Summer Science Experience!

Brought to you by E. Christophe and Craig Darsow at Willow Creek Middle school, June 26-30, 2006

NAME: ______________________________

The Course in a Nutshell:

Day 1: Introduction to Chemistry

Theme I : Matter and the Periodic Table

- What everything is made of: atoms
- Compounds create a variety of substances
- The world around us and how its contents is connected with The Periodic Table
- What are atoms made of: Protons, Neutrons, and Electrons
- Chemistry Basics: Solutions, Mixtures, and how to separate them
- Stations: Mixtures, Solutions, and the Periodic table
- Review with the Chemistry Basics Game

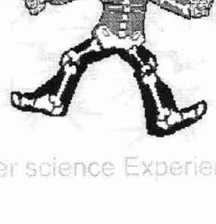
Theme II : The Reaction Between Molecules

- Atoms re-arrange to make new substances: Chemical Reactions
- Using the notation found on the Periodic Table to describe Chemical reactions
- The conservation of mass – The atoms are just rearranging
- Stations: Various chemical reaction
- Chemical Reaction Game

Day 2: Introductory Electricity

Theme I : The Electrical Loop

- Energy comes in all shapes, sizes and colors – The Electron in motion
- Learning to harness energy in the form of electricity – Conductors, Insulators, and The Loop
- Electrical energy can be converted into many forms to do the best work
- Harnessing light energy – The Solar Cell
- Stations: The Electrical Loop – Making Bunches of Circuits
- The Loop Game

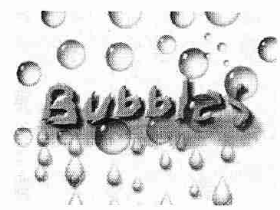


Making Electricity

Day 3: Exploration of Unique Chemicals

Theme I : Acids, Bases, pH, and Indicators

- Substances containing Hydrogen and Oxygen often have a measurable pH
- The pH scale – Exponential relationships - Demonstration
- The many ways to measure pH: paper, opposite test, a pH meter, Indicators
- Explaining the acid-base or neutralization reaction – Describe with Chemical Equations
- Stations: pH, Neutralization, and a whole Slew of Indicators
- Phenolphthalein, Bromthymol Blue, and pH paper
- The pH game



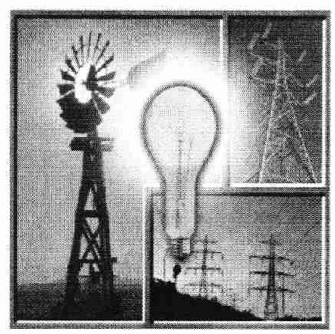
Theme II : Gases and their Pressure

- Three states of matter: Solids, Liquids, and Gasses
- Each state has its own properties – Density, Mass, Weight, Temperature, Pressure
- Chemical reactions producing gasses often involve acids and bases
- Stations: Dry ice, Gasses, Collapsing Cans, Popping Corks
- The pressure we're under game

Day 4: More electrical shocks

Theme I : A Gamut of Shocking Fun

- Looking closer at chemical equations – Balancing chemical equation
- Switches at all shapes, sizes, and colors
- Relays – no not the ones in PE class
- Solar Cells
- Magnetism in wires, compasses, and magnets
- Batteries, inside and outside
- Three way switches and the old-fashioned telegraph
- Inside and out of the proverbial motor
- Seven segment displays and their wide variety of usefulness
- Soldering and Solenoids
- House wiring and burglary fun



Day 5: Chemistry at every corner : Blending Chemistry with Electricity

Theme I : Getting Technical with Chemistry and Wrap-up

- Looking closer at chemical equations – Balancing chemical equations
- Class-wide chemical equation workshop
- Learning about electrolysis – Class Demonstration
- Group project of using Red Cabbage Indicator to make an array of pretty colors
- Making Slime as a class – Food coloring if you wish
- Slime races as game
- Elementary education about fireworks – Break into groups and make experimental mixtures
- Final course evaluation

Day One : An Introduction to chemistry

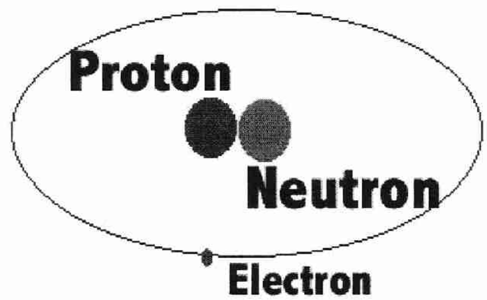
Theme I : Matter and the Periodic Table

If you were to look up the word chemistry in a dictionary, you would find that chemistry is defined as the study of matter. Then a logical question to ask is: What is matter? **Matter** is a term for anything that has **mass**. Or in other words, anything that you can feel, touch, hold, breath or smell. Matter is "all of the stuff" around us. We now ask: What is all of this matter made of? All matter, or all things that have mass, are made of incredibly small balls. These balls are called **atoms.** Atoms are so small that on the head of a pin, there are literally billions of them - on the head of a pin! You cannot ever see a single atom….ever. Even the most powerful microscopes have only seen clumps of atoms together.

When you hear the word atom, always think of really little balls all clumped together to make up all of the big stuff we see around us.

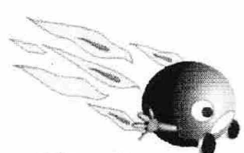
The Atom

We have learned that matter is all around us, and is made of atoms. But we now can ask ourselves, what are atoms themselves made of? They are made of yet smaller balls. These really tiny balls, or particles, are **subatomic** because they are smaller than the atom. The word "sub" refers to below and "atomic" refers to the atom. To the right is a diagram of an atom. The diagram shows where the three subatomic particles are positioned in the atom. The following list summarizes the three particles that make up the atom. Remember that all atoms are made up the same particles, it is just the number of each that varies with each new element.



The Electron:

The most important part of the atom is the electron. These tiny little balls fly **around** the center of the atom, called the **nucleus**. They spin so fast that they circle the nucleus a million times in a billionth of a second! The track that they run on is called the electron's orbit. Electrons do all of the interacting with the other atoms. Electrons can be transferred to other atoms, and atoms can take electrons from other atoms. Electrons are so small that sometimes they are just considered pure energy. They have a mass of 9.110×10^{-28} g. That is so small that if you were to fill up a teaspoon measure with all electrons, you would need 91,100,000,000,000,000,000,000,000,000 electrons! All electrons have a negative charge.


"Hot Electron"

The Proton:

The proton is large compared to the electron. About 2000 electrons could fit into one proton. Protons stay in the middle of the atom, or the nucleus, and never touch the electrons. In most cases, the protons are never exchanged with other atoms. All protons have a positive charge. They also provide ½ of all of the mass in an atom.

The Neutron:

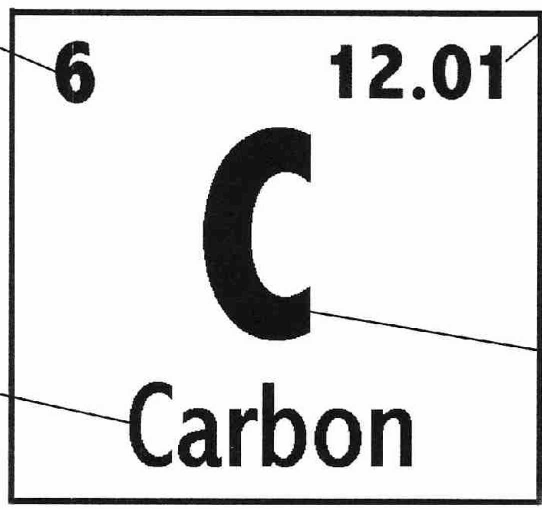
The neutron is the last particle that makes up the atom. The neutron has no charge at all and is placed in the center of the atom, or the nucleus, with the protons. The mass of one neutron is about the same as a proton. The neutron contributes to the other ½ of the weight of the entire atom.

Each atom, except an atom named Hydrogen, has all three of these tiny little balls in it. Remember, the electron is what does most of the work, and the electron is what chemists usually study when they think of atoms. Electrons may be really really small, but they do so much in chemistry! The protons and the neutrons are in a bunch in the middle of the atom, called the nucleus. You can think of each little atoms as a tiny solar system. The sun is like the nucleus and all of the planets that revolve around the sun are like the electrons that fly around the nucleus. The electrons move so fast around the nucleus, that they go around one entire revolution a million times in a billionth of a second! That's really fast!

As we said, everything around us is made of atoms, even the air we breathe. Atoms come in different sizes, in fact there are 110 different sizes of atoms. Atoms change size when there are more protons, neutrons, and electrons in them. Each individual size of atom has its own name and we call them elements. You have probably even heard of some elements like helium or oxygen. IF SOMETHING IS AN ELEMENT IT IS MADE OF ALL THE SAME SIZE ATOM. Each different size of atoms looks and feels different, almost as if each element has its own special personality. Chemists study these different elements all the time because they are the building blocks of all other materials around us.

Chemists have made a table that shows each of the 110 different sizes of atoms, their names and how many of each subatomic particle are within them. This is called the periodic table and can be found on page 6 of your binder. If you look at the periodic table on page 6 of this book, you see lots of little boxes. Lets take a closer look at one of the boxes and what all of the numbers in it mean.

