Guidebook
and Quizzes

A companion guide to the Chemistry 101 DVD set

Wes Olson
A guide to the Guidebook

Alkali Metals

This is the place where I say all manner of wise and clever things. Things you always wondered about and lots of things you never wondered about...but do now. You might especially wonder why I would even mention them or put them in a film on chemistry. Like, what in the world does a squirting nickel and a snake-in-the-can possibly have to do with chemistry? And will it be on the test? Could happen!

1. Introduction

1. The real question here is this: "Does anybody ever read this section? I seriously doubt it because not one person has ever written in and said, "Mr. Olson, I read it!" But if you are that person, send me an email!

2. Noble gases are almost always being misspelled as Nobel gases. This would be fine except Nobel is a person and noble is a quality a person or object should have. In other words, Nobel is a noun whereas noble is an adjective. Except in this case where Noble Gas is a noun also.

3. The number three, as we have here, is representative of the third number. It is the first odd prime number. In literature there were three little pigs, three musketeers, three blind mice and three bears. Clearly an important number.

Chemistry Trivia.

And just what kind of "trivia" might I put here? Well, not just trivia but additional facts or data that supplements what is in the main text. Like I might say did you know that sodium is the first element in the periodic table whose atomic symbol is not based on its English name. The symbol Na is Latin for sodium. And hey wouldn't you be impressed?

Radioactive Elements. Radioactive elements are, in a word, active with radio. This may come as a surprise to many of you who thought the word radioactive meant something else. A common mistake, I assure you. Radioactivity was much more common in the 1950's through the 1990's. But with the advent of mp3 players, most elements of this kind are now considered ipodactive instead.

Footnotes.

1. Dr. Bob Schwartz, Lithium Lollipops and other Commercial Failures; P. 36. Dr. Schwartz follows the history of bad commercial ideas. Great for the beginning entrepreneur!

Side Bar Trivia. The text on the left side of the page contains interesting facts on a whole host of chemistry related subjects.

Film Information. This area with black text is information from the film.

Stories & Commentary The text in a box contains interesting biographies and observations.
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Introduction

There was a time, and it wasn't that long ago, when people would be digging in the hills making a house or a garden or playing. They would move dirt and rocks and then come across something different - something that wasn't rocks or dirt. It was metal and the curiosity of these metals and how to manipulate them was the beginning of what we call Chemistry.

1. Chemistry: "The study of matter and energy and the interactions between them."

2. Physics: "The study of matter and energy and the interactions between them.

3. Chemistry disassembles the watch into the component pieces so you can reassemble it again into new and useful things

4. Physics is like the watch of the universe and how it all works. The sound, the light - the physical mechanism.

5. Solve et Coagula is the Latin phrase for Separate and Join Together. This phrase from the alchemists is the essence of modern chemistry. The chemist separates the pieces-the elements- then rejoins the pieces to make something new.
PART 1 - THE ROAD TO THE PERIODIC TABLE

1. The Last Alchemist

Early chemistry spans nearly 5000 years from earliest times to 1700 AD. The idea that the name "Vulcan" comes from the Biblical "Tubal-Cain" is mildly controversial because there is not universal support for it. Some sources say yes, other say there is not enough evidence for it.

1. Early Chemistry

A. One of the earliest statements of chemistry comes from the Bible in Genesis 4. It specifically mentions he was a worker in iron and bronze. This testimony means that from earliest recorded history, men had a working knowledge of how to work with some of these basic metals.

B. Seven metals have been known from ancient times: gold, silver, copper, lead, tin, iron and mercury. Of these seven, mercury is the only one not mentioned in the Bible.

C. The alchemists never adequately answered the question, "What is everything made of at the smallest level?" Most cultures believed that the smallest level was made of things like earth, wind and fire.

D. The Greeks said the basic essences were earth, water, air and fire. They were called "The Four Essences." There was also a fifth essence called ether which bound them all together.

E. Democritus was the Greek who said that everything was made of uncuttable particles. He used the word atomos. "A-tomos" means "uncuttable."

F. The word Alchemy probably comes from the Arab word meaning "Art of the Egyptians." Apparently the Egyptians were pretty skilled in this and the Arabs learned it from them. Our word chemistry comes from this word. Nearly every scientist or curious person in the 1700's toyed around with alchemy to one extent or another. It was the "chemistry" of the day.
G. The objective of the alchemist was to discover the "philosophers stone" which would turn ordinary metals into gold. It might also prove to be the key to eternal life. They never found it by-the-way.

H. They thought things burned because it contained a material called phlogiston. Things stopped burning because it gave up all its phlogiston which literally means "burning up."


Distillation
Water distillation involves boiling water and then collecting the vapor that condenses back to water. The condensed vapor will not include salt and other impurities.

Evaporation does the exact same thing... only slower.

Freeze at 32°?
Why would someone invent a weird scale where water freezes at the bizarre number 32? The story says that Daniel Fahrenheit got water as cold as he could in a salty solution and used this as his 0° and used the average human body temperature (98.6°) as his 100°. A few years later Anders Celsius made a scale where water boiled at 0 and froze at 100. This was obviously confusing and was later reversed so water freezes at 0 and boils at 100. The United States is virtually the only country in the world still using the Fahrenheit scale. (and since I live in the United States...)

Who is The Father? Boyle and Lavoisier are pretty much universally acknowledged as the Fathers of Modern Chemistry. But there is a Persian contender for the title. He is Abu Musa Jābir ibn Hayyān whose name is completely unpronounceable to the west so he is generally called "Geber." The identity and collected works of Geber have been disputed for centuries so he is generally regarded as "The First Practical Alchemist" which is obviously a step down from being "The Father of Modern Chemistry."

Celsius Temperature Rhyme
When it's zero it's freezing, when it's 10 it's not, when it's 20 it's warm, when it's 30 it's hot!
2. Robert Boyle

A. Robert Boyle lived around 1650 AD. He is considered one of the two fathers of modern chemistry. Boyle broke away from the mysticism of alchemy and insisted on rigorous recordkeeping and experimentation. His book was called "The Skeptical Chemist."

B. Boyle believed that atoms actually existed and that the reason gases compress is because there is lots of space between the atoms in a gas. Solids have no such space and thus they could not be squeezed together as easily.

C. Boyle believed the reason the universe was orderly and systematically understandable was because it was created by God to be orderly. It was the same God who revealed himself in the Bible—a book which Boyle believed to be God's revealed word to mankind.

D. The Boyle Lectures continued for nearly 200 years before they were suspended between 1900 and 2000. They were revived in 2004 to once again, "prove the truth of the Christian religion."

Boyle Quotes

"The vastness, beauty, orderliness of heavenly bodies; the excellent structure of animals and plants; and other phenomena of nature justly induce an intelligent, unprejudiced observer to conclude a supreme, powerful, just, and good author."

"God would not have made the universe as it is, unless He intended us to understand it."

Discussion Questions

- Note that the Bible says Tubal-Cain was an instructor of craftsmen of iron and bronze. Does that suggest this man was actually the main teacher or professor at an early school of metallurgy?

- Why do you think belief in God and the Bible was important to Robert Boyle?

- The Renaissance artists are not known for being particularly modest artists and freely made art of people with no clothes, then assigned Biblical names to the statues or the paintings. Just because a work of art is done well, does this justify the content of the art? Is anything so sacred we shouldn't depict it in art? Are there limits to what even the "masters of old" should or should not have created?
Quiz One - The Last Alchemist

1. *Solve et Coagula* literally means
   a) Heat and join together
   b) Dissolve the chemicals
   c) Separate and join together
   d) Solve the problem

2. The Bible mentions an early chemist in Genesis 4. What was his name?
   a) Naamah
   b) Tubal-Cain
   c) Cain
   d) Enoch

3. Which of these metals is NOT one of the seven oldest known element metals?
   a) Iron
   b) Tin
   c) Lithium
   d) Mercury

4. *Quintessential* literally means what?
   a) The fifth essence
   b) The essential quint
   c) Carried away
   d) The best of the best

5. *Atom* literally means
   a) First
   b) Earth
   c) Foundations
   d) Essential
   e) Uncuttable

6. The word *chemistry* comes from the word
   a) To protect the seeds
   b) Alchemy
   c) To defend the plant
   d) To hold the plant up
   e) None of the above

7. The primary objective of the alchemist was to
   a) Find new elements
   b) Find the quintessential element
   c) Find the philosopher's stone
   d) Find the universal solvent

8. *Phlogiston* means
   a) Burning up
   b) Essence of life
   c) Alchemy
   d) Iron rust

9. *The Skeptical Chemist* was written by
   a) Lavoisier
   b) Robert Boyle
   c) Joe-Bill Turner
   d) Robert Hook

10. Why did people generally wear big wigs?
    a) It was popular because the rich and famous were doing it
    b) Their heads were cold and there was little heat
    c) It covered their baldness
    d) Nobody knows

11. Air is an element.
    a) True
    b) False

12. Boyle wanted the Christian religion taught as historically accurate and true.
    a) True
    b) False

Answers are on page 114
2. The Birth of Modern Chemistry

1. Antoine Lavoisier
   A. Lavoisier was the other Father of Modern Chemistry.
   
   B. He helped construct the metric system, wrote the first extensive list of elements, and helped to reform chemical naming. He discovered that, you cannot create or destroy matter which he called The Conservation of Matter. He did not discover any element and many say Lavoisier's real contribution was explaining the work that others did before him.
   
   C. His book Traité Élémentaire de Chimie (Elementary Treatise on Chemistry, 1789) is considered to be the first modern chemistry textbook. Lavoisier named the element of oxygen.
   
   D. Lavoisier was murdered by a band of French revolutionaries. He was fairly wealthy, popular with the government and was a tax collector. This is usually seen as a bad combination during a revolution.
   
   E. Lavoisier's first biographer, Edouard Grimaux, had access to his papers. Grimaux said, "Lavoisier was raised in a pious family which had given many priests to the Church, and he had held to his beliefs. In responding to an English author who had sent him a controversial work, Lavoisier wrote, "You have done a noble thing in upholding revelation and the authenticity of the Holy Scripture."

2. Joseph Proust
   Proust came up with the law of Definite Proportions. Substances combine in definite proportions so you can accurately predict how much stuff will combine with other stuff.

3. Joseph Priestley
   A. Mr. Soda water. We have Priestly to thank for the fizz in our soft drink, for discovering oxygen and starting the Unitarian church.
   
   B. Priestly was a very popular writer and speaker. Benjamin Franklin and Thomas Jefferson were among his admirers.
   
   C. Priestly was also a very unpopular writer and speaker and he managed to alienate his fellow scientists, Christians and politicians in his day.
4. Henry Cavendish
Mr. Eccentric. I mention Priestley, Proust and Cavendish especially because they were so unusual, eccentric and memorable. Cavendish especially so. Cavendish found hydrogen and discovered that water was made of two gases. He was also the first person to accurately weigh the earth.

5. John Dalton
A. John was first and foremost a meteorologist.
B. John was also colorblind and quiet.
C. He was a Christian Quaker and the man responsible for the first atomic theory. Atomic theory is the theory of atoms - that they exist and weigh something and that weight is what makes the difference between atoms.
D. Eventually we discovered that the real defining difference in elements is how many positive protons are in the nucleus. This was close to what Dalton had going, but is a definite refinement.
E. John determined the weight of atoms by measuring the proportions they combine in. If Oxygen always combines eight parts to one part of Hydrogen, then that probably means that one oxygen atom is eight times heavier than one hydrogen atom. From there, you can do any number of comparison weights and come up with a whole list of numbers. One gold atom weighs 197 times what 1 hydrogen atom weighs.
F. John assigned hydrogen the weight of one-one atom unit.
G. Atoms like to combine with other atoms. Their ability to do this is usually called their "Valence." Valence comes from the word valor and means strength. The atoms strength to combine with other atoms.

**Newton Quote**
"...God in the beginning formed matter in solid, massey, hard, impenetrable, moveable particles."
-Sir Isaac Newton

**Discussion Questions**
-Who was your favorite person in this segment? Why?
-Explain how Dalton determined that hydrogen should be atomic number 1 and oxygen should be atomic number 8.
-Many of these scientists believed in God. Many did not. How do these beliefs affect the results of the science? How do they affect the interpretation of the results?
Quiz Two - The Birth of Modern Chemistry

1. Carbon Dioxide is lighter than air.
   a) True
   b) False

2. The earth was first weighed by
   a) Lavoisier
   b) Boyle
   c) Cavendish
   d) Rutherford

3. Who discovered oxygen?
   a) Priestley
   b) Democritus
   c) Rutherford
   d) Einstein

4. The idea that you cannot create or destroy matter is often called
   a) Law of Natural Selection
   b) Law of Definite Proportions
   c) Conservation of Matter

5. The idea that substances combine themselves in specific amounts is called
   a) Law of Natural Selection
   b) Law of Definite Proportions
   c) Conservation of Matter

6. Henry Cavendish was admitted into the Royal Society because
   a) He graduated from Harvard
   b) He graduated from Cambridge
   c) He had an honorary degree
   d) He was an excellent speaker
   e) Nobody knows how he got in

7. Joseph Priestley
   a) Invented Soda water
   b) Was liked by Jefferson
   c) Discovered oxygen
   d) Got his house burned down by a drunken mob
   e) All of the above

8. Why did Dalton assign hydrogen the weight of one?
   a) Because it weighs one
   b) Because that's its valence
   c) Because it's the lightest element
   d) He didn't

9. Dalton is primarily remembered for
   a) His work on plants
   b) His weather record keeping
   c) His atom theory
   d) The red socks he gave his mother

10. Phlogiston was the theory explaining
    a) Why things burned up
    b) Modern chemistry
    c) Why atoms are attracted to each other
    d) Why water rises in a sealed bell jar

   **Answers are on page 114**
3. The Bold Russian

1. How Science Works Sometimes

Life doesn't always go the way we want...and neither does science. Sometimes you just get surprised by an unexpected event. Sometimes you need to make guesses to get going. Sometimes people nudge the data and sometimes a lot of hard work pays off. (See side bar on Scientific Misconduct)

2. Galvani and Volta.

A. A new way was needed to separate out more of the elements from the world. The way was electricity.

B. Volta invented a battery using a pile of copper and zinc plates with cardboard soaked in saltwater. The result was a reliable source of electrical power.

3. Sir Humphry Davy

A. Davy was a pioneer in the field of electrolysis. Volta's new battery allowed Davy to discover sodium, potassium, calcium and others.

B. What didn't Humphry Davy do well in science? He was inventive, brilliant, handsome, well liked, the President of the Royal Society, a great inventor, world traveler and on and on.

C. Later in life he was injured in a lab which prompted him to hire an assistant, Michael Faraday. He also loved fly fishing for salmon and wrote a book on it.

Scientific Misconduct

We mentioned at the beginning of this segment that sometimes scientists will nudge the data to fit the hypothesis. Why?

A recent survey by the Public Library of Science (PLoS) asked how many scientists knowingly falsified or fabricated research.

14% said they were aware of falsification by their colleagues and 75% were aware of questionable research practices.

This merely underscores the fact that scientists are simply men and women and the Bible says men and women have a definite heart problem...even if they are peer reviewed.

Recent Examples of Misconduct

> The 2002 fabricated evidence at Berkeley Labs for creation of elements 116, 118 by researcher Victor Ninov.

> The 2002 Schön scandal with fraudulent semiconductor research.

> 2004 Andrew Wakefield fraud in medical vaccine/autism research.

> Hwang Woo-Suk 2005 stem cell research fraud.

> 2010 research data falsification by Marc Hauser at Harvard University in animal behavior studies.

4. Michael Faraday

A. Davy’s assistant is largely responsible for our understanding of electricity. He invented the first electric motor and nearly everything else that formed the foundation of electrical invention.

B. Historians of science refer to Faraday as the best experimentalist in the history of science.

C. Nearly every biographer comments on the strength of Faraday’s belief in God and the Bible noting that, “Faraday found no conflict between his religious beliefs and his activities as a scientist and philosopher...a strong sense of the unity of God and nature pervaded Faraday’s life and work.”

D. Even though Faraday turned down the honor of burial in Westminster Abbey, a memorial plaque was put there right next to the tomb of Sir Isaac Newton!

Michael Faraday’s Last Words

When asked if he ever pondered what his occupation in the next world would be Faraday answered: “I shall be with Christ, and that is enough.”

5. Electrolysis

Electrolysis was responsible for the discovery of many new elements in the 1800’s. Electrolysis means, “To electrically loosen.”

6. John Newlands ♫♪

A. A chemist in a London sugar factory who discovered the periodic law of repeating elements.

B. Newlands equated the law of octaves with the repeating eights in the elements. His peers mocked him but later realized he was actually onto the truth of the matter...minus the music part.

7. Alexandre-Emile Béguyer de Chancourtois

A French geologist who was the first to make a table of the elements showing Newlands’ periodic repetition.

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2. Jim Baggot, in "The myth of Michael Faraday: Michael Faraday was not just one of Britain’s greatest experimenters. A closer look at the man and his work reveals that he was also a clever theoretician" in New Scientist No. 1787 (21 September 1991)
8. Dmitri Ivanovich Mendeleev

A. That bold Russian with the wild hair. Oh, and he is the Father of the Periodic Table too.

B. Played a game of chemical solitaire on train rides and BOLDLY left spaces where missing elements should be and BOLDLY predicted what the characteristics of those elements would be.

C. Lothar Meyer came up with an identical periodic table at the same time and leaves gaps just like Mendeleev does. Meyer misses becoming the Father of the Periodic Table by a whisker...Mendeleev's whisker.

Mendeleev Trivia
It is very commonly reported that on the night of Feb. 16, 1869, Mendeleev had a dream in which he saw almost all of the 65 known elements arrayed on a grand table. The following morning, he committed this to paper—the rest is history.

In 1906, Mendeleev came within one vote of receiving the Nobel Prize in chemistry. The reason cited is that Mendeleev’s 1869 work had already been widely accepted as a basic part of chemical knowledge, and had already been put forward by the Italian chemist, Stanislao Cannizzaro. Thus Mendeleev missed a Nobel Prize... by a whisker.

Discussion Questions
- Read the sidebar item on "Science Misconduct." Discuss this with your family or class. Do these statistics surprise you?

- Who was your favorite person in this segment? Why?

- Every major sporting event has two fairly equal competitors racing to win and who generally win by one or two points. The winner gets everything and the loser is generally just the loser. Does this happen in many areas of life also like science, law, entertainment and just about anywhere there is something to gain and lose? Is this fair, unfair or just the way it is?
Quiz Three - The Bold Russian

1. The man who just missed being the father of the periodic table.
   a) John Newlands
   b) Demitri Mendeleev
   c) Lothar Meyer
   d) Humphry Davy

2. Alessandro Volta is known for what?
   a) Inventing a battery
   b) Being a gentleman
   c) Being an Italian
   d) All of the above

3. Humphry Davy discovered
   a) Many elements with electrolysis
   b) The periodic table
   c) The radio
   d) Carbonated soda

4. Historians generally regard Michael Faraday as the best experimental scientist of all time.
   a) True
   b) False

5. Faraday is primarily known for
   a) Work in x-rays
   b) Work on the periodic table
   c) Work with electricity
   d) None of these

6. Electrolysis was used in the 1800's
   a) To make plants grow faster
   b) To make a frog's leg twitch
   c) To electrically separate elements from each other
   d) To electrically weld metals
   e) None of the above

7. John Newlands got in trouble for
   a) Challenging his science peers
   b) Linking the periodic law with music law
   c) Falsifying his data

8. Newlands is remembered today as the
   a) Father of oxygen
   b) Father of electricity
   c) Discovered of the law of repeating elements.
   d) Discoverer of animal electricity

9. Mendeleev is
   a) The Father of the periodic table
   b) The inventor of the soda water
   c) The man who invented magnetism
   d) The first man to discover nitrogen

10. Mendeleev was bold because
    a) He did what others refused to do
    b) He piloted a balloon to see an eclipse
    c) He predicted elements and their characteristics
    d) His hair was bold

Answers are on page 114
4. Lots of Mystery Rays

1. Cathode Rays (electrons)
   A. William Crookes
   Crookes is primarily known for his pioneering work in the construction and use of vacuum tubes—Crookes tubes. (A light bulb is also a type of vacuum tube.)

   • Cathode ray discovery
     Crookes found that these rays traveled in a straight line and would cause objects they struck to fluoresce. Plus, and most important, these rays would bend toward the positive side of a magnet. It remained for J.J. Thomson to correctly interpret what these rays were.

   • A popular scientist
     The breadth of his interests and his brilliance made him a very well-known and popular personality and he received many public and academic honors.

   • Spiritualism
     He was better at conducting experiments than he was at interpreting what the results meant. Perhaps this is why he got involved with spiritualism and could not go the extra step in recognizing that the data meant it wasn’t true.

