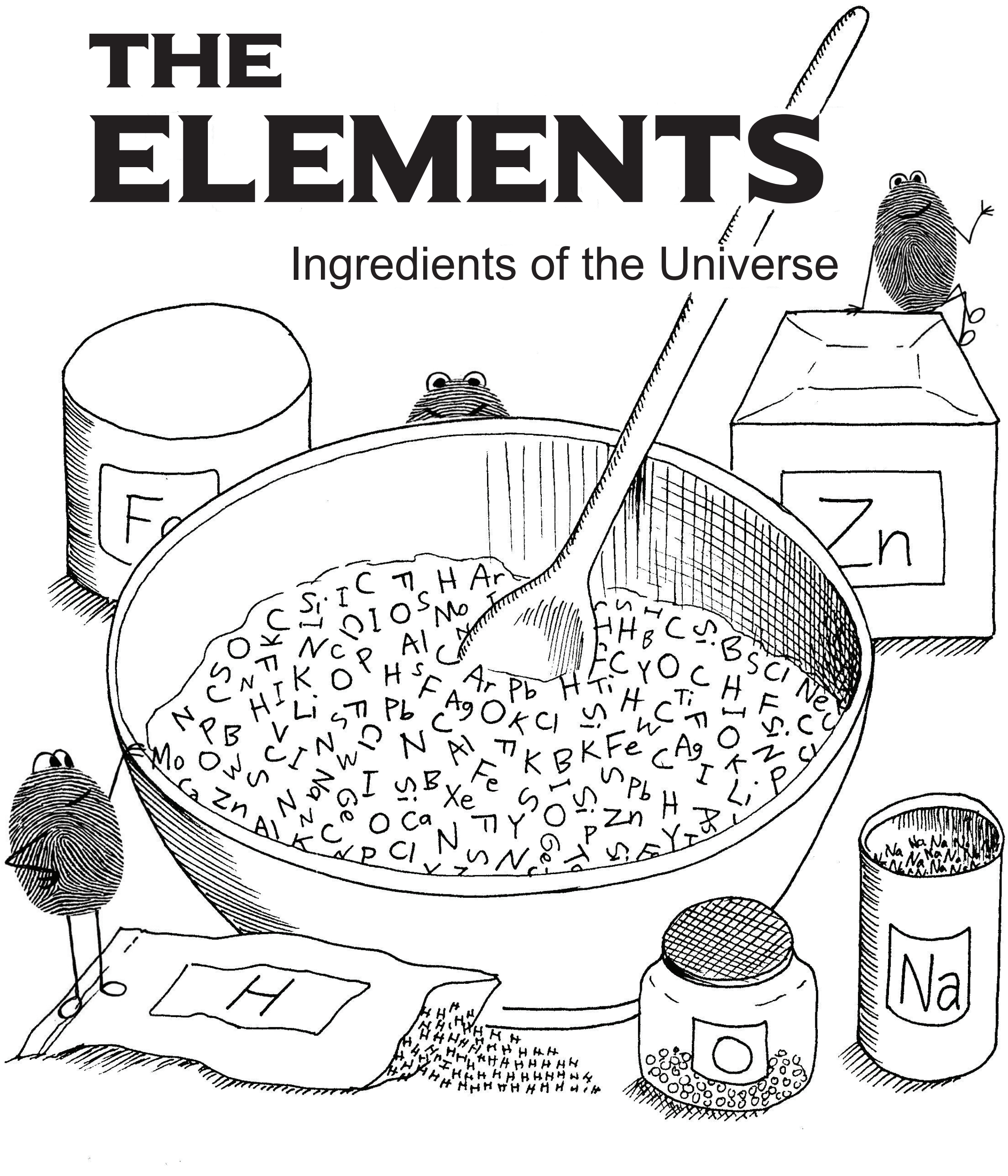
THE ELEMENTS

Ingredients of the Universe



Written and illustrated by
Ellen Johnston McHenry

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Ellen McHenry's Basement Workshop
www.ellenjmchenry.com
State College, PA 16801
ejm.basementworkshop@gmail.com

Periodic Table of Elements

Atomic Number → 7
Chemical Symbol → N
Chemical Name → NITROGEN
Relative Atomic Mass → 14.007

alkali metals
alkaline metals
transition metals
other metals
metalloids
nonmetals
halogens
noble gases
lanthanoids
actinoids

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H HYDROGEN 1.00794																	2 He HELIUM 4.002602
3 Li LITHIUM 6.941	4 Be BERYLLIUM 9.012182											5 B BORON 10.811	6 C CARBON 12.0107	7 N NITROGEN 14.0067	8 O OXYGEN 15.9994	9 F FLUORINE 18.9984032	10 Ne NEON 20.1797
11 Na SODIUM 22.9903	12 Mg MAGNESIUM 24.305											13 Al ALUMINUM 26.9815386	14 Si SILICON 28.0855	15 P PHOSPHORUS 30.973762	16 S SULFER 32.065	17 Cl CHLORINE 35.453	18 Ar ARGON 39.948
19 K POTASSIUM 39.098	20 Ca CALCIUM 40.078	21 Sc SCANDIUM 44.955912	22 Ti TITANIUM 47.867	23 V VANADIUM 50.9415	24 Cr CHROMIUM 51.9961	25 Mn MANGANESE 54.938045	26 Fe IRON 55.845	27 Co COBALT 58.933195	28 Ni NICKEL 58.6934	29 Cu COPPER 63.546	30 Zn ZINC 65.39	31 Ga GALLIUM 69.723	32 Ge GERMANIUM 72.64	33 As ARSENIC 74.92160	34 Se SELENIUM 78.96	35 Br BROMINE 79.904	36 Kr KRYPTON 83.798
37 Rb RUBIDIUM 85.468	38 Sr STRONTIUM 87.62	39 Y YTTRIUM 88.90585	40 Zr ZIRCONIUM 91.224	41 Nb NIOBIUM 92.90638	42 Mo MOLYBDENUM 95.94	43 Tc TECHNETIUM 97.9072	44 Ru RUTHENIUM 101.07	45 Rh RHODIUM 102.90550	46 Pd PALLADIUM 106.42	47 Ag SILVER 107.8682	48 Cd CADMIUM 112.411	49 In INDIUM 114.818	50 Sn TIN 118.710	51 Sb ANTIMONY 121.760	52 Te TELLURIUM 127.60	53 I IODINE 126.90447	54 Xe XENON 131.293
55 Cs CESIUM 132.91	56 Ba BARIUM 137.33	57-71	72 Hf HAFNIUM 178.49	73 Ta TANTALUM 180.94788	74 W TUNGSTEN 183.84	75 Re RHENIUM 186.207	76 Os OSMIUM 190.23	77 Ir IRIDIUM 192.217	78 Pt PLATINUM 195.084	79 Au GOLD 196.966569	80 Hg MERCURY 200.59	81 Ti THALLIUM 204.3833	82 Pb LEAD 207.2	83 Bi BISMUTH 208.98040	84 Po POLONIUM 208.9824	85 At ASTATINE 209.9871	86 Rn RADON 222.0176
87 Fr FRANCIUM 223.0197	88 Ra RADIUM 226.0254	89-103	104 Rf RUTHERFORDIUM 261.1088	105 Db DUBNIUM 262	106 Sg SEABORGIUM 266	107 Bh BOHRIUM 264	108 Hs HASSIUM 277	109 Mt MEITNERIUM 268	110 Ds DARMSTADTIUM 271	111 Rg ROENTGENIUM 272	112 Cn COPERNICIUM 285	113 Nh NIHONIUM 284	114 Fl FLEROVIUM 289	115 Mc MOSCOVIUM 288	116 Lv LIVERMORIUM 293	117 Ts TENNESSINE 294	118 Og OGANESSON 294

57 La LANTHANUM 138.90547	58 Ce CERIUM 140.116	59 Pr PRASEODYMIUM 140.90765	60 Nd NEODYMIUM 144.242	61 Pm PROMETHIUM 144.9127	62 Sm SAMARIUM 150.36	63 Eu EUROPIUM 151.964	64 Gd GADILINIUM 157.25	65 Tb TERBIUM 158.92535	66 Dy DYSPROSIUM 162.500	67 Ho HOLMIUM 164.93032	68 Er ERBIUM 167.259	69 Tm THULIUM 168.93421	70 Yb YTTRTBIUM 173.04	71 Lu LUTETIUM 174.967
89 Ac ACTINIUM 227.027	90 Th THORIUM 232.03806	91 Pa PROTACTINIUM 231.03588	92 U URANIUM 238.02891	93 Np NEPTUNIUM 237.0482	94 Pu PLUTONIUM 244.0642	95 Am AMERICIUM 243.0614	96 Cm CURIUM 247.0704	97 Bk BERKELIUM 247.0703	98 Cf CALIFORNIUM 251.0796	99 Es EINSTEINIUM 252.0830	100 Fm FERMIUM 257.0951	101 Md MENDELEVIUM 258.0984	102 No NOBELIUM 259.1010	103 Lr LAWRENCIUM 262.1097

Solid at room temperature
Liquid at room temperature
Gas at room temperature
Artificially created
Radioactive

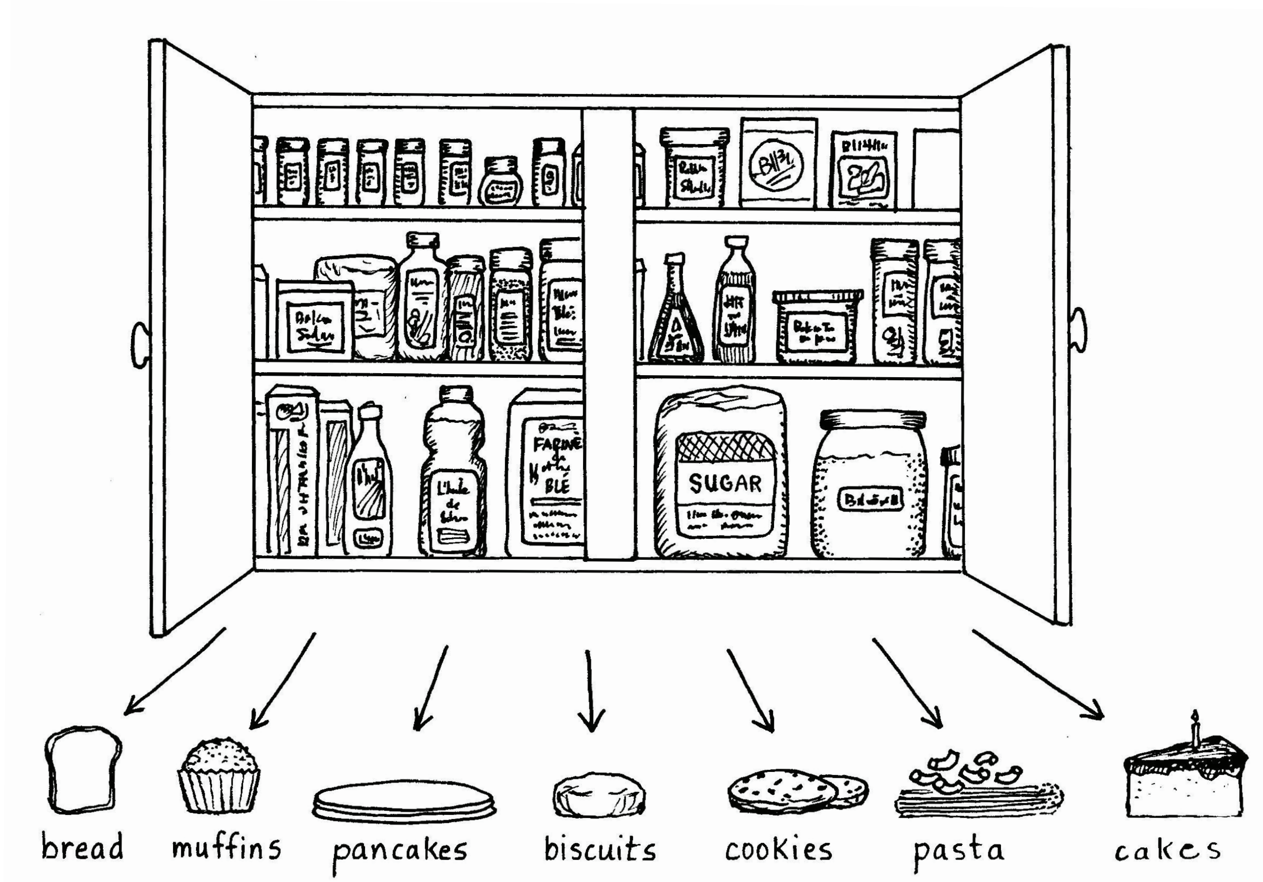
In your reading, you may come across the names of these elements and be unsure of how to pronounce them. This pronunciation guide will help you to say them correctly. The syllable with the capital letters is the one that you give emphasis. (For example, the word "element" would be "EL-eh-ment.")
Turn back to this page whenever you need to!

