

## Periodic Table of the Elements

The periodic table is a classification system for the elements. There are 92 naturally occurring elements and at present 17 man-made ones.

**The elements on the periodic table are arranged according to increasing atomic number.** Remember! Atomic # is determined by an atom's number of protons. The elements on the periodic table display periodic properties.

An element's properties are determined by its atom's structure.

**Groups** or families are the vertical (up and down) columns on the periodic table. Elements in the same group have the same amount of valence electrons. Valence electrons are responsible for the chemical behavior of elements. Therefore; elements in the same group display very similar properties.

**Periods** are the horizontal (side to side) rows on the periodic table. The # of the period an element belongs to is the same as the element's # of occupied principle electron energy levels (rings or shells).

Examples: Element # 38 "Strontium" belongs to period 5, therefore it has 5 occupied principle energy levels. Element # 2 Helium "He" is in period 1 and has 1 principle energy level.

### Phases of the Elements

You are required to know the phases of the elements at room temperature. Reminder! Room temperature is  $25^{\circ}\text{C}$  or  $298\text{K}$ .

To memorize all the phases would be a difficult job. Therefore; look at the periodic table when you try to recall what the phases are.

**There are only 2 liquid elements: Mercury "Hg" and Bromine "Br".**

List the 2 liquid elements \_\_\_\_\_ and \_\_\_\_\_

**There are 11 gas elements: Hydrogen "H", Nitrogen "N", Oxygen "O", Fluorine "F", Chlorine "Cl", and all of group 18.**

Think of it this way.

Hydrogen "H" is a gas.

All of Group 18 (Noble gases) are gases.

Earth's atmosphere is gas, it is composed of the elements nitrogen "N" and oxygen "O".

Fluorine "F" and chlorine "Cl" (they rythm) are gases.


List the 11 gas elements \_\_\_\_\_

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As long as you know the 2 liquids and 11 gas elements, the rest must be solid.

## Note Packet # 9

**Diatomic Elements: Atoms of diatomic elements exist in pairs.**

Ex:  Diatomic nitrogen is represented as N<sub>2</sub>.  
The list of 8 diatomic elements is easy to remember.

The diatomic elements are Hydrogen "H", Nitrogen "N", Oxygen "O", and all of group 17.

List the diatomic elements. \_\_\_\_\_

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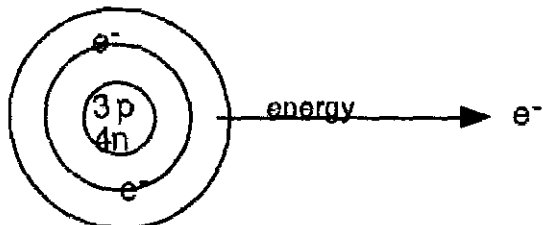
**Some elements are always Radioactive.** These elements have no stable isotopes. They emit (give off) radiation. See **Table O** for types of radioactive emanations. Elements with atomic # 84 and above are always radioactive. Also; elements with mass is in parentheses on the periodic table are radioactive.

Ex:  ${}_{43}^{(98)}\text{Tc}$  Technetium's mass is in parentheses. Therefore; it is always radioactive.

It has no stable isotopes.

## Note Packet # 9

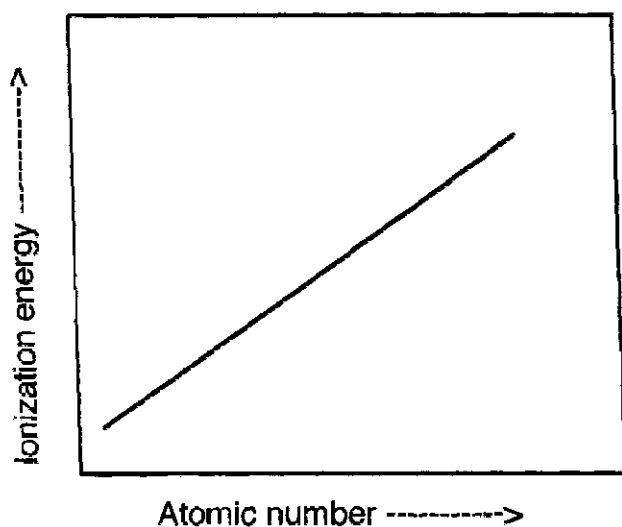
**Ionization Energy** is the amount of energy required to remove (take away) an electron from an atom. The units of ionization energy are kilojoules per mole ( kJ/mol).