   Crookes also invented this cool device called a Radiometer.

2. J.J. Thomson
   • Achievements
     Joseph John Thomson but everyone called him “J.J.” since he was just a kid. He is best known for discovering the electron - AND isotopes- AND inventing the mass spectrometer-AND winning the 1906 Nobel prize in physics.

   • The Plum Pudding Model of the Atom
     Thomson advanced the atom from a solid billiard ball to the plum pudding model where his negative electrons were swimming in a positive dough-like background.

   Dead Technology
   The use of cathode ray tubes (crt) for computer and television screens is a dead technology. They are bulky and heavy and are being completely replaced by light-weight, large, flat-panel display screens.
2. X-Rays

A. Wilhelm Conrad Röntgen
The only time in English we put two little dots above the letter O is when we are making emoticons. Most English references to Röntgen spell his name Roentgen. But he spelled it with the umlauts (that's what the little dots are called) so I did too. Röntgen is credited with the discovery of X-rays.

B. Ivan Puluyi
An early developer of x-rays, civic engineer and Bible translator. The Ukrainians believe he developed x-rays years ahead of Röntgen but the necessary proof is lacking and all we really have are unconfirmable reports.

Twins?
Is it me or do Röntgen and Puluyi look like brothers...or even the same guy? They lived 900 miles apart and not only do they look like each other, they ended up wearing the same coat and tie!

Röntgen
Puluyi

C. What are X-rays?
X-rays are just like visible light except they have more energy to them. It's like what is the difference between Grandpa and his grandson? They are both men except the grandson has more energy in him. When electrons are produced in a cathode ray tube, they slam into a metal plate, slow down and the energy given off when they slowdown are these high energy photons...x-rays.

"Burn it all."
In his will Röntgen requested that at his death all his papers, including his personal and scientific papers be destroyed, which they were. This seems like a highly irregular request for a scientist.

Maybe I have a suspicious mind, but the obvious first reason would be to hide any evidence that Puluyi was indeed the discoverer of X-rays. But Röntgen's character just doesn't lend itself to that conclusion. He gave the x-ray information away and never made a dime off of it. Then he gave the money from his Nobel prize away and was pretty much universally known as a very good man. So we are left to simply wonder.
It is interesting that Röntgen, much like Einstein and Edison several years after him, did not do well in the classroom environment. In fact, he was kicked out of the University after laughing at a caricature of a teacher (whom he disliked) which another student had drawn. Röntgen wouldn’t divulge the artist's identity and was expelled. He studied to privately pass exams in another college but his examiner turned out to be one of the teachers responsible for expelling him from the University.

Röntgen would later write, “Student examinations generally find no clues whatever for the judgment of ability in a special field. Plus they cause repeatedly bad dreams. The real test of ability in any chosen profession or occupation actually comes much later in life.”

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**Myth of the Isolated Genius**

A major advance in science almost never comes from a single person working alone, without contact with others. Einstein was not an isolated genius: he was in constant contact with many colleagues, often worked in collaboration with others and spent time discussing his thoughts with others.

Each discovery has had many men running very close in that particular race to be the first. An amazing parallel of identical research often happens simultaneously even if done hundreds of miles apart. Then, a critical mass develops and often within days or even hours or even simultaneously, the discovery is made and one man gets associated with the discovery because he had just one extra special something over the others, or happened to catch the attention of the popular media or maybe his letter got lost on the mailroom floor or his taxi hit every red light on the way to the patent office. This sort of research race happened with Röntgen and Thomson and Mendeleev and many other scientists.

The "isolated genius" is often working in a fevered race against scores of other "isolated geniuses" all to win the prize of being recognized as the new "isolated genius."

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**Did You Notice?**

In the film at 14:00:00 is a picture of Thomson in his office. The picture behind him has four photographs in it. One of them is a copy of Röntgen's first x-ray photo!
3. Radiation Rays

A. Henri Becquerel

Henri Becquerel thought uranium crystals were absorbing sunlight energy and reemitting it as x-rays. They weren't. Uranium is a special kind of rock that was emitting an entirely new kind of energy called "radiation."

B. Marie Curie

The Polish/French physicist who is best known for her untiring, pioneer work in radioactivity. Marie and her husband Pierre extracted the elements Polonium and Radium from tons of pitchblende ore. The total amount of radium they extracted was less than the weight of a housefly!

C. Radium Girls

Around 1920, several thousand female factory workers were hired by the United States Radium Corporation in New Jersey, to paint watch dials with glow-in-the-dark paint. Even though the company knew radium was dangerous, they told the women the paint was harmless. The women ingested deadly amounts of radium by licking their paintbrushes to sharpen them; some also painted their fingernails and skin with the glowing substance. Five of the women sued the corporation for damages, and won. Sort of.

Discussion Questions

- How easy is it to get swept away in fad and fashionable ideas of the day? Have you ever gotten swept up in any fad? How about your parents? Have you ever looked at their high school pictures?

- Who was your favorite person in section 4? Why?

- What reasons might Röntgen have had for wanting his notes and personal correspondence destroyed?

Becquerel Family

Henri Becquerel married Lucie, the daughter of a physics professor in Paris. Lucie died four years after giving birth to their son Jean. Twelve years later, Henri married his second wife Louise-Désirée.

Henri's son, Jean Becquerel, also became a physicist and was the fourth Becquerel to occupy the chair of physics at the Museum of Natural History.

Henri's grandfather, also a physicist, fought alongside Napoleon at the Battle of Waterloo in 1815.

$130,000 penalty for deliberate poisoning your workers.

Each of the five Radium Girls in the law suit was awarded $10,000 (the equivalent of about $130,000 in today's money) and $600 per year while they lived, plus the company paid all medical and legal expenses.

If the same lawsuit happened today, the five Radium Girls would OWN the United States Radium Corporation and maybe the state of New Jersey as well. Plus film rights.
Quiz Four - Lots of Mystery Rays

1. William Crookes is mostly known for
   a) His involvement with spiritualism
   b) Inventing television
   c) His work with cathode ray tubes
   d) Discovering the proton

2. J.J. Thomson is primarily known for
   a) Discovering the electron
   b) His work with spiritualism
   c) Inventing the cathode and anode
   d) Discovering x-rays

3. “Electron” is a Greek word that means
   a) Electric
   b) Amber
   c) Created
   d) Out from

4. Wilhelm Röntgen is primarily known for
   a) Inventing the Crookes tube
   b) Discovering x-rays
   c) Discovering the electron
   d) Discovering plum pudding

5. What tool convinced Thomson that electrons were negative particles?
   a) Curie's Electric Meter
   b) Photographic plates
   c) Magnets
   d) None of the above

6. Cathode ray tubes are a kind of discharge tube. What other tubes are similar?
   a) Neon lights
   b) Fluorescent lights
   c) Mercury vapor lights
   d) Old television tubes
   e) All of the above

7. Röntgen accidentally discovered x-rays while he was
   a) Experimenting with sodium
   b) Experimenting with cathode ray tubes
   c) Combining two different chemicals
   d) Playing scrabble with Anna

8. What kind of evidence exists that Puluyi discovered x-rays ahead of Röntgen?
   a) Existing x-rays
   b) Patented notes
   c) Eye witness accounts
   d) Unconfirmed reports

9. Becquerel accidentally discovered radiation while he was
   a) Experimenting with uranium
   b) Building a new battery
   c) Experimenting with new chemicals
   d) Experimenting with frogs

10. X-rays can be made when
    a) Sunlight hits uranium crystals
    b) High voltage batteries are charged
    c) Electrons suddenly slow down in a cathode ray tube
    d) X-rays can’t be made

11. J.J. Thomson invented the Plum Pudding model of the atom.
    a) True
    b) False

12. Marie and Pierre Curie discovered
    a) Uranium
    b) Plutonium
    c) Radium and polonium
    d) Radiation

Answers are on page 114
5. The Likeable Rutherford

Ernest Rutherford is one of the most likeable characters in the history of science. He was born in New Zealand and is the *Father of Nuclear Physics*. Rutherford proved that radioactivity is the transmuting of one element into another and figured out that there is a nucleus at the center of the atom.

1. Alpha & Beta Particles
   
   **A. Blocking the Particles**
   
   Rutherford found that blocking the particle coming from the uranium demonstrated that there was a very weak particle present. BUT...another electrically detectable particle was getting through—something stronger and more penetrating was there!

   **B. Naming the Particles**
   
   The heavy, weak particles he called *alpha particles*. The light penetrating particles called *beta particles*, sometimes called *beta rays*.

   **C. Explaining the Particles**
   
   Rutherford was finding the pieces and parts that made up the atom. What he was actually observing was the radioactive decay of uranium.

2. Nucleus Discovered

   Rutherford wanted to probe into the atom. The way to do this was to shoot atom particles at the atom and see how it reacted.

   **A. Ray gun in a Box**
   
   Rutherford needed something stronger than uranium. His friends, Marie and Pierre Curie provided something a MILLION times more radioactive than uranium...Radium. With it, Rutherford made the first particle ray gun.

   **B. Positive and Negative Particles**
   
   Rutherford fired the particles at magnets and discovered that Alpha particles were heavy, slow and positively charged particles. Beta particles were speedy, penetrating, very light and negatively charged particles.

   **They are all Electrons**

   - Crookes' Cathode Rays: ...electrons.
   - Thomson's particles: ...electrons.
   - Rutherford's Beta Particles: ...electrons.
3. The Gold Foil Experiment
Possibly one of the most famous experiments in the history of science is when Rutherford shot alpha particles from his ray gun at ultrathin gold foil. The resulting ricochets proved that there was a positively charge nut, or kernel, or nucleus in the center of the atom.

"How do we know atoms exist?"

Nobody has seen an atom. As a result, physicists have to base their understanding of atomic structure solely on experimentation and indirect observation.

**First** consider the alternative. If water is *not* made of molecules of hydrogen and oxygen, then what *is* the structure of water made of?

**Second** you can divide water into two gases, hydrogen and oxygen (as we saw in segment 3.) You can't divide hydrogen into anything smaller (without atom smashers) so what is the structure of hydrogen?

**Third** we found that hydrogen has both a positive and negative electrical charge. Plus, it is evident that the positive charge is at the center of hydrogen. In addition, we found you can actually strip the negative charge off of hydrogen. All this suggests what eventually developed into the modern model of the atom because it fits the data.

It is highly likely that atoms are not as we currently imagine them to be. But it is also highly likely that science is on the right trail and we are close. Three centuries of world-wide experiments on something that is, for all purposes completely invisible, has yielded a boat-load of evidence that atoms do indeed exist and are, in some fashion, the building blocks of the observable, physical universe.

**Discussion Questions**

- Why is Rutherford considered the Father of Nuclear Physics?
- How is Rutherford's model of the atom different than his friend J.J. Thomson's model?
- How is it different from John Dalton's model?
Quiz Five - The Likeable Rutherford

1. Rutherford was from
   a) England
   b) America
   c) Australia
   d) New Zealand

2. Rutherford is known as the Father of
   a) Chemistry
   b) Physics
   c) Nuclear Physics
   d) Stamp Collecting

3. Rutherford was the first person to actually see an atom.
   a) True
   b) False

4. The center of the atom is called
   a) The nucleus
   b) The neutron
   c) The proton
   d) The electron

5. Electrons are
   a) Positive particles
   b) Neutral particles
   c) Negative particles
   d) Solid particles

6. For an atom to be electrically neutral, there must be more protons than electrons.
   a) True
   b) False

7. Alpha particles
   a) Are heavy and negative particles
   b) Are heavy and positive particles
   c) Are light and negative particles

8. Beta particles are
   a) Heavy and negative particles
   b) Heavy and positive particles
   c) Light and negative particles

9. Protons are positively charged particles in the center of the nucleus.
   a) True
   b) False

10. In the gold foil experiment, alpha particles deflected or came straight back because
    a) The center is so hard
    b) The alpha particles are so weak.
    c) Alpha particles and the nucleus are both positively charged
    d) We aren’t sure why

11. Radiation itself tends to glow a soft blue light.
    a) True
    b) False

12. The most malleable metal is
    a) Lead
    b) Aluminum
    c) Tin
    d) Gold

Answers are on page 114
6. The Periodic Table at Last!

1. What is radiation?
   
   A. Rocks Degenerating
   
   It was Rutherford and his assistant, Frederick Soddy, who figured out why uranium and thorium and other rocks were radiating. They said these rocks were decaying or transmuting from bigger elements into smaller elements.

   **Dating Rock by Decay**
   
   By calculating the amount of time the decay took place and how much of each element is in the rock, you can assign an age to the rock. You can assign an accurate age to the rock only if you know three things:

   - how much of each element was in the rock to begin with.
   - you are fairly certain nothing other than radioactive decay has altered the amount of each element in the rock.
   - you are fairly sure the rate of change has been constant.

   Given those things, you can accurately date the rock.

   **As an Example**
   
   You can determine how far a car has traveled by knowing that this car has a 20 gallon tank and gets 20 miles per gallon and there's 10 gallons left. With ten gallons left that must mean it has used ten gallons and at twenty miles per gallon the car has traveled 200 miles. This is true only if:

   - you know it started out with a full tank to begin with. (If there were only ten gallons to start with the car hasn't even gone one mile.)
   - They never stopped at a gas station adding more gas and there are no fuel leaks subtracting gas.
   - you know the miles per gallon never varies.

   Given those things, you can accurately determine how far the car has traveled.
B. Fruitful Analogy
The case of decaying fruit with big watermelons (uranium) → decaying into smaller cantaloupes (thorium) → decaying into grapefruit (polonium) → and finally settling into a stable orange (lead) or apple (bismuth).

C. Half-Life
Half-life is a measure of time, like minute or second. It's the amount of time that must pass before the element decays into something else.  

Accelerated Decay or Constant Decay?
As we observe half-life rates today, they seem pretty constant. This results in apparent ages of millions and billions of years for some rock samples. A scientific research group called RATE (Radioisotopes and the Age of The Earth) was formed by the Institute for Creation Research and the Creation Research Society to study this issue.

They determined that the half-lives of all naturally radioactive elements may not have always been constant but have been accelerated in the past. Therefore, the assumption of unchanging decay rates may be inaccurate.

2. Henry Moseley
A. Atomic Number
Moseley gave us a measureable reason to build the periodic table the way we do. Prior to Moseley, the periodic table was based on atomic mass or weight. Moseley proved that the proton number or atomic number increases by exactly one as each element is added. Thus, it is the electrically positive charge that changes the element which is a more accurate method of arranging the table than by atomic mass alone.

This was the key allowing the arrangement of the table as we have it today.

B. Spectroscopy
The elements have natural fingerprints or identifiers that are unique to each element. Atomic weight is one of those identifiers. Electron configuration is another and so are density and melting points. They also have unique fingerprints when light or x-rays interact with them. Moseley studied their x-ray fingerprints.

Discussion Questions
- Why do most active elements eventually decay into lead and bismuth?
- What difference does it make if decay rates are constant or accelerated?

3 http://creationwiki.org/Accelerated_decay
Quiz Six - The Periodic Table at Last!

1. Rutherford discovered that radioactive decay is one element decaying into another.
   a) True
   b) False

2. Most elements on the periodic table aren't radiation active.
   a) True
   b) False

3. Current radioactive decay rates can take
   a) Seconds
   b) Fractions of a second
   c) Millions of years
   d) A few days
   e) All of the above

4. Uranium eventually decays into
   a) Gold
   b) Lead
   c) Hydrogen
   d) Californium

5. Henry Moseley is best known for
   a) Assisting Ernest Rutherford
   b) Discovering x-rays
   c) Showing how the radioactive decay chain operates
   d) Getting killed in World War I
   e) Giving a definitive reason for arranging the periodic table by atomic number, not atomic weight.

6. Spectroscopy means
   a) Looking with light
   b) Examine the spectrum
   c) Working with light
   d) Physics of color

7. Every element gives off identical spectroscope fingerprints
   a) True
   b) False

8. As the x-ray spectroscope lines increase by one, so also
   a) The atom weight increases by one
   b) The positive charge in the atom increases by one
   c) The color of the atom changes
   d) The number of electrons increase

9. Scientists found many new elements using spectroscopy.
   a) True
   b) False

10. Put the following in chronological order:
    a) Ernest Rutherford
    b) Tubal-Cain
    c) Robert Boyle
    d) Dmitri Mendeleev
    e) Wilhelm Röntgen

11. Dating some rocks as millions of years old depends on unchanging decay rates.
    a) True
    b) False

12. The Bible indicates the universe is only thousands of years old.
    a) True
    b) False

Answers are on page 114
7. The Periodic Table - Main Group

The main group elements are much like a box of crayons. When you put the basic eight colors in order and repeat those colors, the families with similarities line up in columns. The main group elements do the same thing. The main group is also called "Group A" or "The Representative Group" but not very often.

1. The Four Outer Columns

   Hydrogen and Helium

Hydrogen just wants to defy being categorized (remind you of anyone in your life?). The doomed airship Hindenburg was filled with hydrogen gas. Helium is a bit more conciliatory, able to sort of blend in with the Noble Gases without making a fuss.

A. Alkali Metals

The Ferocious Metals. They immediately want to react with other elements, and substances, especially water. They are all soft, shiny and need to be submerged in oil or kerosene or argon gas. They are called alkali because when added to water, they react and form bases or alkalies which neutralize acids.

B. Alkaline Earth Metals

The more down-to-earth family, but still pretty reactive. They have a much higher melting temperature and are a bit more stable. They are called Earth Metals as the old alchemists saw that dirt ("earth essence") didn't melt easily. Thus if a metal didn't melt easily it obviously had lots of the earth essence in it. They are alkaline because they will also form bases or alkalies which neutralize acids.

C. Noble Gases

Here is the nobility of the periodic table-quiet and reserved. They don't readily combine with any other element, though some can be coaxed to join with enough persuasion-except helium and neon. They won't join anybody for any reason.

D. The Halogens

An remarkable periodic table family. Halogens are the only family with gases, solids and liquids in them at room temperature. They tend to be pretty reactive and some, like chlorine, are poisonous. Halogen means salt producing as they often make salty crystals when combined with other elements...like table salt.
2. Element Abbreviations

Most of the elements have abbreviations that are pretty intuitive. Neon is Ne and Argon is Ar. But there are eleven weird ones:

1) **Copper** is Cu from the Latin word for the Island of Cyprus, *Kypros* or *Cuprum*, where copper was mined in the past.

2) **Silver** is Ag for the Latin word *Argentum* meaning shiny white. Argentina was named after this word as they thought there was silver there.

3) **Mercury** is Hg from *Hydrargyrum* meaning watery silver. Hydra-Argentum...Silver that runs.

4) **Gold** is Au for the Latin word meaning the golden color of dawn, *Aurum*.

5) **Iron** is Fe from *Ferrum* the Latin word for Iron and where we get the word Ferrier...to show horses with iron.

6) **Lead** is Pb from *Plumbum* the Latin word for lead. Plumber comes from this word.

7) **Potassium** comes from the word *potash* and the Latin for plant ash is *Kaliunum* which is why Potassium gets the totally weird letter K.

8) **Sodium** is Na from *Natrium* or *Natrum* the Latin word for soda. Soda is that white salty mineral on the edges of dry lake beds.

9) **Tin** is Sn because early miners called the metal *Stean* which became the Latin word *stannum*. Nobody knows what Tin means.

10) **Tungsten** is W which is really weird except that many Europeans refer to this element as Wolfram....because extracting tungsten consumed lots of tin and produced a white foam...like a wolf's mouth while eating its prey.

11) **Antimony** is Sb for *Stibium*, as the black form of antimony makes a black mark. Stibium means 'a mark.'
3. The Stair-step Metals

Almost nobody calls these the "stair step" metals but I thought it was memorable. It refers to the line that roughly divided the non-metals from the poor metals. It is sometimes called "The Aluminum Staircase" since the top of the stair rests on aluminum.

A. The Poor Metals

"Poor Metal" is the trivial name for these metals. Technically, they are the metals of the "P" block of elements. (Look at page 32 for where the "P" block is.) They are poor in that they are softer, with lower melting points and often fragmentable in comparison to the other metals. There are ten commonly recognized poor metals: Aluminum, Gallium, Germanium, Indium, Tin, Antimony, Thallium, Lead and Bismuth and sometimes Polonium. The advantage of counting Polonium is that it makes your stair step metals into a neat 4x5 grid.

