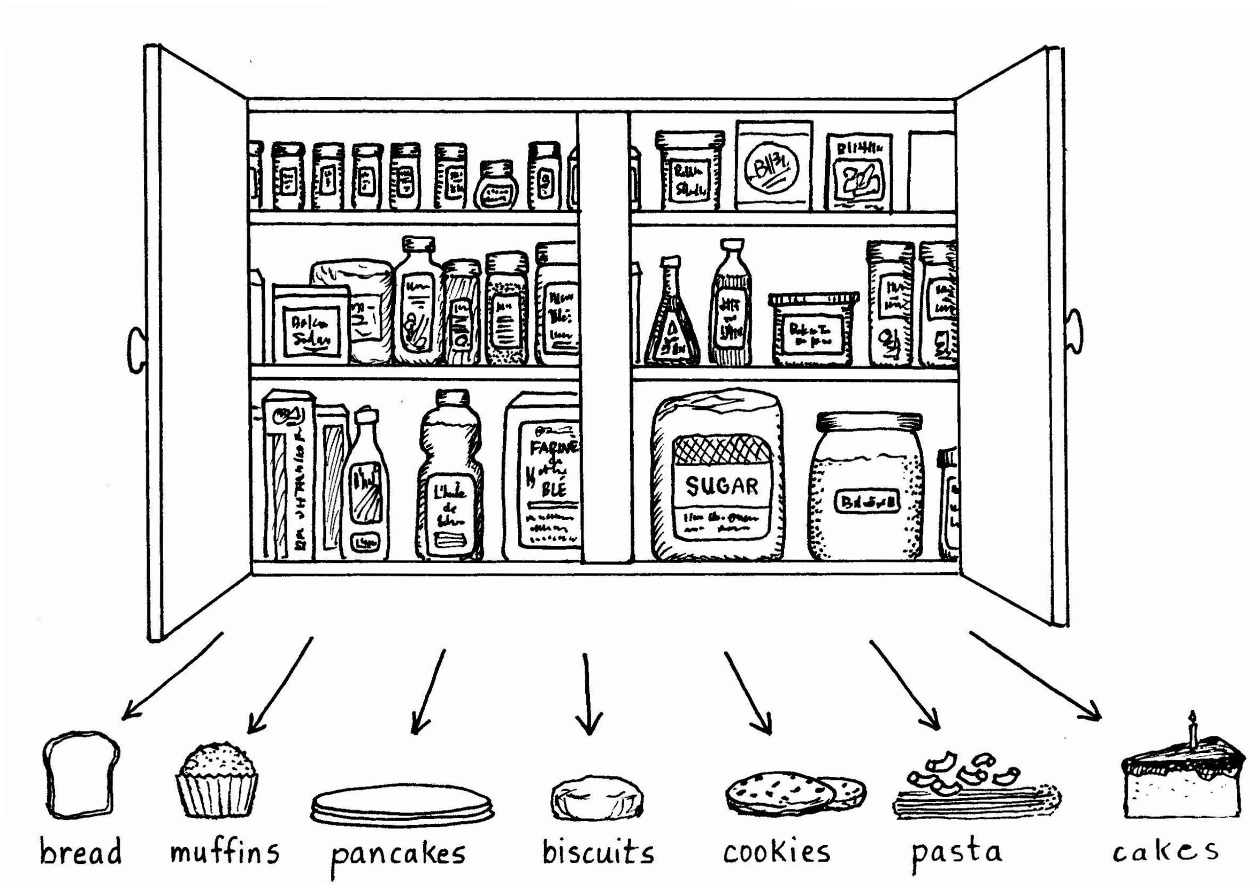
CHAPTER 1: WHAT IS AN ELEMENT?

Do you ever help bake things like cookies, cakes, biscuits, or bread? If so, you may have noticed that all baked goods are made from basically the same ingredients: flour, sugar, salt, eggs, butter, vegetable oil, baking powder, yeast and flavorings. The ingredients can be the same, or at least very similar, yet you have no problem telling the difference in taste and texture between pancakes and donuts, or biscuits and bread.

Even though these foods contain many of the same ingredients, the ingredients are used in different proportions. Cookies, for example, have lots of butter and sugar and not too much flour. Biscuits have less sugar than cookies do, and contain no eggs. Bread is mostly flour, with only a small amount of sugar and butter or oil (and some yeast to make it rise). Some recipes call for flavorings such as cinnamon, chocolate or lemon. The same ingredients in your kitchen can be used in many different ways to make many different foods.



All of these foods can be made from the ingredients in your cupboard. The reason they are different is that they have more of some things and less of others. Just a pinch of flavoring or spice can change one recipe into another. It doesn't take thousands or millions of ingredients to make a wide variety of recipes. Most of us have less than 100 ingredients in our cupboards, yet we can use them to make just about any recipe we find in a cookbook.

Activity 1.1

Use a cookbook to find the information for this activity, or ask an adult who knows a lot about cooking. For each baked good, put check marks in the boxes, showing what ingredients it contains. You are free to choose any recipes you like. (Flour means any kind, including gluten-free types. You may also cross out banana or chocolate put in something like blueberries or nuts instead.)

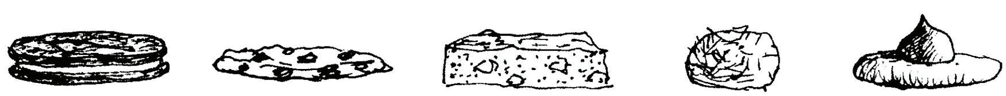
	flour	sugar	oil or eggs	milk or butter	water	yeast	baking powder	vanilla	banana	chocolate or other flavor
BREAD										
COOKIES										
BISCUITS										
PANCAKES										
CAKE										
BANANA MUFFINS										

Name an ingredient that is found in all of the baked goods:_____________

Name an ingredient that is found in most of the baked goods: ______________

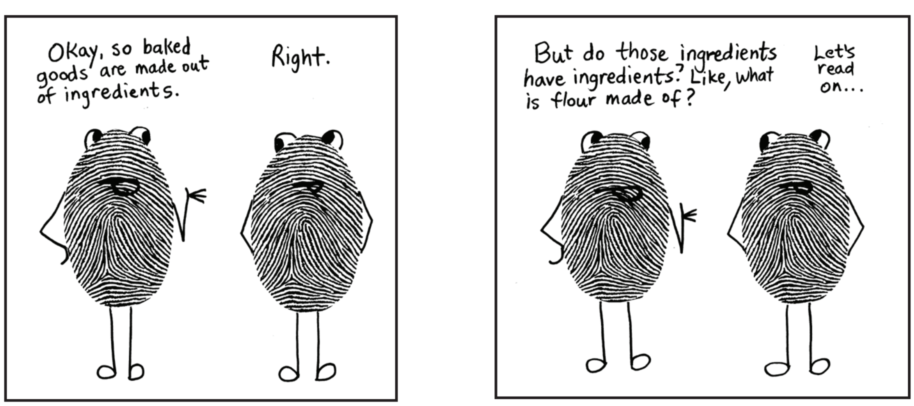
Name an ingredient that is found in only one of the baked goods: ____________

Activity 1.2

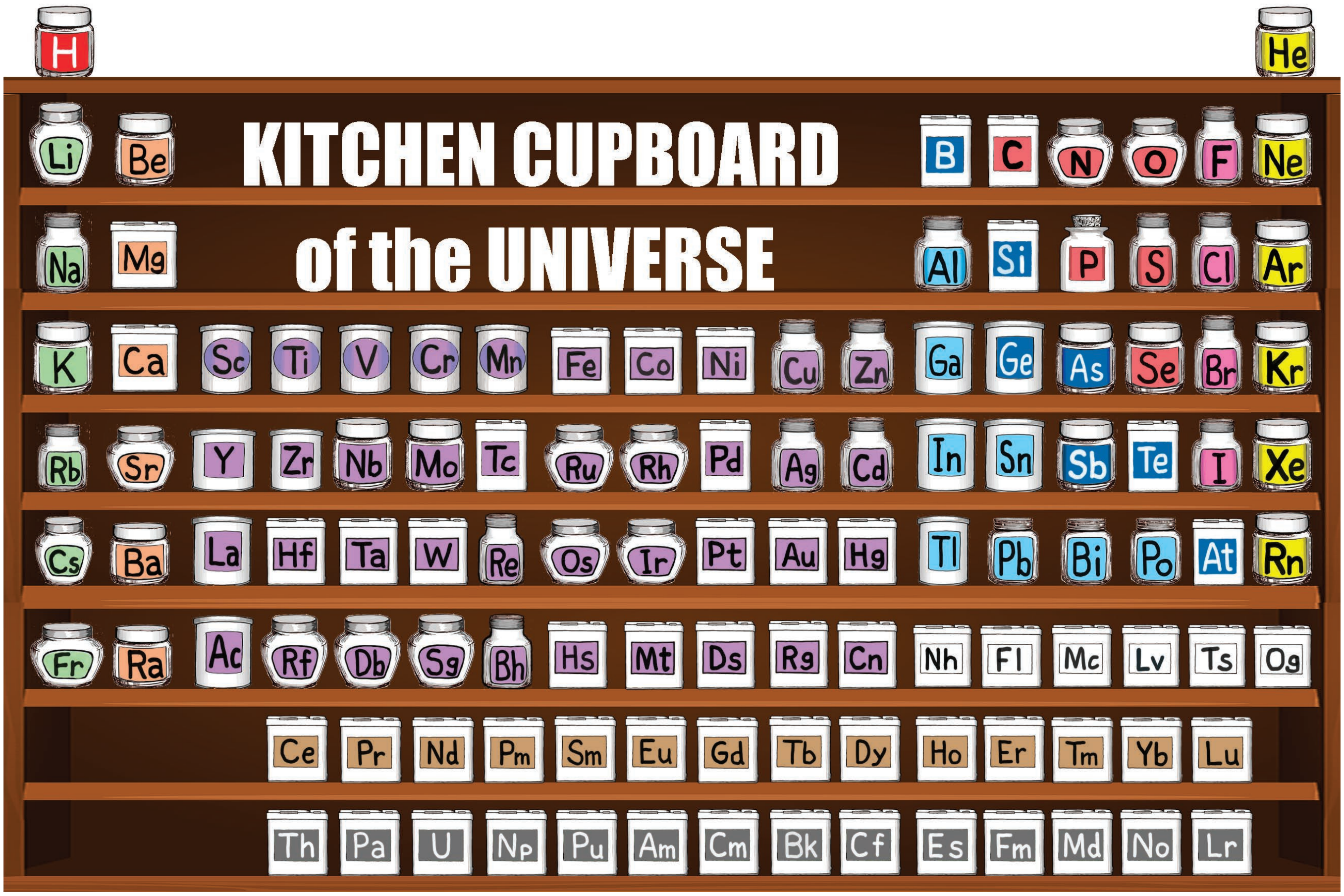


Think about cookies (tough assignment, eh?) and answer these questions:

1) How would a cookie change if you put it in the freezer?
2) How would a cookie change if you let it sit out somewhere for a week?
3) How would a cookie change if you put it in a glass of water?
4) Do these changes mean that the recipe changed?
5) Do other factors, not just the recipes, contribute to the quality of foods?

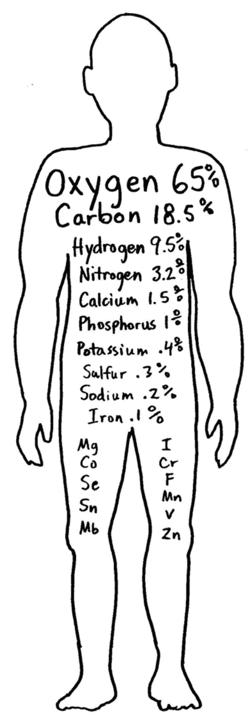


We know that baked goods are made of ingredients. But what are *ingredients* made of? What is flour made of? What is water? What is oil? These baking ingredients are made of chemical ingredients called **elements**. The chemical elements are the most basic ingredients of all. They are the things that everything else is made of. There are a little over 100 chemical elements, and if we could put a sample of each into a little bottle or box, we'd have sort of a "kitchen cupboard of the universe."



These are the ingredients that make up anything you can think of: plants, animals, rocks, plastic, metal, fuel, fabric, computers, food, water, air, garbage... anything! Your body is made of these elements, too. You are a "recipe" of these chemical ingredients.

Some of these chemical elements are very common and are found in practically everything, just like flour is found in so many baked goods. You may already be familiar with the names of some of these common elements: hydrogen, carbon, nitrogen, oxygen and silicon. These five elements account for most of the matter (stuff) in the universe! Other elements are less common and have names you've never heard of, such as osmium or ruthenium. These uncommon elements are a bit like the spices lurking at the back of your cupboard— the ones you use only once in a while, such as dill weed or coriander.



Isn't it great to find out that you already know some of these elements? Another chemical element you are already familiar with is helium. You've known about that one since you were old enough to hold a balloon. You just didn't know it was one of the basic ingredients of the universe. You probably know quite a few more, too, like gold, silver, lead, iron, copper, nickel, and aluminum. How many others do you know?

Activity 1.3 Elements you already know

How many of these elements do you recognize? Circle any name that you have heard of, even if you don't know exactly what it is. (This is not a complete list of all elements, only about half of them.)

hydrogen	helium	lithium	boron	carbon
nitrogen	oxygen	fluorine	neon	sodium
magnesium	aluminum	silicon	phosphorus	sulfur
chlorine	potassium	calcium	manganese	titanium
chromium	iron	cobalt	nickel	copper
zinc	lead	silver	gold	platinum
mercury	arsenic	selenium	tin	radon
uranium	plutonium	iodine	zirconium	tungsten

ELEMENTS IN HISTORY:

Some of these elements were familiar to ancient peoples. Silver and gold, for example, have been used for thousands of years. The ancients also knew about iron, tin, lead, copper, sulfur, and mercury. (They didn't understand what a chemical element was, however, and thought that everything was made of fire, water, earth and air.) In the 1800s, electricity was used to discover magnesium, potassium and sodium. Also in the 1800s, new elements were discovered in mines. In the 1900s, radioactive elements such as uranium and plutonium were discovered. They were named in honor of the discovery of Uranus and Pluto just a few years previously. Elements with numbers above 92 did not exist until they were artificially made in the mid-1900s.

