UNIT STORYLINE

Unit Question: How can we find, make, and recycle the substances we need to live on and beyond Earth?

How students will engage with each of the phenomena

Lesson Set 1: How can we find water and other substances we need to survive on other objects in space?

Lesson Question

LESSON 1

Lesson Set 1

4 days

What substances would we need and how would we get them to live and work beyond Earth?

Anchoring Phenomenon

Phenomena or Design Problem

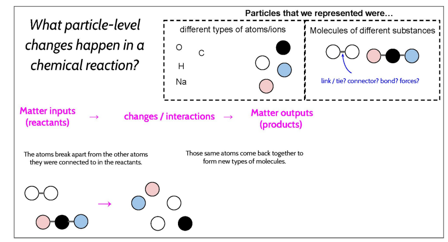
Hundreds of crews have lived and worked in space for limited amounts of time. Future space travel would require us to remain there for longer amounts of time.

What we do and figure out

We examine a video of NASA's plans in the near future. We identify criteria, constraints, and solutions for living and working beyond Earth for longer periods of time. We develop models of how new substances are made through chemical reactions. We add questions to a Driving Question Board and brainstorm ideas for data and investigations that could help answer them. We figure out:

- People need certain substances to live and support the kinds of work they might want to do in places beyond Earth.
- The scale of the solar system and the cost and speed of space travel mean that most of the substances that we need to live and work would have to be found, recycled, or made on-site.
- New substances (product(s)) can be created from one or more reactants through the rearrangement of matter in chemical reactions.

How we represent it



⇓ **Navigation to Next Lesson:** Though we have lots of ideas for investigations and data that we will need to answer our questions, we prioritized figuring out more about our water-related questions first.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

LESSON 2
Lesson Set 1

2 days

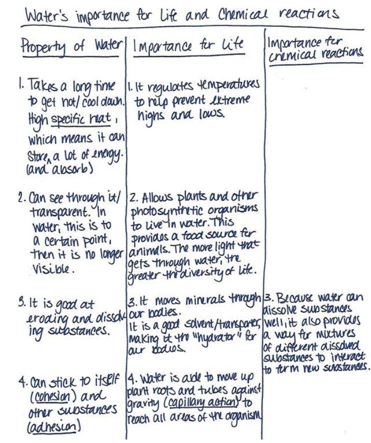
How does water support life and chemical reactions?

Investigation

Substances have different properties such as specific heat, ability to dissolve other substances, and transparency to light.

We discuss other chemical reactions that include water, what is special about water, and properties of water we previously studied. We gather information on water's properties from two out of six investigation stations. We integrate our information from across the six investigation stations. We figure out:

- Water supports life and is used in chemical reactions because of its properties.
- Some of those properties include surface tension, high specific heat capacity, transparency, and ability to dissolve most substances.



Water's importance for Life and Chemical reactions

Property of Water	Importance for Life	Importance for chemical reactions
1. Takes a long time to get hot/cool down. High specific heat, which means it can store and a lot of energy. (and absorb)	1. It regulates temperatures to help prevent extreme highs and lows.	
2. Can see through it/ transparent. In water, this is to a certain point, then it is no longer visible.	2. Allows plants and other photosynthetic organisms to live in water. This provides a food source for animals. The more light that gets through water, the greater the diversity of life.	
3. It is good at eroding and dissolving substances.	3. It moves minerals through our bodies. It is a good solvent/transporter, making it the "hydrator" for our bodies.	3. Because water can dissolve substances well, it also provides a way for mixtures of different dissolved substances to interact to form new substances.
4. Can stick to itself (cohesion) and other substances (adhesion)	4. Water is able to move up plant roots and tubes against gravity (capillary action) to reach all areas of the organism.	

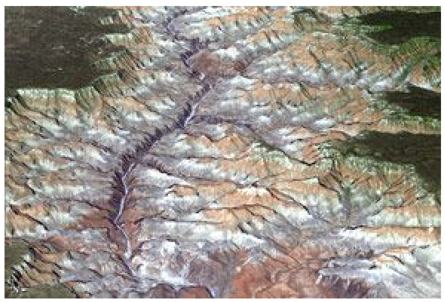
⇓ **Navigation to Next Lesson:** We identify pictures as a source of evidence we could use to figure out whether there is water on other places beyond Earth.