B. The Non-metals

Yep, not metals. It's kind of odd that all the non-metal elements congregate up in this top triangle. The Noble gases and Halogens are also not metals but are distinctive enough to earn their own categories. The ten commonly accepted non-metals are Boron, Carbon, Nitrogen, Oxygen, Silicon, Phosphorus, Sulfur, Arsenic, Selenium and Tellurium. All total, there are eighteen elements that are not metals but they make up:

- 85% of our Earth's crust
- 99% of the atmosphere
- 99% of the oceans.
- 98% of all living organisms

C. The Metalloids

Means "sort of like metal" just like android means "sort of human." This is like a sub-group as it takes elements from both non-metals and poor metals... the middle of the aluminum staircase. These famous elements have unique properties of being better conductors than non-metals but not as good as poor metals-sort of a metal. The commonly accepted metalloids are Boron, Silicon, Germanium, Arsenic, Antimony, Tellurium and Polonium. (See "Poorest Poor Metal" sidebar.) Silicon is a semiconductor, used to make computer chips.

Discussion Questions

- Why do they put a noble gas in household light bulbs?
- Why are the 2nd column elements called alkaline earth metals?
- If there was another civilization in a different galaxy, do you think their Periodic Table of the Elements would look like ours?
Quiz Seven - Periodic Table/Main Group

1. Which is not one of the four outer columns?
   a) Alkali Metals
   b) Transition Metals
   c) Alkaline Earth Metals
   d) Noble Gases
   e) The Halogens

2. Why is the Main Group sometimes called the Representative Group?
   a) It isn't.
   b) Because it best represents the periodic nature of the table
   c) Because it represents the best elements on the table
   d) Because it represents the most stable elements on the table

3. Hydrogen is usually listed with the Alkaline Earth Metals.
   a) True
   b) False

4. Why is one family called "The Halogens"?
   a) They are used in halogen lights
   b) They produce halo-like effects
   c) They produce salts
   d) They bond easily with other elements

5. The abbreviation for gold is
   a) Gd
   b) Ag
   c) Hg
   d) Au

6. Stair step metals are made of non-metals and the poor metals.
   a) True
   b) False

7. Poor metals are called this because
   a) They have little commercial value
   b) They are easily accessed by even poor people
   c) They aren't as strong as most of the other metals
   d) None of the above.

8. The Metalloids are found within the Alkali Metals.
   a) True
   b) False

9. The abbreviation for sodium is
   a) Sa
   b) Sd
   c) Na
   d) Ns

10. Alkali Metals are stored in
    a) Mineral oil.
    b) Kerosene
    c) Argon gas
    d) Any of the above

11. Alkaline Earth Metals have a much higher melting temperature than the Alkali Metals.
    a) True
    b) False
    c) Depends on the metal

Answers are on page 114
8. The Periodic Table - Quantum Mechanics

You would think that this segment would be called something like "The Periodic Table - Transition Metals" instead of "Quantum Mechanics." But we wanted to establish the ideas that caused the transition metals and the other elements to be placed where they are. And it's because of how we view the world of the atom that the arrangement of the table looks like it does today.

1. Transition Bridge

The transition elements form a transitioning bridge between the two sides of the Main Group. It was ideas in quantum mechanics that ultimately caused this split.

2. Classical & Quantum Mechanics

There are two main divisions in the world of physics that describe how physical things work and the forces that make them work.

A. Classical Mechanics

Classical Mechanics are also known as "Newtonian Mechanics" after Isaac Newton who developed most of the concepts. These mechanics describe the motion and forces of bigger things: billiard balls, bowling balls, machines and planets. Things we deal with on a daily basis and that move slower than the speed of light.

B. Quantum Mechanics

Quantum Mechanics are sometimes called "Einsteinian Mechanics." When objects become really small, the rules change. It becomes necessary to introduce a new set of rules that describe the world of the atom and the molecule...things we don't ever directly interact with and that travel very close to or at the speed of light.

Light and matter come in distinct packages-quantities. Light also behaves like a particles and a wave-supposedly both are right. Plus part of the theory says everything in the universe is connected and one end knows what's happening with the other end and can affect it...instantly.

Max Planck is the Father of Quantum Mechanics.

Max Planck Quotes on God

"Anybody who has been seriously engaged in scientific work of any kind realizes that over the entrance to the gates of the temple of science are written the words: "Ye must have faith." It is a quality which the scientist cannot dispense with."

"Both Religion and science require a belief in God. For believers, God is in the beginning, and for physicists He is at the end of all considerations… To the former He is the foundation, to the latter, the crown of the edifice of every generalized world view."
C. The Invisible Atom

Atoms aren't really invisible, you just can't see them...with anything...which is sort of the definition of invisible. Hmmm. Actually one of the main problems is they are so absurdly small that light waves pass right over them.

3. Why We Needed Quantum Mechanics

Rutherford proposed that electrons fly around the nucleus like planets around the sun. The problem: positive and negative particles attract each other...just like magnets. The negative electrons should spin immediately into the positive nucleus and destroy everything. But they don't. Was Rutherford wrong?

Max Planck and Neils Bohr rescued Rutherford by coming up with a new set of mechanical rules...quantity rules. Quantity Mechanics said that the electrons are locked in specific, defined energy levels. They can't wander around wherever they want. They must suddenly jump up or down in these energy levels. There is no "in-between" world in Quantum Mechanics.

In the film, we used the analogy of a light switch. Classical Mechanics is like a dimmer switch. Quantum Mechanics is like a 3-way switch.

Another analogy. When riding your Classical Bicycle around town you continuously ride from street to street. But riding your Quantum Bicycle, you can only ride up and down one street. When you want to ride on another street, you and your Quantum Bicycle suddenly disappear from one street and reappear on another street.

The modern model does not have them locked in orbits like planets, but rather locked in specific "energy levels" or "energy shells" where they must be acted upon in order to gain or lose energy.

4. "Empty" Space

We think matter is continuously solid stuff, front to back. But the evidence from the atom says that is not the case. In size, the nucleus is like a grain of sand in the middle of a football field with the electrons clouding around it. In between the electrons and the nucleus is an electric field. Everything is the universe is separated or held together by electric/magnetic fields. The world has an appearance of being solid, when in actuality, it is mostly empty space filled with electricity.

"Toto, I have the feeling we're not in Kansas anymore."
5. Quantum & The Periodic Table

The main place where quantum mechanics impacts the periodic table is where the electrons are placed in an atom—also known as electron configurations. Each of the seven rows on the periodic table represent a new and higher energy level.

- **The Main Group**
  Electrons in the main group are added to the outer energy level shell. Thus, each column represent how many valence electrons are in the outer shell of the atom. In the main group you can count one through eight and know exactly how many bonding electrons are in the outer shell.

- **The Transition Metals**
  The transition metals don't add new electrons to the outer shell. They generally stop with two outer shell electrons and squirrel the new electrons in the second to last energy level shell. That's why the Transition Metals form the transitioning bridge between column 2 on the left and column 3 on the right. This means their valence shells are the last two shells, not just the last shell.

- **The Rare Earth Metals**
  The same applies to the Rare Earth Metals. They don't add new electrons to the outer shell either. They stop with two outer shell electrons and squirrel the new electrons in the third to last energy level shell. That's why the Rare Earth Metals form another bridge between column 2 on the left and the Transition Metals on the right. *(You only see this on extended versions of the Periodic Table. Most periodic tables move the Rare Earths and Radioactives at the bottom of the table).*
6. Today's Periodic Table

The modern periodic table looks like it does based on three ideas:

a. Protons - (atomic number)

The atomic number is the number of positive protons in the nucleus. Add a single positive charge and you add a new element. If this was the only rule, the Periodic Table would be one continuous line of 118 elements.

b. Electrons - (noble gas rule)

There are a number of very light, negatively charged electrons clouding around the nucleus equal in number to the protons. It is the electrons in the outermost orbit that largely determines the chemical behavior of the element. Those with the same number in the outer shell tend to behave similarly. No outer shell will hold more than eight electrons, and this explains why there are periodic repetitions of similar chemical properties and behaviors in the periodic groups and families.

c. Valence Shell

The first two rules produce the modern periodic table. But the table also helps show which shell the new electrons are going to. The main group electrons go into the last shell, transition metals the second to last shell and lanthanoid and actinoids go to the third to last shell.
7. Blocks

You will notice in this periodic table there are the letters s, p, d and f. We did not cover this in the film as it is a bit complex, but we'll mention it here. As you get more involved with electron configurations, you'll see that chemists refers to these section by these letters. Electrons get added to the shells in a very specific pattern and chemistry has a code that shows this pattern. For example the electron configuration code for Hydrogen is 1s\(^1\). This means the first row, the s block and there is one electron there. Lithium's configuration is 2s\(^1\). Second row, s block and there's one electron in the outer shell. Carbon is 1s\(^2\), 2s\(^2\), 2p\(^2\). In the first row the s block is full with two electrons. Then the second row s block has two electrons then it goes to the p block with two electrons in the outer shell.

This is only to introduce you to this concept of electron configuration code or address. If you study it a bit, you'll get the idea and it won't seem nearly so complex.

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Discussion Questions

- If it's too small to see, is it really 'invisible'? What is the definition of 'invisible'?

- Why do you think quantum mechanics is so difficult to understand and Newtonian mechanics seems so much easier?
Quiz Eight - Periodic Table/ Quantum Mechanics

1. Quantum means
   a) Quality
   b) Quarter
   c) Query
   d) Quantity

2. The transition bridge forms a link between the split sides of the Main Group.
   a) True
   b) False

3. Quantum Mechanics is also known as Newtonian Mechanics.
   a) True
   b) False

4. Who is the father of quantum mechanics?
   a) Max Planck
   b) Albert Einstein
   c) Ernest Rutherford

5. Why was quantum mechanics invented?
   a) To make the periodic table
   b) To explain why protons are positively charged.
   c) To explain the behavior of the tiny world of the atom.
   d) To explain why noble gases are unreactive.

6. The octet rule is
   a) The rule of music octaves.
   b) The rule that eight protons are in the nucleus.
   c) The rule that no outer shell holds more than eight electrons.
   d) None of the above

7. Transition metals usually add electrons to which shell?
   a) Last shell
   b) 2nd to last shell
   c) 3rd to last shell

8. Rare Earth Elements add their electrons to which shell?
   a) Last shell
   b) 2nd to last shell
   c) 3rd to last shell

9. Noble gases add their electrons to which shell?
   a) Last shell
   b) 2nd to last shell
   c) 3rd to last shell

Answers are on page 114
9. Neutrons, Isotopes & Ions

There are only about 90 stable elements on the periodic table. But subtle differences in each atom and the usability of many radioactive elements increase the number of useful forms of the elements to about 400.

1. Neutrons
   A. The nucleus is clearly heavier than the sum of the protons inside. This observation led scientists to an ingenious conclusion. Something else was in the nucleus that was heavier than a proton but with no electrical charge—it was neutral. Thus they called it a neutron.

   B. The neutron is responsible for the added weight in the atomic mass. Helium has a proton count of two and a mass of four. Two protons and two neutrons. Neutrons also exert a strong force helping to overcome the positive repulsion of the protons that keeps the nucleus together.

   C. James Chadwick received the Nobel Prize in physics for this discovery. He also endured many sleepless nights.

2. Isotopes
   A. You can't mess with the positive charge in an element and still have the same element. But you can change the number of neutrons inside without disturbing the positive electrical charge.

   B. If you add neutrons to an atom, the atom gets heavier and that changes it into a slightly different version of that element. Same place on the periodic table but slightly different. It's called an isotope meaning equal place.

   C. This discovery was the third most important impact on the periodic table. It demonstrated that there were varieties of the same element stacked behind each of the elements in the periodic table.
D. The other number for each element on the periodic table is called the atomic mass. This is the weight of the atom and is calculated by averaging all the weights (masses) of the isotopes plus their relative abundance in the universe. As an easy example, carbon has three stable isotopes 12, 13 and 14. Average it together and you get $12+13+14=39$ divided by 3 is and average atomic mass of 13. But that's incorrect because there aren't equal quantities of 12, 13 and 14 in nature. In any given carbon there's about 99% of 12 and less than 1% of 13 and only a tiny, tiny bit of 14. So now if you average out the 12, 13 and 14 including the amount in any sample, you come up with a new average mass of 12 because there's so much 12 out there.

3. Ions
A. The other part of an atom you can mess with is the number of electrons. If you do it becomes an ionized. Ion means to go since electrically charged atoms can be made to go places, especially with magnets. You can ionize a comb and affect a small stream of water as shown in the film.

B. Subtract an electron and the positive charge in the nucleus become the dominant charge. A positively charged ion...a cation.

C. Add an electron and the negative electrons are greater in the atom and it becomes a negatively charged ion...an anion.

Mass vs Weight
Mass is the amount of stuff, the amount of matter in something. As long as you don't add to it or subtract from it, the mass is always the same.

Weight is a measurement of the pull of gravity on that stuff. If the pull of gravity changes, so does the weight...but the mass remains the same.

Apollo 15 astronauts took a 3 pound hammer to the moon to do work and conduct a demonstration. The mass of the hammer never changed but on the moon the hammer only weighed half a pound.

The Grand K
The International Prototype Kilogram, or The Grand K is a bar of 90% platinum and 10% iridium that is the standard for a kilogram. It weighs exactly 1 kilogram by definition. It also weighs less by about 1 grain of sand than when it was manufactured in 1880.

Everything weighed in the world is ultimately weighed against this piece of metal that is slowly getting lighter and lighter. The General Conference on Weights and Measures is very close to finding a replacement for the Grand K.

Discussion Questions
- Why was the neutron key in developing a nuclear chain reaction?
- What is the problem with the Grand K getting lighter?
- Why would there be a limit to the number of stable elements?

* No Big Deal
**Quiz Nine - Neutrons, Isotopes & Ions**

1. There are about 90 stable isotopes in the periodic table.
   a) True  
b) False

2. If an isotope is unstable, that means it is radioactive.
   a) True  
b) False

3. Neutrons were discovered by
   a) Albert Einstein  
b) Ernest Rutherford  
c) James Chadwick  
d) Henry Moseley

4. It was this discovery that made nuclear chain reactions possible.
   a) Protons  
b) Isotopes  
c) Neutrons  
d) Ions

5. Isotope means
   a) Equal place  
b) Equal size  
c) To go  
d) Neutral

6. An isotope is an element with
   a) The same electrons but different number of protons  
b) The same protons but different number of electrons  
c) The same protons but different number of neutrons  
d) None of the above

7. The "average atomic mass" takes into consideration the abundance of each isotope in nature.
   a) True  
b) False

8. Mass and Weight are the same thing.
   a) True  
b) False

9. Ions are atoms
   a) In the equal place in the periodic table.  
b) With no electric charge  
c) With an electrical charge

10. Atoms with one less electron are
    a) Cations  
b) Anions  
c) O'brians  
d) Samoans

   **Answers are on page 115**
10. Compounds & Molecules/pt 1

Although there are about 90 stable elements, we currently have maybe 400 isotopes that we can make things with. And IUPAC may have listed its 50 millionth chemical compound, only about 1/5 of these are really used in industry on a regular bases. Still, that's 10-15 million substances that exist just because the original handful of isotopes can make compounds and molecules.

1. Definitions

A. Element

We know what an element is. It's on the periodic table. You can also include the element isotopes in the equal place hiding behind the primary element (which of course is merely the representative of that atom...isotopes all containing the same number of protons).

B. Compound

This is two or more different elements that are chemically compounded together—not just mixed together. Mix sodium & chlorine and you get a bottle with sodium metal and chlorine gas...nothing happens. The sodium just sits in a cloud of chlorine. But add a drop of water on the sodium and you get a flaming reaction with lots of heat. The result is tiny crystals of salt in the glass...a compound. Ionic bonds form compounds.

C. Molecule

Molecule is French for a tiny piece. The word is often used for any combination of any two or more elements electrically bonded together. But technically, it only refers to atoms electrically joined through covalent bonding...not ionic bonding. Nonmetals form molecules.

D. Mixture

A mixture blends two substances together with no chemical bonding. Sand is a mixture of small bits of quartz and other minerals. Milk comes out of the cow as a heterogeneous mixture (inconsistent throughout). Milk processors remove some of the components, like cream, to make butter and other milk products. Then they homogenize the rest so that when you buy it from the store, it is homogeneous (uniform throughout).

E. Solution

Mixtures that are completely uniform throughout are also called solutions or homogeneous mixtures. Lemonade is a mixture but a solution mixture. Ketchup looks like a solution but it isn't completely uniform as the tomato solids aren't uniformly distributed. A solution is "when one material completely dissolves in a liquid" but with no chemical alterations.
2. Bonding
A. Covalent Bonding
Covalent bonding means *sharing valence*. These kind of bonds happen between the non-metals and form molecules. The vast majority of bonds are covalent bonds because the vast majority of the universe is made up of hydrogen, helium, oxygen, carbon and other non-metals.

- **Water Example**

Hydrogen has one valence electron since it is in column one and wants one more to fill the first shell with two electrons. Oxygen is in column six and wants two more to make the noble eight. By sharing their electron clouds they are able to fill their shells and be content as water molecules.

B. Ionic Bonding
Bonding between metals and non-metals is called *ionic bonding*, because they don't share...they actually hand over an electron and take an electron. This ionizes the atoms. Now you've got a positively charged cation and a negatively charged anion...these attract and bond. Ionic bonds tend to be stronger than covalent bonds.

- **Salt Example**

Sodium in column one has one outer valence electron which it easily gives away. Chlorine in column seven really wants one more electron to make a noble eight electrons. Sodium willingly hands over it's single valence electron which ionizes the sodium atom- a positive cation. Chlorine accepts the extra electron becoming a negative anion. Now they behave like two magnets and powerfully bond together forming Sodium chloride. All salts are formed with ionic compounds.

C. Metallic Bonding
Metal to metal bonds happen a bit differently as the electrons loosen and form "a sea of electrons." The nuclei float in the sea, sort of like chocolate chips in a chocolate chip cookie.

3. Lewis Dot Diagrams
Invented by Gilbert Lewis to give an easy way to illustrate the bonding between the atoms of covalent molecules. Here's how a water molecule looks:

\[
\begin{array}{c}
\cdot \\
H & O & H \\
\cdot \\
\end{array}
\]

The lines represent the bonds. The two dots are lone pairs on the oxygen atom.
4. **Modeling Molecules**

Based on simple laws of magnetic attraction, chemists make models of how the molecules probably look and how they relate to each other.

**A. VSEPR**

Valence Shell Electron Pair Repulsion. Electrons are attracted to the central atom since opposite charges attract. But they are repulsed from each other because of their like charged electrons. As a result, they form at the farthest angle possible to stay away from each other.

**B. 3-D Models**

There are hundreds of different modeling techniques to show bonding in molecules and compounds. The ball and stick models are probably the most famous and widely used.

- **Covalent Bonds**

  The ball and stick shows the atom and the stick illustrates the "sharing bond" between them.

- **Ionic Bonds**

  These are usually illustrated as a tightly grouped lattice network to show the electrically tight ionic bond.

---

**Discussion Questions**

- Read the sidebar on Lincoln's Water. Is it difficult to believe that every glass of water you drink has some of Lincoln's water molecules in it? Why?

- What is the difference between an element and a compound. Can you give examples?

- Describe the process by which two or more elements combine to form a compound.
Quiz Ten - Compounds & Molecules/pt 1

1. There are millions of elements.
   a) True
   b) False

2. A compound is two or more elements chemically bonded.
   a) True
   b) False

3. Lewis Dot Diagrams were invented by
   a) Albert Einstein
   b) Jerry Lewis
   c) Gilbert Lewis
   d) Gilbert & Sullivan

4. Molecules are formed through ionic bonding.
   a) True
   b) False

5. Molecule means tiny piece
   a) True
   b) False

6. A homogeneous mixture is the same throughout the mixture and is called a solution.
   a) True
   b) False

7. When atoms share electrons this is called
   a) Metallic bonding
   b) Covalent bonding
   c) Ionic bonding

8. An atom that gains an electron will have
   a) A negative charge
   b) A positive charge
   c) A neutral charge

9. A positively charged atom is called
   a) A cation.
   b) An anion
   c) An isotope

10. An example of ionic bonding will occur between
    a) Hydrogen + oxygen
    b) Hydrogen + sulfur
    c) Sodium + chlorine
    d) Magnesium + magnesium

Answers are on page 115
11. Compounds & Molecules/pt 2

1. Allotropes

Allotropes are very similar to Isotopes because they are the same element only different. Isotopes mean *equal place* because they are in the same place in the periodic table. Allotropes are in the equal place too but...they are in a different shape. And that's what *allotrope* means... *different shape*.

**Carbon Example**

Carbon is the best known element for allotropes as it has the most, eight. Here are the famous allotropes of carbon.

- **Graphite**
  It means *to draw* because you can do that with graphite. Graphite carbon looks like thin sheets which makes it brittle but strong, easy to flake and heat resistant.

- **Diamond**
  Diamond allotropes are locked together in a tight network making them the hardest substance known. You can't scratch a diamond unless you use another diamond.

- **Amorphous**
  Soot and coal. Amorphous means *no shape* or *shapeless* because it lacks the nice crystal shape of other solids.