Actinium: act-IN-ee-um
Americium: am-air-ISH-ee-um
Antimony: AN-teh-mo-nee
Arsenic: AR-sen-ick
Berkelium: BERK-lee-um (*though many people say* ber-KEEL-ee-um)
Beryllium: beh-RILL-ee-um
Boron: BORE-on
Cerium: SEER-ee-um
Cesium: SEE-zee-um
Curium: KYOOR-ee-um
Dysprosium: dis-PRO-zee-um
Europium: yoo-ROPE-ee-um
Fluorine: FLOR-een
Gadolinium: GAD-o-LIN-ee-um
Gallium: GAL-ee-um
Germanium: jer-MANE-ee-um
Iridium: er-RID-ee-um
Krypton: KRIP-tohn
Lawrencium: lore-EN-see-um
Lithium: LITH-ee-um
Lutetium: loo-TEE-she-um
Manganese: MANG-gan-eez *(don't confuse it with magnesium!)*
Mendelevium: men-dell-EE-vee-um
Molybdenum: moll-IB-den-um
Neodymium: NEE-o-DIM-ee-um
Palladium: pal-AID-ee-um (*or* pal-AD-ee-um)
Praseodymium: PRAZ-ee-o-DIM-ee-um
Promethium: pro-MEE-thee-um
Protactinium: PRO-tack-TIN-ee-um
Rhodium: ROE-dee-um
Rubidium: roo-BID-ee-um
Ruthenium: roo-THEE-nee-um
Samarium: sam-AIR-ee-um
Selenium: seh-LEEN-ee-um
Strontium: STRON-tee-um (*or* STRON-shee-um)
Technetium: teck-NEE-she-um
Tellurium: tell-LOOR-ee-um
Thulium: THOO-lee-um
Vanadium: van-AY-dee-um
Xenon: ZEE-non
Ytterbium: i-TER-bee-um
Yttrium: IT-ree-um

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. All baked goods are made of basically the same ingredients, yet you have no problem telling the difference in taste and texture between pancakes and donuts, or biscuits and bread.

Even though they 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. And 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.)

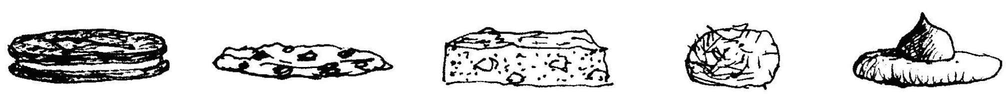
	flour	sugar	oil or eggs	milk or butter	water	yeast	baking powder	vanilla	banana	chocolate or other flavor
BREAD										
COOKIES										
BISCUITS										
PANCAKES										
CAKE										
BANANA MUFFINS										

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

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

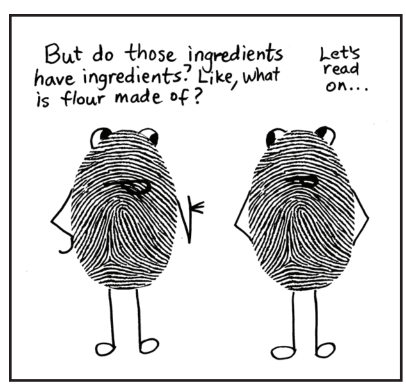
Name an ingredient that is found in only one of the baked goods: ____________

Activity 1.2

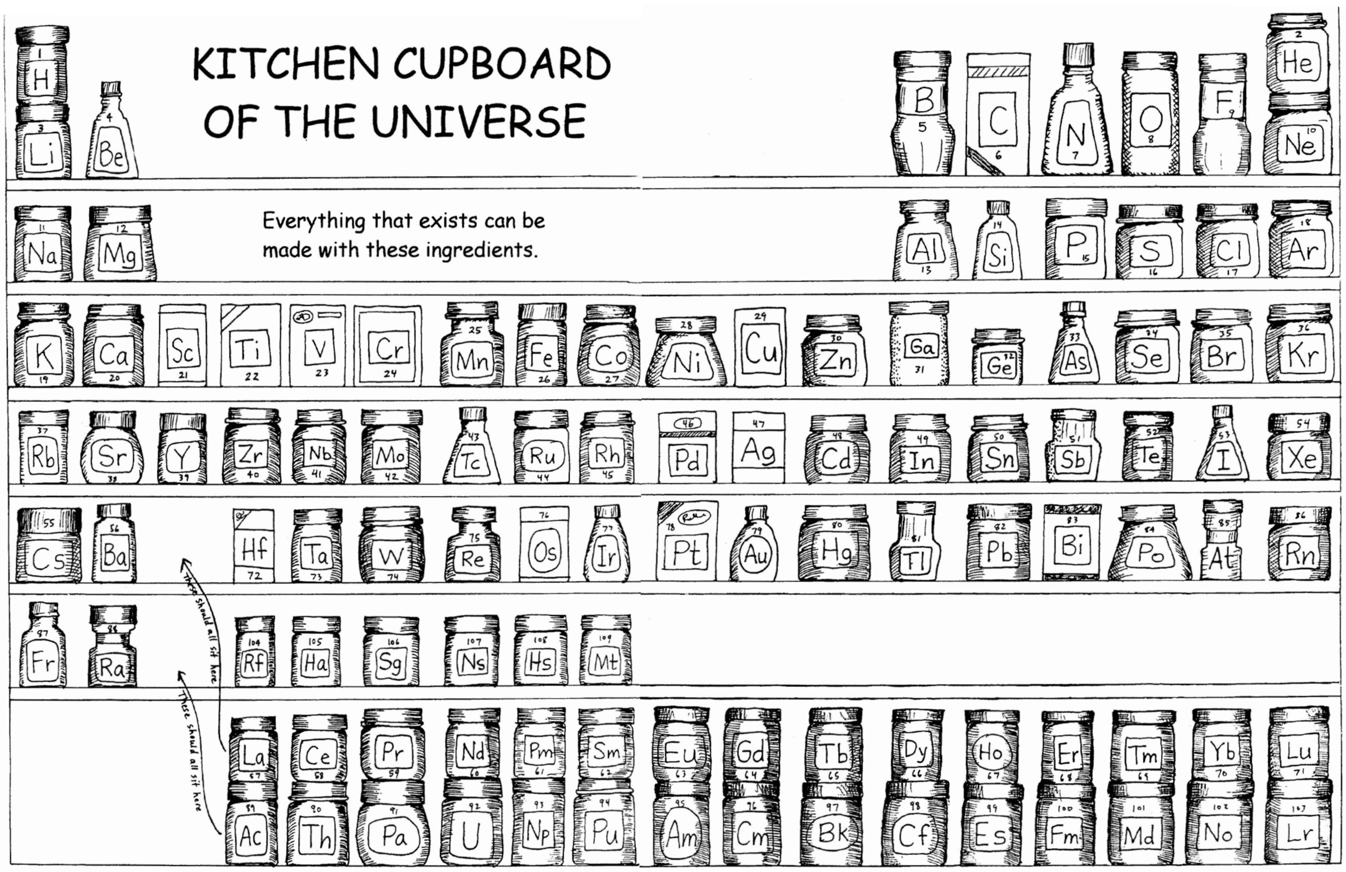


Think about cookies (tough assignment, eh?) and answer these questions:

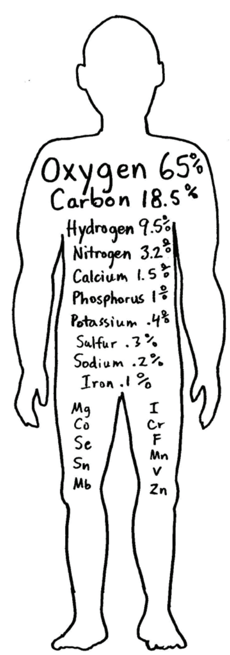
1) How would a cookie change if you put it in the freezer?
2) How would a cookie change if you let it sit out somewhere for a week?
3) How would a cookie change if you put it in a glass of water?
4) Do these changes mean that the recipe changed?
5) Do other factors, not just the recipes, contribute to 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 of these 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 know 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 they also considered fire, water, earth and air to be elements.) In the 1800s, electricity was used to discover magnesium, potassium and sodium. In the 1900s, radioactive elements such as uranium and plutonium were discovered. (These two elements were named in honor of the recent discovery of Uranus and Pluto.) The elements with numbers above 100 are artificially made in nuclear reactors and only exist for a split second.

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.

You choose three more:

	cereal	medicine or toothpaste	bread			
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 for these ingredients are what we call the **chemical elements**. 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 atoms of each one 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 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.)

So, that's 2 atoms of hydrogen and 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 molecule 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 = $NaHCO_3$

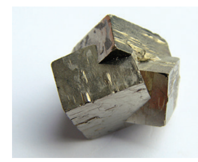
That's 1 atom of sodium, 1 atom of hydrogen, 1 atom of carbon, and 3 atoms of oxygen. Those are all the same ingredients we just used to make salt and sugar, but if you combine them in this proportion you will make baking soda. (Baking soda's job in kitchen recipes is to make things "puff up" in the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

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.

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, Gall _________________

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 ____________

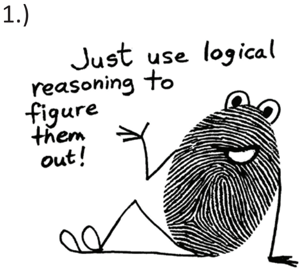
23) The name comes from the German word “Kupfernickel,” meaning “Satan’s copper” ______________

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

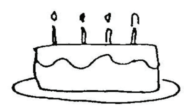


Activity 1.7 "The Chemical Compounds Song"

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 track if you use it as a hand-clap game.

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!



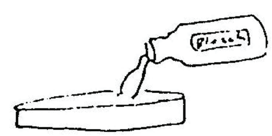
I put in lots of H_2O, 3 cups NaCl,
Some $NaHCO_3$, and other things as well.

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!

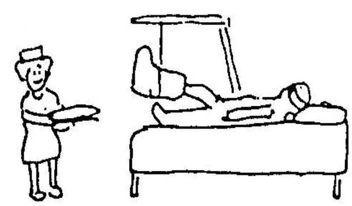
I had to clean and scrub the pan, so Mom would never know.
First I tried to bleach the pan with NaClO.

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 $MgSO_4$.



