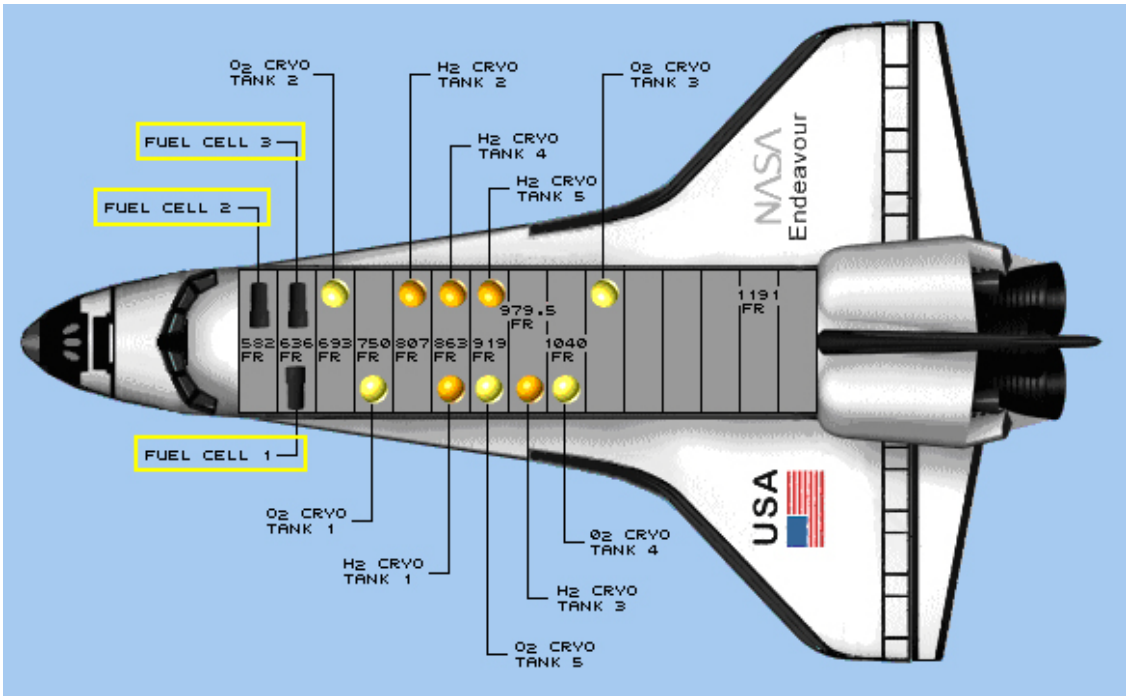

Figure 1: Typical space shuttle cryogenic tank layout

One of the flight controllers in the Space Shuttle MCC is the Electrical Generation and Illumination (EGIL) engineer. The space shuttle requires carefully metered power for operation during missions, and it is EGIL's responsibility to monitor the electrical systems, fuel cells, and associated cryogenics on the vehicle. Electricity is generated using three onboard hydrogen-oxygen fuel cells. A fuel cell is a device

that combines externally stored reactants (a fuel and an oxidizer) to produce electricity and byproducts. Hydrogen (the fuel) and oxygen (the oxidizer) are stored in liquid cryogenic storage tanks located in the mid-body of the space shuttle. Custom built software is used in both preflight planning and real-time predictions for the management of these storage tanks which require constant monitoring.

Problem

The cryogenic storage tanks that contain the reactants (hydrogen and oxygen) are thermally insulated, double-walled spheres. The fuel cells operate when a series of heaters within the cryogenic storage tanks are actuated to provide pressure above the minimum tank pressure. The pressurized reactants flow through a manifold and into a dual-gas regulator that maintains a specific flow of gas to the fuel cells. During normal operations on the space shuttle, 0.544 kg of hydrogen is used per hour and 4.58 kg of oxygen is used per hour. Some of the oxygen is used in the space shuttle cabin for breathing. The standard heat of formation of water is -242 kJ per mole.

Equation: $2H_2 + O_2 \rightarrow 2H_2O$

A. Use the above information to determine, quantitatively, which reactant is the limiting reagent.

B. Assuming a 12 day mission, what is the total amount of energy in joules generated by the fuel cells?

C. What is the total mass of water produced on the space shuttle which must be used by the astronauts, stored, or dumped into space?

D. Energy is generated on the space shuttle in three fuel cells that use a chemical reaction between hydrogen and oxygen in a potassium hydroxide electrolyte.

Half-Reactions	Standard Reduction Potential, $E°$
$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$	+0.40 V
$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$	-0.83 V

I. Write the half reactions for the anode and the cathode.

II. Write the net equation for the galvanic cell.

E. Calculate the standard cell potential ($E°_{cell}$).

F. Determine the standard free energy change, ΔG^o_{rxn} at 298K.