LESSON 3
Lesson Set 1

1 day

How can we find evidence of the water we need on the surfaces of other objects in space?

Investigation



Photos of the surfaces of Earth, the Moon, and Mars have been taken from satellites or uncrewed mission vehicles above them.

We develop the "Surface Features and Causes" poster we use as evidence to support claims about which geologic processes caused the formation of surface features on Earth, the Moon, and Mars. We figure out:

- Some surface features on Earth were produced primarily by water erosion, while others were produced primarily by tectonic processes or meteor impacts.
- Mars's surface has some features that look similar to those produced by water erosion on Earth, while the Moon's does not.

Surface Features and Causes	
Water interacting with the surface	Some other process interacting with the surface
River beds - erosion Sedimentary deposits - deposition by a river or glacier Cracks - drought (lack of water) Avalanches - too much water (fast melting or a lot of rain) Canyons - erosion Sea/ocean cliffs - erosion Beaches - erosion	Volcanoes - movement of magma (plate movement) Cracks - earthquakes (plate movement) Craters - asteroid or meteorite impact Avalanches, rocks falling - gravity or wind Trenches - earthquakes (plate movement) Mountains - plate movement

⇓ **Navigation to Next Lesson:** We conduct investigations into what other liquids, if any, interacting with materials could have produced the surface features we see on the Moon and Mars.

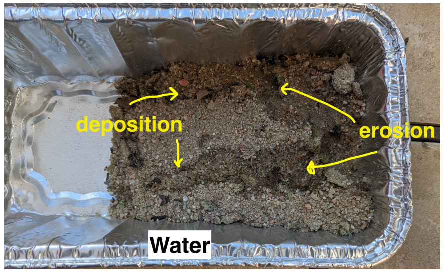
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

LESSON 4
Lesson Set 1

3 days

How and why do water and other liquids interact with materials to make surface features?

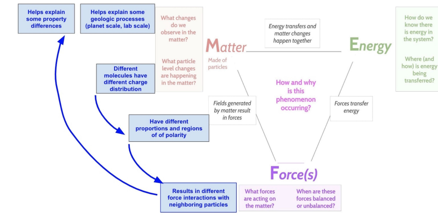
Investigation



Different liquids behave differently on the erosion table. Water erodes surface materials and expands when it freezes because of its polarity.

We investigate how liquids interact with surface materials to help us determine that surface features on Mars were likely made by water. We examine molecular models of them to compare polarities of different liquids. We figure out:

- Polar regions on molecules are due to a greater amount of negative or positive charge in that region of the molecule.
- Polar regions on molecules will produce force interactions with nearby polar regions on neighboring molecules, which can be used to explain some property differences between substances.
- Polar molecules could more easily erode some materials in their surroundings than nonpolar molecules.



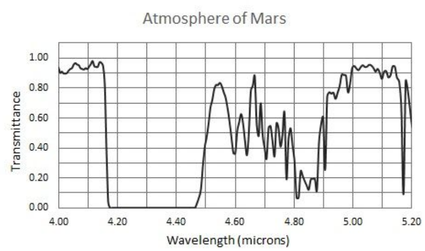
⇓ **Navigation to Next Lesson:** We wonder where we can look for or find water other than on the planetary surface.

LESSON 5
Lesson Set 1

2 days

How can we tell what is in the atmosphere (and just below the surface) of objects in space?

Investigation



Substances in an object's atmosphere, surface, or subsurface can be identified based on the light they absorb and transmit (spectroscopy).