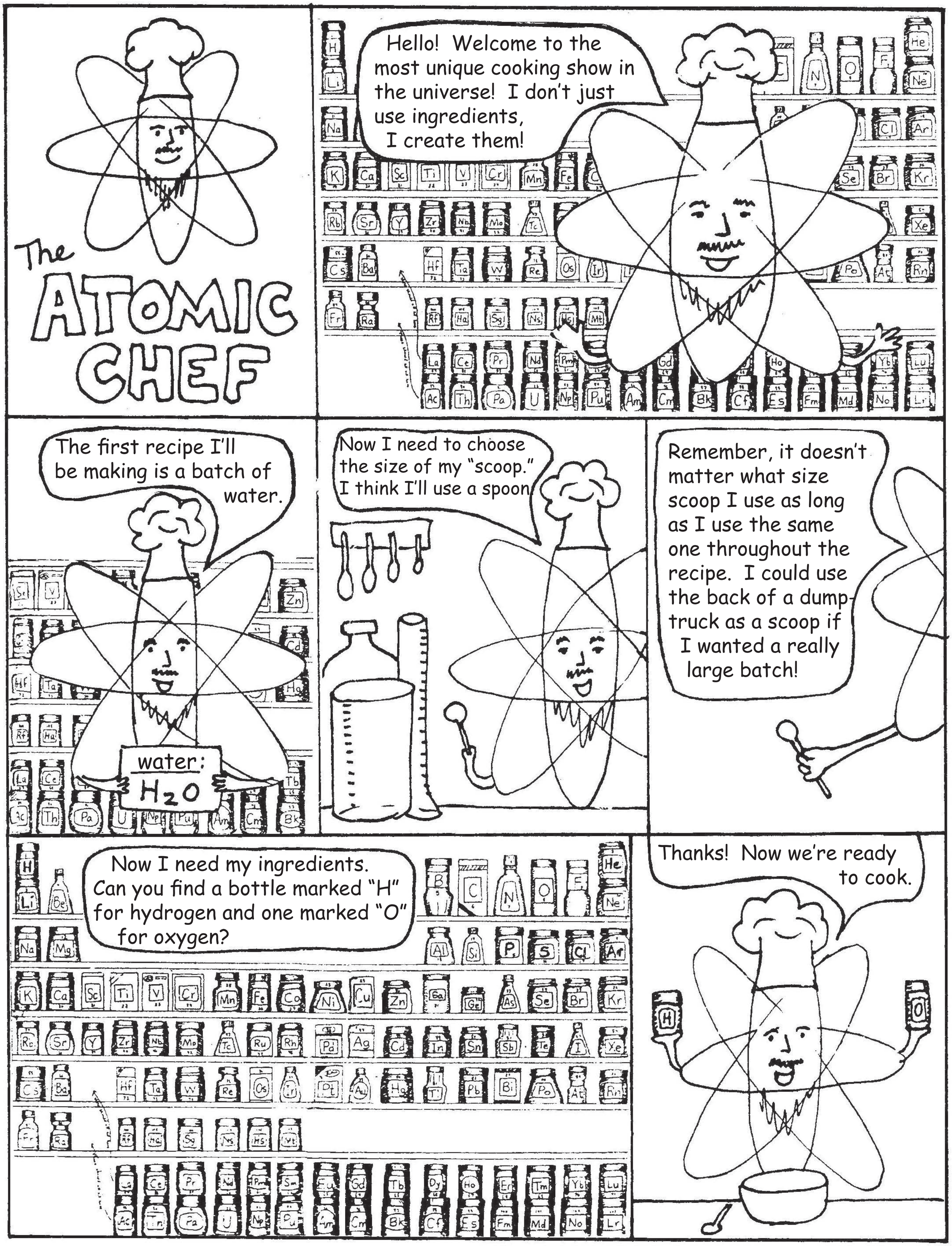
Next year for Mama's birthday, I'll buy a cake, instead,
'Cause if I tried to bake again, I think I'd end up dead!

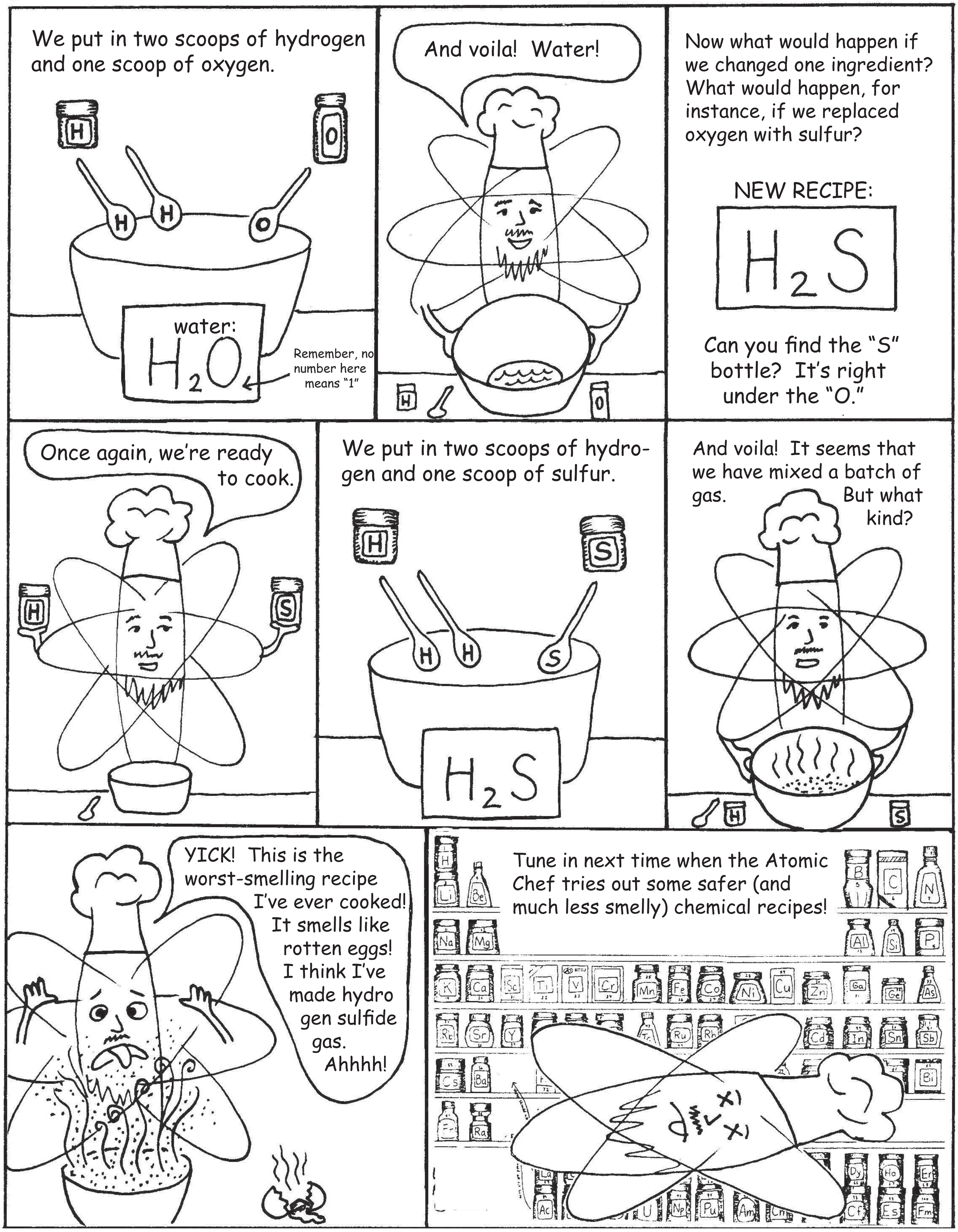
H_20 = water
NaCl = salt
$NaHCO_3$ = baking soda
C_2F_4 = Teflon
CH_4 = natural gas
NaClO = bleach

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!

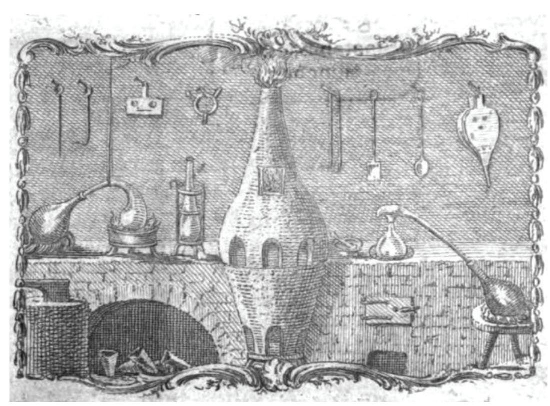
CHAPTER 2: THE PERIODIC TABLE

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.

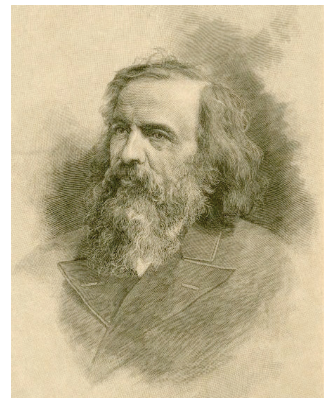
Several hundred years went by with no new discoveries of any more basic ingredients. Then, in the 1700s, chemists really began to catch on to the idea of elements, and began intentionally looking for them. They were able to add many more substances to the list of basic elements, including hydrogen, oxygen, 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

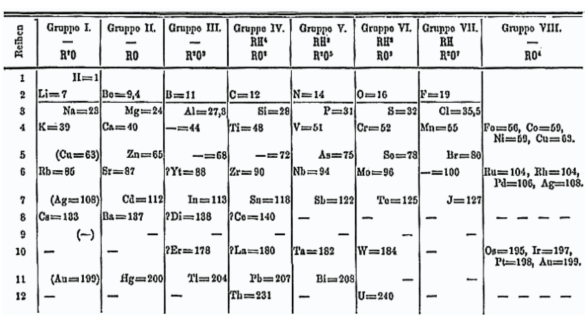
After the discovery of gallium, Mendeleyev became braver about making predictions. He announced that sometime soon a scientist would discover a new element that would be a dark gray metal with a weight that was 72 times heavier than hydrogen, a specific gravity of about 5.5, and having the ability to 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."

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

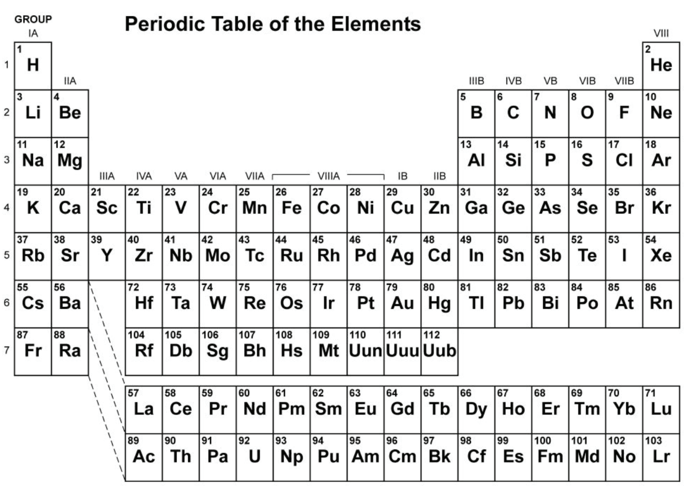
After Mendeleyev, chemists continued to discover elements. Every time a new element was discovered it was added to the Periodic Table. The number of elements grew from 63 to over 100. Some adjustments had to be made to Mendeleyev's original table in order to accommodate all the new discoveries. They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

Mendeleyev's table:



Reihen	Gruppo I. — R^2O	Gruppo II. — RO	Gruppo III. — R^2O^3	Gruppo IV. RH^4 RO^2	Gruppo V. RH^3 R^2O^5	Gruppo VI. RH^2 RO^3	Gruppo VII. RH R^2O^7	Gruppo 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	VIIIA	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.

