Oakland Schools Chemistry Resource Unit

Periodic Table

Andrew D. Hulbert
Bloomfield Hills Schools
Andover High School

Periodic Table

Content Statements:

P1.1D

Identify patterns in data and relate them to theoretical models.

C4.9

Periodic Table - in the periodic table, elements are arranged in order of increasing number of protons (called the atomic number). Vertical groups in the periodic table (families) have similar physical and chemical properties due to the same outer electron structures.

C4.9x

Electron Energy Levels - The rows in the periodic table represent the main electron energy levels of the atom. Within each main energy level are sublevels that represent an orbital shape and orientation.

Content Expectations:

C4.9A Identify elements with similar chemical and physical properties using the periodic table.

C4.9b Identify metals, non-metals, and metalloids using the periodic table.

C4.9c Predict general trends in atomic radius, first ionization energy and electronegativity of the elements using the periodic table.

Instructional Background

Patterns in Element Properties (History):

Elements vary widely in their properties, but in an orderly way. In 1869, the Russian chemist Dmitri Mendeleev produced the first orderly arrangement, or periodic table, of all 63 elements known at the time. Mendeleev wrote the symbol for each element, along with the physical and chemical properties and the relative atomic mass of the element. Mendeleev arranged the elements in order of increasing atomic mass. Mendeleev started a new row each time he noticed that the chemical properties of the elements repeated. He placed elements in the new row directly below elements of similar chemical properties in the preceding row. Amazingly, Mendeleev predicted the properties of the missing elements in his table, leaving blanks to be filled in later. Mendeleev did not have knowledge of atomic numbers or electron configuration. Families were arranged according to increasing atomic mass and their observed properties.

Forty years after Mendeleev published his periodic table, an English chemist named Henry Moseley found a different physical basis for the arrangement of elements. Moseley discovered that appropriate structure of the periodic table correlated to the atomic number.

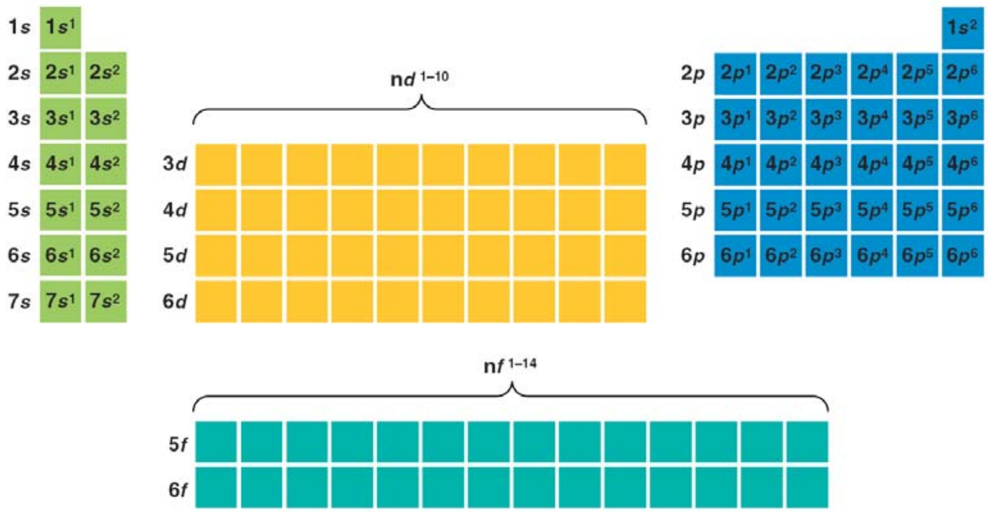
Periodic Law

- Mendeleev's principle of chemical periodicity is known as the **periodic law,** which states that when the elements are arranged according to their atomic numbers, elements with similar properties appear at regular intervals.

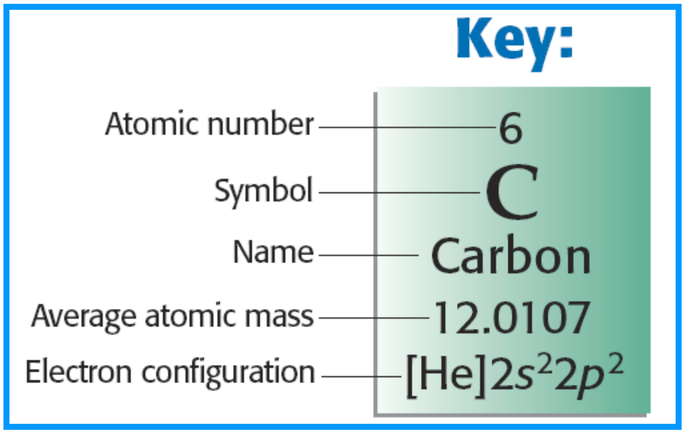
Organization of the Periodic Table

- Elements in each column of the periodic table have the same number of electrons in their outer energy level (valence electrons).
- The electrons in the outer shell are called valence electrons.
    - Valence electrons are found in the outermost shell of an atom and that determines the atom's chemical properties.
- Elements with the same number of valence electrons tend to react in similar ways.
- Because *s* and *p* electrons fill sequentially, the numbers of valence electrons in s- and p-block elements are predictable.
- A vertical column on the periodic table is called a group. Elements in a group share chemical properties.
- A horizontal row on the periodic table is called a period. Elements in the same period have the same number of occupied energy levels.
    - Example: all elements in Period 2 have atoms whose electrons occupy two principal energy levels, including the 2*s* and 2*p* orbitals.

- Provide a periodic table of elements.



- The periodic table provides information about each element.
    - atomic number
    - symbol
    - name
    - average atomic mass
    - electron configuration



The Main Group Elements

- Elements in groups 1, 2, and 13–18 are known as the main-group elements. Main-group elements are in the *s*- and *p*-blocks of the periodic table.
- The electron configurations of the elements in each main group are regular and consistent: the elements in each group have the same number of valence electrons.
- Four groups within the main-group elements have special names. These groups are:
    - *alkali metals* (Group 1)
    - *alkaline-earth metals* (Group 2)
    - *halogens* (Group 17)
    - *noble gases* (Group 18)

The Alkali Metals Make Up Group 1

- Elements in Group 1 are called **alkali metals.**
    - lithium, sodium, potassium, rubidium, cesium, and francium
- Alkali metals are so named because they are metals that react with water to make alkaline solutions.
- Because the alkali metals have a single valence electron, they are very reactive.
    - In losing its one valence electron, potassium achieves a stable electron configuration.
- Alkali metals are never found in nature as pure elements but are found as compounds.

The Alkaline-Earth Metals Make Up Group 2

- Group 2 elements are called **alkaline-earth metals.**
- The alkaline-earth metals are slightly less reactive than the alkali metals.
  - They are usually found as compounds.
- The alkaline-earth metals have two valence electrons and must lose both their valence electrons to get to a stable electron configuration.
  - It takes more energy to lose two electrons than it takes to lose just the one electron that the alkali metals must give up to become stable.

The Halogens, Group 17, Are Highly Reactive

- Elements in Group 17 of the periodic table are called the **halogens.**
- The halogens are the most reactive group of nonmetal elements.
  - When halogens react, they often gain the one electron needed to have eight valence electrons, a filled outer energy level.
- Because the alkali metals have one valence electron, they are ideally suited to react with the halogens.
- The halogens react with most metals to produce salts.

The Noble Gases, Group 18, Are Unreactive

- Group 18 elements are called the **noble gases.**
- The noble gas atoms have a full set of electrons in their outermost energy level.
- The low reactivity of noble gases leads to some special uses.
- The noble gases were once called inert gases because they were thought to be completely unreactive.
  - In 1962, chemists were able to get xenon to react, making the compound XePtF6.
  - In 1979, chemists were able to form the first xenon-carbon bonds.

Hydrogen Is in a Class by Itself

- Hydrogen is the most common element in the universe.
  - It is estimated that about three out of every four atoms in the universe are hydrogen.
- Because it consists of just one proton and one electron, hydrogen behaves unlike any other element.
- Hydrogen is in a class by itself in the periodic table.

- With its one electron, hydrogen can react with many other elements, including oxygen.
- The majority of elements, including many main-group ones, are metals.
- Metals are recognized by its shiny appearance, but some nonmetal elements, plastics, and minerals are also shiny.

Metals Share Many Properties

- All metals are excellent conductors of electricity.
    - Electrical conductivity is the one property that distinguishes metals from the nonmetal elements.
- Some metals, such as manganese, are brittle.
- Other metals, such as gold and copper, are ductile and malleable.
    - *Ductile* means that the metal can be squeezed out into a wire.
    - *Malleable* means that the metal can be hammered or rolled into sheets.

Transition Metals Occupy the Center of the Periodic Table

- The **transition metals** constitute Groups 3 through 12 and are sometimes called the *d*-block elements because of their position in the periodic table.
    - A transition metal is one of the metals that can use the inner shell before using the outer shell to bond.
- A transition metal may lose one, two, or even three valence electrons depending on the element with which it reacts.
- Generally, the transition metals are less reactive than the alkali metals and the alkaline-earth metals are.
    - Some transition metals are so unreactive that they seldom form compounds with other elements.

Other Properties of Metals

- An **alloy** is a solid or liquid mixture of two or more metals.
- The properties of an alloy are different from the properties of the individual elements.
    - Often these properties eliminate some disadvantages of the pure metal.
- A common alloy is brass, a mixture of copper and zinc.
    - Brass is harder than copper and more resistant to corrosion.

Metalloids

- Metalloids are found on the periodic table between the metals and nonmetals.
- A metalloid is an element that has some characteristics of metals and some characteristics of nonmetals. All metalloids are solids at room temperature.
- Metalloids are less malleable than metals but not as brittle as nonmetals.
- Metalloids tend to be semiconductors of electricity.

Nonmetals

- Many nonmetals are gases at room temperature. (Bromine is a liquid at room temperature).
- Solid nonmetals include carbon, phosphorus, selenium, sulfur, and iodine. These solids are brittle at room temperature.
- A nonmetal is an element that is a poor conductor of heat and electricity.
- Nonmetals are found on the right hand side of the periodic table.

