

Hello AP Chemistry Students!!

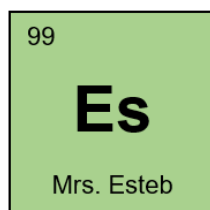
Here is your highly anticipated AP Chemistry SUMMER ASSIGNMENT. Your assignment includes a basic review of your first-year chemistry course, along with a few topics that may be new. You will complete Unit 1: “Atomic Structure and Properties” as outlined by the College Board AP Chemistry Curriculum. Unit 1 is divided into 8 topics (1.1 – 1.8), most of which were covered in first-year chemistry. AP Chemistry moves at a much faster pace than Honors Chemistry, and we will not have time to revisit topics such as nomenclature, dimensional analysis, electron configuration, and periodic trends. Completing this review is a great way to get a “feel” for how the topics in this course are organized and will help us begin lab activities early in Unit 1. If you find that tackling this review is too difficult or causes you an unusual amount of anxiety or stress, please reach out to me so we can discuss how I can help you as we move forward. Please contact me by email or GChat if you have questions or concerns. resteb@brebeuf.org

Now for the summer assignment:

You may pick up a paper copy from just outside the science office during Freeze Days/Final Exam week or access a digital copy via the [link](#) included with the summer homework information. Each topic begins with “Enduring Understanding,” “Learning Objective,” and “Essential Knowledge” information, along with any necessary equations you will use. These equations are also given on the included equation sheet. After that section, you will see notes, examples, and useful diagrams/tables. You should highlight and/or underline important information in this section as you read through it. Many students rewrite their own notes from what they read so that the information is translated into their own words. The physical act of taking notes helps us learn by engaging our brains with the material as we emphasize and organize important concepts. It also creates a condensed record for study and review. You will then see an “I Do” and “We Do” section. You should try both problems, then go [here](#) for video explanations of how I solved these problems. Last, complete the “You Do” section. I will post answer KEYS for topics 1.1 – 1.8 before the first day of class; however, you should begin working on the Unit 1 topics as soon as possible. I suggest completing 2 topics per week, but the pace at which you work is up to you! There is no penalty for completing this assignment early, but it must be completed before the first day of class to receive full credit.

Looking forward to a great year!!

See you in August,





Link to I Do/We Do Solution Videos

Topic: 1.1 Moles and Molar Mass

Enduring Understanding:

SPQ-1 The mole allows different units to be compared

Learning Objective:

SPQ-1.A Calculate quantities of a substance or its relative number of particles using dimensional analysis and the mole concept.

Essential Knowledge:

- | | |
|-----------|---|
| SPQ-1.A.1 | One cannot count particles directly while performing laboratory work. Thus, there must be a connection between the masses of substances reacting and the actual number of particles undergoing chemical changes. |
| SPQ-1.A.2 | Avogadro's number ($N_A = 6.022 \times 10^{23}$ particles/mole) provides the connection between the number of moles in a pure sample of a substance and the number of constituent particles (or formula units) of that substance. |
| SPQ-1.A.3 | Expressing the mass of an individual atom or molecule in atomic mass units (amu) is useful because the average mass in amu of one particle (atom or molecule) or formula unit of a substance will always be numerically equal to the molar mass of that substance in grams. Thus, there is a quantitative connection between the mass of a substance and the number of particles that the substance contains. |

Equation(s):

$$n = m/M$$

moles = mass/molar mass

Notes:

It is impractical to count atoms as they are so small, so in chemistry we can "count" atoms by weighing them or measuring them in some other way. We need to convert the measurements that we make into numbers of atoms so that we can be sure to react the right amounts of materials. Atomic masses are measured in atomic mass units, amu, which is a relative unit, based on the carbon-12 isotope being assigned a mass of exactly 12 grams per mole. A mole is a term used to describe a group of atoms containing 6.022×10^{23} items. Chemists use moles to discuss amounts of atoms because using the actual amount of atoms is such a large number it is often impractical. You can calculate the mass for one mole of a substance by referring to the periodic table to find the average atomic mass of each atom then adding up the total mass for the formula.