- **Fullerenes**
  Fullerenes are a bit hard to understand because we really don't have anything in our daily experience to relate to it. A fullerene is made of carbon but in the shape of a hollow ball or a tube. Yeah, and...? Well...they are atom-size particles that can uniquely carry electricity and nanosized medicines, possibly revolutionizing how we deliver electricity and fight diseases. So in the future, they may prove to be *really useful*...or *really dangerous*. But right now they are pretty much in the research phase.

---

**Diamonds Are Forever**

One company in the world dominates the entire diamond market, the De Beers Company.

In 1947 De Beers hired the N.W. Ayer & Sons advertising agency to come up with an ad to help slouching diamond sales. They came up with "A Diamond is Forever."

60 years later, *Advertising Age* magazine determined that their ad was the most successful advertising slogan of the 20th century:

Diamonds are a plentiful and relatively inexpensive mineral. De Beers stores the diamonds from their mining operations to keep the supply fairly low and prices fairly high.

The song *Diamonds are a Girl's Best Friend* was written in 1949 for a popular Broadway musical and greatly helped the connection of diamonds to romance.

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The song *Diamonds are a Girl's Best Friend* was written in 1949 for a popular Broadway musical and greatly helped the connection of diamonds to romance.
2. Naming Compounds

There are millions of compounds out there and naming them all can be a chemistry nightmare. Fortunately some rules were developed to make it easier but some of the technicalities bring tears to chemistry students every year. We'll skip those parts.

A. Nomenclature

One of the few times where name calling is okay! In Rome, it was tough for a Senator to do all his duties and remember everyone's name too. So he had a slave whose main job was to recall the names of people his master met during important political campaigns. He was the name caller...the nomenclator.

B. Element

It is easy to name an element. Just read it off the periodic table. Done!

C. Covalent Compounds

With simple covalent compounds it’s pretty easy. Whichever element is first on the table gets first billing and a capital letter-Hydrogen. The second element in the compound gets a small first letter AND ide stuck on the end. Oxygen becomes oxide which means belonging to oxygen. Sodium chloride. Gallium arsenide.

- **Chemical Abbreviation**
  Gallium (Ga) and Arsenic (As)= GaAs

- **Chemical Numbers**
  With more than one atom in the same molecule, you use the Greek prefixes for numbers: Mono, di, tri, tetra, penta, hex, hepta, octa, nona and deca-only nona is Latin. Sulfur dioxide / Carbon monoxide / Sulfur hexafluoride

D. Ionic Compounds

One easy rule is that with a two-word name, the cation is named first then the anion, like Sodium chloride. If there is a transition metal involved, you need to know stuff like the charge of the element and if it needs a Roman numeral in the name. It can get a little complex with ionic compounds.

E. Everyday names

Some compounds are so common they have developed trivial or everyday or non-scientific names. Ammonia, salt, baking soda, caffeine, ozone and water.
3. Minerals

The parlor game 20 Questions always starts with, "Is it an animal, vegetable or mineral?" That's because in some ways, the definition for a mineral is so broad that almost everything seems to be a mineral. Here's what qualifies you to be a mineral:

- **solid** (not a gas or liquid)
- **natural** (not made in a laboratory)
- **not alive** (not organic... from plant or animal)
- **predicable composition** (usually crystal structure)

There's about 4,000 minerals in the world. Almost all of them are so rare you never hear of them. About 100 are common. Only a few minerals are so unique that they are classified as gems or precious stones.

Special Discussion Question Segment

**THE MINERAL QUIZ!**

Based on what you know about minerals, which of the following do you think is a mineral?

Answers are at the bottom.

1. quartz 2. granite 3. gold 4. amber 5. charcoal 6. hematite 7. plastic 8. iceberg
Quiz Eleven - Compounds & Molecules/pt 2

1. Allotropes are different shapes of the same element.
   a) True
   b) False

2. Graphite is an allotrope of coal.
   a) True
   b) False

3. Amorphous means
   a) Another kind
   b) Crystal shape
   c) Shapeless
   d) Not brittle

4. Chemical nomenclature is
   a) Naming compounds
   b) Counting atoms in a compound
   c) Weighing compounds

5. Copper sulfide is
   a) CuS
   b) Cs
   c) CuSa
   d) CpSu

6. Diamonds are a mineral.
   a) True
   b) False

7. Element 47 is
   a) Silva
   b) Gold
   c) Platinum
   d) Silver

8. Ice is a mineral
   a) True
   b) False

9. A mineral is
   a) Not living
   b) Natural
   c) Usually crystal structured
   d) Solid
   e) All of the above

10. Dihydrogen monoxide is
    a) Chlorine
    b) Ozone
    c) Sodium bicarbonate
    d) Water

Answers are on page 115
12. Balancing Equations

The purpose of balancing equations is to ensure repeatability. If you hit on something big and want to repeat it, you better be sure you know exactly how much stuff you put in and how much stuff you get out. Same thing with a good recipe. You can be a cook who puts stuff together and makes it taste great. But if you want to exactly repeat and pass down the formula, you need to measure what goes in and how much comes out.

1. Stoichiometry - Cooking & Chemistry

It was Jeremias Richter that named the art of measuring elements. It's a goofy sounding name but if you say "element measuring" in Greek, you say stoichiometry.

A. Law of Definite Proportions

This law was discovered by Joseph Proust. Proust's law assures you that a water molecule is always two hydrogen's to one oxygen. It measures in the same proportions. If it's different or if it changes, then it's not a water molecule.

B. Law of Conservation of Matter

What goes in the oven comes out of the oven. You don't mix enough for a dozen cookies then only get two cookies out of the deal. Matter doesn't magically appear and disappear. Likewise, Lavoisier proved that the atoms you start with in a reaction will exactly balance the atoms you end up with. You can't create or destroy matter. (However Einstein did show that matter can be changed into energy and vice versa...but that's physics.)

2. Analyzing a Molecule

You see these molecular formulas all the time...like H₂O₂ which is hydrogen peroxide. How can you know that's exactly what makes up a substance. How did they know it's made of two hydrogen atoms and two oxygen atom? How do they accomplish what is called elemental analysis?

A. Glass & Fire - How Dalton did it

Based on the two laws mentioned above, John Dalton determined that what happened on the big scale, was also happening on the small scale. When he did Solve et Coagula, he would heat and separate a known amount of a substance into the component elements, then weigh the components in his glass vessels. If he got a ration of 16 to 1, he could add this to a list of how all these substances weighted and combined in relation to one another. Do a few thousand of these and you start seeing patterns of how nature combines various substances.
B. Mass Spectrometers - How We do it

Another way to do elemental analysis it is build a big shiny machine that does the *Solve et Coagula* for you. It burns a sample and sends the gases through a computerized analyzer. As the ionized atoms are shot down a curved tube. As they curve around a bend, their weight makes them hit a detector in a very predictable place. Get a computer to count the hits and you know what atom or molecule is in the substance.

---

**Chemistry 101 Chocolate Chip Cookies**

- 1 cup butter, softened
- ½ cup white sugar
- 1½ cup packed brown sugar
- 2 eggs
- 2 teaspoons vanilla extract
- 3 cups all-purpose flour
- 1 teaspoon cream of tartar
- 1 teaspoon baking soda
- 2 teaspoons hot water
- ½ teaspoon salt
- 2 cups semisweet chocolate chips
- 1 cup chopped walnuts

Preheat oven to 325º F.
Cream together the butter, white sugar, and brown sugar until smooth. Beat in the eggs one at a time, then stir in the vanilla. Dissolve baking soda in hot water. Add to batter along with salt. Stir in flour, chocolate chips, and nuts. Drop large spoonfuls of dough onto ungreased pans or pass spoons out and dig in! Bake for about 10 minutes in the preheated oven, or until edges are nicely browned.

---

**The Size of an Atom**

- One atom is to an apple as an apple is to the entire planet.
- If you scale the nucleus to the size of a quarter, the electrons are over 1½ miles away.
- An average atom is about ½ nanometer in diameter.
- A nanometer is to a yardstick as a marble is to the planet Earth.
- If we cut a pie in half repeatedly, it takes 90 cuts to get from apple pie to atom.
- If an atom were the size of an M & M candy, you would be over 10,000 miles tall.
3. **Balancing Equations**

Now that you understand a bit about why we need to balance equations and how they figure how many atoms are in a compound and how to make great chocolate chip cookies, we can balance a few equations.

**A. Example #1**

You need to start off with a formula to begin with...unless you're a fourth-year chemistry student, in which case, you aren't reading this. So you are informed that hydrogen plus chlorine make hydrochloric acid. But what's the recipe?

1. Write the formula out. Hydrogen atoms come in twos (diatomic molecule) and so does chlorine and HCl is hydrochloric acid.

   $\text{H}_2 + \text{Cl}_2 = \text{HCl}$

2. Isolate each compound in a box so you don't change it.

   ![Diagram]

3. Take an inventory of the atoms on each side of the equal sign.

   $\begin{align*}
   \text{2} & \quad \text{Cl} \quad \text{1} \\
   \text{2} & \quad \text{H} \quad \text{1}
   \end{align*}$

4. Write numbers in front of the boxes until the inventory is the same.

   ![Diagram]

In this reaction, two hydrogen atoms and two chlorine atoms will chemically combine and give you two hydrochloric acid molecules.
B. Example #2
Magnesium metal burns and combines with oxygen to make Magnesium oxide. The formula is Mg and O\textsubscript{2} gives MgO.

1. Write the formula out.

\[ \text{Mg} + \text{O}_2 = \text{MgO} \]

2. Isolate each compound in a box so you don't change it.

3. Take an inventory of the atoms on each side of the equal sign.

4. Write numbers in front of the boxes until the inventory is the same.

Two magnesium molecules and one oxygen molecule (two atoms in the diatomic molecule) burn to form two units of magnesium oxide.
C. Example #3
Sodium chloride or table salt. The formula is sodium and chlorine combine to make salt or Na + Cl₂ → NaCl

1. Write the formula out.

\[ \text{Na} + \text{Cl}_2 \rightarrow \text{NaCl} \]

2. Isolate each compound in a box so you don't change it.

\[
\begin{array}{c}
\text{Na} \\
\text{Cl}_2 \\
\text{NaCl}
\end{array}
\]

3. Take an inventory of the atoms on each side of the equal sign.

4. Write numbers in front of the boxes until the inventory is the same.

\[
\begin{array}{c}
2 \text{Na} \\
2 \text{Cl}
\end{array}
\] → \[
\begin{array}{c}
2 \text{NaCl}
\end{array}
\]

It balances! When sodium and chlorine ionically combine, they do so in the ratio of two atoms of sodium and two atoms of chlorine (one diatomic molecule) and form two units of the salt sodium chloride.

At the periodic table, we see that each sodium atom weight (has a mass) of 23.0 and chlorine is 35.5. Add it up. Two sodiums are 46 and two chlorines are 71 and the yield is 117.

46 grams of sodium plus 71 grams of chlorine give 117 grams of table salt.
4. The Mole

A. For Starters

The concept of a mole is really weird and not intuitive.

Scientists wanted to know, "How many atoms are we talking about?" Since Dalton's scale was based on hydrogen, they asked, "How many atoms in 1 gram of hydrogen?"

It took almost 150 years to arrive at the answer that there are... 60,200,000,000,000,000,000,000,000 atoms in 1 gram of hydrogen. That's a lot of atoms.

The question with the mole isn't "how many things are there in a mole?" We know how many there are. There are 6.02 x 10^23. The question is how much does a mole of that stuff over there weigh? A mole of gold weighs more than a mole of hydrogen because a gold atom weighs more than a hydrogen atom.

Likewise....

The question with a dozen isn't "How many things are there in a dozen?" We know how many there are in a dozen. There are 12. The question is how much does a dozen of that stuff over there weigh? A dozen bowling balls weighs more than a dozen marbles because one bowling ball weighs more than one marble.

B. Stay with me here...


To figure out the weight of a given compound, just look at the periodic table and add it all up.

CH\textsubscript{4}O (methanol) weighs 32 grams. C=12; H=1x4; O=16. 12+4+16=32. This means that 60,200,000,000,000,000,000,000,000,000 molecules of methanol weighs 32 grams. But it's normally written as 32 g/mol which means grams per mole.

HCl (hydrochloric acid) weighs 36.5 grams. H=1; Cl=35.5 -HCl. It is normally written as 36.5 g/mol.

To figure out molecular mass or weight, just use the periodic table. (Avogadro's number doesn't even enter into the equation and nobody is in the corner of the lab counting atoms!)

C. The Mole Men on the Cube

These are the men pictured on the mole cube in the video. They were responsible for arriving at the mole number.

Amedeo Avogadro► Stanislao Cannizzaro► Josef Loschmidt► Jean Baptiste Perrin
Quiz Twelve - Balancing Equations

1. Mass Spectrometers can analyze a compound and tell you what's in it.
   a) True
   b) False

2. Stoichiometry means "measuring the elements."
   a) True
   b) False

3. The molecular mass for water (H₂O) is
   a) 18
   b) 19
   c) 20
   d) 21

4. A mole is a measurement of weight.
   a) Sounds good to me
   b) No, the mole is a quantity of things not the weight of things

5. Molecular mass for ammonia (NH₃) is
   a) 16
   b) 17
   c) 18
   d) 19

6. A mole is equal to 1 gram
   a) Yes, that's right
   b) No. A mole is just a number- 6.02 x 10²³. You need a mole of something before you can weigh it

7. Molecular mass for sulfuric acid (H₂SO₄) is about
   a) 98
   b) 101
   c) 111

8. A diatomic molecule is
   a) Two of the same atom
   b) Two of the same molecule
   c) Any two molecules
   d) Two moles
   e) All of the above

9. A balanced equation has the same number of atoms on both sides of the equation.
   a) True
   b) False

Answers are on page 115
13. Essentials Wrap-up

There are lots of areas of chemistry to explore and in this section we are going to touch on a few more chemistry essentials used every day in the chemistry laboratory.

1. Phases of Matter

   Matter usually presents itself to us in one of three states or phases: solid, liquid and gases. You and I do not interface with matter on the quantum or atomic or sub-atomic level. At these tiny levels, the obvious differences between solid, liquid and gas virtually disappear and everything is reduced to electrical charges.

   A. Kinetic Molecular Theory of Matter - the assumptions
      1) Gases are made of molecules that are far apart from each other.
      2) Molecules are in constant, rapid motion.
      3) Molecules exert a force when they run into something.

   B. Density, mass and volume
      Mass is the amount of stuff. Volume is a measure of the space your stuff takes up. Density is the combination of your stuff into the volume...or how tightly packed your stuff is in the space provided. Diet cola is less dense than regular cola.

      - All matter gets more dense as it gets colder. Except water.

      - Water has a density of one. Everything is compared to that standard.

   C. Solids
      Tightly packed molecules holding their own fixed shape.

   D. Liquids
      Liquids have a fixed volume but not as much as solids. They move past each other easily and expand to fill the container you put them in.

   E. Gases
      The invisible matter, usually. Gases are moving fast and expand to fill their container or to get out of a container. Slamming against the walls of non-rigid containers like a balloon gives the appearance of static pressure.

   F. Super Hot plasma
      If you trap a gas and pass an electric current through it, the electrons strip off and the gas gets ionized. Lightning is a perfect example. Electric gas.
G. Super Cold superfluid
Most liquids simply freeze solid but some, like helium, behave very strangely when cooled to near absolute zero. It defies gravity by crawling up out of containers and seeps through solid glass.

2. Acids and Bases
Acid means sour. Acids are defined as something that tastes sour, is corrosive to metal and will turn litmus paper red. Alkalis (also called base) come from the Arabic word meaning the ashes. Alkalis feel slippery and turn litmus paper blue. Water is balanced between acid and base. If a compound increases the positive hydrogen in the water, it becomes more reactive, unstable and more acidic. If a solution decreases the amount of positive hydrogen, it becomes more base.

A. pH Scale
Soren Sorensen developed the pH scale to give a gauge on how acidic or alkaline a substance is. The more acidic, the closer the substance moves toward the zero. The more alkaline or base, the more it moves toward the 14 scale. The "H" stands for hydrogen and the "p" either means potential or power.

B. Oops!
In our pH test, we accidentally put the cup with the baking soda solution on the wrong side of the water! Baking soda is slightly alkali or basic not slightly acid. See if you can spot our mistake!

3. Organic Chemistry - The chemistry of carbon
Organic chemistry is really a higher level chemistry course. As one professor put it, "Organic chemistry is a concept based class that requires you to assimilate a huge amount of cumulative information in the form of concepts, reasoning, and (to a lesser extent) memorization, and then apply it to totally unfamiliar situations." Some people hate organic chemistry. Some people love it.
4. Radiation Revisited

In the film, we divided the types of radiation into electromagnetic radiation and particle radiation. It is also common to divide it into ionizing radiation and non-ionizing radiation. Ionizing radiation will knock electrons off atoms. Non-ionizing radiation does not have enough energy to break atoms.

A. Electromagnetic

The electromagnetic spectrum is really part of physics. But part of the spectrum, beyond visible light, has wavelengths so energetic that they will ionize atoms. This includes x-rays and gamma rays. Both are ionizing forms of radiation on the electromagnetic spectrum.

- **Gamma Rays**
  When a nucleus decays, a byproduct is to give off a pulse of gamma radiation. Gamma is the most penetrating of all radiation; it is the Superman of radiation. Able to leap long distances and only stopped by thick concrete or lead. They are nearly identical to x-rays except how they are produced. In addition, most gamma rays have higher energy than most x-rays.

B. Particle

- **Alpha particles**
  An alpha particle is produced when a heavy nucleus loses two protons and two electrons (which is the same as a helium atom). These heavy, slow particles are stopped by a piece of paper or skin. But they will do damage to delicate lung tissue if you inhale them...like you'll find in radon gas.

- **Beta particles - back to alchemy?**
  A nucleus can also undergo beta decay and throw off an electron! Remember we are talking about how a nucleus decays and gives off ionizing radiation. There are no electrons in the nucleus. The current atomic theory tells us that a neutron can spontaneously turn into a proton and in the process, spontaneously generate an electron. These electrons speed out of the nucleus and knock off other electrons, ionizing the atom.

- **Neutron particles**
  This is a form of ionizing radiation you don't hear about too often as it only occurs in nuclear reactors and nuclear weapons. Free neutrons tend to readily attach to the nucleus in an atom, instantly making the atom radioactive. This will kill cells in your body.

Discussion Question 🤔

- The Kinetic Energy Molecular Theory is based on three assumptions. Why do you think they call them assumptions and not facts or laws?
Quiz Thirteen - Essentials Wrap-up

1. If something has a density of two, it floats.
   a) True
   b) False

2. Ionized gases are called superfluids.
   a) True
   b) False

3. Glow sticks are an example of bioluminescence.
   a) True
   b) False

4. Acids and Bases are gauged on what scale?
   a) pH scale
   b) Ph scale
   c) Spectrometer scale
   d) Three beam scale
   e) Phish scale

5. Organic chemistry is
   a) The chemistry of nitrogen compounds
   b) The chemistry of hydrogen compounds
   c) The chemistry of oxygen compounds
   d) The chemistry of carbon compounds

6. Lemon juice will probably show up where on the pH scale?
   a) 9
   b) 7
   c) 5
   d) 2

7. Ionizing radiation can be found on the electromagnetic spectrum.
   a) True
   b) False

8. The most penetrating radiation of these three is
   a) Alpha
   b) Beta
   c) Gamma

9. Beta decay is when
   a) An electron jumps from its orbital
   b) An electron is added to an atom
   c) A neutron turns into a proton and an electron is ejected
   d) An electron emits radiation

10. Another name for an alpha particle is
    a) A hydrogen atom
    b) A helium atom
    c) An electron
    d) A positron

Answers are on page 115
14. The Four Main Columns

There are a total of 118 elements on the periodic table as of the production of Chemistry 101. It is unlikely that element 118 will be given a proper name anytime soon. These things usually take decades. Element 113 doesn't have a name yet either but that could happen anytime.

Ores
An ore is a rock containing a desired mineral or element. You need to crush it, heat it and separate the compounds out before getting the treasures inside.

a. hydrogen (H)
   - Hydrogen means *The water maker*.
   - Hydrogen is the most abundant element in the universe and the lightest. Colorless, odorless, tasteless and highly flammable.
   - The Space Shuttle's main engine burns 750 gallons of liquid hydrogen every second, producing a nearly invisible 6,000º F flame.
   - Hydrogen is used in Hydrogen peroxide, used as a fuel and it can make powerful nuclear weapons.

