Name _____

AP Chemistry Unit 1 Notes and Practice Packet

Summer Assignment 2025-26

Directions: Watch the videos for Unit 1 uploaded by Dr. Mitchell to our Teams feed. Follow along and fill out the notes as you go. Complete any practice problems assigned. Bring this packet to your first day of class in the fall. It will be turned in for a daily grade and returned for you to study for the Unit 1 test which will be a few weeks into the school year.

1.1 MOLES AND MOLAR MASS

Atomic Mass and Molecular Weight (or Formula Weight)

The _____ of a substance is the sum of the atomic weights of the atoms in the chemical formula of the substance.

Example: What is the molecular weight of sulfuric acid (H_2SO_4)?

*On the AP exam all calculations should be done using the Atomic Weights provided with the Formula Sheet. You have an AP periodic table included in your summer packet.

Molar Mass

The easiest way to 'scale up' to real world quantities is to use the same number but move from measuring mass in amu to measuring mass in grams.

This involves using a very large number called _____.

1 mole of given particles weighs the same number of grams as one of those particles weighs in amus.

Where one **molecule** of H_2SO_4 weighs _____, one **mole** of H_2SO_4 weighs _____.

Quick Check :

How much does 1 **molecule** of H_2O weigh?

How much does 1 **mole** of H_2O weigh?

Hydrates

If you have a **hydrate** (a compound that attracts and absorbs water) the molar mass _____bound to the hydrate. For example, the molar mass of iron (III) chloride hexahydrate ($FeCl_3 \cdot 6\ H_2O$) has a molar mass of:

Molar mass (grams/mole) is used as a conversion factor to convert between moles and grams.

Avogadro's Number (6.022 x 10^{23}) particles/mole is the conversion factor to convert between the number of particles (molecules, atoms, formula units, ions) and moles.

Formula unit: a set of an ionic compound. Ex. 3 formula units of PbI_2 contain 3 Pb^{3+} ions and 6 I^- ions.

Moles and Molar Mass Practice Questions

1. A chemist has a 25.0 grams sample of Lead (II) iodide, PbI_2. How many formula units of PbI_2 are present?

Step 1: How many moles of PbI_2 are present in this sample?

Step 2: How many formula units (f.u) of PbI_2 are present in this sample?

Extension: If the question asked for atoms of one element, you'd need to multiply by the subscript to get the answer. For example, if the question asked for how many atoms of iodine are present, you'd need to multiply 3.27x10^{22} f.u by 2 I atoms per PbI_2.

$$3.27 \times 10^{22} \text{ f.u } PbI_2 \times \frac{2 \text{ I atoms}}{1 \text{ f.u } PbI_2} = 6.54 \times 10^{22} \text{ I atoms}$$

2. A 0.244 g sample of calcium carbonate, $CaCO_3$, was recovered from a sample of hard water. How many oxygen atoms were in the sample?

1.1 Additional Practice Questions

Directions: Answer each practice question below. **Show your work for EVERY question.** Focus on making sure you understand the process behind answering the question correctly. Check your answers on the key provided at the end of the practice problems.

1. What is the molar mass of each compound shown below?
    a. NaBr

    b. Li_2O

    c. $(NH_4)_3PO_4$

2. Methane, CH_4, is the gas commonly found in labs to fuel Bunsen burners.
    a. How many moles of methane are there in a 7.21 gram sample?

    b. How many molecules of methane are there in the sample?

    c. How many atoms of hydrogen are found in the sample?

3. Helium, He, is used in balloons, deep sea diving tanks, and in industry. While it is the second most abundant element in the universe, in 2019 there was a shortage of helium which caused the prices to rise. If 150.0 grams of helium is needed to cool a superconductor, how many atoms of helium are used?

4. If you know the mass and identity of a sample, what other information do you need in order to find the number of atoms in the sample?

5. What is the mass of 2.30×10^{24} particles of water, H_2O?

6. What is the mass of 2.1 moles of the hydrate Nickel (II) carbonate pentahydrate ($NiCO_3 \cdot 5H_2O$)?

7. Which is a greater mass, 0.25 moles of carbon dioxide, CO_2, or 1.5×10^{23} particles of carbon monoxide, CO?

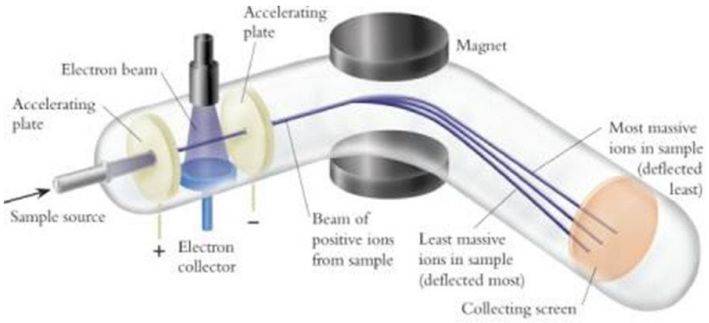
Answer key directions: When you check your answers, rank your understanding from 1-5. 1 means you still do not understand, 5 means you answered the questions correctly before checking it.

Question	**Correct Answer**	**Ranking/Self reflection. Any question(s) you still need help on?**
1a	102.89 g/mol	
1b	29.88 g/mol	
1c	149.12 g/mol	
2a	0.449 mol CH_4	
2b	2.70×10^{23} molecules CH_4	
2c	1.08×10^{24} H atoms	
3	2.26×10^{25} He atoms	
4	Avogardo's Number (6.02×10^{23} atoms/mol)	

5	68.8 g H_2O	
6	440 g $NiCO_3 \cdot 5H_2O$	
7	11 g CO_2 > 6.98 g CO	

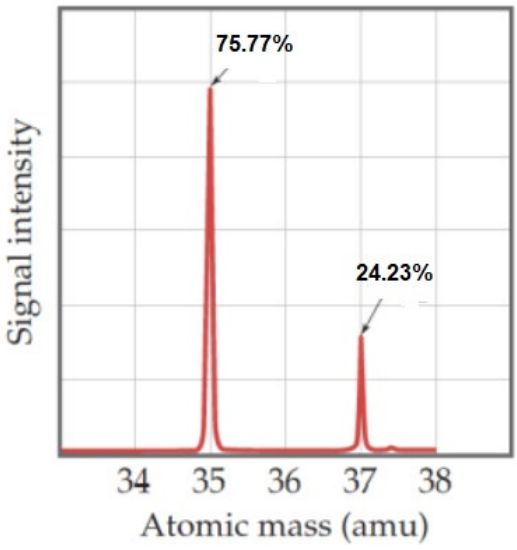
1.2 MASS SPECTROSCOPY

How Does A Mass Spectrometer Work?



Schematic representation of one type of mass spectrometer. An electron beam fragments gas atoms or molecules into positively charged ions. The ions are accelerated and then deflected by a magnet. More massive particles are deflected by smaller amounts than less massive particles.

Since each proton and each neutron contribute *approximately* one amu to the mass of an atom, and each electron contributes far less, **the atomic mass of a single atom is *approximately* equal to its mass number** (a whole number).



The mass spectrometer provides us with three important pieces of information:

1. _____
   _____
2. _____
   _____
3. _____
   _____

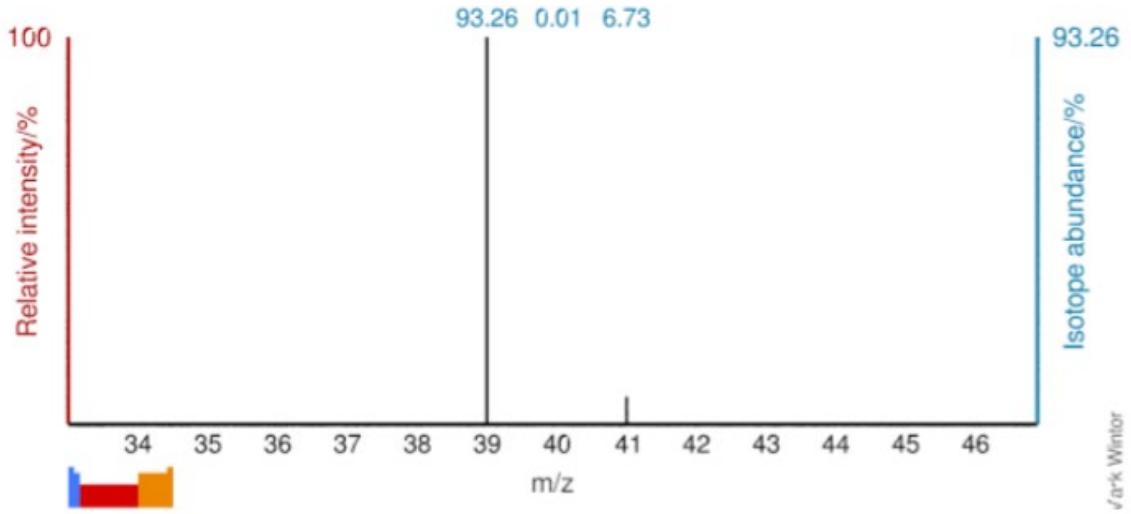
Average Atomic Mass

From mass spec data we can calculate the average or relative atomic mass:

$$Average\ Atomic\ Mass = \sum_{n} (relative\ abundance\ of\ isotope\ n) \times (mass\ of\ isotope\ n)$$

Using the Chlorine data from above:

Groups Try!



Show Your Work

1. The mass spectrum of a sample of a pure element is shown above. Calculate the average atomic mass of the element.

2. What is the identity of the element? Hint: use the Periodic Table.

3. How many protons and neutrons does the most abundant isotope contain?

Rhenium, Re, is one of the rarest elements on Earth. Alloys containing rhenium are used for oven filaments and x-ray machines.

The average atomic mass of naturally occurring rhenium is 186.21 amu. There are two common isotopes of naturally occurring rhenium. Using the information given below, calculate the percent abundance of naturally occurring rhenium.