This is the **Atomic Number.** This number is the number of protons in the atom. To find the number of neutrons, subtract the atomic number from the weight. **So the number of neutrons in this atom is 12.01 – 6 = 6. Always round the atomic weight if needed.**

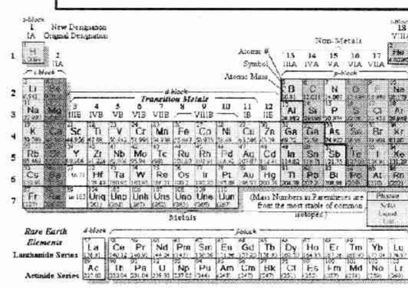


This is the **Atomic Weight.** This number is the total weight of the atom in a unit called atomic mass units. Each neutron and each proton weighs 1 amu. **An electron as no significant weight. The weight of the electron is never used in any calculations**

This is the **Element Name.** Each element has a name and a symbol.

This is the **Symbol.** Each element on the table has a symbol. They are used refer to the element quickly such as in chemical equations and in writing chemical formulas.

How can there be only 110 different seizes of atoms but more than 110 different kinds of materials around us? The nearly infinite variety of substances usually comes not from atoms being different sizes but the atoms gluing themselves to other atoms in different arrangements. A **molecule is two or more atoms glued, or bonded together to make a completely new substance.** The term **compound** means a substance that is made of all the same molecule.



PERIODIC TABLE AND ATOMIC DATA

WITH ILLUSTRATED TEXT OF NUCLEAR TERMS

Period	1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII	10 VIII	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 NOBLE GASES
1	1 H Hydrogen 1.008																	2 He Helium 4.003
2	3 Li Lithium 6.939	4 Be Beryllium 9.012											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 15.999	9 F Fluorine 19.00	10 Ne Neon 20.18
3	11 Na Sodium 22.99	12 Mg Magnesium 24.31											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.06	17 Cl Chlorine 35.45	18 Ar Argon 39.95
4	19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.90	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.71	29 Cu Copper 63.54	30 Zn Zinc 65.37	31 Ga Gallium 69.72	32 Ge Germanium 72.59	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.91	36 Kr Krypton 83.80
5	37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium (99)	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3
6	55 Cs Cesium 132.9	56 Ba Barium 137.3		72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.9	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.5	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium (210)	85 At Astatine (210)	86 Rn Radon (222)
7	87 Fr Francium (223)	88 Ra Radium (226)		104 Unq Unnilquadium (261)	105 Unp Unnilpentium (262)	106 Unh Unnilhexium (263)	107 Uns Unnilseptium (264)											

GROUP DESIGNATIONS

Group notations used on this table reflect changes recommended by IUPAC to standardize numbering schemes currently in use. The numbers 1 to 18 shown in red will eventually replace existing group designations IA to VIIA. During a transition period both notations will appear on periodic tables.

RADIOACTIVE ELEMENTS

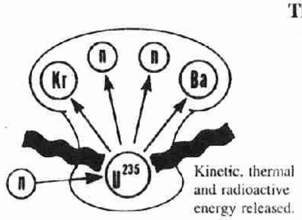
Elements 43, 61, and 84 through 107, appear in blue signifying that they are radioactive. Elements beyond 107 have been identified by independent researchers but have not been formally recognized by the International Union of Pure and Applied Chemistry (IUPAC). When recognized, new elements will be added to this chart.

KEY: 82 (ATOMIC NUMBER) 207.2 (ATOMIC WEIGHT) Pb (ATOMIC SYMBOL) Lead (ELEMENT NAME)

57 La Lanthanum 138.9	58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (147)	62 Sm Samarium 150.4	63 Eu Europium 152.0	64 Gd Gadolinium 157.3	65 Tb Terbium 158.9	66 Dy Disprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 Lu Lutetium 175.0
89 Ac Actinium (227)	90 Th Thorium 232.04	91 Pa Protactinium (231)	92 U Uranium 238.0	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (260)

Atomic Fission Process

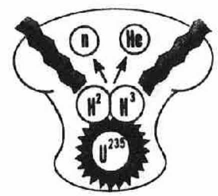
This simplified diagram illustrates a form of nuclear fission used in the original atom bomb. A neutron (n) is forced to penetrate an atom of uranium 235. The uranium nucleus breaks up into nuclei of krypton and barium with release of 2 neutrons and large quantities of energy. Each released neutron then penetrates another uranium atom to cause an explosive chain reaction.



Kinetic, thermal and radioactive energy released.

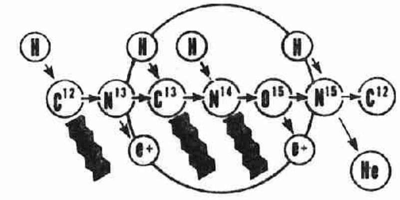
Thermonuclear Fusion Process

A form of hydrogen reaction used in military weapons is illustrated by this diagram. A source of intense heat, shown there as a uranium fission device, causes the fusion of two hydrogen isotopes - deuterium (H^2) and tritium (H^3). Helium nuclei are thus formed along with the release of neutrons and tremendous energy. No chain reaction takes place.



The Source of Solar Energy

Illustrating the solar carbon-nitrogen cycle which results in the fusion of four hydrogen nuclei into one helium nucleus. A hydrogen nucleus unites with a carbon nucleus (C^{12}) changing it to an isotope of nitrogen (N^{13}) and releasing large amounts of energy. The unstable N^{13} releases a positive electron (e+) and changes to stable C^{13}. C^{13}, penetrated by another hydrogen nucleus, changes to N^{14} with much energy release. The cycle continues until finally the fourth hydrogen nucleus causes N^{15} to be converted to the original C^{12} with the creation of a helium nucleus.



Questions for Review: Atoms and molecules

1. What are atoms?
2. What is the difference between an element and a compound?
3. How many atoms are in a molecule?
4. What are the three particles that make up each atom?
5. What two of the particles above are found in the center of the atom?
6. Which particle is found flying around the outside?
7. How fast do electrons spin?
8. Where can we find a list of all of the 110 different sizes of atoms?
9. What does the atomic # of an element tell us?

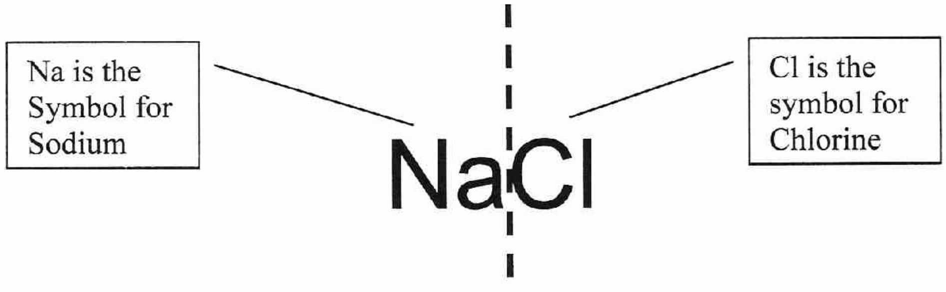
Complete the below Table:

#	Element	Symbol	Atomic #	Atomic Weight	# Electrons	# Neutrons
1	Tungsten					
2		Sr				
3				238.0		
4					50	
5			7			

A Closer Look at Compounds: Using the Symbols on the Periodic Table

We have talked briefly about the periodic table and all of the elements on it. But not everything is made of just one size of atom! As we have learned, they are made of atoms glued or bonded together. **Bonding** is what atoms do with each other to create compounds. There are literally millions of compounds all around us, and they are all made of various combinations of elements on the periodic table. Look at plain table salt. It is made of Sodium, Na, number 11, and Chlorine, Cl, number 17! Chemists say that the two atoms are *bonded* together to make a new substance called Sodium Chloride. Chemists often have fancy, or longer names to give to chemicals, so salt and sodium chloride are the exact same thing.

Instead of chemists writing out the words Sodium Chloride each time they want to talk about salt, they write an abbreviated version. They call them **chemical formulas**. Lets use the example of the last paragraph. If we wanted to write the chemical formula (people usually just say *the formula*) for salt, or sodium chloride, we start by finding the symbols of the two elements on the periodic table. You can see sodium in the upper left-hand corner, and chlorine in the upper right-hand corner. You see that their symbols are Na and Cl. To write the formula for salt, first write the symbol of the element farthest to the left, followed by the element on the right. It's that easy.



Introduction to the Building Blocks of Chemistry Station Set

In this station exercise, there will be 6 stations that you will rotate through and learn about different compounds, elements, and pieces of the periodic table.

Station 1: Elements and their Placement on the periodic table

1. What is the symbol for aluminum? ________ Atomic Number? ___________
2. What are some properties of aluminum?

____

____

3. Circle or record the right property of each element listed in the table.

#	Element	Color	Placement on periodic table	Weight (circle)	Break or bend	Texture
1	Sulfur			HEAVY LIGHT	BREAK BEND	
2	Copper			HEAVY LIGHT	BREAK BEND	
3	Carbon			HEAVY LIGHT	BREAK BEND	
4	Magnesium			HEAVY LIGHT	BREAK BEND	
5	Iodine			HEAVY LIGHT	BREAK BEND	
6	Helium			HEAVY LIGHT	BREAK BEND	

4. What do copper and magnesium have in common? (Do they both bend? Are they both heavy? Where are they found on the periodic table?) ______________________________
5. What do Sulfur, Carbon, and Iodine have in common? (Are they bendable, shiney?)

____

6. Is helium anything like the other five elements you looked at? ______________________
7. What side of the periodic table holds the nonmetals?