Periodic Trends

- The arrangement of the periodic table reveals trends in the properties of the elements.
- A *trend* is a predictable change in a particular direction.
- Understanding a trend among the elements enables you to make predictions about the chemical behavior of the elements.
- These trends in properties of the elements in a group or period can be explained in terms of electron configurations.

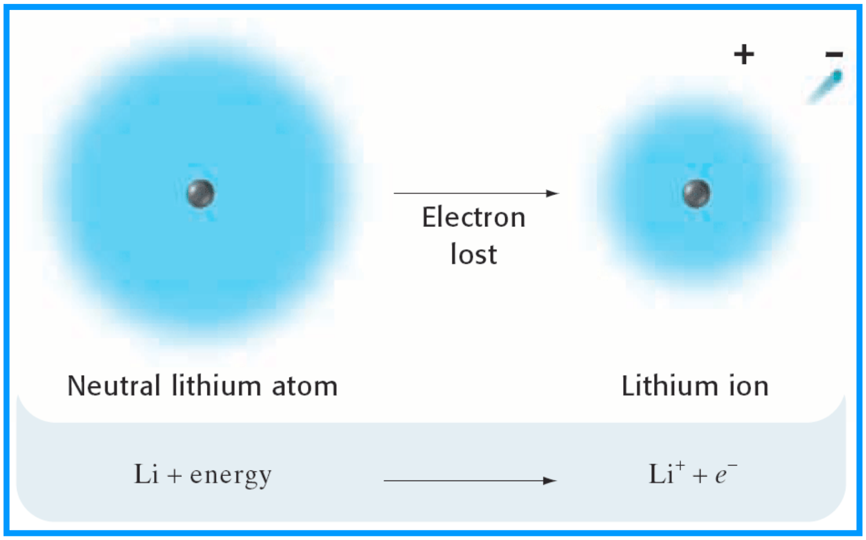
Atomic radius - distance from the center of an atom's nucleus to its outer most electron

First ionization energy - the amount of energy needed to remove one (the outermost) electron from an atom.

Electronegativity - the measure of an atoms attraction for electrons in a chemical bond

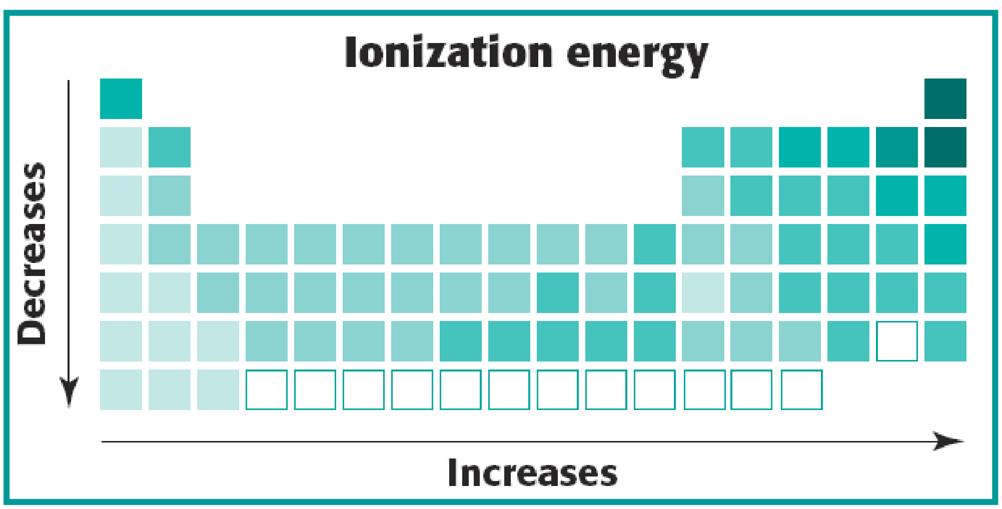
Ionization Energy

- The **ionization energy** is the energy required to remove an electron from an atom or ion.



Ionization Energy Decreases as You Move Down a Group

- Each element has more occupied energy levels than the one above it has.
    - The outermost electrons are farthest from the nucleus in elements near the bottom of a group.
- As you move down a group, each successive element contains more electrons in the energy levels between the nucleus and the outermost electrons.
    - **Electron shielding** is the reduction of the attractive force between a positively charged nucleus and its outermost electrons due to the cancellation of some of the positive charge by the negative charges of the inner electrons.



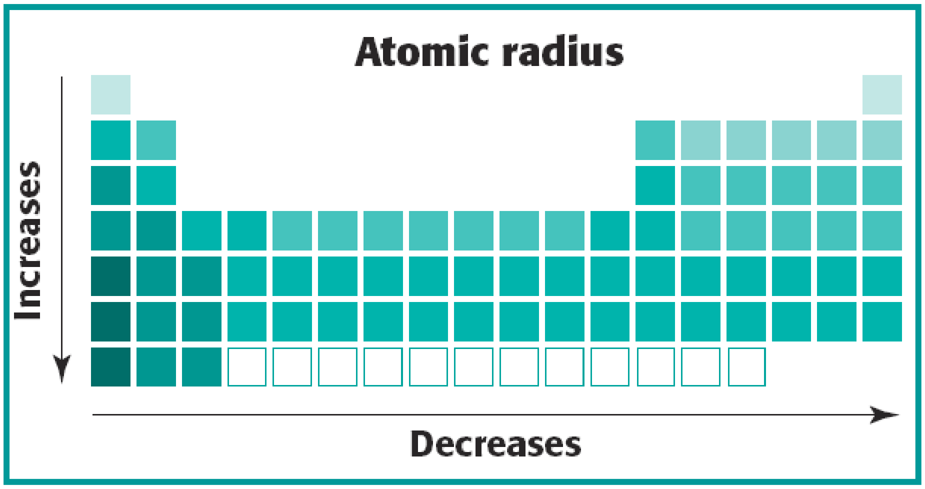
- Ionization energy tends to increase as you move from left to right across a period.
- From one element to the next in a period, the number of protons and the number of electrons increase by one each.
  - The additional proton increases the nuclear charge.
  - A higher nuclear charge more strongly attracts the outer electrons in the same energy level, but the electron-shielding effect from inner-level electrons remains the same.

Atomic Radius

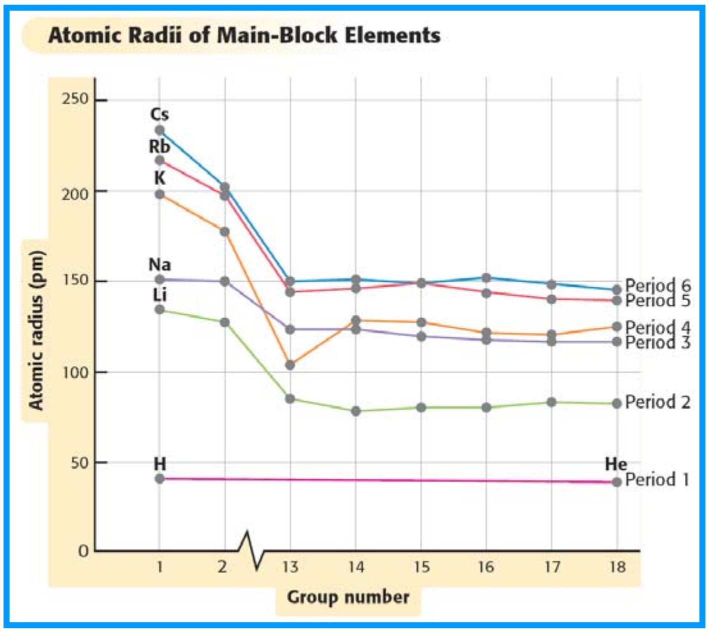
- The exact size of an atom is hard to determine.
- The volume the electrons occupy is thought of as an electron cloud, with no clear-cut edge.
- In addition, the physical and chemical state of an atom can change the size of an electron cloud.
- One method for calculating the size of an atom involves calculating the bond radius, which is half the distance from center to center of two like atoms that are bonded together.
  - The bond radius can change slightly depending on what atoms are involved.

Atomic Radius Increases as You Move Down a Group

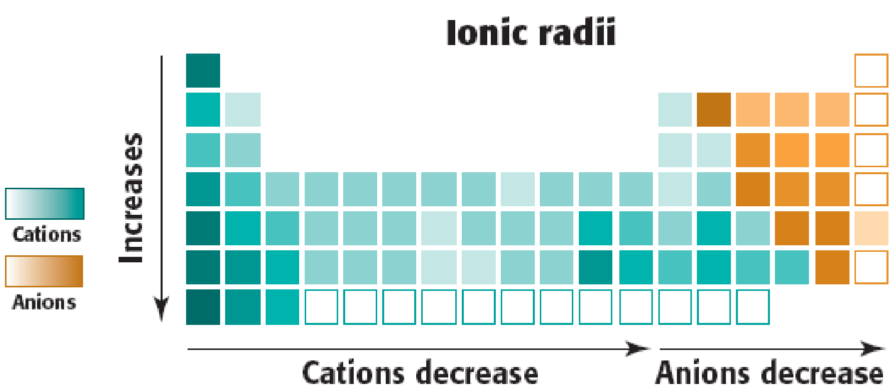
- As you proceed from one element down to the next in a group, another principal energy level is filled.
- The addition of another level of electrons increases the size, or atomic radius, of an atom.
- Because of electron shielding, the effective nuclear charge acting on the outer electrons is almost constant as you move down a group, regardless of the energy level in which the outer electrons are located.
- As you move from left to right across a period, each atom has one more proton and one more electron than the atom before it has.
- All additional electrons go into the same principal energy level—no electrons are being added to the inner levels.
  - Electron shielding does not play a role as you move across a period.
  - As the nuclear charge increases across a period, the effective nuclear charge acting on the outer electrons also increases.



