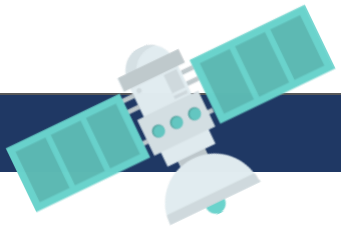
Martian Chemistry



Overview

Age Range:

10-14

Lesson Time:

45 Minutes (including 2 videos)

Equipment Needed:

Computer

Projector

Topics Covered:

Chemistry (solubility, saturation, compound structures)
Biology (life in extremes)
Astronomy (Mars surface conditions)

Activity Outline

Understand how the chemistry of the martian soil may affect the habitability of the Red Planet. This involves taking a closer look at how temperature and salinity can affect the chemistry of Mars.

Learning Outcomes

After completing this activity, pupils will:

- Understand what effect temperature has on the chemistry of Mars.
- Be able to explain how salinity affects freezing points.
- Review how all the above affect habitability.

Background Material:

Slide 1 - Introduction

In this lesson we will be looking at the chemistry of Mars and how this can affect its potential habitability.

Slide 2 - Objectives

Can be seen above in Learning Outcomes.

Slide 3 – CO_2 on Mars - Atmosphere

First, we are going to turn our attention to the martian atmosphere. The air on Mars is far thinner than the air which we breathe here on Earth. The density of Earth's atmosphere is approximately 1.2 kg/M^3 whereas the atmosphere on Mars is only 0.02 kg/M^3 - more than 50 times thinner.

The martian atmosphere also differs significantly from our own in terms of chemical composition. Earth's atmosphere is about 78%

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nitrogen, 21% oxygen, 1% argon, 0.04% carbon dioxide, and small amounts of other gases. Air also contains a variable amount of water vapour, on average around 1% at sea level, and 0.4% over the entire atmosphere. In stark contrast the atmosphere of Mars is 96% carbon dioxide.

Slide 4 – Introduction to CO_2

Knowing that, let's take a look at carbon dioxide. Carbon dioxide is a double covalent bonded molecule consisting of 2 atoms of oxygen bonded to 1 carbon atom, giving us 4 bonded electrons in total. Carbon dioxide is usually found in the form of a gas here on Earth, but at -80°C it will freeze into a solid compound commonly known as dry ice. Solid carbon dioxide can be found at the poles of Mars, where it can drop to temperatures as low as -120°C. These regions, known as permafrost, are known to also contain molecules of water (but we'll touch upon that a bit later).

Carbon dioxide has some interesting properties: one of example of this is that it only forms a liquid phase under high pressure. Without that pressure it passes from a solid to a gas in a process known as sublimation.

Slide 5 – Dry Ice Sublimation Video

Here is a video showing this in action: https://youtu.be/JZM0soeTp5o

Video background information: Sublimation is the transition of a substance directly from the solid to the gas state, without passing through the liquid state. Sublimation is an endothermic process that occurs at temperatures and pressures below a substance's triple point in its phase diagram, which corresponds to the lowest pressure at which the substance can exist as a liquid. The reverse process of sublimation is deposition or de-sublimation, in which a substance passes directly from a gas to a solid phase. Sublimation has also been used as a generic term to describe a solid-to-gas transition (sublimation) followed by a gas-to-solid transition (deposition). A transition from liquid to gas is described as evaporation if it occurs below the boiling point of the liquid, and as boiling if it occurs at the boiling point. However, there is no such distinction within the solid-to-gas transition, which is always described as sublimation.

Slide 6 – Subglacial Lake on Mars

Despite the temperature on the poles of Mars being easily low enough for the deposition of dry ice, some theorise that there may be lakes of water beneath the ice. This has been debated for the last 30 years as a possibility then between 29 May 2012 and 27 December 2015. A European Space Agency (ESA) mission (MARSIS instrument on Mars Express) surveyed a 200 km-wide area of Planum Australe on the martian South pole. This was done using a technique similar to sonar to gather the information on the composition of the permafrost. There

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	was an area that was surveyed that was anomalous in nature; here is an image of the data collected by this survey.
Slide 7 – Review Diagrams	Discuss in your groups if you think this is enough evidence to justify the claim of a liquid water lake. How could this exist in such a cold climate? (Allow time for discussion) (Take answers)
Slide 8 – Salts and Freezing points of water	Whether or not there is a subglacial lake is still up for debate. However, one proposed explanation for how it could exist is the high levels of salinity. Sodium chloride, or table salt, has often been used for clearing ice - consider how salt grit is used on roads during the winter.
Slide 9 – Salts and freezing point video	Here is a video of an experiment comparing the freezing of water and salt water by the means of dry ice: https://youtu.be/4thXp3lqGy4 Video background information: Salt (NaCl) dissolves into its ions in water, Na^+ and Cl^-. The ions diffuse throughout the water and block the water molecules from getting close enough together and in the right orientation to organise into the solid form (ice). Ice absorbs energy from its surroundings to undergo the phase transition from solid to liquid. This could cause pure water to re-freeze, but the salt in the water prevents it from turning into ice. However, the water gets colder than it was. The temperature can drop below the freezing point of pure water. Adding any impurity to a liquid lowers its freezing point. The nature of the compound does not matter, but the number of particles it breaks into in the liquid is important. The more particles that are produced, the greater the freezing point depression. So, dissolving sugar in water also lowers the freezing point of water. Sugar simply dissolves into single sugar molecules, so its effect on freezing point is less than you would get adding an equal amount of salt, which breaks into two particles. Salts that break into more particles, like magnesium chloride ($MgCl_2$) have an even greater effect on freezing point. Magnesium chloride dissolves into three ions -- one magnesium cation and two chloride anions.
Slide 10 – Discuss what happened? Why?	What did you observe in that video? Discuss in your groups and feedback. (Allow time for discussion) (Take answers)

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Slide 11 – Kangerlussuaq Field Site

One way that researchers are hoping to gain more information on this possibility is by exploring analogues here on Earth. One of the best analogues for the martian poles are areas such as Kangerlussuaq in Greenland. Greenland is the world's largest island and over three-quarters of its surface is covered by the only permanent ice sheet outside of Antarctica. It is therefore one of the few truly extreme cryogenic environments on Earth and yet is relatively accessible.

Kangerlussuaq is on the west coast of Greenland and is one of the most accessible regions of the island, having an international airport. Once there, it is possible to access the glacial ice sheet and vast regions of permafrost.

Slide 12 – Could life exist in Kangerlussuaq or a subsurface lake on Mars?

Do you think life could exist within either Kangerlussuaq or the potential subsurface lakes on Mars? Please discuss in your groups.

(Allow time for discussion)

(Take answers)

Slide 13 - Review

From this lesson, you should be able to answer the following:

- What effect does salt have on the freezing point of water?
- What is dry ice? What is permafrost?
- How does the chemistry on Mars affect habitability?

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