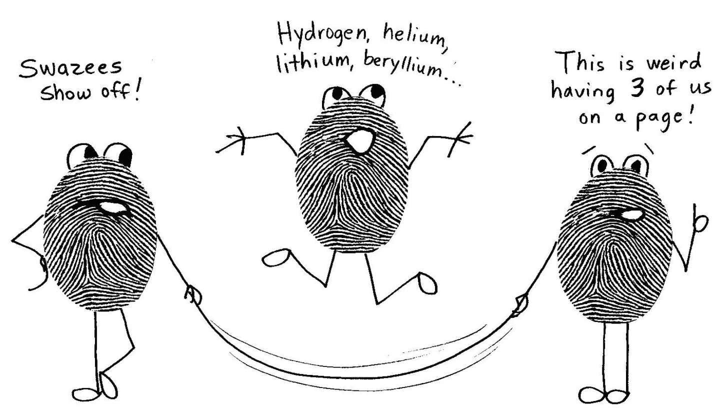
Unfortunately, this type of thing happens fairly often. New theories that don't fit with current opinions are often scorned or even ridiculed. The Royal Chemistry Society did try to right this wrong in 1884 by asking Newlands to give a lecture at the Society. This time no one laughed at him. And today 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.

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. ______________

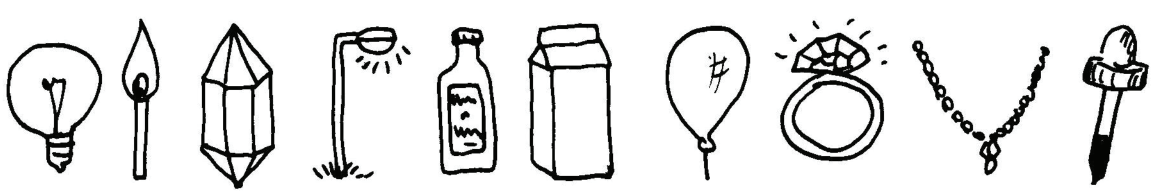
16) Find an element that has no neutrons. ____________

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 special playlist for this curriculum at the YouTube channel that goes with Ellen McHenry's curricula. The address is: www.YouTube.com/TheBasementWorkshop. Click on PLAYLISTS and then on The Elements. There you will find videos for each chapter. The videos have been previewed and pre-selected by Ellen McHenry, so you don't have to worry about inappropriate words or images. Watch the videos for chapter 2. 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 any law saying that you can't arrange the chemical elements in some other shape besides a rectangle. Over the past century, quite a few arrangements of the elements have been proposed. We can't print them here due to copyright restrictions, but you can see them online at various websites that have been set up to catalog these alternative Periodic Tables. If you are interested, you can check out these two resources:

1) Wikipedia article: "Alternative Periodic Tables" (pictures are at the bottom)
2) http://www.meta-synthesis.com/webbook/35_pt/pt_database.php

There are also interactive Periodic Tables online, where you can click on an element and information will pop up. Try this one: http://humantouchofchemistry.com/periodic-table.htm

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--such as highly radioactive elements--or elements that are manufactured in nuclear labs and only exist for a few seconds at a time).

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.

____ ____ ____ did the ____ ____ ____ ____a ____
tungsten hydrogen yttrium molybdenum uranium selenium sulfur yttrium

____ ____e____, ____ ____e____," ____ ____ ____ the
carbon helium phosphorus carbon helium phosphorus tungsten helium nitrogen

____ ____d'____ ____ ____e ____ll a____art? ______ ____ ____
boron iridium sulfur carbon silver iron phosphorus Helium tungsten arsenic

____ ____ l ____ ____g ____ ____ ____r the ____ ____d
fluorine iodine lithium nitrogen indium fluorine oxygen boron iridium

____ ____ ____ ____ad the da____ ____ ____ ____.
tungsten hydrogen oxygen hydrogen 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 sulfur vanadium americium phosphorus iridium

with a ____ ____ ____? A ____rr ____ ____ ____ed ____ ____!
molybdenum uranium selenium tellurium iodine fluorine iodine carbon astatine

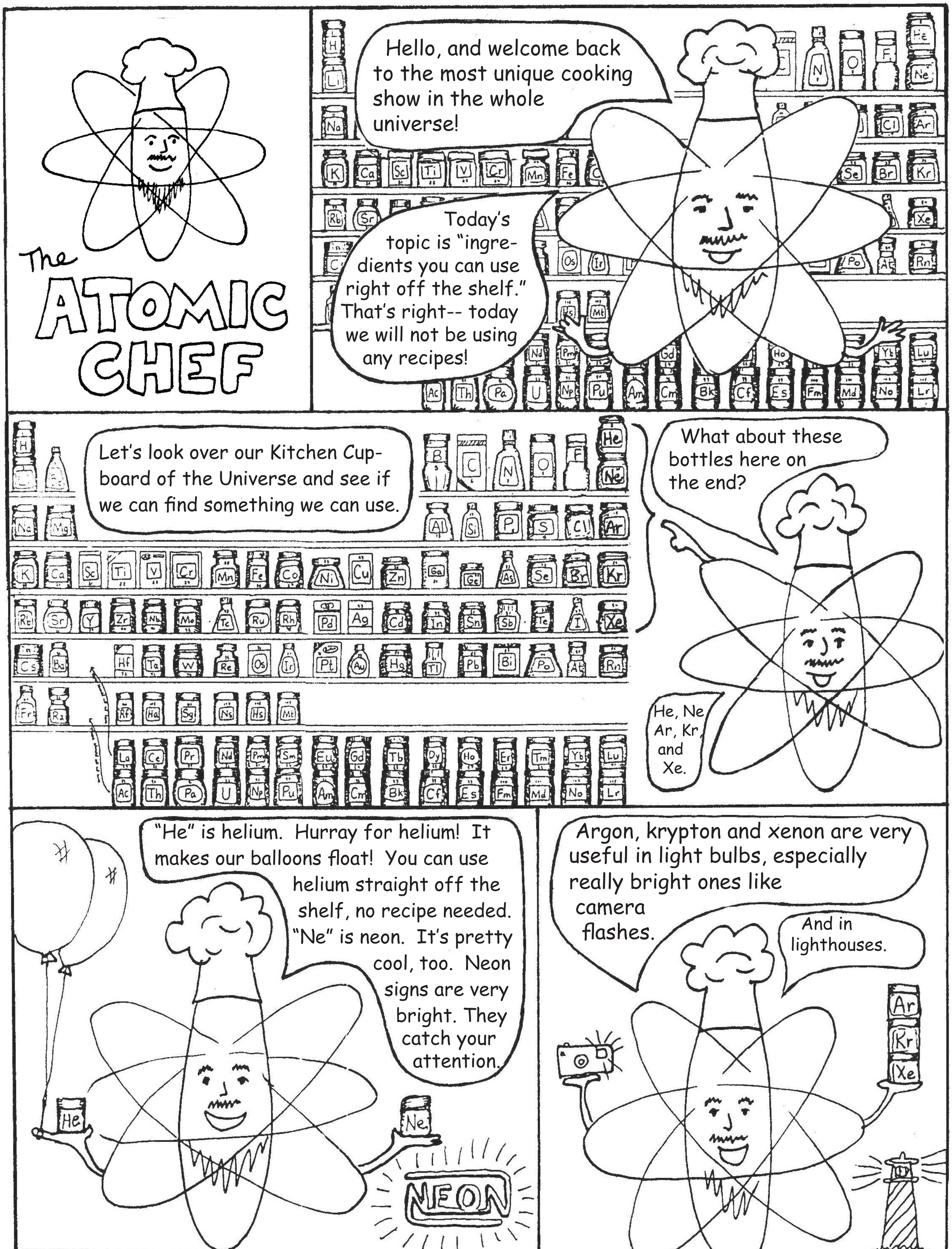
And one last riddle:

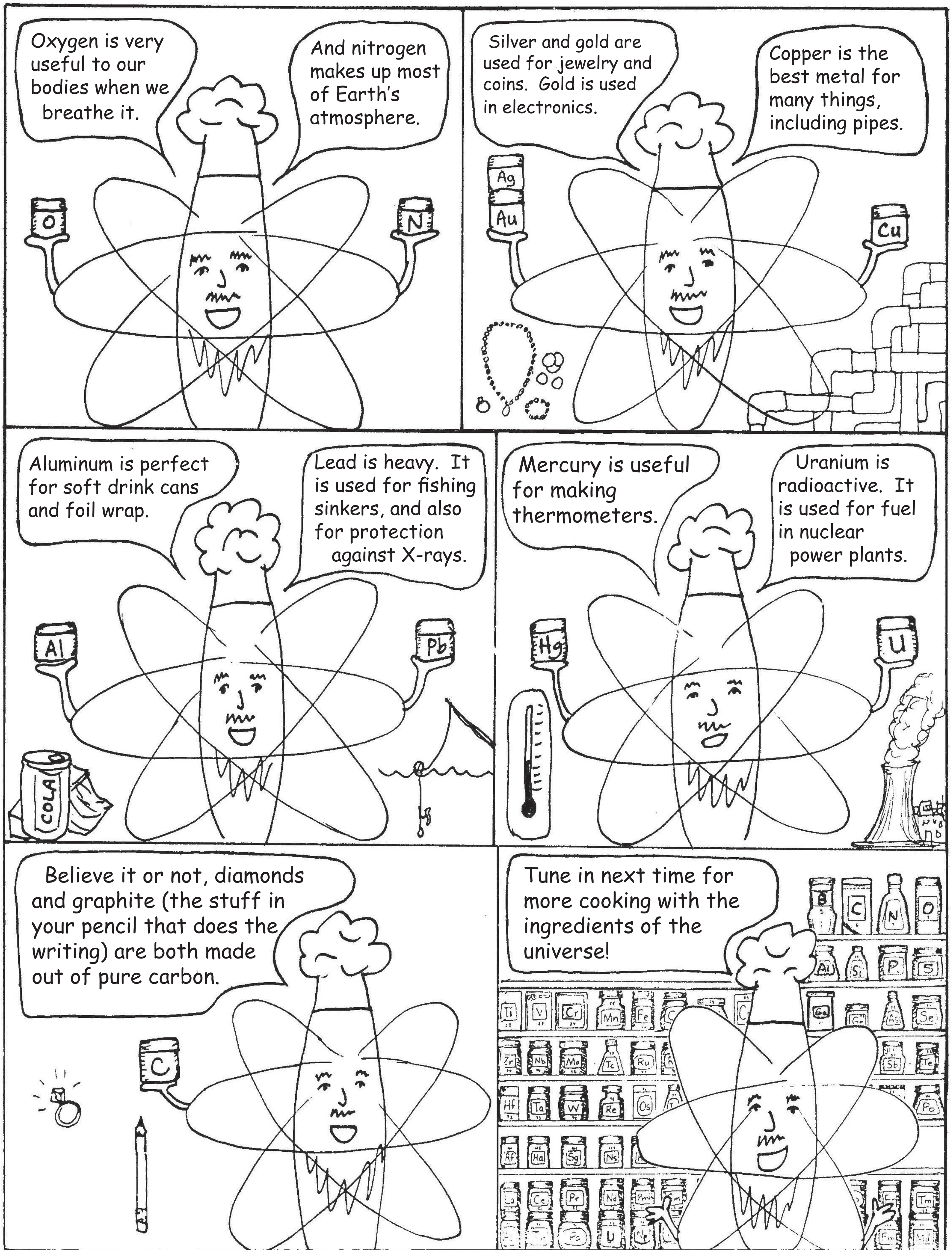
____ ____ ____ ____ ____e ____ ____a ____ a____ R____ ____ ____'____
tungsten hydrogen astatine tungsten erbium Barium thulium nitrogen neodymium oxygen bismuth nitrogen sulfur

____ ____ ____ ____ ____ 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.
He
Ne
NEON
Argon, krypton and xenon are very useful in light bulbs, especially really bright ones like camera flashes.
And in lighthouses.
Ar
Kr
Xe


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!