14.0067	15.9994
N	O
7	8
Nitrogen	Oxygen

How to calculate Molar Mass:

- 1) List the atoms
- 2) Count the atoms
- 3) Find the mass of each atom from the periodic table
- 4) Multiply the number of atoms (#2) by the mass of each atom (#3)
- 5) Add together the values (#4)

Calculate the molar mass of dinitrogen tetroxide:



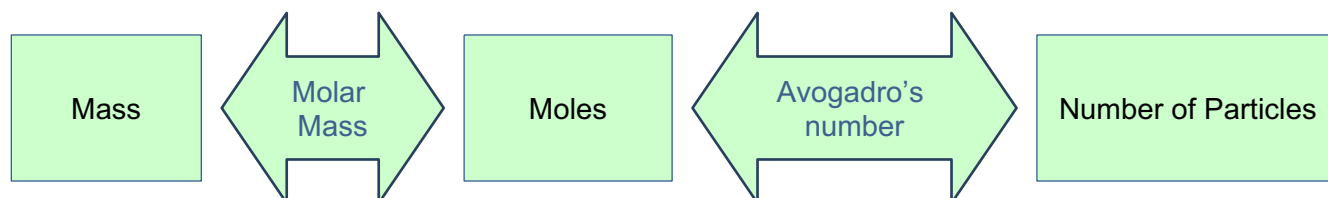
$$N = 2 \times 14.0067 = 28.0134$$

$$O = 4 \times 15.9994 = 63.9976$$

$$92.0110 \text{ g/mole}$$

Molar mass can be used as a conversion factor to convert between moles and grams. It is unique for each sample.

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



I do:

How many moles of Lead (II) iodide, PbI_2 , are there in a 25.0 gram sample?

How many atoms of lead, Pb, are in the sample?

We do:

A 0.244 g sample of calcium carbonate, CaCO_3 , was recovered from a sample of hard water. How many formula units of CaCO_3 were in the sample?

You do:

- 1) 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 particles of methane are there in the sample?
 - c) How many atoms of hydrogen are found in the sample?

- 2) 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. grams of helium is needed to cool a superconductor, how many atoms of helium are used?

- 3) If you know the mass and identity of a sample, what other information do you need in order to find the number of each atom in the sample?

- 4) Given 10.0 gram samples of LiCl , LiBr , LiF and LiI , place the samples in order of least to greatest number of atoms of Lithium, Li.

- 5) What is the mass of one atom of carbon-12?

- 6) What is the mass of 2.30×10^{24} particles of water, H_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 ?

TOPIC: 1.2 MASS SPECTROSCOPY OF ELEMENTS

ENDURING UNDERSTANDING:

SPQ-1 The mole allows different units to be compared.

LEARNING OBJECTIVE:

SPQ-1.B Explain the quantitative relationship between the mass spectrum of an element and the masses of the element's isotopes.

ESSENTIAL KNOWLEDGE:

SPQ-1.B.1 The mass spectrum of a sample containing a single element can be used to determine the identity of the isotopes of that element and the relative abundance of each isotope in nature.

SPQ-1.B.2 The average atomic mass of an element can be estimated from the weighted average of the isotopic masses using the mass of each isotope and its relative abundance

EQUATION(S):

N/A

NOTES:

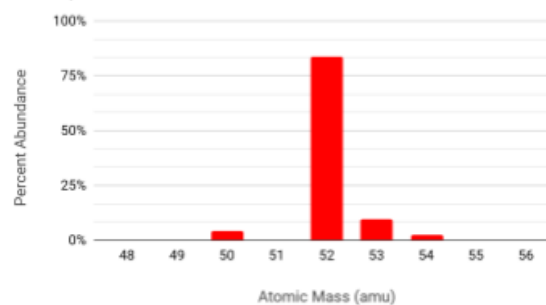
A sample of a pure element contains a variety of *isotopes* (atoms with the same number of protons and electrons, but different numbers of neutrons and therefore different mass numbers). The percentage of each atom with a specific atomic mass in the sample is that isotope's *relative abundance*.

For example, chromium has four naturally occurring isotopes- which are shown in the data table below.

We can see that most of the naturally occurring chromium is chromium-52, so we expect the *average atomic mass* (the weighted average of the masses of all of the naturally occurring isotopes of an element, the mass given on the periodic table) to be close to 52 amu. When we check the periodic table, we see that chromium's average atomic mass is in fact 52.00 amu.