____

8. What side holds the metals? ______________________________
9. What are semimetals, or metalloids? ______________________________

Station 2 : Compounds

1. What do we call an abbreviated name of a compound? ______________________
2. What is the formula for salt? _______________ What does the Cl stand for? __________
3. Which element in a chemical formula is written first? ____________________________

4. What are the little numbers lowered to the lower right-hand corner of the symbols called? ________
5. What do those little number tell us? ____
6. Where can you find a list of all of the elements and their symbols? ____________________
7. Fill in the blow table. Start on row one, and look at how many of each element you are given. Number one says the first atom is hydrogen, and you have two of them. The second element you have is oxygen, and you have two of those also. You now need to write the formula of the compound made of those elements in the column labeled "Formula" Number one was done for you.

#	Atom 1	Write Formula Here	Name
1	Two hydrogen atoms bonded to two oxygen atoms	H_2O_2	Hydrogen Peroxide
2	Two potassium atoms, one carbon atom, and three oxygen atoms bonded together		Potash
3	One sodium atom bonded to one chlorine atom		Salt
4	One hydrogen atom, two carbon atoms, three hydrogen atoms, and two oxygen atoms bonded together		Vinegar
5	Two nitrogen atoms bonded to one oxygen atom		Laugh Gas
6	Twelve carbon atoms, 22 hydrogen atoms, and eleven oxygen atoms bonded together		Sugar
7	One calcium atom bonded to one oxygen atom		Like
8	Two aluminum atoms bonded to three oxygen atoms		Alumina
9	Two carbon atoms, five hydrogen atoms, one oxygen atom, and one hydrogen atom bonded together		Grain Alcohol
10	Three magnesium atoms bonded to two nitrogen atoms		N/A

Station 3: The Classification of Matter

1. Why is classifying matter important? ____
2. What is an element? ____
3. What is the difference between an element and a compound?

   ____
4. What two categories can all matter be divided into? ______________________________

5. What are the two parts of a chemical solution? ______________________________
6. What is the solid part called? ______________ The Liquid part? ______________
7. Using the 7 samples at the station, classify each item in the table below by checking the type of matter it is:

#	Sample	Element	Compound	Solution	Plain Mixture
1	Sodium Bicarbonate				
2	Beads and Paper				
3	Sulfur				
4	Cotton				
5	Copper				
6	Air				
7	Ethyl Alcohol				
8	Salt and Water				

8. What is another name for a Homogeneous Mixture? ______________________
9. What is another name for a standard mixture? ______________________
10. If you put salt into water, and stir, what part of the solution is the water? ______________
11. What part of the solution is the salt? ______________
12. What is the water doing to the salt? ______________________

Station 4: Mixtures and How to Separate Them

1. When does magnetic attraction work? ______________________________
2. In this station, what were the magnetic objects? ______________________________
3. What two substances did you separate while using the shaking method? ______________
4. How does this method work?

____

5. Do you think that the same thing would happen if rice were replaced with sand? ___________
6. What was the tool you used to filter the beads and the water? ______________________
7. When does the filtration method not work? ______________________
8. What were the objects in the water addition method that floated? ______________
9. What is the only condition when this method works? ______________________
10. What are the four ways to separate mixtures? Are all of them physical methods?

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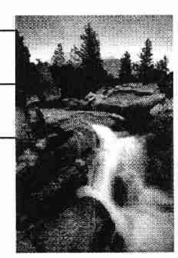


Station 5: Making Atomic Models

#	Atom	Symbol	# Electrons	#Protons	#Neutrons
1	Hydrogen	H	1	1	
2	Helium	He		2	2
3	Carbon		6	6	6
4	Lithium	Li	3		4
5	Beryllium	Be	4		5

1. Why is making atomic models useful?

   ____

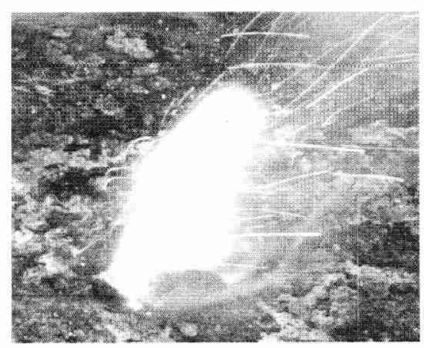
2. What about the atomic models is not correctly proportioned? Are all the particles in atoms the same size? ____
3. What particle does Hydrogen not have? ______________________________
4. Do all of the atoms that you made have an equal number of all three particles? ____________

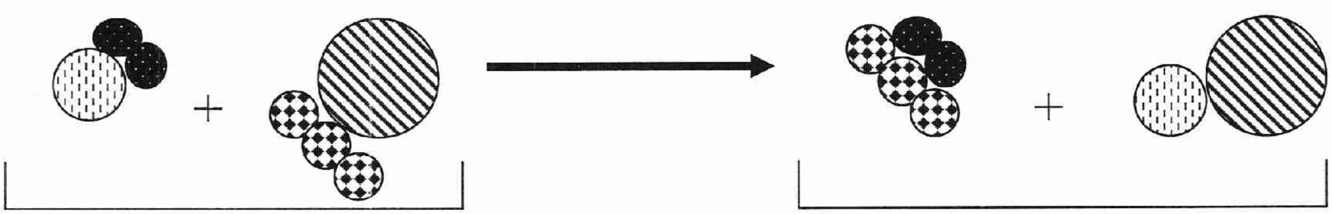
   Which atoms had an uneven amount? ______________________________

Theme II : Chemical Reactions

So far we have learned all about substances and their properties. But we have studied all of these different compounds and we don't know how they are made? Compounds can be created by a chemical reaction. A **chemical reaction** is when the atoms of the original compounds rearrange with themselves to form new compounds(substances). Chemical reactions happen constantly all around us – even inside us. Fires, baking a cake, cleaning hard water stains, and eating food are all examples of chemical reactions.

We are going to do a number of chemical reactions today. Some chemical reactions are **called exothermic because they release heat, and some are called endothermic because they take in heat.** All fire is an example of an exothermic chemical reaction. We will do more with exothermic chemical reactions later. Remember that chemical reactions are a rearrangement of the atoms that make up molecules. **No atoms are created or lost in a chemical reaction. The atoms are just re-arranging!** Look at the diagram below to see how a chemical reaction works.

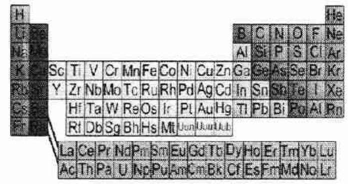




The starting molecules are called reactants *The ending molecules are called products*

Molecule A mixed with **Molecule B** Yields or Equals **New Molecule C** and **New Molecule D**

Notice that there are the same number of circles(atoms) on each side of the arrow



Day 1 : Review – some questions are multiple choice

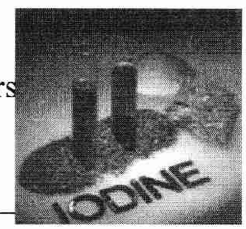
1. What side of the periodic table can you find the nonmetals?

    a. Right
    b. Left

2. Who won when you played the periodic table game? ________________________________\
3. What color are the Alkali metals? ________________________________
4. What color of the noble gasses? ____________________
5. What color are the transition metals? ____________________
6. What was the hardest thing about putting the table together?

    ____

7. What side of the periodic table are the alkali earth metals on? ____________________
8. What were the reactants in the classic blue color change?
    a. Water and Sodium Ferrocyanide
    b. Sodium Ferrocyanide and Ferric Ammonium Sulfate
9. What color was the product of the reaction between Iodine and Sodium Thiosulfate?
    a. Blue b. Orange c. Brown d. Clear



10. What was the name of the chemical that was used in making two different colors
    a. Corn Starch b. Cobalt Chloride c. Aqua Ammonia
11. What was the most challenging station that you did today? ____________
12. Which station were the most fun? Why?

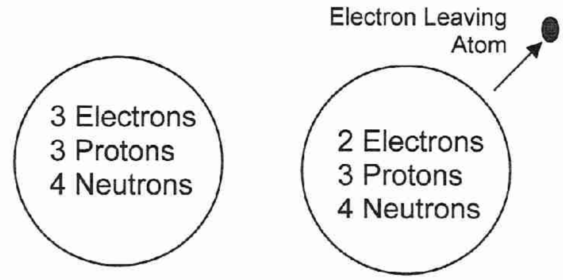
    ____

13. How would you define a solution
    a. A mixture of two or more substances where you can easily see its components
    b. A system that involved a solute dissolving in a solvent
    c. A system that has its components evenly spread out throughout the entire container
    d. Just b and c
    e. All of the above
14. Are you looking forward to coming back tomorrow? YES NO
15. In a chemical reaction, what are the molecules called that you start with? ____________
16. What do the atoms do in a chemical reaction? ____________________
17. Are new substances created in a chemical reaction? ____________________
18. Are atoms broken in a chemical reaction? ____________________

Day 3: Acids, Bases, Gases, and Pressure

Theme I :Special kinds of matter – Acids, Bases, and Salts

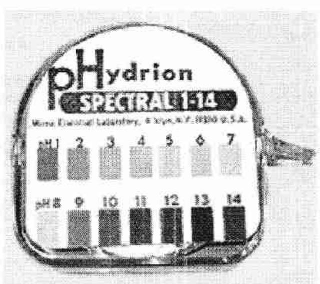
We have so far talked all about matter, and how it interacts with other matter. We will now explore a few special groups of matter. These special substances are grouped together because they all have some atoms in common. When one or more atoms is charged, meaning it lost or gained an electron, it is called an ion. **An ion** is an atom or group of atoms that has an electrical charge. (See Right)



Regular Lithium Atom **Positive (+) Lithium Ion (Li^+)**

Acids and bases are special because both of them release special ions when they are put into water. Acids release a charged Hydrogen atom. This is written H^+. It is really not much of an atom because the H^+ means that the atom has lost an electron, so all a H^+ ion is a proton. So when a substance is put into water, and releases a Hydrogen ion, that substance is an acid. On the contrary, bases release an ion that is two atoms bonded together. This ion is called a Hydroxide ion It's a charged molecule of hydrogen and oxygen. It is written OH^-. The minus sign means that that molecule has gained an electron.