Isotope Mass (amu)

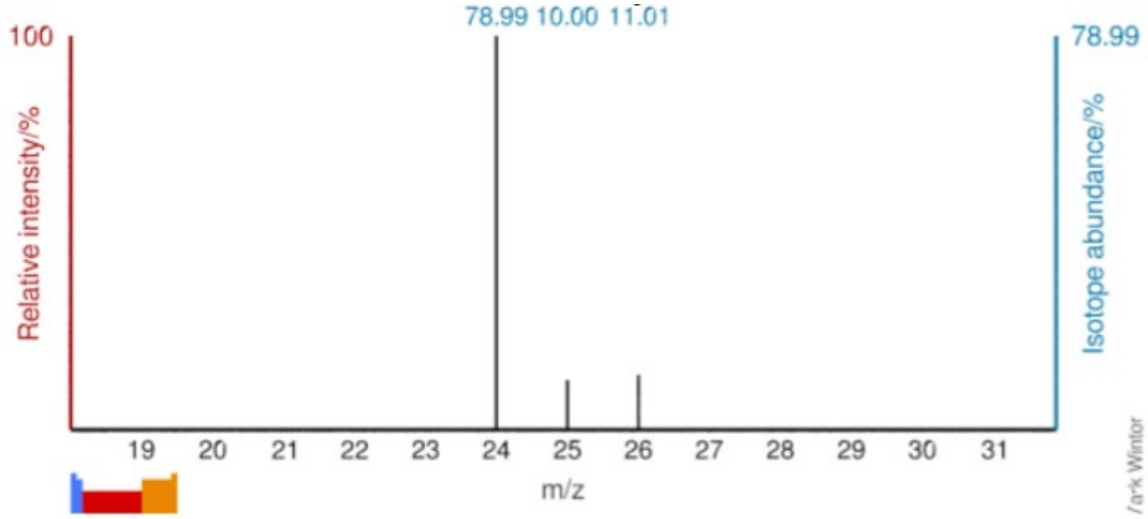
Re-185 184.95

Re-187 186.96

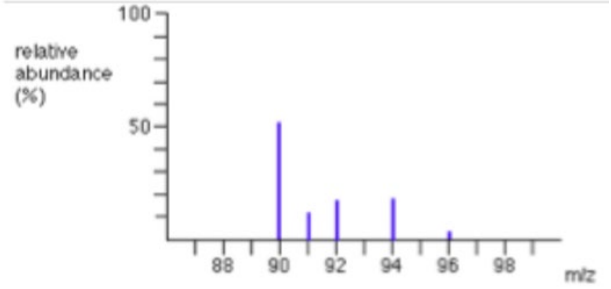
Hint: You will need to call the relative abundance of one of the isotopes x, then solve algebraically.

1.2 Additional Practice Questions

1. The mass spectrum of a sample of a pure element is given below. Calculate the average atomic mass of the element. What is the identity of the element?



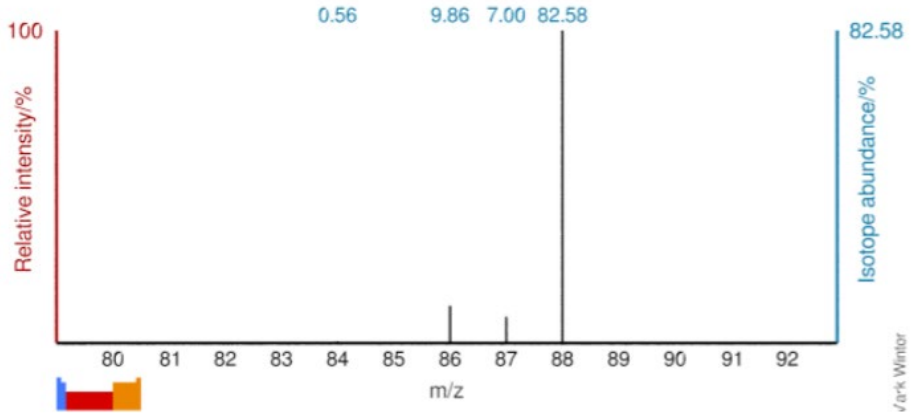
2. Determine the most likely element for the mass spectrum given below. Justify your answer. Note: you do NOT need to calculate the average atomic mass to answer this question. You can approximate it using the graph below.



a. Tungsten
b. Niobium
c. Zirconium
d. Plutonium

Explanation:

3. Use the mass spectrum below to fill out the information in the table about each isotope.



Isotope	Protons	Neutrons	Mass (amu)	Relative Abundance

Answer key directions: When you check your answers, rank your understanding from 1-5. 1 means you still do not understand, 5 means you answered the questions correctly before checking it.

Question	Correct Answer	Ranking/Self reflection. Any question(s) you still need help on?
1	24.32 amu (24 amu with correct sig figs); Mg is the element	

2	Zirconium (Zr) because the average mass is around 91amu	
3		

3 Answer Key

Isotope	Protons	Neutrons	Mass (amu)	Relative Abundance
Strontium - 84	38	46	84	0.56%
Strontium - 86	38	48	86	9.86%
Strontium - 87	38	49	87	7.00%
Strontium - 88	38	50	88	82.58%

1.3 ELEMENTAL COMPOSITION OF A PURE SUBSTANCE

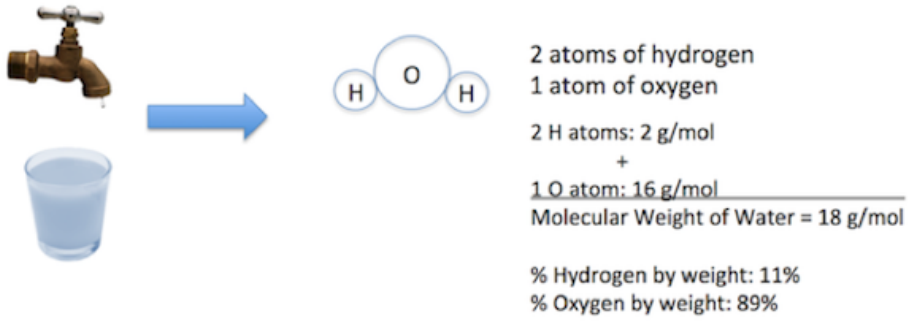
Pure Substances

A **pure substance** is one with constant composition; a pure substance can either be an element or a compound.

When dealing with compounds you can assume it follows the **law of definite proportion**, which states compounds with the same elements in the same proportion are the SAME compound.

Following the law of definite proportion, you can find the **percent composition** which is the percent by mass of each element that makes up a compound.

Law of Definite Proportions



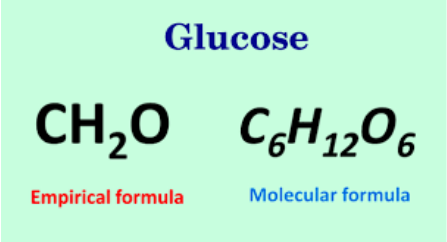
Law of Definite Proportions: % by Weight of Hydrogen and Oxygen in Water

To calculate the percent composition, you divide the mass of each element in a compound by the total molar mass of the substance.

Empirical and Molecular Formulas

In compounds, the **empirical formula** represents the _____ of one element to another in a compound.

The **molecular formula** represents the _____ for the substance.



To determine the Empirical formula

Determine the *empirical formula* for the compound **when given percent of each element**:

1. Assume you are given a 100g sample so you can change percent to grams
2. For each element take grams / molar mass to get moles of each element
3. Divide each mole value by the lowest of the values
4. If you are within 0.1 of a whole number round to the whole number, if you are not you must multiply by a factor that gives you whole numbers for all.
5. The values you found are the subscripts for each element

Example 1.3A

Find the empirical formula of a compound of 69.94% iron and 30.06% oxygen.

To Determine the Molecular Formula

Determine *molecular formula* (**can only determine if given molar mass of substance**)

1. Find mass of empirical formula
2. Molar mass/ empirical formula mass to find factor
3. Multiply all subscripts in the empirical formula by the value

Example 1.3B

A piece of iron ore is found to contain a compound containing 72.3% iron and 27.7% oxygen with a molecular mass of 694.7 g/mol. What is the molecular formula of the compound?

1.3C

1. A certain sugar used in treating patients with low blood sugar has the following chemical composition: 40 percent carbon, 6.7 percent hydrogen, and 53.3 percent oxygen. What is the empirical formula?

2. The molar mass of the compound is 180 grams/mole. What is the molecular formula of this compound?

Review Example 1.3D

1. A compound is found to contain 56.5% carbon, 7.11% hydrogen, and 36.4% phosphorus. Find the empirical formula.

2. If the compound has a molar mass of 170.14 g/mol, what is its molecular formula?

1.3a Additional Practice Questions

1. Iron can form three different oxides, FeO, Fe_2O_3 and Fe_3O_4. What are the percent compositions of iron and oxygen in each of the substances? The first example has been completed for you.

Substance	Percent Iron	Percent Oxygen
FeO	$\frac{55.85\ g/mol}{71.85\ g/mol}$ = 77.7% Fe	$\frac{16.00\ g/mol}{71.85\ g/mol}$ = 22.3% O
Fe_2O_3		

Fe_3O_4		

2. Arginine is one of the amino acids; it is used in the biosynthesis of proteins. Analysis revealed that a sample of arginine was 41.368 % carbon, 8.101% hydrogen, 32.162 % nitrogen and 18.369% oxygen. The molecular weight of arginine is 174.24 grams/mole. What is the molecular formula?

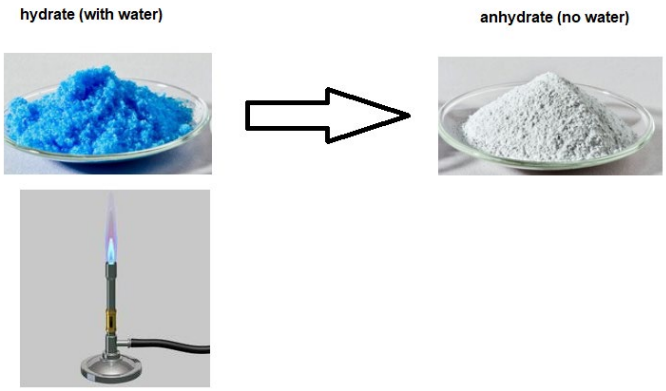
3. Emeralds are composed of 4 different elements in a fixed proportion. They are composed of 5.030 % beryllium, 10.040 % Aluminum, 31.351% Silicon and 53.579% oxygen. The empirical and molecular formulas are the same. Calculate the empirical formula.

