Read, Annotate, and Analyze: "Liquid Oxygen"

Directions: Read the following article. As you read, annotate it by adding comments and answer the embedded questions throughout. Try to use **each** of the following annotations with the symbols at least once as you read. You should have at least one annotation per page.

! Main Idea: Underline and add a **"!"** symbol for the sentence you think is the article's main idea

? Question: Choose a word/sentence that you have a question about or is confusing. Add a comment, add the **"?"** symbol to the comment, and explain your question or confusion.

∞ Connection: Choose a word/sentence and add a comment with the '∞' symbol when you make a connection. Explain your connection and remember that there are many types of connections but here are a few possible categories: (Types of connections: A- connection to self, B- connection to the science/content, C- connection to the world)

How to add a comment:

1. Highlight a word or sentence and click on the "+" symbol to the right to add a comment
2. Highlight and double/right click until **Comment** option appears and click on it
3. Highlight the word/sentence and then click on "insert" then **Comment**
4. Highlight the word/sentence and then use the shortcut "Ctrl+Alt+M" to insert a comment

**** **Add a symbol at the beginning of your comment.**
**** ***Make sure you save each comment***

→ **Finally**, answer the analysis questions embedded within, **and** at the end as you move through the article.

Liquid Oxygen

Oxygen is most commonly found in the gas phase, but scientists can make it change phase into a liquid. © U.S. Air Force

Oxygen is pale blue when it is condensed into a liquid. © Shutterstock

In your daily life, oxygen is everywhere. It's in the air all around you, and even inside you, traveling from your lungs to every cell in your body. You probably think of oxygen as a gas, because that's how you encounter it—but it isn't always a gas. Oxygen can also exist as a liquid with a beautiful blue color. However, you'll never see puddles of liquid oxygen on the ground, and you can't buy a bottle of liquid oxygen at the store. Oxygen is very different from water, the most common liquid on Earth. Scientists can produce liquid oxygen, but it's not easy. Why is oxygen gas all around us, while liquid oxygen is so rare?

- **Explain** the change in the freedom of movement of the oxygen molecules when scientists cause a phase change from oxygen gas to liquid oxygen.

→ The molecules have more freedom of movement as a gas, as they're moving away from each other, and less as a liquid, when they're moving around each other.

The Role of Attraction

Liquid oxygen is much harder to find than liquid water because oxygen molecules aren't strongly attracted to other oxygen molecules. Every substance has a certain level of attraction between its molecules that pulls the molecules toward each other. This molecular attraction is stronger in some substances, like water, than it is in other substances, like oxygen. Molecules in liquids and solids stay close together because of the attraction between molecules. In the gas phase, molecules are able to move away from each other because they have a lot of kinetic energy, but attraction between the molecules still keeps them in the same general area. Different substances have different levels of attraction, but the level of molecular attraction for any one substance is always the same.

Since attraction never changes for a substance, something else has to change before the substance can change phase. You can think of each substance as always being in a game of tug-of-war at the molecular level. Attraction is always pulling the molecules together, while kinetic energy allows the molecules to move around. Substances change phase when either molecular attraction or kinetic energy wins the **tug-of-war**—and since each substance's molecular attraction is always the same, the change must be in the amount of kinetic energy the molecules have. A large increase in kinetic energy can move molecules so fast that they overcome the pull of attraction and move away from each other. The opposite is also true: a large decrease in kinetic energy allows attraction to overcome kinetic energy and pull the molecules toward each other.

- **Read the scenario and answer the question**: In a glass of liquid water, the molecules are constantly moving due to their kinetic energy. At the same time, they are attracted to each other because of molecular attraction. *How does the "tug-of-war" between kinetic energy and molecular attraction explain why water stays liquid at room temperature?*

→ Water stays a liquid at room temperature because the molecular attraction cannot change, and since the temperature is not moving, the kinetic energy is not changing, so the water doesn't change phase.

For oxygen gas to change to a liquid, the attraction that pulls the oxygen molecules toward each other must overcome the kinetic energy that pulls them away from each other. Because the attraction between oxygen molecules is weak, a great deal of kinetic energy needs to be removed from the molecules (by making the oxygen very cold) before their attraction can pull the molecules toward each other.

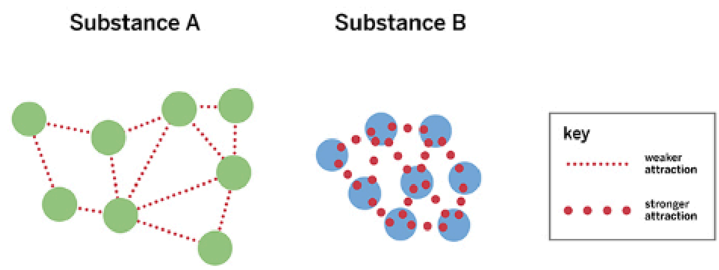
Analysis: Make sure to read the caption below the image to the right.

- **Explain** the diagram to the right: What is the relationship between the red circles and the spaces between the molecules (colored circles).

→ When the red circles are stronger, or bigger the molecules are closer together (substance b), but when the red circles are smaller, or the molecular attraction is weaker, the molecules are further apart. (Substance a).

- How could you **change** substance A so that the molecules are closer together?