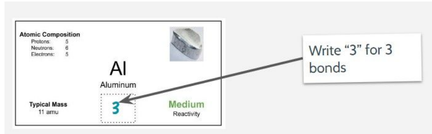
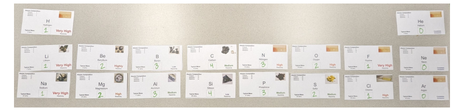
We use a projector-based spectrometer to investigate the absorption and transmission of light by solutions of pure substances and construct a way to graphically display this phenomenon. We use reference spectra to identify gasses in simple mixtures and in the atmospheres of objects in space. We figure out:

- Different substances absorb and transmit different colors of visible light and different wavelengths of non-visible light (e.g., infrared).
- Spectroscopy is the study of the light that is transmitted or emitted by different objects and is used to determine the presence of different gasses.
- Scientists can perform spectra analysis on the interactions of solids with sunlight to determine the presence of substances in the soil or ice.

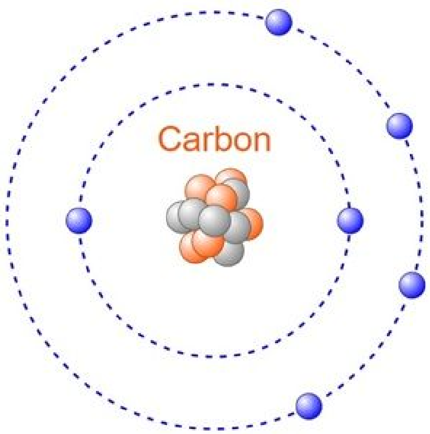
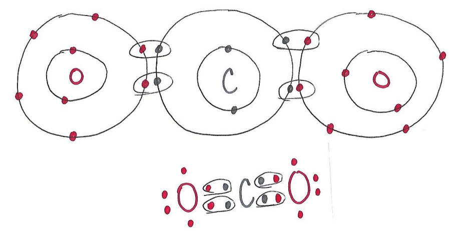
⇓ **Navigation to Next Lesson:** We figure out that water can be found in some atmospheres in the solar system, but we are still wondering about other elements we need for survival.

Lesson Set 2: Why do we need certain types of atoms to create the substances we need?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 6 Lesson Set 2 2 days **What patterns are there between the types of atoms and the number of bonds they form in the resources we need?** Investigation, Problematizing	 *Different elements have different numbers of subatomic particles and can be organized into patterns based on their atomic composition, numbers of bonds/charges formed, and chemical properties.*	We identify patterns in the numbers of subatomic particles (especially protons) and of bonds that different elements form and use these patterns to organize the elements. We figure out: • Elements have varying numbers of protons, electrons, and neutrons which correspond to changes in typical mass and atomic number. • Each element forms a specific number of bonds/charges when it combines with other elements. • Elements are arranged on a table based on their repeating properties (numbers of bonds/charges formed, reactivity, composition, etc.). • Patterns in elements’ bonds/charges repeat (periodicity), while atomic mass and number of protons increase across rows.	

⇓ **Navigation to Next Lesson:** We compare the number of electrons in carbon to the number of bonds it forms and notice that the numbers do not match. We wonder where the missing electrons went.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 7 Lesson Set 2 2 days **Why is there a difference between the number of electrons an element has and the number of bonds an element forms?** Investigation	 *The electron shell model can account for differences in electron numbers in elements and connections formed by elements.*	We examine new models of atomic structure and evaluate the usefulness of different models to explain and make predictions about interactions between elements (bonds). We figure out: • Various models of atomic substructures can be used to try to account for differences in the numbers of electrons and connections formed by the element carbon. • A model of atomic structure illustrating valence electrons is best for determining the number of interactions (connections) each element will have with other elements.	

⇓ **Navigation to Next Lesson:** We wonder what is exactly happening between two elements when electrons bond to each other.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

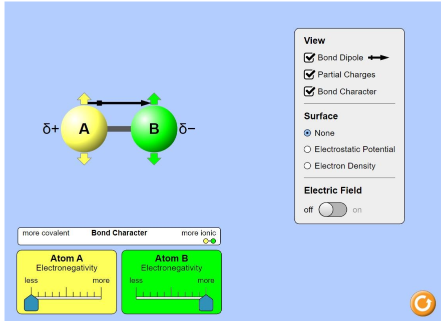
LESSON 8

Lesson Set 2

2 days

Could another substance serve as a substitute for water for some of the processes we need to use it for in space?

