Common Student Ideas about Matter, Molecules, and the Water Cycle

Common Student Idea(s)	Scientific Explanation
1. Matter isn't conserved. When water is boiled, the water disappears.	Matter is conserved in all physical changes. When water is boiled, the liquid water changes into water vapor.
2. Ice and liquid water contain some water molecules. Water molecules are inside them.	All matter is made of molecules. Ice and liquid water are *made up of* water molecules. In other words, ice and liquid water **are** water molecules (matter); they don't **contain** some water molecules. These water molecules are arranged and move differently in the solid and liquid states.
3. Water molecules can be seen with a microscope.	Water molecules are too small to be seen with a microscope.
4. When water freezes, it's because the water molecules get hard. When water is a liquid, it's because the water molecules become softer. When water is a vapor, it's because the molecules become too small to see.	States of matter are due to different arrangements and motions of molecules; the molecules themselves never change, just their arrangement: • **Solid water:** molecules vibrate in place • **Liquid water:** random motion of molecules within limits • **Water vapor:** random motion of molecules, no limits
5. Steam, fog, and clouds are water vapor that can be seen in the air.	Steam, fog, and clouds exist as liquid water, not water vapor. Water vapor isn't visible in the air.
6. Solid water is denser than liquid water because all the molecules in a solid are more closely packed than the molecules in a liquid.	Water is a unique molecule. Solid water is *less* dense than liquid water. When water freezes, the molecules arrange themselves in such a way that they are spread apart in a rigid formation. This causes space among water molecules to exist, thus allowing ice to float on liquid water.
7. Gas is the same as gasoline.	The term *gas* describes a state of matter (solid, liquid, *gas*). Gasoline is a fuel that people put in their vehicles. Gasoline can exist as both a liquid and a gas.
8. The moisture on the outside of a cold glass of water is the result of water seeping through the wall of the glass. The moisture on the outside of a cold glass of water is the result of water evaporating from the inside of the glass and condensing on the outside.	The moisture on the outside of a cold glass of water comes from water molecules in the air (existing as water vapor), not from water in the glass. The water molecules in the air get colder as they come near the outer wall of the glass, causing them to slow down and combine to form liquid water. This liquid water is the resulting moisture you see.

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9. Freezing and condensing are the same. Melting and evaporating are the same.	Freezing and condensing are similar in that they happen when water molecules lose thermal energy. However, these terms describe different changes in states. **Condensing:** water vapor → liquid water **Freezing:** liquid water → solid water (ice) Similarly, melting and evaporating are alike in that they happen when water molecules gain thermal energy. However, these terms describe different changes in states. **Melting:** solid water (ice) → liquid water **Evaporating:** liquid water → water vapor
10. When water evaporates, it immediately goes up to the clouds. Clouds somehow "pick up" or attract the water that evaporates from oceans, rivers, and lakes.	Clouds don't "pick up" the water. When water evaporates, it rises into the air as water vapor. When the water vapor cools, it condenses *to form clouds*, which are liquid water.
11. When water evaporates, the hydrogen and oxygen atoms separate. Water changing from a liquid to a gas is an example of a chemical change.	The hydrogen and oxygen atoms don't separate. When liquid water evaporates, the H_2O molecules that are joined together come apart as individual H_2O molecules. The individual H_2O molecule stays intact. This is an example of a *physical change*, not a chemical change, because the water molecule remains the same. $H_2O_{(liquid)} \rightarrow H_2O_{(gas)}$
12. The oxygen and hydrogen atoms in the air come together when they're cooled to form water. Water changing from a gas to a liquid is an example of a chemical change.	Condensation doesn't occur as a result of hydrogen and oxygen atoms coming together to form an H_2O molecule. Condensation is when individual H_2O molecules, existing as water vapor, lose energy and join together to form liquid water. This is an example of a *physical change*, not a chemical change, because the water molecule remains the same. $H_2O_{(gas)} \rightarrow H_2O_{(liquid)}$
13. Water "sticks" to cold things and "bounces off" hot things. Water is like a magnet because it's attracted to cold things and is repelled by hot things.	Temperature differences don't cause water molecules to stick to one another or become attracted to each other. Rather, water molecules are attracted to one another because of their charges. An H_2O molecule is a dipolar molecule, meaning the oxygen atom is slightly negative with respect to the hydrogen atoms, which are slightly positive. So the negative charge of the oxygen atom of one H_2O

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	molecule is attracted to the positive charge of a hydrogen atom from another H_2O molecule. This attraction is called a *hydrogen bond* (H-bond). Temperature differences don't cause water molecules to bounce off of or repel one another. Water molecules move randomly. Molecules of water vapor move fast and without limits. That means individual water molecules may collide with one another, but they have enough energy to break free and continue moving around individually. However, when individual water molecules lose thermal energy and slow their motion, they may randomly collide with one another but not have enough energy to break free; thus, they form hydrogen bonds.
14. Cold is a "thing." We can feel it move across our feet when we open a refrigerator or freezer.	Everyday language that describes how cold something is helps us reference the amount of heat it contains.
15. When water evaporates from the ocean, the molecules gain heat energy as they rise in the air; this is because the molecules get closer to the Sun.	As water vapor rises, it gets colder. It can be quite cold high up in the atmosphere—often well below freezing just a mile or two overhead.