The periodic table trend shows **ionization energy increasing left to right** across a period.

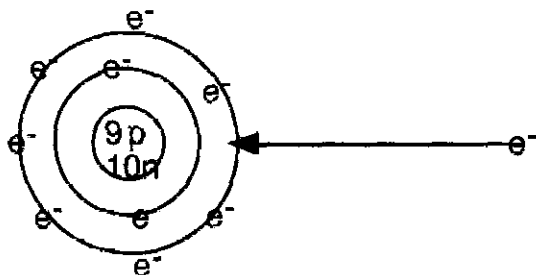
When **ionization Energy** is plotted vs. atomic number in a period the pattern can be easily seen.

As you move from **left to right across a period ionization energy increases**. There may be some fluctuation but the overall pattern is clear.



## Note Packet # 9

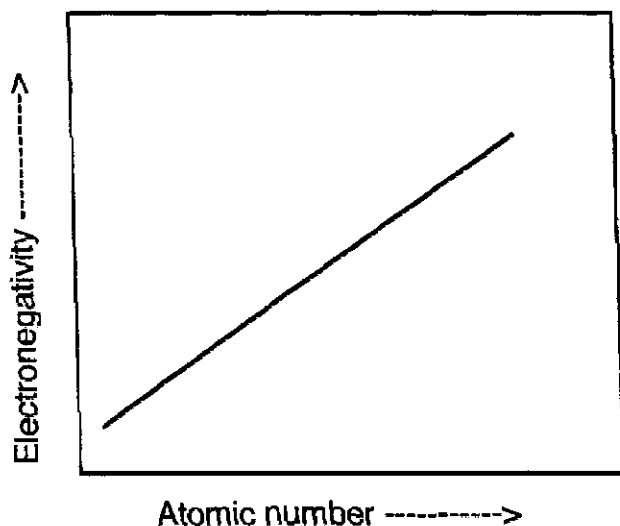
**Electronegativity** is an atom's attraction for electrons during chemical bonding. Fluorine has the highest electronegativity "4". The electronegativities of the other elements are based on (compared to) Fluorine's electronegativity. Therefore; there are no units for electronegativity. **Most Group 18 (noble gases) have no electronegativity values!**



The periodic table trend shows **electronegativity increasing left to right** across a period.

When **Electronegativity** is plotted vs. atomic number in any period the pattern can be easily seen.

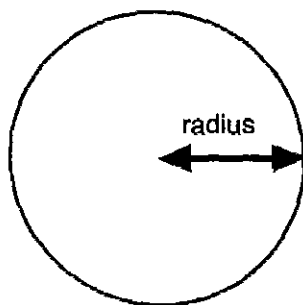
As you move from **left to right across a period electronegativity increases**. There may be some fluctuation but the overall pattern is clear.



**Remember! Most Group 18 elements don't have electronegativity values!**

## Note Packet # 9

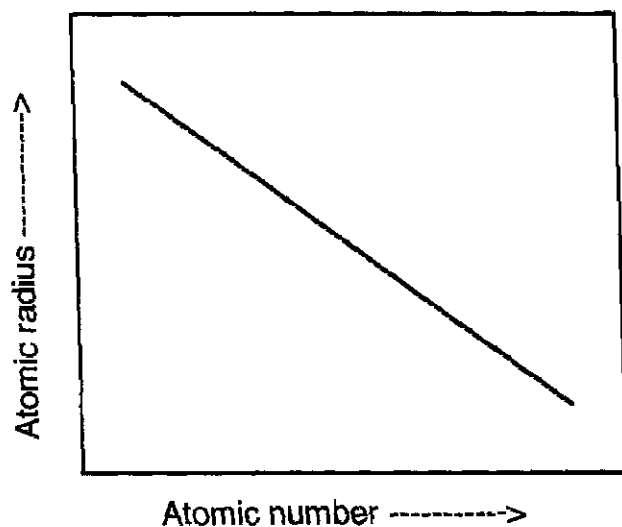
**Atomic Radius** is a measure of the size of an atom.



The periodic table trend shows **atomic radius decreasing left to right** across a period.

