SCIENCE 1206

UNIT II: CHEMICAL REACTIONS *Text: Chapters 5-8*

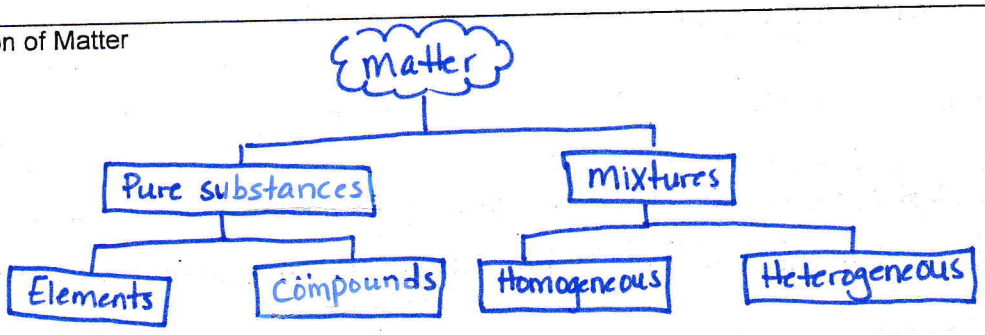
Chemistry:

the study of matter, its properties and its changes.

Matter:

anything that has mass and takes up space.

Classification of Matter



Classification of Matter as Pure Substances or Mixtures:

Pure Substances:

have constant composition; all the particles that make up the substance are the same.

1. **Elements:**

- the simplest form of matter
- composed of only one type of atom
- cannot be broken into simpler substances by chemical means
- combine to form other substances.

2. **Compounds:**

substances composed of two or more different kinds of atoms can be broken down into simpler substances by chemical means.

ELEMENTS & THE PERIODIC TABLE

All elements are classified as metals or nonmetals, depending on their properties.

PROPERTY	METALS	NONMETALS
LUSTRE	Shiny	dull
MALLEABILITY	malleable (bendable)	brittle
CONDUCTIVITY OF HEAT & ELECTRICITY	good conductors	poor conductors
STATE AT ROOM TEMPERATURE	all solids except Hg(l)	most gas, some solid and Br is liquid
LOCATION (PERIODIC TABLE)	Left of staircase	Right of staircase

METALLOIDS (Semimetals)

- elements that have some properties of metals and some properties of nonmetals
- include all elements on either side of the staircase line **except Al and At**
- also includes one form of Carbon, **graphite**, which is dull and brittle (nonmetal), but is a good conductor of electricity (metal)

CHEMICAL FAMILIES (GROUPS):

Groups of elements in the same vertical column that have similar physical and chemical properties.

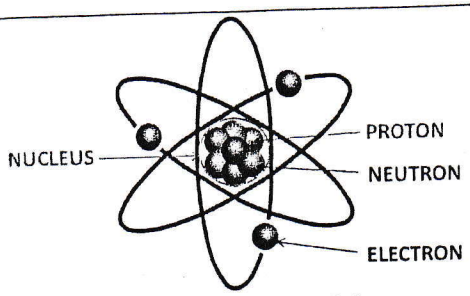
1. **Alkali Metals:** - Group 1, IA
   - show metallic properties (see table above)
   - highly reactive, especially with water; reactivity increases going down the group

2. **Alkaline Earth Metals:** - Group 2, IIA
   - show metallic properties (see table above)
   - less reactive than alkali metals; reactivity increases going down the group.