Answer key directions: When you check your answers, rank your understanding from 1-5. 1 means you still do not understand, 5 means you answered the questions correctly before checking it.

Question	**Correct Answer**	**Ranking/Self reflection. Any question(s) you still need help on?**
1	Fe_2O_3: 69.9% Fe, 30.1% O Fe_3O_4: 72.4% Fe, 27.6% O	
2	Empirical: $C_3H_7N_2O$ Molecular: $C_6H_{14}N_4O_2$	
3	$Be_3Al_2Si_6O_{18}$	

1.3b: Experimental Analysis of Compounds

Hydrate Analysis



Hydrate Analysis Example 1.3E

Anhydrate: _____

A student is assigned the task of determining the moles of water in one mole of $MgCl_2 \bullet nH_2O$. The student collects the data shown to the right.

Mass of empty container	22.347 g
Initial mass of sample and container	25.825 g
Mass of sample and container after first heating	23.982 g
Mass of sample and container after second heating	23.976 g
Mass of sample and container after third heating	23.977 g

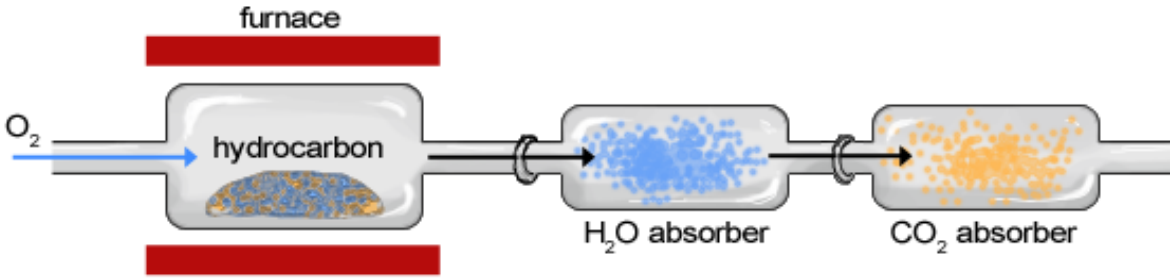
a. Explain why the student can correctly conclude that the hydrate was heated a sufficient number of times in the experiment.

b. Use the data above to:

i. Calculate the total number of moles of water lost when the sample was heated

ii. Determine the formula of the hydrated compound.

Combustion Analysis: burning of a hydrocarbon to determine its empirical formula.



Example 1.3F:
A sample of a compound that contains only the elements C and H is combusted completely in O_2 to produce 44.0 g CO_2 and 45.0 g H_2O. What is the empirical formula of the compound**1.3b Additional Practice Questions**

1. In an experiment, a student is assigned the task of determining the number of moles of water in one mole of the hydrate $Na_2SO_4 \bullet nH_2O$. The student collects the data shown in the following table.

Mass of empty container	22.347 g
Initial mass of sample and container	25.959 g
Mass of sample and container after first heating	24.677 g
Mass of sample and container after second heating	23.941 g
Mass of sample and container after third heating	23.940 g

   a. Explain why the sample was heated three times.

   b. Explain why the student can conclude that all of the water was driven off of the hydrate.

   c. Use the data above to …
      i. Determine the mass of the sample before heating.

      ii. Determine the mass of water in the sample.

d. Determine the moles of water in the sample.

e. Determine the mass of anhydrate in the sample.

f. Determine the moles of anhydrate in the sample.

g. Determine the formula of the hydrated compound.

2. In an experiment, a student is assigned the task of determining the number of moles of water in one mole of the hydrate $CuSO_4 \bullet nH_2O$. The student collects the data shown in the following table.

Mass of empty container	22.347 g
Initial mass of sample and container	25.959 g
Mass of sample and container after first heating	25.700 g
Mass of sample and container after second heating	25.046 g
Mass of sample and container after third heating	25.045 g

a. Determine the moles of water in the sample.

b. Determine the moles of $CuSO_4$in the sample.

c. Determine the formula of the hydrated compound.

d. Determine if the calculated mass of the water would increase, decrease, or remain the same if …

i. While heating the substance some solid spattered out. Explain your reasoning.

ii. After heating the hydrate completely it was left out on the counter for an entire day before the final weighing. Explain your reasoning.

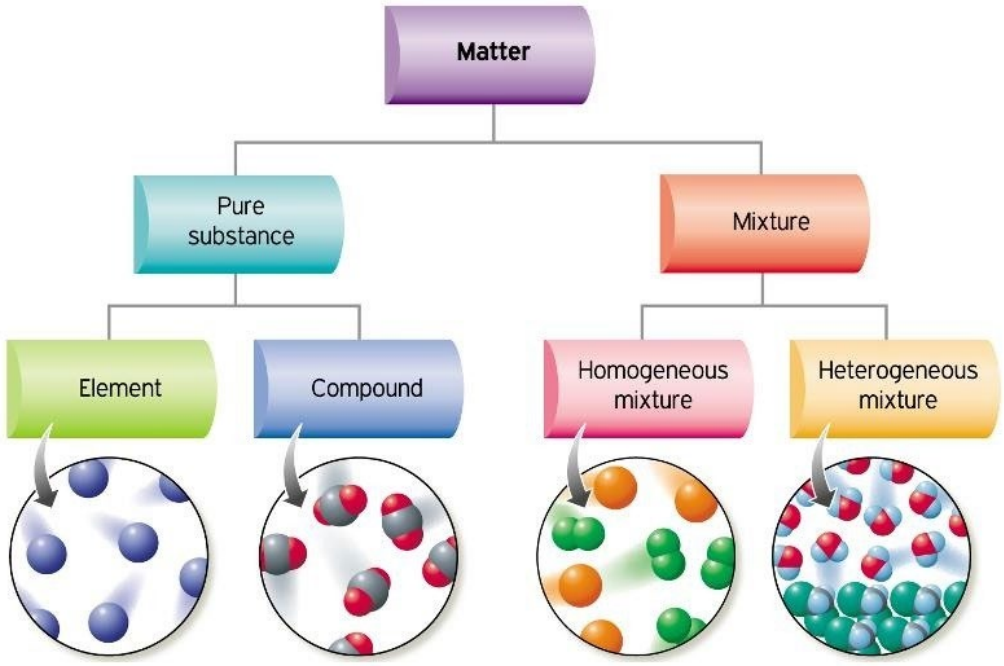
iii. The sample was heated too long and some of the anhydrate vaporized and left the container. Explain your reasoning.

Answer key directions: When you check your answers, rank your understanding from 1-5. 1 means you still do not understand, 5 means you answered the questions correctly before checking it.

Question	**Correct Answer**	**Ranking/Self reflection. Any question(s) you still need help on?**
1a	To make sure all of the water is vaporized off the sample.	
1b	The mass did not change significantly between the 2nd and 3rd heatings.	
1c	i. 25.959g - 22.347g = 3.612 g ii. 25.959g - 23.940g = 2.019 g	
1d	0.112 mol H_2O	

1e	23.940g - 22.347 g = 1.593 g	
1f	0.0112 mol Na_2SO_4	
1g	$Na_2SO_4 \bullet 10H_2O$	
2a	0.0507 mol H_2O	
2b	0.0169 mol $CuSO_4$	
2c	$CuSO_4 \bullet 3\ H_2O$	
2d	i. Lost solid would seem like more water, so mass of water would increase (too high) ii. Mass of water would decrease. If left out, the anhydrate would absorb water from the air and regain mass, causing water lost to seem lower. iii. Mass of water would increase because lost solid would seem like more water.	

1.4 COMPOSITION OF MIXTURES Classification of Matter:



When two or more pure substances (elements and compounds) are combined they form a mixture. In mixtures the composition can vary. The mixture can be analyzed in order to determine the _____ of each substance in that mixture.

You can use stoichiometry (_____) to convert the masses of the products from the analysis to find the amounts of reactants that were in the original mixture.

Mass Percentage
The mass percentage of a substance in the mixture can be calculated:

Elemental Analysis, used _____
can be qualitative (identify the different elements present) or quantitative (identify the amounts of elements present.)

Elemental analysis is a part of analytical chemistry.

Example: Combustion Analysis - All of the carbon in a sample is converted into carbon dioxide, all of the hydrogen is converted into water, all of the nitrogen into nitrogen monoxide or nitrogen dioxide…

Example 1.4A:

A 2.4 g sample of a mixture of calcium chloride, $CaCl_2$ and sodium chloride, NaCl. NaCl is found to contain 0.12 g Na. What percent of the sample is NaCl?

1. Determine moles of Sodium, Na.

2. Determine moles of sodium chloride, NaCl.

3. Determine mass of sodium chloride, NaCl.

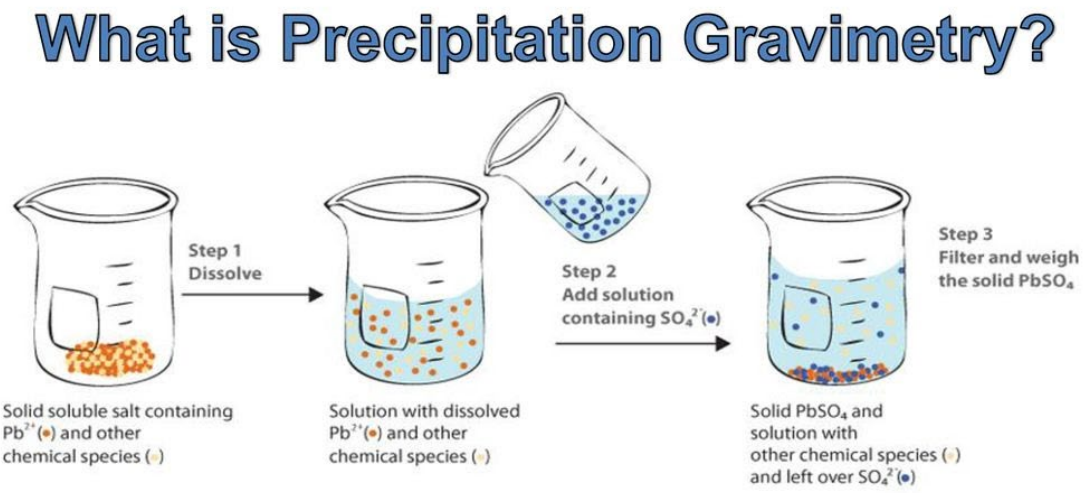
4. Calculate percent mass sodium chloride, NaCl in sample.