When **Atomic Radius** is plotted vs. atomic number in any period the pattern can be easily seen.

As you move from **left to right across a period atomic radius decreases**. There may be some fluctuation but the overall pattern is clear.



## Note Packet # 9

**Metals** The majority of the elements are metals. Most people have a good idea of what a metal is. The metal elements are located to the left of the bold zig-zag line on the periodic table.

### Properties of Metals

1. Low ionization energy and electronegativity
2. Easily lose electrons to form + ions called "cations".
3. Solids at room temperature (except for liquid mercury)
4. Metallic luster (metallic shine)
5. Good conductors of heat and electricity
6. Malleable (able to be hammered into sheets like aluminum foil)
7. Ductile (able to be stretched into wire)

Define: malleable

Define: Ductile

**Non-metals** The non-metals are found on the right side of the zig-zag line on the periodic table (exception: Hydrogen is a non-metal gas on the upper left of the periodic table.)

### Properties of Non-metals

1. High ionization energy and high electronegativity.
2. Easily gain electrons to form negative ions called "anions".
3. Poor conductors of electricity and heat.
4. Non-metal solids are brittle (crumble when hammered).

Define: Brittle

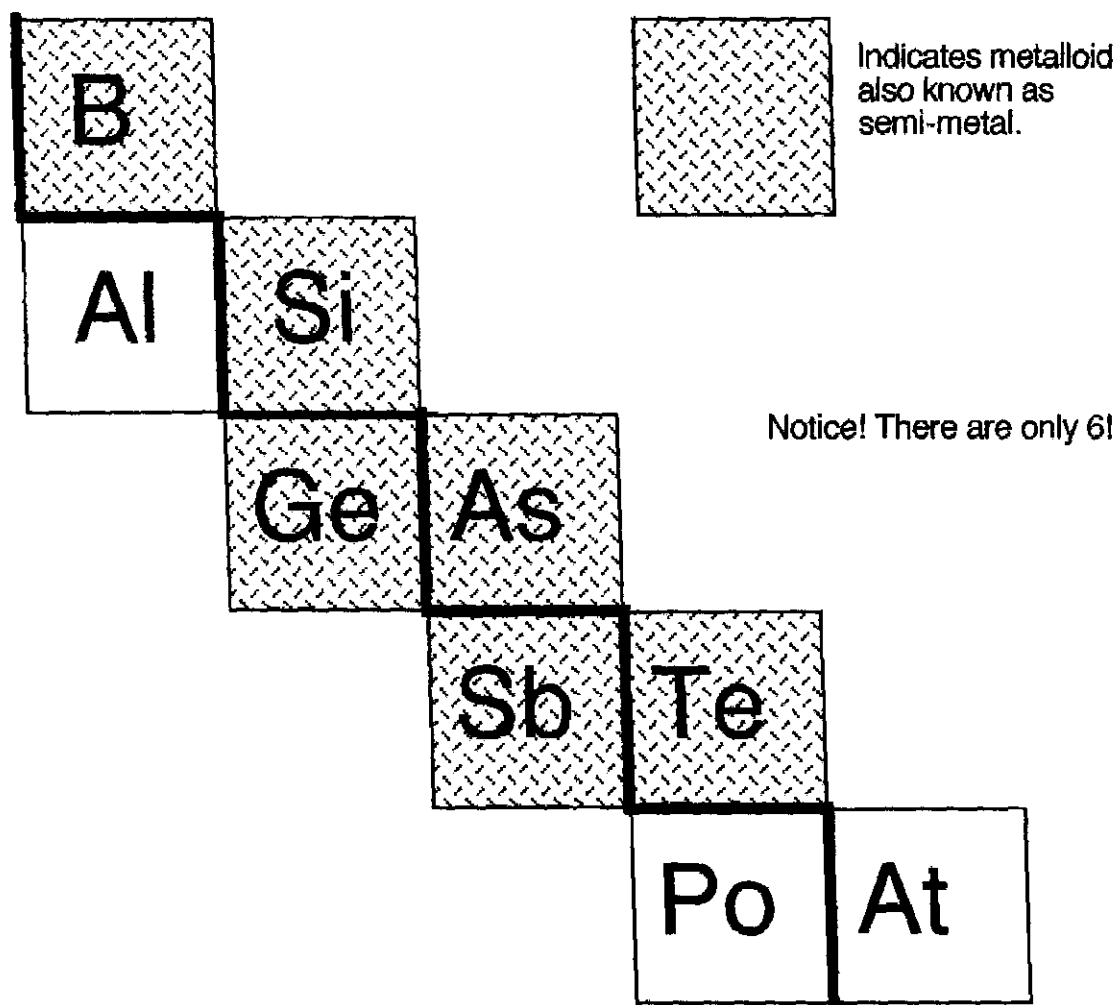
## Note Packet # 9

**Metalloids**, also known as **semi-metals** exhibit properties of both metals and nonmetals. There are 6 metalloid elements. They are found along the **bold zig-zag line**.

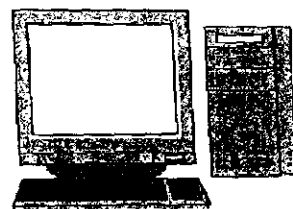