Activity 1.4 A scavenger hunt for elements

Read the labels on some food packages or other household products and see how many elements you can find. (Pet foods are especially good choices.) Put a check mark in the box if you find that element. The names of the elements might be slightly disguised. For example, instead of sulfur you might see "sulfite," or instead of phosphorus you might see "phosphoric acid." Look for the first part of the names, and don't worry too much about the endings. The three empty spaces at the bottom are for you to add other elements that you find.

	cereal	medicine or toothpaste	bread	You choose three more:		
calcium						
carbon						
chlorine						
copper						
fluorine						
iodine						
iron						
phosphorus						
potassium						
magnesium						
zinc						

So what are *ingredients* made of? Is there a recipe to make salt or sugar? Yes, there is! The ingredients are the chemical elements and the recipes are called formulas. For example, to make salt, you need two chemical elements: sodium and chlorine. If you combine these two elements together, you will get table salt. The recipe for sugar calls for three elements: carbon, hydrogen, and oxygen. Some chemical recipes, like sugar and salt, are fairly simple. Other materials have recipes that are extremely complicated. Livings things, such as plants and animals, are also made of chemical elements but are mixtures of so many different substances that you really can't come up with a recipe for them.

A cooking recipe looks like this:

Sugar cookies:

2 cups flour	1 egg
1/2 cup sugar	1 teaspoon vanilla
1/2 cup butter	1/2 teaspoon baking soda

A chemical recipe looks like this:

glucose sugar = $C_6H_{12}O_6$

The letters are abbreviations, or **symbols**, for elements. C stands for carbon, H stands for hydrogen, and O stands for oxygen. The numbers below the letters tell you how many of each atom go into the recipe. This recipe calls for 6 atoms of carbon, 12 atoms of hydrogen and 6 atoms of oxygen. Just like with a cooking recipe, you can make a small, medium, or large batch. Theoretically, you could make a batch as small as a few molecules or large enough to fill a dump truck. As long as you keep the number of atoms in the ratio 6, 12, 6, you will get glucose sugar.

Let's look at the recipe for water:

water = H_2O

The elements in this recipe are similar to the one for glucose sugar, except that there is no carbon. You will need just hydrogen and oxygen. How much of each? There are 2 hydrogen atoms and... but there is no number after the O. Now what? If you don't see a number, it means there is only one. Scientists decided a long time ago that it was too much work to put in all the 1's in the recipes, so they agreed to just leave them out. If you don't see a number after the letter, that means there is only one. (You could think of the 1's as being invisible.)

We'll need 2 atoms of hydrogen for every 1 atom of oxygen. How much of the recipe will you make? A glass of water, or enough to fill a swimming pool? (The fascinating thing about this recipe is that when you combine two gases you get a liquid. And if you break water apart, you get two gases again.)

What about the recipe for salt?

table salt = NaCl

We don't see any numbers here at all. That means one atom of each. What are the ingredients? **Na** is the letter symbol for sodium (which used to be called natrium) and **Cl** is the abbreviation for chlorine (yes, chlorine goes in your pool, too, but it is also in salt).

Let's look at the recipe for baking soda:

baking soda = $NaHCO_3$

That's 1 atom of sodium, 1 atom of hydrogen, 1 atom of carbon, and 3 atoms of oxygen. Those are all the same ingredients we just used to make salt and sugar, but if you combine them in this proportion you will make baking soda. (Baking soda's job in kitchen recipes is to make things "puff up" in the oven.)

What else can we make with chemical elements? Here are some recipes that aren't edible:

sand: SiO_2

Epsom salt: $MgSO_4$

gold: Au

pyrite ("fool's gold"): FeS_2

We have some new elements in these recipes. **Si** is silicon, **Mg** is magnesium, **Fe** is iron, **S** is sulfur, and **Au** is gold. You can see that the recipe for gold is pretty simple—it's just the element gold with nothing added. Until the 1700s, scientists did not have a clear idea about the chemical elements. They thought that perhaps it was possible to change other materials into gold. You can see why fool's gold can never become real gold. Iron and sulfur will always be iron and sulfur.

Here is a really long recipe:

a mineral called Vesuvianite: $Ca_{10}Mg_2Al_4(SiO_4)_5(Si_2O_7)_2(OH)_4$

Wow! We won't be cooking up any of that!

* *

Activity 1.5 Making larger batches

Recipes can be doubled, tripled, or cut in half, depending upon how much of the product you want to make. See if you can figure out the answers to these recipe questions.
(Note: We're just using an imaginary "scoop" that accurately counts the atoms for us. In real life, measuring elements and mixing them requires special equipment and more difficult math.) Answers are in answer key on page 81.

1) The recipe for the mineral calcite is $CaCO_3$. If we use 2 "scoops" of Ca (calcium), how many "scoops" of the other ingredients will we need? C = ____ O = _____

2) The recipe for the mineral called cinnabar (sounds delicious, but it's poisonous) is HgS. If we make a batch of cinnabar using 3 "scoops" of Hg (mercury), how many "scoops" of S (sulfur) will we need? ________

3) You are a practical joker and want to make a batch of fool's gold to trick a friend. The recipe for fool's gold is FeS_2. If you use 4 "scoops" of S (sulfur) how many "scoops" of Fe (iron) will you need? _____

4) A mineral gemstone called zircon can sometimes resemble a diamond. The recipe to make zircon is $ZrSiO_4$. If you use 2 "scoops" of Zr (zirconium), how many "scoops" of the other ingredients will you need? Si = _____ O = _____

Activity 1.6

See if you can match the element with the meaning of its name. (Answers are in answer key, pg. 81.)

1) Named after Alfred Nobel, inventor of dynamite and founder of the Nobel Prizes ____________

2) Named after Vanadis, a goddess from Scandinavian mythology _____________

3) Named after Johan Gadolin, a Finnish chemist ______________

4) Named after Poland, the country in which famous chemist Marie Curie was born ___________

5) Named after Albert Einstein ______________

6) Named after the city of Berkeley, California ______________

7) Named to honor our planet, Earth, but using the Greek word for Earth: “Tellus” _____________

8) Named for the area of Europe called Scandinavia (Norway, Finland, Sweden, Denmark) ____________

9) Named for the Swedish town of Ytterby ______________

10) Named for Niobe, a goddess in Greek mythology who was the daughter of Tantalus _____________

11) Named for Tinia, a mythological god of the Etruscans (in the area we now call Italy) ____________

12) Named for Stockholm, Sweden ______________

13) Named in honor of the discovery of the planet Neptune _______________

14) Named in honor of Marie and Pierre Curie, who discovered radium and polonium _______________

15) Named after the Roman messenger god, Mercury, who had wings on his feet ______________

16) Named after the Greek god Tantalus (father of Niobe) _________________

17) Named in honor of the discovery of the asteroid Ceres _______________

18) Named after France, but using its ancient name, Gaul _________________

19) Named after the moon, but using the Greek word for moon, “selene” _____________

20) Named for its really bad smell, using the Greek word “bromos” which means “stench” ____________

21) Named after the Latin word for rainbow, “iris,” because it forms salts of various colors __________

22) Named after Thor, the Norse god of thunder ____________

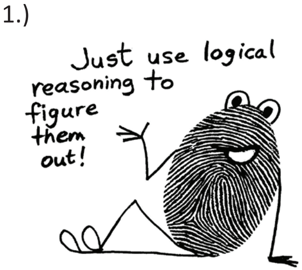
23) The name comes from the German word “Kupfernickel,” meaning “Satan’s copper” ______________

24) The name comes from the German “Kobald,” a mythological gnome who lived in mines ____________

25) Named for its color, yellowish-green, using the Greek word for this color: “chloros” _____________

THE POSSIBLE ANSWERS: (If you need help with pronunciation, use the key before page 1.)

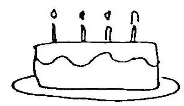
berkelium, bromine, cobalt, cerium, chlorine, curium, einsteinium, gadolinium, gallium, holmium, iridium, mercury, neptunium, nickel, niobium, nobelium, polonium, scandium, selenium, tantalum, tellurium, thorium, tin, vanadium, ytterbium



Activity 1.7 "The Chemical Compounds Song"

Here is a very silly song about chemical recipes. The audio tracks for this song can be found at www.ellenjmchenry.com/audio-tracks-for-the-elements (or in the zip file if you have the digital download). There are two versions of this song. The first one has the words so you can learn how they match the tune. The second version is accompaniment-only so you can sing it yourself. When singing it becomes easy, try it as a hand-clap game, like "Miss Merry Mack" or "Down, Down Baby." You don't even need the music if you use it as a hand-clap game. (Also, there is a music video of this song posted on the YouTube playlist mentioned at the top of page 17.)

The Chemical Compounds Song



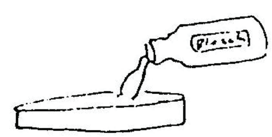
Today was Mama's birthday; I tried to bake a cake.
I didn't use a recipe, that was my first mistake!

I put in lots of H_2O, 3 cups NaCl,
Some $NaHCO_3$, and other things as well.

I poured it in a non-stick pan (Teflon, C_2F_4)
I popped it in the oven (it cooks with CH_4).

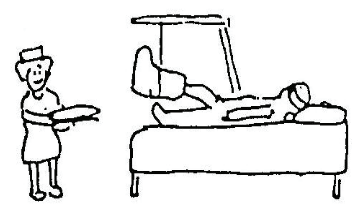
I set the oven way too hot, the cake got black and charred.
Oh, why did I make birthday cake? I should have bought a card!

I had to clean and scrub the pan, so Mom would never know.
First I tried to bleach the pan with NaClO.



I needed something stronger, so I tried some HCl.
I added grit, SiO_2, and FeO, as well.

Then something awful happened, I'll never know just why.
I woke up in the hospital with stitches near my eye!



My leg was in a plaster cast of $CaSO_4$.
The nurse brought $Mg(OH)_2$ and $MgSO_4$.

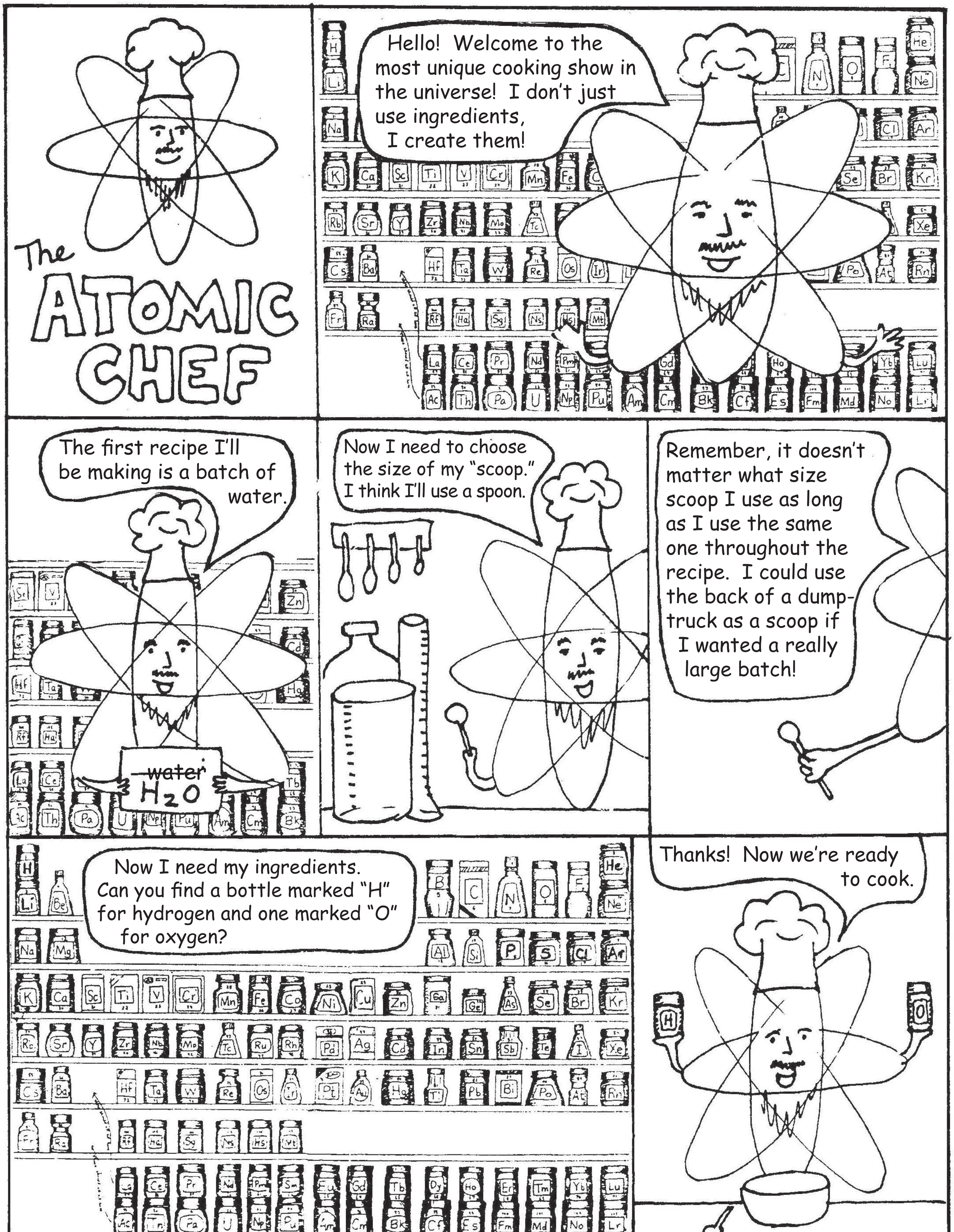
Next year for Mama's birthday, I'll buy a cake, instead,
'Cause if I tried to bake again, I think I'd end up dead!