1. Alkali Metals
   The first group on the periodic table and the most reactive. They are kept submerged in oil or kerosene to isolate them from moisture in the air.

a. lithium (Li)
   - Lithium means *The Stone* as lithium is found in many minerals.
   - Lithium is kept in mineral oil or it will react with the moisture in the air.
   - Lithium is also the lightest of all metals and easily floats on water. But it will react with that water and burst into flame.
   - 1 cubic foot of aluminum weighs 168 lbs—but lithium… only 33 lbs.
   - Lithium alloys make strong, light metals like lithium batteries. Used as a medicine, lithium can stabilize extreme mood swings but the effective dose is close to the toxic dose and must be carefully monitored.
b. **sodium (Na)**
- Sodium from the word *soda*.
- The symbol Na is from *Natrum*, the Latin word for soda.
- Soft enough to cut with a knife and highly reactive.
- Sodium is essential for life, carrying electrical impulses along nerves.
- Sodium chloride, table salt, the most common sodium compound and the principle source of sodium production. Salt is collected in sea water evaporation vats or collected in piles from salt flats. Like this gigantic salt flat located in Bolivia.
- Compounds of Sodium are used in making soap, paper, glass and in most industries. It is the yellow orange glow in sodium vapor street lights. It is one of the cheapest of all metals.

c. **potassium (K)**
- Potassium: from “Potash,” the ash used in ancient times for making soap and fertilizer.
- The symbol “K” is from Kalium - Latin for ash.
- A soft, highly reactive or explosive element.
- Similar to sodium in its use for making glass and soap and both have important biological function.
- Potassium is used in making inks and dyes, explosives, fireworks, but mostly for fertilizers.
- Bananas are known for their high potassium content but an avocado has 3x the potassium of one banana.

d. **rubidium (Rb)**
- Rubidium: *Deep Red* because of its predominant spectral red colors.
- Related to the word *ruby*.
- Rubidium ignites spontaneously with air and reacts violently.
- Rubidium is usually sealed in glass ampoules along with a noble gas.
- It melts on a warm day, at just over 100° F.
- It is used in photocells, but in general there are relatively few commercial uses for Rubidium.
e. **caesium (Cs)**

- Cesium: “sky blue” because of its blue color in the spectroscope.
- Caesium and gold are the only gold colored elements.
- Like Rubidium, cesium is usually sealed in an ampoule under argon gas.
- It is liquid at warm, room temperature.
- The ‘cesium clock’ or atomic clock, is the standard instrument to measure time: 9,192,631,770 oscillations of the cesium atom takes exactly one second…accurate to about 1 second every 2 million years.
- Aside from a few medical and scientific applications, cesium has only a few commercial uses.

f. **francium (Fr)**

- Francium will be covered under the heavy radioactive elements.

2. **Alkaline Earth Metals**

The second family is the Alkaline Earth metals. Reactive, but not as reactive as the ferocious Alkali Metals.

a. **beryllium (Be)**

- Beryllium –containing beryl since it was first found in this mineral.
- A very light metal but one of the highest melting points—nearly 2,500 °F.
- It is light, stiff and is structurally stable. Ideal for use in high-speed aircraft, cogs, gears and structural components of the space shuttle.
- Expensive and toxic, but unbeatable when cost is no object.
- The word *beryl* means *sweet* and early experimenters verified the presence of beryllium by its strangely sweet taste, but beryllium and its compounds are highly poisonous and should only be handled with the greatest care.

b. **magnesium (Mg)**

- Magnesium from *Magnesia*—the area in Greece where it was discovered.
- Thin shavings ignite easily and burn brightly and are used in flares and magnesium fire starters.
- Lightweight and strong, magnesium alloys are found almost everywhere—bicycle frames, airplane parts, luggage, catcher masks, and rocket missiles.
- Magnesium is dissolved in seawater. Mining is another source of Magnesium
- So-called “milk of magnesia” and Epsom salts are common medical uses of magnesium.
- Your body has about 20 grams of this essential element.
c. **calcium (Ca)**
   - Calcium is Latin for “lime.” Limestone is an ancient building material and cement and contains this element.
   - The Great Pyramid is made entirely of limestone.
   - Say *calcium* and most people think of milk, bones and chalk, but pure calcium is a highly reactive metal and is rarely seen.
   - Pure calcium has very few applications, but compounds of calcium are used to make everything from dry wall and paint to chalk and antacids.
   - Marble used for statues is actually calcium limestone squeezed under great pressure.
   - Dairy products are rich in this metal and Vitamin D is often added to help the body absorb it.
   - Calcium in water is responsible for calcification in pipes and stalactite and stalagmite formations in caves.
   - Calcium is the most abundant metal in humans—averaging two pounds of this metal in your body. 99% of it in your teeth and bones. If you were completely dried out, 1/3 of your remaining weight would be calcium.

   d. **strontium (Sr)**
   - Strontium named after *Strontian, Scotland* where the element was discovered.
   - Another highly reactive element that is kept under argon gas or in oil to keep it from reacting with the moisture in the air.
   - Regular strontium is not radioactive and is used in fireworks to burn bright red and to make safe glow-in-the-dark paints. Strontium-90 is highly radioactive and is residual of nuclear explosion fallout. This isotope also holds potential in fueling remote whether stations and future space vehicles.

   e. **barium (Ba)**
   - Barium is Greek for *heavy* as it's ore is one of the more dense minerals.
   - The last alkaline earth metal that isn’t radioactive but still highly reactive and kept safely in a nonreactive argon gas tube.
   - Some Barium compounds are poisonous. Others make fireworks green.
   - There are relatively few commercial uses for barium.
   - When patients drink a barium solution the barium absorbs the x-rays allowing visibility of the digestive tract.
f. radium (Ra)
   • Radium will be covered under the heavy radioactive elements.

3. The Halogens
   Halogen means produces salt, as salts are often produced when combined with these elements. Table salt is the best example.

a. fluorine (F)
   • Fluorine means to flow because the main ore has a very low melting point and thus, flows. The ore also glows in ultra violet light which is where we get the word fluorescent.
   • Fluorine is a poisonous, corrosive, pale yellow gas and the most reactive element on the table, even more than the ferocious alkali metals.
   • It cannot be stored in ordinary glass: It soon eats the glass. It is so reactive it will even try and bond with the noble gases.
   • Though controversial, some toothpaste and city drinking water contain small amounts of fluorine to help prevent tooth cavities.
   • Combined with carbon, fluorine is stable and forms polytetrafluoroethylene also known as Teflon.
   • In fact, most compounds of fluorine are very stable as fluorine is such an aggressive binding element.

b. chlorine (Cl)
   • Chlorine greenish yellow in Greek. The 4th horseman in the Apocalypse is called Chloros, Greek for pale green.
   • A powerful disinfectant. In small doses, Chlorine is used to purify drinking water and swimming pools.
   • Chlorine is extracted from molten salt by electrolysis where the sodium and chlorine separate.
   • Chlorine is used in a wide range of products in agriculture, pharmaceuticals, plastics- 85% of all medicines, 96% of all crops and 98% of all drinking water are affected by the chlorine industry.
   • Chlorine gas is highly poisonous or debilitating and has been used as a weapon as shown in John Sergeant’s famous 1918 painting.
c. **bromine (Br)**
- Bromine is Greek for *it stinks* because of its strong, disagreeable odor which resembles chlorine.
- Bromine is extracted from sea water. Bromine is a brown-red liquid and the only non-metal liquid.
- Bromine combines with metals to produce salts, some of which are used to purify hot tubs.
- The largest single use of Bromine is manufacturing flame retardant chemicals used in clothing, furniture and plastics to inhibit fire.
- Israel's bromine reserves are contained in the waters of the Dead Sea.

d. **iodine (I)**
- Iodine comes as shiny, blueblack crystals which cannot melt. When heated, it sublimes—it goes immediately from a solid to a gas, a beautiful purple gas. Thus iodine means violet.
- It is the heaviest element your body needs and can mean the difference between good or bad health. The amount of iodine in your body would fit on the head of a pin. Located mostly in the thyroid. Iodine is a powerful disinfectant.
- Iodine is generally found in seaweed where, after being heated, it sublimes and the crystals are collected.

e. **astatine (At)**
- Astatine will be covered under the heavy radioactive elements.

4. **Noble Gases**

   The Noble gases are also called *inert gases*. Elements so satisfied with themselves they don’t combine with other elements. They bear odd Greek names which reflects their exclusive nature...noble.

a. **helium (He)**
- Helium was first discovered looking at the sun using spectroscopy.
- Helium is Greek for *sun*.
- Colorless, odorless, tasteless, helium glows peach colored when an electric current runs through it.
- Compressed helium super cools materials, lifts balloons, and provides an inert gas in arc welding.
- Helium is normally trapped with natural gas. When the temperature of natural gas is lowered, it liquefies and the helium separates away. Both products are then collected and stored.
- No compounds of helium have ever been made.
b. neon (Ne)

- Neon from Greek Neo meaning “new,” the new element.
- Neon filled lights glow a bright red/orange.
- Neon is also being tested as a refrigerant.
- Neon is extracted out of normal air. Air is super cooled to a liquid. As it warms, each element changes back to a gas at a different temperature and is collected. Neon changes back at -410° Fahrenheit.
- Neon is chemically inactive. So far, it has been impossible to make neon react with any other element.

c. argon (Ar)

- Argon is chemically inactive but an electric current causes argon to glow a rich sky-blue.
- One of the least expensive noble gases, Argon is used as a gas shield for arc welding and cutting.
- It’s also the inert filler gas in most light bulbs.
- Like neon, argon is extracted from the air through fractional distillation.
- Argon lasers are used in research and smaller versions are used in precision eye surgery.

d. krypton (Kr)

- Krypton means hidden because it is colorless, tasteless, odorless and is a very rare gas in our atmosphere.
- An electric current causes krypton to glow a very pale lavender color, almost white.
- Krypton filled light bulbs are about the only commercial use of krypton.
- Krypton is chemically unreactive. Flourine can bond with Krypton but is only a laboratory curiosity.
- Like Neon and Argon, Krypton is extracted by allowing liquid air to evaporate.
- Krypton is the birthplace of the DC comic book hero Superman. (This noble gas was discovered 40 years before the fictional story was invented.)
e. xenon (Xe)

- Xenophobia is the fear of something foreign or strange.
- Xenon means *foreign or strange* and was the last noble gas discovered.
- Electrified Xenon glows violet though it is seldom used due to the cost.
- Air contains very little Xenon, therefore Xenon is very expensive.
- Many neon sign colors are made by combining gases or coloring the glass itself.
- Xenon is used for studio flash lamps, as an anesthesia and headlights. Amazingly, over 80 compounds have been made using this noble gas.

f. radon (Rn)

- Radon will be covered under the heavy radioactive elements.

Discussion Questions

- Why does hydrogen belong with the Alkali Metals? Why doesn't it? Should it go with the noble gases? Is it odd that the very first element in the periodic table doesn't seem to really fit anywhere?

- What is your favorite family of the four main columns? Why?
Quiz Fourteen - The Four Main Columns

1. Neon has many compounds even though it is a noble gas.
   a) True
   b) False

2. Lithium is the lightest metal in the universe.
   a) True
   b) False

3. The family that does not belong to the four main columns is
   a) Alkali metals
   b) Transition metals
   c) Noble gases
   d) Halogens

4. "Hydrogen" means
   a) First element.
   b) Fire maker
   c) Breath
   d) Water maker

5. The total number of elements to date is
   a) 116
   b) 117
   c) 118
   d) 119

6. Beryllium is lightweight and strong.
   a) Yes, that's right
   b) No it's soft and very malleable

7. An element your body least requires is
   a) Sodium
   b) Iodine
   c) Fluorine
   d) Calcium

8. Calcium is
   a) A fairly reactive metal
   b) A chalky, reactive non-metal
   c) Highly toxic and gold colored

9. Which is not a halogen?
   a) Fluorine
   b) Xenon
   c) Iodine
   d) Bromine
   e) Chlorine

10. The element krypton was discovered after the creation of the Superman comic and was named in honor of the popular character.
    a) True
    b) False

Answers are on page 115
15. Non-Metals & Poor Metals

The stair step elements are found in these two triangular blocks, with a stair step right in the middle. Often called the aluminum staircase since the top step rests on aluminum. The metalloids are taken from the elements in the middle.

1. Poor Metals

We start with the poor metals, a trivial name given for the softer metallic elements with lower melting points. These are often called post-transition metals as they come right after the transition metals. Polonium is usually included but will be counted with the heavy radioactive elements.

a. aluminum (Al)
   - Aluminum is from *alum*, an common compound used to heal wounds and make pickles.
   - Aluminum is the most abundant metal on earth, even more than iron but separating aluminum is quite difficult. It was so rare that a small bar of aluminum used to be on display next to the French Crown Jewels.
   - Aluminum production is now relatively inexpensive.
   - 30% of all aluminum makes cars, trucks and aircraft.
   - It is very malleable and easily formed so another 25% is in aluminum foil, soda cans and other containers.
   - Aluminum is separated from the ore bauxite through electrolysis.

b. gallium (Ga)
   - Gallium, from "Gallia", meaning both France (where it was discovered) and Rooster (named after the discoverer Lecoq whose name also meant Rooster).
   - When a little electricity is touched to the compound gallium arsenide, parts of the crystal will, incredibly, light up. Seal a chip of the crystal in plastic and you've got an L.E.D, a light emitting diode.
   - Nearly all Gallium is used to make gallium arsenide crystals.
   - Gallium also makes amazing mirrors.
   - Five metals are liquid at or near room temperature: Cesium, rubidium, francium, mercury and gallium.
   - A chunk of Gallium will melt in your hand. And a spoon made of Gallium will surprise the user!
c. indium (In)
- Indium named for the distinctive *blue indigo* spectral color.
- Like Gallium, Indium is almost sticky and very soft.
- Evaporated onto glass it also makes excellent mirror surfaces.
- The compound of indium plus tin creates indium tin oxide—a transparent metal. Tiny strands are used on the surfaces of Flat panel displays, touch panels and liquid crystal displays so you can’t see them.
- Indium is used as solder and in solar cells converting pulses of light into electrical signals.

d. thallium (Tl)
- Thallium meaning *green twig* after the beautiful green spectral line that identifies the element.
- The pleasant name is somewhat deceptive as Thallium and it’s compounds are extremely poisonous, even contact with the skin is dangerous. Thallium was widely used for rat and ant poisoning but has since been banned.
- It is odorless and tasteless giving no warning of its presence.
- Some industrial and medical uses exist but the line between the toxic and therapeutic use is very small.
- Surprisingly, the paint pigment called Prussian blue, is the antidote to Thallium poisoning.
e. tin (Sn)

- The meaning of the word "tin" has been lost in history.
- The symbol Sn comes from *stein* (pronounced *stin*) which was an ancient word for this metal.
- Most tin is alloyed with lead to make solder.
- Tin cans are actually steel cans with a thin coat of corrosion resistant tin and so-called tin foil is actually cheaper aluminum foil.
- Before plastic, most toys were made from tin.
- Windows are made by floating molten glass on a bed of molten tin to producing a perfectly flat surface.
- Tin plus copper makes Bronze, like the bronze statue of Auguste Rodin’s “The Thinker”.
- Tin plus a little copper or lead or antimony makes Pewter. Pewter was used as tableware for centuries until glass replaced it in day-to-day life.
- Just like carbon comes as an allotrope of diamond and graphite, so tin has two allotropes; the familiar shiny white metal and a crumbly, gray nonmetallic powder.
- At temperatures below 56 F, pure tin will automatically change from the shiny version into the grey powder form, in a startling transformation the old timers called Tin Pest, Tin Disease or Tin Plague. Historically Tin Pest caused decomposition of church pipe organs and even buttons on military garments.
- Tin pest is avoided by mixing small amounts of antimony, bismuth or even lead with molten tin. This alloy gives the tin greater strength when the temperatures drop.

Why You Speak "English"

Some historians believe the word *Britain*, *Bri-Tin*, also literally means *The Land of Tin*.

And while we’re talking about Britain, what about the word *England*? England, another part of Great Britain means *The Land of Angles*.

Which brings us to the very Northern part of Germany.

See the little ‘x’ on the map by the fish hook point? To get to the North Sea, the shortest route for the people at the ‘x’ was to sail out of that fish-hook shaped bend then walk the rest of the way to the ocean. Thus these people were called the *Anglen* because of that bend. *Anglen* means *bend*.

In the 400’s, they navigated out and landed in England and called it *Angle Land*—land of the Angle people.

Thus, we speak *Anglish*, *English*, because the people who settled Britain came from a part of the world that is angled like this fish hook.... which is why fishing is called *angling* because a fishing hook is also angled... just in case you were wondering.
f. lead (Pb)
   - The symbol for lead is Pb from Latin "Plumbum" where we get plumber but the word “lead” itself is of uncertain origin and meaning.
   - An ancient, soft metal used, for water pipes, roofing, paints, carvings and art work like the huge lead statue of Louis 14th in Paris France.
   - Lead is poisonous so it’s use has been reduced but it is still found in batteries, bullets and as a shield against x-rays
   - Lead added to glass makes beautiful vases, stemware and serving dishes.

g. bismuth (Bi)
   - Bismuth probably means “white lump” but nobody is certain.
   - Bismuth looks white with a pinkish tinge but underneath the uniform surface, is an amazing iridescent crystal structure. Using acid to etch the top exposes the crystal structure beneath.
   - Bismuth is used in many cosmetics and in over-the-counter medicines for stomach problems, commonly known as Pink Bismuth (Pepto-Bismol®).
   - Bismuth alloys tend to have a low melting temperature. These metals are used in metal fire sprinkler systems and electrical fuses.
   - Lead and bismuth are the very last stable elements before the heavy radioactive elements.

h. germanium, antimony and polonium
   - Often grouped as a poor metal, these will be considered as metalloids and polonium as a radioactive.

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**Is Lead Crystal Glassware Safe?**

Lead crystal is glass that has up to 30% lead mixed in as the lead gives a dazzling sparkle to the glass. Plus the lead makes cutting and decorating the glass much easier. The word *crystal* means, in most of the western world, the presence of lead—even 1% lead.

There is a small quantity of lead contained in every ordinary diet. The amount of lead that leaches into any beverage during the normal use of a lead crystal glass is much smaller than the quantity of lead consumed daily in your ordinary diet.

However, a 1991 Columbia University study determined that there is significant lead contamination when food and beverages are stored in lead crystal.

**How do you know if it is lead crystal?**

Lead crystal is heavier than normal glass. It is often ornately cut and decorated and appears more brilliant and sparkling to the eye. The more lead the glass contains, the more brilliant the lead crystal appears.
2. Non-Metals

The non-metals are found in the top triangle in the main group.

a. carbon (C)

- Carbon is from the Latin Carbo meaning Charcoal.
- Sometimes called "The King of Elements".
- The foundation element for life. More compounds are made with Carbon than all the other elements combined. Over ten million known substances- so many that an entire branch of chemistry is devoted to the study. Organic Chemistry is the study of compounds with carbon in them.
- Three common forms or allotropes of carbon are: amorphous, graphite and diamond.
- There seems to be no limit to the size and shape of molecules that can be made with carbon.

b. nitrogen (N)

- The ancient name for nitrogen was azote and it means lifeless. Nitrogen acts like a noble gas.
- Alchemists used nitric acid in many experiments. They called it aqua fortis, or strong water. When element #7 was discovered inside nitric acid, they named it Nitrogen-- The Nitric Acid Maker.
- Nitrogen makes up 78% of the air we breathe and is one of the most nonreactive elements that isn't a noble gas.
- Manufactures extract nitrogen it from common air through distillation.
- Nitrogen is used mostly in ammonia as an agricultural fertilizer. Liquid nitrogen is used to freeze other materials.

c. oxygen (O)

- Oxygen is similar to nitrogen. Oxygen means acid maker as it was wrongly thought to be a component in every acid.
- Colorless, odorless, tasteless, oxygen makes up 21% of the air. With nitrogen, these two elements make up 99% of our air. The remaining 1% is mostly the noble gas argon with traces of about a dozen other gases.
- If your hand represented the air we breath, your four fingers would be nitrogen, the thumb would be oxygen, the nail on your pinky would be argon and the freckles would be traces of other gases.
- Essential for life, over half of your body weight is oxygen, mostly combined with hydrogen to form water.
- As unlikely as it sounds, liquid oxygen is actually paramagnetic meaning that liquid oxygen is weakly attracted to magnetic fields.
d. phosphorus (P)

- Phosphorus is Greek for *brings light* as white or yellow phosphorus glows in the dark as depicted in the painting "The Alchemist Discovering Phosphorus" by Joseph Wright.
- White phosphorus ignites on contact with air and is highly unstable.
- Red phosphorus is more stable. Strike anywhere matches combine the red phosphorus on the match itself. Strike the sandpaper surface
- and it ignites.
- Safety matches leave the red phosphorus off the match and mix it with powdered glass then paste it on the outside of the box as a striker.
- An average adult stores about two pounds of essential phosphorus compounds in his body.