**Important! All metalloids touch the zig-zag line. However; not all elements that touch the zig-zag line are metalloids.** Think of the zig-zag line as steps.

Four of the metalloids are on top of the first 4 steps. The remaining 2 are under the middle of the steps.

**Important! Aluminum "Al" touches the zig-zag line, but we recognize aluminum as a true metal.**



Silicon "Si" is an important semi-metal. Silicon is used in the manufacture of computer chips. Computer chips are also known as semi-conductors. Metals are good conductors of electricity. Semi-metals are semi-conductors of electricity. Hence: the computer term "semi-conductor".



## Note Packet # 9

**Patterns and Trends** The periodic table is full of patterns and trends. As you head left or right across a period or up and down in a group patterns emerge.

When **Ionization Energy** is plotted vs. atomic number in any period the pattern can be easily seen. As you move from **left to right across a period ionization energy increases**. There may be some fluctuation but the overall pattern is clear.

When **Electronegativity** is plotted vs. atomic number in any period the pattern can be easily seen.

As you move from **left to right across a period electronegativity increases**. There may be some fluctuation but the overall pattern is clear.

When **Atomic Radius** is plotted vs. atomic number in any period the pattern can be easily seen.

As you move from **left to right across a period atomic radius decreases**. There may be some fluctuation but the overall pattern is clear.

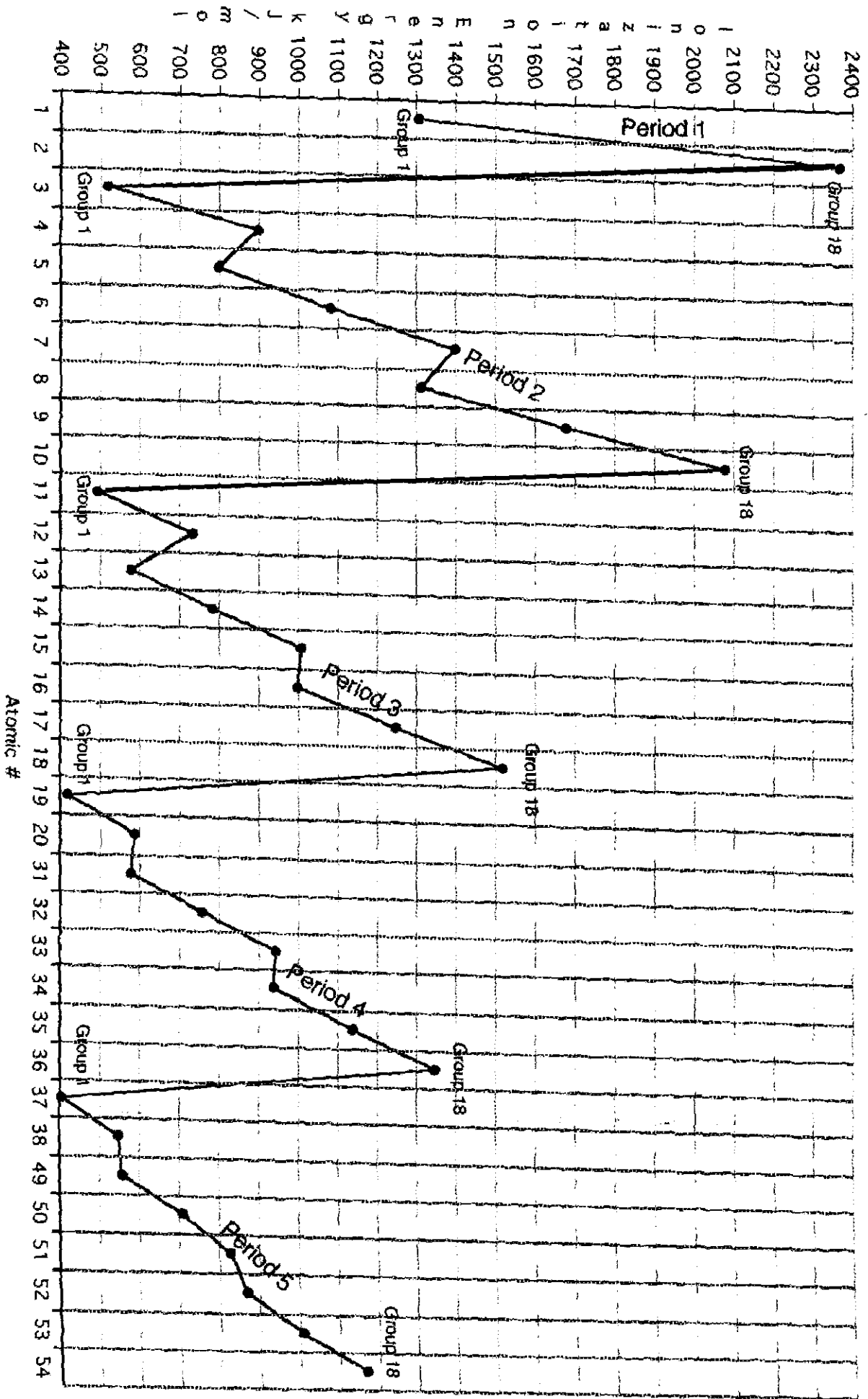
**Look at your periodic graphs** to see these patterns!