These special properties create two of the three groups that we will focus on. The final group is neutral substances. These are all substances that are half way between being a base and being and acid. Water is the most common neutral substance. Here is a summary of some properties of acids, bases, and neutral substances.



Besides physical characteristics, we have another identification method for acids and bases which is used very commonly because of its precision and reliability. This method is called pH. **pH** stands for Power of Hydrogen. Substances that contain those Hydrogen or Hydroxide ions have a measurable pH. Look below at what chemists call the pH scale : pH is measured on a 0-14 scale, 0 being very strong acids that we rarely or never encounter, 7 being neutral, or not being acidic or basic (water), and 14 being very strong bases.

<table>
<tr><th colspan="7">ACIDS have pH < 7</th><th>pH= 7</th><th colspan="7">BASES have pH > 7</th></tr>
<tr><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td></tr>
<tr><td colspan="3">Strong Acids</td><td colspan="4">Weak Acids</td><td rowspan="2">NEUTRAL</td><td colspan="4">Weak Bases</td><td colspan="3">Strong Bases</td></tr>
<tr><td colspan="7">• Sour Taste
• React with metals to form Hydrogen Gas
• Release hydrogen ions (H^+) in water</td><td colspan="7">• Bitter taste
• Used a lot in cleaners
• Produce Hydroxide ions (OH^-) in water</td></tr>
</table>

The Reaction Between Acids and Bases

The classic baking soda and vinegar reaction is one that has a special name, it is called a acid-base, or neutralization reaction. A **neutralization** reaction is a chemical reaction that specifically involves mixing acids and bases. When an acid is mixed with a base, a gas called Carbon Dioxide is formed. Alongside Carbon Dioxide, water and a substance called a **salt** is formed.

The reaction is called a neutralization reaction because the acid and the base react to form a neutral substance, water. In a way, you could say that the acid and the base cancel each other out. The general idea behind this reaction, in terms of the atoms that make up the substances is explained below.

$$H^{+} + OH^{-} \longrightarrow H_2O$$

H^+	+	OH^-	$\longrightarrow$	H_2O
An Acid pH < 7	and	**A Base** pH > 7	Equals or yields	**Water** pH = 7

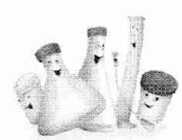
The + and the – superscripts (small, raised letters) on the left side's substances indicate a loss or gain of electrons which creates an electric charge. In some ways it could be thought of as a hole and a peg. The minus represents the peg and the plus represents the hole. The atoms with these "holes and pegs" tend to always bond to each other, making new substances. In this case it was H_2O, or water.

Compound Review:

Tell what and how many atoms are in each of the below compounds:

#	Formula	Elements Present	Number of atoms
1	$NaBiO_3$		
2	$C_{21}H_{18}O_5S$		
3	$PbSO_4$		

Acids and Bases Station Set



Station 1 : Writing Formulas and learning the names of acids and bases

There are many different acids and bases, but each one does the same thing: when put in water they release either Hydrogen (H+) Ions or Hydroxide (OH-) ions. Remember that an ion is a charged atom or group of atoms. Those charged atoms have either lost or gained electrons. It is the ions are what make the solutions they are put in acidic or basic.

1. What ion do acids give off when put into water? ______________________
2. What ion do bases give off when put into water? ______________________
3. Do all acids and bases harm you? ______________________
4. Name 2 different acids ______________________
5. Name 2 different bases ______________________
6. After each formula, write whether it is an acid or a base, or neutral. Remember that a formula for an acid always starts with an "H" and the formula for a base always has one or more "OH" in it.
   a. HCl ______________
   b. $Ca(OH)_2$ ______________
   c. $Mg(OH)_2$ ______________
   d. HNO_3 ______________
   e. H_2SO_4 ______________
   f. $HC_2H_3O_2$ ______________
   g. NH_4OH ______________
   h. $H_3C_6H_5O_7$ ______________

7. Tell the elements present and the number of each by completing the table below:

#	Formula	Elements Present	Number of atoms
Example	HNO_3	**Hydrogen**	**1**
		Nitrogen	**1**
		Oxygen	**3**
1	H_2SO_4		
2	$NaHCO_3$		

Station 2 : Phenolphthalein Indicator

1. What pH range must the solution be for phenolphthalein to turn pink? ______________________
2. What was the name of the acid that was used to neutralize the base? ______________________
3. Why did the solution turn clear when the acid was added to the base?

____

4. Why are you able to go back and forth between pink and clear as many times as you want?
    a. There are lots of extra chemicals to use up
    b. None of the base is ever turned into water
    c. The phenolphthalein is never used up
    d. The acid is really strong

Station 3 : The Bromthymol Blue Indicator

INITIAL PH ______________________

YELLOW PH ______________________

BLUE PH ________________________

Explanation: The reason this experiment worked was because you used the Bromthymol Blue indicator to tell you what the pH of the solution was. You simply used the Acid to neutralize the base.

1. Was the solution an acid or a base when it was yellow? ____________________
2. Was the solution an acid or a base when it was blue? ______________________
3. What color is the Bromthymol blue in a neutral solution? ____________________
4. What did the acid do to the base when you added the acid?

   ____
5. What is the pH range for acids? ____________________________
6. What is the pH range for bases? ____________________________
7. What is the pH of a neutral solution? ________________________

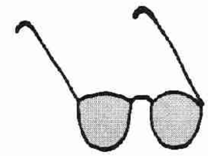
Station 4 : Monitoring the Temperature of an Acid-Base Reaction

START TEMPERATURE: ______________________ Degrees F

FINAL TEMPERATURE: _______________________ Degrees F

1. What was the base that you used in your acid-base reaction? ___________________
2. What is another name for an acid-base reaction? __________________
3. What is the formula for Sodium Carbonate? ______________________________
4. Did the temperature of the solution go up or down during neutralization? __________________
5. Do you know why the temperature went up or down? ________________________________
6. What are the atoms doing in the chemical reaction? _________________________________

Station 5 : Watching Neutralization



BEGINNING WATER pH : ______________________

BEGINNING ACID pH : ________________________

1. Why did you stop adding base at pH 7 ? ______________________________________
2. What substance did you create from the acid and the base? ________________________
3. Would it have taken more sodium carbonate solution to make pH 7 if you started with more acid? Explain : ____
4. Why did you pour the sodium carbonate solution slowly? ______________________________

Station 6 : Measuring pH with pH Paper

#	Substance	PH	Acid	Base	Neutral	Neither
1	Vinegar					
2	Drano					
3	Baking Soda Solution					
4	Corn Starch					
5	Salt					
6	Water					
7	Strong Acid					
8	Weak Acid					
9	Strong Base					
10	Milk					

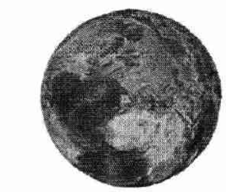
1. Which substance above has the lowest pH? _________________________________
2. Which substance above had the highest pH? ________________________________
3. What was the pH of milk? ____________________
4. How could a substance not be an acid, a base or neutral? _______________________
5. What pH must a substance have to be an acid? _____________________________
6. What pH must a substance have to be a base? ____________________________
7. What pH must a substance have to be neutral? ____________________________

Day 3 Review

1. What are the little balls that make up matter called? ______________________
2. What is the symbol for Potassium? ___________________________________

3. How many electrons do element number 63 have? ______________________________
4. If you must bush down both home made switches in a circuit to make a light go on, then those switches and the light bulb are connected in … Series or Parallel .
5. The name of the person sitting next to you is _________________________________
6. How do you pronounce "world" spelled backward? ______________________________
7. True or False : This is the most fun science class you have every been to. _______________
8. pH stands for _______________________________________
9. Chemistry is the study of _______________________________
10. Today is __________________________

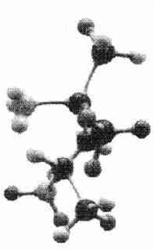
Theme II : Gasses and Pressure

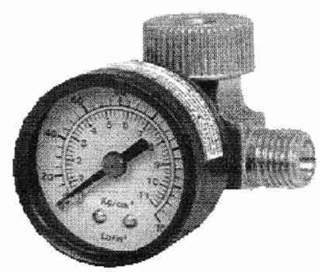


Gasses are very important to each one of us because we all depend on oxygen gas to live. You know that you need oxygen to live, but what else do you know about oxygen? Did you know that out of all the air around you, oxygen makes up only 20% of it. Here is a chart that shows all of the gasses that make up that air that you and I breathe everyday:

Composition of Dry Air		
Substance	**Percent**	**Boiling Point**
Nitrogen (N)	78.1	-195.78
Oxygen (O)	20.9	-182.98
Argon (Ar)	0.934	-185.87
Carbon Dioxide (CO_2)	0.033	-78.477
Neon (Ne)	0.0018	-246.1
Helium (He)	0.00053	-268.94
Krypton (Kr)	0.00012	-153.4
Xenon (Xe)	0.00009	-108.1
Hydrogen (H)	0.00005	-252.77
Methane (CH_4)	0.00002	-161.5
Nitrous Oxide (N_2O)	0.00005	-88.48
Ozone (O_3)	Trace	-111.3

You can easily see that the gas that makes up most of the air around is nitrogen. There are a number of things about gasses that you can measure. Each one of these measurable elements of gas has special mathematical equations to describe them but we will not explore them now.





