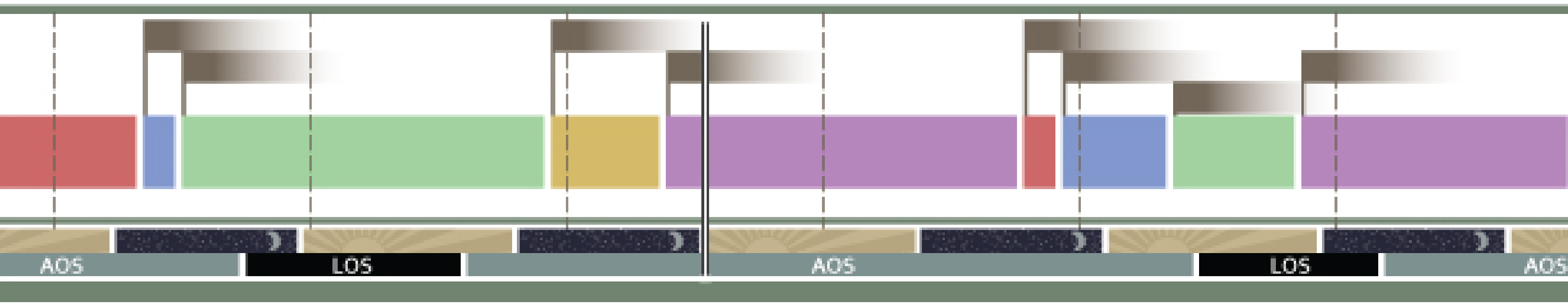
ISSLive!

The ISSLive! project is a JSC innovation award- winning, combined MOD/Education project to publish export control and PAO-approved ISS telemetry, and simplified and scrubbed crew timelines. The publication of this data will be real-time or near real time and will include links to the crew's social media feeds and existing streaming public video/audio feeds, via public-friendly website, mobile devices and tablet applications. Additionally, the project will offer interactive virtual 3D views of an ISS model based on real-time telemetry and a 3D virtual mission control center based on existing Front Room console positions in "made for public" displays. The ISSLive! project is MOD-managed and includes collaborations with subject-matter expertise from the ISS flight controllers regarding daily operations and planning, education program specialists from the JSC Office of Education, instructional designers, human computer interface experts, and software/hardware experts from MOD facility organization, and senior web designers.

In support of the Agency's Strategic Goal #6 with respect to using the ISS National Laboratory for education activities, ISSLive! uses the Station itself as STEM education subject matter and provides data for STEM-based lessons plans using national standards. Specifically, ISSLive! supports and enables the National Laboratory Education (NLE) project to address the Agency's Strategic Goal #6. This goal mandates, "sharing NASA with the public, educators, and students to provide opportunities to participate in our Mission, foster innovation….." ISSLive! satisfies the Agency's outcomes of Strategic Goal; that is, engages the public in NASA's missions by providing new pathways for participation (Outcome 6.3) and it informs, engages, and inspires the public by sharing NASA's missions, challenges, and results (Outcome 6.4). Additionally, ISSLive! enables MOD's support of JSC Outreach and NASA's Open Data and Open Government Initiatives. The audience for the ISSLive! website and its application(s) are: teachers, students, citizen scientists, and the general public who will be given new and interactive insights on how the ISS Operates.



Enivronmental Control and Life Support	Console Position: ETHOS
Reactions, Electrochemistry, Stoichiometry	

HOW IS OXYGEN GENERATED ON THE INTERNATIONAL SPACE STATION?

Instructional Objectives

Students will

- write balanced equation for electrolysis reaction;
- predict the direction of oxidation-reduction reactions;
- determine oxidation numbers before and after reaction;
- use ΔG°_{rxn} to determine behavior of reaction; and
- determine mass and volume relationship.

Degree of Difficulty

This problem requires students to integrate several aspects of the AP Chemistry curriculum to obtain the solution. For the average AP Chemistry student, the problem may be moderately difficult.

Total Time Required

Teacher Prep Time: 10-15 minutes

Class Time: 60-80 minutes

(To decrease amount of class time students can complete research as homework)

- Introduction: 5-10 minutes
- Student Research: 20-25 minutes
- Student Work Time: 25-30 minutes
- Post Conclusion: 10-15 minutes

AP Course Topics

Reactions

- Reaction Types
    - Oxidation-Reduction reactions
    - Oxidation number
    - The role of the electron in oxidation-reduction
    - Electrochemistry: electrolytic and galvanic cell; Faraday's laws; Nernst equation; prediction of direction of redox reactions
    - Stoichiometry
        - Mass and volume relations with emphasis on the mole concept, including empirical formulas and limiting reactants.