The following 3 pages show the patterns and trends for **ionization energy, electronegativity, and atomic radius**.

**You must know these!**

Ionization energy is measured in kilojoules per mole

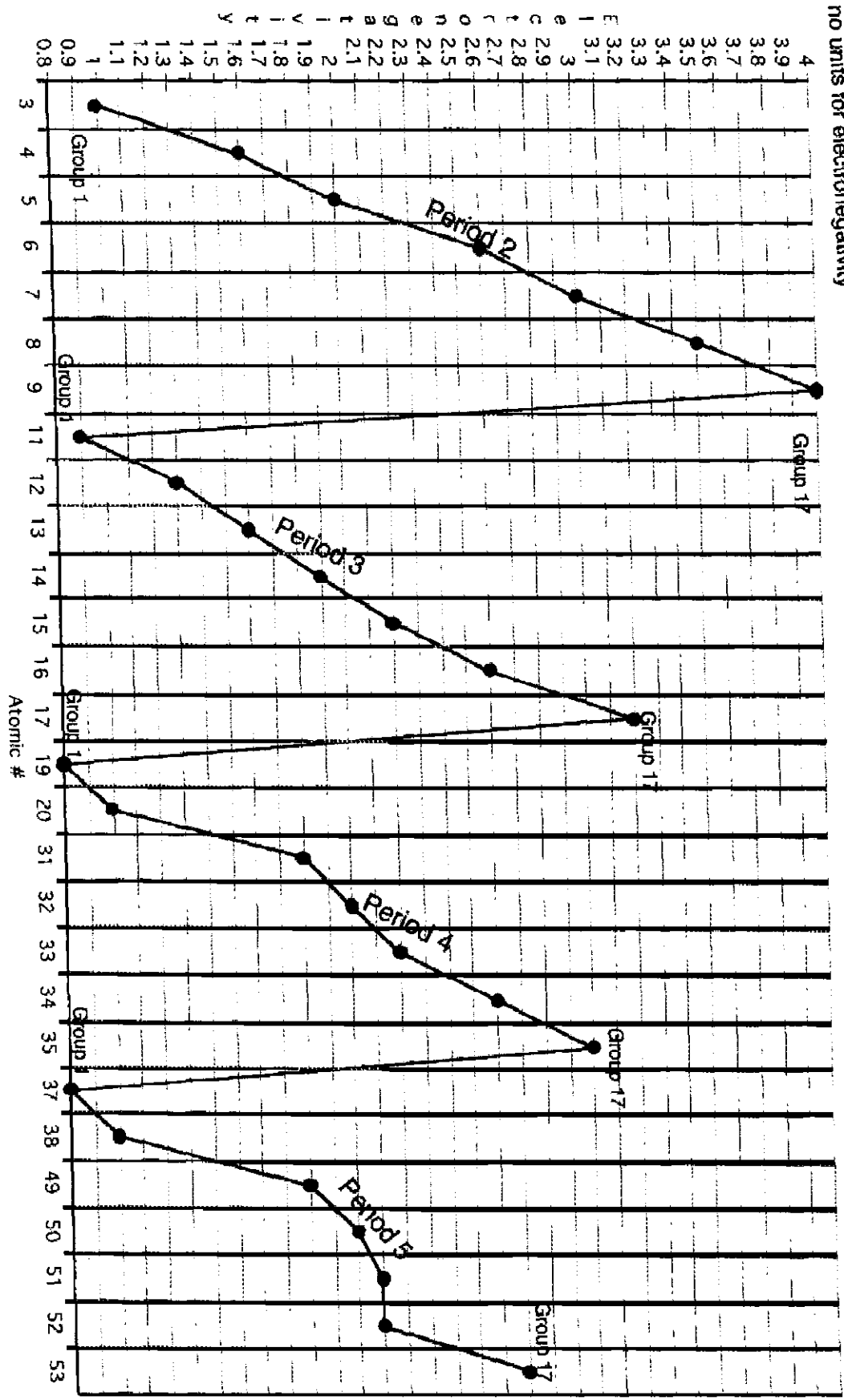
Ionization Energy vs. Atomic #



Ionization Energy is a periodic property of the elements. For any period, ionization energy is at a minimum at group 1. It increases left to right to a maximum at group 18.