ANSWER KEY

CHAPTER 1

Answers will vary for the activities not listed here.

Activity 1.5:

1) C= 2, O= 6 2) 3 3) 2 4) Si= 2, O= 8 5) 20

Activity 1.6:

1) nobelium 2) vanadium 3) gadolinium 4) polonium 5) einsteinium 6) berkelium
7) tellurium 8) scandium 9) ytterbium 10) niobium 11) tin 12) holmium
13) neptunium 14) curium 15) mercury 16) tantalum 17) cerium 18) gallium
19) selenium 20) bromine 21) iridium 22) thorium 23) nickel 24) cobalt 25) chlorine

CHAPTER 2

Activity 2.3

1) phosphorus 2) fluorine 3) calcium 4) gallium 5) titanium 6) silicon
7) rhodium 8) iodine 9) scandium 10) palladium 11) tin 12) sulfur
13) chlorine 14) argon 15) nitrogen 16) hydrogen 17) carbon 18) boron
19) potassium 20) xenon

Activity 2.4

1) "Why did the mouse say, "Cheep, cheep," when the bird's cage fell apart?"
"He was filling in for the bird who had the day off."
2) "What do you get when you cross a vampire with a mouse?"
"A terrified cat!"
3) What were Batman and Robin's new names after they were run over by a car?
Flatman and Ribbon!

CHAPTER 3

Activity 3.4

Nitrogen: $1s^2\ 2s^2\ 2p^3$
Sulfur: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$
Neon: $1s^2\ 2s^2\ 2p^6$
Chlorine: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$
Lithium: $1s^2\ 2s^1$
Boron: $1s^2\ 2s^2\ 2p^1$
Silicon: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$
Fluorine: $1s^2\ 2s^2\ 2p^5$

Activity 3.5

Ag-47	H-1	Os-76
Am-95	He-2	P-15
At-85	I-53	S-16
As-33	In-49	Se-34

Activity 3.6

1) Be 2) N 3) Na 4) S 5) P 6) Ca Challenge: Fe

Activity 3.6

Just use the Periodic Table as your guide. It tells you what all the symbols are!

ACTIVITY IDEAS FOR CHAPTER 1

1) GROUP GAME: "Symbol Jars"

The purpose of this game is to learn the letter symbols of some of the common elements. Students do not need to have any previous knowledge. If players do already know some of the symbols, they can still play along with those who are beginners and just focus on the symbols that they don't know. More difficult symbols can always be added to the mix.

NOTE: This game is similar to the fishing game in chapter 2. If you are short on time, you might want to just play one or the other.

You will need: photocopies on card stock, scissors, pencils or crayons

Set up:

Photocopy the pattern page, (the empty bottles, page 84), onto white card stock. Make enough copies so that you have a bottle for each element you want to learn. Cut out the bottles. Write an element's symbol on the bottle, then write the name of the element on the back. (Important: Make sure you don't use anything that will bleed through to the other side! Also, don't press too hard, or your letters might show through to the back. This isn't the time to practice your engraving skills!) You could also reverse this, and put the name on the front and the symbol on the back. Either way is fine.

NOTE: If you are making several copies of the game so that you can play it with a class, make each set of cards a different color. If some cards get mixed up while the students are playing, they will be easy to sort back into their sets. (You won't end up with two of something in one set and none in another.)

How to play:

Before you begin, make sure each player has a little slip of paper with his name on it. Lay the jars out on the table in random fashion. Each player must "call" the jar he wants to play by saying the letter symbol. For example, a player might say, "C." Then the player has a choice: he can either "guess" or "peek."

If the player chooses "guess," he must say the name of the element that is represented by that symbol. After he says the name, he checks his answer by turning over the jar and reading the name on the back. If he is correct, he gets to pick up that jar and keep it. If not, he must leave the jar on the table.

If the player doesn't know a symbol and wants to learn it, he chooses the "peek" option. The player still begins by "calling" the jar he wants to play by saying the letter symbol. Then the player states his option, "peek," and turns the jar over to read the name on the back. After returning the jar to its original position, the player may then "reserve" the jar for his next turn by putting his slip of paper (with his name on it) on top of the bottle. No other player may call that jar while the name slip is on it. When that player's next turn comes around again, he can call that jar but this time use the "guess" option (assuming he does remember the name on the back-- if he doesn't, he can always use the "peek" option again). If he guesses correctly, he keeps the jar.

The game is over when all the jars have been taken.

2) GROUP GAME: "Quick Six" (Round one—we'll play it again later with more cards!)

The purpose of this game is to become familiar with the names and numbers of the elements from hydrogen to xenon. Players do not need any previous knowledge for this game.

You will need: scissors, photocopies of the pattern pages (85-90) on white card stock, and colored pencils if you would like the students to color the cards (I suggest using the digital version of the curriculum to print the cards on your computer's printer, or at a print shop.)

Set up:

Cut apart the cards. If you would like the students to add color to the cards, provide colored pencils and some extra coloring time.

How to play:

The object of the game is to be the first player to collect six cards.

Decide which player will be the "caller." This player must read from the list below instead of being one of the card players. If an adult is supervising the game, this is the obvious adult job. An adult caller may want to choose particular attributes from the list below to emphasize facts recently learned. It is easiest to go down the list in order, but the caller need not go in order, and may also use items from the list more than once (as long as the caller is being fair and is not purposely aiming to benefit any one card player, of course!) Feel free to add your own ideas to the list given below!

Each card player receives five cards, which he places face up in front of him. The rest of the cards go face down in a draw pile. The caller reads one of the attributes from the list (the first on the list if they are going in order). Each player looks at his five cards to see if he has a card that has that attribute. If he does, he slaps his hand down on the card. The caller looks to see who is the first player to slap his hand down. That player then shows the card under his hand. If the caller agrees that this card qualifies, then the player may remove that card from the line up and put it face down into a "keeper" pile. Then he draws a card from the draw pile to replace that card and restore him to five cards, face up.

NOTE: There's a chance that a student might know extra information about an element that is not on the card. If the adult in charge determines that the student's answer is accurate, I'd recommend allowing the student to use the information. This encourages integrated thinking, which is a critical part of intelligence.

The caller then reads off another attribute from the list and the game continues in this manner until one player has six cards in his "keeper" pile. If no player has a card that qualifies, the caller simply goes on to the next one on the list.

NOTE: You might have to institute a rule that says only one slap per round. If they slap and get it wrong, the other players get to guess again, but they don't. Sometimes students slap before they read the card carefully. Using this rule will prevent careless slapping.

If you reach the end of the list below, just start over at the beginning again. (Or, better yet, add your own clues.)

A single game could take as little as 5-10 minutes, so play multiple games. You can switch callers between games.

Atomic number has a 3 in it
Name has two syllables
Used in lasers
Has something to do with the color green
Named after someplace in Scandinavia
Has something to do with teeth
Starts with the letter C
Atomic number has a 5 in it
Name has something to do with color
Used to make tools of some kind
Is named after a city (not a country)
Name has three syllables
Atomic mass does not contain a 0
Is used to make jewelry
Named after a country
Used for something that burns
Named after something in the solar system
Atomic number has a 7 in it
Is named after a country (not a city)
Used in fireworks
Has something to do with bones
Name starts with a vowel
Gemstones are made from it
Atomic mass is greater than 100
Is named after a country (not a city)
Name has a double letter, such as "dd" or "ss"
Symbol has only one letter
Atomic symbol contains a vowel
Is used to make some kind of medicine

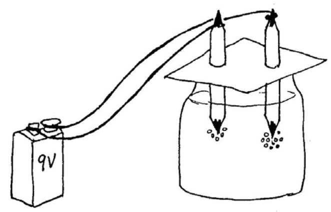
Used in steel production
Used to repair the human body
Used in light bulbs
Is found as a gas in the air around us
Has something to do with eyes
Conducts electricity
Atomic mass is less than 50
Last three letters of the name are I-U-M
Name is from a Latin word
Is used in batteries or fuel
Has something to do with glass
First letter of name does not match first letter of the symbol
Is found in some kind of gemstone
Name begins with the letter S
Name ends with letters O-N
Name starts with the "K" sound (C or K)
Is used in magnets of any kind
Used in something that makes light
Used to make coins
Symbol contains one of these letters: X, Y, or Z
Name has four syllables
Number has a 1 in it
Atomic mass contains a 1
Name begins with the letter R
Atomic number is a prime number
Is mixed into metal alloys

3) LAB DEMO: "A Recipe in Reverse" (Electrolysis of water)

In this experiment, you will start with H_2O and "break" it into its ingredients: H and O.

<u>You will need</u> a clear container, a 9V battery, a piece of cardboard (cereal box is fine), aluminum foil, tape, two pencil stubs (sharpened at both ends), water, salt

<u>How to set it up</u>:



Think about how important the discovery of electricity was to chemists. If there was no way to separate water into its ingredients, how would you know it wasn't an element? Figuring out which substances were elements and which were not was a major puzzle for hundreds of years. Elecgtricity was necessary for the discovery of a number of elements including sodium, potassium and magnesium.

1) Put 2 teaspoons of salt into the cup of water and stir until dissolved.
2) Cut strips of aluminum foil and roll them into "wires." Curl one end around a battery terminal (tape in place if necessary) and put the other end around the sharpened pencil point and secure with tape. Make sure the graphite of the pencil is in good contact with the foil.
3) Push the pencils through the cardboard, as shown, so that the bottom points are in the water. (You can even strip off some of the wood with an X-acto knife if you want to, exposing more graphite. The more graphite showing, the more bubbles you will get.)

<u>What will happen:</u>

You will see bubbles forming around the ends of both pencils. If you look carefully, you will notice that there are about twice as many bubbles on one pencil as the other. Have the students guess which is which, by thinking about the recipe: H_2O. (Hint: The recipe says that for every oxygen atom there are two hydrogen atoms.)

4) SONG: "The Chemical Compounds Song" activity

<u>You will need</u>: the audio tracks (There are two versions: one with vocals, and one "karaoke" style.)
(from digital download zip file, or from www.ellenjmchenry.com/audio-tracks-for-the-elements)

Here is an activity you can do with this song. It can be done in pairs or in a group, whatever works in your situation. Use the song as the chant for any type of hand-slapping game, such as "Miss Mary Mack." ("Miss Mary Mack, Mack, Mack, all dressed in black, black, black...") The students may be able to suggest their favorite hand-slapping patterns. Any hand slap pattern will work, as long as both partners are doing the same pattern. For a large group, they can sit in a circle and slap thighs, then clap, then turn hands to the side and slap hands of person on their left and right simultaneously.

Also, there is a funny music video to watch on the YouTube playlist, made by a family who did this curriculum a few years ago. (www.YouTube.com/TheBasementWorkshop, click on "Show all playlists," then on "The Elements."