Discussion 1.4B:

The mass percent of carbon in pure glucose ($C_6H_{12}O_6$) is 40.0%. A chemist analyzes an impure sample of glucose and determines that the mass percent of carbon is 38.2%. Which of the following impurities could account for the low mass percent of carbon in the sample?

a. Water, H_2O
b. Ribose, $C_5H_{10}O_5$
c. Fructore, $C_6H_{12}O_6$, an isomer of glucose
d. Sucrose, $C_{12}H_{22}O_{11}$
e. **Example 1.4C:**

A 5.0 g sample of a mixture of $CaCO_3$ and SiO_2 contains 1.5g Ca. What is the percent $CaCO_3$ in the mixture?



- In precipitation gravimetry, the analyte (substance we are studying) is converted to an _____.
- This precipitate is filtered, washed free of impurities, dried completely, and weighed.
- The point of this is to determine the _____ _____

Example 1.4D:

A student is given a mixture of NaCl*(s)* and $NaNO_3$*(s)* and is tasked with determining the percent of NaCl in the mixture. The student dissolves 3.613 g of the mixture in 50 mL of DI water. The student then adds excess $AgNO_3$*(aq)* to precipitate the chloride ion as AgCl*(s)*. The student determines that 2.268 g of AgCl is formed. The reaction can be shown using the chemical equation shown below.

$AgNO_3$ (aq) + NaCl (aq) → AgCl (s) + $NaNO_3$ (aq)

What is the percent by mass of NaCl in the original mixture?

Step 1: Find mass of NaCl in the original mixture using the mass AgCl formed.

Step 2: Divide mass NaCl by mass of mixture:

1.4 Additional Practice Questions

1. A sample of brass weighing 1.203 grams was analyzed. Brass is an alloy composed of copper, Cu, and zinc, Zn. The zinc in the alloy was reacted with 35.123 grams of hydrochloric acid, HCl, in excess, according to the following balanced equation:

   $$Zn_{(s)} + 2\ HCl_{(aq)} \rightarrow H_{2\,(g)} + ZnCl_{2\,(aq)}$$

   After all of the zinc reacted the mass of the remaining solution weighed 36.309 grams.

   a. What mass of hydrogen gas was produced?

   b. What mass of zinc reacted?

   c. What was the percentage of zinc (by mass) in the alloy?

2. A sample of sodium bromide, NaBr, has a mass percentage of sodium of 22.34%.
   a. If the sample of sodium bromide were contaminated with sodium chloride, NaCl, would the mass percentage of Na in the sample be higher or lower than the pure sample? Justify your claim.

   b. If the sample of sodium bromide were contaminated with sodium iodide, NaI, would the mass percentage of Na in the sample be higher or lower than the pure sample? Justify your claim.

3. A sample of a mixture containing an unknown hydrocarbon and some nitrogen dioxide, NO_2, had a total mass of 31.25 grams. The mixture was analyzed using combustion analysis, producing 78.44g of carbon dioxide, CO_2, and 32.12g of water, H_2O.
   a. Calculate the empirical formula of the hydrocarbon.

   b. The molar mass of the compound was found to be 252.48 g/mol. What is the molecular formula of the hydrocarbon?

c. What percentage (by mass) of the original sample was the hydrocarbon?

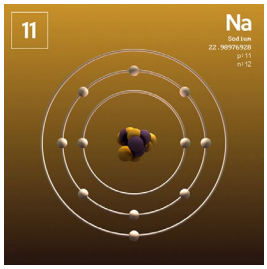
Answer key directions: When you check your answers, rank your understanding from 1-5. 1 means you still do not understand, 5 means you answered the questions correctly before checking it.

Question	**Correct Answer**	**Ranking/Self reflection. Any question(s) you still need help on?**
1a	Total mass reactants (36.329) minus mass left after reaction (36.309 g) = 0.017 g H_2	
1b	0.55 g Zn	
1c	46% (2 sig figs)	
2a	Higher. NaCl has greater percent Na because Cl has a smaller mass than Br. So mass percent of Na would be higher than pure NaBr.	
2b	Lower. NaI has lower percent Na because I has a larger mass than Br. So mass percent of Na would be lower than pure NaBr.	
3a	CH_2	
3b	$C_{18}H_{36}$	
3c	79.99% $C_{18}H_{36}$	

1.5 ATOMIC STRUCTURE AND ELECTRON CONFIGURATION

Atoms

Atoms are made up from **protons** (positive), **neutrons** (neutral) and **electrons** (negative). The nucleus contains the protons and neutrons, while the electrons move around the nucleus.



The majority of the mass of the atom comes from the protons and neutrons, while most of the volume of an atom comes from the electrons.

Atoms and Ions Review Questions

1. To the right is the periodic table square for Copper, Cu. How many protons, neutrons and electrons does copper have?

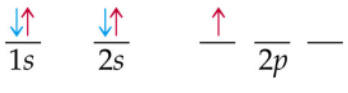
29
Cu
63.55

2. One way for copper to stabilize is by reacting with a nonmetal to create the copper (I) ions, Cu^+. How many protons, neutrons and electrons does Cu^+ have?

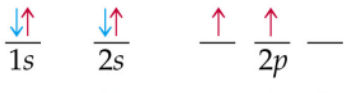
Electron Configurations

Electron Configurations are a way of describing the arrangement of electrons within an atom.

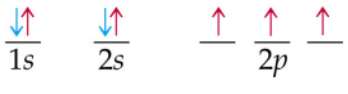
B: $1s^2\ 2s^2\ 2p^1$ or



C: $1s^2\ 2s^2\ 2p_x^1\ 2p_y^1$ or



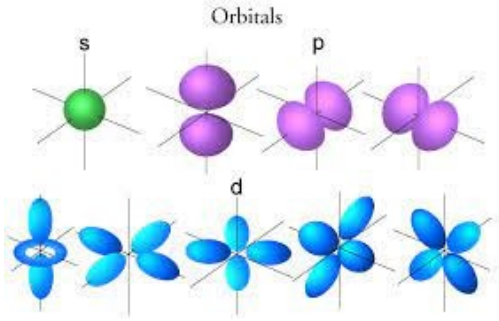
N: $1s^2\ 2s^2\ 2p_x^1\ 2p_y^1\ 2p_z^1$ or



The inner electrons are called _____

The outer electrons are called _____

Energy Levels



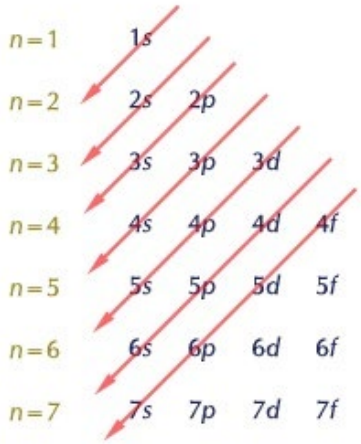
Energy Level	Possible Shapes (orbitals)	Number of Electrons
1	s	2
2	s p	8
3	s p d	18
4	s p d f	32

The first shell is small and only has room for the _____ orbital.

The second shell is larger and there is room for a _____ orbital and a set of 3 _____ orbitals which are dumb-bell shape.

The third shell is even larger and there is room for a ____ orbital, a set of _____ orbitals and a set of 5 _____ orbitals which are double dumb-bell shape.

Sublevel Increasing Energy

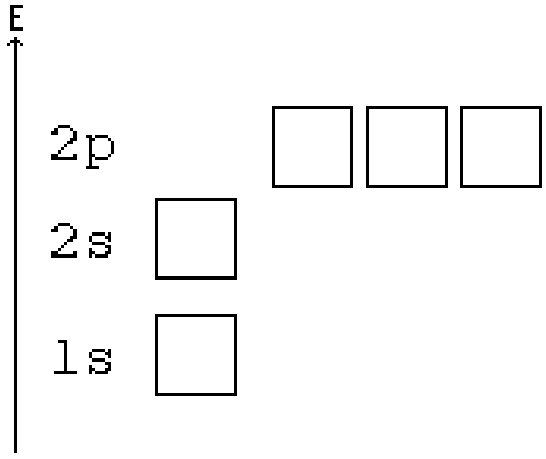


RULES FOR ELECTRON CONFIGURATIONS:

1. **Aufbau principle:** electrons are added to the lowest subshells first and build up.

2. **Hund's Rule:** each subshell should have one electron before any are doubled up.

3. **Pauli Exclusion Principle:** no two electrons can have the same set of 4 quantum numbers.