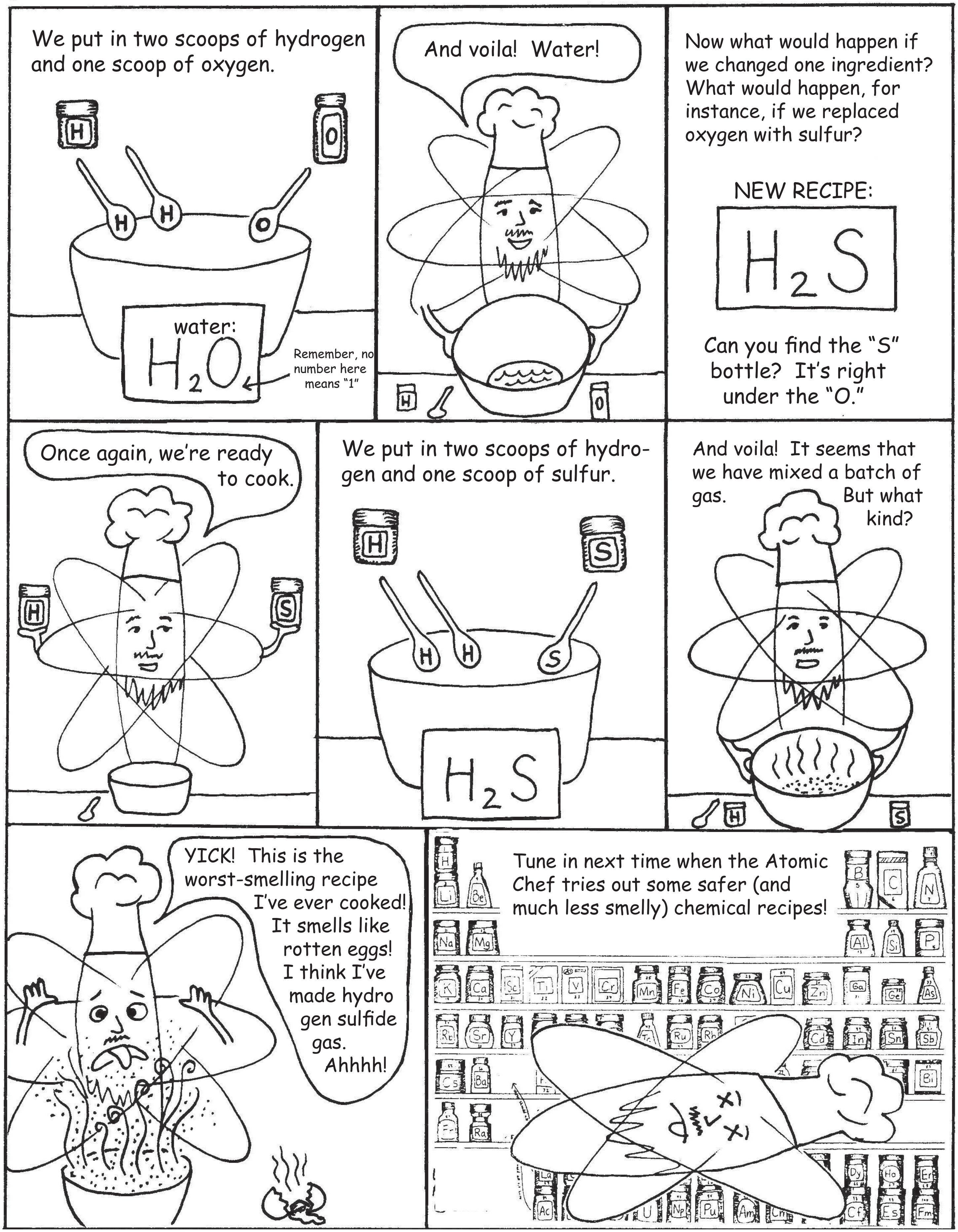
H_20 = water
NaCl = salt
$NaHCO_3$ = baking soda
C_2F_4 = Teflon
CH_4 = natural gas
NaClO = bleach

HCl = hydrochloric acid
SiO_2 = sand
FeO = a type of rust [or FeO(OH) to be more accurate] *
$CaSO_4$ = plaster
$Mg(OH)_2$ = milk of magnesia (good for intestines)
$MgSO_4$ = Epsom salt (good for skin)

* Rust is complicated. More commonly it is written as $Fe_2O_3(OH)$ or $Fe_2O_3.nH_2O$. But those don't fit the rhyme.

And now it's time for our first episode of The Atomic Chef!





Tune in again at the end of the next chapter for more adventures with the Atomic Chef!

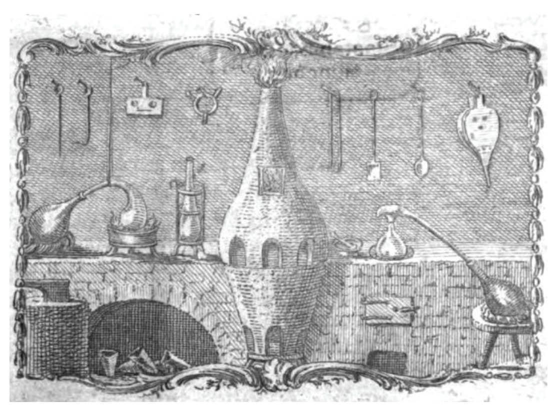
CHAPTER 2: THE PERIODIC TABLE

Have you ever read stories from medieval times where a person called an "alchemist" tried to make gold? The alchemists were part scientist and part magician, and although they experimented with other forms of chemistry, they are famous for trying to make gold. They boiled up mixtures of every substance they could find: copper, tin, lead, iron, coal, silver, mercury, unusual rocks, gold-colored minerals, medicinal plants, parts of animals, and anything else they could think of. They even said magic spells over their boiling pots, but they never produced a single drop of gold.

What the alchemists did not know is that gold is one of the basic ingredients in the Kitchen Cupboard of the Universe. They thought gold had a recipe like water or salt or sugar. But you can't make gold. It's a basic ingredient that comes naturally in the Earth. The letter symbol for gold is **Au**. Ancient peoples called gold by the name "aurum" and that is where we get the letters "Au." Can you find gold in the Kitchen Cupboard of the Universe?

The confusion of the alchemists is very understandable. Metals don't come with labels on them telling you what they are made of. Bronze and copper were both metals. Bronze could be melted down into its two ingredients: copper and tin. The alchemists wondered why copper couldn't be boiled down into its ingredients. They didn't know that copper, like gold, is an element. It was only after years of experimenting that ancient scientists began a list of substances that they believed could not be reduced down any further. During the 300 years between 1200 AD and 1500 AD, the list of substances believed to be basic ingredients of the universe grew to include carbon, sulfur, iron, copper, silver, tin, mercury, lead, arsenic, antimony, bismuth, zinc, platinum and gold. (The alchemists eventually had to give up and admit that gold had no recipe.) All of these elements are in our kitchen cupboard of the universe, though they are not sitting all in a row.

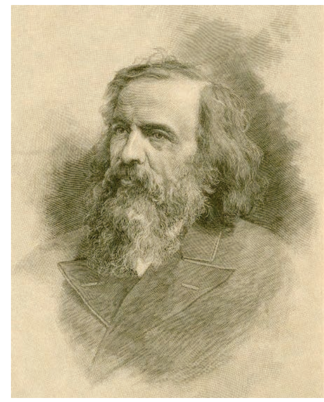
Several hundred years went by with no new discoveries of any more basic ingredients. Then, in the 1700s, chemists really began to catch on to the idea of elements, and began intentionally looking for them. They were able to add many more substances to the list of basic elements, including hydrogen, oxygen, nitrogen, magnesium, chlorine, cobalt, nickel, bismuth, platinum and tungsten. In many cases, chemists had not yet been able to produce these substances in a pure form, but they were still pretty sure that these things were basic ingredients, not mixtures. The chemists now began calling these basic ingredients "elements," and by the year 1800, the official list of elements also included phosphorus, fluorine, barium, strontium,



Chemistry labs of the 1700s still looked a lot like the alchemists' labs of the Middle Ages.

molybdenum *(moll-IB-den-um)*, zirconium, chromium, and uranium. These elements were still very mysterious, however, and little was known about them.

The list kept growing during the 1800s, and by the middle of the century there were over 60 elements on the list. By now there was no confusion about what an element was. Scientists understood very clearly that elements were the basic ingredients of the universe. An element could not be boiled down into anything else. They also understood that there was probably a limited number of elements, and once they were all found the fun of discovery would be over. Thus, there ensued a sort of international "scavenger hunt" for new elements, with every chemist dreaming of being one of the lucky winners who would find one of the remaining unknown elements.



Amidst all this frenzy for discovering the remaining elements, a Russian chemist named Dmitri Mendeleyev *(men-dell-AY-ev)* (also spelled Mendeleev) began giving chemistry lectures at St. Petersburg University in 1867. As Mendeleyev studied in order to prepare for his lectures, he began to have the feeling that the world of chemistry was like a huge forest in which you could easily get lost. There were no trails or maps, and there were so many trees! It was all a muddled mess of elements, mixtures, oxides, salts, acids, bases, gases, liquids, crystals, metals, and so much more. The subject of chemistry was confusing to his students, and he could see why. There was no overall structure to this area of science. It was just a massive collection of facts and observations about individual substances. Each scientist had a different way of arranging the substances, and that confused students. Some scientists grouped all the gases together, while others grouped them by color, or listed them from most to least common, or even alphabetically. Was one arrangement better than all the rest? Mendeleyev decided that he would search for some kind of overall pattern that could be applied to chemistry, making it easier for his students to learn.

Mendeleyev began by cutting 63 squares of cardboard, one for each of the elements that were known at that time. On each card he wrote the name of an element and all its characteristics: whether it was solid, liquid, or gas, what color it was, how shiny it was, how much it weighed, and how it reacted to other elements. He then laid out the cards in various ways, trying to find an overall pattern. One evening he was sitting, as usual, in front of his element cards, staring at them and trying to think of some new way to arrange them. He had been working on this puzzle for three days straight, without any sleep. Mendeleyev was exhausted as he fell asleep that night. While he slept, he dreamed about the cards. In his dream he saw the cards line up into rows and columns, creating a rectangular "table."

When he woke up, he realized that his brain had solved the problem while he had slept. The way to arrange the elements was first by weight, then by chemical properties. He began laying out the elements in order of their weight, starting with the lightest, hydrogen.

Then came helium, lithium, berylium, boron, carbon, nitrogen, oxygen, and fluorine. The next element was sodium. Instead of putting it next to fluorine, he put it underneath lithium because it had similar chemical properties to lithium. So the second line began with sodium. Then he began filling in with the elements arranged by weight again: magnesium, aluminum, silicon, phosphorus, sulfur, and chlorine. When he got to the next element, potassium, he decided to start a third line, putting potassium right underneath sodium because they had similar chemical properties. Then it was back to listing them by weight: calcium, titanium, vanadium, chromium... As he laid the cards out in order of their weight, every once in a while, or "periodically," he had to go back and start a new row so that elements that had similar chemical properties would be in the same column. This method of arranging the elements became known as the "Periodic Table" because it is a table (chart) that has patterns that repeat periodically.

This is how the main part of Mendeleyev's chart looked.

lithium	beryllium	boron	carbon	nitrogen	oxygen	fluorine
sodium	magnesium	aluminum	silicon	phosphorus	sulfur	chlorine
potassium	calcium	eka-boron	titanium	vanadium	chromium	manganese
copper	zinc	eka-aluminum	eka-silicon	arsenic	selenium	bromine
rubidium	strontium	yttrium	zirconium	columbium	molybdenum	?
silver	cadmium	indium	tin	antimony	tellurium	iodine
cesium	barium					

Mendeleyev ran into some problems with his Periodic Table. It seemed that there were awkward areas where things did not fit perfectly. He guessed that this was because there were cards missing. His set of 63 cards must be incomplete. Mendeleyev started leaving blank spaces in his chart where he believed there was a missing element. He began to predict what these elements would be like when they were discovered. He even gave them temporary names. The empty space under boron and aluminum he named "eka-boron." ("Eka" means "one more" in the Sanskrit language.) The empty space under carbon, silicon, and titanium was "eka-silicon."

Many chemists of Mendeleyev's day laughed at him for trying to predict the discovery of new elements. They did not believe in his Periodic Table and thought he was a fool for making up all these fictional elements—elements that did not even exist!

In 1875, one of Mendeleyev's predictions came true. A new element was discovered by a French chemist with a long name: Paul Emile Lecoq de Boisdaubran. He had decided to name this new element after his country, France, but using a very old word for France: Gall. He named the element "gallium." Mendeleyev listened to the description of this new element and proudly announced that gallium was, in fact, the missing element he had called eka-aluminum. Mendeleyev had already known what this element would be like. It would be a soft, silvery-blue metal with a very low melting point—so low that this metal might even melt in your hand. This is exactly how Boisdaubran described gallium. Some chemists thought this was just a coincidence and waited to see if any more of Mendeleyev's predictions would come true.

Gallium, from Wikipedia, credit for photo: en:user:foobar

Germanium looks a lot like gallium. (Photo credit: wikipedia article on germanium.)

After the discovery of gallium, Mendeleyev became braver about making predictions. He announced that sometime soon a scientist would discover a new element that would be a dark gray metal with a weight that was 72 times heavier than hydrogen, a specific gravity of about 5.5, and having the ability to combine with oxygen to make oxide compounds that are very hard to melt even in a hot fire. Fifteen years after this prediction, a scientist in Germany discovered a new metal that he named "germanium" (after Germany, of course). As you might guess, the characteristics of this new metal were exactly what Mendeleyev had predicted! The scientific world was stunned as they compared Mendeleyev's predictions with the actual experimental results for this new metal—they were almost identical. Germanium was Mendeleyev's "eka-silicon." Mendeleyev was happy to have a real name for "eka-silicon" and gladly replaced it with "germanium."

Eventually, Mendeleyev and his Periodic Table became famous all over the world. He received gold medals and honorary degrees from universities in other countries, and was invited to join important scientific societies. Sadly, however, his homeland of Russia refused to acknowledge him. When his name was presented to the Russian Academy of Sciences he was rejected. Mendeleyev was unpopular in Russia because he said things the Russian government did not want to hear. He told them they needed to be careful with Russia's supply of crude oil because it was a precious resource and would not last forever. He said that Russia's technology was lagging behind that of other nations and they needed to catch up. Sadly, the government didn't really care about improving the country, and they ingnored Mendeleyev's advice.

