Fluids Part 2: Properties

We ended last week's discussion on the existence of **air** with two questions; we'll examine them one at a time.

Q1: Since we stated that the primary focus of this series is **air**, why is this series of emails titled **Fluids**?

Here we again run into a discrepancy with language. In common usage, we equate *fluids* with *liquids*. However, in the scientific domain, the definition is different:

Fluid: a substance that takes the shape of the container in which the substance is located

This includes both **liquids** and **gases**. Although initially this language difference may seem detrimental, it's actually to our advantage. As stated in **Fluids 1**, we plan to use the properties of water to help students understand the properties of **air**. Since **air** and water share some common properties, it will help in our comparisons to think of them both as **fluids**.

A look at some properties

All matter, solids, liquids and gases, share two physical properties:

- They occupy space.
- They have mass.

It seems so obvious that solids and liquids take up space that even saying it seems silly. But the idea that gases occupy space is less obvious. The immersed glass/dry cotton investigation in **Fluids 1** provided evidence that air occupies space. An explanation for our observation that the

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cotton ball remained dry is that, because there is air in the container, and because two substances can't occupy the same space at the same time, the air keeps the water away from the cotton ball.

Using a balance, it is easy to show that solids and liquids have mass. But because gases have such low densities, it takes a huge amount of air to tip a balance. Here's a "thought experiment" that may illustrate the mass of gases.

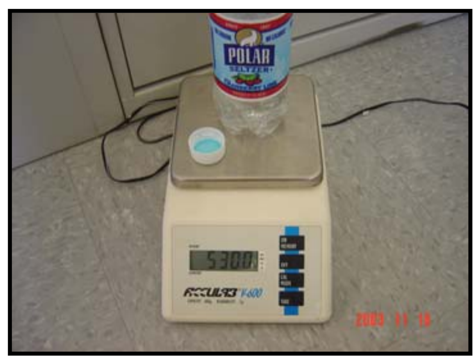
Seltzer water experiment

You'll need:

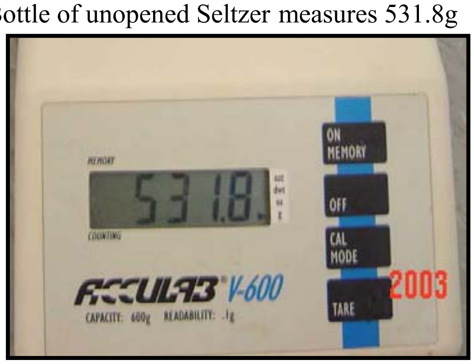
- 1 bottle of seltzer water
- triple beam balance or electronic scale

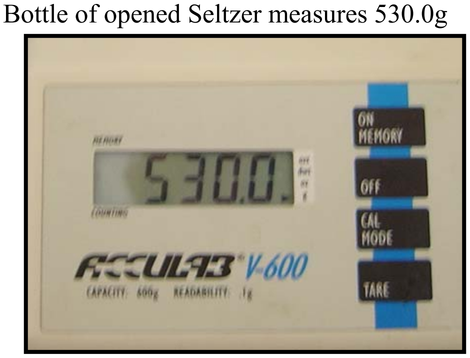
1. Place the unopened bottle of seltzer water on the balance.
2. Balance the scale.
3. Open the bottle of seltzer water, being sure to put the bottle top back on the pan.
4. What do you predict will happen to the triple beam balance?

Bottle of unopened Seltzer measures 531.8g



Bottle of opened Seltzer measures 530.0g





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So what happened?

Opening the bottle of seltzer water allows carbon dioxide (which gives seltzer its "fizziness") to escape. The scale will tip, with the seltzer water end rising, indicating that there is less mass on that side. Although invisible, the carbon dioxide did have mass, and its absence throws the scale off-balance.

Another property: shape

Shape is one way in which solids are different from fluids.

We know that a fluid takes the shape of its container. On the other hand, a solid object does not; the solid object's shape is independent of the shape of its container. (We are specifically saying *object* here, not just solid. Sugar is a solid, but a spoonful of sugar will take the shape of its container, the spoon. However, a single particle of sugar, sand, or baking soda does not take the shape of its container.)