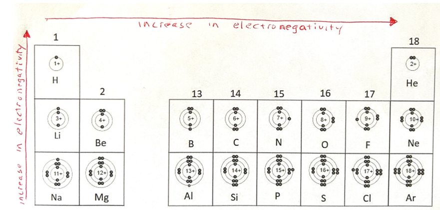
Investigation



Many properties of water are different from the properties of hydrogen sulfide.

We predict whether another substance could replace water for some processes and model the structures of H_2O and H_2S molecules. We explain why the electronegativities of O and S are different and use a simulation to explore how electronegativity differences affect where electrons are in a bond, the bond characteristic, and its polarity. We figure out:

- Differences in the polarity of H_2O and H_2S molecules help explain some of their property differences.
- Electronegativity is a measure of how strongly a nucleus is attracted to shared electrons. Greater electronegativity equals stronger attraction.
- Atoms of elements with more electron shells are larger. The size of an atom is called the atomic radius.
- Electronegativity is affected by an atom's atomic radius and amount of charge.



⇓ **Navigation to Next Lesson:** We brainstormed examples of substances with undesirable properties or side effects to begin to consider substitute substances that we can use in some of the processes needed for living and working in space and on Earth.

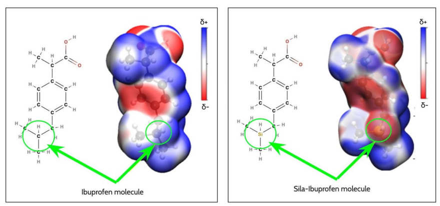
LESSON 9

Lesson Set 2

2 days

How can the ideas we developed be applied to making a possible substitute for another substance?

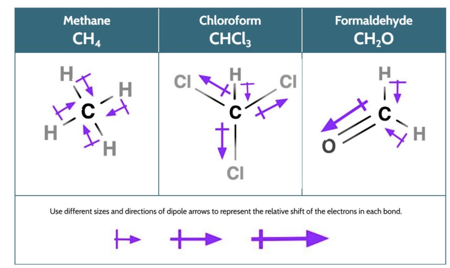
Putting Pieces Together



Biochemists have developed a new medicine, sila-ibuprofen, by substituting a single silicon (Si) atom for a carbon (C) atom in the ibuprofen molecule.

We describe bond characteristics in salt, wood, and metal and consider salt substitutes in our diets. We complete the Mid-Point Assessment. We figure out:

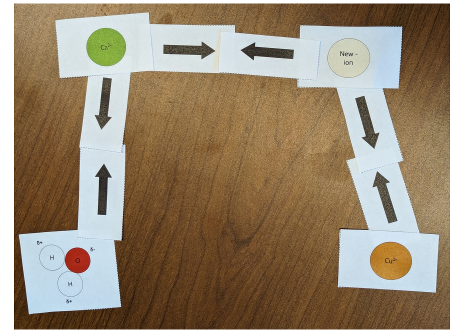
- Some pairs of atoms can form double or triple bonds.
- The polarity of a molecule can be determined by comparing the relative polarities of bonds within it. Which can be determined from the difference in the electronegativities of the atoms that make up the bond.
- Some biochemistry and environmental chemists work on designing new substances, like medicines, that have more desirable properties or fewer side effects than those we use now.



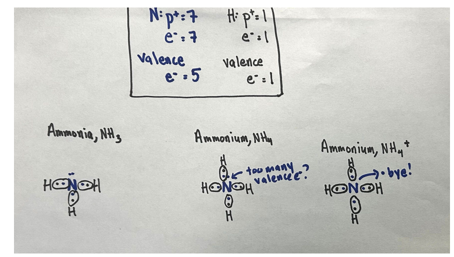
⇓ **Navigation to Next Lesson:** We made progress on many of our DQB questions, but we have a lot of questions about the role of water in so many of these chemical reactions.