5) "MAKE FIVE" A game about mineral recipes

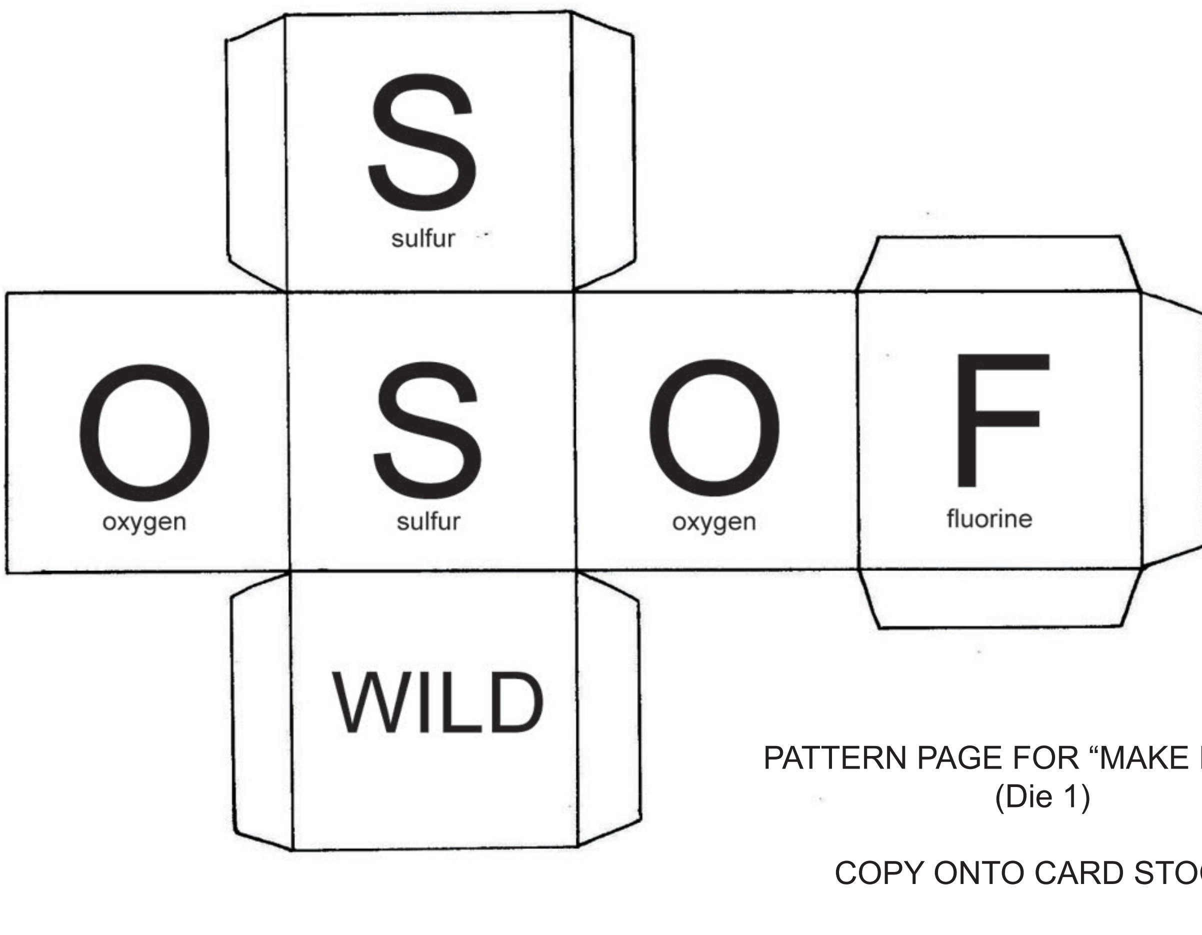
This game is recommended for older students, or those who are very enthusiastic about rocks and minerals. If "Symbol Jars" was enough, you can skip this game. You could also wait and play this game after the next chapter.

By definition, a mineral has a definite chemical composition (a recipe). In this game you will be introduced to the recipes for some common minerals. It's also an opportunity to keep on learning all those letter abreviations (symbols).
You will need: copies of the pattern pages copied onto card stock, scissors, and white glue (if you are assembling the paper dice) If you are using wooden cubes for the dice, you'll also need one or more markers.
(In a pinch for time, just take a fine point marker (red?) and write on real dice. Everyone can ignore the dots.)

NOTE: If you can get three wooden cubes, this is the best option. Most craft stores sell wooden cubes by the "each" or in small units and fairly inexpensively. If you want this game sturdy enough to survive future uses, consider using wooden cubes.

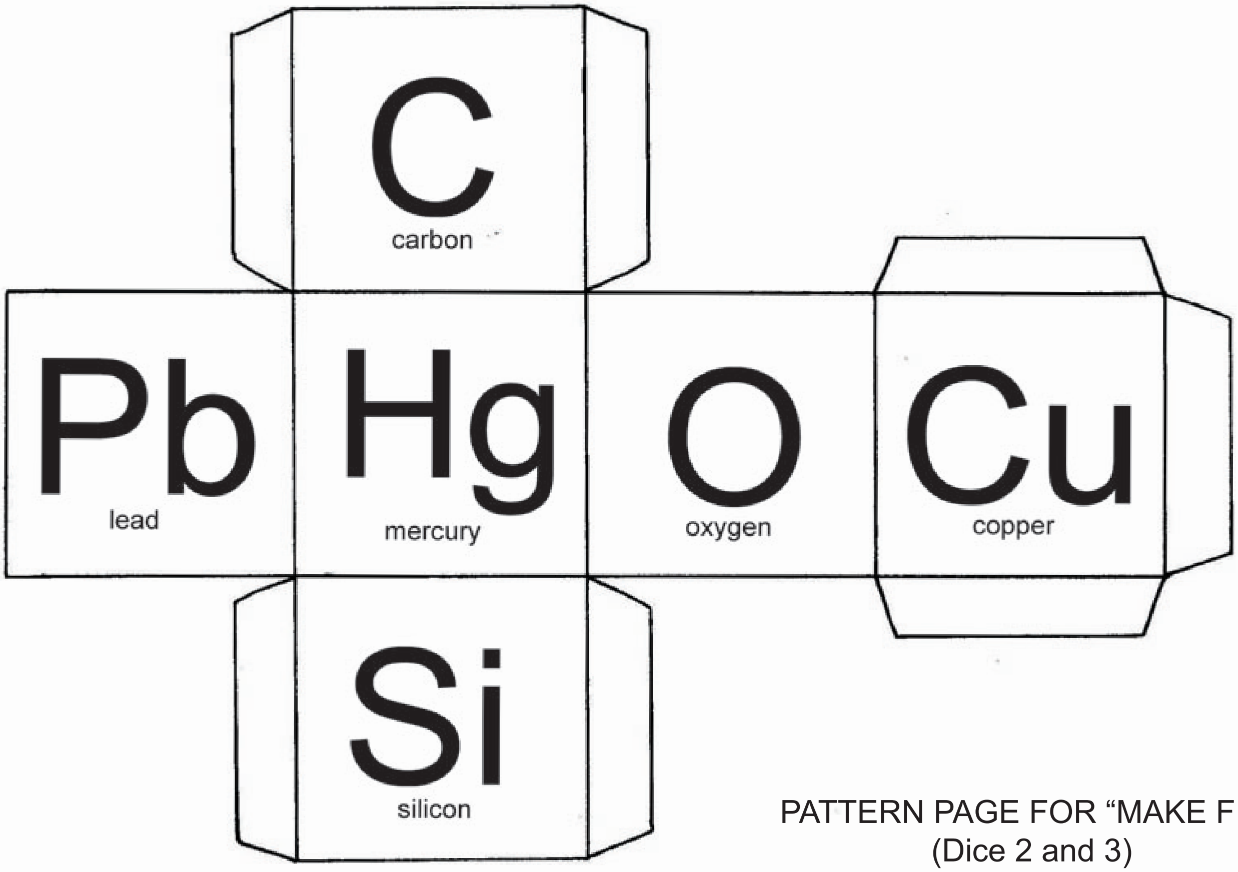
Preparation:
1) Cut out the dice patterns (copied onto heavy card stock) and make into cubes, using small dabs of white glue on the tabs. (Or, write the symbols on wooden dice or even regular dice.)
2) Cut apart the 16 mineral cards.

How to play:
Place the mineral cards on the table, face up, so they form a 4 x 4 square. Each player will have a turn rolling all three dice at once. The goal is to roll the ingredients to form a mineral. (One roll of the three dice per player per turn.) For example, if the first player rolls: Cu, Fe, and S, he should notice that those are the ingredients of chalcopyrite. Therefore, that player picks up the chalcopyrite card. If the next player rolls Ca, C, and WILD, he could make the wild card into O, and be eligible to pick up calcite.
The first player to collect five cards wins the game.



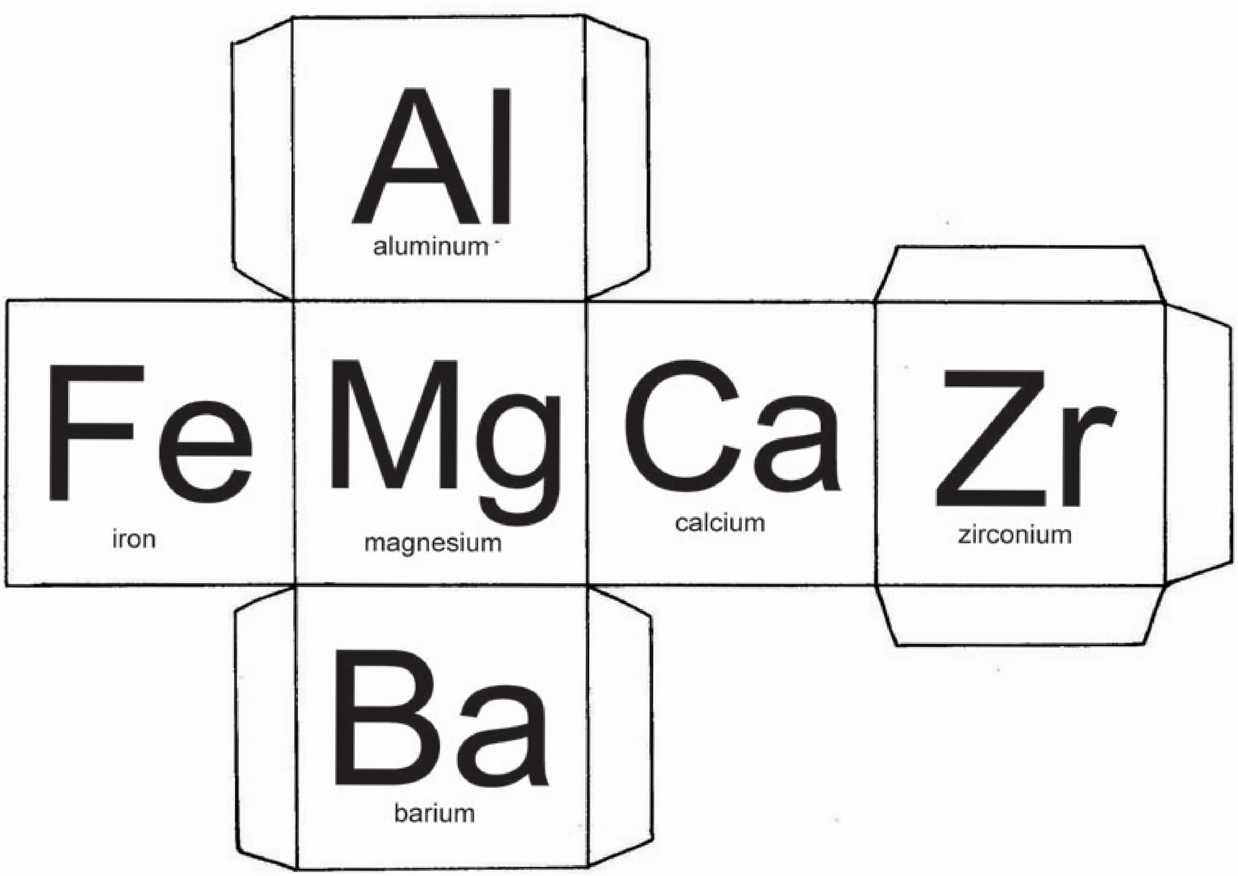
PATTERN PAGE FOR "MAKE FIVE"
(Die 1)

COPY ONTO CARD STOCK

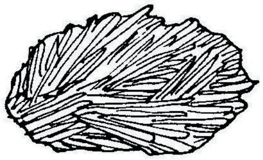


PATTERN PAGE FOR “MAKE FIVE”
(Dice 2 and 3)

COPY ONTO CARD STOCK



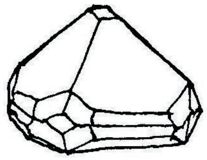
barite



$BaSO_4$

Often found in limestone or hot spring areas. Usually white or light brown. Sometimes crystalizes into rose shapes, which are popular with collectors.