How do we explain why solids have shape and fluids take the shape of their containers? Let's examine a mental model of solids, liquids, and gases.

Ball Analogy

We can explain many of the physical properties of solids, liquids, and gases if we imagine that they are composed of tiny balls (which represent the molecules). The balls are in constant random motion, and they collide with each other and with the wall of their container, but no energy is lost in the collision. There are **forces of attraction** among the balls.

What are the differences between the balls in solids and those in **fluids**? The primary difference is in the **forces of attraction**.

- The **force of attraction** among the balls composing solids is the strongest. The balls are held close together, so they cannot move around independently. You can't push the balls apart by poking your finger at a solid piece of glass or wood. Even though the particles of solids are in motion, the **force of attraction** among them is so great that the particles do not readily escape from the body of the solid. If, however, certain solids (e.g., sugar or salt) are put in water, the particles of water bouncing off the surface of the sugar weakens the **forces of attraction** between the particles of sugar, and the particles of sugar mix with the water. The sugar seems to disappear, but it is just mixing with the water or dissolving.

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- In **liquids, the force of attraction** among the balls is weaker than solids. The balls move independently, taking the shape of the container. However, the **force of attraction** among the balls is great enough that the balls do not readily escape from the liquid. Some do escape, but most stay in the liquid. (The **force of attraction** among the balls in **liquids** that evaporate rapidly [e.g., alcohol and gasoline] is less that the **force of attraction** among the balls in **liquids** like water that evaporate more slowly.)
- In **gases**, the **force of attraction** among the balls is the weakest. The balls move even farther apart than in **liquids** and with almost total independence. In a closed container, this means that the balls have so little attraction for each other that they will move apart to fill the container.

Dissolving candy

Here's a "thought experiment" to help us consider the "motion of the balls."

You'll need:

- Clear container of very hot water
- Red candy

1. Place the candy in the container of hot water.
2. Predict what will happen as you observe the container.

So what happened?

You may notice a number of things.
Two that are important here are:

1. The candy begins to dissolve.
2. The color of the candy moves through the water, making a red path.

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These observations are evidence of the motion of the balls, both for the solid and the fluid. It's often difficult to convince students that all molecules are in motion, especially in stationary solids. However, the candy could not dissolve if the solid balls were not in motion. As described above, particles of water bounce off the surface of the candy and weaken the **force of attraction** in the candy, causing the candy to mix with the water. Then, once in the **liquid**, the motion of the tiny balls of water causes the color to move through the water. If the candy is left in the water long enough, the balls of water will have circulated enough so the color of the water is a uniform red.

Last week we also asked you to examine the Elementary Core Curriculum Major Understanding 3.1a: *Matter takes up space and has mass. Two objects cannot occupy the same place at the same time.*

> Q2: Based on what you have learned in this e-mail [Fluids 1], how would you modify Major Understanding 3.1a?

Major Understanding 3.1a is not incorrect; it's just incomplete. We stated that an important understanding for students is: two objects or substances cannot occupy the same space at the same time. The Elementary Core Curriculum limits this understanding to objects. This would make the students think of solids, such as books, chairs, houses, themselves… This does not include the concept of **fluids**. We don't think of **fluids** such as water and air as objects, because they have no definite boundaries, unless they are in a container. (In that case, a student may understand that nothing can be in the same place as a bottle of water, but it's the *bottle* that makes the point.)

But let's consider a seemingly unbounded body or water, such as an ocean. What happens if a boat sinks in the water? The boat does not occupy the same space as the water does; it pushes the water out of the way. This can be modeled by immersing a large stone into an aquarium. What do you observe? The water level in the aquarium has risen, because the rock has pushed the water out of the way.

It's the same with the **fluid** air. When we observe a balloon as it inflates, we see the sides of the balloon move apart as the **air** enters. The **air** pushes the balloon out of the way; **air** does not take up the same space as the balloon.

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Upcoming

Next week, we'll look more closely at two more properties of air and water: temperature and density.

In the meantime, consider this:

In our homes, we put heating registers on the floor rather than up by the ceiling because (in common language) "Hot air rises." Scientifically, though, this isn't exactly correct and may cause confusion for students. What's the real story?

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 3, 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.*
- 3.1d *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.*

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