Session 8 – Our Cosmic Connection to the Elements

General Description

An interactive discussion of elements and compounds begins with the leader and class breaking down a substance into smaller and smaller pieces that still retain its identity. The discussion continues with the periodic table, common elements and compounds, and the astronomical origin of the elements that make up our bodies. Students determine the composition of a sample of "space particles" and discuss the difficulties of finding a truly representative sample. They view printed elemental spectra and discuss how astronomers determine the composition of distant objects (reinforces Session 4 on spectroscopy).

Objectives

- To introduce students to the idea of elements.
- To explore composition in the context of the Universe and astronomical objects.
- To draw the connection between elements in space and elements in the human body.

Concepts Addressed

- Elements and compounds
- Composition of the Universe
- Spectroscopy

Materials

- One poundcake. Choose one with the fewest artificial ingredients so that the students will recognize the ingredients. This activity will work best if you choose something that is as uniform looking as possible. If you substitute with a different type of cake, or another type of food, keep in mind that it must be dense enough to not fall apart when cut.
- Knife to cut the cake
- Gloves or wet wipes for safe food handling
- Enough paper plates to hold pieces of cake as it is cut (enough to serve the class, if allowed)
- Sample of a pure element (a piece of copper pipe works well)
- Periodic table, one copy per student (black and white version included in Appendix E and color version included in Appendix F) *
- *Universe Trail Mix* ingredients (see *Universe Trail Mix* Procedure for amounts): rice, split peas, macaroni, black beans, pink beans, and colored sprinkles
- Large bowl to mix the trail mix
- Plain white paper towels or printer paper, one sheet per student
- Plastic spoons (only one is required, but have extras on hand)
- *Universe Trail Mix* worksheet (included in Appendix E)

- Universe Trail Mix key (included in Appendix F) *
- Elemental Spectra handout (included in Appendix F) *
- Paper to write on, 1 sheet per student

** You can laminate these handouts if you want to use them with other groups. You only need to hand out one of these sheets per group of students.*

Other Requirements

- A room with sufficient space for students to spread out and count their "elements"
- Access to a blackboard or flip chart is advised

Background

Atom: The smallest particle of an element that still has the characteristics of that element

Element: A *material* consisting of all the same atoms

Molecule: Two or more atoms of the same or different elements that are chemically bound together

Compound: A *material* consisting of atoms of two or more different elements that are chemically bound together

The copper/other pure element used here is an element, while the pound cake is a compound since it is made of many different substances (or elements).

The lightest elements (hydrogen, helium, and some lithium) were created in the Big Bang.

Then, as the Universe cooled, matter clumped together to form stars. In the stars, those first elements were fused into heavier ones by the energy from the stars' gravity — up to a certain point. Remember that we covered this is Sessions 6 and 7.

The formation of elements heavier than iron and lead requires more energy than a star has. But the explosion of a star at the end of its life (a supernova) provides enough energy to make the much heavier elements. A supernova throws all of its elements out into space, where new stars can use them as they form.

We know the Sun is a later-generation star because it has those heavier elements (we know that from spectroscopy, among other ways). So the elements in our bodies — like carbon, hydrogen, nitrogen, oxygen, and trace amounts of many others — came from the explosion of earlier stars!

We are made of star stuff!

Session Overview

An interactive discussion of elements and compounds begins with the leader and class breaking down a substance (poundcake) into smaller and smaller pieces that still retain its identity (its "atoms").

The discussion continues with the periodic table, common elements and compounds, and the astronomical origin of the elements we are made of. Students take a sample of "space particles in the Universe" (a prepared mixture of rice, beans, etc.), determine its composition, and discuss the difficulties of finding a truly representative sample.

Students view a chart of spectra matched with the elements that produce them, and they discuss how astronomers determine the composition of distant objects (reinforces Session 4 on spectroscopy).

Preparation

- ***Universe Trail Mix***

  This takes a bit of time, so prepare this mixture at least a few hours before you implement this session:

  Using the recipe below, measure the ingredients into a large bowl and mix well. Use the same size "measuring cup" (a plastic spoon) for all of the ingredients.