Writing Electron Configurations
(Energy Level)(orbital name)$^{\#\ of\ e^-}$

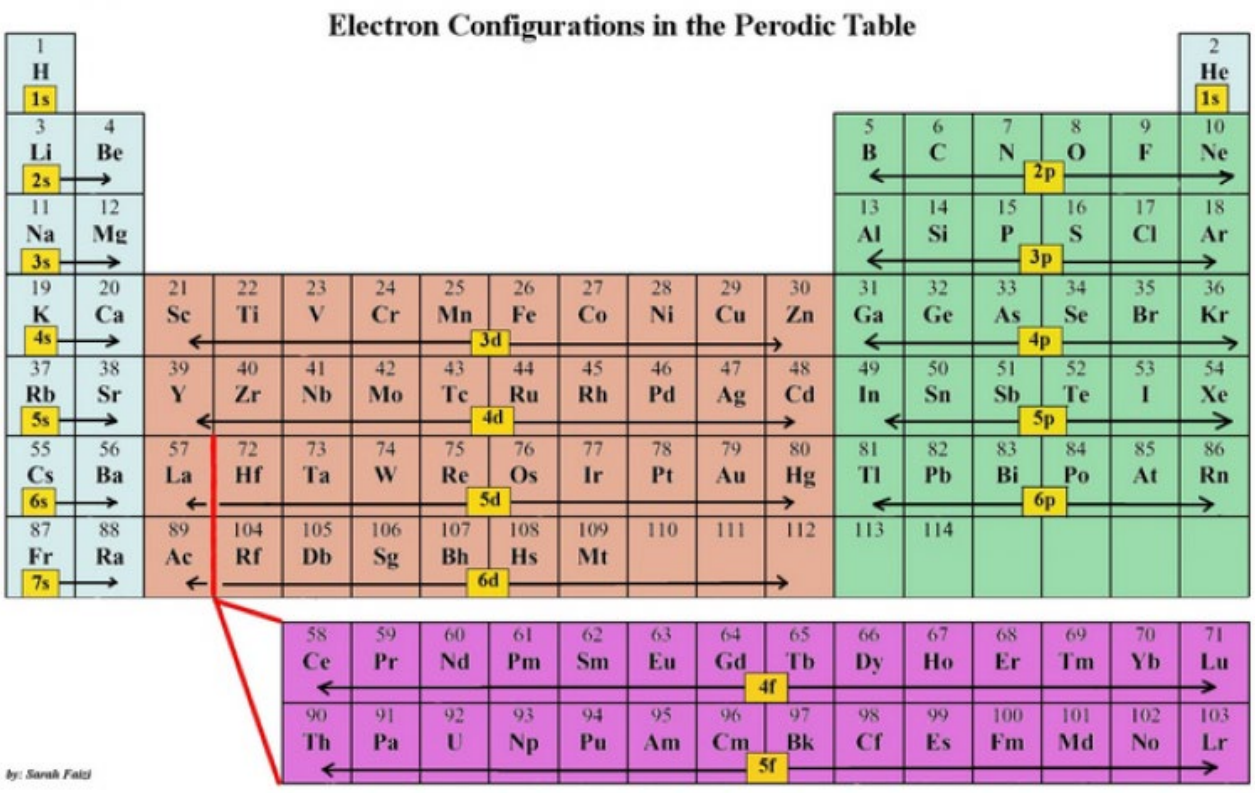
Fluorine Example: $1s^2\ 2s^2\ 2p^5$

Fluorine has 2 electrons in the s orbital in the first energy level, 2 electrons in the s orbital in the second energy level, and 5 electrons in the p orbitals in the second energy level. Fluorine has a total of 9 electrons.

Example1.5A: Write the electron configuration of neutral Iron, Fe.

1. Determine how many electrons are in the atom using the Periodic Table

2. Fill each sublevel until all 26 electrons are accounted for. Remember s holds 2 e^- max, p holds 6 e^-, d holds 10 e^- and f holds 14 e^-.



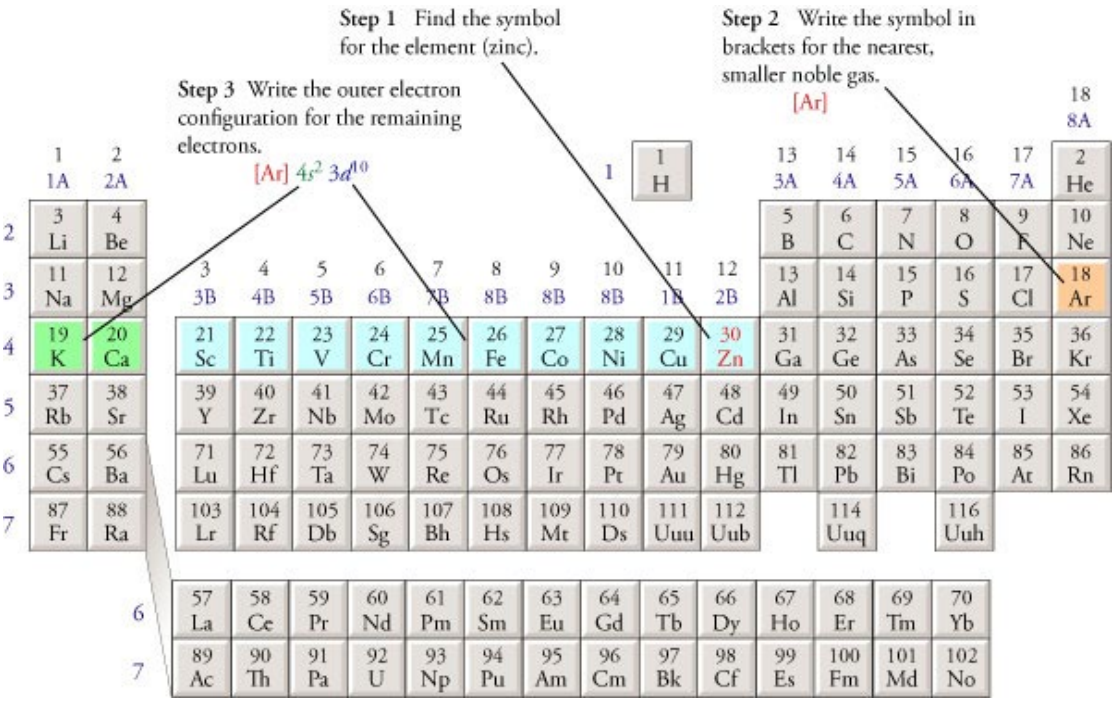
Noble Gas Abbreviation/Shorthand Electron Configuration

An abbreviated form of electron configurations was developed using the final column of the periodic table, the noble gases.

Example: Scandium

Sc: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^1$

Abbreviated version can be written as: _____



Example 1.5B: Write the ground state electron configuration for Arsenic.

Standard (whole):

Abbreviated (Noble Gas):

Example 1.5C: Write the electron configuration for Calcium ion, Ca^{2+}. Hint: how many e^- does this ion have?

Standard (whole):

1.5 Atomic Structure and Electron Configuration Practice Questions

1. Write the ground state electron configuration for Chlorine, Cl.

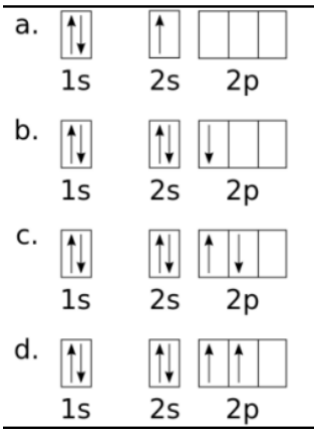
2. Write the electron configuration of fluorine ion, F^-.

3. Write the electron configuration for Aluminum ion, Al^{3+}.

4. The electron configuration for an unknown element is $xs^2\,xp^4$, where x is an integer. Based on your knowledge of ion formation, predict the charge for the ion that would form when this element loses or gains electrons.

5. Write the noble gas electron configuration for Barium, Ba.

6. In the diagram on the right, three of the orbital diagrams are correct and one is incorrect. Identify the elements shown for each and correct the one that is wrong.



7. When an electron in an atom gains sufficient energy it can move to a higher energy level (further away from the nucleus). This is called an excited state.
    a. Write the electron configuration for ground state (normal) sodium, Na.

    b. Write an electron configuration for an excited state of sodium in which one of the 2p electrons jumps up to the 3p orbital.

Answer key directions: When you check your answers, rank your understanding from 1-5. 1 means you still do not understand, 5 means you answered the questions correctly before checking it.

Question	Correct Answer	Ranking/Self reflection. Any question(s) you still need help on?
1	$1s^2 2s^2 2p^6 3s^2 3p^5$	
2	$1s^2 2s^2 2p^6$	
3	$1s^2 2s^2 2p^6$	
4	-2 charge. It has 6 valence, so it needs to gain 2 e^- to stabilize	
5	$[Xe]6s^2$	
6	a. Correct, element is Lithium b. Correct, element is Boron c. Incorrect, 2p needs electron in second orbital to be up arrow (D is correct version of this). D. Correct, element is Carbon	
7a	$1s^2 2s^2 2p^6 3s^1$	
7b	$1s^2 2s^2 2p^5 3s^1 3p^1$	

1.6 PHOTOELECTRON SPECTROSCOPY

Electromagnetic Forces

Chemistry is governed by the forces that exist between charged particles.

The strength of these electromagnetic forces are determined by two factors:

- **the amount of charge** (+1, +2, -1, -2, etc.)
    - _____ charges have _____ attractions
- **the distance between charges** (r)
    - The _____ the oppositely charged things are, the

_____ the attractions.

★ Coulomb's Law ★

$$F = k\frac{q_1 q_2}{r^2}$$

The force between charged particles is proportional to the product of the two charges and the force is inversely proportional to the squared radius between them.

The force will decrease the further away the particles are.

Higher charges and smaller distances between the charges result in a greater force of attraction. **This explains** _____

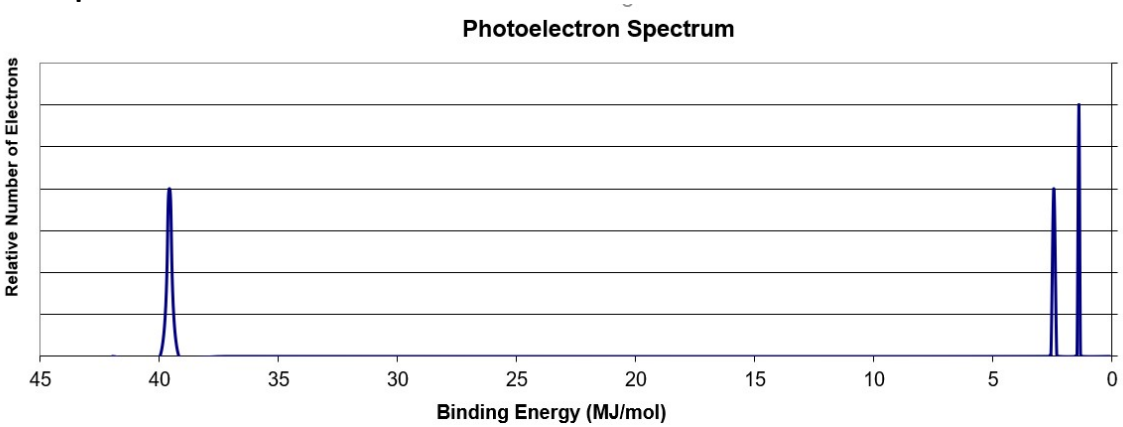
_____

Photoelectron Spectroscopy (PES)

PES is an experimental technique that measures the relative energies of electrons in atoms or molecules.