Lesson Set 3: How can we make the substances we need to survive off of Earth using the existing matter in the solar system?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 10 Lesson Set 3 1 day **Why do we need water in so many reactions?** Problematizing 	 *Dissolved copper ions can be cleaned from water with certain types of reactions.*	We return to the different processes we encountered in Lesson 1, with more information about the reactions that are occurring. We read about how copper can be cleaned from water by forming a precipitate and model this reaction. We figure out: • Water is involved in many reactions and must be clean for them to work properly. • Ions come together so that the substance formed is neutral. • The intermolecular forces between water (a polar molecule) and certain ions allow for the observed cleaning reaction to occur. • Some substances cannot be easily dissolved because their bonds are too strong.	

⇓ **Navigation to Next Lesson:** We wonder what other substances we might need to remove from the water we find on Mars before we use it.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 11 Lesson Set 3 2 days **How can we grow food in space?** Putting Pieces Together, Investigation 	 *Plants can be grown in space to give us many materials for survival, but we need to enrich the soil with fertilizer.*	We engage in a reading about growing plants in space and model the differences between ammonia (NH_3) and ammonium (NH_4^+). We read about perchlorate ions in martian soil and model chemical reactions. We figure out: • To successfully grow plants off of Earth, nitrogen must be added to the soil. Two possible fertilizers, ammonia (NH_3) and ammonium (NH_4^+), could be added to the soil. • NH_3 and NH_4^+ have different structures and charges. Ammonium could be made successfully in space. • Polyatomic ions are substances that have many atoms but carry an overall net charge.	

⇓ **Navigation to Next Lesson:** We look to outer space to find the other materials we need to survive beyond Earth.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

LESSON 12
Lesson Set 3

2 days

Which location(s) in the solar system has the elements we need and what relative amount is required to make any substance?

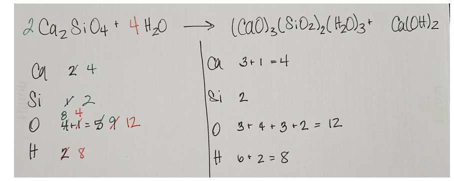
Investigation

Process	Reactants				Products	
Photo-synthesis	Carbon dioxide CO_2	Water H_2O			Glucose $C_6H_{12}O_6$	Oxygen O_2
Making steel	Iron Fe	Carbon C	Manganese Mn		Steel* $Fe_{59}CMn$	
Making glass	Silica SiO_2	Sodium carbonate Na_2CO_3	Calcium carbonate $CaCO_3$		Glass* $(Na_2O)(CaO)(SiO_2)_6$	Carbon dioxide $CaCO_3$
Making hardened cement	Tricalcium silicate Ca_3SiO_5	Dicalcium silicate Ca_2SiO_4	Tricalcium aluminate $Ca_3Al_2O_6$	Water H_2O	Hardened cement* $(CaO)_{34}(Al_2O_3)(SiO_2)_{20}(H_2O)_{38}$	
Making plastic	Terephthalic acid $C_8H_6O_4$	Ethylene glycol $C_2H_6O_2$			Polyethylene terephthalate* $\sim(C_{10}H_8O_4)_n\sim$	Water H_2O

Three Mars rovers have sampled the chemical composition of surface material at three different locations. Experimental studies of sulfur-based concrete have been carried out on Earth.

We add more molecules of some reactants and products to ensure there are equal numbers of elements on both sides of the equation. We obtain information about cement production using substances on Mars. We figure out:

- Since matter cannot be created or destroyed, balanced chemical equations must have equal numbers of each element in the reactants and products. This is done by adding coefficients to reactants and products in the chemical reaction.
- Mars has more of the elements needed to make the substances to live and work in space than any other location in the solar system.
- It is possible to develop processes to make the substances we need that utilize in situ resources if we know what elements are present on an object in space and their amounts.



⇓ **Navigation to Next Lesson:** We wonder about recycling sulfur concrete and other materials on Mars and here on Earth.