After Mendeleyev, chemists continued to discover elements. Every time a new element was discovered it was added to the Periodic Table. The number of elements grew from 63 to over 100. Some adjustments had to be made to Mendeleyev's original table in order to accommodate all the new discoveries. They added a middle section, plus two rows at the bottom.

Mendeleyev's table:

Reihen	Gruppe I. — R^2O	Gruppe II. — RO	Gruppe III. — R^2O^3	Gruppe IV. RH^4 RO^2	Gruppe V. RH^3 R^2O^5	Gruppe VI. RH^2 RO^3	Gruppe VII. RH R^2O^7	Gruppe VIII. — RO^4
1	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59, Ni=59, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —

The Periodic Table as it looks today:

Periodic Table of the Elements

GROUP	IA	IIA	IIIA	IVA	VA	VIA	VIIA	VIIIA			IB	IIB	IIIB	IVB	VB	VIB	VIIB	VIII
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba		72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra		104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Uun	111 Uuu	112 Uub						
				57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
				89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

Many decades after Mendeleyev's death, scientists realized that there was nothing on the Periodic Table to commemorate the very man who had created it. So in 1955, when a new element was discovered, the discoverers decided to honor the memory of Dmitri Mendeleyev by naming the new element "Mendelevium." It is number 101 on the Periodic Table and its letter symbol is Md.

To be fair, we really should mention that Mendeleyev wasn't the only person who saw repeating patterns in the elements. A chemist named John Newlands had noticed this in the mid 1800s and published what he called the "Law of Octaves" in 1864 (just a few years before Mendelyev's discovery). Previously, chemists had noticed groups of 3's that behaved similarly and called them "triads." (For example, lithium, sodium and potassium in the first column all reacted violently in water.) Newlands suggested that the triads were part of a larger pattern based on the number 8. He also suggested that atomic weights were a key to organizing the elements. Newlands turned out to be right about both. However, when Newlands presented his theory at the Royal Chemistry Society in London, they laughed at him and even made fun of him. They told him to go play chemistry on a piano.

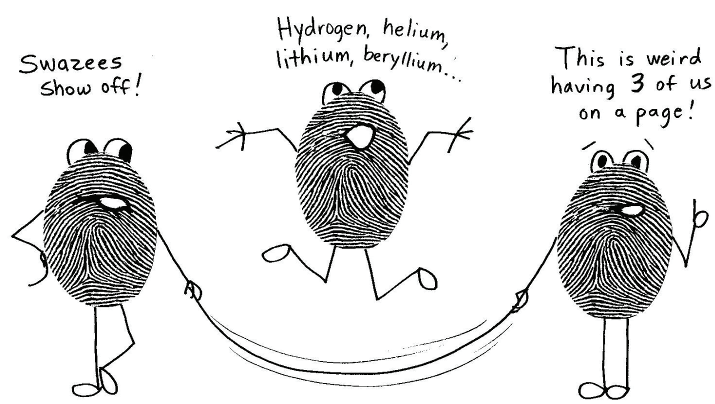
Unfortunately, this type of thing happens fairly often. New theories that don't fit with current opinions are often scorned or even ridiculed. The Royal Chemistry Society did try to right this wrong in 1884 by asking Newlands to give a lecture at the Society. This time no one laughed at him. And today if you go to the Royal Society of Chemistry website, they proudly suggest that the real discoverer of the periodic arrangement of elements was British, not Russian. In fact, they've even placed a big, blue sign on his birthplace, telling all who pass by that this is where the discoverer of the Periodic Table was born.

Why did Mendeleyev get credit and Newlands did not? Mendeleyev's stroke of genius was to assume that all the elements had not been discovered, and to leave blank spots at points where the pattern seemed to fail. Newlands' table did not leave blanks for undiscovered elements, so it was bound to have problems in the end. Mendeleyev's table was not perfect, either, but it was enough better than Newlands' that Mendeleyev is remembered as the inventor of the Periodic Table.

Activity 2.1 The Periodic Jump Rope Rhyme

Use the first four rows of the Periodic Table as a jump rope rhyme. Why not? Most jump rope rhymes are pretty silly and don't make sense, anyway! The audio track will show you how to say the rhyme. Then try it on your own. If you mess up and trip over the rope, you have to start at the beginning again. Can you get to krypton? Can your friends do it?

Hydrogen, helium,
Lithium, beryllium
Boron, carbon
Nitrogen and Oxygen
Fluorine, neon



Sodium, magnesium
Aluminum and silicon
Phosphorus, sulfur
Chlorine, argon

Potassium, calcium
Scandium, titanium, vanadium, chromium, manganese!

FeCoNi's my CuZn
His last name is Gallium
He lives in Germanium
Once he ate some arsenic, thought it was selenium;
Drank it down with bromine, now he's strong as krypton!

(The audio track can be found at www.ellenjmchenry.com/audio-tracks-for-the-elements, or in the zip file if you bought the digital download version.)

Activity 2.2 What are these elements?

Use the "Quick Six" playing cards to find these elements. (Check answer key, page 81.)

1) Find an element that is used to make matches, fireworks, and detergents. _______________

2) Find an element that is used in toothpaste, but is also one of the ingredients in Teflon (The recipe for Teflon is in the "Chemical Compounds Song.") ______________

3) Find an element that is found in chalk, plaster, concrete, bones and teeth. _________

4) Find an element that is used in lasers, CD players and cell phones. ___________

5) Find an element that is used to repair bones and is also used in paints. ____________

6) Find an element that is found in sand, clay, lava, and quartz. ___________

7) Find an element that is rose-colored and is used to make catalytic converters and headlight reflectors for cars. ____________

8) Find an element that is used as a disinfectant for cuts and scrapes, is used to make lamps and photographic film, and is needed by our thyroid glands. ___________

9) Find an element that is used in stadium lights and in large-screen TVs. ____________

10) Find an element that is used in dentistry and jewelry, and is also used to purify hydrogen gas and to treat tumors. _____________

11) Find an element that is an ingredient of pewter, and can also be mixed with copper to make bronze. _____

12) Find an element that is used to vulcanize rubber and is a component of air pollution. ________

13) Find an element that is used to sterilize swimming pools. ______________

14) Find an element that is used in lightbulbs and lasers and won't bond with other elements. ____

15) Find an element that makes up most of the air we breathe. _____________

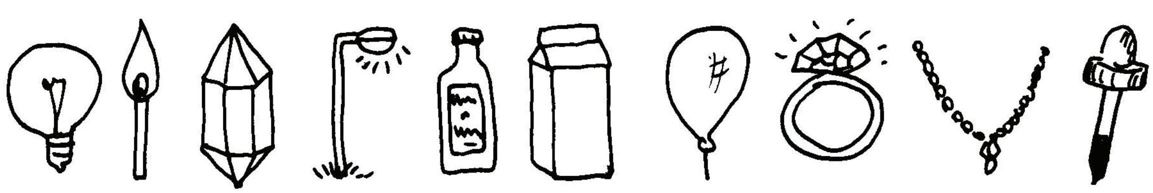
16) Find an element that has no neutrons. ___________

17) Find an element that makes diamonds, graphite and coal. _______________

18) Find an element that is used in antiseptic eye washes but is also used to make heat-resistant glass, as well as being used in nuclear power plants. __________

19) Find an element that you eat in bananas but can also be used for gunpowder. ___________

20) Find an element that is used in lights that need to flash brightly, such as camera flashes and strobe lights. ________________



Activity 2.3   Watch some videos

There is a playlist for this curriculum at: www.YouTube.com/TheBasementWorkshop. Click on PLAYLISTS and then on "The Elements." (If you can't see that playlist, use the arrow on the right to scroll through each row of videos. If you still can't see it, click on the drop-down and choose "created playlists.")

It isn't possible to tag the videos to show which chapter they go with, but they are listed in order, with the chapter one videos first, the chapter two videos second, etc. There are several videos about Mendeleyev, plus a few on gallium and germanium, the elements Mendeleyev predicted correctly.

NOTE: You will notice that there is more than one way to spell Mendeleyev. Some of the videos use the spelling Mendeleev, but it is still pronounced like it has a Y between the two E's. (Recently, spelling it without the Y has become more popular, but it is harder for students to remember how to pronounce it when you don't see the Y.)

Activity 2.4   Alternative Periodic Tables

There isn't a law saying that you can't arrange the chemical elements into a shape that isn't a rectangle. Over the past century, quite a few arrangements of the elements have been proposed. They can't be printed here due to copyright restrictions, but you can easily find them online by typing "alternative Periodic Tables" in a search engine set on "images." You could look at the image gallery at the bottom of the Wikipedia article titled "Alternative Periodic Tables."

Activity 2.5   Play an online quiz game to help you learn the symbols

You can choose to play easy or harder levels, so this game is great for beginners:
http://www.funbrain.com/periodic/

Check out this amazing Periodic Table! It's so large that it covers a whole wall! It is located at the Ruth Patrick Science Education Center in South Carolina. Each box in this table contains an actual sample of the element (except for the elements that are either too dangerous or too rare).

Activity 2.6

Here is a just-for-fun puzzle using the symbols (letter abbreviations) for some of the elements. Write the symbols in the blanks to make some silly riddles. (Check answer key if you need to.)

____ ____ ____ did ____e ____ ____ ____ ____a ____

tungsten hydrogen yttrium thorium molybdenum uranium selenium sulfur yttrium

"____ ____e____, ____ ____e____," ____ ____ ____ the

carbon helium phosphorus carbon helium phosphorus tungsten helium nitrogen

____ ____d'____ ____ ____e ____ll a____ ____t? ____ ____ ____

boron iridium sulfur carbon silver iron phosphorus argon Helium tungsten arsenic

____ ____ l ____ ____g ____ ____ ____r the ____ ____d

fluorine iodine lithium nitrogen indium fluorine oxygen boron iridium

____ ____ ____ ____ad ____e da____ ____ ____ ____.

tungsten hydrogen oxygen hydrogen thorium yttrium oxygen fluorine fluorine

Here's another one:

____ ____ ____ do ____ ____ ____ ____t ____ ____ ____

tungsten hydrogen astatine yttrium oxygen uranium germanium tungsten helium nitrogen

____ ____ ____ ____r ____ ____ a ____ ____ ____ ____e

yttrium oxygen uranium carbon osmium sulfur vanadium americium phosphorus iridium

____i____ a ____ ____ ____? A ____rr ____ ____ ____ed ____ ____!

tungsten thorium molybdenum uranium selenium tellurium iodine fluorine iodine carbon astatine

And one last riddle:

____ ____ ____ ____ ____e ____ ____a ____ a____ R____ ____ ____'____

tungsten hydrogen astatine tungsten erbium Barium thulium nitrogen neodymium oxygen bismuth nitrogen sulfur

____ ____ ____ ____ ____ a____ ____r t____ ____ ____ ____e

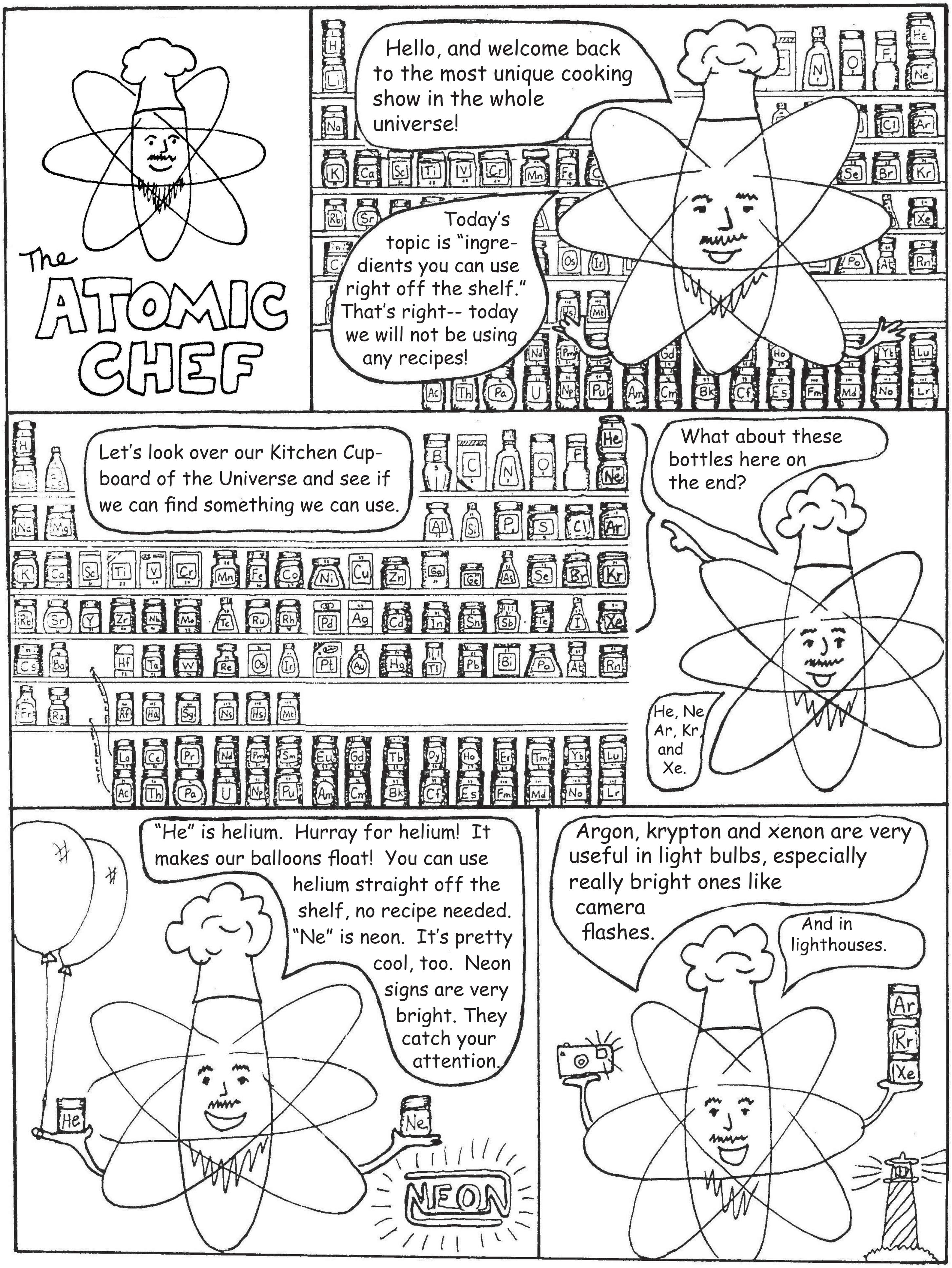
neon tungsten nitrogen americium einsteinium fluorine tellurium helium yttrium tungsten erbium

