**Unit Essential Question:** *How does energy and matter flow within natural and designed ecosystems?*

**Introduction**

In the last task, students began to explore chemical changes by looking for changes in properties, implying a molecular change. In this task, students continue their exploration of chemical changes with a few example reactions—combustion and cellular respiration. Students are first engaged with the mystery of the extinguished candle, which allows them to practice modeling a chemical reaction and also helps them to begin to explore the concept of conservation of matter. By analyzing a chemical reaction as a molecular model, students begin to see that when molecules are broken down, they don’t just disappear; rather matter is conserved, molecules are rearranged, and energy is released in the process. Students then apply what they have learned to a chemical reaction that is very important to their river environment—cellular respiration. Students create both physical and visual models of this chemical equation to explore the idea that the total number of atoms is conserved and thus mass is conserved. This is one way matter and energy move through ecosystems. Armed with understanding of this chemical reaction, students will be able to first decide what components are needed in their aquaponics system, and then begin to conceptualize what the cycling of energy and matter looks like in their system.

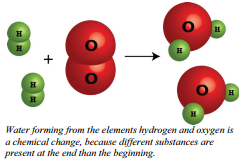
**Alignment Table**

|  |  |  |  |
| --- | --- | --- | --- |
| **Performance Expectations** | **Science and Engineering Practices** | **Disciplinary Core Ideas** | **Crosscutting Concepts** |
| **MS-LS1-7.** **Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release energy as this matter moves through an organism.** [Clarification Statement: Emphasis is on describing that molecules are broken apart and put back together and that in this process, energy is released.] [Assessment Boundary: Assessment does not include details of the chemical reactions for photosynthesis or respiration.] | **Developing and Using Models**   * Develop a model to describe unobservable mechanisms. | **LS1.C: Organization for Matter and Energy Flow in Organisms**   * Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, and to release energy.   **PS3.D: Energy in Chemical Processes and Everyday Life**   * Cellular respiration in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials (*Secondary*). | **Energy and Matter**   * Matter is conserved because atoms are conserved in physical and chemical processes. |
| **MS-PS1-5.** **Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved**. [Clarification Statement: Emphasis is on law of conservation of matter and on physical models or drawings, including digital forms that represent atoms.] [Assessment Boundary: Assessment does not include the use of atomic masses, balancing symbolic equations, or intermolecular forces.] | **Developing and Using Models**   * Develop a model to describe unobservable mechanisms. | **PS1.B: Chemical Reactions**   * Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules and these new substances have different properties from those of the reactants. * The total number of each type of atom is conserved, and thus the mass does not change. | **Energy and Matter**   * Matter is conserved because atoms are conserved in physical and chemical processes. |
| **Equity and Groupwork**   * Discuss observations of models and experiments. * Work within group roles to co-construct models of different chemical equations. * Use a successive pairing structure to share ideas and feedback. | | | |
| **Language**   * Use compare and contrast language to compare the opposite sides of a chemical reaction. * Describe a phenomenon using pictures, arrows, and words. * Practice oral language and refine written language using the Stronger and Clearer Protocol. | | | |

**Learning Goals**

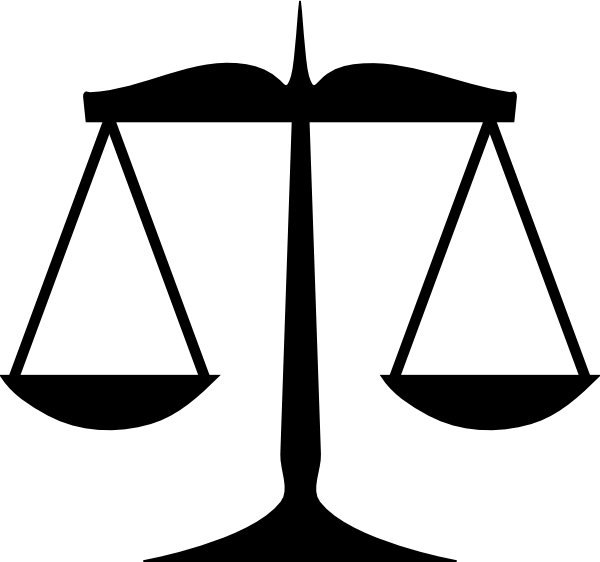
This learning task asks students to explore how chemical reactions work on an atomic level. More specifically, the purpose is to:

* Engage prior knowledge of chemical changes and use it to analyze a familiar model.
* Explore what happens when you take away a reactant in a chemical reaction.
* Develop a model for cellular respiration that shows conservation of matter.
* Practice explaining a model to peers and revise based on feedback.
* Apply knowledge of cellular respiration to an aquaponics system design.