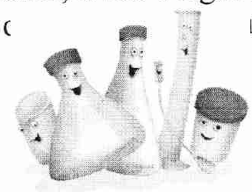
Pressure: This is how hard the molecules of a gas push on the container it's in.
Volume: This is how much space a gas takes up
Temperature: This is the temperature of the gas. If the temperature is higher, the molecules

are bouncing around in the container faster than that are in a cooler gas.
Number of Molecules: This is just as it sounds – the actual number of molecules of gas in a given container.

Gasses are special for a number of reasons. Unlike solids and liquids, the molecules that make up gasses are flying all over the place, like one of those giant ball tents in a fair; those little kids are bouncing around all over! Gasses are crazy that way – they bounce around at speeds of millions of miles per hour. If the molecules slow down too much, they change back into a solid or a liquid!

All gasses exert a pressure. Did you know that there is 14.7 pounds of pressure pushing down on your head right now!! There is. This is the air pressure caused by the *weight* of the air above you. There is a lot of air above your head, and just like an other substance, it has weight too! You don't feel that air pressure because an equal amount of pressure pushes c … lungs!

Gasses and Pressure Station Set



Station 1 : Crushing Cans

1. What state of matter did the water you put in the bottom of the can change into when you heated it? ________________ What did you "add" to the water to get it there? ____________
2. Why did you have to flip the can upside-down to get it to collapse?

   ____
3. How much air pressure is pushing down on us all the time? ____________________
4. What force was actually doing the crushing or the can? ____________________
5. What did we replace the air in the can with when we boiled the water? ______________
6. What game is this experiment like in real life? ____________________

Station 2 : The Gasses Produced by and Acid-Base Reaction

1. What is the name and the formula for the gas produced in this reaction? ______________
2. What else did the reaction produce? ____________________
3. What is the name for this type of reaction? ____________________
4. What were the names of the TWO basses that you used? Why not use just one?

   ____

Station 3 : Dry Ice!!

Remember when you are working with dry ice that Carbon Dioxide is NOT white. The white "smoke" that you see coming off of the beakers is colorless carbon dioxide with little tiny water droplets in it!

1. What is the temperature of Dry Ice? ______________________
2. What is it called when a substance changes form a solid to a gas without being a liquid? ________
3. What was your favorite thing to do with the dry ice? ____________________
4. What percent of our air is Carbon Dioxide? ____________________

5. Can you think of any other place where carbon dioxide is produced?

____

Station 4: Carbon Dioxide and Carbonic Acid

1. What two chemicals did you combine to make carbon dioxide?

____

2. What was the name of the indicator that you used to determine the pH of the water?

____

3. What did the pH of the water have to be if the Bromthymol blue turned yellow? ____________
4. What evidence besides the color change is there that gas was produced? ________________

Day 5: Advanced Chemistry plus Odds and Ends

Theme I : Chemical Equations and Balancing them

As you saw when we discussed acids and bases, there is a special way that chemists write out what goes on in a chemical reaction. These are called **chemical equations**. They are like sentences in English except for chemists. There are rules we must follow when we use them. Chemical equations can describe ANY chemical reaction around us- and all chemists understand them!

Remember that **reactants** are the chemicals that we start with in a chemical reaction, and **products** are what we get. In a chemical reaction the atoms of the reactants **RE-ARRANGE** to form the products. Here is an example of a chemical equation. This equation is for the chemical reaction that your instructor did on the first day of chemistry class when he mixed two clear solutions and produced a milky white precipitate, or solid, in the beaker.

$$AgNO_3 + NaCl \longrightarrow AgCl + NaNO_3$$

Silver Nitrate + Sodium Chloride (Equals or Yields) Silver Chloride + Sodium Nitrate

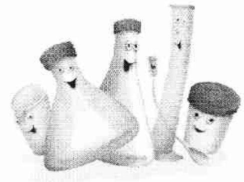
Reactants are on the Left Side of the Equation

Products are on the Right Side of the Equation

You need to notice what happened. The "NO_3" switched places with the "Cl." That is all that happened. The atoms **RE-ARRANGED**. Count how many of each atom there are on each side of the arrow – They are equal. You can think of the arrow in the middle as an equal sign, chemists simply use an arrow instead. When there are an equal number of atoms on each side of a chemical equation, we call that equation **balanced**.

Odds and Ends Station Set

Station 1: Using Red Cabbage Indicator



Test Tube #	Position	pH from paper	Color with Cabbage Indicat.
1	Far Left		
2	Mid Left		
3	Middle		
4	Mid Right		
5	Far Right		

1. What was the range of pH that the test tubes covered? ______________________
2. What color does red cabbage indicator turn in a weak base? ______________________
3. What color does red cabbage indicator turn in a strong acid? ______________________
4. What color does red cabbage indicator turn in a weak acid? ______________________
5. What color does red cabbage indicator turn in a strong base? ______________________
6. What color does red cabbage indicator turn in a neutral solution? ______________________

Station 2: Making Slime

Due to popular demand, there will be no questions for you to answer. Be sure to think long and hard about the meaning of this statement. A Joke: What did the farmer say when he couldn't find is tractor? The answer is: "Where's my tractor?" Ha! Have fun with the slime, even if there have been numerous recorded accounts of small children being eaten from it.

Station 3: Performing an Exothermic Reaction

You have all probably been to a fireworks show at some point in your life. Did you ever wonder how all of those pretty colors are made. They are made from burning different elements on the periodic table. Here is a list of the element and the color that it produced.

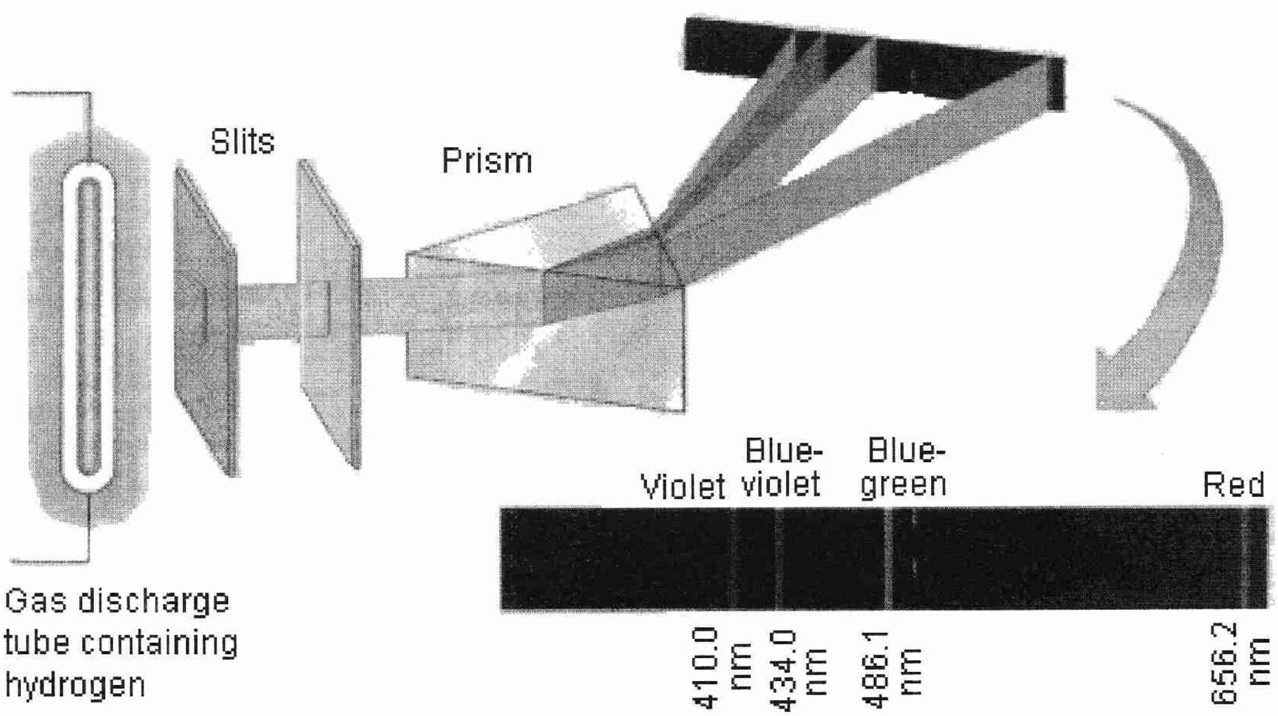
Color	Metal
Red	*Carmine*: Lithium compounds. Masked by barium or sodium. *Scarlet or Crimson*: Strontium compounds. Masked by barium. *Yellow-Red*: Calcium compounds. Masked by barium.
Yellow	Sodium compounds, even in trace amounts. A yellow flame is not indicative of sodium unless it persists and is not intensified by addition of 1% NaCl to the dry compound.
White	*White-Green*: Zinc
Green	*Emerald*: Copper compounds, other than halides. Thallium. *Blue-Green*: Phosphates, when moistened with H_2SO_4 or B_2O_3.

	Faint Green: Antimony and NH_4 compounds. *Yellow-Green*: Barium, molybdenum.
Blue	*Azure*: Lead, selenium, bismuth, $CuCl_2$ and other copper compounds moistened with hydrochloric acid. *Light Blue*: Arsenic and come of its compounds. *Greenish Blue*: $CuBr_2$, antimony
Violet	Potassium compounds other than borates, phosphates, and silicates. Masked by sodium or lithium. *Purple-Red*: Potassium, rubidium, and/or cesium in the presence of sodium when viewed through a blue glass.