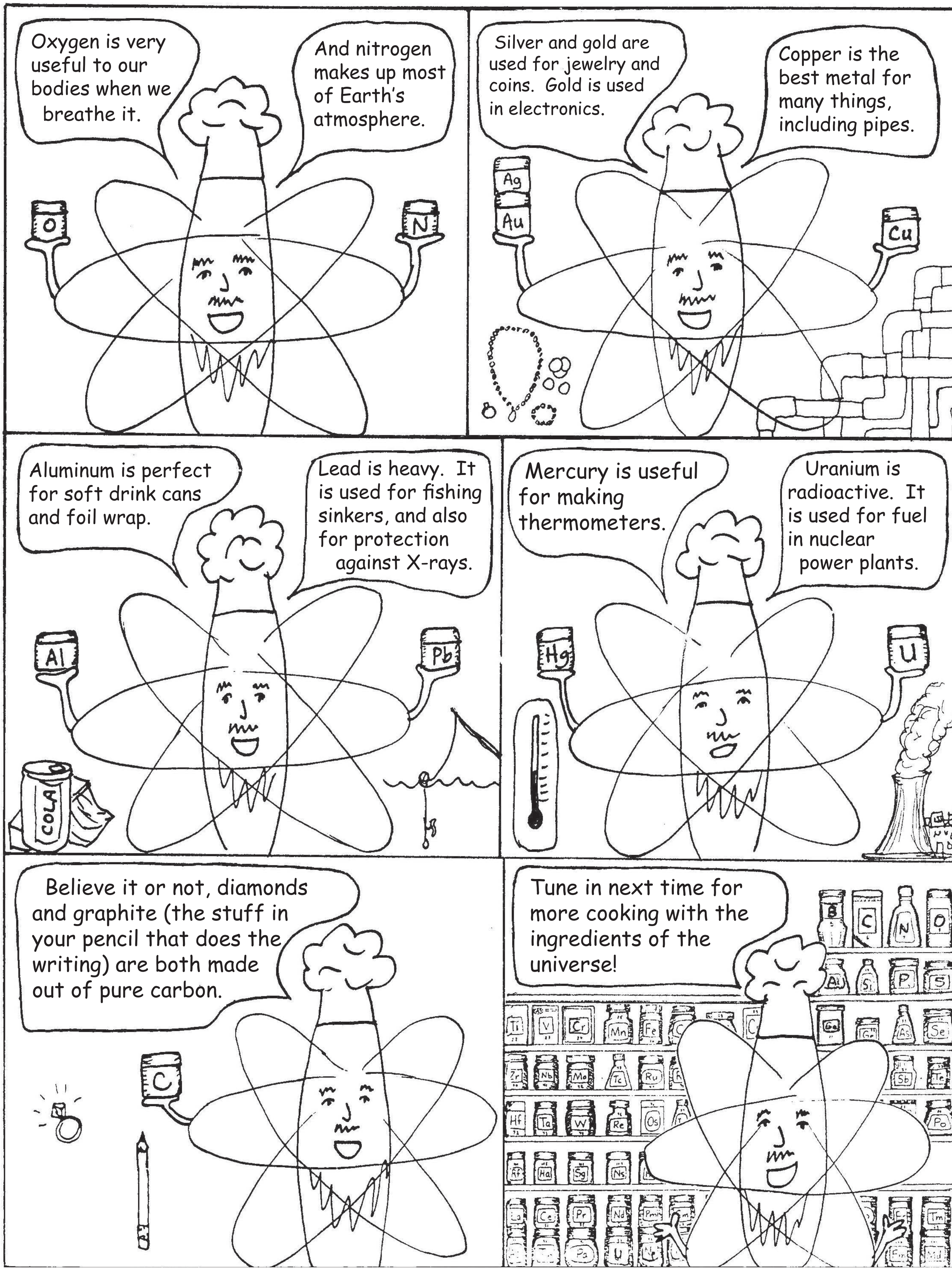
____ ____ ____ ____ ____ ____ ____ a ____r?

ruthenium nitrogen oxygen vanadium erbium boron yttrium calcium

____ ____ ____a____ a____ R____ ____ ____ ____ ____!

fluorine lanthanum thulium nitrogen neodymium iodine boron boron oxygen nitrogen

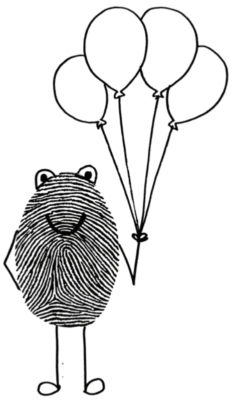

The ATOMIC CHEF
Hello, and welcome back to the most unique cooking show in the whole universe!
Today's topic is "ingredients you can use right off the shelf." That's right-- today we will not be using any recipes!
Let's look over our Kitchen Cupboard of the Universe and see if we can find something we can use.
What about these bottles here on the end?
He, Ne Ar, Kr, and Xe.
"He" is helium. Hurray for helium! It makes our balloons float! You can use helium straight off the shelf, no recipe needed. "Ne" is neon. It's pretty cool, too. Neon signs are very bright. They catch your attention.
NEON
Argon, krypton and xenon are very useful in light bulbs, especially really bright ones like camera flashes.
And in lighthouses.

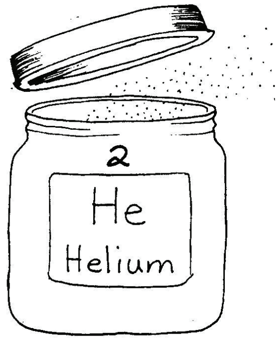

Oxygen is very useful to our bodies when we breathe it.
And nitrogen makes up most of Earth's atmosphere.
O
N
Silver and gold are used for jewelry and coins. Gold is used in electronics.
Copper is the best metal for many things, including pipes.
Ag
Au
Cu
Aluminum is perfect for soft drink cans and foil wrap.
Lead is heavy. It is used for fishing sinkers, and also for protection against X-rays.
Al
Pb
COLA
Mercury is useful for making thermometers.
Uranium is radioactive. It is used for fuel in nuclear power plants.
Hg
U
Believe it or not, diamonds and graphite (the stuff in your pencil that does the writing) are both made out of pure carbon.
C
Tune in next time for more cooking with the ingredients of the universe!

CHAPTER 3: ATOMS

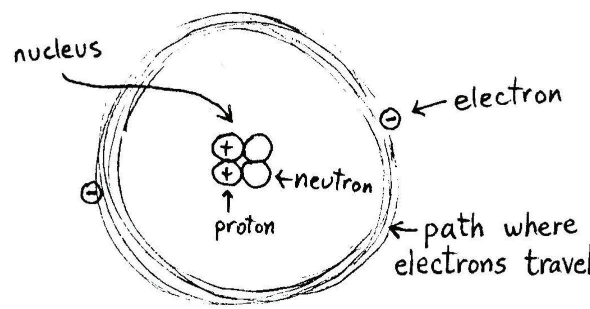
The scientists in Mendeleyev's day understood many things about the elements. They had even written books describing the characteristics of certain elements. However, one thing they were never able to do was examine just one particle of an element. It was not until the 1900s that scientists were able to figure out what the elements themselves were made of.

Let's open one of those ingredient jars and find out what the stuff inside looks like. How about He, helium?





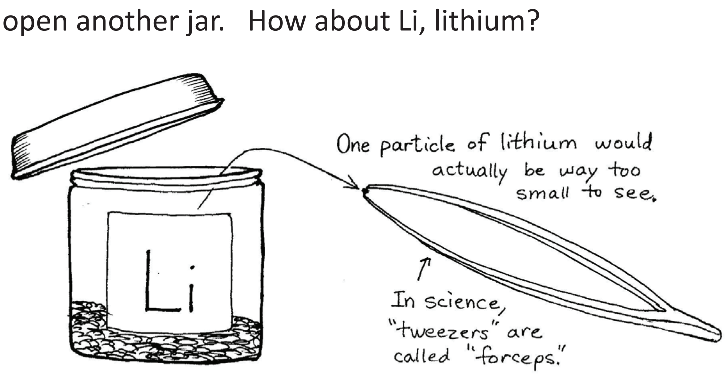
ONE PARTICLE (AN ATOM) OF HELIUM:

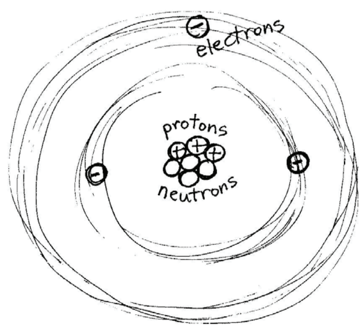


Let's look at just one of those little particles in the jar. One single particle is called an **atom**. An atom is a very strange-looking thing, and is made of up three even smaller types of particles: **protons**, **neutrons**, and **electrons**. The protons and neutrons like to hang out together in the center while the electrons go whizzing around the outside at about a million miles an hour. The central clump is called the **nucleus** of the atom, and the pathways the electrons travel in are called **orbits**, just like the pathways of the planets around the sun.

Your next question might be: "What are these particles made of?" That's a tough question, because they aren't really made of anything—they <u>are</u> the stuff that other stuff is made of. However, if you asked a physicist this question, he or she would give you a long, complicated answer that included words like "up quarks" and "down quarks." Atomic particles such as quarks are still not fully understood and require knowledge of very difficult math. (If you want to explore the world of sub-atomic particles, the Internet can help you.) All we need to know is that the proton has a postive electrical charge, the electron has a negative electrical charge, and the neutron has no charge at all. The electron is much, much smaller than either the proton or the neutron. In fact, it is so small that it adds almost nothing to the weight of the atom. When scientists figure out how much an atom weighs, they don't even bother with the electrons. They just count the protons and neutrons.

Let's open another jar. How about Li, lithium?

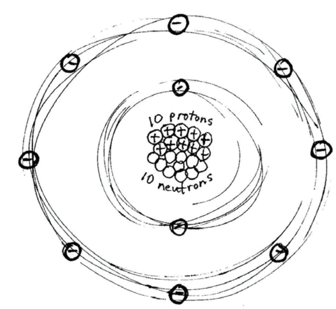




A lithium atom has three protons, three electrons, and four neutrons. The number of neutrons is often the same as the number of protons, but not always, as we see here with lithium. Smaller atoms tend to have equal, or almost equal numbers, but as the atoms get larger they begin requiring more neutrons. By the time you get to number 92, uranium, there are about 50 more neutrons than protons.

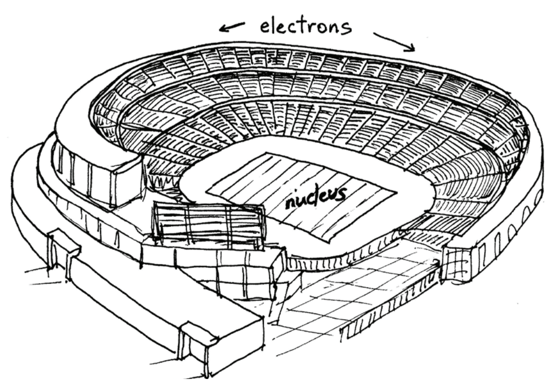
You may be wondering why the lithium atom has two rings around it instead of just one, like helium. Why isn't the third electron whizzing around in the first pathway with the other two electrons? The reason is that each ring can only hold a certain number of electrons, and although that first ring may look big enough to you, the electrons think it only has room for two of them. If a third electron comes along, the atom has to add another ring for it. The second ring is a bit bigger, and can hold up to eight electrons.

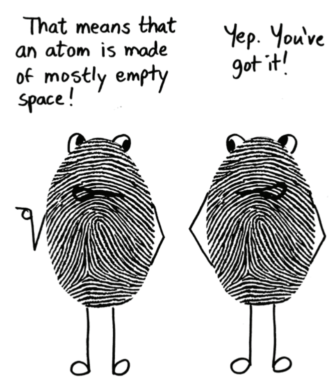
Let's look at an atom of neon. It has two completely full rings, with two in the first ring and eight in the second ring. Atoms that have full rings with no leftovers are very happy atoms. Neon is very content and good-natured. It is well-behaved and never tries to steal electrons from anyone.



By the way, don't forget that the electrons aren't really as big as they look in these drawings. In fact... now might be a good time to discuss the dimensions of an atom.

If we were to increase the size of an atom until it reached the size of a football stadium, the nucleus would look like a marble sitting on the 50 yard line. The electrons would be smaller than the head of a pin, and they would be whizzing around the outer edge of the stadium.

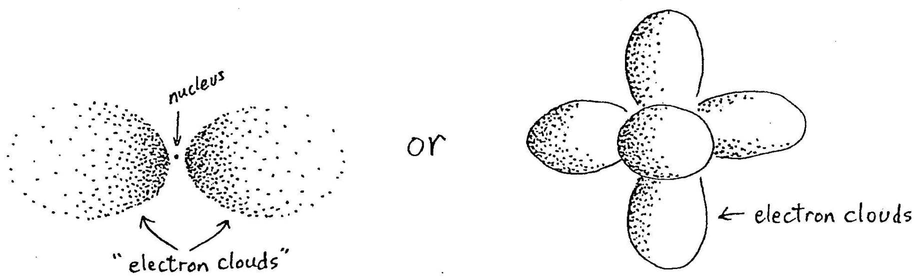




You can see why we have to draw atoms out of scale. If we drew them correctly, either you would not be able to see them, or you would have to have a book about a mile wide.