NSES Science Standards

Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Science in Personal and Social Perspectives

- Science and technology in local, national and global challenges

Physical Science

- Chemical reactions
- Conservation of energy and increase in disorder

Science and Technology

- Abilities of technological design
- Understanding about science and technology

History and Nature of Science

- Science as a human endeavor
- Nature of scientific knowledge

Lesson Development

This problem is part of a series of problems associated with the NASA ISS Live! website at www.isslive.nasa.gov.

Teacher Preparation

- Review the Environmental Control and Life Support information on the ISS Live! website. This can be found in the Operations tab.
- Review the ETHOS Handbook, paying specific attention to the Oxygen Generator System. The handbook can be found at the ETHOS console position in the 3D Mission Control Center environment, and in the Handbooks tab.
- Review the interactive activity at the ETHOS console position in the 3D Mission Control Center environment on the ISS Live! website. This activity demonstrates the operations of the Oxygen Generator System.
- Review the ETHOS console display in the 3D Mission Control Center environment and the live data associated with the Oxygen Generator System. *{{insert screen shot of display screen and highlight the right data}}*
- Prepare copies of the student worksheet located at the end of this document.

Inquiry-Based Lesson (Suggested Approach)

The research (step 4) can be assigned as homework.

1. Pose this question to the class: ***Since the International Space Station is a closed loop environment, how could oxygen be generated for the crewmembers to safely live and work?***
2. Allow students to discuss in small groups or as a class. Have students build their own questions and possible solutions to the problem.
3. Allow students to explore the 3D Mission Control Center of the ISS Live! Website. If needed guide students to the ETHOS console position. They should access the ETHOS Handbook, ETHOS console displays, as well as the interactive activity, as they prepare to answer the questions on the student worksheet.
4. Distribute the student worksheets to the class. Students may work individually or in small groups (2-3 members per group) to conduct the research.
5. Allow students to explore the 3D Mission Control Center of the ISS Live! Website. If needed guide students to the ETHOS console position. They should access the ETHOS Handbook, ETHOS console displays, as well as the interactive activity, as they prepare to answer the questions on the student worksheet.
6. Once the research is completed, students may work individually to complete the questions on the worksheet. They will need to refer to the live data on the ISSLive! Website on the ETHOS console display in order to answer the entire problem.

Post Conclusion

7. A solution key is provided below using data that is typical for normal operations of the Oxygen Generator System. Students' answers will vary depending on the actual live data.
8. Have students discuss their answers in small groups or with the entire class and tie back to the original question: Since the International **Space Station is a closed loop environment, how could oxygen be generated for the crewmembers to safely live and work?**
9. Ask students to explain the Oxygen Generator System and the data they used in their calculations.
10. Assessment of student work may be conducted by using the provided rubric (modeled after AP Free Response Question scoring).

Extension

Other possible uses for the ISSLive! website focused on ETHOS and Environmental Control and Life Support:

- Based on the oxygen generated calculate the amount of hydrogen gas produced for the Sabatier Reactor.
- Revisit the ETHOS console position to check the live data at different times of the day, or when more or less crewmembers are onboard the ISS. (Check the timeline for activities).

SOLUTION KEY: Oxygen Generator System

The Environmental Control and Life Support system is primarily monitored and controlled by the ETHOS (Environmental and Thermal Operating Systems) flight controller. The EHTOS flight controller works in the Mission Control Center for the internal Space Station along with a team of other flight controllers who monitor the operations of the ISS to keep the crew members and the vehicle safe. Explore and interact with the 3D ISS Mission Control Center on the ISSLive! website to learn more.

1. Write the balanced equation for the electrolysis of water. Calculate the value of the standard cell potential, E°, for the reaction using the information from the table below.

Half-Reaction	E° (V)
$2\,H_2O + 2\,e^- \rightarrow H_2 + 2OH^-$	-0.83 V
$O_2 + 2H_2O + 4\,e^- \rightarrow 4OH^-$	0.40 V

$2(2H_2O + 2e^- \rightarrow H_2 + 2OH^-)$ -0.83V

$\underline{4OH^- \rightarrow O_2 + 2H_2O + 4e^-}$ $\underline{-0.40V}$

$2H_2O \rightarrow 2H_2 + O_2$ E°= -1.23V

2. Determine the total number of electrons transferred in the overall reaction.

4 electrons

3. What is the oxidization number of oxygen before the reaction occurs? What is the oxidation number of oxygen after the reaction occurs?

Before -2 After 0

4. All electrolysis reactions have the same sign for ∆G°. Is the sign positive or negative? Justify your answer.

$\Delta G° = +$

$\Delta G° = -nFE°$ therefore, $+\Delta G = -nF(-E°)$

Each crew member consumes approximately 0.84 kg of oxygen per day.

5. According to the ISSLive! website, what is the current crew size? Calculate the amount of O_2 required to sustain the size of the current crew per day.