![Gunpowder](Image)

**Gunpowder**

For centuries *gunpowder* or *black powder* has been of great historical importance in chemistry. It's principle use is for a propellant in rifles for hunting game and to feed and protect families.

The charcoal acts as the fuel, the saltpeter is an oxidizer to make it burn faster and the sulfur acts as a stabilizer. As the mixture burns, it quickly produces the nitrogen and carbon dioxide gases that provide the propelling action.

One of the most common formulas for gunpowder is:

75% Saltpeter
15% charcoal
10% sulfur

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e. sulfur (S)

- Sulfur is probably from the Arabic word for *Yellow*.
- One of the few elements found pure in nature, for example, it is found in volcanic sulfur vents. When the gas reaches cold air, it changes back to a solid.
- Burning sulfur produces a very strong odor. Both onions and garlic get their smell from sulfur compounds. So does a skunk for that matter.
- Sulfur actually has few industrial uses. 85% is converted into Sulfuric Acid used principally for manufacturing fertilizers.
- Essential for life, the average human carries about 5 ounces of sulfur in their body.
- Sulfur is an essential component in gunpowder.

f. selenium (Se)

- Since Tellurium was named after the Earth, this sister element was given the Greek name for our *Moon*.
- Selenium comes either as a silvery metal or a red powder.
- Selenium’s ability to conduct electricity is affected by the amount of light shining on it. The brighter the light, the better selenium conducts electricity. This makes it perfect for photo detectors and light meters in cameras and copiers.
- Our bodies need about 14 milligrams of selenium to sustain life. A single Brazil nut will give you your daily requirement of selenium.
g. tellurium (Ti)

- Often grouped as a nonmetal, tellurium will be with the metalloids.

3. Metalloids

Metalloids are generally considered a sub-class of the non-metals and poor metals and are often grouped with them. They run along the *aluminum staircase* with the exception, of course, of aluminum itself.

a. boron (B)

- Boron is from *borax* a Persian word meaning *white*, the color of borax.
- Pure boron is a seldom used dark powder or crystal. But boron compounds are used in a wide variety of applications.
- Most boron is used in the production of insulating fiberglass and glassware. Some boron compounds are super hard and used in bullet proof vests.
- A 20 mule team used to pull wagons of borax from Death Valley California in the 1800's, prompting the name of a popular laundry detergent.
- In the 1950’s, the boron compound Pentaborane was used as a highly volatile rocket fuel, but it’s also extremely toxic, being lethal on contact. Chemists called it “The Green Dragon.”

b. silicon (Si)

- Silicon is the Latin word for *flint*. Silicon is glassy like flint.
- Silicon is second most abundant element in Earth’s crust- second only to oxygen.
- Ultra pure silicon is one the best materials to make transistors and computer chips.
- Most silicon is used as an alloy in aluminum and steel for added strength and low shrinkage.
- Silicon and silicone are often confused. Silicon is the natural element, strong and brittle. Silicone is a man-made soft, rubbery compound with silicon as one component.
- Silicon is usually found in quartz crystals. When you see sparkles in the sand, you’re usually looking at tiny pieces of quartz- made largely of silicon.
c. germanium (Ge)
- Germanium after Germany where it was discovered.
- Germanium is used to manufacture high end camera lenses, fiber optic systems and solar panels.
- Germanium was used to build the world’s very first transistor, considered by many to be the greatest invention of the twentieth-century. Transistors are the on/off switches allowing the binary code that runs your computer...much like a spray nozzle acts as the on/off switch for your water hose.
- Enough transistors are built each year to give 60 million of them to every man woman and child on earth.

d. arsenic (As)
- Arsenic is Persian meaning gold colored referring to the color of the main ore.
- Arsenic was long used by the ruling classes to secretly poison each other. Arsenic has been called the Poison of Kings and the King of all Poisons. Easy detection methods now exist.
- Nearly all industrial uses of arsenic have slowly been replaced or banned including the most common use as a wood preservative. Some medical uses for arsenic still exist.
- When added to other metalloids arsenic makes semiconductors run faster.
- Heated Arsenic smells like garlic.

e. antimony (Sb)
- The symbol for antimony is Sb from Stibium meaning a mark for its ancient use as eyeliner. The real meaning of the word antimony has been lost but there is speculation.(See side bar on page 25)
- Antimony is, of course, a semi-metal and used in the semiconductor industry.
- It is shiny silver but can be prepared as a black powder.
- Antimony poisoning resembles arsenic poisoning.
- Most antimony is used in manufacturing flame-retardant fabric and plastics.
- Antimony makes lead stronger and harder like in car batteries and ammunition.
- Antimony adds a clear glaze to glassware...or you can use it to put a dark line on your eyelid.
f. tellurium (Te)

- Tellurium is from the Latin Tellus meaning Earth in honor of our home planet.
- Of course tellurium is used as a semiconductor as it is a semi-metal...it can be made to conduct electricity when you want it to.
- Most tellurium is alloyed with steel or copper making them easier to work with.
- Tellurium also makes soft rubber into hardened car tires.
- Tellurium is one of the few ores of gold besides native gold itself. Few substances combine with gold (gold telluride aka calaverite.)
- It’s mildly toxic, but absorbing even a tiny amount gives you “tellurium breath,” a strong garlic/onion odor to your breath that lasts for weeks.

Discussion Questions

- Do you prefer to break the metalloids out in their separate group or leave them in their non-metal and poor metal categories? Why?

- Notice how there is some latitude in how some elements are categorized. Some metals like germanium are either poor metals or metalloids. Astatine is a halogen or a radioactive metal. Do you like the degree of uncertainty in the periodic table or do you prefer it to be more predictable?

- Can you describe what the function of metalloids are in computers?

- What other elements are used in computers?
Quiz Fifteen - Nonmetals & Poor Metals

1. Tellurium can give you garlic breath if you touch it.
   a) True
   b) False

2. The symbol for lead is
   a) Pb
   b) Ld
   c) pH

3. Another name for poor metals is
   a) Post-transition metals
   b) Pre-transition metals
   c) Post alkali metals
   d) Trivial metals

4. What property of metalloids makes them unique among the elements?
   a) They are reactive under some conditions and nonreactive under certain conditions
   b) They have a lower melting temperature than all other elements allowing for flexibility in manufacturing
   c) They conduct electricity at high temperatures but stop electricity at low temperature

5. Silicon is an element in the metalloid group.
   a) True
   b) False

6. Most sulfur is used to make sulfuric acid.
   a) True
   b) False

7. What is the difference between a metal and a poor metal?
   a) Most metals have 1-2 electrons in their outer shell. Poor metals have 3-7 in their outer shell
   b) Metals are good conductors of electricity & heat. Poor metals are not
   c) Most metals have a luster to them. Poor metals tend to be dull
   d) Metals are solid at room temperature. Poor metals can be solid or soft or liquid around room temperature
   e) All of the above

8. What percentage of the air is made of nitrogen and oxygen?
   a) N 75% O 25%
   b) N 50% O 50%
   c) N 78% O 21%

9. The King of Elements
   a) Carbon
   b) Hydrogen
   c) Oxygen
   d) Aluminum

10. The group of elements most responsible for life are
    a) Halogens
    b) Noble gases
    c) Metalloids
    d) Non-metals

Answers are on page 115
16. Transition Metals

By far the largest family of elements is the Transition Metals, and include some of the most widely known and commonly used elements. They split the Main Group into two and form the transition between the electropositive families on the left side that have one or two electrons to share (positively charged alkali and alkaline earth metals) and the electronegative families on the right side, with four to seven electrons, that want to borrow electrons (like halogens and nonmetals).

1. Defining a Metal

What defines a metal? You may think the definition is a very scientific, hard to grasp formula. Like “a metal is a chemical element or compound whose atoms readily lose electrons to form positive cations.” That is the scientific definition of a metal. But, scientists also define metals by how they appear and behave. In general, a metal is something shiny and dense, conducts heat easily - like a pot or pan - conducts electricity well - like wires - and can be easily shaped without breaking. Just exactly what you always thought a metal was!

2. Transition Families

IUPAC, The International Union of Pure and Applied Chemistry is the recognized authority for chemistry standards. IUPAC does not require or even recommend a specific format for the periodic table, so there is a lot of latitude in how people can group the elements. Here is how Chemistry 101 group transition metals.

- Alloy Metals
- Magnetic Metals
- Noble Platinum Metals
- Coin Metals
- Zinc-Linc Metals
- Fountain Pen Metals
3. The Alloy Metals

Even though all metals form alloys, groups 3-6 are especially useful in forming essential alloys with iron and other elements.

a. scandium (Sc)
   - Scandium from Scandinavia where it was discovered.
   - Scandium has few commercial uses and is expensive to produce. Lightweight alloys are its primary use.

b. yttrium (Y)
   - Yttrium [IT-ree-um] from the village of Ytterby Sweden [IT-er-bee] where it was found.
   - The little village of Ytterby Sweden gives its name to no less than four elements on the Periodic Table: Yttrium (IT-reeum), Erbium (ERB-eem), Terbium (TURB-eem) and Ytterbium (IT-turb-eem). And yes they all sound very similar and slightly confusing.
   - They were all found in the same famous mine just outside of town...long since shut down and overgrown.
   - Four other elements were discovered in the Ytterby Mine: Gadolinium, Holmium, Scandium and Thulium.
   - Sweden holds the world record for element discovery - 20, followed by Britain with 19.

c. titanium (Ti)
   - Titanium is a name arbitrarily borrowed from the Greek myth of the Titan giants because they didn’t know what else to call it.
   - Strong as steel but much lighter, titanium alloys are everywhere from jet engine parts to artificial joints and making white paint.

d. zirconium (Zr)
   - Zirconium is Persian and means, Looks like gold as some zirconium crystals have a golden hue and are cut like gemstones.
   - Zirconium alloys are important in the nuclear industry and for jewelry.

e. hafnium (Hf)
   - Hafnium is the Latin name for Copenhagen where it was discovered.
   - Almost identical to Zirconium above it, and it too is used in nuclear reactors to control the fission rate of uranium and plutonium.
The next three alloy metals are named after a mythological Greek god.

f. vanadium (V)
   - Vanadium is named for the Scandinavian goddess of beauty Vanadis due to the beauty of its compounds.
   - Essential to human life in minute quantities.
   - A touch of vanadium makes steel tough enough to armor tanks.

g. niobium (Nb)
   - Niobium and the next element Tantalum are so similar they were named after a mythological Greek family: The Daughter Niobe and her father Tantalos.
   - Pure niobium is completely nontoxic and harmless to the human body which is why earrings, nose rings and other jewelry are made from Niobium.

h. tantalum (Ta)
   - Tantalum from Tantalos, the mythological Father of Niobi. Tantalos is the Greek form of the Latin Tantalus.
   - The character Tantalos was punished by being unable to quench his thirst or hunger, likewise this element is almost completely immune to corrosion by acid, even aqua regia. It is unable to absorb acid, like Tantalos was unable to absorb or drink water. Thus the name connection.
   - Similar to niobium in nearly every way, tiny amounts of Tantalum are in the capacitors of virtually every cell phone and computer in the world.

i. chromium (Cr)
   - Chromium is the Greek word meaning Color because Chromium compounds are intensely colored.
   - A minimum of 11% Chromium is added to steel to make corrosion resistant stainless steel.
   - Chrome plating makes metal very shiny.

j. molybdenum (Mo)
   - Molybdenum is the Greek word for Lead as this element has been confused with graphite and lead throughout the centuries.
   - Molybdenum is a high strength, high temperature alloy and lubricant.
   - To live, you will need about .3 grams of molybdenum in your lifetime (1/3 of a paperclip).
k. **tungsten (W)**

- Tungsten means *heavy stone* as it is a very dense metal.
- It is often called Wolfram, meaning "wolf's foam" from the foam that develops during tungsten extraction, thus the letter W for Wolfram.
- With the highest melting point of all the metals, tungsten can be heated white-hot without melting.
- The filament in most common household light bulbs is tungsten.

l. **manganese (Mn)**

- The origin of the name manganese is complex but ultimately it is from Latin magnes meaning magnet even though manganese is not magnetic.
- Manganese is essential for all living things.
- Manganese is absolutely essential for the production of all iron and steel alloys making steel more yielding and workable.

m. **technetium (Tc)**

- Technetium is Greek for "artificial" as it was the very first artificially made element.
- Technetium does not occur naturally and is the first radioactive element in the table.
- It is a short lived element used in specialized x-rays as it attaches itself to active areas of bone growth. In a few hours, technetium breaks down to stable elements and is eliminated from the body.

n. **rhenium (Re)**

- Rhenium named for the discoverers homeland in Germany along the "Rhine River".
- Rhenium was the very last natural element to be discovered and, of course, it was the most difficult to find. As a result, Rhenium is one of the most expensive metals selling at one time for $5 million a pound! Currently selling for a mere $10,000 a pound.
- Very small amounts of Rhenium make exotic alloys that withstand stress and heat. It is used, for example, in some military jet engine parts.
4. The Magnetic Metals

Iron, cobalt and nickel are the magnetic metals. They are the only pure elements that can be made into permanent magnets at room temperature. The reason these three metals are so strongly magnetic is not completely understood but their interaction is so strong and their magnetic effects so dramatic that we generally just think of other elements as simply non-magnetic.

a. iron (Fe)

- Iron’s symbol is Fe from the Latin ferrum meaning iron. The word iron is a bit obscure but probably means strong metal to contrast it with the weaker bronze metal.
- One of the oldest and easily one of the most important of all the metals. 90% of all metal refined in the world is iron. Iron can be permanently magnetized.
- Iron is most valuable with added impurities. A little carbon turns iron into steel. A little chromium makes it stainless steel.
- 90% of all metal refined in the world is iron.
- Iron is essential to all life. Your body needs about 4 grams of iron to continue to live, about the same weight as an iron nail.

Eiffel Tower - Paris, France

The metal structure of the Eiffel Tower weighs 8,000 tons while the entire structure including non-metal components is approximately 11,000 tons. Depending on the outside temperature, the top of the tower may shift away from the sun by up to 7 inches because of thermal expansion of the metal on the side facing the sun. The tower also sways 2–3 inches in the wind. Demonstrating the economy of design, if the 8,000 ton metal structure were melted down it would fill the 1100 square foot base to a depth of only 2 inches.

The tower has a mass less than the mass of the air contained in a cylinder of the same dimensions—that is, 1,063 feet high and 290 feet in radius. The weight of the tower is 11,133 tons compared to 11,315 tons of air!

The tower is repainted every seven years with about 60 tons of paint at the cost of about $20 million dollars. The specially chosen colors are named Eiffel Tower brown numbers 1, 2, and 3 as there are three shades of brown to emphasize the shape of the tower as seen from the ground—the lightest shade at the top, and the darkest at the bottom.
b. cobalt (Co)

- Cobalt, oddly enough, is related to the word *goblin* meaning *evil spirit*. Most cobalt ores contain arsenic and smelting them produced nasty, poisonous fumes.
- Cobalt has many uses and has been used for centuries to give a beautiful cobalt blue color to glass and glazes.
- Most cobalt is used in producing magnetic, high-strength superalloys. And if it wasn't enough that cobalt means 'evil spirit', look at its next door neighbor.

c. nickel (Ni)

- Nickel means the Devil's Copper as the ore was easily mistaken for copper. After a great deal of work when miners could not extract any copper from the ore they felt the devil was playing a trick and deceived them and named it *kupfernickel* "Devil's Copper."
- Most nickel is made into stainless steel and superalloys for jet turbines.
- Nickel is the third of the magnetic elements.
- The US nickel coin however is not magnetic as it is an alloy of only 25% nickel and 75% copper. Older Canadian nickels, however, were 100% nickel and would readily jump onto a magnet.

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**Magnetic**

Some substances are magnetized to begin with, like lodestones.

But only some elements can be made into magnets. These include this group of magnetic metals plus a few of the Rare Earth Elements.

Some substances become "magnetic" in the presence of a magnetic field, but are not magnetic in the absence of a magnetic field. These are called paramagnetic.

Other substances form "permanent" magnets and have their own intrinsic magnetic field. These are called "ferromagnetic" materials because iron metal is the "typical" example. These include iron, nickel, cobalt, and some alloys of rare earth metals.
5. The Noble Platinum Metals

Just as we have six noble, unreactive gases, so the metals in this group contains the six noble, unreactive metals. They are also called the Platinum Group as they are all found in the earth grouped around platinum and in the same ores. They are resistant to wear and chemical attack and do not readily combine with other elements, just like the noble gases. This is why these metals are often found in laboratory equipment and in catalytic converters. They won’t combine or react with other chemicals.

a. ruthenium (Ru)

- Ruthenium is the Latin word for Russia the discoverers home country.
- Ruthenium comes from platinum ores and is, of course, one of the noble, unreactive metals.
- It is also one of the rarest metals on Earth, thus expensive and useful.
- Adding just .1% of Ruthenium to titanium makes titanium 100 times more corrosion resistant. This is also one of the three fountain pen metals, the famous Parker 51 fountain pen is tipped with a 96% Ruthenium nib.
- A fountain pen contains an internal supply of ink drawn to the nib through gravity and capillary action. They are comfortable to write with and have a sense of timeless elegance about them. Although ball point pens easily dominate the market, millions of fountain pens are sold every year and many of their nibs are made of ruthenium.

b. osmium (Os)

- Osmium has a distinctive sharp smell, similar to ozone. Osmium means, a smell.
- Another noble platinum metal and a very rare element.
- Osmium is a very wear resistant, tough metal thus it is used for instrument pivots and is the second metal used in fountain pen nibs.

c. rhodium (Rh)

- Rhodium means rose in Greek because the first known compound was a beautiful rose-color.
- A member of the platinum group, rhodium is a very noble metal and won’t even react with fluorine.
- Rhodium is used in catalytic converters because of this noble property.
d. **iridium (Ir)**

- Iridium is Latin for *rainbow* as many iridium compounds are colorful. The same root from where we get the word *iris*.
- Aside from radioactive elements, Iridium is the rarest of all metals in the world, with Rhodium above it coming in a close second.
- Asteroids are particularly high in iridium metal.
- Corrosion resistant and able to take high temperatures, tiny bits of iridium are used in spark plug contacts.
- Ruthenium, Osmium and Iridium are dense, hard, wear resistant metals. Perfect for making fountain pen nibs.
- Plus Iridium and Osmium, sinking down at the very bottom center of the transition metals, are the most dense natural elements in the universe. Because their metallic structure is so incredibly, tightly packed, they are twice as heavy as lead. A 6” cube of iridium or osmium would weigh as much as an average adult.

e. **palladium (Pd)**

- Palladium, named after the asteroid *Pallas*, which was also discovered in 1803.
- Pallas was the Greek goddess of wisdom.
- It is shiny like its next door neighbor silver, but doesn’t tarnish like silver. It's also about 40 times more expensive than silver.
- Being a noble metal and a platinum group member, most Palladium is used in jewelry, surgical instruments and catalytic converters.

f. **platinum (Pt)**

- Platinum comes from the Spanish word *platina* meaning *silver* as it is often mistaken for silver.
- Platinum is a noble metal and the namesake of the Platinum group of noble metals.
- Platinum is about 200 times more expensive than silver and usually twice as expensive as gold.
- Platinum behaves much like gold—it is as corrosion and tarnish resistant as gold, they are equally rare.
- A very noble metal used in catalytic converters, jewelry and scientific instruments.
6. The Coin Group

Group 11 contains the world famous coin metals—metals generally used to make coin money. In low denomination coins, there is the risk that the value of the metal in the coin will exceed its face value. The US silver quarter is worth many times its face value, so quarters today are a copper coin with a nickel/copper plating that looks silvery but only costs about eight cents each to produce. Likewise many lower denomination coins are made of steel or zinc with a plating of copper. Interestingly, the coinage metals are also the three best conductors of electricity in the known universe, copper silver and gold.

a. copper (Cu)

- Copper from the island *Cyprus, Kypres*, where ancient copper mines were located.
- A soft, easily worked metal and one of the first and most important metals worked by man.
- The Statue of Liberty is covered with copper plates turning a green patina after exposure to moisture in the air.
- Add a little tin to copper and you get hard bronze—a main candidate for ancient weapons.
- Add a little zinc and you get corrosion resistant brass.
- At one time pure copper nuggets could be found just lying around on the ground.
- Electrical wiring is the primary use of copper and in alloys like bronze and brass...and of course to make coins.

b. silver (Ag)

- It is uncertain what Silver actually means but the symbol Ag probably comes from Latin *argentum* meaning shiny white and for which the country of Argentina was named.
- Ores rich in silver largely disappeared years ago from extensive mining and today silver is extracted as a by-product from mining other metals.
- With the advent of digital cameras, the demand for silver for making film stock has dropped 50% in just a few years.
- Sterling Silver contains 7.5% copper for strength.
- Electricity flows through silver more easily than it does through any other metal.
- Silver has been used for centuries for jewelry and tableware and of course, for coins.
c. gold (Au)

- Gold means *shinning yellow*. Au is the Latin *Aurum* - the golden color of the morning dawn.
- Gold is the most malleable and ductile metal in the world. A one ounce piece of gold is ductile enough to be drawn into a wire fifty miles long without ever breaking and beaten into a sheet nearly 100 feet square.
- Gold and silver are often included with the six noble metals.
- Since gold is nontoxic, gold foil is often eaten on cake or chocolate as a cake decoration.
- Gold is dense: a cubic foot of gold weighs more than ½ a ton.
- Gold is rare. The total amount of gold ever mined in human history would fit on a volleyball court cubed. Enough to build only 1/3 of the Washington monument.
- Jewelry is the single largest use of gold.
- One of the most ancient metals, gold has been used for centuries in jewelry, artwork and industry.