Courtesy of About inc.

When the elements burn, they give off certain colors of light because of the movement of electrons from a *high energy* to a *low energy* state. Each element on the periodic table gives off a slightly different color of light. You can actually identify each of the elements on the periodic table only by their flame color. Sometimes chemists call the set of colors that an element gives off its **emission spectrum.**

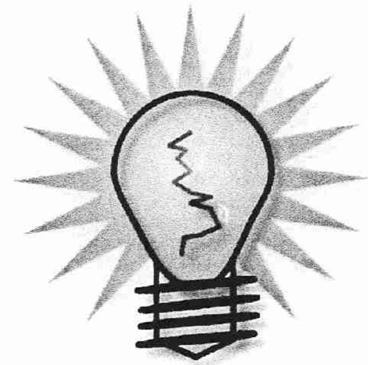
Below is a diagram of how chemists have determined the specific spectrum for each of the elements. Although when we do flame tests and exothermic reactions we only see one color, each element actually produces several different colors on a spectrum.



Day 2 and 4: Basic Electrical Concepts

Theme I: What is Electricity?

Electricity is a form of energy. Energy is what makes things happen in the world.
Other forms of energy that humans use naturally are heat, light, and motion.
Electricity is handy because it lets us take energy that starts as heat, light or motion, and move it to just where we want it and then convert it to heat, light, or motion, whatever we need at that new place. We can start with any of those forms and convert the electricity back to any of those forms. This is the kind of use of electricity we will talk about in this class.

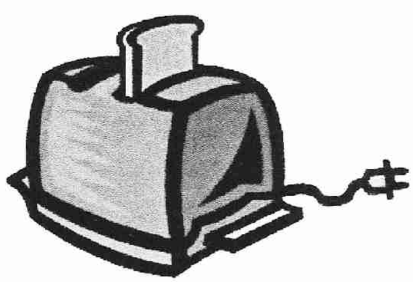


The other very common use of electricity is to carry information. Computers use this feature of electricity but we will **not** talk about how that is done in this class.

We say that electricity follows rules and that we are going to learn the rules of electricity. But we need to be sure we understand that people did not make those rules. Instead, these are rules that people have *figured out* that electricity follows naturally. No person can change the rules electricity follows. But if people take advantage of the rules cleverly they can make electricity do really cool stuff.

Basic Electrical Terms

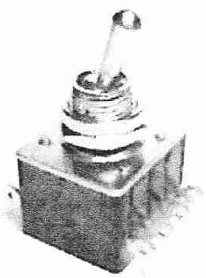
Using electricity to make motion (like turn a fan) can be compared to using water from the water company in your town to run a sprinkler to water your lawn. To water your lawn you need a water company to pump water to your house. The water company pump has two ends – an inlet and an outlet. The water wants to go from the high pressure at the pump outlet to the low pressure on your yard. If you give it pipes and hoses to guide it, it will go just where you want it to go on your yard. You need pipes and hoses to carry the water from the pump to your yard. You need a faucet to turn the water on and off so you don't waste water when you don't need to water. And you need a sprinkler to actually use the water that gets to it in the hose.



What you need to get your fan to spin, toaster to toast, or car lights to glow can be compared very nicely to what you need to water your lawn. The electricity source is like the water company pump. The electricity source has two ends – called *terminals.* The electricity pump tries to push electricity in a loop from its positive terminal (its outlet you could say) to its negative terminal (its inlet you could say). (Electricity naturally wants to go from positive to negative, just like rocks fall from higher to lower – and not lower to higher - when you drop them. That is just its natural way) But electricity won't make it from positive to negative terminals of the power source by going through just any material. Instead, electricity only goes from positive to negative through materials we call *conductors.* A *conductor* is defined as a material which carries electricity easily. (Metals are the most common conductors.) The conductors are like the pipes and hoses in your water system; they guide electricity where you want it to go. The electricity source makes electricity "pressure" to force electricity through the conductors just like water pumps make water pressure to force water through pipes. We talk about electrical pressure using the term *voltage.* We measure voltage in *volts.* Higher voltage – more volts - pushes more electricity energy through a particular conductor than lower voltage does, just like higher water pressure pushes more water through a particular pipe than lower water pressure does. We say that the electricity "flows" in the conductors just like we say that the water "flows" in the pipe. We call flowing electricity *current* just like we call water flowing in a river the "current". We measure how much electricity is "flowing" using the term *amperes* or *amps* (they are the same thing).

Controlling Electricity

The opposite of a conductor is an *insulator*. An *insulator* is a material which does not let electricity flow easily in it. (Wood, plastic, cloth, glass, paper, rock, rubber and – most common of all – air, are good insulators.) If we want to control whether or not electricity flows at some particular spot, we can take advantage of the difference between insulators and conductors. If we insert a conductor at the spot, electricity can flow there. If we insert an insulator at the spot, electricity does not flow there. A gadget that changes from acting like a conductor to acting like an insulator and back again is called at *switch.* The purpose of a switch is simply to control whether or not electricity can flow in it and in conductors around it. A switch is like a faucet in the water pipes; it stops the flow of water when you don't want it to flow and it allows flow when you do want it. You choose which way it is operating – as a conductor or an insulator - at any particular time.



How to Get Useful Energy from Electricity

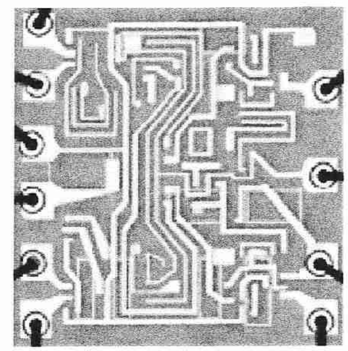
By now you might be thinking, "What good is being able to control flow of electricity in a conductor? Or what good is even having electricity flow in a conductor in the first place?" The answers are: not much good at all if you don't have any gadget to convert the electricity flowing in the conductors in to a form of energy you want. Perhaps you are hot and want a breeze – you want to use electricity somehow to make motion of air. Or if you want toast instead of soft bread for breakfast, so you want to use electricity to heat the bread. Or maybe you want to go somewhere after dark and you want to use electricity to let you see the road in front of your car. You can surely name some gadgets in your house that convert electricity into motion, head, or light. Engineers call these gadgets the *load.* The *load* are the things that use electricity to do useful stuff for us. Some of the coolest things to know about electricity are how we get each of these useful forms of energy (motion, head, and light) from electricity in the "loads" You will be spending some time seeing how this is done in this class. The electrical "load" is like the sprinkler in our comparison of water systems and electricity systems; the sprinkler makes a straight stream, a fine mist, or gentle falling droplets from the water, depending on what kind of sprinkler you attach to the pipe. The same water goes in to all sprinklers, but different shape or water comes out, depending on the sprinkler type. In the same way, the same electricity goes into each kind of electrical "load" but different forms of energy come out.

In this class you will see loads that convert electricity into motion. These are called *motors.*
And other loads that convert electricity into light. These are called *light bulbs* and *LED's*.
And still other gadgets that convert electricity into heat. These have lots of names like "stove" and "furnace" and "hair dryer" and "toaster" and "soldering iron".

An interesting thing about *loads* is that they are not really conductors but they are not really insulators either or insulators.

They are not insulators because they let electricity flow through them. (Electricity has to flow through a load for it do convert any of the electrical energy into a useful form like light or heat or motion.) But they are not really conductors because they do not let electricity just flow super easily through them either. (Remember conductors are materials that let electricity flow *easily* through them.) Whenever some energy is converted from electricity to any other form in a load, it is harder for the electricity to flow through it than it is to flow through a good conductor. We will say that loads are loads, and not call them conductors in this class even though the do let electricity through.

The Circuit



A collection of the electricity source, the conductors, switches, and loads connected together is called a *circuit* (pronounced "sir-kit"). Useful *circuits* are one that guide electricity flow through loads to do something useful to us. Other *circuits* are not useful because they do not cause electricity to be guided so it flows through useful loads. Figuring out why a *circuit* is not doing something useful when you think it should is called *debugging* the circuit. You can expect to do a lot of that while learning about electricity I this class. The most common shape of conductors in electric circuits is as wires. They are most often made of the metal copper. To keep the electricity from going from one wire to another at places you do not intend, the metal wire is usually wrapped in an insulating plastic jacket or painted with an insulating coating called enamel, which is usually clear but makes the wire look a bit darker than a bare copper wire. In order to use the wire inside the insulating jacket or enamel you must scrape the jacket or enamel off with a knife or sandpaper so you can connect to the bare conducting copper part of the wire.

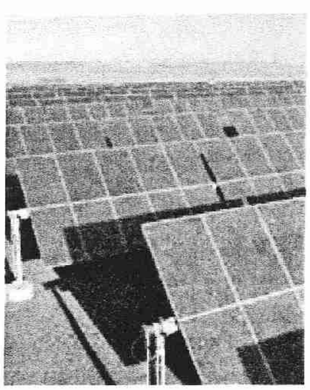
Short and Sweet Summary

In summary, *voltage* is the "electrical pressure" that tries to make *current* flow through *conductors* in a *circuit.* A *switch* starts or stops the flow of current by changing itself back and forth from a *conductor* to an *insulator* to control the flow of electricity as desired. The *load* transforms electricity into a useful form energy for our convenient use.

Theme II: The Loop Rule

The basic rule electricity follows is the "loop rule" which says:

Electricity flows from the positive side to the negative side of the electricity source through good conductors that guide it and through loads that convert the electricity to other forms of energy.