Speaking of drawing atoms, even if we could make the atoms on this page to scale, they would still be wrong. When scientists finally began to be able to "look" at atoms (though you can't look at them like you can look at a bacteria) they discovered that the electrons don't really go around the nucleus in circles. In the mid 1900s, physicists discovered that electrons move in a more random fashion, not in neat little circles like they had originally imagined. Electrons buzz around so fast that they end up looking more like a balloon than a ring. Since these balloon-like areas looked a bit fuzzy, scientists decided to call them "clouds." Drawing electrons clouds, as we will see, is not easy, which is part of the reason you still see orbitals drawn like rings in most pictures. (The correct name for the "solar system model" is actually the "Bohr model," named after physicist Neils Bohr.)

This is a rough sketch of what electron clouds look like:



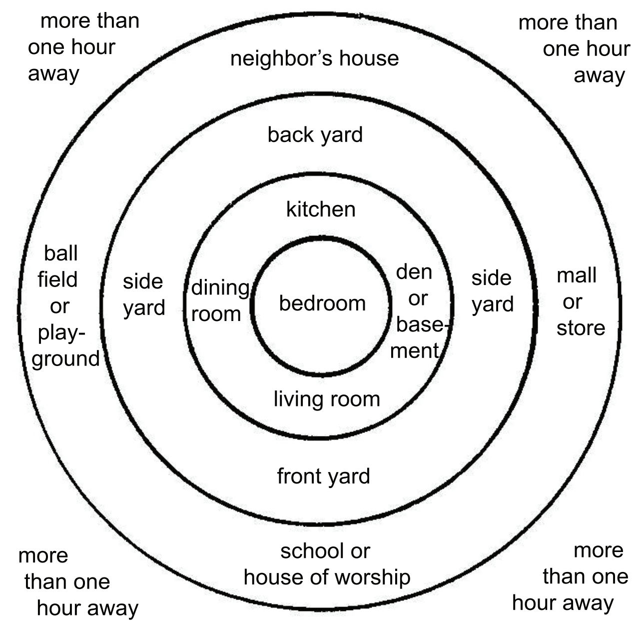
Electrons move around all the time, but they spend more time close to the nucleus than away from it. Electrons like to be in pairs, but in separate clouds on opposite sides of the nucleus. Pairs of electrons hate to be next to each other, too, so each pair will take a position as far apart from the others as possible. The result is that the clouds end up looking like a bunch of balloons tied together, with one electron per balloon.

Large atoms end up having very complicated arrangements of electron clouds and are almost impossible to draw as electron cloud models because so many of the clouds overlap in strange ways.

Activity 3.1

In this activity, you will play the part of an electron. You will map out your location every hour over a weekend. Each hour you will plot your location. For example, if you sleep for eight hours during the first night, you will put eight dots inside the center circle. The next hour might find you in the kitchen eating breakfast, so put a dot there. After that, you might spend an hour watching TV, then three hours at a ball field playing soccer. Put one dot on the TV room, and three dots on the ball field. Continue to plot your locations for several days.

When you are finished, look at your map. Where do the most dots occur? Are they spread out evenly, or is there a definite pattern to the arrangement of the dots? In this model, what represents the nucleus? Do you, the electron, spend more time near the nucleus than away from it?



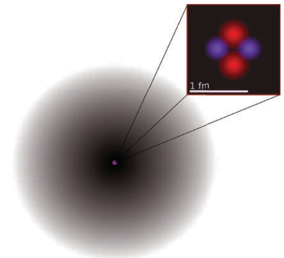
NOTE: You could just remember a recent weekend (or three weekdays) and estimate the number of hours in various places.

Activity 3.2 Looking at electron cloud models

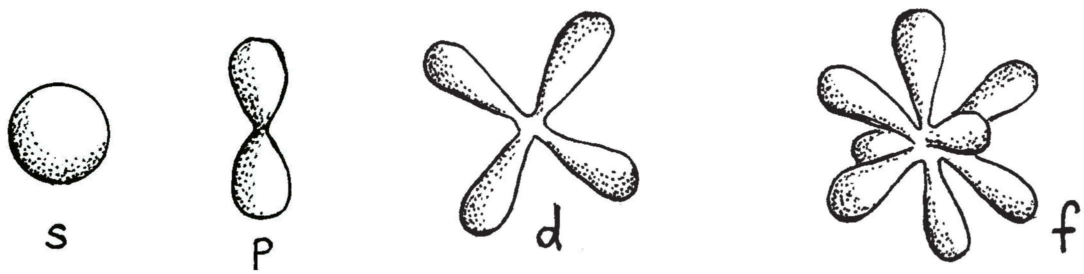
Look at some pictures of electron clouds on the Internet. Use a search engine with the key words "electron clouds." You will find many different images. Do any of the pictures look like balloons? You may see some that have hourglass shapes or ring shapes, as well as balloon shapes.

Then go to the YouTube channel for this curriculum and watch the videos that show 3-dimensional animations of electron clouds. The atoms will spin around so you can see all sides. Don't worry if there are words or letters that you don't know. Just enjoy watching the animations.

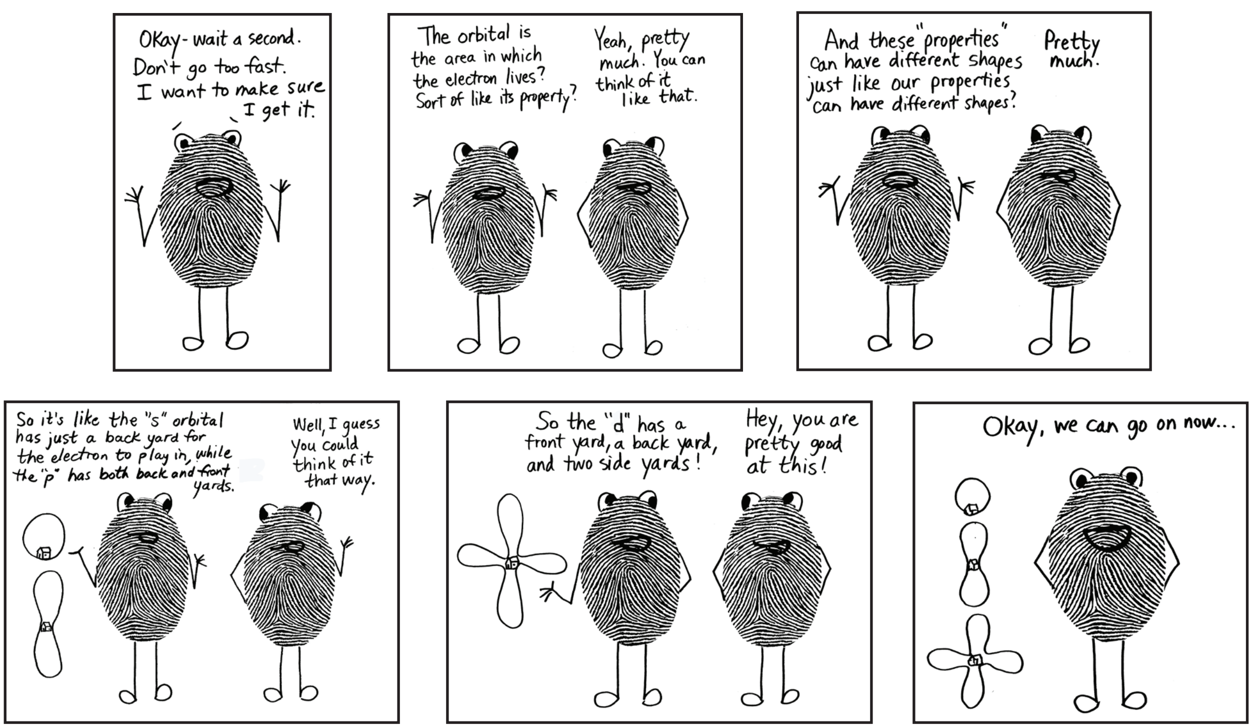
Electron clouds come in four basic arrangements. The first one is spherical in shape and is called an "s" orbital. It seems logical to assume that "s" stands for "spherical," but no... it stands for "sharp." This is very odd, since a sphere is just about the least sharp object a person can think of! The original discoverer of these orbitals was obviously not thinking about their shape when he named them. He was looking at the shape the electron made on something called a spectrograph. However, it's a fortunate coincidence that the word "spherical" also starts with the letter "s," so we can rightly remember the spherical orbitals as being the "s" orbitals.



The nucleus is at the center.

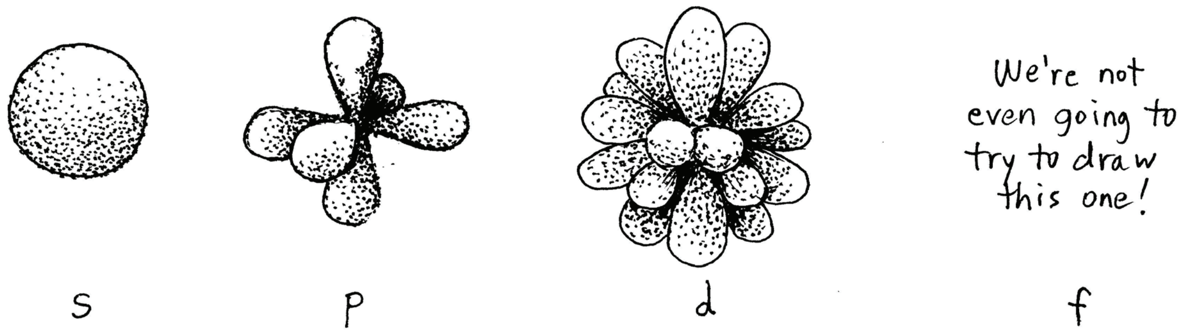


The "p" orbital looks like two balloons tied together. Its name comes from the word "principal" which means "primary" or "the main one." The "d" orbital looks like two p orbitals that were stretched out a bit then tied together. ("D" stands for "diffuse," another name we'll never remember.) The "f" orbital looks like two d's tied together. ("F" stands for "fundamental," which is curious because we already have "principal," and these two words are so similar in meaning.) These letters can be hard to remember. It would have been much easier if they had chosen "a, b, c and d."

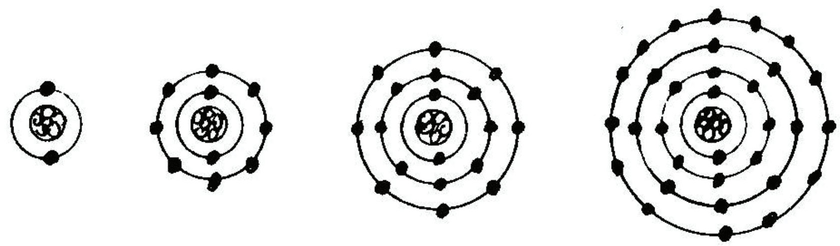


The spherical s orbitals are always found individually, but the other orbitals are found in groups. Yes, it gets even more complicated. P orbitals are found in groups of 3, d orbitals are found in groups of 5, and d orbitals are found in groups of 7. Can you imagine 7 of those f orbitals shown above, all grouped together?

The p orbitals are found in groups of 3, looking like 6 balloons tied together. The d orbitals are found in groups of 5, and since each orbital has 4 lobes, a balloon model would have to have 20 balloons tied together. F orbitals come in groups of 7. How many balloons for this model? 8 (lobes) x 7 = 56!



As you can see, this method of drawing orbitals is not easy. If we go back to using the solar system (Bohr) model, things become easier again:



The central clump is the nucleus with the protons and neutrons in it. The dots on the rings are the electrons. Still a bit complicated, but not as bad as the electron clouds. However, this model has its own problems. Most of those rings represent a combination of several electron neighborhoods (orbitals). For example, the second ring out from the nucleus represents an s neighborhood AND a p neighborhood. S orbitals can only hold 2 electrons, and p orbitals hold 6. That second ring has 8 dots on it, so it combines the s and p orbitals into one ring. These rings are often called "shells." The difference between orbitals and shells is often a major source of confusion for chemistry students.

Wouldn't it be nice if there was a way to combine these two methods, the electron clouds and the solar system model? It would clear up all the confusion about orbitals and shells. Fortunately, there IS a way to combine them, and you are just lucky enough to be using the book that invented it!

Activity 3.3 The Quick-and-Easy "Atom-izer"

Here is a very helpful invention for chemistry students: the Quick-and-Easy "Atom-izer." It lets you "build" atoms so that you can see the electron clouds while using the solar system model. You will find the Atom-izer sheet on the next page, complete with instructions on how to use it. You will need a supply of some kind of tokens that will represent electrons. You could use pennies or pieces of paper, or you might want to add some extra fun by using something edible such as mini-marshmallows or raisins or nuts, so that you can eat each atom you build.

SIDE NOTE: To avoid any scientific confusion, the word "atomizer" is also used to describe a simple device that turns liquids into a spray mist (such as an old-fashioned perfume bottle). We know this, but the name "Atom-izer" just sounded too good to pass up. It sounded like a good name for a device that makes atoms.

Look at the center of the Atom-izer. You will see a dark spot with the letter N on it. This spot will represent the nucleus of our atoms. We know that the nucleus has both protons and neutrons in it, but for this activity we are going to ignore the nucleus. Sorry, nucleus. You'll have to sit out this activity. This is all about electrons and their neighborhoods.

<u>The rules for placing your electron tokens</u>:
1) Always fill smaller rings before larger rings.
2) Always fill "s" orbitals first, before "p" orbitals.

Let's start with the first element: hydrogen. Hydrogen has only one electron. Place a token on one of the black squares in the first ring. It doesn't matter which you choose. Notice that the black squares are not only on the first ring, but they are also on spherical s orbitals. Once you have placed this token, you have made a model of the hydrogen atom.

Now let's make the next element, helium. Helium is number 2 on the Periodic Table and it has 2 electrons. Place a token on the other black square in the first ring. Now you have 2 electrons in the first ring, one on each s.

The next element is number 3 on the Table: lithium. Lithium has three electrons, so you will need to place a third electron token. The first ring is already full, so you will have to go to the second ring. Remember, though, in this second ring you must fill both s spots first. Place a token on either one of the s orbitals. You now have a model of lithium.

Element number 4 is beryllium *(burr-RILL-ee-um)*. It has 4 electrons. Place another token in the other s orbital in the second ring. Presto—you have beryllium!

Boron, element number 5, has 5 electrons. Since the s orbitals in the second ring are now full, you may put your token on one of the black squares on a p orbital. It doesn't matter which p you choose.