### Gold in 1 Year

In one year the total gold mined would:

- pay to launch one GPS satellite- $13 billion dollars
- fit in your living room
- weigh over 3 million pounds

Also...
- 15% will be used in devices that are eventually thrown away and the gold will never be recovered.
- 30% will be held by banks.
- 55% will be held privately as coins, jewelry and use in industry.
7. The Zinc-Link Group

The Zinc-link Group is the last stop before the poor metals. The Zinc group forms a link between the transition metals in back of them and the poor metals in front. In fact, some periodic tables will color them as if they are a transition metal and others as if they are a poor metal. They are softer than most transition metals and all three have low melting points...very similar to the poor metals to come. They are the Zinc-link metals.

a. zinc (Zn)

- A gray metal with a bluish tinge was known to the ancients but the meaning of the word Zinc has been lost to history.
- Rusting metals cost billions of dollars to repair and replace.
- The primary use for zinc is in electrically coating or galvanizing other metals to prevent them from rusting.
- Zinc and copper are alloyed to make brass. Zinc and copper can work together to produce electricity...all you need is a little acid.
- Zinc is an essential micronutrient for humans. Too much and it’s a poison or too little can cause mental and physical health problems. A healthy adult has about 2.5 grams of zinc in their body.

b. cadmium (Cd)

- Cadmium is mostly found in zinc ores including calamine which cadmium was named after.
- From the same ore, cadmium and zinc melt at different temperatures making a way of separating the metals.
- The most important use of cadmium is in the production of nickel-cadmium "nicad" rechargeable batteries.
- Care must be taken when handling cadmium as cadmium is a known poison.
- Cadmium was also a popular compound in brightly colored paints, especially cadmium yellow and cadmium red. Cadmium yellow was a favorite pigment of Vincent Van Gogh and most of his paintings have a distinctive yellow tint to them.

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**Easy Zinc**

All that is needed to free zinc from the ores is to simply heat the ore. The zinc comes right out but unfortunately sublimes, turning immediately into a gas not a liquid. So the gas must be captured in a closed container where it condenses back into a solid. Tubal-Cain must have been familiar with this process as he made brass, a combination of zinc and copper.
c. mercury (Hg)

- Hg is for the Greek hydrargyrum. Hydrargyrum (hig-ahr-DARE-juh-rum) means watery silver. You can see it in the word: “Hydra Argentum” It’s often called quick silver...silver that runs.
- According to the chemistry division of the Los Alamos National laboratories, refined mercury has been found inside Egyptian tombs dating to 1500 B.C.
- Five metal elements are liquid around room temperature: francium melts at 81°F, caesium at 83°F, gallium melts in your hand at 86°F and at rubidium 102°F but only mercury is liquid at the standard room temperature of 70°F.
- Mercury is dense-lead and iron float in mercury.
- Heating the ore cinnabar releases mercury as a vapor. As the vapor cools the mercury is captured as a liquid.
- Mercury is used in thermometers, in tooth fillings and in the separation process of making chlorine gas.
- Mercury and most of its compounds are extremely toxic. As a result, nearly all uses of mercury are slowly being phased out.

Discussion Questions
- Can you explain why this group is called the "transition metals?"

-Discuss what alloys are and the benefit they have over elemental metals.

-Discuss the problem when the "melt value" of a coin exceeds the "face value."
Quiz Sixteen - Transition Metals

1. Chromium plus iron makes stainless steel. The minimum amount of chromium needed is
   a) 5%
   b) 11%
   c) 50%
   d) 80%

2. The primary use of zinc is
   a) Semiconductor material
   b) Making artificial limbs
   c) Coins
   d) Preventing rust

3. 90% of all metal refined in the world is
   a) Thallium
   b) Gold
   c) Vanadium
   d) Iron
   e) Niobium

4. A US nickel coin is made of.
   a) 75% copper 25% nickel
   b) 100% nickel

5. The transition group most like the noble gases is the
   a) Magnetic group
   b) Zinc-link group
   c) Coin group
   d) Platinum group

6. Niobium is a good metal for earrings.
   a) True
   b) False

7. A catalytic converter works by
   a) Catalyzing poor metals into noble platinum metals
   b) Converting toxic substances into non-toxic ones
   c) Converting positive cations into negative anions

8. The most electrically conductive element metal is
   a) Gold
   b) Silver
   c) Platinum
   d) Aluminum

9. Why do we call one group "The zinc-link group"?
   a) They link to make more compounds than any other group
   b) Zink is the linking element that makes the three useful in industry
   c) They have properties of the elements behind and in front of them and thus form a link between them

10. Elements used in dentistry include
    a) Silver, fluorine, and mercury
    b) Lead, silver, and mercury
    c) Silver, gold, and platinum
    d) Fluorine, chlorine, and bromine

   **Answers are on page 115**
17. Rare Earths & Radioactives

**Rare Earth Elements**

1. **The Black Sheep of the Periodic Table**
   The next family is probably the most obscure group of all the elements. "Black Sheep" is actually quite fitting since many were discovered from the black ore called Gadolinite and are currently mined from another blackish ore called Monazite.

   1. All 15 elements are very, very similar and separating them out took a 100 year long, tedious, exasperating process.

   2. The Rare Earth Elements (REE) were thought to be rare when first discovered. They aren’t. In fact Cerium, lanthanum and neodymium are more abundant than lead, gold or silver. But they aren’t concentrated in big enough quantities to be readily economical.

   3. Rare Earth Elements don’t add electrons to their outer shell, which would make their differences more noticeable, like we see in the Main Group Elements. Instead, their electrons are added deep into the third to last shell. So the outward differences between them is very subtle and makes them difficult to separate.

2. **REE Periodic Table Placement**
   1. They are also called the Lanthanoid metals because the element lanthanum heads this reclusive group.

   2. To save space, nearly every periodic table you see moves the rare earth metals down to the bottom, like a footnote to the Periodic Table.

3. **Use in Modern Technology**
   1. Powerful and small rare earth magnets drive the tiny speakers in earphones and cell phones. Every computer hard drive uses powerful rare earth magnets for the motor and actuator arms.

   2. Barcode scanners at the grocery store depend on REE magnets.

   3. Every hybrid car uses about 50 lbs of rare earth metals in the electric motor magnets and brake system.

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“"The rare earth elements perplex us in our researches, baffle us in our speculations and haunt us in our very dreams. They stretch like an unknown sea before us, mocking, mystifying and murmuring strange revelations and possibilities.”

-William Crookes
4. Europium with Yttrium makes the red color and Terbium makes the green color in every flat screen monitor.

5. Wind turbines can use two tons of rare earth magnets in the generator on top of the turbine.

6. It's estimated that 25% of all new technologies use these rare earth elements. And the demand is increasing.

4. China control of REE

Nearly 100% of the world's REE output comes from and is controlled by China and from only one mine, the Bayan Obo in Inner Mongolia. This new demand has strained supply, and there is growing concern that the world may soon face a shortage of the materials.

5. The Rare Earth Elements

a. Lanthanum (La)
- Lanthanum is Greek meaning *I am hidden* which pretty well sums up all the rare earth metals.
- All the rare earth elements can be found in the blackish ore called Monazite.
- Lighter flints, glass coatings & movie lights are uses for lanthanum.

b. Cerium (Ce)
- Cerium [SEER-ce-um] named after the asteroid *Ceres* discovered around the same time, which, it turns out, is much more like a very small planet than an asteroid.
- Cerium is the most abundant Rare Earth.
- Lighter flints, glass coatings & movie lights are uses for cerium.

c. Praseodymium (Pr)
- Praseodymium [praise-ee-oh-DIM-ceum] Compounds of Praseodymium were similar to lanthanum, of course, but with a greenish tint, thus it means *Green twin*.
- Lighter flints, glass coatings & movie lights are uses for praseodymium.

Did you happen to see the black sheep puppet in each of the REE’s on screen?
d. Neodymium (Nd)

- Neodymium [neo-DIM-eum] was discovered as a result of separating out praseodymium and was named the new twin.
- Neodymium magnets are incredibly strong. Two 2" square neodymium magnets can fly together with such force that it will break bones. They are the strongest and least expensive rare earth magnets.

e. Promethium (Pm)

- Promethium [pruh-MEETH-eum] The only radioactive rare earth element and the last to be discovered.
- In Greek mythology Promethius gives fire to mortals by stealing it from the gods. The discovery was so difficult the scientists felt like they too were stealing the element from nature.
- Self-luminance watches and future atomic batteries are typical uses.

f. Samarium (Sm)

- Samarium [Suh-MARY-um] was named after a virtually unknown person, the Chief of Staff of the Russian Corps of Mining Engineers Vasil Samarsky-Bykhovets. The first element named after a person.
- Samarium mixed with cobalt also makes strong but very expensive magnets.
- Lighter flints, strong magnets and special glass are uses for samarium.

Those are the first six and most useful of the REEs. The remaining Rare Earth Elements have very few applications but we will list the main use. Their real value probably remains at sometime in the future.4

g. Europium (Eu)

- Europium was named after the continent of Europe.
- Brilliant red colors in your monitor and television screen.

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h. **Gadolinium (Gd)**

- Gadolinium [gad-uh-LYNN-eeum] was named after another fairly unknown person, the Finnish geologist Johan Gadolin who discovered the very first rare earth element.
- Gadolinium is given to patients to highlight tumors when seen with x-rays.

i. **Terbium (Tb)**

- Terbium[TERB-eeum] is the second element named after that famous little mine in *Ytterby Sweden*.
- Green phosphors in television screens in the main use.

j. **Dysprosium (Dy)**

- Dysprosium [dis-PROSE-eeum] was another rare earth so difficult to separate out that its discoverer named it *hard to find* in Greek.
- This element can preserve other magnets at high temperatures

k. **Holmium (Ho)**

- Holmium is Latin for *Stockholm*, the home town of its discoverer.
- High intensity lasers in the main use.

l. **Erbium (Er)**

- Erbium is the third element named after that famous little mine in *Ytterby Sweden* where it was discovered.
- Fiber optics have a stronger signal with erbium.

m. **Thulium (Tm)**

- Thulium [THEW-leeum] is named after the mythological island of *Thule* the northern most island of the world. Thulium’s discoverer believed Thule Island to be an ancient name for his homeland of Scandinavia.
- "Possibly the most useless element on the periodic table." -John Emsley\(^5\)

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n. Ytterbium (Yb)
- Ytterbium [it-TURB-ceum] is the fourth element named after that famous little mine in Ytterby Sweden where it was discovered.
- Specialty lasers are the specialty of ytterbium.

o. Lutetium (Lu)
- Lutetium [lew-TEESH-ceum] is named after Lutetia the Latin name for the city of Paris.
- Lutetium is generally the most expensive natural element, often around $6000 oz and extremely rare since nobody produces it because nobody uses much of it.
- For people who collect samples of the periodic table of the elements, lutetium is usually the last one they ever get if they ever get it at all.

Radioactive Elements

6. Radioactive
- After Bismuth, every element is so heavy, that it can't hold together and it falls apart at the atomic level. It becomes radioactive.
- Some of the radioactive elements are quite useful in industry, many of them existed only as a single atom in a laboratory experiment...then disappeared forever.
- Most arrangements of the periodic table move the radioactives and the Rare Earth Elements at the bottom to save room.

a. Polonium (Po)
- Polonium was named by Marie Curie for her homeland of Poland.
- Polonium was used as the trigger in the first nuclear bomb test. Today, polonium has almost no industrial uses.
- Polonium is one of the deadliest substances known. If ingested, polonium is at least a billion times more toxic than cyanide.
b. Astatine (At)
- An incredibly unstable and rare element. There is an estimated 1 teaspoon of Astatine in the earth’s crust.
- Astatine is Greek for *unstable*.

c. Radon (Rn)
- Radon is named after Marie Curie’s *Radium*.
- A colorless, odorless gas produced through the natural decay of uranium in granite.


d. Francium (Fr)
- Francium named for *France* where it was discovered. Gallium was also named for this country
- Francium is so short lived that no weighable quantity of Francium has ever been prepared or isolated. Only about 300,000 atoms of Francium have ever been produced.

e. Radium (Ra)
- Radium is Latin for *ray* named by the discoverer Marie Curie who was awarded the Nobel prize in Chemistry for her work.
- The annual production of Radium is less than two pounds per year...actually its closer to about three ounces.

f. Actinium (Ac)
- Radium is the Greek word for ray and Actinium is named for the Latin word for *ray*.
- A nasty, unstable element, quite possibly the most dangerous element on the Periodic Table.
- Due to its intense radioactivity, actinium glows in the dark with a pale blue light.

g. Thorium (Th)
- Named after *Thor*, the Scandinavian god of thunder though nobody really knows why.
- We encounter thorium as a component in many gas light mantles.
h. **Protactinium (Pa)**

- Protactinium (*pro-tact-TIN-eeum*) meaning *first ray...proto actinium* since it first decays into actinium.
- Sixty tons of processed radioactive waste gives you less than five ounces of protactinium.
- There are currently no uses for this element outside of scientific research.

i. **Uranium (U)**

- Uranium is named after the planet *Uranus* which was discovered 8 years earlier.
- Uranium is the last stop for naturally occurring elements, Number 92. After Uranium, all elements are manmade in laboratories and are called “TransUranium Elements” meaning “after Uranium”.
- Only 1% of uranium ores contain the famous isotope Uranium-235 and that’s the one you need to run nuclear power plants and make nuclear weapons.
- Depleted uranium is very heavy, as you can imagine, and is used to make very dense armor penetrating projectiles.

j. **Neptunium (Np)**

- Neptunium is named after the planet *Neptune*. Neptunium is used only in research labs.
k. **Plutonium (Pu)**
- Plutonium was the third element in a row named after a planet—but in this case Pluto is now called a dwarf planet.
- Like Uranium, plutonium is used for nuclear power and atomic weapons. The first nuclear test and the second bomb dropped on Japan both had cores of Plutonium-239.
- Plutonium generators help power space probes and other space instruments.
- If you had a golf ball of plutonium in your hand, you’d need to have several layers of lead-lined gloves on for protection. The ball would be incredibly dense and hard. Cutting it, even with a saw, would be nearly impossible. It would weigh over 2 pounds and would be very hot in your hand just from the sheer amount of radiation decaying out of the material.\(^6\)

l. **Americium (Am)**
- Americium named for America where is was created just as Europium was named for Europe.
- Some pronounce it amr-ISh-ceeum.
- The most common use is in smoke alarms in your house. Thorium in mantles and Americium in smoke detectors are the only radioactive elements you can buy in your grocery store.

m. **Curium (Cm)**
- Curium named in honor of Marie and Pierre Curie.
- Like plutonium, curium decays rapidly and thus, generates a lot of heat.
- Normal satellites use solar panels to generate their needed electricity. But for space probes that travel far from the sun, solar panels don’t work and curium is often placed in a device called a radioisotope thermoelectric generator. The intense heat from curium's radioactive decay is used to generate the necessary onboard electricity.

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n. Berkelium (Bk)

- Berkelium (*ber-KEE-lee-um*) named for the University of California at Berkley where it was created.
- Like several of the other transuranium elements, the use for Berkelium remains a mystery like a treasure waiting to be unlocked in the future.

o. Californium (Cf)

- Californium is also named from the *University of California* at Berkeley.
- Used in chemotherapy and a few specialized applications in industry.
- In forty years less than ten grams of Californium have been made. The cost of Californium is about $10 million per gram.

p. Einsteinium (Es)

- The most famous scientist of all time, *Albert Einstein*, probably deserves to have an element named after him.
- Unfortunately this element decays away completely in a few months, is probably poisonous and has no known applications.

q. Fermium (Fm)

- Fermium is named in honor of *Enrico Fermi* who developed the first nuclear reactor and quantum theory.
- Making Fermium is pretty futile. No sooner does an atom form in a nuclear reactor, than it disappears.
- There are no known applications since there is no piece of Fermium to experiment with.

►Transfermium Radioactive Elements

Here is the Twilight Zone for elements. Beyond this point elements are known as transfermium elements meaning *beyond Fermium*. Only a few atoms ever existed in nuclear accelerators and none survived longer than a few seconds before decaying into atomic debris. In reality, finding new transfermium elements is largely a byproduct of an effort to discover things about the atomic nucleus in particle accelerators.

There is a constant race to be the first to make the next element and name it. The rivalry is between the facilities in Berkeley, Russia, Japan and Germany
a. Mendelevium (Md)
- Mendelevium named for Dimitri Mendeleev, the Father of the Periodic Table. The original batch of seventeen atoms managed to stay around for all of 78 minutes before breaking down into simpler elements.

b. Nobelium (No)
- Nobelium is named for Alfred Nobel the Swedish chemist and founder of the Nobel Prize. They manufactured nobelium by taking curium, with a proton weight of ninety-six protons and bombarded it with carbon with a proton weight of six. 96 plus 6 is a proton weight of 102 protons.

c. Lawrencium (Lr)
- Named for Ernest Lawrence, the inventor of the atom smasher or cyclotron which produced all these transactinide elements. This is the last element that lasted longer than 1 hour. From here, the elements get pretty sketchy and the names are fiercely contested over.

d. Rutherfordium (Rf)
- In 1960 an element naming war broke out between two laboratories starting with this element, number 104...and it took 37 years to resolve it. Both Berkeley and Dubna claimed priority in creating the elements and suggested their own names. Finally in 1997, after a lot of heated talk and horse trading, at the 39th IUPAC General Assembly in Geneva Switzerland, it was agreed that: Element 104 is Rutherfordium named after Ernest Rutherford.

e. Dubnium (Db)
- Dubnium was named for the Research facility in Dubna, Russia

f. Seaborgium (Sg)
- Named for Glenn Seaborg who engineered the production of an incredible ten periodic elements: plutonium, americium, curium, berkelium, californium, einsteinium, fermium, mendelevium, nobelium and this element which was named in his honor while he was still alive. Seaborg was a Nobel laureate, the author of more than 50 books and 500 journal articles.
g. Bohrium (Bh)

- Bohrium named for *Niels Bohr* the Danish physicist who developed the modern theory of atomic structure.

h. Hassium (Hs)

- A third laboratory for creating elements steps in- The Institute for Heavy Ion Research and is first in creating this element and names it after the Latin word for the state in Germany where the research center is located- *Hassium, Germany.*

i. Meitnerium (Mt)

- Named in honor of *Lise Meitner,*(*leezuh MITE-nur*) who was part of the team that discovered nuclear fission, an achievement for which her colleague Otto Hahn was awarded the Nobel Prize, but
- without Meitner.
- Meitner is often mentioned as one of the most glaring examples of scientific achievement overlooked by the Nobel committee. A later study concluded that Meitner's omission from the prize was "a rare instance in which personal negative opinions led to the exclusion of a deserving scientist."
- But Lise Meitner gets the last laugh. Over 800 people have a Nobel medallion. About a dozen people can or ever will have an element named after them and Lise Meitner is one of them.

j. Darmstadtium (Ds)

- Darmstadtium (*darm-SHTAT-eeum*) once again the German Institute beats the competition and names this element after their city - Darmstadt Germany. Three accelerators have an element named after itself: Berkelium, Dubnium and now Darmstadtium.

k. Roentgenium (Rg)

- (*rent-GEN-eeum*) Named in honour of Wilhelm Conrad Röntgen, who produced and detected x-rays.

l. Copernicium (Cn)

- The German team created 112. In 2010, on Copernicus’ 537th birthday PAC officially accepted the proposed name for this element.
m. Ununtrium (113)
   - The joint venture between the Russians & the Americans may have primacy but a lab in Japan has joined in and might have a prior claim.

n. Ununquadium (114)
   - Dubna Russian has this one locked up.

o. Ununpentium (115)
   - The joint venture between the Russians & the Americans probably will win the race to 115.

p. Ununhexium (116)
   - The Russian lab has claim to 116 for constructing several atoms of Ununhexium in 2005.

q. Ununseptium (117)
   - The Dubna Russian Lab along with scientists from Berkley appear to be the winners in creating 117 but Germany is making attempts to do an end run around the joint-venture team and may win the prize!

r. Ununoctium (118)
   - Only 3 atoms of element 118 have been detected in a race between Berkley and Russia for primacy.
7. Daily Use of the Periodic Table of the Elements

1. Easily Find Possible Substitutes
   Since elements with similar properties hang around each other on the periodic table, you can substitute neighboring elements in your experiment to try and find improved versions of your product. Glass manufacturers improved the toughness of television glass by substituting potassium for sodium as they were periodic neighbors.