  – 40 spoonfuls of rice (to represent 89% abundance of hydrogen in Universe)
  – 4 spoonfuls of split peas (to represent 9% abundance of helium)
  – 2 spoonfuls of macaroni (to represent 0.75% abundance of carbon)
  – 2 spoonfuls of black beans (to represent 0.75% abundance of oxygen)
  – 1 spoonful of pink beans (to represent 0.25% abundance of nitrogen)
  – fraction of a spoonful of sprinkles (to represent the tiny abundance of all other elements)

  The amounts of macaroni, black beans, pink beans, and sprinkles are highly exaggerated, because they would not be visible in the mixture in smaller amounts.

- Laminate handouts if desired.
- Have the poundcake and knife ready. Wash your hands or wear gloves while handling the poundcake, if it is to be consumed after use. Save the ingredient label.

Activity

I. Poundcakium activity (15-20 minutes)

1. Remind the group about the previous session and the fact that the calcium and iron — and many other elements — in our bodies were created in a star that exploded. In fact, all of the elements originated well outside our Solar System. Elicit student thoughts about this.

2. Hold up the poundcake. And ask the students what it is.

   Tell the students that you are going to pretend to have just discovered this new element, called "poundcakium." Ask about its characteristics, and let them answer. Answers should include that it's all one flavor, texture, and color (at least on the inside).

3. Cut the cake in half.

   Ask the students what you have now. Will it taste the same? The answer is yes, so it is the same thing we had before. Still poundcakium, but in two pieces.

4. Cut it in half again.

   Ask what it is now. The answer is that it is still poundcakium.

Sliced poundcake.

   If you were to continue to cut it in half, you would eventually get to single crumbs. Ask the students if you would have destroyed or created any poundcakium as you did this? Does it become something else other than poundcakium by cutting it? The answer is no.

5. If allowed, serve the poundcake! You can continue while students munch.

6. Discuss with the students how many things are made of more than one ingredient. Ask them what they think the ingredients are in poundcake (which you used to represent poundcakium). Let them answer, then read through the pronounceable ingredients on the poundcake label.

7. Tell the students that flour, sugar, milk, and eggs (or whatever the recognizable ingredients are) are made of elements such as carbon and hydrogen.

   Pass out the individual copies of the periodic table. Point out carbon and hydrogen.

8. Ask the students if they know anything about elements. Tell them that an element is a material made of atoms of a single type, like carbon or hydrogen. Elements are the building blocks for matter — everything that we can see and touch.

9. Hold up your pure element. (For our example, we will say you are using a piece of copper tubing. You can also use other examples of pure elements if you have them readily available.)

   If the kids handle the copper (or other elements), make sure to have them wash their hands afterwards. Wet wipes might make this process easier.

   Tell them that copper is an element that occurs naturally on Earth.

   Say that copper is very hard to cut, but in theory we could do the same thing we did with poundcakium. If we could cut the copper in half, would it be a different substance? No, it's still the same substance, with the same properties, and the total weight (of the two pieces together) is still the same. Since copper is an element, no matter how many times it's cut it in half, we will always have copper. It is a fundamental property of elements that they retain their characteristics, even down to a single atom.

   Make sure you remember to wash your hands after handing a substance such as copper.

An example of a copper pipe.

10. Refer back to their handouts. Tell them that all of the known elements have been organized into this Periodic Table of the Elements. It is arranged so that the elements in the same rows and columns have common characteristics, though each remains unique. Some are solids, some are gases, and some are liquids at room temperature, for example.

    Ask if they recognize any of the elements. See if they can give examples of everyday objects, and the elements they're made of. (Examples: aluminum in soda cans, silver/gold in jewelry, diamonds (carbon), iron in steel, hydrogen and oxygen in water — "lead in pencils" should be corrected to "carbon (in the form of graphite) in pencils".)

Some common substances like table salt (NaCl — sodium chloride) or water (H_2O) are compounds, which are made of two or more elements chemically bound together.