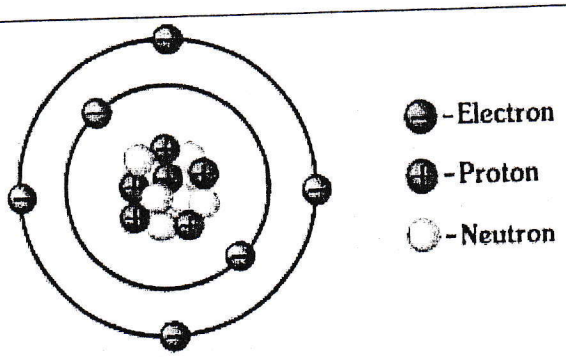
3. **Halogens:** - Group 17, VIIA
   - show nonmetallic properties (see table above)
   - reactivity decreases going down the group

4. **Noble Gases:** - Group 18, VIIIA
   - show nonmetallic properties
   - extremely low chemical reactivity

THE ATOM:



Atom showing the movement of electrons



Atom showing charges

- The basic building block of all matter
- The smallest particle of an element that retains the properties of that element
- Electrically neutral: # of positive charges = # of negative charges

- composed of 3 types of subatomic particles:

PARTICLE	SYMBOL	RELATIVE CHARGE	ACTUAL MASS (g)	LOCATION
Proton	p^+	+	1.67×10^{-24}	nucleus
Neutron	n^o	0	1.67×10^{-24}	nucleus
Electron	e^-	−	9.11×10^{-28}	outside

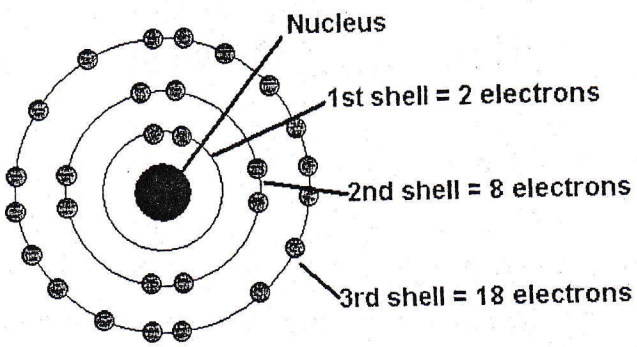
Atomic Number:

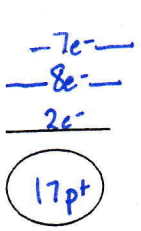
# of protons in an atom

Mass Number:

# of protons AND # of neutrons in an atom.

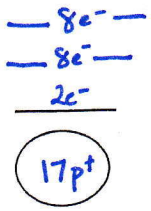
Quantum Mechanics Theory of the Atom:





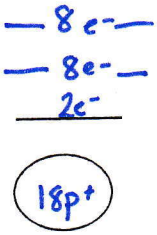
Cl atom

* Gain 1 electron



Cl- ion

Compare to nearest Noble gas:



Argon atom

* Same electron configuration

Summary: When sodium metal and chlorine gas react, the sodium atoms each lose one electron to a chlorine atom. In so doing the atoms form ions of opposite charge:

Cations: (positive ions)

→ ions that lose electrons

Anions: (negative ions)

→ ions that gain electrons.

Naming Ions:

Cations: element name + the word "ion" eg: Na^+ = sodium ion

Anions: stem of element name + ide + the word "ion"

eg: Cl, chlorine becomes Cl^- = chloride ion

P, phosphorus becomes P^{3-} = phosphide ion

O, oxygen becomes O^{2-} = oxide ion

Note:

1. Both cations and anions are more stable than the atoms from which they form since these ions attain the same stable electron configuration as the nearest noble gas.
2. Boron, carbon and silicon do not tend to form ions (they instead share electrons with other atoms)
3. The noble gases do not form ions since they are already stable (have filled orbitals)
4. Hydrogen can form a cation or an anion:
   - Cation: H^+, hydrogen ion has 1 proton but no electrons
   - Anion: H^-, hydride ion has 1 proton and 2 electrons

C. Polyatomic Ions (Complex Ions)

- Cations or anions composed of a group of atoms with a net positive or negative charge
- Eg. NH_4^+ NO_2^- NO_3^- CO_3^{2-}

Ammonium ion | Nitrite ion | Nitrate ion | Carbonate ion

See page 196 for a table of some common polyatomic ions or back of periodic table

*Name the metal and complex ion as is.

Practice Questions:

Write the name for the compound formed by sodium and a carbonate ion.