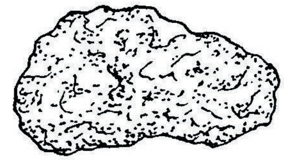
zircon



$ZrSiO_4$

Found in nearly all igneous rocks, although in very small amounts. Because it is so hard, it is often used as a gemstone in jewelry.

hematite



Fe_2O_3

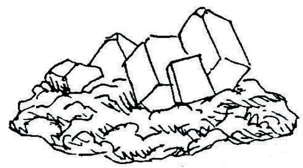
Hematite is a major ore (source) of iron. The name "hematite" comes from its blood-red color ("hema" means blood).

cinnabar

HgS

Cinnabar has a reddish color and is very dense (heavy) because of the mercury (Hg). Pure mercury is a liquid at room temperature, but it is a solid when bound to sulfur.

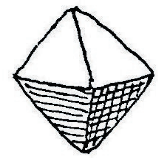
cuprite



Cu_2O

Cuprite forms cubic crystals. It is sometimes called "ruby copper" because of its color. When exposed to air it changes to CuO.

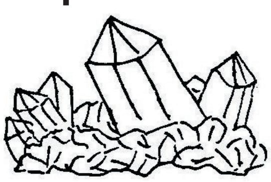
fluorite



CaF_2

Fluorite is used in the production of steel. It has a glassy luster and can look similar to a quartz crystal, except for its tetragonal (4-sided) shape.

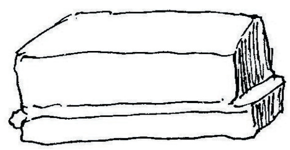
quartz



SiO_2

Quartz is used in electronics, as a gemstone, and in the manufacturing of glass (where it is the main component). Sand is made of very tiny pieces of quartz.

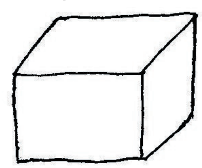
galena



PbS

Galena is very dense (heavy) because of the lead in it. During the era of musket rifles, galena was used as the source of lead to make musket balls.

pyrite



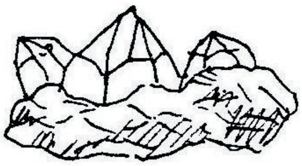
FeS_2

This mineral is often called "fool's gold" because of its golden color and shiny luster. It has no actual gold in it. It leaves a black streak, not gold.

FIRST PATTERN PAGE FOR "MAKE FIVE"

COPY ONTO CARD STOCK

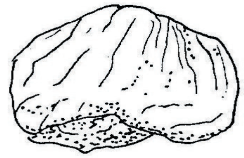
corundum



Al_2O_3

Corundum is very hard. It is so hard that it is used in industry as an abrasive (like sand paper). Blue corundum is called a sapphire and red is a ruby.

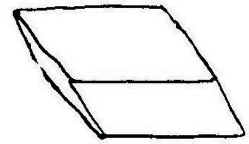
talc



$Mg_3Si_4O_{10}$

Talc is extremely soft. In fact, you can scratch it with your fingernail! Talc is the main ingredient in talcum powder (used to dry off after a shower).

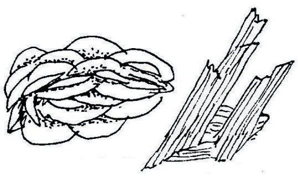
calcite



$CaCO_3$

Calcite is the main ingredient in limestone. It is one of the most common minerals in the world. Caves are made of limestone.

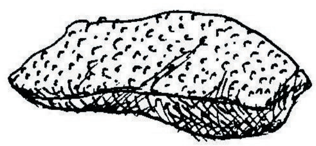
gypsum



$CaSO_4$

Gypsum is a soft mineral. It is one of the main ingredients in plaster and plasterboard. One type of gypsum is called alabaster and was carved by ancient peoples.

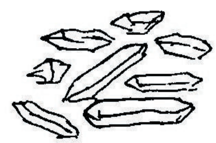
chalcopyrite



$CuFeS_2$

Chalcopyrite is pinkish-purple with flecks of gold. It is found wherever copper is mined. The copper can be taken out of it by using chemical processes.

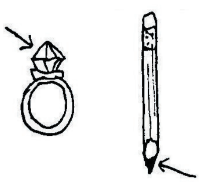
epsom salt



$MgSO_4$

This mineral dissolves into water very easily. It is often used in medical treatment of wounds on hands and feet. It helps in the healing process.

diamond/graphite



C

Strangely enough, both priceless diamonds and the stuff in your pencil are made of the same thing: pure carbon. The difference is how the atoms are bonded together.

SECOND PATTERN PAGE FOR “MAKE FIVE”

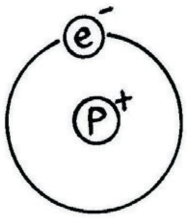
COPY ONTO CARD STOCK

PATTERN PAGE FOR “SYMBOL JARS” COPY ONTO CARD STOCK

H 1

Hydrogen **1.0**

Greek: "hydro–gen" (water-maker)

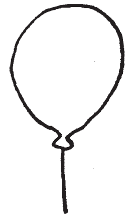


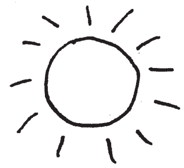
- Has no neutrons.
- Most abundant element in the Universe.
- Used in rocket fuel and fuel cells.

He 2

Helium **4.0**

Greek: "helios" (sun)



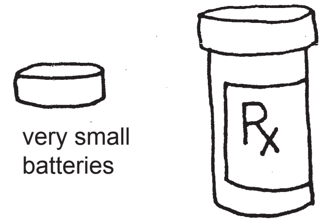


- Used in balloons, blimps and scubing diving tanks.
- Discovered in the sun in 1895 using a spectrometer.

Li 3

Lithium **6.9**

Greek: "lithos" (stone)

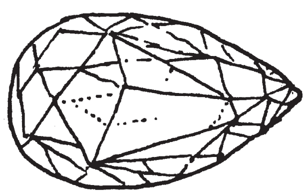


- Used in batteries, lubricants, medicines, and nuclear bombs.
- Is never found by itself in nature (it's always in a compound).

Be 4

Beryllium **9.0**

from the mineral "beryl"



- Found in emeralds.
- Is mixed with copper to make "beryllium bronze," an alloy that will not create sparks.

B 5

Boron **10.8**

from the compound "borax"

- Used to make heat-resistant glass.
- Used to make boric acid, which is used as an antiseptic eye wash.
- Used in nuclear power plants.

C 6

Carbon **12.0**

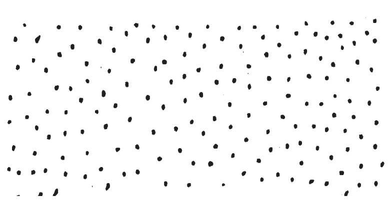
Latin: "carbo" (charcoal)

- Diamonds, graphite and coal are all made of carbon.
- Carbon makes long chains (polymers) that are the basis of fossil fuels and plastics.
- Carbon is necessary for organic molecules found in living organisms.

N 7

Nitrogen **14.0**

Greek: "nitron" (the mineral saltpetre)

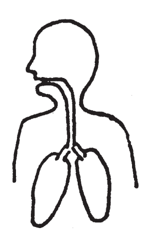


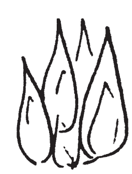
- Most of the air we breathe is nitrogen.
- Used in air bags in cars.
- Doctors use liquid nitrogen to treat skin conditions.
- Proteins and DNA contain nitrogen.

O 8

Oxygen **15.9**

Greek: "oxy-gen" (acid-maker)



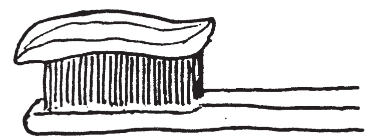


- Found in air, water and sand.
- Necessary for respiration and combustion.
- Ozone is made of pure oxygen.

F 9

Fluorine **18.9**

Latin: "fluere" (to flow)

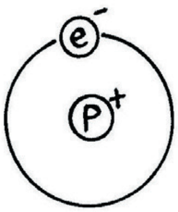


- Found in the mineral fluorite.
- Is put into toothpaste to fight cavities.
- Used as a coolant.
- Used in nuclear power plants.

H 1

Hydrogen 1.0

Greek: "hydro–gen" (water-maker)



- Has no neutrons.
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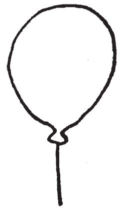
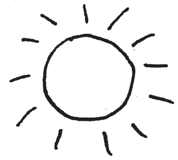
- Used in rocket fuel and fuel cells.

He 2

Helium 4.0

Greek: "helios" (sun)

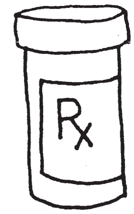
- Used in balloons, blimps and scubing diving tanks.
- Discovered in the sun in 1895 using a spectrometer.

Li 3

Lithium 6.9

Greek: "lithos" (stone)

very small batteries

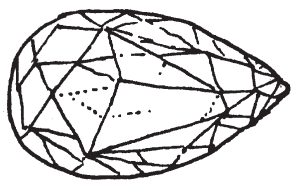


- Used in batteries, lubricants, medicines, and nuclear bombs.
- Is never found by itself in nature (it's always in a compound).

Be 4

Beryllium 9.0

from the mineral "beryl"

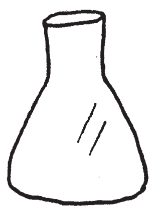


- Found in emeralds.
- Is mixed with copper to make "beryllium bronze," an alloy that will not create sparks.

B 5

Boron 10.8

from the compound "borax"




- Used to make heat-resistant glass.
- Used to make boric acid, which is used as an antiseptic eye wash.
- Used in nuclear power plants.

C 6

Carbon 12.0

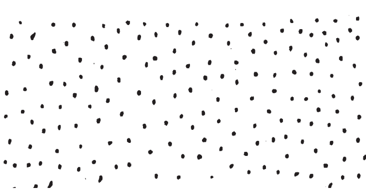
Latin: "carbo" (charcoal)


- Diamonds, graphite and coal are all made of carbon.
- Carbon makes long chains (polymers) that are the basis of fossil fuels and plastics.
- Carbon is necessary for organic molecules found in living organisms.

N 7

Nitrogen 14.0

Greek: "nitron" (the mineral saltpetre)

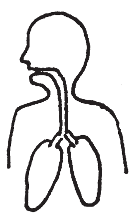


- Most of the air we breathe is nitrogen.
- Used in air bags in cars.
- Doctors use liquid nitrogen to treat skin conditions.
- Proteins and DNA contain nitrogen.

O 8

Oxygen 15.9

Greek: "oxy-gen" (acid-maker)

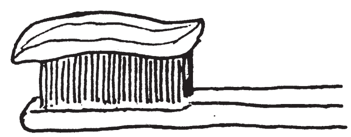



- Found in air, water and sand.
- Necessary for respiration and combustion.
- Ozone is made of pure oxygen.