Ask if poundcakium is an element or a compound. Wait for responses with explanations. They should answer that we were pretending that it was an element for our purposes.

Now ask if the actual poundcake is an element. Again, wait for responses with explanations. The answer is that it is not, because it's made of various ingredients.

11. Ask what are people are made of. Wait for the students to respond and provide explanations. The truth is that we're made of a lot of the elements on the periodic table, many in the form of compounds like water.

Ask the students where they think these elements came from. Wait for ideas. They may remember from Session 7 that the lightest elements (hydrogen, helium, some lithium) were created in the Big Bang and then heavier elements (up to iron) were formed in stars. Anything heavier than that was formed during supernova explosions. So the elements in our bodies — like carbon, hydrogen, nitrogen, oxygen, and trace amounts of many other — came from the explosion of stars!

We are made of star stuff!

II. *Universe Trail Mix* activity (15-20 minutes)

1. Before beginning this activity, everyone should finish eating if they were doing so. Remove all traces of remaining poundcake to avoid distraction.

Distribute the *Universe Trail Mix* worksheets, the *Universe Trail Mix* keys (so that they know which ingredient represents which element), small cups, and sheets of paper towel.

2. Ask the group what element we have the most of in the Universe. If we grabbed a handful of space particles, what would we have? Solicit ideas.

3. Pull out the trail mix and plastic spoon to serve it.

Tell the students that this trail mix was prepared to imitate the proportions of the most common elements in the Universe.

Have each student take a spoonful of the mix and put it in a cup. Back in their own workspace, they empty it onto the paper towel. Students then count or estimate how much of each ingredient (element) they have, and record it on their worksheet.

4. When all have finished, ask how many of them found hydrogen? Helium? Carbon? They should all have mostly hydrogen, some helium, and very few of the others.

Ask how many of them had any oxygen, nitrogen, or sprinkles (which represent small amounts of other elements). Note that these are rare and not found in every spoonful.

On a blackboard or flip chart, draw a table with a column heading for each element. Have each student come up and record how much of each "element" they found. Have two volunteers come up and tally the entries to arrive at total for each element (having two volunteers should verify the addition).

Student participants counting components of their Universe Trail Mix.

5. With prompting as needed, students should discuss the *relative* amounts of the elements.

   Ask why some of the elements not appear in all of the samples. Do they think this would be similar to when we look out into space? That is, if we looked at one region in space near a star, do you think we would find the same sorts of elements as if we looked where there no stars? The answer is no — where we look is very important and tells us what that region is made of.

6. Have everyone look at a periodic table again, and go through the true percentages of elements in the Universe: Almost 90% of the Universe is hydrogen, and more than 9% is helium. The rest of the elements add up to less than 1%, but that 1% includes ***all*** of the heavier elements that are out there.

III. Follow-up discussion (10-15 minutes)

Discuss with the students how they just used spoonfuls of the *Universe Trail Mix* to try to figure out what the Universe is made of. But we can't get a spoonful of things in space, since they are so far away. We have to figure out what they are made of without touching them. We can do this with light.

Remind them about the Session 5 activity on spectroscopy, if they did it.

Remind them that one way you can tell what an object is made of is to look at its spectrum. A spectrum is like an element's "fingerprint." Each element produces a unique pattern of specific wavelengths of light, which we see as bright lines in the spectrum. A scientist looking at the spectrum of an object in