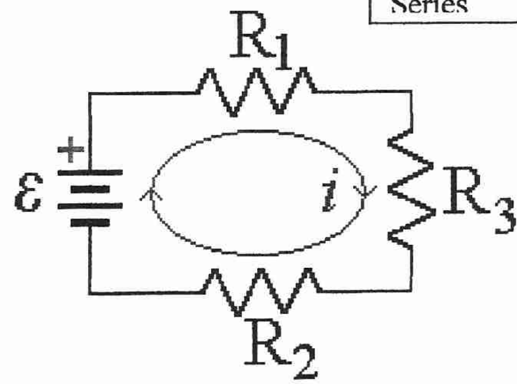


An arrangement of an electricity source and conductors and loads that lets electricity flow is called a ***closed*** *circuit*. If there is something that keeps the electricity from flowing we say we have an ***open*** *circuit*. And if the electricity can flow from positive to negative of the electricity source without doing anything we want it to do, then we say we have a ***short*** *circuit*. Short circuits are almost always accidents and unwanted and bad.

There are several types of electrical sources available. In this class you will discuss three types of electrical sources. One makes electricity from stored chemical energy. Such a gadget is called a "battery". A gadget to make electricity form motion is called a "generator" . And a gadget that makes electricity from light energy is called a "solar cell".

Series and Parallel Connections

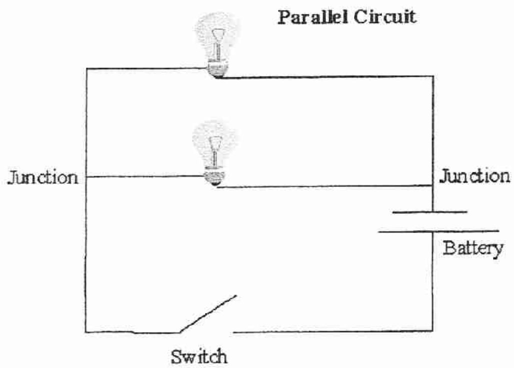
Series



If the parts of a circuit are connected so that all the electricity that flows in any one of them also has to flow in all the rest of them, we say that those parts are "*series connected*".

If the parts of a circuit are connected so that electricity can flow through them *without* flowing through the other parts of the circuit, we say those parts are "*parallel connected*".

We always put a switch in series with the loads it is trying to turn on or off.



And we put the whole combination of a switch and the load it is controlling in PARALLEL with other combinations of switches and their loads if we want to be able to turn each load on or off without thinking about the other loads and switches.

You can have arrangements of switches and loads that have some series connections and some parallel connections in the same circuit; it is not a wrong circuit if you have several different combinations of series and parallel. But it can be a confusing one!

Conductors and Insulators – How to Tell What You Have

If you are unsure whether a material is a conductor or an insulator, you can test it by making it part of a loop (circuit) that contains just a simple electricity source, like a battery, a light bulb, and a couple of wires to connect them. If you make the unknown material part of the loop from battery positive through light bulb back to battery negative, you can tell if it is a conductor or not. If the bulb glows brightly then the unknown material is a conductor. If the bulb does not glow, then the unknown material is an insulator.

Theme III: Important Electrical Phenomena

There are several things that sometimes or always happen when electricity is being used or is present that are the basis for most of the demonstrations and activity stations of this class. We call these things "electrical phenomena". We just know about them; we cannot really explain all about them, but they are very important. This section introduces you to what these phenomena are and where they are used in common loads you find all around your house or in nature.

Heating – the Principle

Whenever a current flows in any ordinary conductor, even a good conductor, like a wire, there is always a small amount of electric energy converted into heat in that wire. That heat makes the wire become warmer. You can remember that heat comes from current flowing in a wire if you think of the current as like a rope being pulled through your hands and your hands as the wire itself. If you pull the rope very fast you will feel warmth in your hand from friction with the rope. You could think of the heat from current in a wire as friction between the electricity moving and the wire guiding it.

Three things affect how much heat is produced in the wire:

1. The more *current* (more *amps*) there is flowing in the wire the more electricity is converted into heat in the wire and the hotter the wire becomes.
2. The smaller the wire the current is flowing in, the more heat is produced in it.
3. The worse the conductor is, the more heat is produced in it. Some metals are much better conductors than others (gold is better than copper which is better than aluminum for instance). And small bits of dirt and rust pressed between two pieces of metal that are themselves good conductors can make the path between them actually a much worse conductor than either of them alone. So the spot near where the dirt is will heat up more than the rest of the metals. .

This phenomenon happens in all wires carrying any electricity, but most of the time we do not notice it because the combination of wire size, current involved, and goodness of conductors causes such a small amount of heat to be produced that it is carried away into the air just as fast as it is created in the wire.

For example, the small wires on your AC adapter for a CD Player or Game boy have only a very small current (half an amp or less) in them so even though they are small they do not heat up enough for you to notice (but they do heat up a little). And because your vacuum cleaner Is designed to use a lot of current. (up to 15 amps) it has a big fat cord so it will not get very hot. It is interesting that you can prove to yourself that your vacuum cleaner cord is heating up a bit if you wind the cord into several loops close together and then let the vacuum run for 10 minutes or so. You will probably find that the coil has gotten warm to the touch. An example of the last principle above, number 3, is at the plug where your vacuum cleaner is plugged into the wall, you will often find it getting hotter than the cord after ten or fifteen minutes of use, because the plug's metal surface does not mate up with the outlet metal surface inside the outlet perfectly and that mating is not as good a conductor as the wires inside the cord.

Heating – the Products

This heating phenomenon is not by any means always bad. It is very very useful in common loads we need and use everyday. Special wires are made to be definitely NOT good conductors, but not so bad as to be insulators. Those wires produce lots more heat in them when any current is passed through them than ordinary wires intended to just guide the electricity. We say that theses special wires have "high resistance" which means the voltage source has to push harder to get electricity to flow in them than in a regular "low resistance" or "good conductor" wire. Wires like this are used in several common products:

1. Hair Dryer – it has a coil of this high-resistance wire near its outlet that gets very hot – hot enough to burn a finger or start a fire – when electricity is pushed through it. The air blown over it by the fan gets heated by the hot wires. If you stop the air from blowing across these coils by putting your hand over the end of the hairdryer, those wire can get so hot that they can melt the hair dryer and start a fire.
2. Toasters, electric stoves, and electric heaters, and electric furnaces all use high resistance wire to make lots of heat on purpose.
3. Glue guns have a small amount of this wire to heat the glue.
4. Model rockets use wire like this in the igniters to start the rocket engine going
5. Electric Arc Welders melt metal by running lots of current

through a welding rod that is made to be not as good a conductor as a regular copper wire.

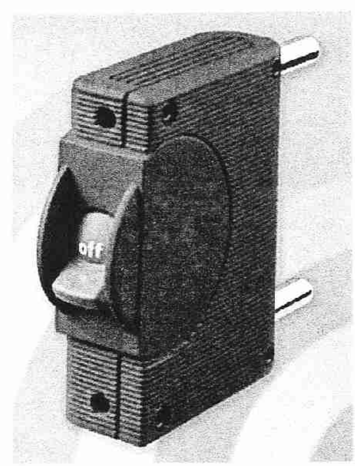
6. A soldering iron and wood burning art/craft tool uses this kind of wire to heat the tip so it can melt special metal called "solder" or burn brown spots into wood.
7. A regular light bulb makes its light by passing current through a small coil of special wire (called the filament) designed to get very hot – so hot that it glows white – when current is pushed through it. Most of the energy those bulbs give off is in the form of heat; the light is what we are trying to get but we get mostly heat which we just try to ignore.

Heating - the Dangers

This heating effect is not always helpful, however. If the wires in your vacuum cleaner cord get too hot because something goes wrong in side the vacuum and more current than ever intended starts flowing them, they could burn you or start a fire in your carpet where they are lying. If the wires in the walls of your house the lead to each of the wall outlets got too much current flowing in them, they could start a fire in the walls of your house. How can we make our homes save from accidents like these where something goes wrong and the wires would like to overheat?

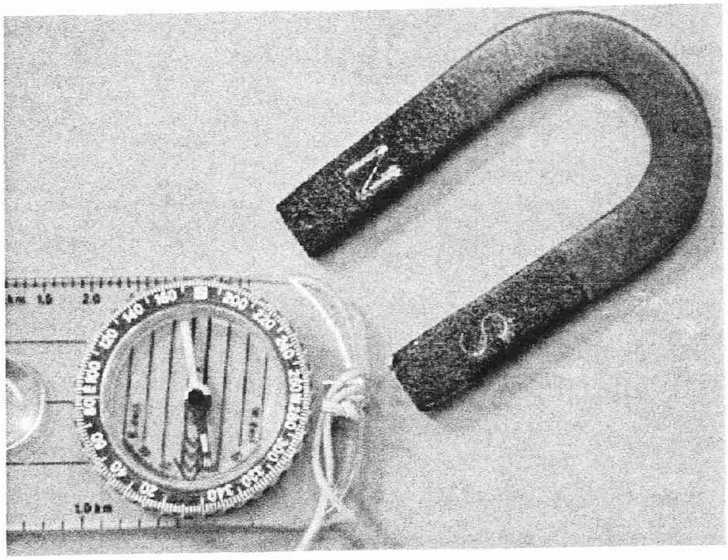
The solution is to put some kind of automatic switch in SERIES with all the wires in your walls and the cords plugged into the outlets. The automatic switch would turn off the current if it high enough that it was dangerous. A gadget for automatically stopping current flow after the current gets too high is called a *fuse* or *circuit breaker*.