Atomic radius
Increases
Decreases



Atomic Radii of Main-Block Elements
Atomic radius (pm)
250
200
150
100
50
0
Cs
Rb
K
Na
Li
H
He
Period 6
Period 5
Period 4
Period 3
Period 2
Period 1
1
2
13
14
15
16
17
18
Group number



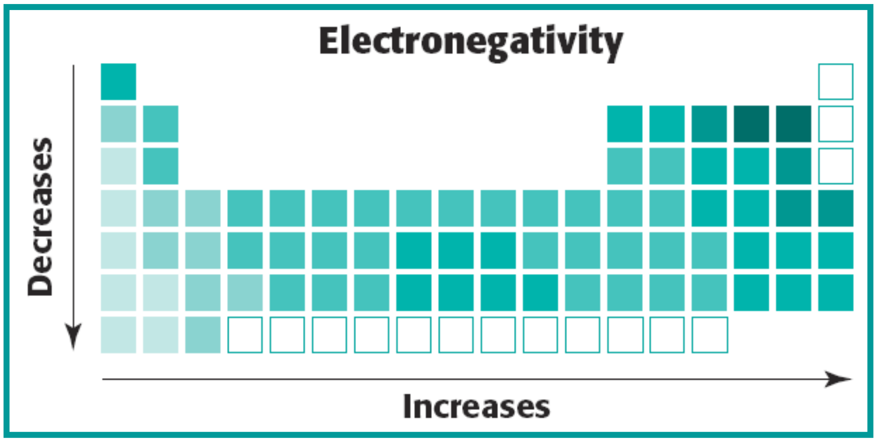
Ionic radii
Cations
Anions
Increases
Cations decrease
Anions decrease

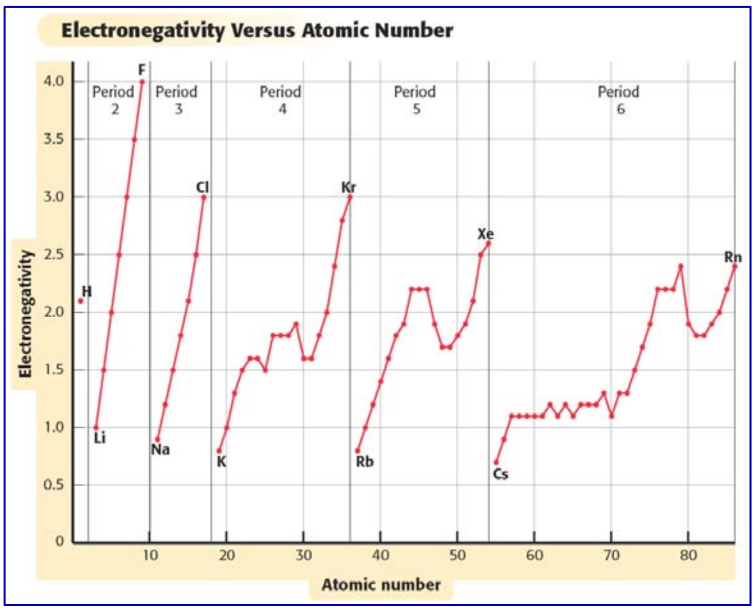
Electronegativity

- Not all atoms in a compound share electrons equally.
- Knowing how strongly each atom attracts bonding electrons can help explain the physical and chemical properties of the compound.
- Linus Pauling, an American chemist, made a scale of numerical values that reflect how much an atom in a molecule attracts electrons, called electronegativity values.
- Electronegativity is a measure of the ability of an atom in a chemical compound to attract electrons.
- The atom with the higher electronegativity will pull on the electrons more strongly than the other atom will.
- Fluorine is the element whose atoms most strongly attract shared electrons in a compound. Pauling arbitrarily gave fluorine an electronegativity value of 4.0.
- Values for the other elements were calculated in relation to this value.

Electronegativity Decreases as You Move Down a Group

- Electronegativity values generally decrease as you move down a group.
    - The more protons an atom has, the more strongly it should attract an electron.
    - However, electron shielding plays a role again.
- Electronegativity usually increases as you move left to right across a period.
- As you proceed across a period, each atom has one more proton and one more electron—in the same principal energy level—than the atom before it has.
- Electron shielding does not change as you move across a period because no electrons are being
added to the inner levels.
- The effective nuclear charge increases across a period.
    - As this increases, electrons are attracted much more strongly, resulting in an increase in electronegativity.
- The increase in electronegativity across a period is much more dramatic than the decrease in electronegativity down a group.



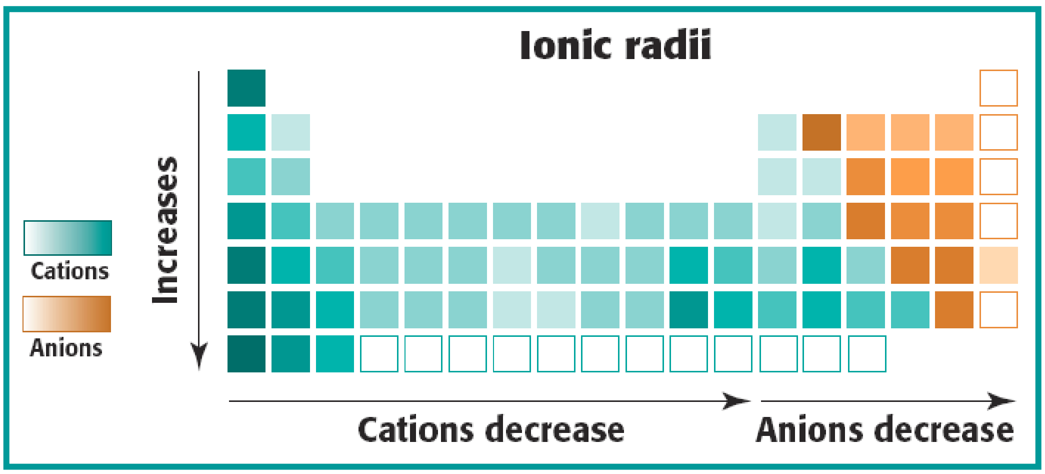


Other Periodic Trends

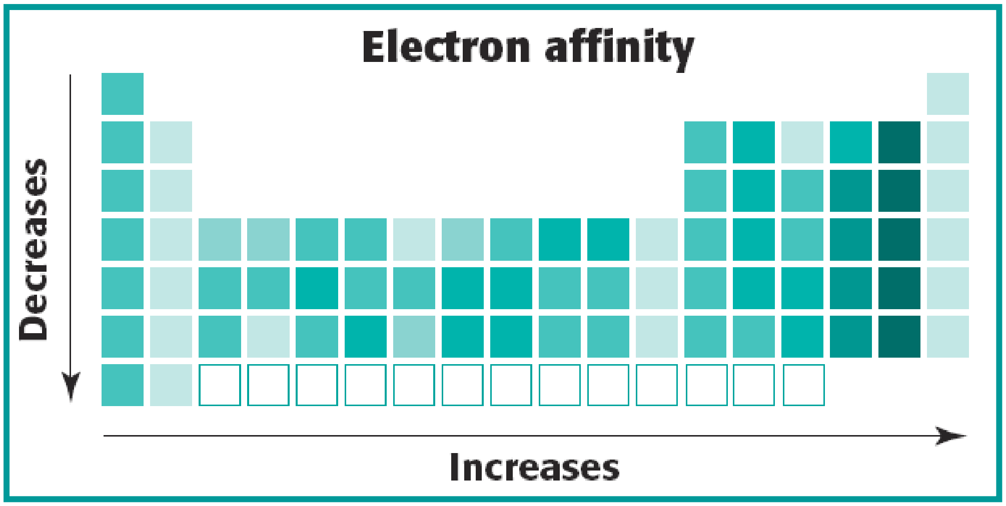
- The effective nuclear charge and electron shielding are often used in explaining the reasons for periodic trends.
- Effective nuclear charge and electron shielding also account for two other periodic trends–ionic size and electron affinity.
- The trends in melting and boiling points are determined by how electrons form pairs as *d* orbitals fill.

Periodic Trends in Ionic Size and Electron Affinity

- Like atomic size, ionic size has periodic trends.
- As you proceed down a group, the outermost electrons in ions are in higher energy levels.
    - The ionic radius usually increases as you move down a group.
        - This trends hold for both positive and negative ions.
- Metals tend to lose one or more electrons and form a positive ion.
    - As you move across a period, the ionic radii of metal cations tend to decrease because of the increasing nuclear charge.
- The atoms of nonmetal elements in a period tend to gain electrons and form negative ions.
- As you proceed through the anions on the right of a period, ionic radii still tend to decrease because of the anions' increasing nuclear charge



- The energy change that occurs when a neutral atom gains an electron is called the atom's *electron affinity*.
    - This property of an atom is different from electronegativity.
- The electron affinity tends to decrease as you move down a group because of the increasing effect of electron shielding.
- Electron affinity tends to increase as you move across a period because of the increasing nuclear charge.


Electron affinity
Decreases
Increases

Terms and Concepts

Chemical Properties	Earth's Elements	Electrical conductivity
Electronegativity	Electron Sharing	Element Family
Elements of Matter	Ionization Energy	Main group Elements
Metalloids	Periodic Table of Elements	

Suggested online resources for instruction (Sources used)

Flinn – www.flinnsci.com/resources

Awesome Science Teachers - http://www.nclark.net/

Chemmybear - http://www.chemmybear.com/

Chemaxon - http://www.chemmybear.com/

Ib Chemistry Help - http://www.mwiseman.com/courses/chem_ib/ib_help.jsp

W.W. Norton & Company: Chemistry - http://wwnorton.com/chemistry/
http://www.wwnorton.com/college/chemistry/gilbert/home.htm

Chemistry Animations - http://dwb4.unl.edu/ChemAnime/index.htm

Physics Education Technology, The University of Colorado at Boulder - http://phet.colorado.edu/index.php

Sources – Jeff Christopherson & John Bergmann, 2007, TeachChem Instructional Support CD v7.3
www.unit5.org/chemistry

Robert Becker of Kirtwood Highschool (12/8/2006)
http://dwb.unl.edu/chemistry/beckerdemos/BDinfo.html

Periodic Table

Activity # 1 - A 3-D Periodic Table – Plotting Trends

Questions to be investigated:

What are the trends that each of the following properties follow on the periodic table; atomic radius, ionization energy, and electronegativity?

Introduction

Does ionization energy increase going up or down a column in the periodic table? Do atoms get smaller or larger from right to left across a row? Most students have a hard time answering these questions. In this cooperative activity, students use micro scale reaction plates and straws of different lengths to construct three-dimensional bar-type charts of element properties. Lets students discover for themselves the existence and direction of periodic trends.