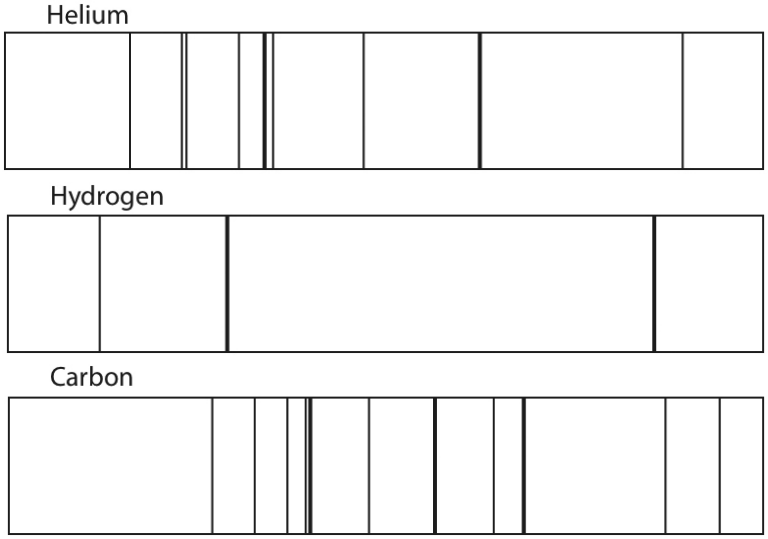
space, like a star or planet, can figure out which elements are in that object by looking at the different lines in its spectrum — they use spectroscopy.

Hand out papers with the spectra of different elements.

Ask them to describe what they see. Wait for ideas.

It looks like a faint rainbow, with some bright lines here and there. Have them look at the spectrum for hydrogen, and discuss where the bright lines are.

Have them look at the spectrum for helium. Discuss where the bright lines are, and compare this spectrum to the spectrum for hydrogen.



Three examples of different elemental spectra.

So when astronomers look out into space and study the spectra of objects, they can figure out which elements are present from the lines they are seeing. Each element has a unique spectrum and how bright or faint it is tells us how much of that element is present.

Suggestions for Running this Session

- If you are unable to have food in your classroom at all, or if food allergies are a concern, you should be able to do the poundcakium activity with a sponge (spongium), styrofoam (styrofoamium), Play-Doh (pladoium), or some other substance that can be easily cut or broken, and with easily recognizable properties.

- Even though the trail mix is not consumed, and none of the ingredients are ones that have significant allergy risk, there is an alternate recipe which uses beads instead of food products. This recipe contains a different ratio of ingredients, because the difference between elements is expressed entirely by color, and not by size. While this is a longer-lasting alternative, it is more expensive to construct, and the supplies are not as readily available from local stores. If you are interested, this recipe is available from the *Big Explosions and Strong Gravity* program (linked below).

- If dark matter comes up, explain that we still don't know exactly what it is, and we are only talking about normal matter in these activities.

Misconceptions

- Elements are substances made up of all one type of atom, that cannot be separated into simpler substances. Compounds are substances made up of two or more elements joined together, like water (hydrogen + oxygen) or table salt (sodium + chlorine). When you're discussing elements, some students will have the idea that compounds are elements, and will name substances like water alongside elements like oxygen or iron.

- In this session, we've invented a fictitious element called Poundcakium to illustrate basic concepts about elements and atoms. In reality, poundcake is a mixture - two or more substances that are mixed together but not chemically joined. Some of the ingredients in poundcake, like sugar and salt, are compounds. We don't go into much depth in this session about compounds or mixtures, because our focus is on elements.

Useful websites for background or activity extension

- **Los Alamos National Laboratory**
  Great interactive periodic table, with much information about each element
  http://periodic.lanl.gov/

- **University of Colorado Physics 2000**
  Good follow-up site if you would like to see spectra for more elements, as well as for white light.
  http://www.colorado.edu/physics/2000/quantumzone/index.html

- ***Imagine the Universe!***

  – Extended activity about composition using beans and rice, with bottles full of objects on Earth and space:
  http://imagine.gsfc.nasa.gov/docs/teachers/elements/imagine/OutThere/outthere.html

  – Good explanations of the electromagnetic spectrum and spectroscopy:
  http://imagine.gsfc.nasa.gov/docs/teachers/lessons/xray_spectra/background-spectroscopy.html

  – Lesson plan at high school level on the origin of the elements and our connection to them:
  http://imagine.gsfc.nasa.gov/docs/teachers/elements/elements.html

  – High-school level activity and discussion of the formation of elements in stars and their release in supernovae:
  http://imagine.gsfc.nasa.gov/docs/teachers/calcium/calcium_intro.html