F 9

Fluorine 18.9

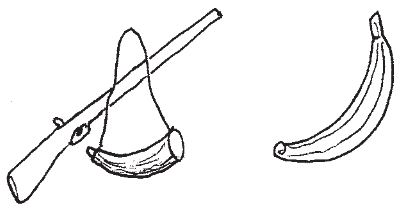
Latin: "fluere" (to flow)



- Found in the mineral fluorite.
- Is put into toothpaste to fight cavities.
- Used as a coolant.
- Used in nuclear power plants.

K 19
Potassium 39.0

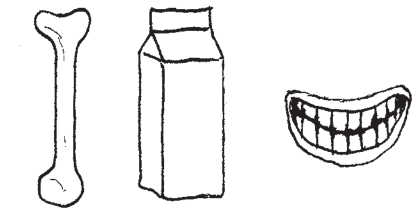
from the word "potash"



- Used in fertilizers.
- Is an ingredient in gun powder.
- Bananas contain a lot of potassium.
- Can form salts, just like sodium can.

Ca 20
Calcium 40.0

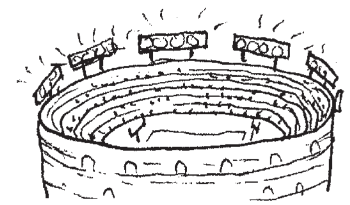
Latin: "calx" (chalk)



- Found in chalk, limestone, plaster, concrete, bones, and teeth.
- Milk contains a lot of calcium.
- Calcium in water makes it "hard."

Sc 21
Scandium 44.9

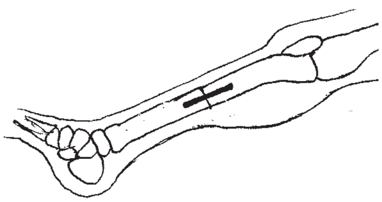
named after Scandinavia



- Used in stadium lighting.
- Used in large television screens.
- Radioactive scandium is used as a "tracer" in petroleum refineries.

Ti 22
Titanium 47.9

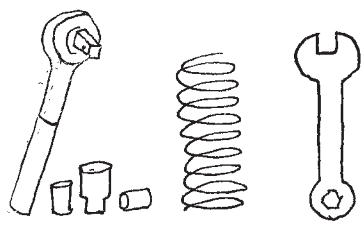
named after the Greek Titan gods



- Used to repair bones.
- Because it is lightweight it is used in airplane motors.
- Is an ingredient in paint pigments.

V 23
Vanadium 50.9

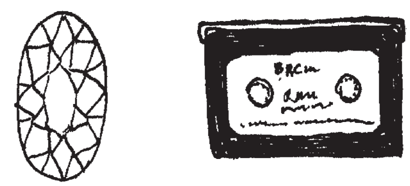
after the Scandinavian goddess Vanadis



- Used in making steel.
- Is an ingredient in metals that are used to make tools, springs and engines.

Cr 24
Chromium 51.9

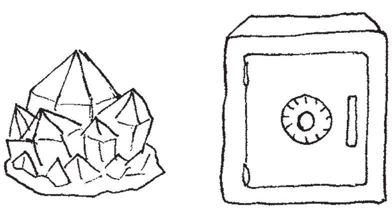
Greek: "chroma" (color)



- Gives rubies their red color.
- Used to make red, green and yellow paint.
- Used as a shiny coating for metals.
- Used to make video tapes.

Mn 25
Manganese 54.9

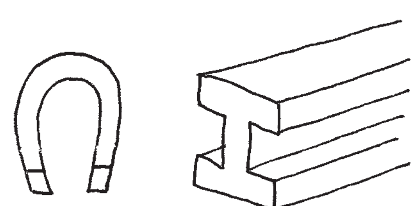
Latin: "magnes" (magnetic)



- Added to steel that needs to be very strong (for example: rifle barrels and bank vaults).
- Is necessary for the functioning of vitamin B1 in our bodies.

Fe 26
Iron 55.8

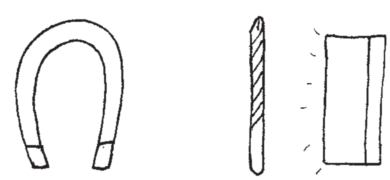
from Old English "iren"



- Discovered in ancient times.
- Used in steel and in magnets.
- Found in red blood cells and in rust.
- Meteorites often contain iron.
- Red rocks usually contain iron.

Co 27
Cobalt 58.9

German "kobald" (evil gnomes)



- Miners used to say "kobald" lurked in the mines (and the name stuck).
- Used in "alnico" magnets.
- Used in making drill bits and razors.
- Can be used to color glass deep blue.

Ni 28

Nickel 58.7

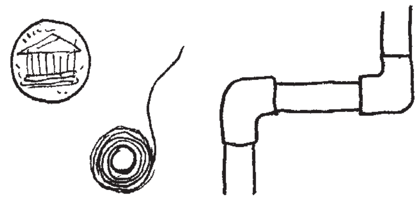
German: "Nickel" (Satan)

- Name comes from "Kupfernickel," meaning "Satan's copper."
- Used in the coloring of glass.
- Used to make coins and utensils.

Cu 29

Copper 63.5

Latin: "Cuprum" (from Cyprus)

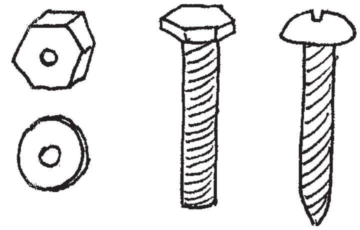


- Used for coins, wires and pipes.
- The Statue of Liberty is made of copper.
- Copper mixed with zinc makes brass.
- Copper mixed with tin makes bronze.

Zn 30

Zinc 65.4

Greek: "zink"

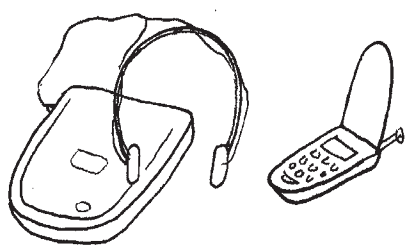


- Used for galvanizing (protecting) metals such as iron and steel.
- Zinc sulfide glows in the dark.
- Zinc oxide is used in photocopiers.

Ga 31

Gallium 69.7

Latin: "Gallia" (France)



- Gallium arsenide is used in lasers and in compact disc players.
- Used in cell phones and in medical devices.

Ge 32

Germanium 72.6

Latin: "Germania" (Germany)

semi-conductor

lens

- Is a semi-conductor and therefore is used in transitors.
- Used in lenses and fiberoptics.

As 33

Arsenic 74.9

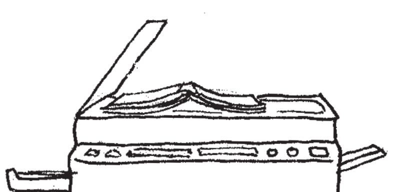
Latin: "arsenicum" (a pigment)

- Famous for its use as a poison.
- Is an ingredient in weed killers and insecticides.
- Used in lasers and LED's.

Se 34

Selenium 78.9

Greek: "selene" (moon)

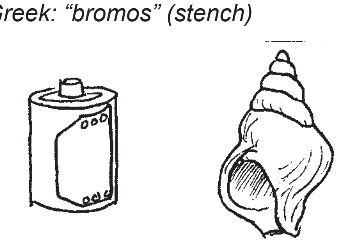


- Used in photocopiers because it conducts electricity in the presence of light.
- Used in robotics and in light meters.
- Selenium is beneficial to our bodies and acts as an anti-oxidant, protecting use from cellular damage.

Br 35

Bromine 79.9

Greek: "bromos" (stench)

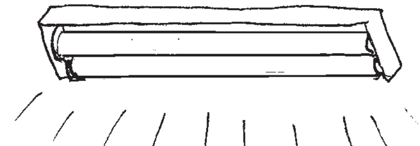


- Bromine is a reddish liquid with a very bad smell.
- Found in sea water and salt mines.
- Used in photographic film.

Kr 36

Krypton 83.8

Greek: "kryptos" (hidden)

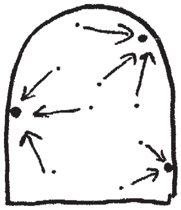


- Used in fluorescent flight, especially photographic bulbs.
- Used in UV lasers and in atomic clocks.

Rb 37

Rubidium 85.5

Latin: "rubidus" (deep red)



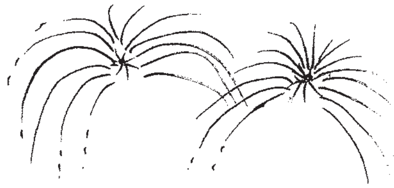
Rubidium captures atoms of gases that should not be in a vacuum jar or tube..

- Is a by-product of the refinement of lithium and cesium.
- Used as a gas "scavenger" (collector) in vacuum tubes.

Sr 38

Strontium 87.6

after the Scottish village of Strontia

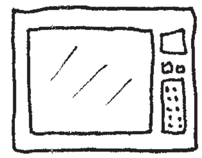


- Used in fireworks (bright red).
- Used in batteries in ocean buoys.
- Used to produce beta radiation.
- Used to research bone structure.

Y 39

Yttrium 88.9

after the Swedish town of Ytterby



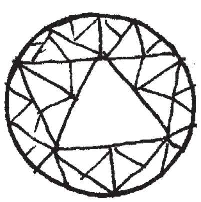
a moon rock

- Used in superconductors and lasers.
- Rocks from the moon contain yttrium.
- Used to make the bright red color in television screens.

Zr 40

Zirconium 91.2

Arabic: "zargun" (gold color)

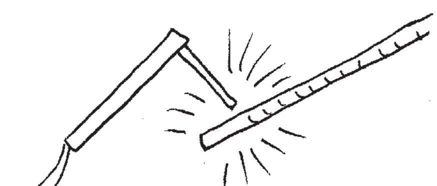


- Made into gemstones.
- Used in catalytic converters in cars.
- Used for heat-resistant parts in nuclear power plants and in space shuttles.

Nb 41

Niobium 92.9

named after the Greek goddess Niobe



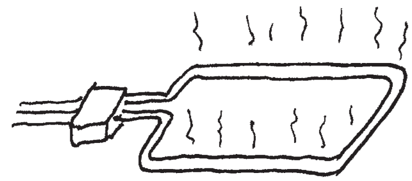
used in welding

- Used in welding rods, cutting tools, and superconducting magnets.
- Is added to steel to make it heat-resistant.

Mo 42

Molybdenum 95.9

Greek: "molybdos" (lead)



- Used for filaments in heaters.
- is an ingredient in steel that is used to make engines for cars and planes.
- Large deposits of molybdenum are found in Colorado.

Tc 43

Technitium 99.0

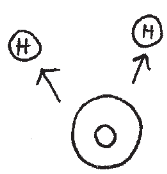
Greek: "teknetos" (artificial)

- Is radioactive.
- Not found in nature. Must be made in a nuclear laboratory.
- Is combined with other elements and used in medical procedures.

Ru 44

Ruthenium 101.1

Latin: "Ruthenia" (Russia)

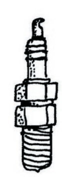


- Used to split water molecules.
- Used in the jewelry making industry.
- Often mixed with titanium and platinum to increase their hardness.

Rh 45

Rhodium 102.9

Greek: "rhodon" (rose)



- Rhodium salts have a rose color.
- Used in catalytic converters in cars.
- Used in headlight reflectors.
- Used in jewelry to prevent tarnishing of sterling silver.
- Combined with **Pt** and **Pd** to make spark plugs, electrodes, and other electronic parts.