MATH AND SCIENCE @ WORK

AP* CHEMISTRY Student Edition

CARBON DIOXIDE REMOVAL – THERMODYNAMICS

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.

One of the flight control positions in the Space Shuttle Mission Control Center is the Emergency, Environmental, and Consumables Manager (EECOM). One of the responsibilities of the EECOM flight controller is to monitor and regulate the cabin atmosphere which includes gas concentrations and pressures within the space shuttle cabin. Maintaining these parameters ensures a habitable cabin atmosphere and temperature on board the space shuttle much like the atmosphere here on Earth.

Figure 1: Astronauts Thomas D. Jones, mission specialist, and Mark L. Polansky, pilot, change out lithium hydroxide canisters on the mid deck of the Earth-orbiting Space Shuttle Atlantis.

The space shuttle uses an absorption method to remove carbon dioxide (CO_2). The absorption of carbon dioxide is accomplished in a chemical reaction using a sorbent known as lithium hydroxide (LiOH). This method relies on the exothermic reaction of lithium hydroxide with carbon dioxide gas to create lithium carbonate (Li_2CO_3) solid and water (H_2O). Lithium hydroxide is an attractive choice for space flight because of its high absorption capacity for carbon dioxide and the small amount of heat produced in the reaction. Disadvantages include the irreversibility of the chemical reaction. This causes the replacement of lithium hydroxide canisters to be a daily activity during space shuttle flights. There is also the potential for some toxicity within the space shuttle cabin due to the lithium hydroxide dust that could be ingested by the crew. Before a space shuttle mission, EECOM flight controllers and crewmembers receive training that ensures correct precautions and procedures are followed while replacing the lithium hydroxide canisters.

Problem

The Contaminate Control Cartridge (CCC), which contains lithium hydroxide (LiOH), is used to remove carbon dioxide (CO_2) from the space shuttle cabin. The removal of the CO_2 is represented by the following equation:

$$2LiOH_{(s)} + CO_{2(g)} \rightarrow Li_2CO_{3(s)} + H_2O_{(g)}$$

A. The removal of the CO_2 occurs in two steps. Determine the value of the Standard Enthalpy change, ΔH°_{rxn}, using the following information:

$$LiOH_{(s)} + H_2O_{(g)} \rightarrow LiOH \cdot H_2O_{(s)} \qquad \Delta H^\circ_{298} = -61.27 \tfrac{kJ}{mol}$$

$$Li_2CO_{3(s)} + 3H_2O_{(g)} \rightarrow 2LiOH \cdot H_2O_{(s)} + CO_{2(g)} \qquad \Delta H^\circ_{298} = -28.18 \tfrac{kJ}{mol}$$

B. Determine the Standard Entropy change, ΔS°_{rxn}, for the removal of CO_2 at 298 K using the following information:

Substance	$S^{\circ}_{298}\left(\frac{J}{mol\ K}\right)$
$LiOH_{(s)}$	42.8
$CO_{2(g)}$	213.7
$Li_2CO_{3(s)}$	90.2
$H_2O_{(g)}$	189.0

C. Determine the Standard Free Energy change, ΔG°_{rxn}, for the reaction at 298 K. Include units with your answer.

D. Is the reaction spontaneous under standard conditions at 298 K? Justify your answer.

E. Calculate the value of the equilibrium constant, K_{eq}, for the reaction at 298 K.