Carbon is next. It has 6 electrons, so you will need to add another token to another porbital. It doesn't really matter which you choose, but if you want to be extra-correct, place it in the p that is farthest away from the first p token you placed when you did boron. You see, electrons really don't like to be next to each other unless they have no choice. Given a choice, they will spread out and stay away from each other. So it is best to put the electrons opposite each other.

After carbon comes nitrogen. It has 7 electrons. Add another token to one of the p orbitals. This electron is going to have to be slightly close to another electron. Tough life.

To make number 8, oxygen, add another token to the second ring. To make the electrons as happy as possible, put it opposite electron number 7. Then add a 9th token to make fluorine, and a 10th token to make neon. (By this point, those electrons have no choice but to be next to each other!) Now we have a full second ring. Atoms love to have their rings full. Neon is a lucky atom.

When we go to make sodium, number 11, we will need to put the 11th electron in the third ring. But don't forget—fill those s orbitals first!

Keep adding electron tokens to make magnesium, aluminum, silicon, phosphorus, sulfur, chlorine, and argon.

What if you wanted to go on to element number 19, potassium? You would have to add a fourth ring to this chart. For now, we are going to stop at 18, argon.

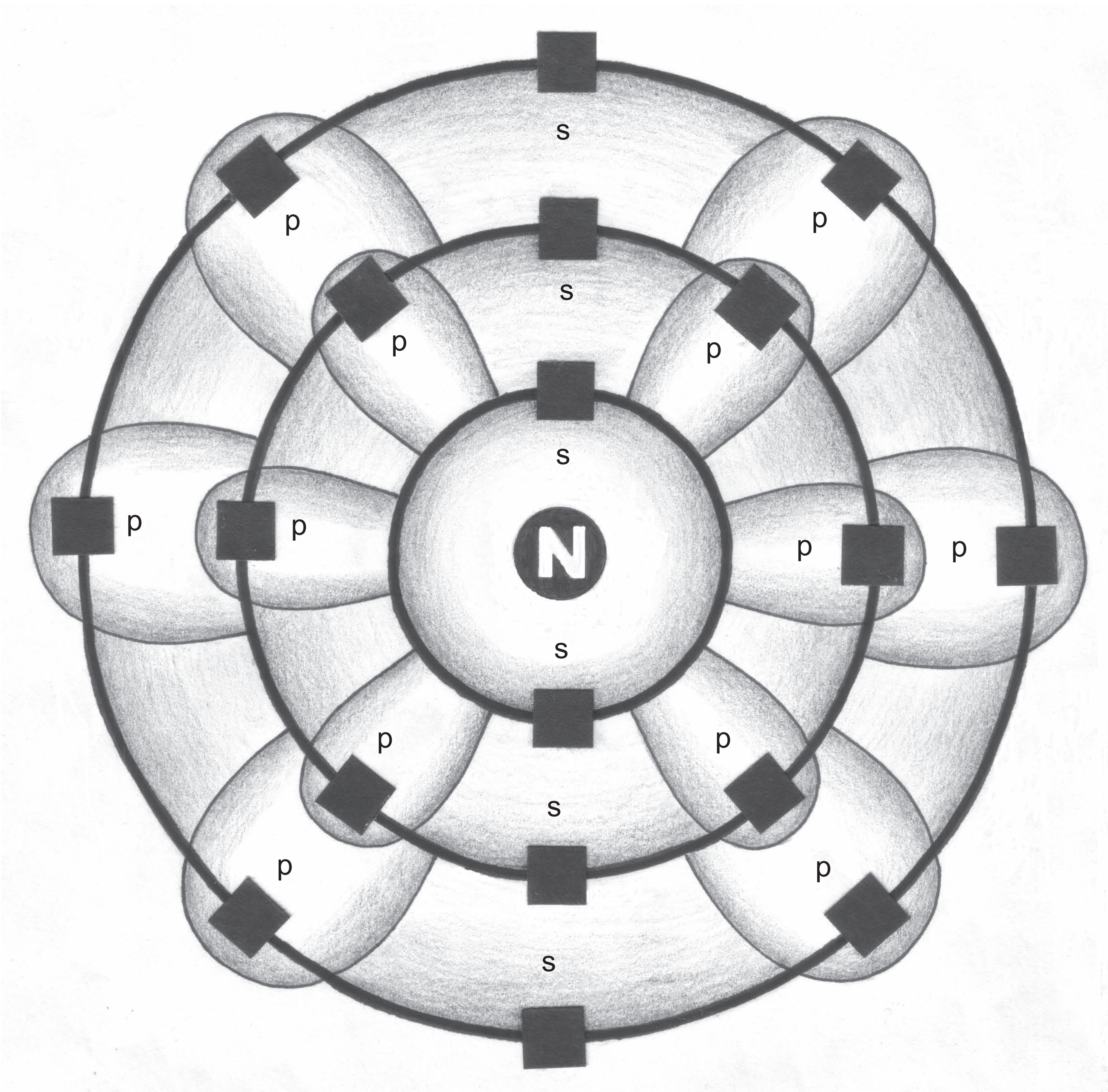
Why don't you practice making some atoms "from scratch"? Clear the board, choose any atom from 1 to 18, and build it one electron at time. Then clear it, and try another one.

NOTE: If you need to print out a few extra copies of the Atomizer and you have only a paperback copy, you can download a digital file to print out by going to www.ellenjmchenry.com, clicking on FREE DOWNLOADS, then on CHEMISTRY. You will see a link for "Printable pages for The Elements curriculum."

THE QUICK-AND-EASY "ATOM-IZER"

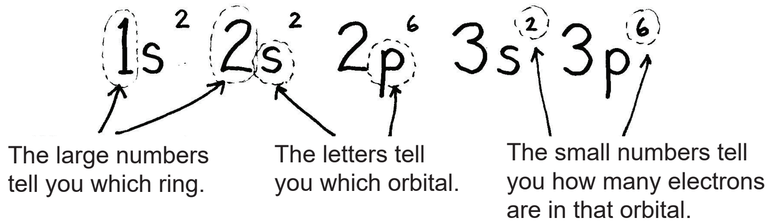
The rules for placing your electron tokens:

1) Always fill smaller rings before larger rings.
2) Always fill "s" orbitals first, before "p" orbitals.



As you can see from the Atom-izer activity, drawing pictures of large atoms would be very time-consuming. So chemists decided to dispense with art altogether and use a string of letters and numbers to show which orbital neighborhoods the atom has, and how many electrons are in each. Their method looks like this: $1s^2 2s^2 2p^6 3s^2$

Look how much space it saves! It's very compact. It means exactly the same thing as a drawing with a whole bunch of rings. Let's look at this method close-up.



You can use this method exactly the same way you use the Atom-izer. Instead of the picture with the rings, just fill in the correct number of electrons in each square.

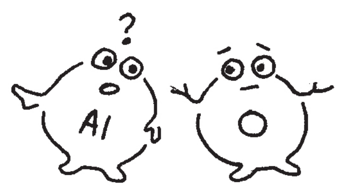
The number of electrons in that orbital goes here.

$$1s^{\square} 2s^{\square} 2p^{\square} 3s^{\square} 3p^{\square}$$

Here is the way chemists would draw oxygen and aluminum:

OXYGEN $1s^{\boxed{2}} 2s^{\boxed{2}} 2p^{\boxed{4}} 3s^{\square} 3p^{\square}$

ALUMINUM $1s^{\boxed{2}} 2s^{\boxed{2}} 2p^{\boxed{6}} 3s^{\boxed{2}} 3p^{\boxed{1}}$



Activity 3.4

Can you switch over from the Atom-izer to this new notation? We've listed some atoms for you to try. All you have to do is write the number of electrons, instead of placing tokens. (You know about the answer key now. It's there if you need it for the rest of the book.)

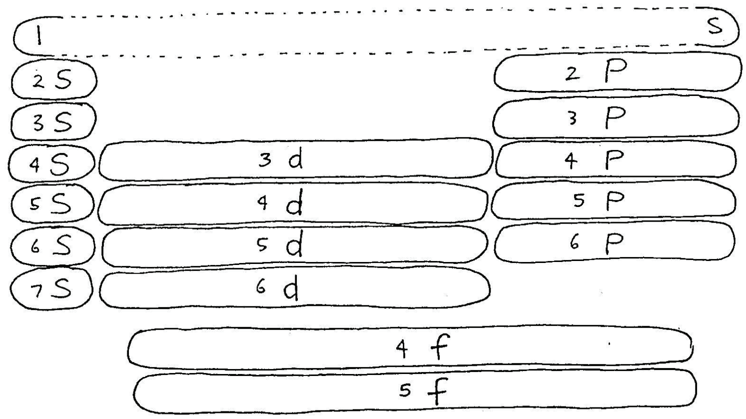
Nitrogen: $1s^{\square} 2s^{\square} 2p^{\square} 3s^{\square} 3p^{\square}$ Sulfur: $1s^{\square} 2s^{\square} 2p^{\square} 3s^{\square} 3p^{\square}$

Neon: $1s^{\square} 2s^{\square} 2p^{\square} 3s^{\square} 3p^{\square}$ Chlorine: $1s^{\square} 2s^{\square} 2p^{\square} 3s^{\square} 3p^{\square}$

Lithium: $1s^{\square} 2s^{\square} 2p^{\square} 3s^{\square} 3p^{\square}$ Boron: $1s^{\square} 2s^{\square} 2p^{\square} 3s^{\square} 3p^{\square}$

Silicon: $1s^{\square} 2s^{\square} 2p^{\square} 3s^{\square} 3p^{\square}$ Fluorine: $1s^{\square} 2s^{\square} 2p^{\square} 3s^{\square} 3p^{\square}$

Now for a very cool chemistry fact. The Periodic Table itself can be your guide to electron orbitals. If we were to circle the elements with similar electron orbitals, it would look like this:



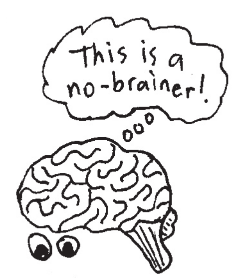
Changing the subject a bit, you may have noticed (during the Atom-izer activity) that the number of electrons seems to correlate with the atom's atomic number on the Periodic Table. This is, indeed, the case, but for a different reason. An atom's atomic number is determined by how many <u>protons</u> it has, not electrons. Each type of atom has a unique number of protons. For example, gold is number 79 on the Table. That means it has 79 protons. Gold is the only type of atom that has 79 protons. If you find an atom that has 79 protons in the nucleus, it's gold. If you added a proton to gold (or took one away) it wouldn't be gold any more. (Such a shame the alchemists didn't know this!)

Since atoms need to be electrically balanced with an equal number of positive and negative charges, they need to have the same number of electrons and protons. This works out nicely for chemists, because they are counting electrons all the time. It's very easy to just look at the Periodic Table for the atomic number and know that not only is it the number of protons, it is also the number of electrons. (Having said this, atoms get out of balance a lot and very often have more or less electrons than protons. We'll see this happen in future chapters.)

Activity 3.5 How many protons?

For each of the following elements, write how may protons it has in its nucleus. (Hint: Remember that the atomic number is defined as the number of protons an element has.)

Ag- silver ____	H- hydrogen ____	Os- osmium ____
Am- americium ____	He- helium ____	P- phosphorus____
At- astatine ____	I- iodine ____	S- sulfur ____
As- arsenic ____	In-indium ____	Se- selenium ____



Activity 3.6 Guess the atom

This is sort of activity 3.4 in reverse. Can you look at these electron configurations and determine what atoms they are? (Hint: The number of electrons is the same as the number of protons, and the number of protons is the atomic number.)

1) $1s^2\ 2s^2$ ____________ 2) $1s^2\ 2s^2\ 2p^3$ _____________

3) $1s^2\ 2s^2\ 2p^6\ 3s^1$ _____________ 4) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$ ______________

5) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$ _____________ 6) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$ ________________

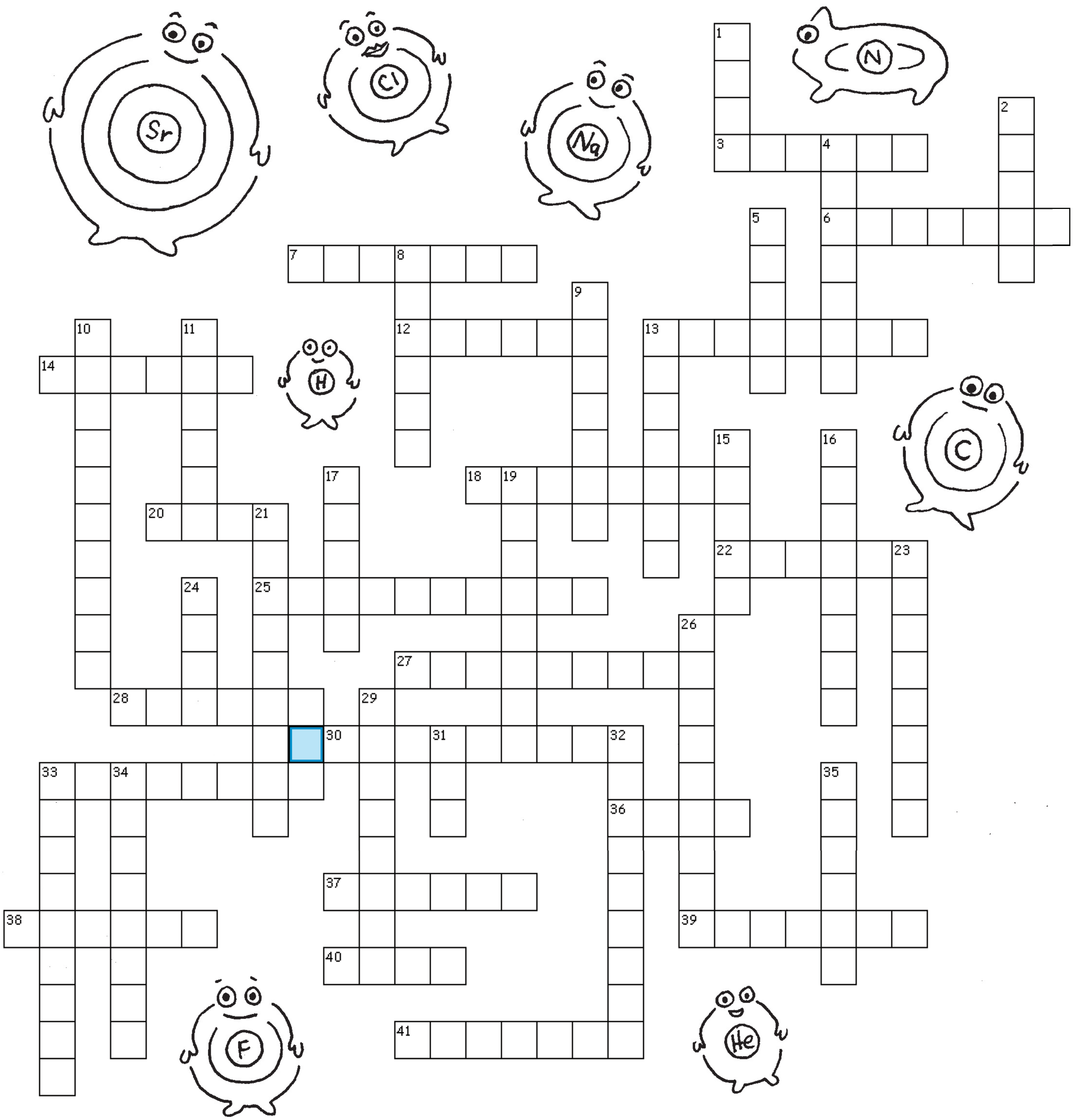
CHALLENGE: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^2$ ________ (looking at the chart at the top of this page might help)