Strange, but true, there are no units for electronegativity

Electronegativity vs. Atomic #

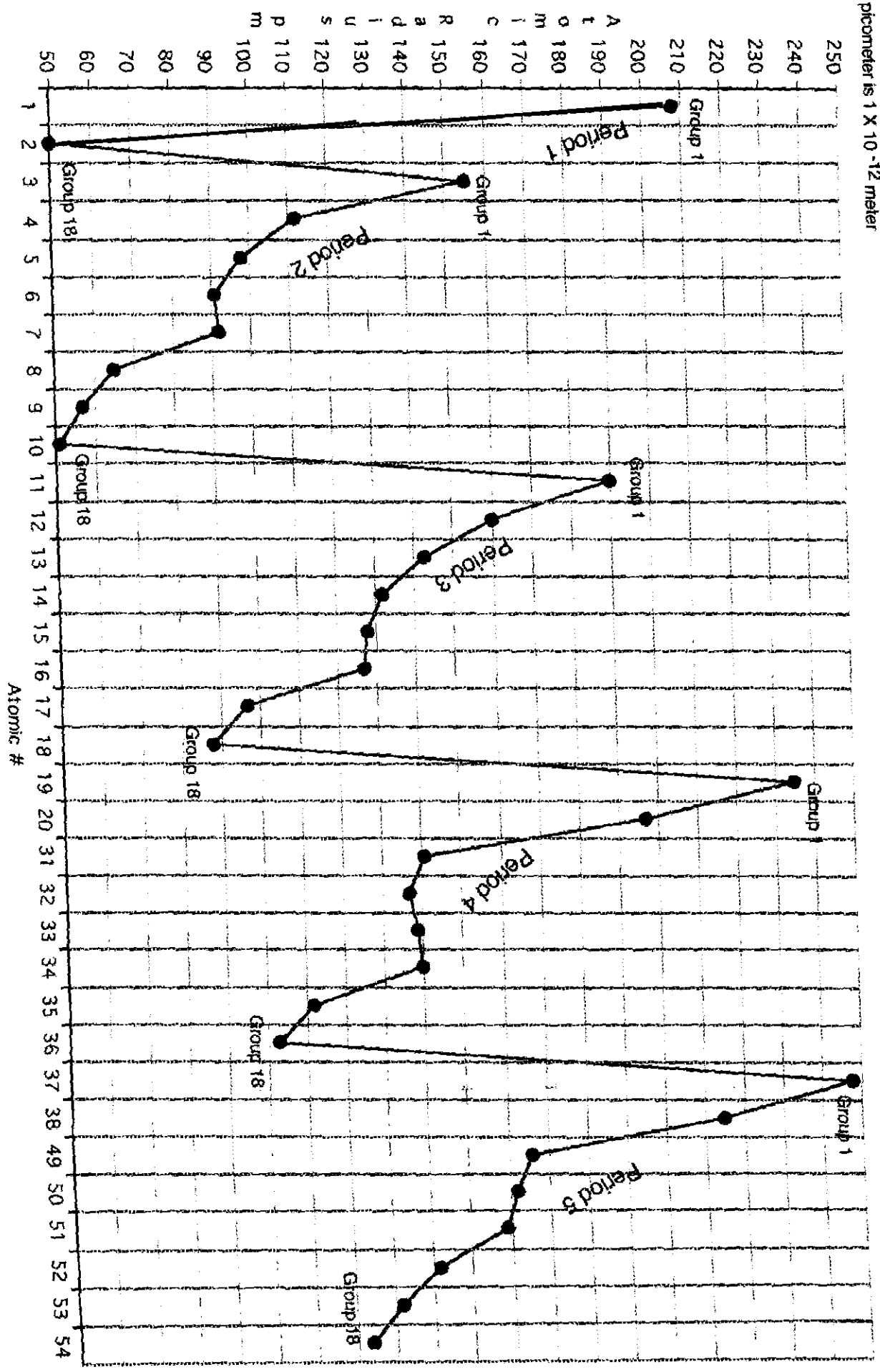


Series 1

Electronegativity is a periodic property of the elements. For any period electronegativity is at a minimum at Group 1 and increases, left to right to a maximum at Group 17.  
 Notice! Group 18 elements do not have an electronegativity.

Atomic radius is measured in picometers (pm).  
 a picometer is  $1 \times 10^{-12}$  meter

Atomic Radius vs. Atomic #



Atomic Radius is a periodic property of the elements. For any period, atomic radius is at a maximum at Group 1. It decreases from left to right to a minimum at Group 18.

## Note Packet # 9

**You will be asked** what happens to electronegativity, ionization energy, reactivity, and atomic radius as you move in any direction on the periodic table.

**If you can't memorize or just forget!**

Choose an element from opposite ends of a period or top and bottom of a group.

**Electronegativity, ionization energy, and atomic radius values are found in**

**"Table S" on pages 10 and 11 of the reference table. Look them up don't guess!**

### **Metallic vs. Non-metallic**

1. Moving **down a group** or to the **left in a period** (or both) results in more **metallic** properties. The most metallic element is Francium "Fr".

2. Moving **up a group** or to the **right in a period** (or both) results in more **non-metallic** properties. The most non-metallic element is Helium "He".