Na^+ Na^+ CO_3^{2-} Sodium carbonate Na_2CO_3

* Note: When you need more than 1 complex ion, you MUST use brackets

Complete the following examples by writing the chemical formulas.

a.) ammonium nitrate

NH_4^+ NO_3^-

NH_4NO_3

c.) potassium carbonate

K^+ CO_3^{2-}

K^+ K_2CO_3

b.) barium phosphate Ba^{2+} Ba^{2+} Ba^{2+} PO_4^{3-} PO_4^{3-} $Ba_3(PO_4)_2$

d.) sodium sulfate Na^+ Na^+ SO_4^{2-} Na_2SO_4

D. Multivalent Ions

- certain transition metals can form more than one type of ion, each with a different charge
- Eg. Fe^{3+} Fe^{2+}
- The more commonly occurring is listed on top, thus Fe^{3+} is more common than Fe^{2+}

Example: Write the chemical formulas for the following

a.) Iron (II) sulphide

Fe^{2+} S^{2-}

FeS

b.) Copper (II) chloride

Cu^{2+} $2Cl^-$

$CuCl_2$

c.) lead (IV) oxide

Pb^{4+} $2O^{2-}$

PbO_2

d.) copper (I) chloride

Cu^+ Cl^-

$CuCl$

* For ions with more than 1 charge, you MUST specify which charge is being used. You have to use Roman numerals:

I - one
II - two
III - three
IV - four
V - five
VI - six

Write the names for the following ionic compounds

a.) NiS

Ni^{2+} S^{2-}

nickel (II) sulfide

b.) CuF

copper (I) fluoride

c.) MnF_4

manganese (IV) fluoride

d.) Cr_2O_3

$2Cr^{3+}$ $3O^{2-}$

chromium (III) oxide

E. Hydrated Ionic Compounds

- Water molecules are loosely held within the ionic compound
- Eg. $ZnCl_2 \cdot 6H_2O$ $CuSO_4 \cdot 5H_2O$

An example of a hydrated compound is copper (II) sulfate pentahydrate, also known as $CuSo_4 \bullet 5H_2O$

Naming Ionic Compounds Review

General Rules:

1. Name each ion
   - Monotomic: cation retains metal name, anion name ends in "ide"
   - Polyatomic: give name from back of periodic table
2. Multivalent: use Roman numerals to indicate charge (I, II, III, IV, V, VI)
3. Hydrated: use Latin prefixes to indicate # of water molecules present

1 = mono	2 = di	3 = tri	4 = tetra	5 = penta
6 = hexa	7 = hepta	8 = octa	9 = nona	10 = deca

Examples:

a.) Monatomic: Ca_3P_2 calcium phosphide

b.) Polyatomic: Na_3BO_3 sodium borate

c.) Multivalent: FeO iron (II) oxide

d.) Hydrated: $BaCl_2 \cdot 2H_20$ barium chloride dihydrate

e.) $AlCl_3$ aluminum chloride

f.) $(NH_4)_2CO_3$ ammonium carbonate

g.) V_3N_5 vanadium (V) nitride

MOLECULAR SUBSTANCES:

* Non metals only!

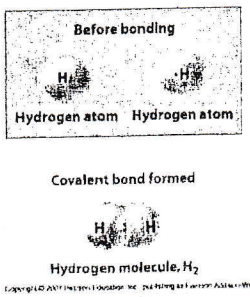
Compare ionic compounds to a molecular compound

Ionic Compound		Molecular Compound	
• cation(+) and anion(-)	• solids at room temp	• only nonmetals	• gas, liquid and solid
• electrons exchanged	• electrolytes	• electrons shared	• nonelectrolytes
• ionic bonds		• covalent bonds	

Covalent Bond:

formed from the SHARING of valence electrons between nonmetal atoms (electron structure that is the same as a noble gas)

Example: H_2 A molecule of hydrogen gas has 2 atoms of Hydrogen, each with one electron. When they bond they share a pair of electrons (one pair = one covalent bond). Si