**Content Background for Teachers**

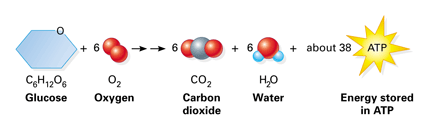
In this task, students continue to develop their understanding of chemical changes by digging deeper into the molecular level of chemical reactions. Students use experimental demonstrations and chemical equations to develop their own conceptions of conservation of matter.

In a chemical equation, the reactants of the chemical reaction are depicted on the left and the products of the chemical reaction are depicted on the right, with an arrow between that represents the reaction. In a chemical reaction, the actual molecules change into new and different molecules. Students were introduced to these concepts and terms in Task 1. Throughout the task, students look at two chemical equations: the chemical equation for burning candle wax and the chemical equation for cellular respiration. In both of these cases, students are analyzing the equations to notice the similarities and differences between reactants and products.



Students should find that the reactants and products are different because the arrangement of atoms is different—in other words, the molecules are different. This is consistent with what they know about chemical changes from Task 1. However, students should also find that the reactants and products are similar in that the number of atoms of each type is the same. This is known as the principle of conservation of matter, which states that atoms cannot be created or destroyed in a chemical reaction. Rather than define this concept for students, students come to this understanding on their own by using models of chemical reactions.

They first use the candle covered by a jar demonstration as the context for discovering conservation of matter. What is happening in this demonstration? The candle wax (a solid) releases the fuel (methane gas) as it melts near the flame and is absorbed into the wick. The fire is evidence of an exothermic reaction between oxygen gas and methane gas (wax vapor). When you cover the jar, it takes away the oxygen, so the reaction can no longer continue. No atoms disappear in this chemical reaction; they are merely rearranged into new substances (carbon dioxide and water). Thus, when you take away oxygen, you cannot create the carbon dioxide and water out of nothing.

This concept of conservation of matter is tested further with an example relevant to the phenomenon of the unit—the changing river environment. In every environment, living organisms eat food (glucose) and breathe in oxygen, which is then converted into energy. Any excess glucose is stored and leads to organism growth. Carbon dioxide and water are created as byproducts in the process of cellular respiration. Students make their own model of this process, using manipulatives of different colors to represent each atom. By weighing each side of the equation on a scale, they will have more proof that the total number of atoms does not change in a chemical reaction, and thus mass is conserved. These ideas can then be represented in their individual visual model and written explanation.

By the end of the task, students will be able to relate the concept of conservation of matter to cellular respiration in a way that will help them think about the needs of their Aquaponics System. Drawing a model of what is needed and created by every organism doing cellular respiration will help students decide what to include in their system.

\*\*If you feel like students need more direct instruction around these ideas, you may provide them with “The Science Behind It” Resource Card during the *Explain*, which is located at the end of this teacher guide.

**Academic Vocabulary**

* Chemical Reaction
* Product
* Reactant
* Molecules
* Atoms
* Cellular Respiration
* Oxygen
* Carbon Dioxide
* Water
* Glucose
* ATP
* Energy
* Matter
* Mass

**Time Needed (Based on 45-Minute Periods)**

4 Days

* Engage: 0.5 period
* Explore: 1 period
* Explain: 1 period
* Elaborate: 0.5 period
* Evaluate and Reflection: 1 period

**Materials**

* Unit 3, Task 2 Student Version

Explore

* Candle
* Match or lighter
* Large Clear Jar

Explain (Per Group)

* Optional: If you feel your students need a more traditional pre-teaching of this material, use the resource card at the end of this Teacher Version, entitled “The Science Behind It,” as either a reading for students or a resource for your own powerpoint presentation.
* Balancing scale or 2 normal scales
* “Atom Pieces”: These can be a modeling kit, unifix cubes, colored beads, legos, jelly beans, or any materials available in three colors
  + 6 for Carbon
  + 12 for Hydrogen
  + 18 for Oxygen
* Colored pencils or crayons