### **Reactivity**

1. **Reactivity** for metals increases as you move to the lower left of the periodic table. Francium "Fr" is the most reactive metal. It is in the lower left

2. **Reactivity** for non-metals increases as you move to the upper right of the periodic table. **However; Group 18 (Noble Gases) are not reactive at all.**

Therefore: Fluorine "F" is the most reactive non-metal.

### **Answer the following.**

- What happens to electronegativity as you move left to right across period 4?
- What happens to ionization energy as you move left to right across period 3?
- What happens to atomic radius as you move left to right across period 2?
- What happens to electronegativity as you move from top to bottom in group 17?
- What happens to atomic radius as you move from top to bottom in group 1?
- What happens to ionization energy as you move from top to bottom in group 17?
- Which element is the most reactive metal?
- Which element is the most reactive non-metal?
- What happens to the reactivity of metals as you move from top to bottom in group 2?
- What happens to the reactivity of non-metals as you move from top to bottom of group 17?

## Note Packet # 9

**Allotropes** are different forms of the **same element** that have very different chemical and physical properties. This results from the way the atoms are bonded to each other.

**Allotropes have different properties because their molecules have a different molecular structure.**

Examples:

Carbon has 3 well known allotropes.

Carbon can exist as:

- a) graphite (the stuff in a pencil that we write with)
- b) coal
- c) diamond

Oxygen has 2 well known allotropes.