4. The prefix mono is usually only used for molecules with 1 atom of oxygen (monoxides).

5. Certain Hydrogen compounds (those with H first in the formula) do not use prefixes.

   eg. $H_2S_{(g)}$ = hydrogen sulfide, **not** dihydrogen sulfide

Examples:

$NO_{(g)}$ nitrogen monoxide

$P_4O_{6(s)}$ tetraphosphorus hexaoxide

$SO_{2(g)}$ sulfur dioxide

$SO_{3(g)}$ sulfur trioxide

$N_2O_{(g)}$ dinitrogen monoxide

ACIDS

- Molecules that ionize in water to produce hydrogen ions, $H^+_{(aq)}$, ions which give acids their properties
- *Properties of acids:*
  - Conduct electricity
  - Turn blue litmus paper red
  - Taste sour
  - React with many metals to produce hydrogen gas, $H_{2(g)}$
  - Have a pH value of less than 7
  - Neutralize or partially neutralize bases
- General Formula: H____ (aq) or ____COOH (aq) *
- *Note:* not all hydrogen containing compounds are acids
  Eg: NH_3 CH_4 CH_3OH C_2H_5OH

Naming Acids

General Rules

- Name the hydrogen compound like an ionic compound, then convert the ionic name to the acid name

  hydrogen _____ide becomes **hydro_____ic acid**

  hydrogen_____ite becomes **_____ous acid**

  hydrogen_____ate becomes **_____ic acid**

Examples:

Acid Formula	Ionic Name	Acid Name
$HCl_{(aq)}$	hydrogen chloride	hydrochloric acid
$HCN_{(aq)}$	hydrogen cyanide	hydrocyanic acid
$HNO_{2(aq)}$	hydrogen nitrite	nitrous acid

- *Note:* Not all compounds that contain OH are bases
  Eg: CH_3OH C_2H_5OH

Naming Bases

- follow the general rules given for ionic compounds

Examples: NaOH sodium hydroxide

NH_4OH ammonium hydroxide

Writing Base Formulas

- follow the general rules given for ionic compounds

Examples: Lithium hydroxide LiOH

Calcium hydroxide $Ca(OH)_2$

$H_2SO_{3(aq)}$	hydrogen sulfite	sulfurous acid
$HNO_{3(aq)}$	hydrogen nitrate	nitric acid
$H_2SO_{4(aq)}$	hydrogen sulfate	sulfuric acid
$H_3PO_{4(aq)}$	hydrogen phosphate	phosphoric acid
$CH_3COOH_{(aq)}$	hydrogen acetate	acetic acid

Writing Acid Formulas

General Rules:

1. Translate acid name into ionic name: hydro___ic acid → hydrogen ___ide
   ___ous acid → hydrogen ___ite
   ___ic acid → hydrogen ___ate

4. Write chemical formulas for each ion, using rules for writing formulas for ionic compounds.

5. Hydrogen symbol is written first (cation), except for carboxylic acids (those with COO group), in which case hydrogen is placed at the end eg: CH_3COOH

6. Give the state as aqueous = (aq).

Examples:

Hydroiodic acid	H^+ hydrogen	I^- iodide	$HI_{(aq)}$
Chlorous acid	H^+ hydrogen	ClO_2^- chlorite	$HClO_{2(aq)}$
Chloric acid	H^+ hydrogen	ClO_3^- chlorate	$HClO_{3(aq)}$
Boric acid	H^+ hydrogen	BO_3^{3-} borate	$H_3BO_{3(aq)}$
Benzoic acid	H^+ hydrogen	$C_6H_5COO^-$ benzoate	$C_6H_5COOH_{(aq)}$

BASES

- most are ionic compounds that contain the hydroxide ion, OH^-, an ion that gives bases their properties
- *Properties of bases:*
  - Conduct electricity
  - Turn red litmus paper blue
  - Taste bitter
  - Feel slippery
  - Have a pH value greater than 7
  - Neutralize or partially neutralize acids