Assume 4 crew members

4 * 0.84 kg = 3.36 kg/day

6. According to ISSLive! website, what is the current oxygen output per day (in kg).

5 kg / day

7. Calculate the amount of water need to produce the current output of O_2 per day.

$$5\text{ kg}\ \frac{1000gO_2}{1kg}\frac{1molO_2}{32gO_2}\frac{2molH_2O}{1molO_2}\frac{18gH_2O}{1molH_2O}\frac{1kgH_2O}{1000gH_2O}5.625\,kgH_2O$$

8. Using the data above calculate the amperage necessary for the production of O_2.

$$\frac{156.25molO_2}{day}\frac{4mol\,e^-}{1molO_2}\frac{96{,}500C}{1mol\,e^-}=60{,}312{,}500C/day$$

$$\frac{60{,}312{,}500C}{day}\frac{1day}{24hr}\frac{1hr}{60\min}\frac{1\min}{60s}=698\,Amps$$

9. If a constant current of 50 amps is applied to the OGS per cell, how many cells are operating in the system?

698 Amps / 50 amps per cell = 13.96 or 14 cells operating

10. The OGS is designed to have a maximum output of 9.09 kg per day to support up to 11 crew members. What is the total number of electrolytic cells in the OGS?

$$\frac{9.09kgO_2}{day}\frac{1000g}{1kg}\frac{1molO_2}{32gO_2}=284.06molO_2\,per\ day$$

$$\frac{284.06molO_2}{day}\frac{4mole^-}{1molO_2}\frac{96{,}500C}{1mole^-}=109{,}647{,}160\,C\ per\ day$$

$$\frac{109{,}647{,}160\,C}{day}\frac{1day}{24hr}\frac{1hr}{60\min}\frac{1\min}{60s}=1269.06\ Amps$$

1269.06 Amps / 50 Amps per cell = 25.4 ≈ 26 cells

Student Worksheet: Oxygen Generator System

The Life Support and Environmental Controls system is primarily monitored and controlled by the ETHOS (Environmental and Thermal Operating Systems) flight controller. The EHTOS flight controller works in the Mission Control Center for the internal Space Station along with a team of other flight controllers who monitor the operations of the ISS to keep the crew members and the vehicle safe. Explore and interact with the 3D ISS Mission Control Center on the ISSLive! website to learn more.

1. Write the balanced equation for the electrolysis of water. Calculate the value of the standard cell potential, E°, for the reaction using the information from the table below.

Half-Reaction	**E° (V)**
$2\ H_2O + 2\ e^- \rightarrow H_2 + 2OH^-$	-0.83 V
$O_2 + 2H_2O + 4\ e^- \rightarrow 4OH^-$	0.40 V

2. Determine the total number of electrons transferred in the overall reaction.

3. What is the oxidization number of oxygen before the reaction occurs? What is the oxidation number of oxygen after the reaction occurs?

4. All electrolysis reactions have the same sign for $\Delta G°$. Is the sign positive or negative? Justify your answer.

Each crew member consumes approximately 0.84 kg of oxygen per day.

5. According to the ISSLive! website, what is the current crew size? Calculate the amount of O_2 required to sustain the size of the current crew per day.

6. According to ISSLive! website, what is the current oxygen output per day (in kg).

7. Calculate the amount of water need to produce the current output of O_2.

8. Using the data above calculate the amperage necessary for the production of O_2.

9. If a constant current of 50 amps is applied to the OGS per cell, how many cells are operating in the system?

10. The OGS is designed to have a maximum output of 9.09 kg per day to support up to 11 crew members. What is the total number of electrolytic cells in the OGS?

Scoring Guide

Suggested 12 points total to be given.

Question		Distribution of points
1	*2 points*	1 point for the correct balanced equation 1 point for the correct E° cell value
2	*1 point*	1 point for the correct number of electrons transferred
3	*1 point*	1 point for the correct oxidation number of oxygen before and after reaction
4	*1 point*	1 point for the correct justification of sign of $\Delta G°$
5	*1 point*	1 point for the correct amount of oxygen for crew
6	*1 point*	1 point for correct the correct amount of oxygen for ISSLive
7	*1 point*	1 point for the correct amount of water needed in OGS
8	*1 point*	1 point for the correct amperage for oxygen produced
9	*1 point*	1 point for the correct number of cells in operation
10	*2 points*	1 point for the correct moles of oxygen 1 point for number of cells needed for maximum output

Contributors

This problem was developed by the ISSLive! team with the help of NASA subject matter experts.

Education Specialist

Tonya York – Tietronix Software, ISSLive! project

NASA Experts

Tess Caswell – Environmental and Thermal Operating Systems (ETHOS) Operator, International Space Station Mission Control Center, NASA Johnson Space Center