Evaluate

* Project Organizer Handout

**Instructions**

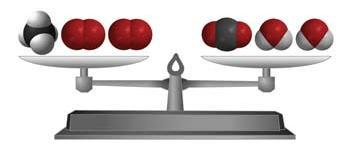
**Engage**

1. Introduce Task 2: In Task 1, you investigated different types of changes that happen in an environment—both physical and chemical changes. Think about what you were still wondering about at the end of the last task (look back if you need to). What questions do you still have?
   * Before you pass out their student guide, give students time to reflect individually or with a partner about the questions they recorded at the end of the last task. Share a few of these out as a class, using facilitating questions to guide students toward questions that relate to this task.
2. Transition to Task 2: When a chemical change, or chemical reaction happens, the initial molecules form new molecules, but we can’t see this happening! In this task, you will explore different chemical reactions and develop a model to show what happens when an important chemical reaction in ecosystems occurs.
   * Now pass out the Task 2 student guide.
3. In pairs, ask students to look at the model of a chemical reaction from Task 1. This is their introduction to the SEP of **Developing and Using Models** in this unit, which they will continue to practice extensively throughout this task.
   * Using the discussion questions, students make observations of the model in partners. The purpose of these questions is to create a foundation for students to understand the concept of conservation of matter. Below are some potential observations students may make:
     + For question 1, students may observe a couple different things: there are three molecules on the left and only two on the right. On the left, the colors are separated, whereas on the right they are mixed together, etc.
     + For question 2, the sides of the equation are similar because there is the same number of each atom on each side. In other words, there are four small green circles on each side and 2 large red circles on each side.
4. After pairs discuss, use equity sticks to share out observations in a class-wide discussion (See “How to Use This Curriculum” for more details on how and why to use equity sticks).

**Explore**

1. In this Explore, students first experience the phenomenon of a candle extinguishing when covered with a jar and then use a model to try to explain what is happening. In the process, students are not only getting comfortable with modeling chemical reactions, but are also implicitly gathering more evidence for the concept of conservation of matter.
2. Read the paragraph from the Student Guide aloud to set the context for the demonstration: Let’s investigate chemical reactions with a familiar example—a burning candle. When a candle burns, the methane gas from the melted candle wax is reacting with the oxygen in the air. This results in a flame, carbon dioxide, and water.
   * Begin the demonstration by showing them the candle on your desk. Light the candle and allow students to watch it burn for several seconds. Then cover the candle with a clear jar and watch as the candle extinguishes. Repeat demonstration a second time as this allows students to generate more detailed observations in their Student Guides.
   * We recommend this be done as a teacher demonstration since it involves an open flame. However, this may be done in small groups if you prefer.
   * We also recommend you facilitate a brief discussion about student observations and initial hypotheses for why the flame eventually goes out when covered with the jar.
3. After seeing the demonstration and recording their observations, students are faced with the phenomenon of the extinguished candle. In order to better understand what is happening, they need to look at the chemical equation.

* In this activity, students are practicing **Developing and Using Models**, by using a model to describe an unobservable mechanism—the chemical reaction for a burning candle.

1. Assign roles to each group. You may use whatever roles you prefer. We recommend the use of the Materials Manager, Facilitator, Harmonizer, and Recorder.
   * Ask the Facilitator to read the directions and to make sure everyone understands the task.
   * Ask the Materials Manager to handle any resources needed to complete the task (ie. if you decide to also use physical manipulatives for the atoms).
   * Ask the Harmonizer to make sure that everyone contributes their ideas and that everyone’s voice is heard.
   * Ask the Recorder to make sure the group is recording their observations in their student guides.
2. Student groups use the chemical equation to count the number of each type of atom on each side of the equation. Recommended: project it on the board and write the common names for each molecule on the board underneath the equation. Methane from melted wax + oxygen > carbon dioxide and water (and flame).
   * You may want to model the process of counting atoms with carbon, which is already filled in on their student guide.
   * Students should come to consensus with the members of their group and record these numbers in the data table in their student guide.
   * They should find that the number of each atom on the left side matches up with the number of each atom on the right side, as shown in the image of the scale above.
3. Once students have modeled the chemical reaction, return to the original demonstration to see if they can now explain the mystery of the extinguished candle. Have students discuss the question on their student guide in pairs.
   * As they modeled the chemical reaction and now attempt to explain the mystery of the extinguished candle, they are emphasizing the CCC of **Energy and Matter** by showing that because atoms are conserved in chemical reactions, matter is conserved. This is why the reaction cannot continue and the flame goes out when one of the reactants—oxygen—is removed by covering the candle with a jar.
   * If students are struggling to figure out this phenomenon, you may want to provide some of the following facilitating questions: What do you notice about the atoms in the left side and the right side of a chemical reaction? Where do the atoms come from that make the carbon dioxide and the water on the right side (products) of the equation? What molecule on the left did we take away by placing the jar on top?
   * After pairs discuss, use equity sticks to share out different explanations in a class-wide discussion, using the facilitating questions above as prompts to guide the discussion if necessary (See “How to Use This Curriculum” for more details on how and why to use equity sticks).