Type	Molecular Elements Examples
Monatomic – one atom	$He_{(g)}$, $Ne_{(g)}$, $Ar_{(g)}$, $Kr_{(g)}$, $Xe_{(g)}$, $Rn_{(g)}$
Diatomic – two atoms/molecule	$H_{2(g)}$, $N_{2(g)}$, $O_{2(g)}$, $F_{2(g)}$, $Cl_{2(g)}$, $Br_{2(l)}$, $I_{2(s)}$, $At_{2(g)}$ * 7 up
Polyatomic – more than 2 atoms/molecule	$P_{4(g)}$ - phosphorus, $S_{8(g)}$ - sulfur, $O_{3(g)}$ - ozone

1. Molecular Compounds

a) Common (**to memorize**):

*memorize

$H_2O_{(l)}$ = water	$CH_{4(g)}$ = methane	$CH_3OH_{(l)}$ = methanol
$H_2O_{2(l)}$ = hydrogen peroxide	$C_3H_{8(g)}$ = propane	$C_2H_5OH_{(l)}$ = ethanol
$NH_{3(g)}$ = ammonia	$C_6H_{12}O_{6(s)}$ = glucose	$C_{12}H_{22}O_{11(s)}$ = sucrose

b) Binary Molecular Compounds

- composed of 2 different kinds of nonmetals eg. CO CO_2 CCl_4 SO_3 N_2O

Writing Molecular Formulas

General Rules

1. Write each atom symbol.
2. Each prefix indicates the subscript for the nonmetal atom that precedes it (# of atoms present).
3. If no prefix is present, then there is only one atom of that nonmetal present. Monoxide = one oxygen atom present.

* Never use "mono" for first atom!

Examples::

Carbon monoxide	CO
Carbon dioxide	CO_2
Carbon tetrachloride	CCl_4
Suphur trioxide	SO_3
Dinitrogen monoxide	N_2O

Naming Molecular Substances

General Rules

1. First element is named in full.
2. Second element name is shortened and given an **ide** ending.
3. Use prefixes (same as for hydrates) to indicate the number of each kind of atom.

Common prefixes used in naming hydrated compounds are:

1- mono	5- penta	
2- di	6- hexa	9- nona
3- tri	7- hepta	10- deca
4- tetra	8- octa	

Write the chemical formula.

a.) Barium hydroxide octahydrate

$Ba(OH)_2 \cdot 8H_2O$

b.) Copper (II) sulphate pentahydrate

$CuSO_4 \cdot 5H_2O$

c.) zinc chloride hexahydrate

$ZnCl_2 \cdot 6H_2O$

d.) barium hydroxide octahydrate

$Ba(OH)_2 \cdot 8H_2O$

Write the names for the following ionic compounds.

a.) $MgSO_4 \bullet 5H_2O$

magnesium sulfate pentahydrate

b.) $Ca(NO_3)_2 \bullet 6H_2O$

calcium nitrate hexahydrate

c.) $FeCl_2 \bullet 5H_2O$

iron (II) chloride pentahydrate

d.) $HgNO_3 \bullet H_2O$

mercury (I) nitrate monohydrate

Writing Ionic Formula Review

a) Monatomic: Silver chloride

$AgCl$

aluminum oxide

Al_2O_3

b) Polyatomic: Ammonium nitrate

NH_4NO_3

potassium carbonate

K_2CO_3

c) Multivalent: Iron(II)sulphide

FeS

lead(IV)oxide

PbO_2

d) Hydrated: Zinc chloride hexahydrate

$ZnCl_2 \cdot 6H_2O$

Copper(II)sulphate pentahydrate

$CuSO_4 \cdot 5H_2O$

IONIC COMPOUNDS

- These compounds form after an electron transfer:
  - usually *from a metal to a nonmetal*
  - the resulting ions (cations and anions) are attracted to each other (since they are oppositely charged) and they form **ionic bonds**