Concepts

- Periodic table
- Periodic trends

Materials

Calculator, at least 1 per student group	Straws (300)
Index cards, 4 x 6 inches (7)	Scissors, at least 1 per student group
Reaction plates, 96-well (8 x 12 layout), 7	Metric rulers, marked in millimeters (28)
Periodic table, (28)	

Procedure

1. Form a working group with three other students.
2. Obtain a periodic table, a reaction plate, a metric ruler, scissors, and 40 plastic straws.
3. Each group chooses or is assigned one element property: atomic mass, atomic radius, ionization energy, electronegativity, electron affinity, density, or melting point.
4. Find your assigned physical property on the periodic table.
5. Find the maximum value of the assigned physical property for the elements 1-20, 31-38, and 49-54 (these are the representative or main group elements in periods # 1-5).
   Example: The maximum value of the density for these elements is 7.31 g/cm^3 (for tin).
6. Let the length of the straw minus one cm represent this maximum value. This length will be the scale for all the other values of the density of the elements.

Example: For a straw that is 19.5 cm long, a straw length of 18.5 cm will represent a density of 7.31 g/cm3. This scale is thus 18.5 cm = 6.31 g/cm3. Round off straw length to 0.1 cm (1 mm).

7. Use this "straw" scale as a ratio; calculate the straw length that is needed to represent the assigned property for each element in the list. Example: The density of beryllium is 1.85 g/cm3. Solving Equation 1 for the straw length (sl) shows that a straw length of 4.7 cm is needed to represent the density of beryllium. Round off all straw lengths to 0.1 cm.
8. Add 1.0 cm to the calculated straw length for each element and cut a straw to that length.
   Example: Cut a straw 5.7 cm (4.7 cm + 1.0 cm) long to represent beryllium.

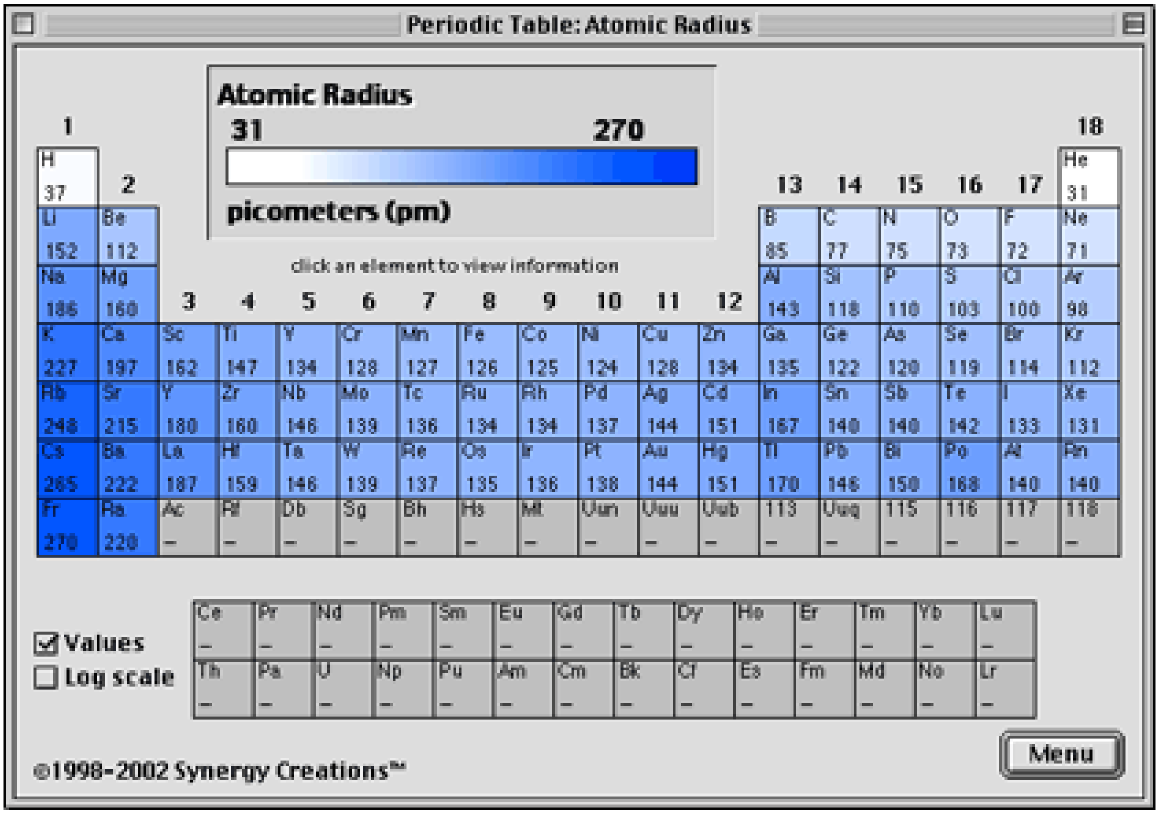
Teacher Tips

1. If the periodic tables you have available do not list all of the suggested physical properties, compile a list of the elements and their properties. An appropriate reference source is the *CRC Handbook of Chemistry and Physics*. See also the Website www.webelements.com.

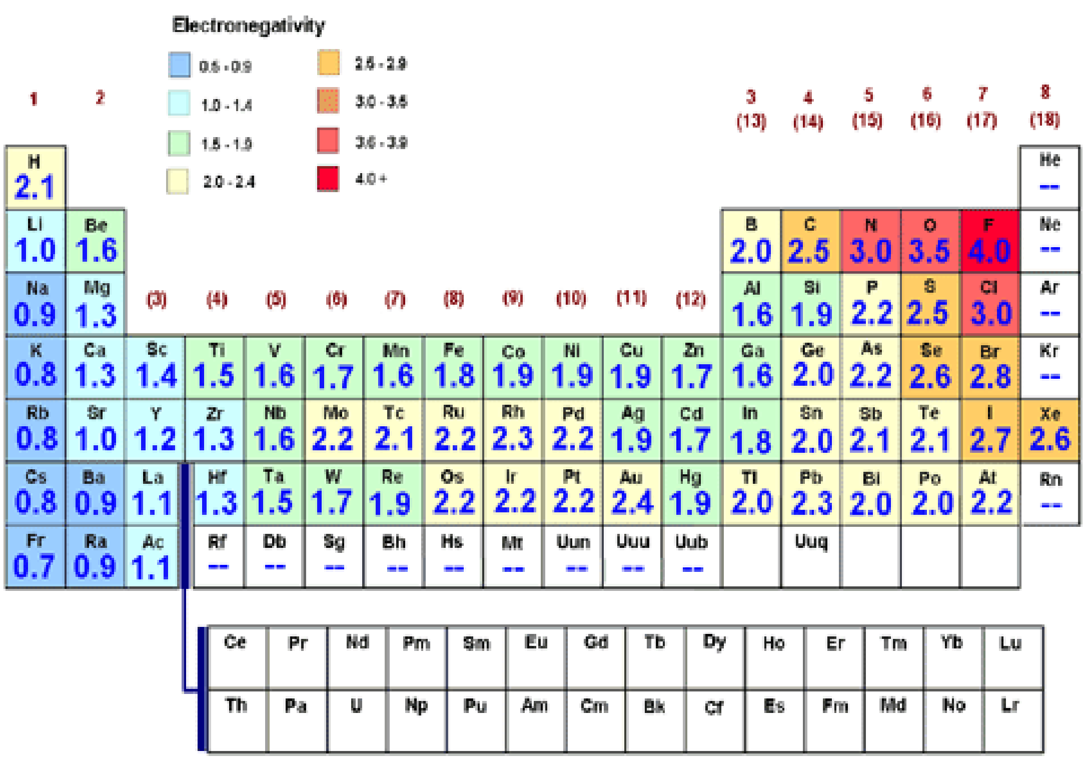
2. A large quantity of straws may be available from a local restaurant - ask them to support science activities.

3. This activity requires 1 full class period.

Atomic Radius



Electronegativity

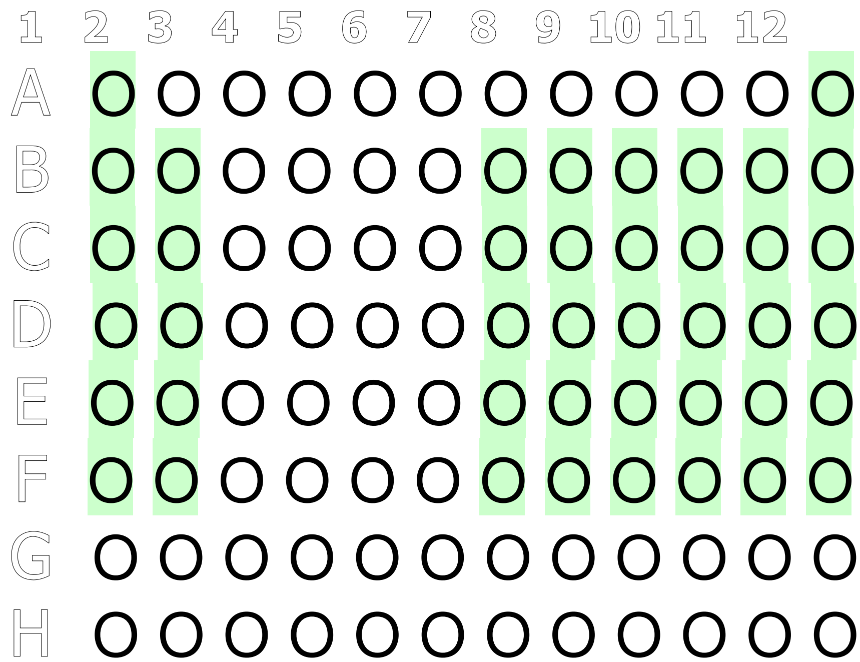


Ionization Energy

1 **H** 1310																	2 **He** 2370
3 **Li** 520	4 **Be** 900											5 **B** 800	6 **C** 1090	7 **N** 1400	8 **O** 1310	9 **F** 1680	10 **Ne** 2080
11 **Na** 490	12 **Mg** 730											13 **Al** 580	14 **Si** 780	15 **P** 1060	16 **S** 1000	17 **Cl** 1250	18 **Ar** 1520
19 **K** 420	20 **Ca** 590	21 **Sc** 630	22 **Ti** 660	23 **V** 650	24 **Cr** 660	25 **Mn** 710	26 **Fe** 760	27 **Co** 760	28 **Ni** 730	29 **Cu** 740	30 **Zn** 910	31 **Ga** 580	32 **Ge** 780	33 **As** 960	34 **Se** 950	35 **Br** 1140	36 **Kr** 1350
37 **Rb** 400	38 **Sr** 550	39 **Y** 620	40 **Zr** 660	41 **Nb** 670	42 **Mo** 680	43 **Tc** 700	44 **Ru** 710	45 **Rh** 720	46 **Pd** 800	47 **Ag** 730	48 **Cd** 870	49 **In** 560	50 **Sn** 700	51 **Sb** 830	52 **Te** 870	53 **I** 1010	54 **Xe** 1170
55 **Cs** 380	56 **Ba** 500	[57-71] *	72 **Hf** 700	73 **Ta** 760	74 **W** 770	75 **Re** 760	76 **Os** 840	77 **Ir** 890	78 **Pt** 870	79 **Au** 890	80 **Hg** 1000	81 **Tl** 590	82 **Pb** 710	83 **Bi** 800	84 **Po** 810	85 **At** …	86 **Rn** 1030
87 **Fr** …	88 **Ra** 510	[89-103] †	104 **Unq** …	105 **Unp** …	106 **Unh** …	107 **Uns** …	108 **Uno** …	109 **Une** …									

