MATH AND SCIENCE @ WORK

AP* CHEMISTRY Student Edition

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CRYOGENIC STORAGE

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.

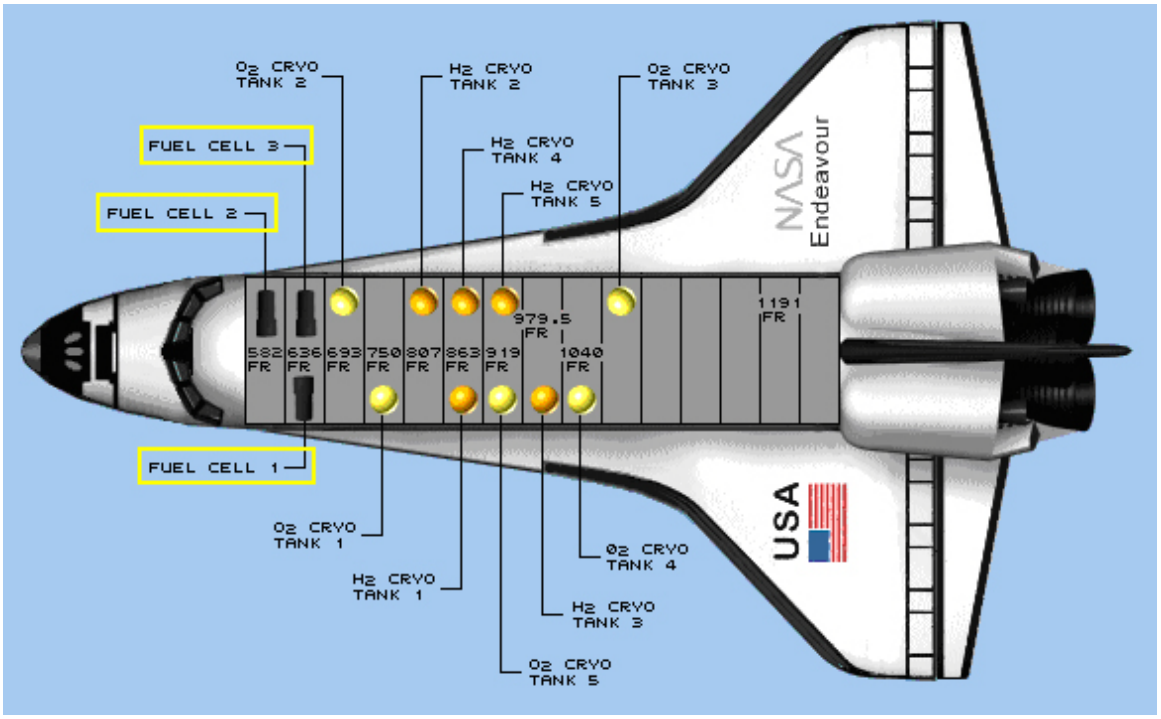

Figure 1: Typical space shuttle cryogenic tank layout

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 reactants are stored in a liquid state and at minimum pressures. Table 1 lists more detailed information on the cryogenic storage tanks. Use the information in Table 1 to answer the following questions.

Table 1: Cryogenic Tank Summary

Tank	**Liquid Hydrogen (H_2)**	**Liquid Oxygen (O_2)**
Number of Tanks	5	5
Total volume of all Tanks	3028.59 Liters	1591.4 Liters
Storage Temperature	-250° C	-183.3° C
Density	0.0678 kg/L	1.141 kg/L

A. Calculate the total number of moles of each of the following:

   I. H_2

   II. O_2

B. Suppose that the oxygen and hydrogen were stored as gases on the space shuttle at Standard Temperature and Pressure (STP).

   I. Find the combined tank volume that would be required to store the hydrogen?

   II. Find the combined tank volume that would be required to store the oxygen?

   III. Explain the advantage for the space shuttle to store the reactants as liquids rather than gases.

The two reactants are maintained in the cryogenic storage tanks at minimum pressures of 12.8 atm for hydrogen, and 49.8 atm for oxygen. The tanks provide a flow of reactant through manifolds to the fuel cells. A minimum pressure is required in the tanks to keep the hydrogen and oxygen supercritical (at a temperature and pressure above its critical point). This prevents local pockets of gas from forming which, under the correct circumstances, could damage tank hardware.

C. Use the data provided in Table 2 to complete the following.

Table 2: Temperature and Pressures for H_2 and O_2

	Normal melting point	Normal boiling point	Triple point	Critical point
H_2	-259° C	-253° C	-259° C and 0.0695 atm	-240° C and 12.8 atm
O_2	-218° C	-183° C	-219° C and 1.14 torr	-119° C and 49.8 atm

I. Sketch a phase diagram for O_2. The diagram should be roughly to scale and include the Triple point and Critical point.

II. Based on the phase diagram, which would be more dense, solid O_2 or liquid O_2?

III. Explain how storing the reactants at minimum tank pressures and below critical temperatures allow conversion from liquid to gas without forming a large volume of gas within the manifold or tanks.