It works by ejecting electrons from the materials using high energy electromagnetic radiation (like UV or x-rays) and then measuring the kinetic energy of those electrons. This process can be described as photoionization.

PES Graphs



PES graphs show the **relative number of** _____ and their corresponding _____ _____.

The **binding energy** can be described as the amount of energy needed to remove an electron from an atom.

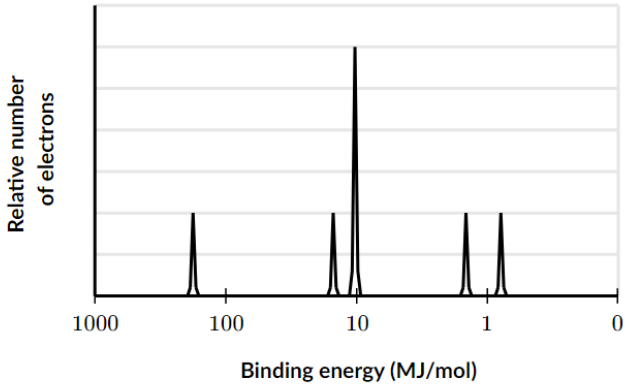
The electrons with the highest binding energy are the ones that have the greatest **coulombic attraction** to the nucleus because they are the closest to the nucleus.

PES Example 1.6A:
Use the PES data provided to the right to answer parts a-c.

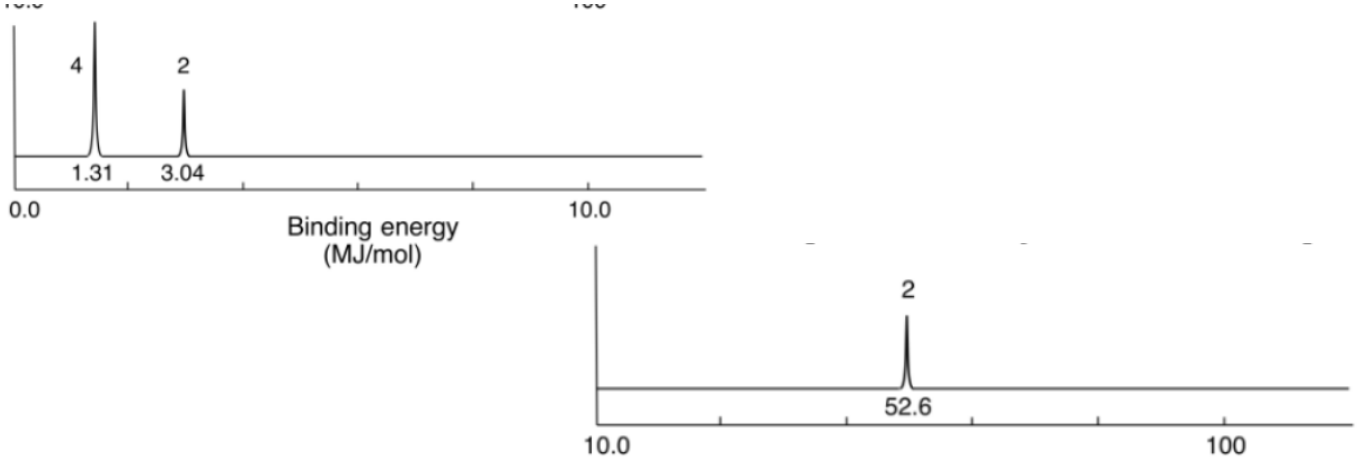
a. Label each sublevel on the diagram, starting with 1s.

b. Write the complete electron configuration of this element.

c. What is the element?



Example 1.6B: Groups



Answer parts a-c below. Notice the direction of the axis!!!

a. Label each sublevel on the diagram, starting with 1s.

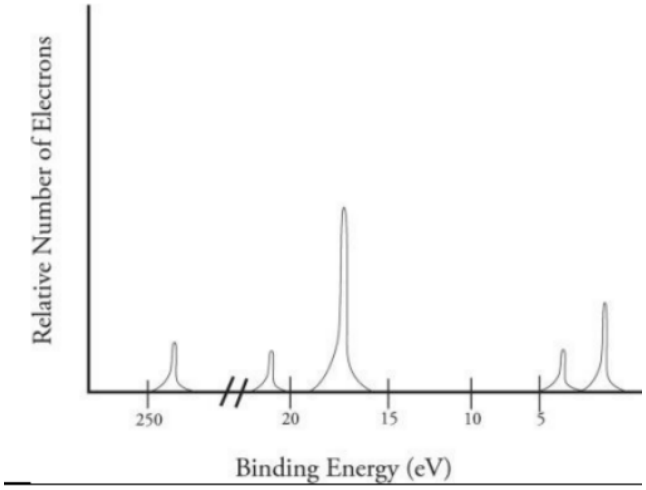
b. Write the complete electron configuration of this element.

c. What is the element?

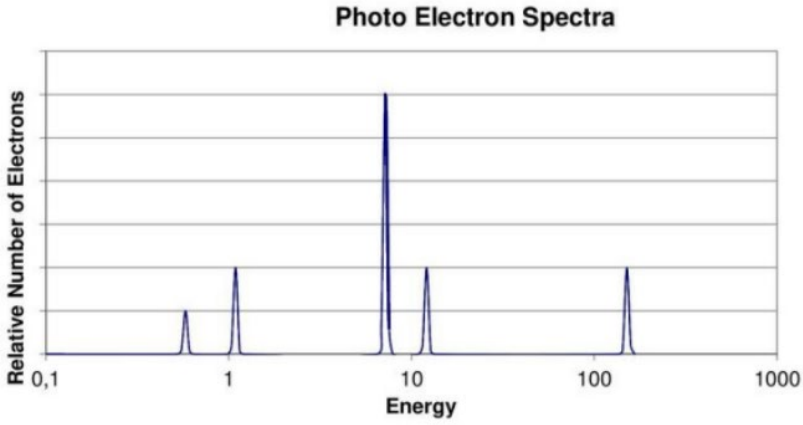
Example 1.6C: Review
Which element is represented by the PES absorption spectra shown?

1.6 Photoelectron Spectroscopy Practice Questions

1. Which element is represented by the PES absorption spectra shown?



2. Inspect the PES spectra provided.



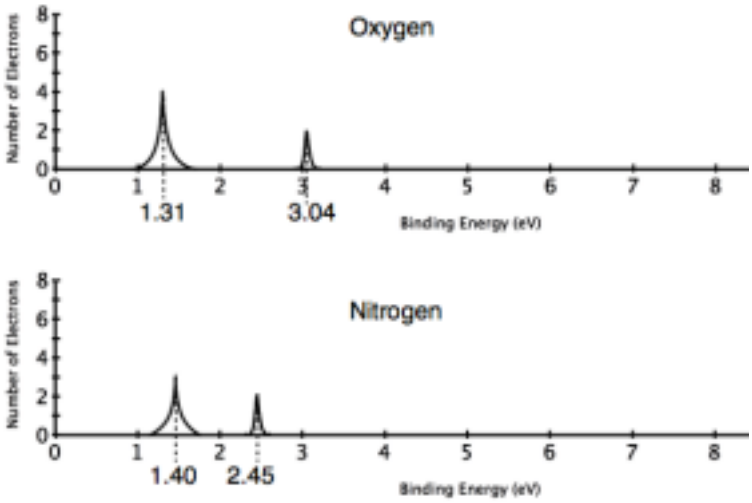
   a) Identify the element shown

   b) Write the electron configuration

   c) Predict the charge this element will form as an ion

3. The PES spectra for the valence electrons for oxygen and nitrogen are given.

a. Write a complete electron configuration for both elements.

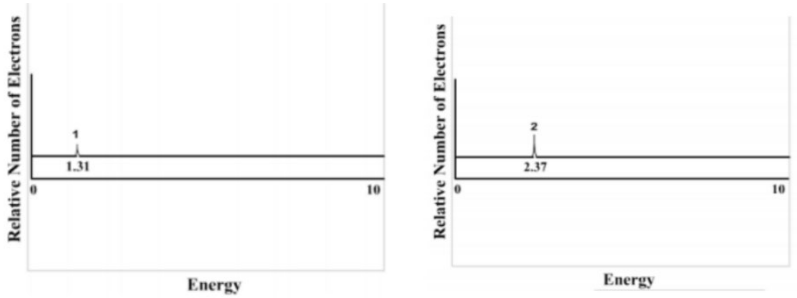


b. Identify the 2s peak and label on each spectra.

c. Explain the difference in energy for the 2s peaks.

d. Write/Draw an electron orbital diagram for each element.

4. The PES spectra for hydrogen and helium are provided.

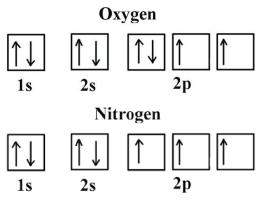


a. Label each graph as Hydrogen or Helium

b. Explain the difference in the intensity (height) of the peaks.

c. Explain the difference in the energy of the peaks.

Answer key directions: When you check your answers, rank your understanding from 1-5. 1 means you still do not understand, 5 means you answered the questions correctly before checking it.