Isotope	Protons	Neutrons	Mass (amu)	Abundance (%)
Chromium-50	24	26	49.95	4.35
Chromium-52	24	28	51.94	83.79
Chromium-53	24	29	52.94	9.50
Chromium-54	24	30	53.94	2.36

Mass Spectrum of Chromium



(Data from IUPAC Periodic Table of Isotopes: <https://applets.kcvs.ca/IPTEI/IPTEI.html>)

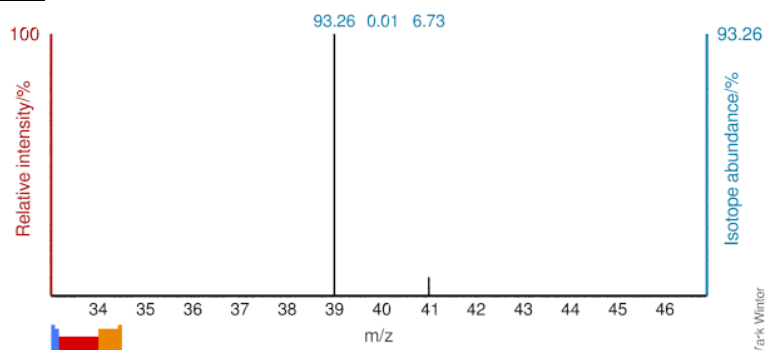
Mass Spectroscopy (Mass Spec) is an analytical chemistry lab technique that separates the components of a sample by their mass.

The mass spectrum of a sample containing a single pure element gives information about the naturally occurring isotopes of that element. By reading a mass spectrum, you can determine the isotopic masses (x-axis) as well as the relative abundances of those isotopes (y-axis).

The average atomic mass of an element can be calculated using the relative abundance and mass of each naturally occurring isotope of that element using the following equation.

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

IDO:



(Mass Spectrum from www.webelements.com)

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

What is the identity of the element?

WE DO:

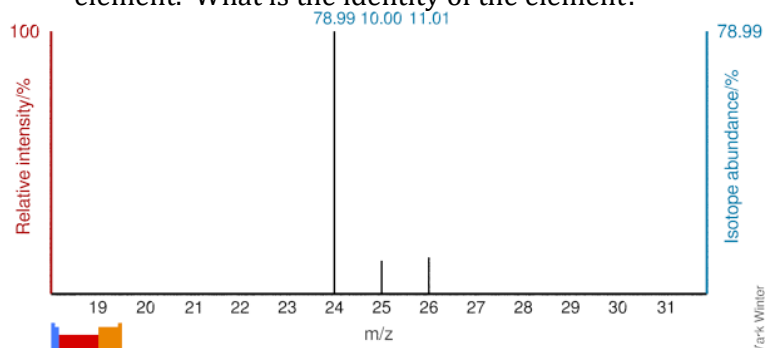
Rhenium, Re, is one of the rarest elements on Earth. Alloys containing rhenium are used for oven filaments and x-ray machines.

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 in the table below, calculate the percent abundance of naturally occurring rhenium.

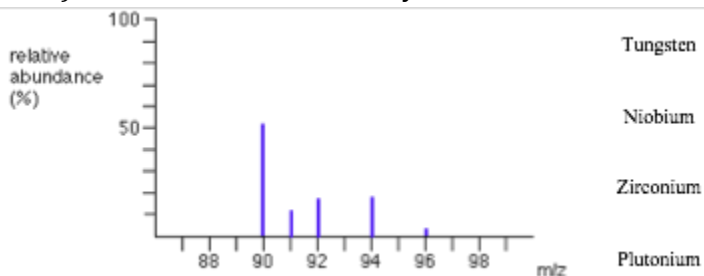
Isotope	Mass (amu)
Re-185	184.95
Re-187	186.96

YOU DO:

- 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?

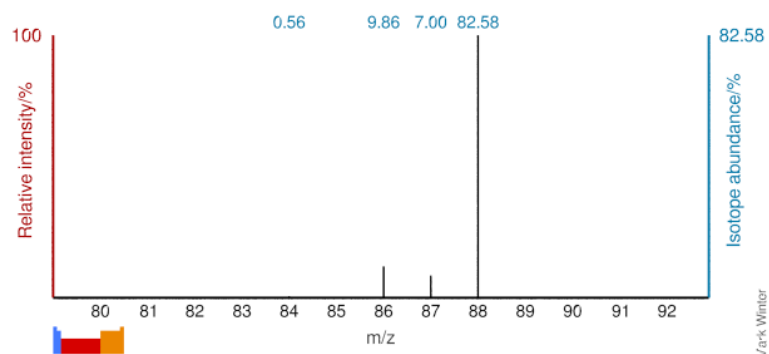


- 2) Determine the most likely element for the mass spectrum given below. Justify your choice.