2. Simplify Choices
   Since you know the noble gas rule of octets, you can try and combine elements that want to loan electrons with those that want to borrow electrons. If they care messing with garlic breath Tellurium, in column 16, it will probably combine with hydrogen in the form of two hydrogens with one tellurium—H₂Te—because that's how the other elements in column 16 combine with hydrogen. Oxygen makes water (H₂O), Sulfur makes Hydrogen Sulfide (H₂S) and Selenium makes Hydrogen Selenide (H₂Se).

3. Oddly Unstable
   It has not escaped the notice of chemists that elements with even atomic numbers, 26, 44, 76, are more stable and also more abundant than the odd numbered elements next to them.

4. Knight’s Move
   They have also noticed similarities in elements with the so called Knight’s move...one down and two over. They aren't in the same group, but they do have similar properties. Like Zinc and Tin. Both alloy to copper to form brass and bronze, both are fairly nontoxic and both can form alloys with iron to prevent rust.

5. Triads
   Likewise scientists have known for years about triads. In a set of three elements whose chemical properties were similar, the atomic weight of the second member of the "triad" was almost exactly the average of the atomic weights of the first and third elements. This striking observation has attracted attention, as yet again, it seems to show an odd numerical law governing chemical behavior.

Discussion Questions
- What are some of the common properties of the Rare Earth Elements?
- Why were they so difficult to separate from one another?
- What is the relationship between lanthanides and color television?
- Can you define the term radioactive?
- Discuss the process by which new elements are created in laboratories. Are these "real elements" since they are manmade and exist for only a fraction of a second?
Quiz Seventeen - Rare Earths & Radioactives

1. Some of the smallest and strongest magnets depend on rare earth elements.
   a) True
   b) False

2. Gamma radiation is just like x-rays but higher energy and more penetrating.
   a) True
   b) False

3. Rare Earth Elements are also called
   a) Alkaline earth metals
   b) Actinoides
   c) Lanthanaoides
   d) Radioactives

4. Color television depends on rare earth elements.
   a) True
   b) False

5. Rare earth elements are all very rare elements.
   a) True
   b) False

6. The time it takes a radioactive element to lose half of its radioactivity is called the half-life.
   a) True
   b) False

7. Radioactive means
   a) A heavy element is decaying into a lighter element
   b) A nucleus is losing protons
   c) Losing beta particles from the nucleus
   d) All of the above

8. The two radioactive elements you can buy at the grocery store are
   a) Americium and thorium
   b) Radium & actinium
   c) Uranium & plutonium
   d) You can't buy any radioactive elements at the store.

9. A common use for rare earth elements is
   a) Lighter flints
   b) High intensity movie lights
   c) Color television reds and greens
   d) Strong magnets
   e) All of the above

10. Which is a common use for the periodic table?
    a) Finding similar elements to do experiments with.
    b) Determining what elements might combine with other elements.
    c) Looking up element properties.
    d) All of the above

Answers are on page 115
PART 4 - THE FUTURE OF CHEMISTRY

18. The Future of Chemistry - part 1

At the turn of the century, who would have predicted that man would walk on the moon and that the walk would last only 2 ½ hours? Or that each of us would have a pocket-size, personal, mobile telephone that we would use to type messages to each other? Or that splitting the atom would release a surprising amount of energy?

Power from the Atom

1. Nuclear Power - Fission
   A. Controlled Reactions

Sustained and controlled nuclear reactions make nuclear power possible and generate about 15% of the world’s electricity.

• Fission
  Fission means *to split or cleave*. It is related to the word *fissure*. Fission cleaves atoms when they snap apart, they release a tiny, but significant, amount of energy that bound the two parts together.

• Uranium 235
  Uranium has three isotopes 238, 235 and U-234. Over 99% of all Uranium in U-238 and only .711% of all Uranium is U-235. U-235 is unique as the only natural isotope that will accept a spare neutron and split into lighter elements. Other elements will do, but not as abundant as U-235.

• Chain Reaction
  Uranium isotope number 235 will accept the neutron and immediately split into lighter elements, release the binding energy that held them together, and of equal importance, will throw off two neutrons of its own. These neutrons will in turn strike other U-235 atoms which split, release energy and throw off their own neutrons. This is fission.

• Glorified Steam Engine
  Boiling water produces steam which expands and turns a generator which makes electricity. U-235 splits and gives off lots of energy-heat. This boils the water that turns the generator.

• Other Uses
  Small nuclear engines are used to power submarines, remote climate stations and space probes.

Natural vs. Artificial Nuclear Reactions

Natural Fission
When the nucleus of a heavy atom is unstable, it will decay into simpler elements by either ejecting a helium atom (alpha particle), or changing a neutron into a proton and giving off an electron (beta decay). The process is not self-sustaining and does not result in chain reactions.

Natural Fusion
The stars are thought to be fueled by natural fusion.

Artificial Fission
Nuclear reactors and atomic weapons force fission reactions at a greatly accelerated rate than normal.

Artificial Fusion
Tokomaks and lasers and Thermonuclear weapons can create man-made fusion for short periods of time.
B. Uncontrolled Reaction

"Uncontrolled" is a bit misleading as nuclear weapons are actually highly engineered. The difference is the speed of decay or rate at which the nucleus splits. Over a long period of time gives heat for power. In a moment of time gives you a bomb.

- **Minimum Requirements**

  There are some pretty technical details to make a sustained nuclear reaction happen. The gun-type device is the simplest, but has least yield. Fire a hollow chunk of U-235 at a spiked piece of U-235 and it could happen. Of course getting the enriched uranium or plutonium will require that you show at least two pieces of I.D.

- **Little Boy and Fat Man**

  "Little Boy" was the codename of the atomic bomb dropped over Hiroshima on August 6, 1945 by the Boeing B-29 Superfortress *Enola Gay*. It was a gun-type device using uranium 235. Of the 140 lbs of U-235 in the device, *less than one ounce was converted into energy* before the device destroyed itself. Yield was about 15,000 tons of TNT.

  "Fat Man" was the codename for the atomic bomb dropped over Nagasaki, Japan. It was dropped three days after "Little Boy" by the B-29 bomber *Bockscar*. It was an implosion device using plutonium-239. Of the 14 lbs. of plutonium in the device, *again less than 1 ounce was converted into energy* before the bomb destroyed itself. Yield was about 21,000 tons of TNT.

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2. Nuclear Power - Fusion

A. Uncontrolled Reactions

- **Fusion**

  Fusion means *to fuse or melt*. It means to melt two things together.

- **Repulsive Forces**

  At the center of each nuclei, a very "strong nuclear force" keeps the positive protons stuck together. But it only works in very short distances. Outside the nucleus, the electromagnetic forces of the positive protons completely repel each other and the two positively charged nuclei *absolutely will not get anywhere near each other. period*. Well...unless you heat them to 50 million degrees. Then they can be persuaded.
Cold Fusion
Cold fusion has largely been relegated to a few fringe researchers since 1989. Most scientists believe there is little hope that cold fusion is attainable in the near or fairly near future. Most countries have stopped funding for further research. The American Chemical Society has included a symposium on cold fusion at their annual meeting just to keep abreast of what is going on in the arena. Otherwise it seems to have been relegated to the realm of science fiction and added to the science wish list along with anti-gravity and faster than light travel.

Sounded Good
Several universities were experimenting with so-called “Bubble fusion” or “Sonofusion” using high intensity sound waves in water around a single bubble to begin the fusion process.

By forcing water bubbles to expand and suddenly collapse using sound waves, a large amount of light and heat was generated.

The joke around physics labs was...”So, no fusion”...

...because they could not produce sustained, repeatable heat...

...and if you want to sell an idea in science, it has to be repeatable.

• got 50 million degrees?
You don’t just generate this kind of heat in your toaster. You need the sun or the middle of an atomic explosion. Since dragging the sun to us is prohibitively expensive and environmentally questionable, we use atomic explosions. We put fusion material inside a fission bomb and the results are apocalyptic.

• Thermonuclear Bombs
The results from a classic atomic bomb are measured in thousands of tons of TNT. The results from thermonuclear bombs are measured in millions of tons of TNT. These are also called Hydrogen Bombs.

B. Controlled Reactions

• Lasers might do it
High energy lasers can generate very, very high temperatures. Almost like a "microsun" focused on the heat of a pin. The trick is getting the whole experiment to give more energy than you put into it.

• Tokamaks might do it
Instead of a laser, you build a donut-shaped magnetic coil where hydrogen fuel is suspended in a magnetic coil and superheated to 50 million degrees.

• Advantages
There is almost no radioactive material (though there is some) and minimal risk of a runaway meltdown as the temperatures needed to sustain fusion immediately cease if something goes wrong. The primary fuel is hydrogen and there’s plenty of water to supply hydrogen. One bath full of water would supply the total energy needs of a single person for 30 years.

• Disadvantages
Research is slow, very expensive and has produced no tangible results. This spells doom in most research arenas. Unless some real breakthroughs occur in the next decade, fusion research may have to wait another century before it is energetically funded again.
3. Island of Stability

A. Smashing atoms

The term "atom smasher" was popular a few years ago before smaller, subatomic particles were discovered. It is fairly routine to disassemble atoms and the real research is in smashing subatomic particles.

B. Cyclotrons & New Elements

By accelerating two elements and colliding them together, you can create a couple of atoms of a new, heavy elements on the periodic table. Plutonium with 94 protons plus calcium with 20 protons will give you an element with 114 protons.

- Quantities of heavy element

Some useful heavy elements, like Americium are the natural by-product of nuclear reactors. One ton of spent nuclear fuel produces about 3 ounces of Americium. Californium is probably the heaviest element that is produced in any measurable, useful quantity—about .02 ounces per year.

- Gone!

After Californium, these heavy elements are almost impossible to generate in any quantity and they have very short half-lives...days at most, then they are gone.

C. The Elusive Island

There is a theoretical possibility that some very heavy elements will stick around for long enough to actually be useful. Trends in the Periodic Table suggest that elements 120 or 126 might be on that island. 114 was supposed to be one of these magic numbers, but it quickly decayed away in a fraction of a second.

There is no active funding just to try and find this island. Making new elements is usually a byproduct of doing other particle research.

Discussion Questions

- Nuclear power is used to boil water and make steam. What are other ways the same thing can be accomplished?

- How is hydroelectric power different than nuclear power? How is it the same?

- In light of research done so far, do you think we should continue to pursue fusion research or spend the money developing other areas of potential energy?
1. The first atomic bomb was dropped on the city of Nagasaki.
   a) True  
   b) False  

2. Plutonium-239 is the unique natural isotope that can sustain fusion and is in natural abundance.
   a) True  
   b) False  

3. The Island of Stability was discovered and verified by the discovery of
   a) Element 114  
   b) Element 118  
   c) The strong nuclear force  
   d) At has not been discovered.  

4. The main difference between a nuclear plant and an oil or coal-fired plant is
   a) The size of the generator  
   b) The fuel  
   c) The shape of the generator  
   d) The disposal of waste  

5. Atomic nuclei repel each other because they are all positively charged.
   a) True  
   b) False  

6. If you can get hydrogen nuclei close enough, the strong nuclear force will overcome their natural repulsion and they will fuse.
   a) True  
   b) False  

7. To prevent overheating, control rods
   a) Move extra uranium out of the way  
   b) Create a barrier between different parts of the fuel  
   c) Absorb excess neutrons  

8. A tokamak is
   a) A donut shaped machine confining hydrogen plasma by magnetic fields.  
   b) A nuclear fission machine generating sufficient temperatures to ionize heavy elements.  
   c) A long linear-type accelerator designed to exponentially increase the power from a laser.  

9. Nuclear power plants produce energy through
   a) Artificial fusion.  
   b) Artificial fission  
   c) Beta decay  

10. Uranium-235 splits when the nucleus is hit by
    a) A proton  
    b) A neutron  
    c) An electron  

Answers are on page 115
19. The Future of Chemistry /part 2

**1. Supercolliders**

**A. Large Hadron Collider**

The Large Hadron Collider (LHC) is the world's largest and highest-energy particle accelerator. The hope is to make a machine massive enough and powerful enough to drill into the deepest parts of the atom and discover the deepest possible secrets of physics and nature.

- **Hadron**
  A hadron is one of the heavy parts in the nucleus—protons and neutrons are hadrons. *Hadron* means *large or heavy* and this machine collides hadrons—protons and neutrons.

- **Hermit Crab Collider**
  The LHC was relatively cheap...7 billion dollars. That's because the LHC actually moved into the old facility formerly created for another accelerator project. The project was done and the LHC moved in.

- **CERN**
  CERN is the French *Conseil Européen pour la Recherche Nucléaire* (European Council for Nuclear Research). CERN is an international science organization whose purpose is to fund and provide the particle accelerators needed for physics research. CERN is also the birthplace of the World Wide Web and the future replacement for the Web called The Grid. Other colliders around the world are also racing to find some of these answers, but the LHC is the largest.

World Wide Web & The Grid

The web was the first, tangible, publically recognizable benefit from collider work. New super colliders have over 40,000 gigabytes of information pouring out of them every day, so a new network has developed called The GRID. Running at speeds 10,000 times faster than our typical high speed internet connections, the Grid could soon make today's internet completely obsolete.
B. How it All Fits...so far

- **Matter**
  All matter is made of small particles called atoms.

- **The Atom**
  The atom is made of electrons that cloud around a heavy core called the Nucleus.

- **The Nucleus**
  The nucleus is made of two subatomic particles called protons and electrons.

- **Protons & electrons**
  Protons and electrons are made of smaller particles called Quarks.

- **Quarks & electrons**
  Quarks & electrons seem to be the end...but that's far from certain.

- **Other particles**
  There are other particles that supposedly carry the force of things (gravity, light photons, nuclear force) and proposed particles to explain the unexplained...but that's physics.

C. Quarks

Quarks were named by Murry Gell-mann because he thought it sounded like the noise a duck makes. The six "quark flavors" are up, down, top, bottom, strange and charm.

D. The God Particle

There is no known particle to explain where the mass of everything resides. Together all the particles have mass. Separated, they weigh nothing at all. It is a great mystery in physics. CERN hopes the LHC will find what is called "The Higgs Boson" or more playfully, "The God Particle" so called because only God can create matter.

E. Hard Sell for Supercolliders

Supercolliders are the playground of theoretical physics. But unless a real result or payback of some kind is discovered, future funding seems unlikely. The Superconducting Super Collider in Texas was a case in point.

A case can be made that there are three main factors that drive countries to spend big money on projects:

1) **War or Conquest**
2) **Economic Gain**
3) **To please God or Kings.**

Unless your project can reach one of these goals, for better or worse, funding for your project seems doubtful.
2. **Nanotechnology**

Nanotechnology is study of manipulating matter on an atomic and molecular scale.

### A. Nanoparticles

When you get things really small, they behave oddly. This is one of the reasons quantum mechanics was developed—to give rules explaining the behavior of matter at the atom level. Some things change color, become electrically conductive, or lose electrical conductivity or transfer heat better, etc.

Here are some of the areas impacted by nanotechnology:

- New clothes that repel all stains
- New cosmetics that are more effective in repelling UV light.
- O.L.E.D (organic light emitting diodes) that are thin as paper but give off bright, vibrant light. All future televisions and monitor displays (if they are even called that) will likely be from O.L.E.D. technology.
- Nanocommunication devices that are powered by the energy absorbed by nanograin and become an integral part of your clothes.
- Nanorobots that can clean bacteria and repair blood vessels.
- Electronic textiles to mimic invisibility.

### B. Easier Sell for Nanophysics

There are real, tangible "return-on-investment" potentials on the fairly near horizon for nanotechnology. Because of this, investment dollars are much easier to come by for those in the nanotechnology field.

3. **Shear Thickening Fluids**

Related to nanotechnology, a shear thickening fluid is a material that instantly thickens when tension or stress is applied. Also called "Non-Newtonian Fluids."

4. **Superfluids**

A superfluid is a fluid that seems to flow without friction. As a result, they will crawl up the sides of a container in a 1-atom thick layer. They seep through what appears to be solid glass. Supercold helium behaves in this way.

5. **Superconductors**

At very cold temperatures, -320° F, some rare earth alloys have no electrical resistance. This means a magnet will levitate indefinitely with no friction loss. The potential for nearly limitless electrical storage or transmission is intriguing.
6. Political Ecology

The "Green Movement" is something of a fad of the 21st century supported by a political philosophy called "Green Politics." Supporters of green politics, called Greens, share many ideas with the ecology, conservation, environmentalism, the feminist movement, the peace movement, population control, civil liberties, social justice and nonviolence. Most of the leaders in the green movement have global goals seeking a united Green Government and Green Religion that replaces national sovereignty and traditional religion, which many see as a major deterrence to the goals and definitions of "sustainable development."

Regardless of your opinion of the politics and spoken or unspoken agendas of the Green Movement, it is clear that political ecology will continue to have an impact on the future of chemistry

- It will continue to shape where the funding for future chemistry research will go.
- It will impact what will be considered important in any future work related to this field.
7. The Pessimists

Many new technologies generate visions of what might happen if the technology goes out of our control.

- Run-away nanorobots.
- Biological cures that turn into biological plagues.
- *The singularity* where machines become self-aware and are able to create machines better than themselves...and perceive mankind as the global threat.
- There could be a leveling off of technological advancement.
- Wars or ecological disasters beyond our control sometimes happen.
- Societies often spend money on things that don't seem to be too future oriented. For example,
  - $500 million dollars on ringtones for their cell phones
  - $4 billion dollars on energy drinks
  - $11 billion dollars at amusement parks
  - $11 billion dollars on bottled water.

_Sometimes we Spend Well_

-from Ian Sample

*guardian.co.uk*

*Sept 2009*

"The Large Hadron Collider might well be the last machine of its kind that ever gets built. But the fact that it was built is extremely heartening. This is a machine so large it takes hours to jog around. It cost billions of dollars and took many years to build. That governments were willing to pay for it, with no idea what it might or might not find, speaks volumes about the price society is often willing to pay to understand more about our place in the universe."
8. The Optimists

Others see technology as having an overall benefit to society. Where the alchemists failed, modern technology has produced a higher standard of living for more people than at any other time in history.

Futurist Ray Kurzweil sees a positive future especially regarding the singularity. If we create a machine capable of making a better machine than itself, it may be the last invention men ever have to make.

“The future holds for them.

“With bold telescopes I survey the old and newly discovered stars and planets and when with excellent microscopes I discern the inimitable subtlety of nature’s curious workmanship; and when, in a word, by the help of anatomical knives, and the light of chemical furnaces, I study the book of nature, I find myself oftentimes reduced to exclaim with the Psalmist, How manifold are Thy works, O Lord! in wisdom hast Thou made them all.”

-Robert Boyle, Father of Chemistry

Discussion Questions

- Do you see technology as having an overall benefit or detriment to society? What have been the benefits? What have been the detriments?

- What are the possible good things of the Green Movement? What are the possible bad things? Is there potential conflict between the Green agenda and Biblical Christianity?

- What does the Bible say about the future? Is it overall positive or negative?
Quiz Nineteen - Future of Chemistry/part 2

1. Supercolliders try to find how the universe is constructed and how it works.
   a) True
   b) False

2. A nanometer is about 100,000 times thinner than your hair.
   a) True
   b) False

3. The basic subatomic particles inside a nucleus are called
   a) Quarks
   b) Protons
   c) Neutrons
   d) Electrons

4. Shear thickening fluids are also called
   a) Supercolliders
   b) Superconductors
   c) Superfluids
   d) Non-Newtonian fluids

5. Superconducting materials work at temperatures around -300º F.
   a) True
   b) False

6. Any element can become a superfluid.
   a) True
   b) False

7. Some of the interests and agendas of the green movement are
   a) Population control
   b) Social justice
   c) Green religions
   d) Green government
   e) All of the above

8. One of the primary objectives of the LHC is to find
   a) How cathode ray tubes work
   b) The "God Particle"
   c) Better superconducting materials

9. Nanotechnology is
   a) Manipulating matter on the atom level.
   b) Making elements with virtually no electrical resistance
   c) Discovering subatomic particles

10. Hadrons are
    a) Heavy particles in the nucleus-protons & neutrons
    b) Quarks
    c) The light part of the atom-electrons & leptons

Answers are on page 115
# Answers to the Quizzes

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