**Explain**

1. Now that students have seen and modeled how atoms are conserved and rearranged through chemical reactions, they are ready to apply this knowledge to a relevant chemical reaction in the river environment—cellular respiration.

* Optional: As you transition from the *Explore* to this *Explain*, you may choose to tell students that this idea that atoms are merely rearranged in chemical reactions, rather than being created or destroyed, is known as “conservation of matter.”

1. While observing the river environment images, students likely noticed that there is a fully-grown deer in the present-day river environment. First have pairs of students reflect on this organism and use their prior knowledge to discuss what all animals need in order to grow and do their daily activities.

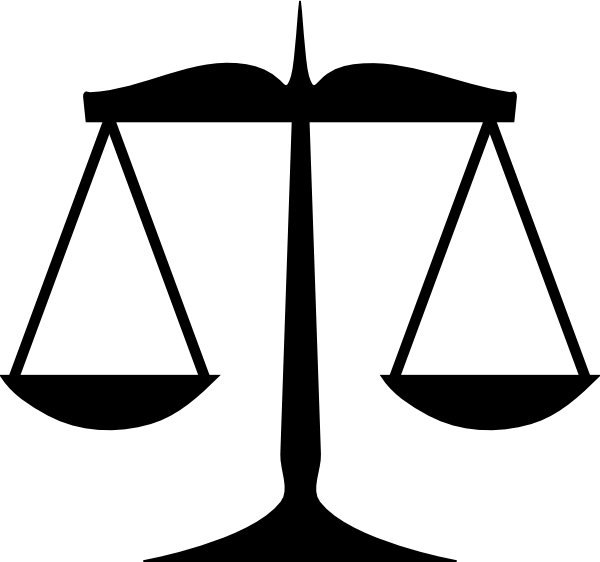
* Students will likely identify that animals need food, water, and air.

1. Building off this prior knowledge, have students read the information on the next page of their student guides individually, in groups, or as a class. This introduces them to cellular respiration, including why organisms do this process as well as the chemical reaction.

* Optional: switch out the word “glucose” for “sugar”.
  + Optional scaffold to aid student understanding: Make connections to what students experience in their everyday lives. For example, the sugar comes from the food they eat and the oxygen comes from the air they breathe. The carbon dioxide is breathed out and the water can be sweat out.
* Discussions of ATP can remain broad: ATP is the energy that our bodies need to do work, like walk around and think, and to grow.
  + Again, if you feel like students need more direct instruction around these ideas, you may provide them with “The Science Behind It” Resource Card at the end of this teacher guide.

1. Once students have a basic understanding of cellular respiration, they are ready to create physical models of the reaction as a group. This activity asks students to continue practicing the SEP of **Developing and Using Models**, as they develop a physical model to again describe the unobservable mechanism of a chemical reaction. With this model, students are also demonstrating understanding of the CCC of **Energy and Matter** as they show that in a chemical reaction, the atoms are conserved and thus matter and mass are conserved.

* Pass out the “Atom Pieces”, at least one set per group. Also provide each group with a balancing scale or two normal scales.
  + Because this is a group activity, we recommend assigning roles to each group, mixing up the roles they were assigned in the *Explore*.
  + Have students analyze the cellular respiration chemical equation and assemble the number of atoms on each side, using one color for each atom.
    - Students should first record the color they choose for each atom in their student guides.
    - Then students weigh these piles on the scales to see whether there is an even amount of mass on each side of the chemical equation.



1. Since students have had an opportunity to discuss and co-construct a physical model, they should be ready to independently make a drawing of their model. Remind students to use the checklist in their student guides to draw their model and write their explanation. Again, students are practicing **Developing and Using Models** and emphasizing **Energy and Matter** in the ways described above.
   * Student models should show a scale with the accurate molecules on each side, including the number and types of atoms identified for the reactants and products. In the model and/or explanation, students should also describe how matter is rearranged during the chemical reaction; in other words, they should identify that the hydrogen in the water molecules comes from the glucose molecule, etc. Because they are using a scale in this model, they should also compare the mass of the reactants and the products to show conservation of matter.