- 3) In the chemical closet, you found an unlabeled vial with a solid piece of an unknown element inside (element Z). You decided to put it in the mass-spec to figure out its atomic mass. The results showed that it has two naturally occurring isotopes, Z-85, and Z-87. Z-85 has a natural abundance of 72.17% and a mass of 84.912 amu. Z-87 has a natural abundance of 27.83% and a mass of 86.909 amu. Calculate the average atomic mass and determine the identity of mystery element Z.

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



Isotope	Protons	Neutrons	Mass (amu)	Relative Abundance (%)

TOPIC: 1.3 ELEMENTAL COMPOSITION OF PURE SUBSTANCES

ENDURING UNDERSTANDING:

SPQ-2 Chemical Formulas identify substances by their unique combination of atoms

LEARNING OBJECTIVE:

SPQ-2.A Explain the quantitative relationship between the elemental composition by mass and the empirical formula of a pure substance

ESSENTIAL KNOWLEDGE:

SPQ-2.A.1 Some pure substances are composed of individual molecules, while others consist of atoms or ions held together in fixed proportions as described by a formula unit.

SPQ-2.A.2 According to the law of definite proportions, the ratio of the masses of the constituent elements in any pure sample of that compound is always the same.

SPQ-2.A.3 The chemical formula that lists the lowest whole number ratio of atoms of the elements in a compound is the empirical formula.

EQUATION(S):

N/A

NOTES:

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.

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

In compounds, the **empirical formula** represents the simplest ratio of one element to another in a compound. The **molecular formula** represents the actual formula for the substance.

An example is glucose which has the molecular formula $C_6H_{12}O_6$ but the empirical formula is CH_2O .

To determine the empirical and molecular formula.

1. Determine the *empirical formula* for the compound when given percent of each element
 - a. Assume you are given a 100g sample so you can change percent to grams
 - b. For each element take grams / molar mass to get moles of each element
 - c. Divide each mole value by the lowest of the values
 - d. 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.
 - e. The values you found are the subscripts for each element
2. Determine *molecular formula* (can only determine if given molar mass of substance)
 - a. Find mass of empirical formula
 - b. Molar mass/ empirical formula mass to find factor
 - c. Multiply all subscripts in the empirical formula by the value

I DO:

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?

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

WE DO:

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

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

YOU DO:

1. The most abundant molecule found in the human body is 88.810% oxygen and 11.190% hydrogen. Calculate the empirical formula for this substance.