Lesson Set 4: How can we be more sustainable in what we use and produce?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

LESSON 13
Lesson Set 4

2 days

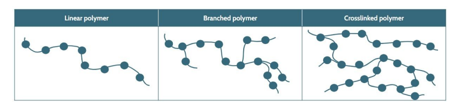
Why can we recycle some of the substances we need and not others?

Investigation

Different people and communities are able to recycle some substances but not others.

We synthesize information from various sources to answer questions about why we recycle some of the substances we need but not others, and how this could apply to our long-term plans for living and working beyond and/or on Earth. We figure out:

- We can recycle some substances by melting, freezing, and reshaping
- Polymers are molecules with chains of repeating subunits (monomers).
- There are a variety of naturally and synthetically produced polymers that have different characteristic properties that make them well suited to specific uses.
- The structure of the polymer affects its properties.



⇓ **Navigation to Next Lesson:** We identified some candidate substances that we hope to see scientists and engineers develop more sustainable substitutes for, and wonder what new research is happening along those lines.

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LESSON 14
Lesson Set 4

1 day

What are some more sustainable approaches we are developing to help us make the things we need off of Earth and on it?

Investigation

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Innovative materials technologies could be more sustainable, both off of and on Earth.

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We read articles about different innovative materials technologies. We share with a partner and evaluate the arguments made in the articles. Then we share our evaluations with a pair that investigated a different set of materials technologies. We figure out:

- New technologies may allow for common materials (or replacement materials) to be more sustainable.
- A given material must have the right microscopic structures and resulting forces in order to produce the desired bulk-scale interactions.
- Technologies that could aid living off of Earth could make life on Earth more sustainable, but in general using less of a given material is best.

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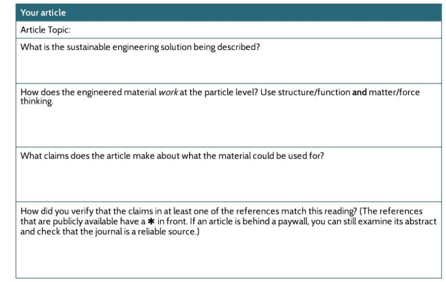

Your article
Article Topic:
What is the sustainable engineering solution being described?
How does the engineered material *work* at the particle level? Use structure/function **and** matter/force thinking.
What claims does the article make about what the material could be used for?
How did you verify that the claims in at least one of the references match this reading? (The references that are publicly available have a ✱ in front. If an article is behind a paywall, you can still examine its abstract and check that the journal is a reliable source.)

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⇓ **Navigation to Next Lesson:** We figure out that different materials technologies could support living off of Earth as well as sustainable living on Earth. We think that human survival beyond Earth could be possible one day, but are unsure whether it is a good idea.

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LESSON 15
Lesson Set 4

3 days

What is the full impact of going to space?

Putting Pieces Together

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Soap scum forms on surfaces due to interactions between dissolved ions.

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Students read about perspectives on space travel, balance a final equation, close out the DQB, and then demonstrate their understanding on a transfer task about the formation of soap scum. We figure out:

- There are competing science and ethics arguments about human survival in space.
- The elements available to us in outer space limit what we can build on another planet. Matter cannot be gained or lost in a chemical reaction.
- Soap scum is formed as a result of interactions between polyatomic ions and other ions that are dissolved in water.

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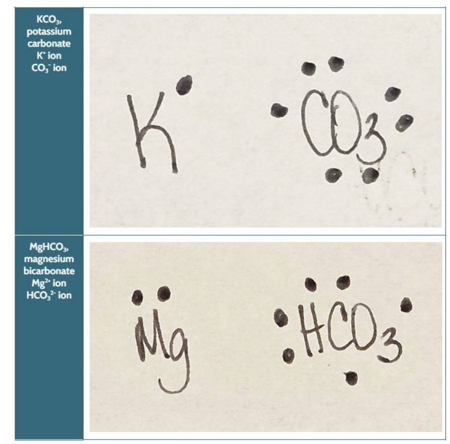

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⇓ **Navigation to Next Lesson:** This is the final lesson of the unit.

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LESSONS 1-15
31 days total