Oxygen can exist as:

- a) diatomic oxygen "O<sub>2</sub>" as in what we need to breath
- b) ozone "O<sub>3</sub>" is a poison if we breath it, but a protector of our atmosphere from ultra-violet light in the upper atmosphere.

**Caution!** Allotrope sounds like isotope! Don't confuse them.

### **Example Question:**

At 298 K, oxygen (O<sub>2</sub>) and ozone (O<sub>3</sub>) have different properties because their

- (1) atoms have different atomic numbers
- (2) atoms have different atomic masses
- (3) molecules have different molecular structures**
- (4) molecules have different average kinetic energies

Answer (3)

## Note Packet # 9

**Special Groups** Some groups of elements have names and special characteristics that you must know.

Remember! Elements in the same group act very much the same since they have the same # of valence electrons (groups 1, 2 & 13 - 18). Elements in the same period are usually very different even if they are next to each other on the periodic table.

**Group 1** elements are known as the **Alkali Metals**, except for Hydrogen. Hydrogen is located with the group 1 metals even though hydrogen is obviously a non-metal. Why is it there? Because it has 1 valence electron like the rest of the group 1 elements.

### Characteristics of Alkali Metals

- 1 valence electron
- They are very reactive. They are not found in the elemental form (by themselves) in nature since they are so reactive that they form compounds. Ex: There is a lot of Na in nature but it is in the compound NaCl.
- They form compounds with group 17 elements in a 1:1 ratio. The sum of the oxidation #s in a compound must be zero. Therefore; if all group 1 elements have a +1 oxidation # and all group 17 elements have a -1 oxidation # they must combine in a 1:1 ratio.  
Examples: NaCl, LiF, and KBr

**Group 2** elements are known as **Alkaline Earth Metals**.

### Characteristics of Alkaline Earth Metals

- 2 valence electrons.
- They are very reactive. They are not found in the elemental form (by themselves) in nature since they are so reactive that they form compounds.
- They form compounds with group 17 elements in a 1:2 ratio. The sum of the oxidation #s in a compound must be zero. Therefore; if all group 2 elements have a +2 oxidation # and all group 17 elements have a -1 oxidation # they must combine in a 1:2 ratio.  
Examples: CaCl<sub>2</sub>, BeF<sub>2</sub>, and MgBr<sub>2</sub>.


**Group 17** elements are known as the **Halogens**.

### Characteristics of Halogens

- 7 valence electrons
- They are very reactive. They are not found in the elemental form (by themselves) in nature since they are so reactive. Ex: There is a lot of Cl in nature but it is in the compound NaCl.
- The halogens are the only group that contain all 3 phases (solid, liquid, and gas) at room temperature.
- All the halogens are diatomic.

**Group 18** elements are known as the **Noble Gases**.

### Characteristics of Noble Gases

- 8 valence electrons (except for Helium "He" has 2). This is a very stable (unchanging) electron configuration. 8 valence electrons is known as a **stable octet**.
- The noble gases are very unreactive. They do not form compounds in nature.
- The noble gases are gases.
- The noble gases are mono-atomic (exist as individual atoms). 

## **Note Packet # 9**

**Transition Elements (Transition Metals)** are the elements in groups 3-11 (does not include group 12).

### **Characteristics of Transition Elements**

- a) Transition elements form colorful compounds, solutions, and minerals.
- b) Many transition elements have multiple + oxidation states. Many of them can form different + ions.

# Periodic Table of the Elements

1	18
1.00794	4.00260
H	He
1	2

**KEY**

Atomic Mass → 12.0111

Symbol → **C**

Atomic Number → 6

Electron Configuration → 2-4

Selected Oxidation States → -4, +2, +4

Relative atomic masses are based on  $^{12}\text{C} = 12.000$

Note: Mass numbers in parentheses are mass numbers of the most stable or common isotope.

	Group																	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1	Li	Be										B	C	N	O	F	Ne	
2	3	4										Al	Si	P	S	Cl	Ar	
3	11	12										13	14	15	16	17	18	
4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
5	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
6	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
7	87	88	89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104

\*The systematic names and symbols for elements of atomic numbers above 109 will be used until the approval of final names by IUPAC.

\*\*Denotes the presence of (Z, B) for elements 72 and above