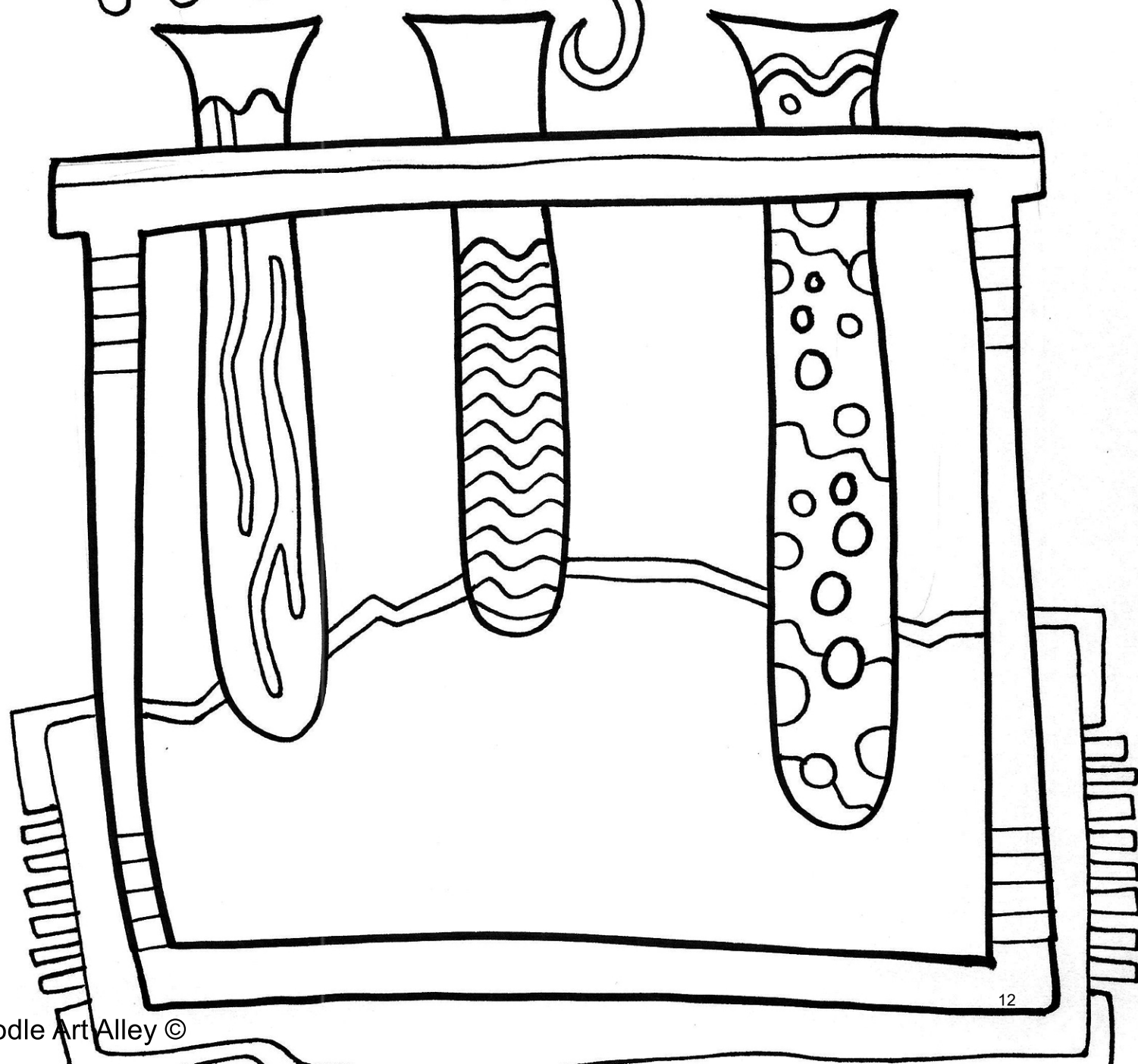
2. Arginine is one of the amino acids; it is used in the biosynthesis of proteins. Analysis revealed that a sample of arginine was 41.368 % carbon, 8.101% hydrogen, 32.162 % nitrogen and 18.369% oxygen.
 - a. What is the empirical formula of arginine?

 - b. The molecular weight of arginine is 174.204 grams/mole. What is the molecular formula?

3. The empirical and molecular formulas of urea are the same. 90 % of the world's urea is used for fertilizer. If the percentage composition of the elements in urea are 19.999% carbon, 6.713% hydrogen, 46.646% nitrogen and 26.641% oxygen. Calculate the empirical formula.

4. A compound containing phosphorus and oxygen is a powerful desiccant. The compound is 43.642% phosphorus and 56.358% oxygen.
- Calculate the empirical formula for this compound.
 - The molar mass of this compound is 283.889044 g/mol, determine the molecular formula.
5. 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 formula are the same.
- Calculate the empirical formula.
 - Calculate the molar mass.
6. Iron can form three different oxides, FeO , Fe_2O_3 and Fe_3O_4 . A sample of iron oxide was analyzed and was found to contain 69.943% iron with the rest of the mass from oxygen. Determine the empirical formula to determine the identity of the iron oxide.
7. Serotonin is a chemical that nerve cells produce from an essential amino acid called tryptophan. Tryptophan must enter our body through a balanced diet, and is commonly found in nuts, cheese and red meat. Serotonin is considered to be a natural mood stabilizer as it helps with sleeping, eating and digestion. A sample of serotonin was found to be 6.864% hydrogen, 68.159% carbon, 15.897% nitrogen and 9.079% oxygen. Calculate the empirical formula for serotonin.

CHEMISTRY



TOPIC: 1.4 COMPOSITION OF MIXTURES

LEARNING OBJECTIVE:

1.4.A	Explain the quantitative relationship between the elemental composition by mass and the composition of substances in a mixture.
-------	---

ESSENTIAL KNOWLEDGE:

1.4.A.1	While pure substances contain molecules or formula units of a single type, mixtures contain molecules or formula units of two or more types, whose relative proportions can vary.
1.4.A.2	Elemental analysis can be used to determine the relative numbers of atoms in a substance and to determine its purity.