1. A fuse is just a special short piece of metal designed to get hot enough to melt itself when the current in it goes above a certain level. It is arranged in its holder so when it is not melted, it connects two conductors together but when it melts it is no longer in a shape that will connect those two conductors in its housing. So any current that was flowing in it will have to stop. And anything in your house that was getting that current will also stop getting it, and will not be able to get hot either. Once a fuse has melted, it cannot ever be made to conduct again. It has to be replaced with a new fuse before the circuit that gets current through it will work again.
2. A circuit breaker is a gadget that has the same purpose as a fuse to protect your house from fire when current goes too high for the wiring. It will stop letting current flow through it if the current goes to high, just like a fuse. The big difference with a circuit breaker is that it is able to be switched back to be a conductor after it has switched to a non-conductor. The reason it can be switched back is that a circuit breaker does not let anything melt when it gets hot. Instead it uses a spring-loaded switch to stop the current. Circuit breakers cost more to buy than fuses but are a lot more convenient to use because you do not have to replace them after they go off – you just push the lever back to "on".



Magnetic Effect From Electricity

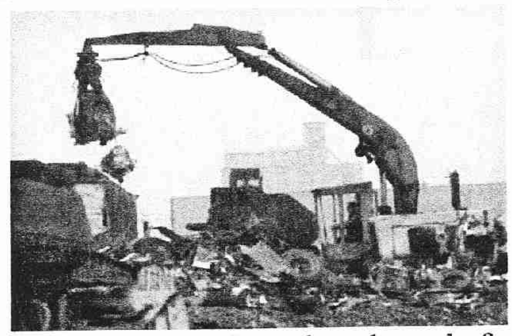
You surely have at sometime played with a permanent magnet and noticed that it will attract objects like paper clips or other magnets a short distance away, when it is not even touching the paper clips or other magnet. That happens because around a magnet there is what we call a "magnetic field" or "magnetic effect" . When iron objects get in that magnetic field, they feel a force that makes them move. You have also probably noticed that if you have two permanent magnets, you can position them so they either



attract or push away from each other. This shows that both ends of the magnet are not the same. Indeed, we say one end is a "north pole" and the other a "south pole". Two north poles pushed together will repel each other, as will two south poles. But a north will attract a south.

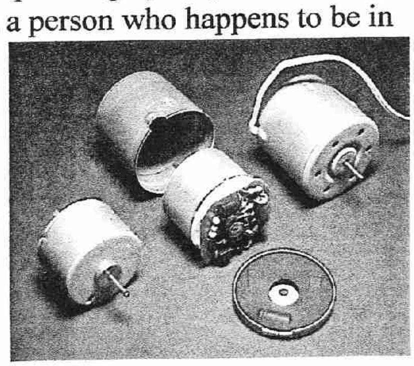
What does this have to do with electricity? Well, whenever electricity flows in a wire, something very interesting happens around the wire. What happens is that the wire starts to act like a tiny magnet. We say that the wire gets a "magnetic field" around it. But the magnetic field is only there when the current is flowing. You can see it affects a compass like a permanent magnet when you move a wire with current in it over a compass (this does not work with power cords for household appliances however, because there are two wires in the cord canceling each other out.)

If you wind a wire into a coil around a solid iron nail and then run the electricity through it, all those little magnetic effects pile on top of each other and add up to make a stronger magnetic field., one big enough to do even more than any permanent magnet could. We call this an *electro magnet*. If you bring a permanent magnet up near it, you can determine which end is the north and which end is the south And if you swap the ends of the wire between + and – on the electricity source so the current is flowing the other way, and then check it again with the permanent magnet, you will find that the north and south poles of the electromagnet reverse!

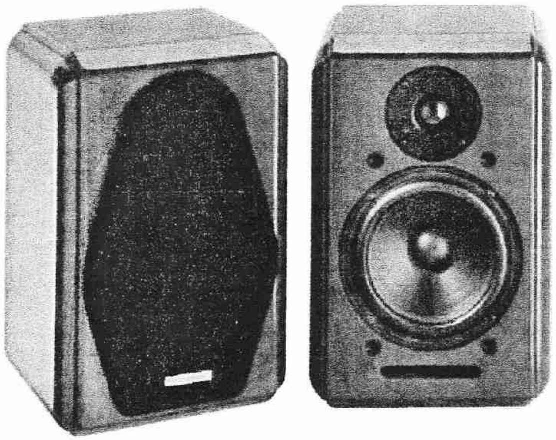


This phenomenon of getting a magnet from electricity is very very useful. It is the basis for a large number of products you use every day and some that you don't see very often.

1. The least common use of this phenomenon that many people know about is in huge electromagnets used to lift old cars and scrap metal at junk yards. Such magnets can lift several tons of metal on the end of a crane cable.
2. A more common but still not really common use is to make very very powerful magnetic fields for Magnetic Resonance Imaging (MRI) scanning done by doctors to look at the shape of internal organs of the body to find tumors and internal damaged done by accidents. These electromagnets are so strong that if you walk within six feet of one with a small iron object like a screw driver in your pocket, the screwdriver will be pulled so hard that it could rip through your pocket and fly like a bullet toward the magnet, possibly injuring or even killing a person who happens to be in the way of its travel to the magnet.
3. The next most common use of this magnetic effect is in electric motors. An electric motor is a kind product or *load* that uses electricity to convert electric energy into motion energy. It does this by cleverly arranging to get electromagnets made from wires wound around the spinning part called the "armature" to be pulled around and around by other magnets (electric or permanent) mounted on the body of the motor (which does not spin). There are hundreds of

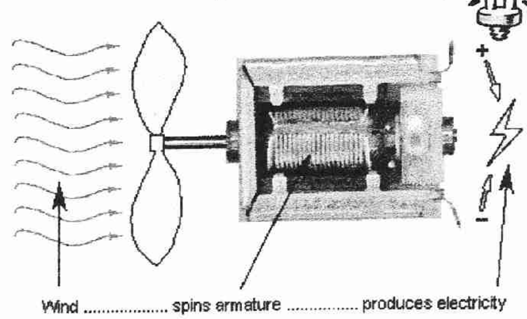


clever ways of getting this to happen and lots of engineers make their whole careers just designing motors of various sizes and shapes.



4. The very most common use of this phenomenon of magnetic effect surrounding a wire with current in it is to make music. How does the magnetic effect make music? Well, to start we need to say that music is just sound, and sound is just very speedy compressions and expansions of the air hitting our ear drum. We make sound with electricity using a device or *load* called a "speaker". The simplest speaker is just a paper cone mounted on a frame so it can scoot forward an backward a short distance very easily. An electromagnet is mounted on the tip of the cone and a permanent magnet is mounted on the frame very near the tip of the cone and the electromagnet. Electricity fed into the electromagnet causes the electromagnet to be pulled toward or pushed away from the permanent magnet, making the cone move. If the electrical current in the coil is just as speedy as the compressions and expansions needed to make the sound of music, then the paper cone produces music in the air from the electrical current.

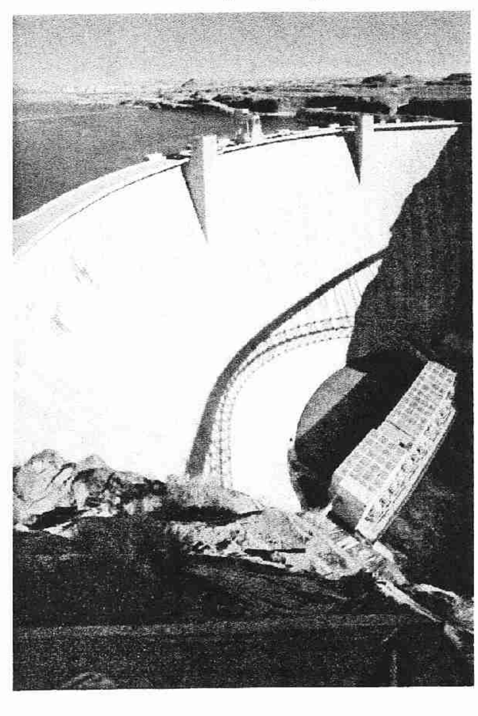
Generator produces electricity



Electricity from Magnetism

Another very important phenomenon of electricity is that if you move a magnet near a wire you get a voltage in the wire, and if that wire is connected to a load, you get a current in the wire. Thus, this is one way of making electricity, and is in fact the most common way electricity is made. A gadget that makes electricity from moving a magnet near a wire is called a *generator.*

The motion of magnet near wire can be produced by spinning a turbine with water from behind a dam or with steam created by boiling water with coal or nuclear energy. Or magnet can be made to move near the wire by the turning of a gasoline engine (as in your car where they call the generator the "alternator" or by turning a diesel engine (as on a ship). But no matter how you get the turbine spinning to move the magnet near the wire, the basic principle of making electricity in a generator is the same.



Lightning

When the electrical pressure called *voltage* is very high pushing across an insulator, sometimes the insulator will just give up being an insulator and become a weak conductor. Sort of like when a balloon filled very full pops. The rubber of the balloon is trying to keep the air from getting through it but finally when it cannot stand the pressure any more, it gives up trying to stop the air and disintegrates in a big bang and all the air goes right through where the balloon rubber used to be.

The most common insulator in the world is common ordinary air. When big storms are created up in the sky, large electrical voltages can be developed between clouds and the ground or clouds and other clouds. The air normally tries to keep these voltages from pushing current between the clouds or the clouds and the ground, but it when the voltage gets high enough, the air just gives up being an insulator and becomes a weak conductor, and large currents flow between the clouds and the ground.. Because it is a weak conductor the current flowing causes lots of heat and the heat causes the air to glow brightly, making lighting bolts in the sky.