*Lanthanide series	57 **La** 540	58 **Ce** 670	59 **Pr** 560	60 **Nd** 610	61 **Pm** …	62 **Sm** 540	63 **Eu** 550	64 **Gd** 600	65 **Tb** 650	66 **Dy** 660	67 **Ho** …	68 **Er** …	69 **Tm** …	70 **Yb** 600	71 **Lu** 480
†Actinide series	89 **Ac** 670	90 **Th** …	91 **Pa** …	92 **U** 400	93 **Np** …	94 **Pu** …	95 **Am** …	96 **Cm** …	97 **Bk** …	98 **Cf** …	99 **Es** …	100 **Fm** …	101 **Md** …	102 **No** …	103 **Lr** …

Trend ______________________



Scale: 1 cm = _________

Definition of trend:

Names

Instructions: In this activity, you will need to create a 3-dimensional periodic table showing a trend of the periodic table.

Examples of trends: atomic radius, ionic radius, electronegativity, electron affinity, density, melting point, boiling point, atomic mass, 1st ionization energy, etc...

Sources – Jeff Christopherson & John Bergmann, 2007, TeachChem Instructional Support CD v7.3

www.unit5.org/chemistry

Periodic Table

Activity # 2 – Metal, Nonmetal, or Metalloid?

Teacher Notes

Purpose: To investigate several properties of seven elements and based on those properties identify each element as metal, nonmetal, or metalloid.

Materials: Seven elements, Conductivity tester, Hammer, 1M HCl,

Procedure:

1. At each lab table a different element is located. You will perform the same tests and/or observations at each station. You will move at the direction of the teacher.
2. Appearance: Observe and record the appearance of each element, including physical properties such as color, luster, and form.
3. Conductivity: You will test the conductivity of each element. An element is either a conductor or a nonconductor.
4. Crushing: Gently tap each element with your hammer. Each element is either brittle (shatters when struck) or malleable (flattens in a thin sheet).
5. Reactivity with acid: Place a small piece of the element in a well place with 15-20 drops of 1M HCl. Remember the indicators of a chemical reaction.
6. Observe and record your results at each lab station.

Data Table:

Element	Appearance	Conductivity	Result of Crushing	Reaction with HCl
a.				
b.				
c.				
d.				
e.				
f.				
g.				

Analysis/ Assessment:

1. Classify each property tested in this activity as either a physical property or a chemical property.

Activity	**Physical or Chemical**
Appearance	
Conductivity	
Result of Crushing	
Reaction with HCl	

2. Sort the coded elements tested into two groups based on similarities or differences in their physical or chemical properties.

3. Which element (s) can be placed into either group?

4. Using the following information, classify each element tested as a metal, nonmetal, or metalloid.
   a. Metals have a luster, are malleable, and conduct electricity.
   b. Many metals react with acids.
   c. Nonmetals are usually dull in appearance, are brittle, and do not conduct electricity.
   d. Metalloids have some properties of both metals and nonmetals.

Element	**Metal, Nonmetal, or Metalloid**
a.	
b.	
c.	
d.	
e.	
f.	
g.	

Sources: http://www.nclark.net/, http://www.nclark.net/MetalNonmetalLab.htm
Awesome Science Teachers Resources

Periodic Table

Activity # 3 – Operation: Periodic Table

Names ______________________________ Class _____ Date ___________

Operation: Periodic Table

Mission Directive

You have been given data on 24 mystery elements. Your team's mission is to arrange these elements in a table according to their chemical and physical properties. The goal is to display as many patterns among the properties as possible. Use the following guidelines to help you accomplish your mission:

1. Tables typically contain vertical columns and horizontal rows. This format is recommended but not required.
2. First, sort the elements into groups according to similar *chemical* properties (hydride, oxide, chloride). Make each group as specific as possible. Try a few different methods and choose the one that works best.
3. Within each of your groups, arrange the elements in some logical order according to at least one *physical* property. Try to develop a pattern that incorporates as many properties as possible. Also, try to incorporate both horizontal and vertical patterns into your layout.
4. Once you have finalized the layout of your table, glue it to as piece of poster paper. In the space below, write a brief, but *specific*, description of how your table is organized. Make sure your names are on both papers. You may decorate your table if time allows.

Periodic Table Description

A Black crystalline solid Melting point = 3652°C Boiling point = 4200°C Ionization energy = 1088 kJ/mol Hydride = AH_4 Oxide = AO_2, AO Chloride = ACl_4	**B** Colorless gas Melting point = -233°C Boiling point = -188°C Ionization energy = 1682 kJ/mol Hydride = BH Oxide = B_2O Chloride = BCl	**C** Black crystalline solid Melting point = 114°C Boiling point = 184°C Ionization energy = 1031 kJ/mol Hydride = CH Oxide = C_2O Chloride = CCl	**D** Silver-white, soft metallic solid Melting point = 186°C Boiling point = 1336°C Ionization energy = 519 kJ/mol Hydride = DH Oxide = D_2O Chloride = DCl
E Colorless gas Melting point = -272°C Boiling point = -268°C Ionization energy = 2372 kJ/mol Hydride = none Oxide = none Chloride = none	**F** Silver-white, soft metallic solid Melting point = 28°C Boiling point = 670°C Ionization energy = 375 kJ/mol Hydride = FH Oxide = F_2O Chloride = FCl	**G** Colorless gas Melting point = -112°C Boiling point = -107°C Ionization energy = 1170 kJ/mol Hydride = none Oxide = GO_2 (unstable) Chloride = GCl_4 (unstable)	**I** Gray crystalline solid Melting point = 1420°C Boiling point = 2355°C Ionization energy = 787 kJ/mol Hydride = IH_4 Oxide = IO_2 Chloride = ICl_4
J Silver-white, soft metallic solid Melting point = 842°C Boiling point = 1240°C Ionization energy = 590 kJ/mol Hydride = JH_2 Oxide = JO Chloride = JCl_2	**K** Colorless gas Melting point = -249°C Boiling point = -246°C Ionization energy = 2080 kJ/mol Hydride = none Oxide = none Chloride = none	**L** Silver-gray, soft metallic solid Melting point = 1280°C Boiling point = 2970°C Ionization energy = 898 kJ/mol Hydride = LH_2 Oxide = LO Chloride = LCl_2	**M** Silver, soft metallic solid Melting point = 62°C Boiling point = 760°C Ionization energy = 418 kJ/mol Hydride = MH Oxide = M_2O Chloride = MCl

N	P	Q	R
Silver, pale yellow metallic solid Melting point = 774°C Boiling point = 1140°C Ionization energy = 551 kJ/mol Hydride = NH_2 Oxide = NO Chloride = NCl_2	Colorless gas Melting point = -157°C Boiling point = -153°C Ionization energy = 1346 kJ/mol Hydride = none Oxide = PO_2 (unstable) Chloride = PCl_4 (unstable)	Gray-white metallic solid Melting point = 958°C Boiling point = 2700°C Ionization energy = 780 kJ/mol Hydride = QH_2 Oxide = QO_2, QO Chloride = QCl_2, QCl_4	Red-orange solid Melting point = -7.2°C Boiling point = 59°C Ionization energy = 1148 kJ/mol Hydride = RH Oxide = R_2O Chloride = RCl
S Colorless gas Melting point = -189°C Boiling point = -186°C Ionization energy = 1519 kJ/mol Hydride = none Oxide = none Chloride = none	**T** Silver-white metallic solid Melting point = 651°C Boiling point = 1107°C Ionization energy = 736 kJ/mol Hydride = TH_2 Oxide = TO Chloride = TCl_2	**U** Silver-white, soft metallic solid Melting point = 38°C Boiling point = 700°C Ionization energy = 410 kJ/mol Hydride = UH Oxide = U_2O Chloride = UCl	**V** Silver, pale yellow metallic solid Melting point = 725°C Boiling point = 1140°C Ionization energy = 504 kJ/mol Hydride = VH_2 Oxide = VO Chloride = VCl_2
W Pale yellow gas Melting point = -103°C Boiling point = -34°C Ionization energy = 1255 kJ/mol Hydride = WH Oxide = W_2O Chloride = WCl	**X** Gray-white metallic solid Melting point = 232°C Boiling point = 2260°C Ionization energy = 709 kJ/mol Hydride = XH_4 Oxide = XO_2, XO Chloride = XCl_2, XCl_4	**Y** Gray metallic solid Melting point = 327°C Boiling point = 1620°C Ionization energy = 715 kJ/mol Hydride = YH_4 Oxide = Y_2O, YO_2 Chloride = YCl_2, YCl_4	**Z** Silver, soft metallic solid Melting point = 97.5°C Boiling point = 880°C Ionization energy = 498 kJ/mol Hydride = ZH Oxide = Z_2O Chloride = ZCl

Sources

Awesome Science Teacher Resources
http://www.nclark.net/PeriodicTable

Periodic Table

Activity # 4 – Alkali Metal Property Demonstration

Teacher Notes

Description:

Lithium, sodium, and potassium metals are sliced and then a small sample of each is reacted with water. Alternative: video available that shows Rb and Cs also.