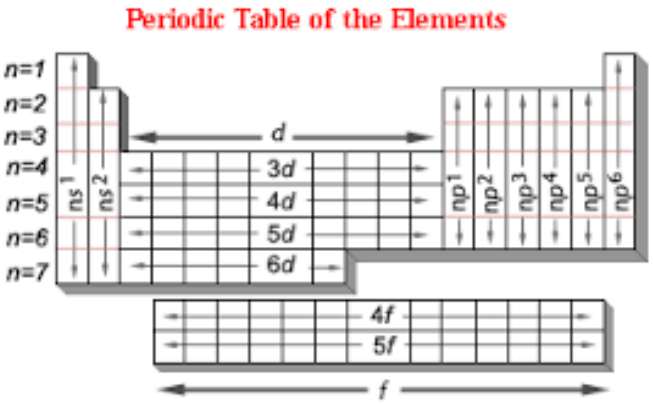
Question	Correct Answer	Ranking/Self reflection. Any question(s) you still need help on?
1	Phosphorous; the element has 15 electrons (3 in 3p)	
2	a. Aluminum (13 electrons) b. $1s^2 2s^2 sp^6 3s^2 3p^1$ c. Lose 3 electrons (+3 charge)	
3a	Oxygen: $1s^2 2s^2 2p^4$ Nitrogen: $1s^2 2s^2 2p^3$	
3b	2s peak for each is the peak further to the right	
3c	Oxygen has a greater binding energy because it has more protons than Nitrogen, so oxygen has stronger attractions and will need more energy to remove the electron	
3d		
4a	Hydrogen - left Helium- right	
4b	He has a higher peak because it has more electrons (2) than H (1)	
4c	He has higher	

	binding energy because it has more protons, so it has a stronger attraction to the electrons than H.	

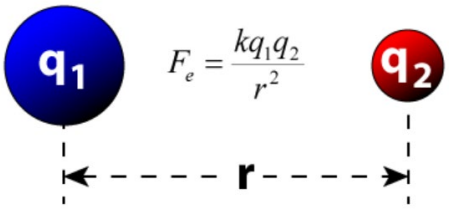
1.7 PERIODIC TRENDS

Chemical Properties

- Elements that have the same valence electron configuration tend to have similar chemical properties.
- Name 2 elements that will have similar properties to Calcium, Ca.



Coulombic Attraction



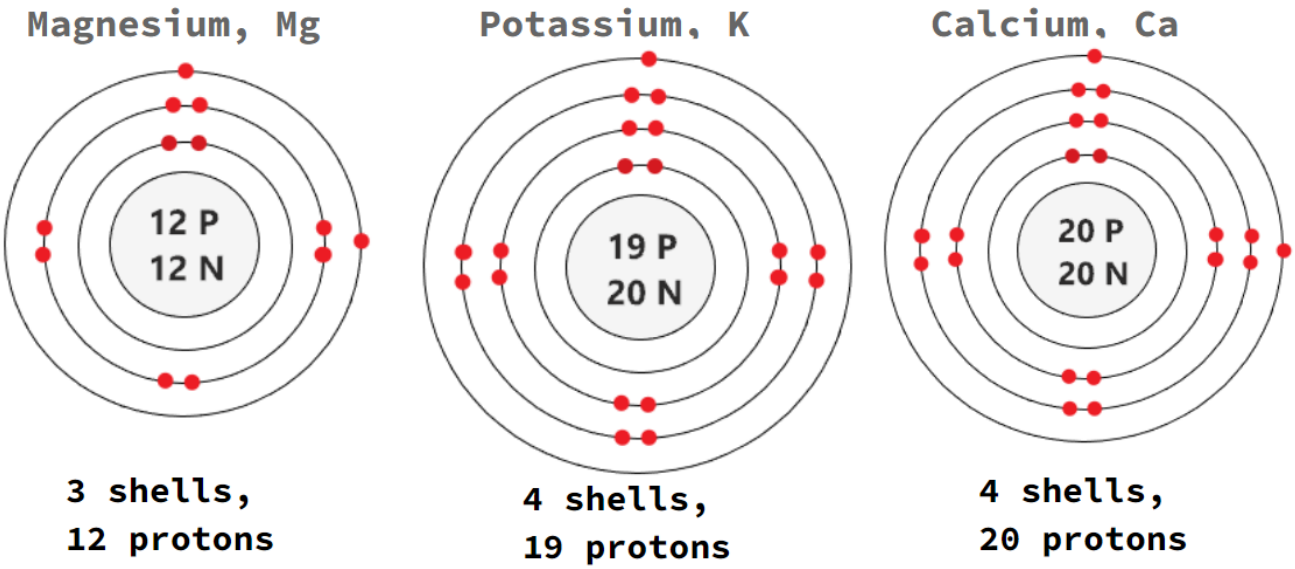
- Explains most periodic trends.
- Negative electrons in the electron cloud and positive protons in the nucleus are attracted to each other.
- The larger the charge, the more attractive forces between the particles.

_____

- The further away the particles are from each other, the weaker the attractive forces.

_____

Example 1.7A: Which atom Has the Strongest Attractions?

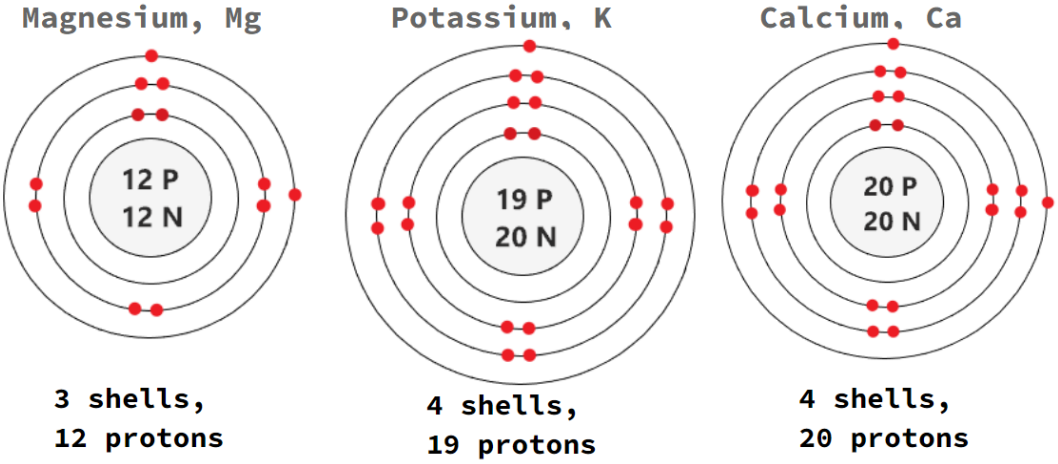


Periodic Trends

Periodic trends can be explained by the arrangement of the electrons and the number of protons in the atoms.

IMPORTANT: Stating a trend is not EXPLAINING a trend. Explanations of trends should never be in terms of the location of the periodic table.

First Ionization energy: The energy required to remove the outermost (highest energy) electron from a ground state, neutral atom in its gaseous form.



Example 1.7B: Which atom shown above would require the most energy to remove a valence electron? Explain your answer.

Example 1.7C: Which atom shown above would require the least energy to remove a valence electron? Explain your answer.

First Ionization Energy Takeaways:

- The element with the **least shells** will have the highest **first IE** because its valence electrons are closer to the nucleus. Since the electrons are **closer to the nucleus**, the attraction between the protons and valence electrons are stronger, so **more energy** is required to remove the electron.
- When elements have the **same number of shells**, the element with the **most protons** will have the **highest first IE** because more protons attract the electrons more. Since the electrons are more strongly attracted by more protons, it will require **more energy** to remove the electron.

Subsequent Ionization Energies: the energy required to remove the second, third, etc. electron from a ground state atom in its gaseous form.

- Once an element is stable, there will be a large jump in its ionization energy.
- Magnesium Ionization Energies:
  - Electron configuration: $1s^2s2^2 2p^6 \mathbf{3s^2}$
  - _____ valence electrons
  - The 3rd IE is significantly higher than the 2nd because…

    _____

    _____

Ionization Energies (kJ/mol)

1st	737.75
2nd	1450.68
3rd	7732.68

Atomic Radius: a measure of the size of its atoms, the mean or typical distance from the center of the nucleus to the boundary of the surrounding cloud of electrons.

- More shells = _____

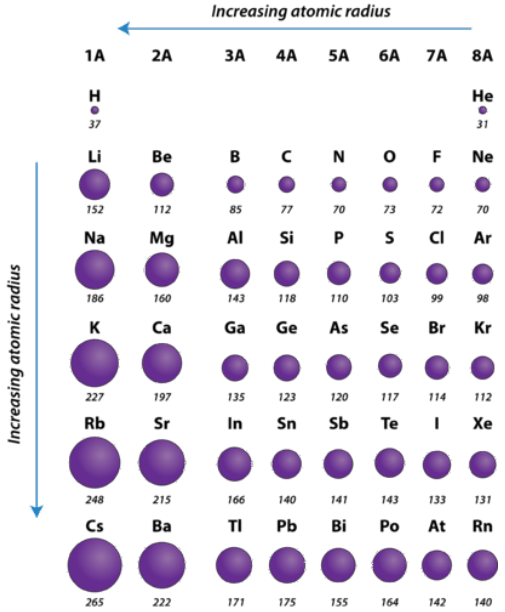
  because _____

  _____
- Same number of shells, but more protons =

  _____

  because _____

  _____



Atomic Radius: a measure of the size of an ion (an atom with a charge).

- **Cations (positive) are always smaller than the parent atom.**
  - Because _____
- **Anions (negative) are always larger than the parent atom.**

- Because _____

_____

_____

Electron Affinity: The energy change that occurs when an electron is added to a gaseous atom or ion:

$$E_{(g)} + e^- \rightarrow E^-_{(g)} \qquad \text{energy change} = EA$$

- The energy change that occurs when an electron is added to a gaseous atom or ion:
- In general, the electron affinity **increases from left to right** on the periodic table. Electrons are filling the valence shell and effective nuclear charge (therefore coulombic attraction) is increasing.
- In group 1, electron affinity **decreases down a group**. This is sort of true for other groups. The distance from the nucleus to the valence shell increases, decreasing the coulombic attraction.