- Together all of the ions present form an **ionic crystal lattice** in which the net charge is zero
  - Eg: (1) in a sample of sodium chloride, NaCl, for every Na^+ ion there is one Cl- ion
  - Eg: (2) in a sample of calclium chloride, $CaCl_2$, for every Ca^{2+} ion there are 2 Cl- ions

https://www.youtube.com/watch?v=xTx_DWboEVs&feature=related&safe=active

Types of Ions and Ionic Compounds

A. Monatomic Ions (Simple Ions)
- Single atoms that have lost or gained one or more electrons
- Form *Binary Ionic Compounds* (2 simple ions)

- Eg. Na^+ Cl^-

B. Binary Ionic Compounds

Metals and nonmetals combine to form ionic compounds by transferring electrons.

Rules for naming Binary Ionic Compound
1) Name the metal ion
2) Name the non-metal ion (* change the ending to "ide")
3) Never use Prefixes! 4) use lowercase to name

Example: Name the compound when aluminum (metal) combines with chlorine (non metal)
aluminum chloride

Rules for writing the chemical formulas for the formation of an ionic compound
1) write the symbols for the ions
2) Balance the charges
3) Write the formula

Example: What is the chemical formula when aluminum (metal) combines with chlorine (non metal)
Al^{3+} Cl^- Cl^- Cl^- *will need 3 of these to balance charges. $AlCl_3$

Complete the following examples by writing the chemical formulas.

a.) silver chloride
Ag^+ Cl^-
$AgCl$

b.) barium fluoride
Ba^{2+} F^- F^- BaF_2

c.) aluminum oxide
Al^{3+} Al^{3+} O^{2-} O^{2-} O^{2-} Al_2O_3

d.) magnesium nitride
Mg^{2+} Mg^{2+} Mg^{2+} N^{3-} N^{3-} Mg_3N_2

Complete the following examples by writing the names for the following ionic compounds

a.) K_3N
Potassium nitride

b.)Li_2O
lithium oxide

According to this theory, an electron with a specific energy occupies a region in space (**orbital**) or electron energy level.

Electron Energy Diagrams of Atoms:

- An energy level represents a specific value of energy of an electron and corresponds to a general location
- The number of occupied energy levels in any atom is normally the same as the **period number** in which the atom appears
- for the first 3 energy levels, the maximum number of electrons that can be present are 2, 8 and 8 in order of increasing energy (increasing distance from nucleus)
- a lower energy level is filled with electrons to its maximum before the next level is started.
- the electrons in the highest (outermost) occupied energy level = **valence electrons,** which is the same as the **group number** (for group A elements)

STABLE ATOMS

- have low chemical reactivity
- include noble gases, all of which have 8 valence electrons (except He, which has 2)

- other atoms can become more stable by reacting and changing the number of their electrons, thereby attaining the same stable electron configuration (structure) of the nearest noble gas:

  - atoms can follow one of two rules:

  a) Octet Rule: - atoms attempt to obtain 8 valence electrons
  - includes most atoms

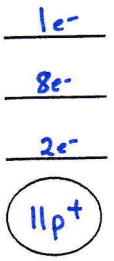
  b) Duet Rule: - atoms attempt to obtain 2 valence electrons
  - includes H, Li and Be

- one way atoms can achieve a stable octet or duet is by forming *ions*

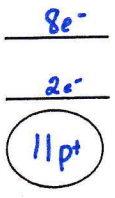
ION

- an atom or group of atoms that has a positive or negative charge, due to the loss or gain of one or more electrons
  - single atoms: form simple ions (*monatomic ions*)
  - group of atoms: form complex ions (*polyatomic ions*)

Example: Sodium metal and chlorine gas react to produce NaCl, a very stable and unreactive substance, compared to Na (alkali metal) or Cl (halogen).
They do so by first forming ions.

