Problem set:

On the International Space Station, a device called the Contaminant Control Cartridge, which contains lithium hydroxide (LiOH), removes carbon dioxide (CO_2) from the air. This process is represented by the following equation:

$2\ LiOH(s) + CO_2(g) \rightarrow Li_2CO_3(s) + H_2O(g)$

1. Using the mass of carbon dioxide captured by your filter, determine how much lithium hydroxide each of your filter cartridges would need in order to effectively produce oxygen.

   ___G x (1 mol CO_2 / 44g) x (2 mol LiOH/ 1 mol CO_2) x (24g / 1 mol LiOH) = _____g

2. A typical crew consists of six individuals and each Contaminant Control Cartridge contains 750 g of LiOH. Assuming that each crew member expels 42.0 g of CO_2 per hour on average and that a mission is scheduled to last 18 days, how many cartridges must be carried on board the station?

   42g CO_2 x (6 crew) x (24 hours) x (18 days) x (1 mol CO_2 / 44g) x (2 mol LiOH/ 1 mol CO_2) x (24g / 1 mol LiOH) x (1 cartridge / 750g) = 158 Cartridges

On Mars, a device called the Mars Oxygen ISRU Experiment, or MOxIE, could convert the toxic carbon dioxide atmosphere to oxygen and vent out carbon monoxide in order to provide a breathable atmosphere for astronauts upon arrival. Balance the equation below and answer the following questions:

$2CO_2(g) \rightarrow O_2(g) + 2CO(g)$

1. How many grams of oxygen would be produced by 1kg of carbon dioxide? How many grams of carbon monoxide?

   1 kg x (1000g /1kg) x (1 mol CO_2/ 44g) x (1 mol O_2/ 2 mol CO_2) x (32g /1mol O_2) = 363g

2. Presently, MOXIE is capable of producing oxygen at a rate of 12g per hour. If the astronauts require 30kg of oxygen per month, how many days would MOXIE have to run in order to supply one month's worth of oxygen?

   12g /hr x 24hr = 288g/day   30,000g x (1 day/288g) = 104 days for 1 month of oxygen

3. The byproduct of MOXIE, carbon monoxide, is also very poisonous. Discuss with your group how you could design a system to be sure CO is kept away from the astronauts and handled safely.

Extensions:

Another stoichiometry issue facing astronauts on prolonged missions is loss of bone density. On Earth, we lose roughly 1% of bone mass (calcium carbonate) every year, yet astronauts lose 1-2% every month! One theory is this is due to buildup of sulfuric acid in our blood, arriving via amino acids obtained from animal protein.

1. Write a complete balanced equation for the reaction between sulfuric acid and calcium carbonate to form calcium sulfate, carbon dioxide and water.

   $H_2SO_4 + CaCO_3 \rightarrow CaSO_4 + CO_2 + H_2O$

2. While in space, an astronaut loses approximately 200 mg of calcium carbonate per day. Calculate the mass of sulfuric acid used in this process.

   200mg x (1g/1000mg) x (1mol $CaCO_3$/100g) x (1 mol H_2SO_4/1 mol $CaCO_3$) x (98g/1mol H_2SO_4) =0.196 g

3. A visit to Mars is on the horizon, but the duration of time required for a Mars mission is a concern to NASA. Currently, astronauts spend an average of 6 months on an ISS mission. A trip to Mars, however, would require 18 months of round-trip travel and an extra two to six months of on-the-ground research. It is currently projected that an astronaut would lose 1.5% of his or her pre-flight bone mineral density per month while on a Mars mission. Assume that there are 1500 g of calcium in an astronaut's bones pre-flight. Predict the mass of calcium that would remain after one year of a Mars mission.

   1.5% x 1500g x (18 months travel +12 months on the ground) = 675g of bone!