Electronegativity: A measure of the ability of an atom (or group of atoms) to attract shared electrons **in a bond.**

- More shells = _____ because…

  _____

  _____
- Same shells, but more protons = = _____ because…

  _____

  _____
- _____ is the most electronegative element.
- _____ do not have electronegativity values because they typically do not form bonds since they are already stable.

Example 1.7D: For each of the following pairs of elements circle the element with:

a. Higher first ionization energy

Li or F

b. Larger atomic radius
Na or O

c. Higher electronegativity
Li or F

Example 1.7E: Rank the following from smallest to largest atomic/ionic radius.

a. Na, Na^+, Na^-

b. C, N, O

c. Cl, Ar, K

d. Be, Mg, Ca

1.7 Periodic Trends Practice Questions

1. On the basis of their position on the periodic table determine which element in the pair would have a larger atomic radius. Give the "stats" (energy levels and protons) to support your answer.
   a. P or S
   b. Cl or Br

2. Based on the ionization energies for element "X" predict the formula that would be formed when "X" reacts with chlorine, Cl.

Ionization Energy Number	Enthalpy (kJ/mole)
1st	577
2nd	1820
3rd	2740
4th	11600
5th	14841

3. The first ionization energy for potassium, K, is 419 kJ/mol and the second ionization energy for calcium, Ca, is 1145 kJ/mol. Using concepts from this unit explain why they are different

even though they are isoelectronic (have the same number of electrons).

$$K_{(g)} \rightarrow K^{+}_{(g)} + e^{-}$$

$$Ca^{+}_{(g)} \rightarrow Ca^{2+}_{(g)} + e^{-}$$

4. Element X has an electron configuration of $1s^2 2s^2 2p^6 3s^1$, while element Z has an electron configuration of $1s^2 2s^2 2p^5$.

   a) Which element would have greater first ionization energy?

   b) Which element would have a larger radius?

   c) Which element would have higher electronegativity?

   d) Which element would form an ion that has a larger radius?

   e) Which element would release more energy when it gains an electron?

5. Predict two elements that would have properties similar to:

   a) Chlorine

   b) Sodium

   c) Calcium

6. Based on the given electron configurations, group together the elements that would have similar chemical properties.

a. $1s^2 2s^2 2p^6 3s^1$

b. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$

c. $1s^2 2s^2 2p^5$

d. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 4p^6 5s^2$

e. $1s^2 2s^1$

f. $1s^2 2s^2 2p^6 3s^2 3p^5$

Answer key directions: When you check your answers, rank your understanding from 1-5. 1 means you still do not understand, 5 means you answered the questions correctly before checking it.

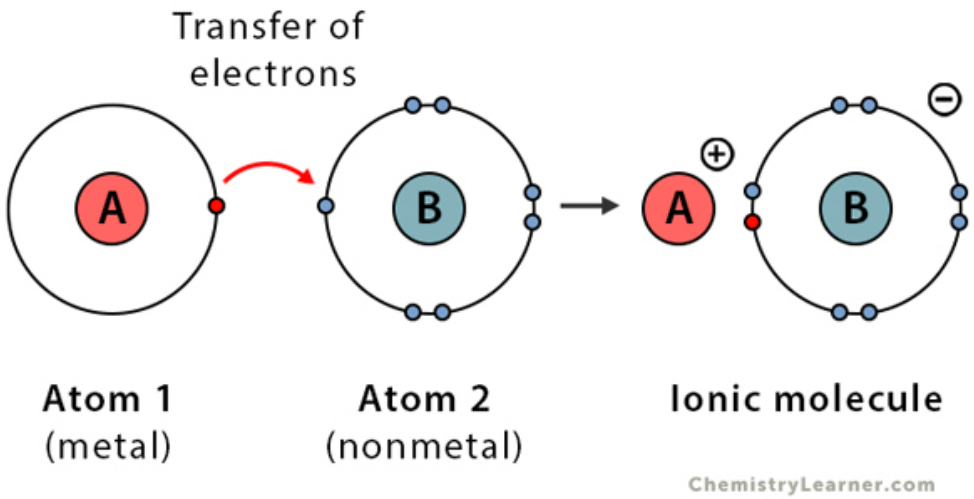
Question	**Correct Answer**	**Ranking/Self reflection. Any question(s) you still need help on?**
1a	P has larger radius. S and P both have 3 energy levels, but P has fewer protons (15), so it has a weaker attraction than S (16 protons) resulting in a larger radius.	
1b	Br has larger radius because it has more energy levels (4) than Cl (3).	
2	Element X has 3 valence electrons because it has a large jump in the fourth IE. Formula: XCl_3	
3	Ca has more protons (20) than K (19), so Ca has stronger attractions between the nucleus and electrons resulting	

	in a higher ionization energy.	
4	a. Element Z b. Element X c. Element Z d. Element Z e. Element Z	
5	a. Any halogen (F, Br, I) b. Any alkali metal (Li, K, Rb, Cs). c. Any alkaline earth metal (Be, Mg, Sr, Ba).	
6	Group 1: a, e (1 valence e^-) Group 2: b, d (2 valence e^-) Group 3: c, f (7 valence e^-)	

1.8 VALENCE ELECTRONS AND IONIC COMPOUNDS

Ionic Bonds

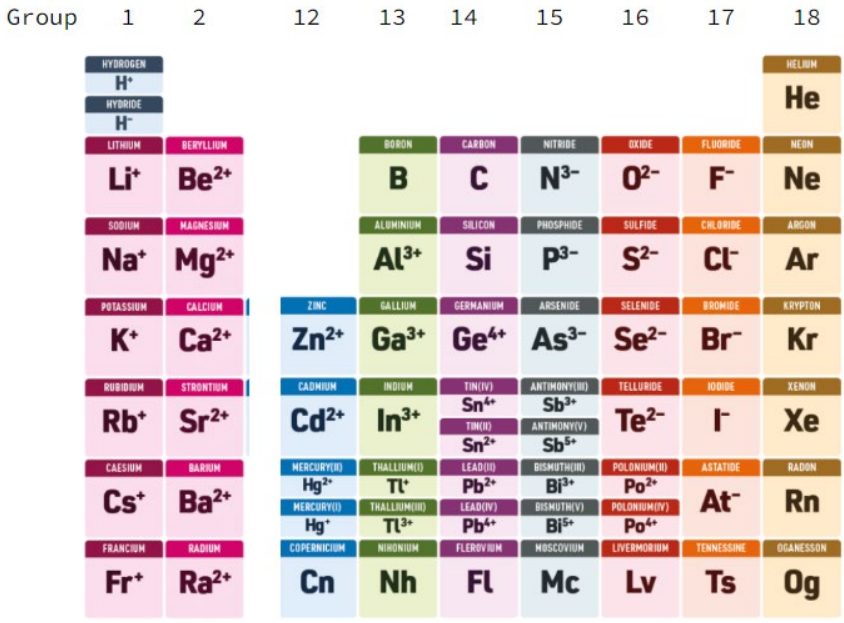
An **ionic bond** always involves the _____ from the least electronegative species to the most electronegative. Traditionally, ionic compounds are described as being between a metal and a nonmetal.



- Based on electron configuration, elements will either lose or gain electrons in order to have a complete s^2p^6 outer valence shell.
- Cation: _____
- Anion: _____
- Ionic compounds are held together by an _____

Periodic Table

- We can use the periodic table to predict how many electrons will be gained or lost by each atom.
- Nonmetals only want to gain enough electrons to fill their octet.
- Metals only want to give away enough electrons to have a pseudo-noble gas configuration.
- **The only 3 transition metal charges you are required to memorize:**
- **Ag^+ , Cd^{2+} , Zn^{2+}**



When ionic compounds form, the number of electrons lost by the metal must equal the number of electrons gained by the non-metal.

Example 1.8A: Sodium and phosphorus form an ionic compound. What is the molecular formula?

Example 1.8B: Calcium reacts with a certain element to form a compound with the general formula CaX_2. What would be the most likely formula for a compound formed between sodium and element X?

a. NaX_2
b. Na_2X
c. Na_3X_2
d. NaX

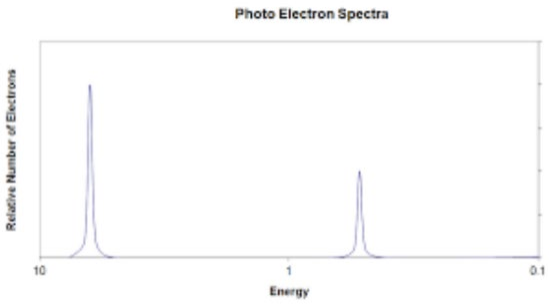
Example 1.8C: Element 117 was recently discovered and is named Tennessine. Assuming that periodic trends are followed, write the noble gas electron configuration and predict the formula when it forms an ionic compound with Mg.

1.8 Valence Electrons and Ionic Compounds Practice Questions

1. Which of the following is isoelectronic (same number of electrons) with Cl^-?
    a. F^-
    b. S
    c. Al^{3+}
    d. K^+

2. KCl dissolves in water, forming a solution able to conduct electricity. Which of the following would behave similarly?
    a. $PbCl_2$
    b. LiK
    c. LiCl
    d. $SrCl_2$

3. The complete photoelectron spectrum for an element is shown. What oxide compound would it most likely form?



   a. XO_2
   b. X_2O
   c. XO
   d. X_2O_2

4. Identify the correct electron configuration for the aluminum ion.

   a. $1s^2 2s^2 2p^6$
   b. $1s^2 2s^2 2p^6 3s^2 3p^1$
   c. $1s^2 2s^2 2p^6 3s^2 3p^6$
   d. $1s^2 2s^2 2p^6 3s^2$

Answer key directions: When you check your answers, rank your understanding from 1-5. 1 means you still do not understand, 5 means you answered the questions correctly before checking it.

Question	**Correct Answer**	**Ranking/Self reflection. Any question(s) you still need help on?**
1	D	
2	C	
3	B	
4	A	