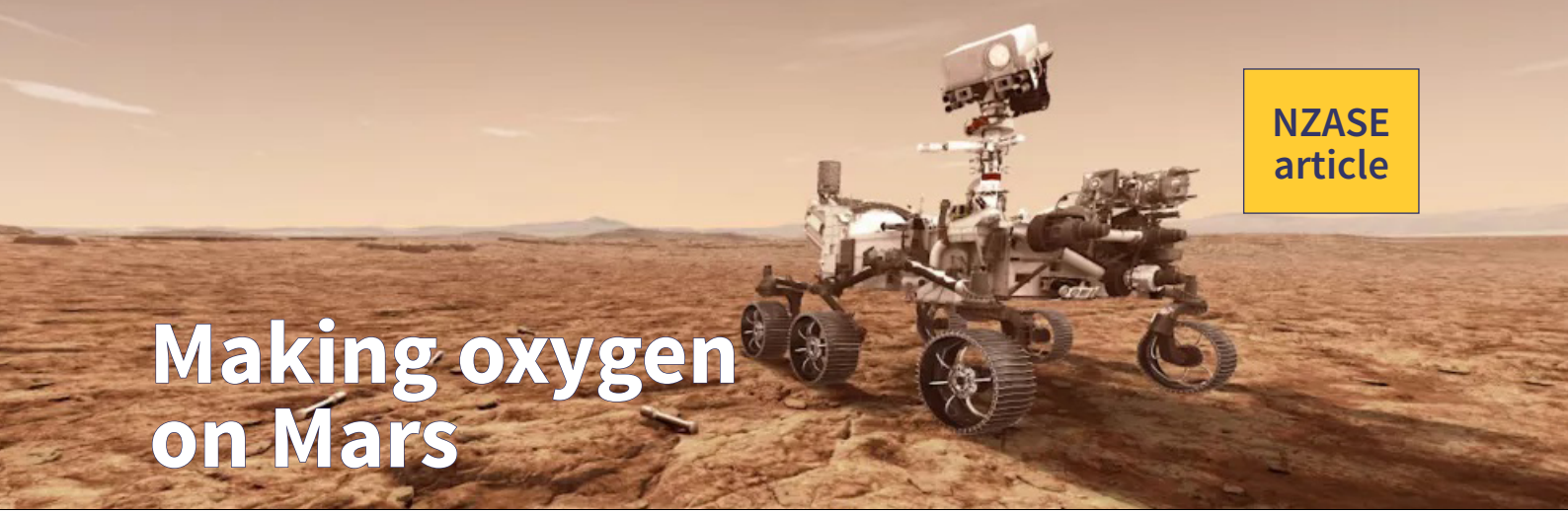


NZASE article

Making oxygen on Mars

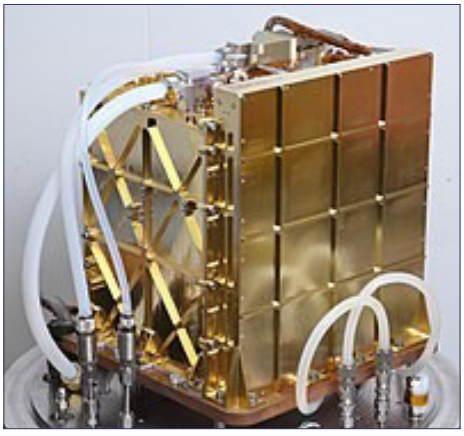
The production of oxygen on Mars is an application of electrolysis and reaction rate that is in the news.

NASA's Perseverance rover launched on July 20, 2020 and landed safely on Mars on February 18. As well as finding out more about the planet, NASA will use it to test several ideas in preparation for human missions to Mars.

Mars is a challenging planet for astronauts. Its average temperature is -81°C, about that experienced in central Antarctica. It has a thin atmophere (0.2% of earth's), which exposes astronauts to harmful radiation from the sun in much greater quantities than on earth[1].

For humans to explore Mars, several problems need to be solved[2].

- How to keep astronauts safe from **dust storms and radiation** – earlier missions analysed dust chemistry and measured radiation, providing parameters for protection.
- **How to land large vehicles** on the planet – four NASA rovers have now landed safely.
- How to **bring fuel, and oxygen and construction materials** to Mars – using Martian resources would save a lot of space, weight, fuel, and money for the journey to Mars. This problem is still to be solved.



MOXIE is about the size of a toaster, 30cm each side. Photo: NASA/JPL-Caltec.

Astronauts need oxygen to breathe on Mars (about one tonne each per year). Much more is needed (25 tonnes) to burn the fuel to take them home[3]. Such a volume and mass is too heavy and bulky to bring to Mars, so NASA scientists need to learn how to make it there.

Enter MOXIE, the Mars OXygen In-situ resource utilization Experiment (MOXIE). This instrument in Perseverance uses atmospheric CO2 to make a small quantity of oxygen, as a trial to see if the process will work on Mars.