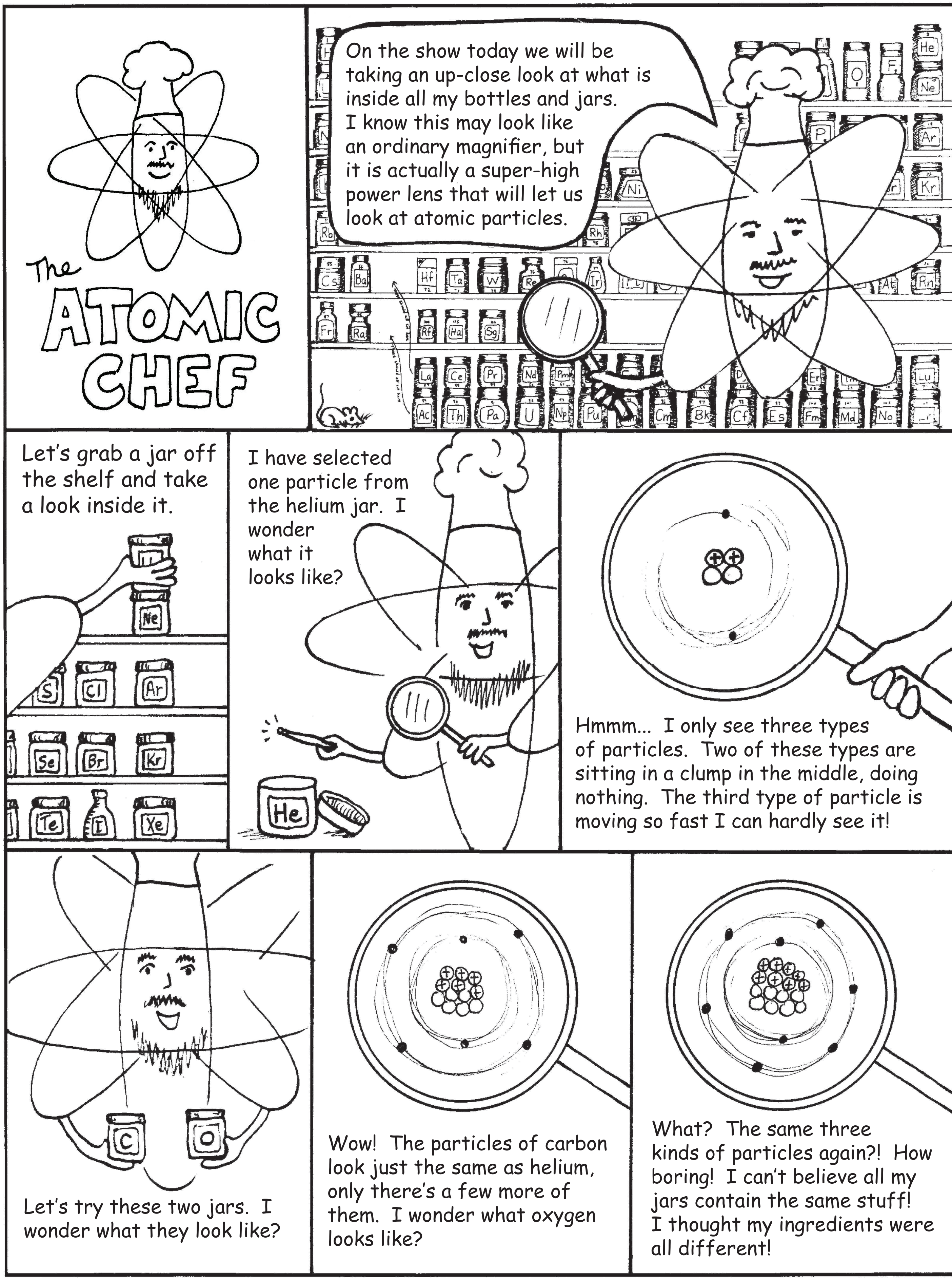
Activity 3.7 Time to review!

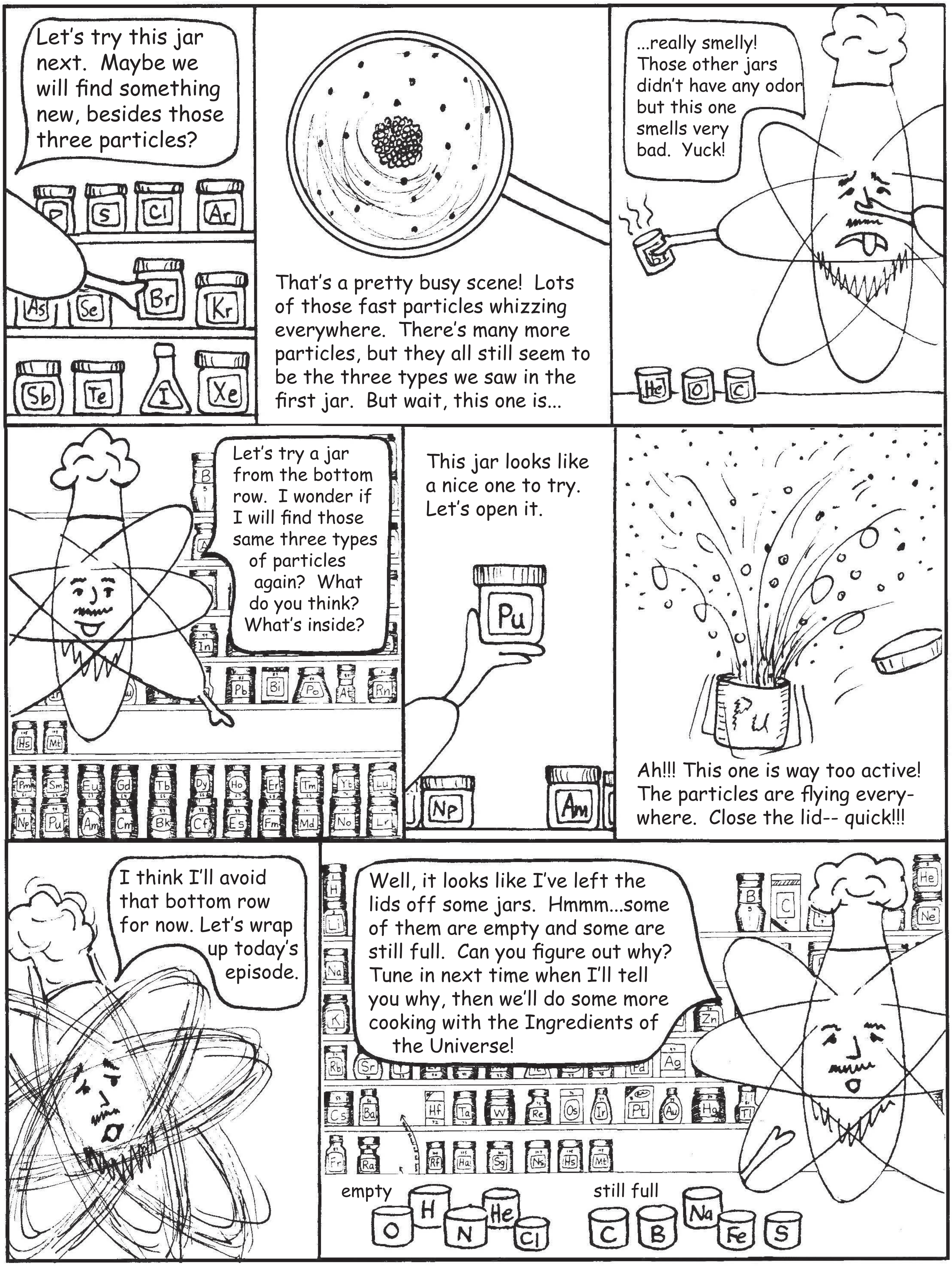
Use the symbol clues to write in the names of the elements.

ACROSS: 3) Co 6) Si 7) U 12) Cu 14) Na 13) Cr 18) Cl 20) Fe 22) O 25) P 27) Mn 28) I 30) Pu 33) Pt 36) Au 37) Ag 38) Os 39) Hg 40) Ne 41) Li

DOWN: 1) Zn 2) Rn 4) As 5) Ar 8) Ni 9) Kr 10) Mo 11) S 13) Ca 15) Xe 16) W 17) B 19) H 21) Np 23) N 24) Pb 26) Be 29) F 31) Sn 32) Mg 33) K 34) Al 35) He




The ATOMIC CHEF
On the show today we will be taking an up-close look at what is inside all my bottles and jars. I know this may look like an ordinary magnifier, but it is actually a super-high power lens that will let us look at atomic particles.
Let's grab a jar off the shelf and take a look inside it.
I have selected one particle from the helium jar. I wonder what it looks like?
Hmmm... I only see three types of particles. Two of these types are sitting in a clump in the middle, doing nothing. The third type of particle is moving so fast I can hardly see it!
Let's try these two jars. I wonder what they look like?
Wow! The particles of carbon look just the same as helium, only there's a few more of them. I wonder what oxygen looks like?
What? The same three kinds of particles again?! How boring! I can't believe all my jars contain the same stuff! I thought my ingredients were all different!


Let's try this jar next. Maybe we will find something new, besides those three particles?
That's a pretty busy scene! Lots of those fast particles whizzing everywhere. There's many more particles, but they all still seem to be the three types we saw in the first jar. But wait, this one is...
...really smelly! Those other jars didn't have any odor but this one smells very bad. Yuck!
Let's try a jar from the bottom row. I wonder if I will find those same three types of particles again? What do you think? What's inside?
This jar looks like a nice one to try. Let's open it.
Pu
Ah!!! This one is way too active! The particles are flying every-where. Close the lid-- quick!!!
I think I'll avoid that bottom row for now. Let's wrap up today's episode.
Well, it looks like I've left the lids off some jars. Hmmm...some of them are empty and some are still full. Can you figure out why? Tune in next time when I'll tell you why, then we'll do some more cooking with the Ingredients of the Universe!
empty
O H N He Cl
still full
C B Na Fe S

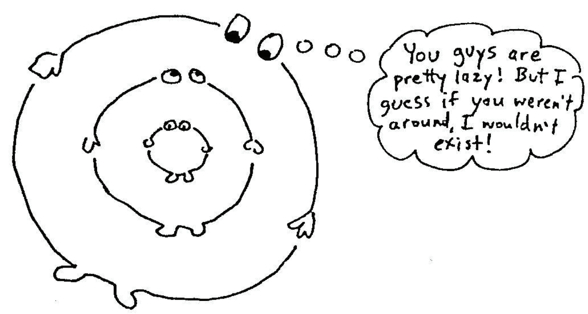
CHAPTER 4: MORE ABOUT ATOMS

We will now learn more about the incredibly interesting and wonderfully amazing subject of electrons. The reason this subject is so important is because it's the arrangement of the electrons in the orbitals (especially the ones in the outer ring) that give each element its chemical characteristics. You can suck helium out of a balloon without hurting your lungs because of the way helium's electrons are arranged. Pure chlorine gas is poisonous because of the arrangement of its electrons. If you stick a metal fork in an electrical outlet, you'll get a shock because of the way the electrons are arranged. Carbon can form thousands of different compounds (many of them organic, living molecules) because of the arrangement of its electrons. Understanding the electrons is the key to understanding the chemistry of every substance.

Here are the basic rules that electrons live by:

1) **Spin!**
2) **Always try to pair up with someone of the opposite spin.**
3) **Get plenty of privacy—stay away from other electron couples!**
4) **Try to live in a perfect neighborhood, which is often a group of 8.**

These rules were discovered by combining very complicated mathematics with high-tech scientific experiments. It's kind of funny that the rules sound so simple and yet are based on very complicated math and physics. These four rules are the key to understanding many aspects of basic chemistry.



Chemists often refer to the rings of electrons in those solar system (Bohr) models as "shells." It is the outermost shell (ring) that interacts with the environment around the atom. The electrons in the inner shells just sit there. They almost never come into contact with other atoms. The outer shell is where all the action is.

The most important thing to know about outer shells is that the electrons in them take rule #4 very seriously. They are almost neurotic about it. Atoms in the first three rows of the Periodic Table live by the motto: "8 is great!" If there is only one electron in the outer shell, that electron is so miserable that it would rather go off and join another atom than be alone in the outer shell of its own atom. If an outer shell has seven electrons, which is just one short of perfection ("8 is great!"), those seven will try anything to get an eighth electron in the shell. They will even try to steal an electron from the outer shell of any atom that comes close enough. Even when there are two electrons in the outer shell, the electrons are still not very happy. You'd think that they would be content because they have an electron buddy to form a pair with, but those two electrons are still lonely and will look to join with six others to form an "octet." ("8 is great" is often called "the octet rule.")