Concept:

The alkali metals are soft and silvery. They are also the most reactive metals having the lowest ionization energies. They react readily with water, lithium being the least reactive and potassium the most.

Materials:

- Explosion Shield or ventilation hood
- Knife
- Li, Na, and K
- Paper Towel
- 3 watch glasses
- 3 dishes
- Forceps
- Water

Safety:

These metals are very reactive. Be careful to put only small pieces (1/2 pea sized) in to the water. Wear goggles and use the explosion shield. Store these metals under oil.

Procedure:

Remove a piece of Li wire and wipe the oil off with a paper towel.
On a watch glass, cut a small piece of Li from the lithium wire.
With forceps, set the small piece on to the water in a dish.
Do the same with the Na and K metal. Use only a ½ pea sized piece of K.

Clean-up:

Return any leftover metal to its container. Make sure all the metal you added got to react and, when it has, the remaining water and hydroxide can be washed down the drain.

Notes:
This demo was developed by Prof. Ewing for his C100 class.
He notes: "Na burns with characteristic yellow flame, K is violet. If you are lucky Li will display red flame."

Reaction:

$$2\ Li\ (s)\ +\ 2\ H_2O\ (l)\ =\ 2\ LiOH\ (aq)\ +\ H_2\ (g)$$

Similar for Na and K

***Option*:**
The ACS Video "Close-Up on Chemistry" includes a demo showing the properties of the alkali metals Li through Cs. The reactivity of Rb and Cs is definitely shown to be greater than that of Li, Na, and K.

Resources - http://www.chem.indiana.edu/academics/demos/7-2%20Alkali%20Metal%20Properties.doc
Indiana University Department of Chemistry, Bloomington Indiana

Periodic Table

Activity # 5 – Alkaline Earth Metal Demonstration

Teacher Notes

Description: Samples of Mg and Ca are displayed. Mg and HCl produce fewer bubbles than Ca and HCl. Mg and H_2O produce less hydroxide and therefore less pink with phenolphthalein than Ca and H_2O.

Concept: The alkaline earth metals are less reactive and harder compared to the alkali metals. They do not react as readily with water. Mg is less reactive than Ca.

Materials:

- Mg ribbon
- Bunsen burner or propane torch
- flint striker
- tongs
- dishes
- water
- dilute acid (1 M HCl)
- Ca
- phenolphthalein

Safety:
If you have contact with the acid, wash it off. Wear safety goggles and gloves.

Procedure:

Ca turnings and Mg ribbon can be passed around in closed dishes.

Put a piece of Ca in a dish of water. Place a piece of Mg in water. Add a few drops of phenolphthalein to each dish. Compare the amount of pink after about 45 minutes.

Put a piece of Ca in a dish of acid and a piece of Mg in a dish of acid. Compare the amount of fizzing that result.

Clean-up:
Make sure the Ca is completely reacted. When it has, the remaining water and hydroxide can be washed down the drain.

Notes:

Reactions:

$$Ca\ (s) + 2\ H_2O\ (l) \rightarrow Ca(OH)_2\ (aq) + H_2\ (g)$$
$$Mg\ (s) + 2\ H_2O\ (l) \rightarrow Mg(OH)_2 + H_2\ (g)$$
$$Ca\ (s) + 2\ HCl\ (aq) \rightarrow CaCl_2\ (aq) + H_2(g)$$
$$Mg\ (s) + 2\ HCl\ (aq) \rightarrow MgCl_2\ (aq) + H_2(g)$$

(displacement reactions)

Demonstration developed for Ewing's C100.
Also done in C101 and C105.

Resources –
http://www.chem.indiana.edu/academics/demos/7-2%20Alkali%20Metal%20Properties.doc
Indiana University Department of Chemistry, Bloomington Indiana

Periodic Table

Activity # 6 – Periodic People – Top Secret Activity

TOP SECRET!

Question to be investigated

What are the trends that are seen in the construction of the periodic table of elements? This activity is designed to help students identify trends and relationships that are identified in the periodic table.

Because of the skills you have demonstrated in the organization of the Periodic Table, you have been chosen for a top-secret mission. The mission, should you choose to accept it (and it is in your best interest that you do), is to work with the sketches of the characters contained in the envelope. These represent members of a family of secret agents, but the most important member has never been sketched. You are to organize the pictures and sketch the missing secret agent.

CLUE ONE: You could begin by grouping the people by similar characteristics or you could, sequence the pictures. For example, if you were given 100 cards with numbers from 0 to 99 on them, you could put them all in one long row from 0 to 99. Then you could make shorter rows and create columns, still maintaining the original order.

0	1	2	3	4	5	6	7	8	9	
10	11	12	13	14	15	16	17	18	19	
20	21	22	23	24		26	27	28	29	
30	31	32	33	34	35	36	37	38	39	etc.

In this arrangement each ROW has something in common; the first row contains single digits and the remaining rows contain numbers beginning with the same number. Each COLUMN has something in common; they all end with the same number. You can tell the missing number must begin with 2 and end with 5. You must apply the same thinking when you arrange the secret agents by identifying their characteristics. They have hair, body designs, fingers, arms, expressions, body sizes, etc.

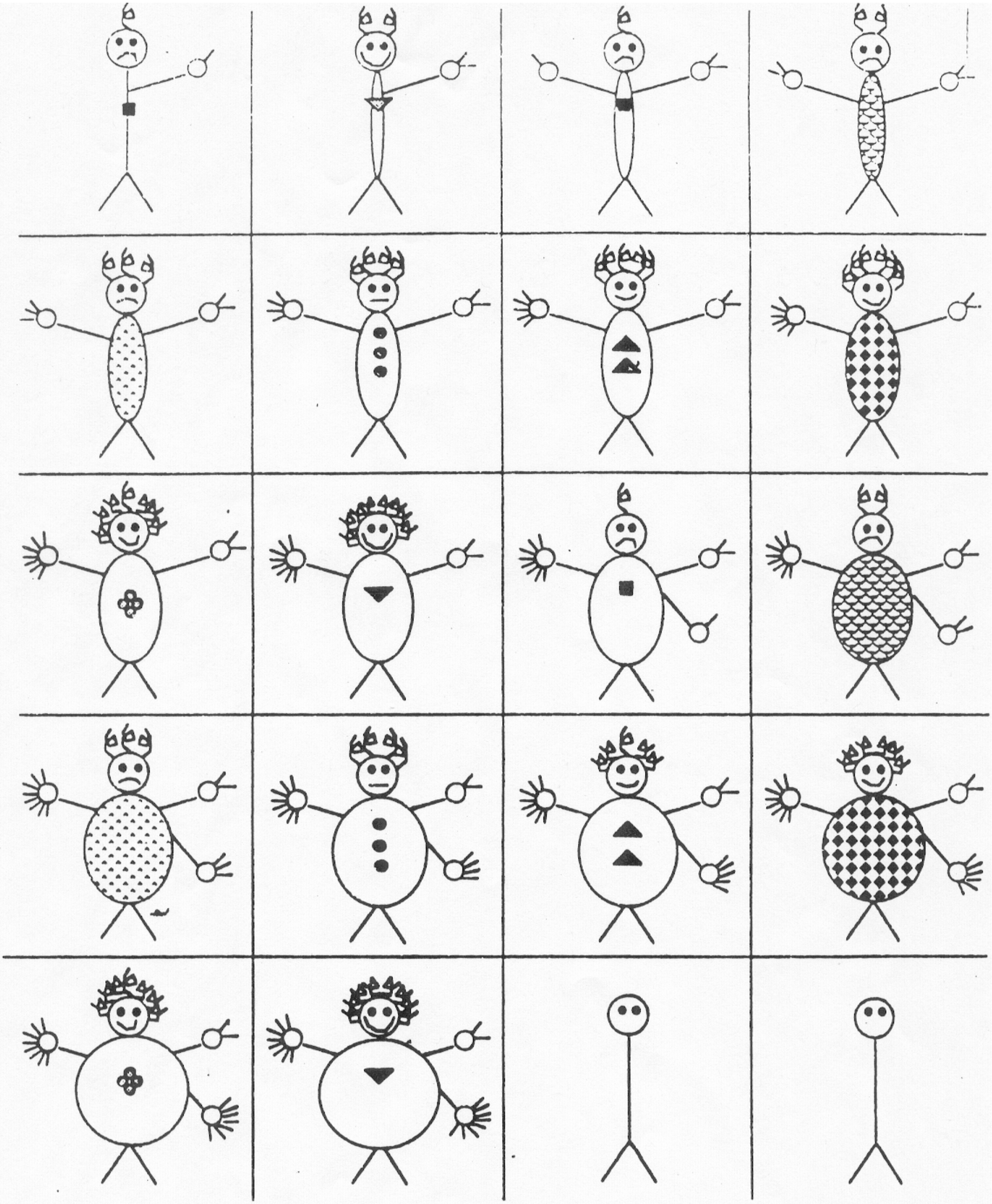
CLUE TWO: Each secret agent is different from every other one in TWO of the properties. No two sketches have the same amount or kind of these properties. If you can find one of these two, it will be possible to sequence the sketches correctly.

CLUE THREE: You will have three rows when you are finished. The rows DO NOT have to have the same number of sketches in each row. The goal is that all members of a row will have something in common and all members of a column have something in common.
After you have organized the "family", answer the following questions on another sheet of paper.

1. In what TWO ways are all the secret agents different?
2. What do the agents in a ROW have in common?
3. What do the agents in a COLUMN have in common?
4. Draw the missing agent.

EXTRA CREDIT: Relate some characteristics of the agents to properties of elements on the Periodic Table.

If you do not accomplish this task in 30 minutes, this envelope will self-destruct! GOOD LUCK!



TOP SECRET!!! FOR YOUR EYES ONLY

Because of your expertise in such matters, you have been chosen for this top secret mission. Your mission, should you choose to accept it, is to work with the "photographs" of the suspicious characters on the secret agent sheet. They are part of a family of secret agents, but the most deadly of all has never been photographed. Your job is to arrange the photographs in a pattern so that you can draw the missing secret agent.