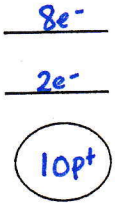


Na atom

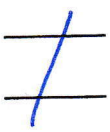


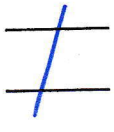
Na^+ ion

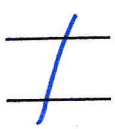
Compare to nearest Noble gas:



Neon atom







SERIES OF ELEMENTS:

1. **Representative Elements:** A groups or groups 1, 2, 13 –18

2. **Transition Elements:** B groups or groups 3 – 12

HYDROGEN: - the lightest element and most abundant element in the universe
- doesn't really belong to any group
- it sometimes behaves like an alkali metal, sometimes like a halogen and at other times in its own unique way ie. as an acid

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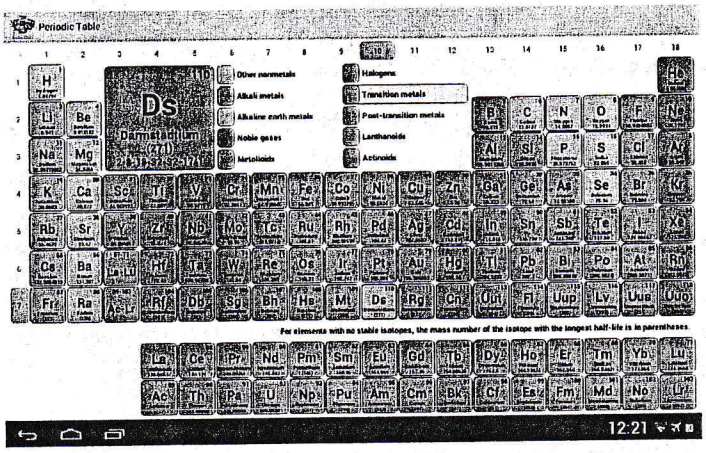
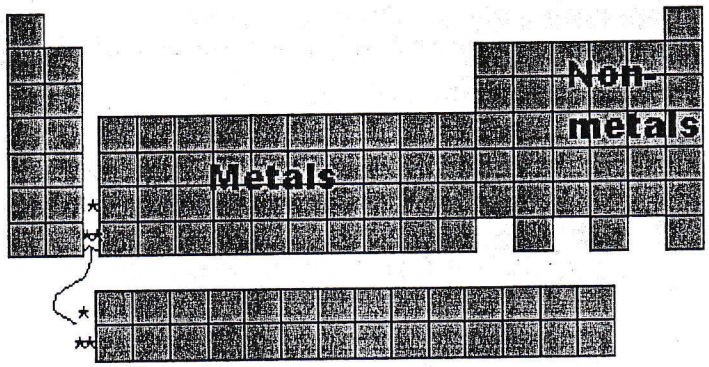
PERIODS: horizontal rows of the periodic table

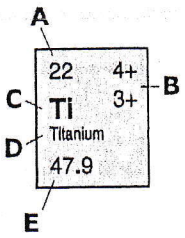
GROUPS: vertical rows of the periodic table



All elements are classified as a metal or a non metal



The information provided by the periodic table for each element. Fill out the information below.



Mixtures:

Composed of 2 or more substances

1. **Homogeneous Mixtures:** (solutions)

· have only one visible component

· looks the same throughout

2. **Heterogeneous Mixtures:**

· have 2 or more visible components

· can see different parts.

Properties and Changes of Matter:

1. **Physical Property:**

Characteristics of matter used to identify substances

ex: state, boiling and melting point, color, solubility, mass, conductivity, etc.

2. **Physical Change:**

a change in the size or form of a substance that does not change its composition ex: cutting, bending, boiling, melting, dissolving, etc.

3. **Chemical Property:**

Characteristic of matter that can be observed when matter undergoes a change in composition.

4. **Chemical Change:**

a chemical reaction; a new change in which at least one or more new substances are formed.

The products have different properties than the reactants.

Evidence...

1) Color change
2) Energy (light, temp.)
3) Gas bubbles
4) Precipitate
5) Hard to reverse.