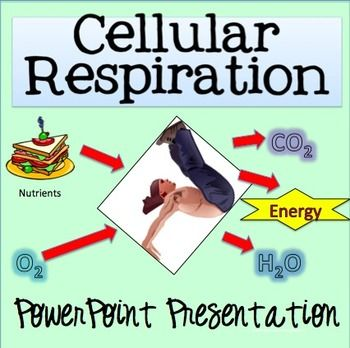
**Elaborate**

1. Students will now participate in a language routine known as *Stronger Clearer*. This activity gives students the opportunity to share their ideas, gather feedback, and revise their models and explanations. This protocol is especially useful for this task since they are practicing both modeling and writing explanations.
2. Students will cover up their written explanations and share their models with three different partners from different groups; in this process, they also have opportunities to discuss feedback and record any notes. Once complete, have students return to their original model and explanation to revise based on their discussions. A protocol is provided in their student guide.
3. These revised models and explanations represent an opportunity for formative assessment. Collect student work to identify trends in students’ ability to develop models of cellular respiration, including a demonstration of conservation of matter. See “How to Use This Curriculum” for strategies on utilizing formative assessment data to provide feedback to students and inform classroom instruction.
4. Return to the whole-class concept map from the Lift-Off Task.

* In small groups, have students brainstorm new concepts and new connections that they have learned in this task, as well as any new questions that have come up for them. Then have groups share these aloud in a class-wide discussion and add to the class concept map. The use of equity sticks is encouraged for more equitable participation in class-wide discussions (See “How To Use This Curriculum” for more details).
  + Some possible facilitating prompts to ask students are: What new ideas/concepts do you want to add to the map? What connections do you want to add or change? What is your reason for that addition/revision? What connections can we make between the questions/ideas already on the map? What new questions do you have about the phenomenon?
  + Draw circles around each question and boxes around each concept.
  + Write connector words to describe connections between the concept boxes.
  + For this task, students may begin to connect some of their previous question circles to concept boxes about the following: the conservation of matter in chemical reactions, specifically cellular respiration.
* Have students analyze the additions to the class concept map for as many examples of this task’s crosscutting concept as they can find. Once a student has identified the crosscutting concept, you can trace the circle in the corresponding color (decided on in the Lift-Off task). We recommend asking students to share key words that helped them identify the crosscutting concept for that concept or question. Some identifying words students might look for are:
  + **Energy and Matter**: These could be phrases such as, “is made by,” “is put into,” “is added to,” “is cycled within,” “is taken out by,” “is extracted for,” “is conserved,” “is changed into,” etc.
* Once again, the purpose of this concept map is to facilitate the generation of student questions, promote language development, and support understanding of the science content throughout the unit. Allowing students to ask their own questions and use their own words to make meaning of the concepts will not only help them make deep connections about science content, but will also help their oral and written language development.

**Evaluate: Connecting to the Culminating Project**

1. Students independently complete the Task 2 section of the Unit 3 Project Organizer in class. Revisions can be done for homework, depending upon student’s needs and/or class scheduling.



1. Students have been tasked with creating a sustainable aquaponics system that mimics the properties of the river environment, including any chemical reactions that may occur. Their prompt is as follows: Identify or add an organism to your aquaponics system that does cellular respiration.

* Identify what molecules the organism requires for cellular respiration. How will your system provide these molecules?
* Identify what molecules the organism will create through this process. How will your system use up the products that it creates?
* Draw a picture of your organism and the molecules identified. Use arrows to show which molecules enter or leave the organism.

**Reflection**

1. At the end of the task, ask students to reflect on what they have learned over the course of this task by answering the following three questions in their student guide:

* At the beginning of this task, you were asked to analyze a model of a chemical equation and compare the two sides of the equation. Look back at your comparisons: after exploring chemical reactions today, how would you change or add to your comparisons? Use evidence from the task to justify your changes or additions and record below.
* In this task, we focused on the crosscutting concept of **Energy and Matter**: Matter is conserved because atoms are conserved. Where did you see us looking at **Energy and Matter** in this task?
* Now that you have learned about another important chemical reaction in environments—cellular respiration—and how matter is conserved in these types of reactions, what questions do you still have?

1. There are no right answers, but encourage students to look back at their student guides and their class concept map. They should not change their initial responses, but rather use this reflection space to add to their ideas and questions based on what they have learned through this task. By generating more of their own questions, students continue to engage in sense-making of the phenomenon and gathering knowledge and skills for their final projects.