Here are some clues. If you had the numbers from 0 to 99 written on little squares of paper, and were told to arrange them, you could put them in order with each number, one greater than the last. Now that they are in one long row 100 squares long, WITHOUT CHANGING THE ORDER, break the sequence so that there are similarities in columns as well as rows:

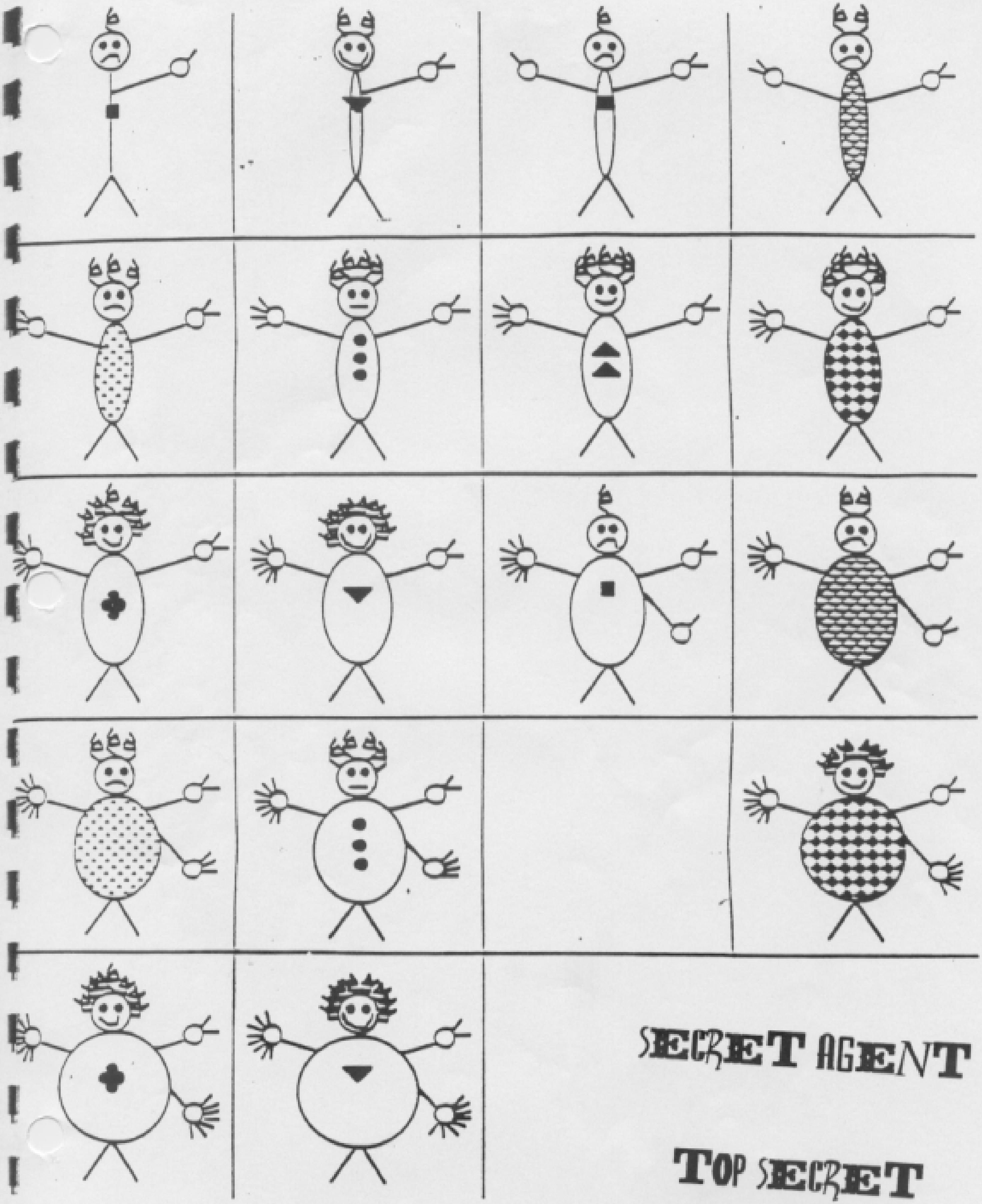
0	1	2	3	4	5	6	7	8	9
10	11	12	13	14	15	16	17	18	19
20	21	22	23	24	25	26	27	28	29
30	31	32	33	34	35	36	37	38	39

Notice that each number is one greater than the last. Also, now there is organization in columns as well – all the numbers in a column end in the same digit and begin with digits in consecutive order. And, finally, all the numbers in a row begin with the same digit. It might be useful to point out here that "columns" are vertical lists of numbers, and "rows" are horizontal strings of numbers.

Use this same idea with the pictures. First arrange them in one single line, using one of the two ways in which each little man is DIFFERENT from every other. Once you have that arrangement, break the sequence (as done with the numbers) so that you have commonalities in columns as well as row. Remember to keep the original arrangement as you do this! Hint: unlike the numbers, all the columns and rows need now have the same number of squares.

- **Once you have the correct arrangement, you will be able to draw the missing secret agent. Draw him and add him to your chart.**
- **On another sheet of paper, complete the following:**
  - **List ALL the relationships you see as you look down a column.**
  - **List ALL the relationships you see as you look across a row.**
- **Staple the answers to your chart and turn this in.**

TOP SECRET



SECRET AGENT

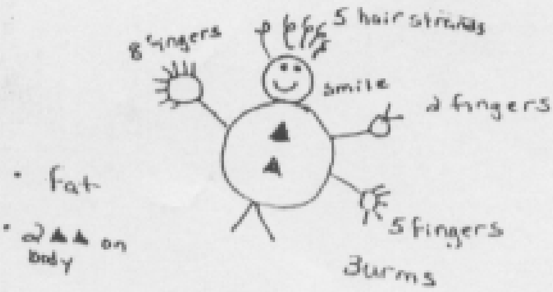
TOP SECRET

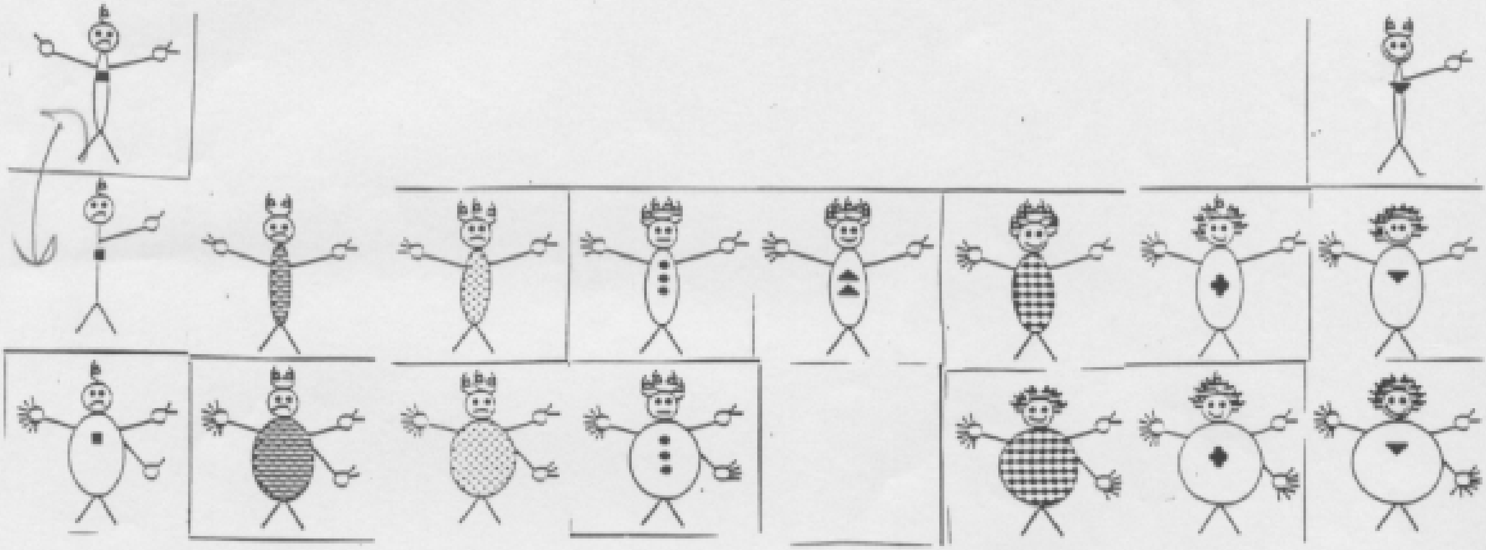
I. List the relationships going down a column

A. same clothing design
B. same number of hair strands
C. same facial expression
D. size increases from thin to fat
E. number of arms increases

II. List the relationships going across the chart

A. increasing number of hair strands
B. facial expression goes from sad to happy
C. all thin or all fat
D. number of fingers





Activity # 6 – Option 2 (Top Secret) Top Secret Periodic Table

Purpose

To discover patterns from various kinds of information in order to arrange elements or items into a meaningful sequence.

Discussion

Because of your expertise in such matters, you have been chosen for this top secret mission. Your mission, should you choose to accept it, is to work with the "sketches" of the suspicious characters on the secret agent list. They are part of a family of secret agents, but the most deadly of all has never been sketched. Your job is to arrange the sketches in a pattern so that you can draw the missing secret agent.

Procedure

1. Here is a helpful activity en route to solving your caper. You are given the numbers from 0 to 99 written on little squares of paper. You can arrange these numbers in order so that each number is greater than the previous number by placing them all one by one in order from lowest to highest. Once they are in one long row of 100 squares, you can now, WITHOUT CHANGING THE ORDER, organize the sequence of 100 numbers into columns and rows so that there are similarities in columns as well as rows. You must still keep the numerical sequence: each number is greater than the previous number.

0	1	2	3	4	5	6	7	8	9
10	11	12	13	14	15	16	17	18	19
20	21	22	23	24	25	26	27	28	29
30	31	32	33	34	35	36	37	38	39 ….

