Guidebook and Quizzes

A companion guide to the Chemistry 101 DVD set

Wes Olson
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.

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**Weight of the Earth**

The earth weighs about 6 sextillion tons (give or take) and gains about 100,000 pounds a year from meteors and space dust. BUT... weight is a measure of the force of gravity on an object. Since the object we are measuring is the earth itself, one could say the earth has mass but cannot be weighed.

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**Newton Quote**

"...God in the beginning formed matter in solid, massey, hard, impenetrable, moveable particles."

-Sir Isaac Newton

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50 million atoms fit across this candy.

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**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
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 are 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.

A. 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."
B. 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...quantum 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.
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.

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
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:

```
O
H H
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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
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 mallable 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 its 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.
Why You Speak "English"

Some historians believe the word Britain, Brit-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.

e. tin (Sn)
- The meaning of the word "tin" has been lost in history.
- The symbol Sn comes from stean (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.
<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.

</f>

<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.

</g>

<h. germanium, antimony and polonium

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

2. Non-Metals

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

i. 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.

j. 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.

k. 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.
l. 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.

m. 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.

n. 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.
o. 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.

p. 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.”

q. 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.
r. 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.

s. 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.

t. 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.
u. 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
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.

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### 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.

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.
• 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?
Quiz Eighteen - Future of Chemistry/part 1

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 do
   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