**Assessment**

1. You may collect students’ Project Organizer and assess using:

* *Criteria of your choice.* We recommend using the 3-Dimensional Assessment matrix at the beginning of this document to inform your criteria.
* This can be a formative tool to periodically look for trends in student understanding after the completion of a task. You can then use this formative data to inform any re-teaching as necessary.

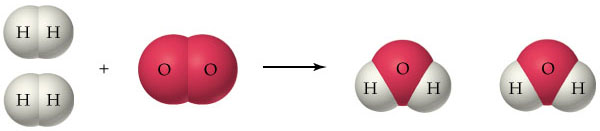
1. You may also give students time to make revisions with one of the two options:

* Students may make changes to their Project Organizer according to your comments OR
* Ask students to exchange Project Organizers with a partner and give partners 5 minutes to give written feedback. Then allow students time to make changes to their work according to the feedback.

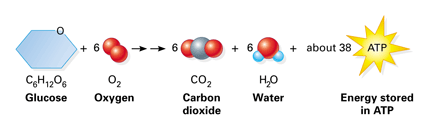
**“The Science Behind It” Resource Card**

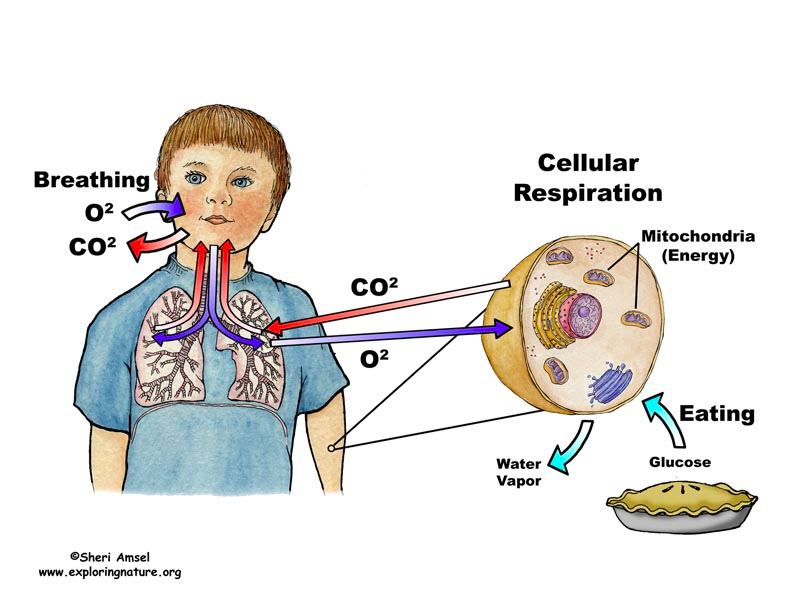
|  |  |
| --- | --- |
| **Atoms** are the building blocks for all types of matter. They are like the letters that make up every language.  https://lh5.googleusercontent.com/hUDPMusS79xrjJVkfSPJHx4Nkx78_6L4LBtPbuVgBvGKO4jLqZqq-lZCrXiYQyfEcuEgcI4koqoe0zLwAdAjhjGoK2EEWIBiZL09zV6rT6Uk5_i7QXOvtuUcl4p8IGdjw2cNe9h2 | Each type of atom is known as an **element** and each element has its own different characteristics and properties.  https://lh6.googleusercontent.com/NgqFa1F9zULlCOoNR6c4y1XJVe7ALAQ32kEvQA2hX-mpkZw4wQO_n0huh5k4DgC239NFRvhwlmPTzx1ch8dpBtYE4oAYGyI8M4waREkZIpAeQqVLcCMLDbnHTTrDPbc_dirq9z8p |

When one type of atom combines with another type of atom, it creates a **molecule**. For example, when you combine hydrogen atoms with oxygen atoms, it makes a whole new type of molecule that you may know: water!



When two or more molecules interact and the molecules change, it is called a **chemical reaction.** This means that the bonds between atoms are broken and new bonds are formed. Because breaking bonds makes energy and it takes energy to make new bonds, energy is either released or absorbed in a chemical reaction. A great example of this is cellular respiration:



All living things, including humans, do cellular respiration to make energy. The chemical reaction starts with glucose and oxygen. The glucose is a sugar that comes from the food we eat and the oxygen comes from the air we breathe. These molecules are broken down in order to create ATP, which is the type of energy our bodies need to do their jobs. As a result, this also creates carbon dioxide, which we breathe out, and water, which our bodies either uses or gets rid of in other ways.