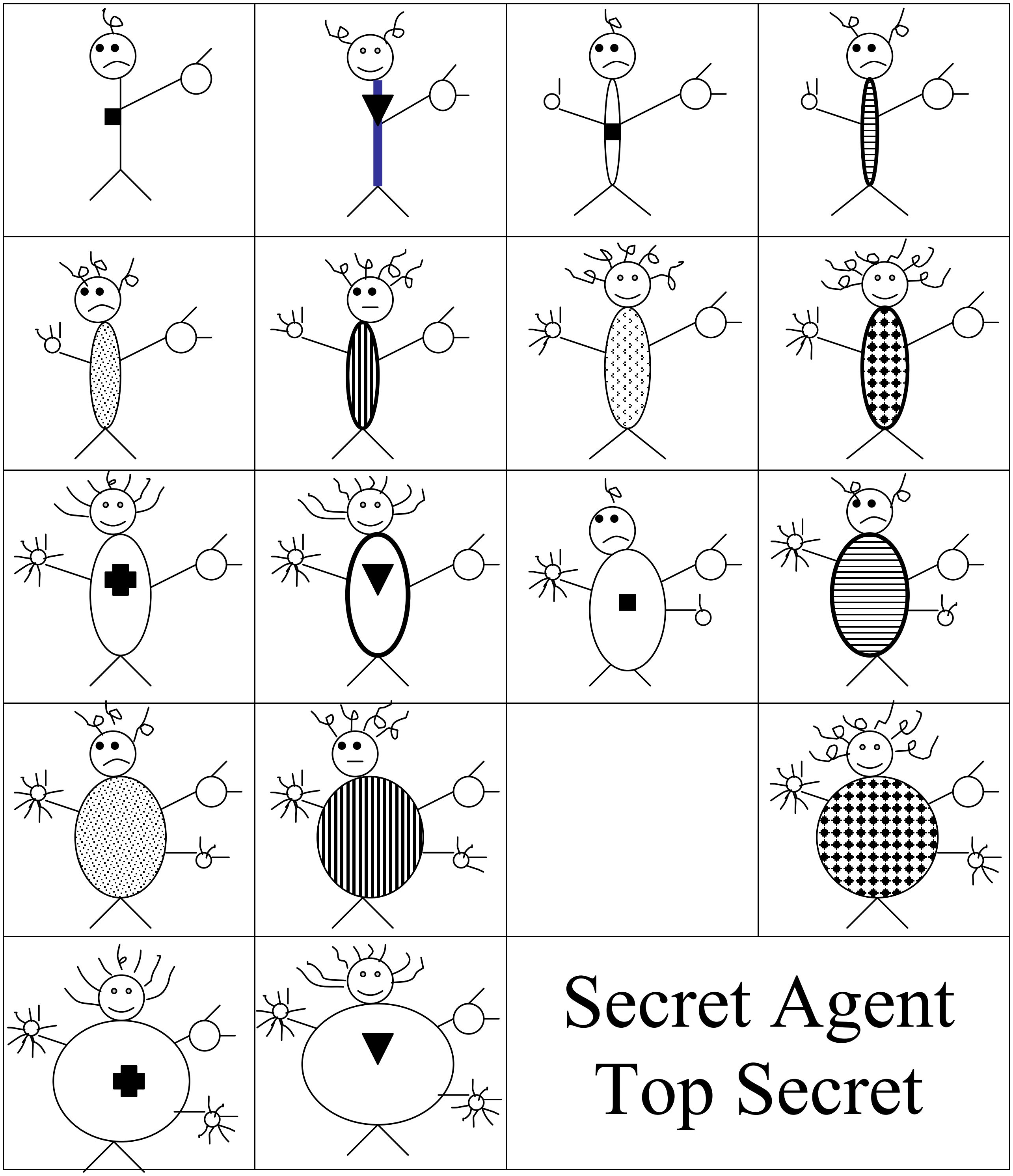
Notice that each number is one greater than the last. Also, now there is organization in columns as well → all the numbers in a column end in the same digit and begin with digits in consecutive order. And, finally, all the numbers in a row begin with the same digit. It might be useful to point out here that "**columns**" are vertical lists of numbers, and "**rows**" are horizontal strings of numbers.

2. Use this same idea with the sketches of suspicious characters. First arrange them in one single line so that each little man is DIFFERENT from every other by one item. Once you have that arrangement, organize the sequence (*as done with the numbers*) so that you have commonalities in columns as well as rows. Remember to keep the original arrangement as you do this! Unlike the numbers, not all the columns and rows need to have the same number of squares. HINT: look at the pattern of the actual Periodic Table.

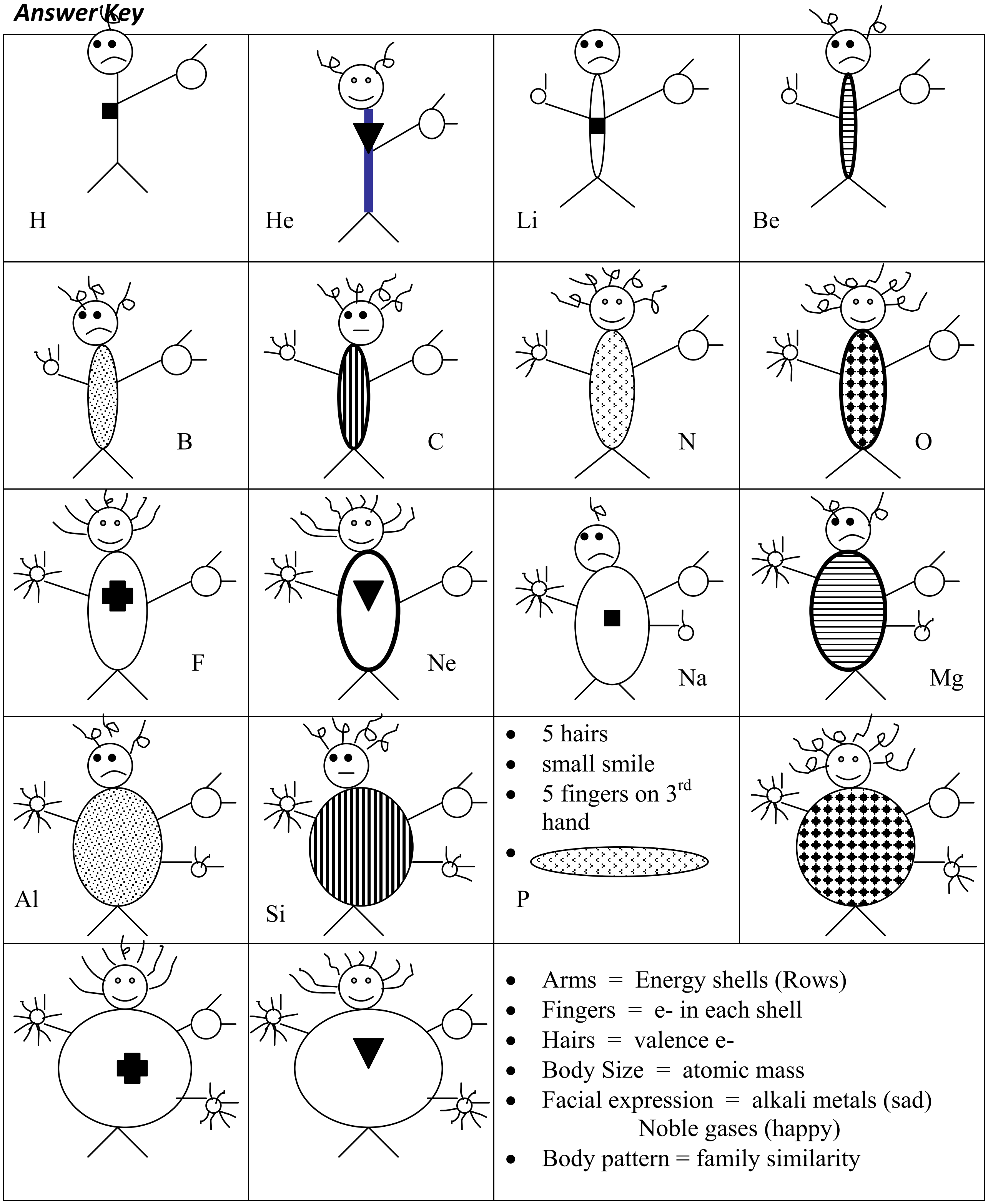
3. Once you have the correct arrangement, you will be able to draw the missing secret agent. Draw him and add him to your chart.

4. Now list ALL the relationships you see as you look down a column of agents.

5. List ALL the relationships you see as you look across a row.



Answer Key


H
He
Li
Be
B
C
N
O
F
Ne
Na
Mg
Al
Si
5 hairs
small smile
5 fingers on 3rd hand
P
Arms = Energy shells (Rows)
Fingers = e- in each shell
Hairs = valence e-
Body Size = atomic mass
Facial expression = alkali metals (sad)
Noble gases (happy)
Body pattern = family similarity

Periodic Table
Activity # 7 – Periodic Trend Tell Me Why Stations

Questions to be investigated –
What are the periodic trends, patterns of atomic radius, electronegativity, and ionization energy?

Teacher notes
Set up a minimum of three stations with a copy of one of the periodicity trends at each station. Use the transparencies that do not have the arrows indicating the trends. Break the class up into groups and have them analyze each individual station. Goal one is to identify the trends. Goal two is for the students to begin to identify what is causing the trends of atomic radius, electronegativity, and ionization energy.

Materials:
Copies of each period table with the values of atomic radius, electronegativity, and ionization energy.

Sources:
Michelle Tindall, Chemistry Teacher, Birmingham Groves High School

Procedure:

Periodic Trend Tell Me Why Stations

1. What trend is observed between the size of an atom and the size of the atom's cation? Why?

2. What trend is observed between the size of an atom and the size of the atom's anion? Why?

3. What is electronegativity? (Look in the glossary of your book).

4. What is the general trend in electronegativity across a period? Why?

5. What is the general trend in electronegativity down a group? Why?

6. What is the general trend in atomic radii across a period? Why?

7. What is the general trend in atomic radii down a group? Why?

8. What is ionization energy? (Look in the glossary of your book).

9. What is the general trend in ionization energy across a period? Why?

10. What is the general trend in ionization energy down a group? Why?