Fluids Part 5: Compressibility

Last week we left you with a fill-in-the-blank item:

The two reoccurring themes for the **Fluids** series are:

- Matter is made up of ________.
- They are in _____________.

From the last several emails, you have seen many examples that illustrate:

- Matter is made up of **molecules** (the tiny balls).
- They (molecules) are in **motion**.

In this e-mail we will examine other properties of fluids to see what they suggest about the structure of matter. One property is **compressibility**.

Let's start with a definition:

compressibility: "A measure of the change in volume resulting from a pressure change."[1]

What do you know about the **compressibility** of fluids?

- Are gases compressible?
- Are liquids compressible?

Let's use air and water as examples of a liquid and a fluid and test their **compressibility**.

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Air and syringe investigation

You'll need:

- syringe
- water

- Is air compressible?
- Does the volume of a sample of air decrease when the pressure on the sample is increased?

Procedure for first thought investigation:

1. use water to wet both parts of the syringe (the plunger and the case)
2. pull the plunger all the way up, filling the syringe with air,
3. cover the bottom of the syringe with your finger, then
4. push the plunger down.

What do you predict?

- Will you be able to depress the plunger? Why or why not?
- What do you predict will happen when you let go of the plunger? Why?

So what happens?

The volume of the air decreases as you increase the pressure on it. When the push on the plunger is released, it will pop back up. Why?

We can explain these observation by assuming that there is space between the molecules of the gases in air, and that when the pressure on the air increases, the molecules are pushed closer together, reducing the empty space between the molecules. When there is no longer a downward push on the plunger, the pressure on the air is reduced to its former value, the gas molecules move apart, and the air returns to its original volume.

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Now try this:

1. fill the syringe half-filled with air,
2. cover the opening of the syringe on the bottom,
3. pull up the plunger
4. then release the plunger.

What do you predict?

- Will you be able to depress the plunger? Why or why not?
- What do you predict will happen when you let go of the plunger? Why?

Your observations from this investigation can be explained by assuming that there is space between gas molecules, and that increasing pressure reduces that space.

- Is water compressible?
- Is there space between the molecules of water?

Water and syringe investigation

First the thought investigation…

You'll need:

- syringe
- water

Procedure:

- you fill the syringe with water,
- cover the bottom of the syringe with your finger,
- push down on the plunger

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What do you predict?

- Will you be able to depress the plunger? Why or why not?

So what happens?

Contrary to the results of the first investigation, you will not be able to depress the plunger. Does that mean there is **no** space between the molecules of water?

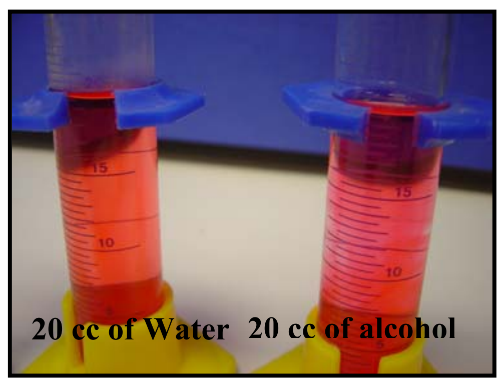
If we can't compress the water molecules in this investigation, how do we know if there's space between molecules in a **liquid**? Another "thought investigation" will examine this…

Water and alcohol investigation

Let's see what happens when we mix two **liquids**.

You'll need:

- One 20cc graduated cylinder filled with water
- One 20cc graduated cylinder filled with rubbing (isopropyl) alcohol
- One 50cc graduated cylinder (empty)



Procedure:

1. carefully pour the all the water into the 50 ml graduated cylinder, then

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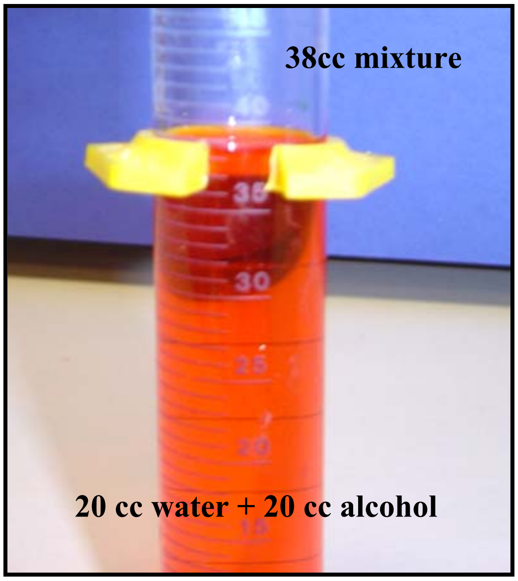
2. carefully add all the alcohol to the 50 ml graduated cylinder

- **What do you predict the volume of liquid in the 50cc graduated cylinder will be? Why?**

So what happens?



Intuitively, you might think that 20 cc of **liquid** added to 20 cc of **liquid** would add up to 40 cc of **liquid**. However, when we combine the water and the alcohol, we end up with less than 40cc of the mixture. We actually get **38cc**. How do we account for this? Why is the **liquid** taking up less room? If we assume that there is space between the molecules of the liquids, we can explain our observations by assuming that either the molecules of water fit into the spaces between the molecules of alcohol or that the molecules of alcohol fit into the spaces between the molecules of water. Because alcohol molecules are now in-between water molecules (or vice versa), the combined **liquids** take up less space than the sum of their separate volumes. It's as if you mixed equal volumes of shelled peanuts and sugar. Because the sugar particles are smaller than the peanuts, the sugar molecules fit between the peanuts and the volume of the mixture is less than the sum of the two volumes. [Certainly, if you add 20 ml of water to 20 ml of water (or 20 ml of alcohol to 20 ml of alcohol), you'll end up with 40 ml of **liquid**.].

Based on these observations, it seems easier for students to accept that there is empty space between molecules of a **gas**. It's more difficult for them to understand that there is empty space between molecules of a **liquid.** These investigations can be one step in guiding them along toward that understanding.

Upcoming

We'll take a short break..
In the meantime, have a healthy, happy, and well-deserved vacation!

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What do the standards say?

In the Elementary Core Curriculum, Standard 4, The Physical Setting,

Major Understandings state:

- 3.1b Matter has properties (color, hardness, odor, sound, taste, etc.) that can be observed through the senses.
- 3.1c Objects have properties that can be observed, described, and/or measured: length, width, volume, size, shape, mass or weight, temperature, texture, flexibility, reflectiveness of light.
- 3.2a Matter exists in three states: solid, liquid, gas.
    - solids have a definite shape and volume
    - liquids do not have a definite shape but have a definite volume
    - gases do not hold their shape or volume

In the Intermediate Core Curriculum, Standard 4, The Physical Setting, Major Understandings state:

- 3.1a Substances have characteristic properties. Some of these properties include color, odor, phase at room temperature, density, solubility, heat and electrical conductivity, hardness, and boiling and freezing points.
- 3.1c The motion of particles helps to explain the phases (states) of matter as well as changes from one phases to another. The phases in which matter exists depends on the attractive forces among its particles.
- 3.1d Gases have neither a determined shape nor a definite volume. Gases assume the shape and volume of a closed container.
- 3.1e A liquid has definite volume, but takes the shape of a container.

[1]http://www.webref.org/chemistry/c/compressibility.htm

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