The Mars Perseverance Rover. Photo: NASA/JPL-Caltec.

Reaction steps inside MOXIE

1. Filtration: Filters remove any dust and other particles from the air, and are designed not to clog in Martian conditions[4].

2. Compression: The air has to be compressed because the thin Martian atmosphere means atmospheric pressure is low, and any volume of air only contains only a very small amount of CO_2.

3. Heating: The electrolyte/catalyst operates at 800°C so the gases need to be heated for 2.5 hours before the reaction will occur. The nickel alloy parts inside MOXIE are heat-tolerant. A light-weight aerogel helps protect the other instruments on Perseverance. The box is made out of gold so it does not interfere with other electronics in the Rover, and because it doesn't radiate heat effectively[5].

4. Solid oxide electrolysis – a ceramic oxide, yttria-stabilized zirconia (YSZ), conducts oxide ions (O^{2-}) when heated, so acts as a solid electrolyte. A thin, nonporous disk of YSZ is sandwiched between two porous electrodes. CO_2 diffuses through the porous cathode (negative electrode) and on reaching the hot electrolyte releases an oxygen atom, picking up two electrons from the cathode to become an oxide ion (O^{2-}).

This is transported through the crystal

Main constituents	Earth (%)	Mars (%)
Oxygen	20.9	0.17
Nitrogen	78.1	1.9
Carbon dioxide	0.04	96
Argon	0.93	1.9
Other trace gases	0.03	0.03

lattice of the electrolyte, transferring its charge to the anode, and combining with another oxygen atom to form oxygen gas (O_2), which diffuses out of the anode.

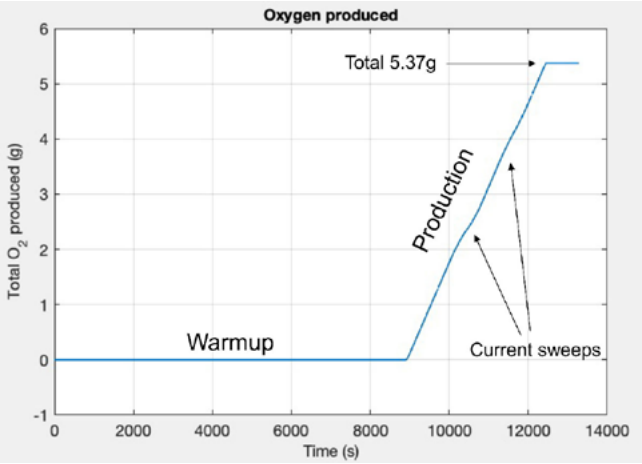
The net reaction is thus 2 CO_2 → 2 CO + O_2. Other gases in the air (see table above) are returned to the atmosphere with the carbon monoxide (CO) and unused CO_2.

MOXIE draws on Perseverance's batteries, which it must share with other instruments. This means that MOXIE must cycle on and off, alternately freezing and sweltering. This cycling is harmful, so some carbon monoxide is recirculated to prevent carbon dioxide from degrading the reaction site.

So far MOXIE has been tested only once (below). While the oxygen produced is not being stored, MOXIE can detect oxygen production from a pressure sensor, an oxygen indicator molecule and an ammeter. A microphone detects the compressor's health from its hum.

MOXIE makes only about six grams of O_2 an hour, enough for a small dog. Humans need six times that amount to breathe, and a rocket needs about 200 times that amount to return home.

MOXIE will be tested at various times of the day and night, in different seasons and during a dust storm. If the instrument proves successful over a Martian year, 687 earth days, then it could be scaled up for later missions.



MOXIE's first Martian oxygen production test, April 20, 2021

Questions

1 Work out the change in oxidation numbers in the net reaction, to determine which element is being reduced and which is being oxidised.

2 How are steps 1-4 designed to increase the rate of reaction?

References

1 Wikipedia, 2021. Atmosphere of Mars

2 *Smithsonian Magazine*, 2020. To make oxygen on Mars, NASA's Perseverance Rover needs MOXIE.

3 NASA, 2021. NASA's Perseverance Mars Rover extracts first oxygen from red planet.

4 Imperial College London, 2021. Mars rover makes breathable oxygen on red planet for first time.

5 *The Science Times*, 2020. NASA to use gold in creating oxygen on the moon soon? How is that possible?

6 European Space Agency, 2018. Comparing the atmospheres of Mars and Earth.

Videos

Seeker, 2020. NASA's gold box will make oxygen on Mars. (5m30s)

Crazy Engineering, 2019. Making oxygen on Mars with MOXIE. (3m)

Ngā Kupu

Hāora – Oxygen
Hauhā – Carbon dioxide
Hihinga – Radiation
Kaipōkai tuarangi – Astronaut
Kōhauhau – Atmosphere
Kōura – Gold (Au)
Matawhero – Mars
Papatipu – Mass
Tauhohe pāhiko – Electrolysis
Waro – Carbon
Whakamātau – Experiment, trial.

From Paekupu