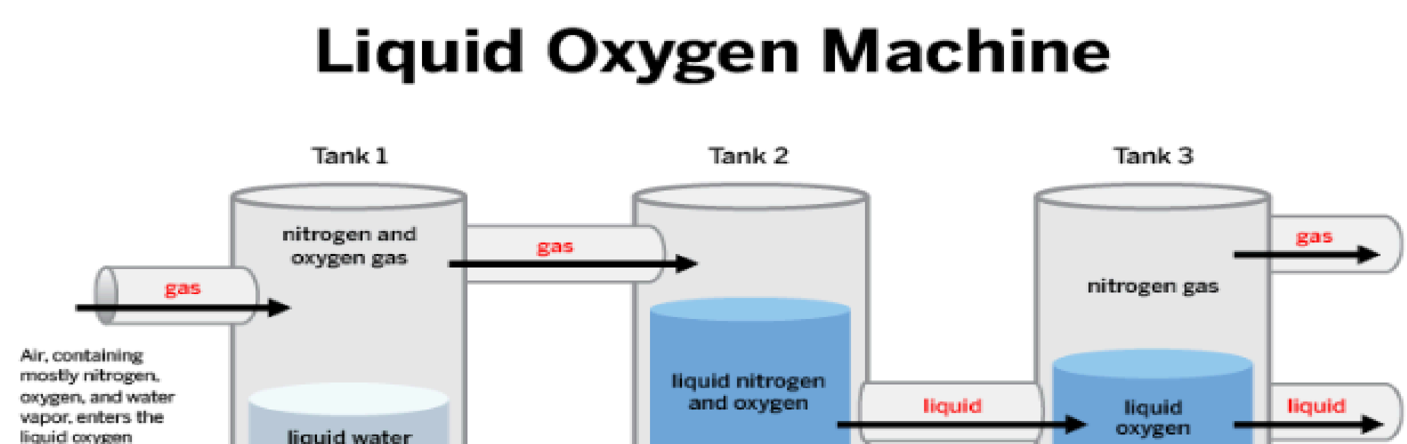
→ You could change the kinetic energy, by decreasing it, to make the molecules closer together.



Substance A is a gas and Substance B is a liquid. They are at the same temperature. Why is one a gas and one a liquid? Substance A has weaker attraction, and its molecules have enough energy to overcome the attraction between the molecules and fly apart. Substance B has a stronger attraction, and its molecules don't have enough energy to overcome the attraction between the molecules. Therefore, its molecules stay together.

Using Attraction to Make Liquid Oxygen

Scientists use their knowledge of attraction to produce liquid oxygen. They know they need to allow the weak attraction between oxygen molecules to pull them together. They do this by



transferring energy out of the oxygen, lowering the temperature of the oxygen molecules until their kinetic energy is so low that it can't overcome the attraction between molecules. The temperature required to turn oxygen gas to liquid is far colder than what's required to turn water vapor to liquid. That's why oxygen needs to be extremely cold to change phase into a liquid, while water doesn't need to be very cold at all.

When scientists need liquid oxygen, they can get it by separating oxygen molecules right out of the air. Air is a mixture of nitrogen and oxygen combined with small amounts of other gases like water vapor and carbon dioxide. Since the gases in air have different levels of molecular attraction, scientists can separate them by sending the air through a machine with different tanks that are at different temperatures.

Analysis Question:

Based on the reading and the diagram above, order the three molecules *from strongest to weakest molecular attraction*: **oxygen, water, nitrogen**

- Strongest = water
- Medium = nitrogen
- Weakest = oxygen

In the first tank, scientists decrease the temperature enough to condense the water into a liquid—that is, they decrease the kinetic energy of the molecules so the attraction between them can pull the molecules together. The liquid water that forms in the first tank is drained away. Then the remaining gases are put into a second tank and cooled below -183°C (-297.4°F). That's cold enough that the molecules in those gases have very little kinetic energy to push molecules apart. Because of this, the attraction between the molecules pulls them together and condenses the gases into a liquid, just like the water in the first tank. This liquid contains the molecules from the remaining gases in the air, including oxygen. The liquid mixture is then moved into a third tank that is heated up just a little so the nitrogen evaporates—the kinetic energy of the nitrogen becomes too strong for the attraction between molecules, and they escape into a gas. When the nitrogen evaporates, the liquid left behind is mostly oxygen.

Oxygen isn't the only substance that's hard to condense because of weak attraction. Hydrogen and methane also have very weak attraction, and so are difficult to condense. Like oxygen, these are substances we tend to think of as only being gases on Earth. However, also like oxygen, they can become liquid if they are cooled enough. Cooling these substances just a little won't cause them to condense: these gases reach extremely cold temperatures before condensing into liquids. It's all about the attraction.

Analysis:

- **Theoretical science research** involves gathering information to better understand phenomena and concepts, like the scientist in this reading, and it may not have a direct impact on the world. **Applied science research** involves trying to solve a particular problem, like when you were a geohazard engineer intern and you designed a tsunami warming system. They are both important for different reasons. <u>Which of these two types of research do you find more interesting and explain why?</u>

  → I find Theoretical science research more interesting, just because I don't like solving problems, so I prefer gathering information.