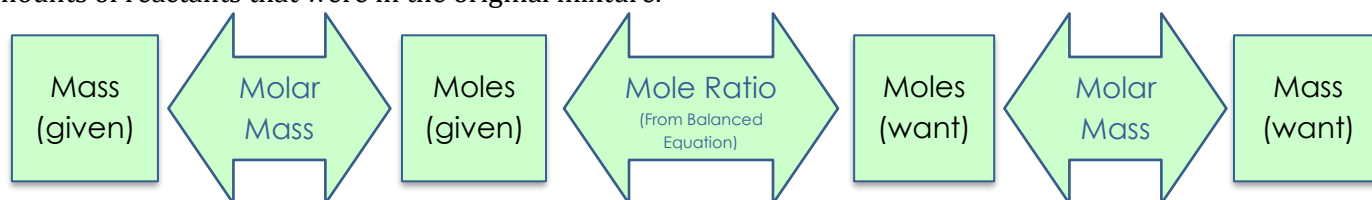
EQUATION(S):

N/A

NOTES:

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 to determine the mass composition of each substance in that mixture.

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



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

$$\frac{\text{Mass of Substance}}{\text{Total Mass of Mixture}} \times 100 = \text{Mass Percentage}$$

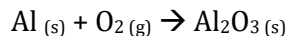
Elemental Analysis to determine the composition of a mixture can be qualitative (identify the different elements present) or quantitative (identify the amounts of elements present.) Elemental analysis is a part of analytical chemistry.

Some examples of elemental analysis include:

- CHNX - Used by organic chemists to identify the mass fractions of carbon, hydrogen, nitrogen and other atoms such as halogens or sulfur. One form of this is combustion analysis. All the carbon in a sample is converted into carbon dioxide, all the hydrogen is converted into water, nitrogen is converted into nitrogen monoxide or nitrogen dioxide and sulfur (for example) is converted into sulfur dioxide.
- Spectroscopy
 - Optical – light is passed through a colored solution and the amount of light absorbed or transmitted is measured to determine the concentration of the solution (3.13 Beer-Lambert Law)
 - Mass – The charge to mass ratio is measured by atomizing then ionizing a sample, then accelerating the sample between charged plates and measuring the deflection of the sample. Greater deflection is found in smaller masses or larger charges. (1.2 Mass Spectroscopy)
 - Photoelectron – The energy to remove electrons from atoms is measured and can be translated into the electron configuration (arrangement) for an element. (1.7 Photoelectron Spectroscopy)

I DO:

Aluminum metal reacts with the air and forms a thin, corrosion resistant coating of aluminum oxide, Al_2O_3 , according to the following unbalanced equation.

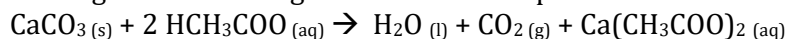


A sample of a mixture of aluminum and aluminum oxide weighing 120.91 grams were analyzed and the total mass of aluminum in the sample was found to be 120.32 grams of aluminum.

- Balance the equation provided.
- What mass of oxygen was in the sample?
- What mass of aluminum oxide was in the mixture?
- What is the mass percent of aluminum oxide in the aluminum and aluminum oxide mixture?

WE DO:

The main component of egg shells is the compound calcium carbonate, CaCO_3 . If you react egg shells with acetic acid, HCH_3COO , from vinegar the following reaction will take place.



If 4.421 grams of carbon dioxide, CO_2 , was produced from 10.57 grams of egg shells, what percentage of the mass of the egg shells was calcium carbonate?

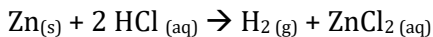
YOU DO:

- A 15.0 gram sample of sodium hydrogen carbonate, NaHCO_3 , was contaminated with an impurity. In order to determine the purity of the sample, it was heated to decompose the material according to the following reaction:

$$2\text{NaHCO}_3 \rightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{O} + \text{CO}_2$$

If 6.35 grams of sodium carbonate, Na_2CO_3 , were recovered, what percentage (by mass) of the sample was sodium hydrogen carbonate, NaHCO_3 ?
- Devise a method to separate a mixture of sand, salt and iron filings.

- 3) 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:



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

- What mass of hydrogen gas was produced?
- What mass of zinc reacted?
- What was the percentage of zinc (by mass) in the alloy?

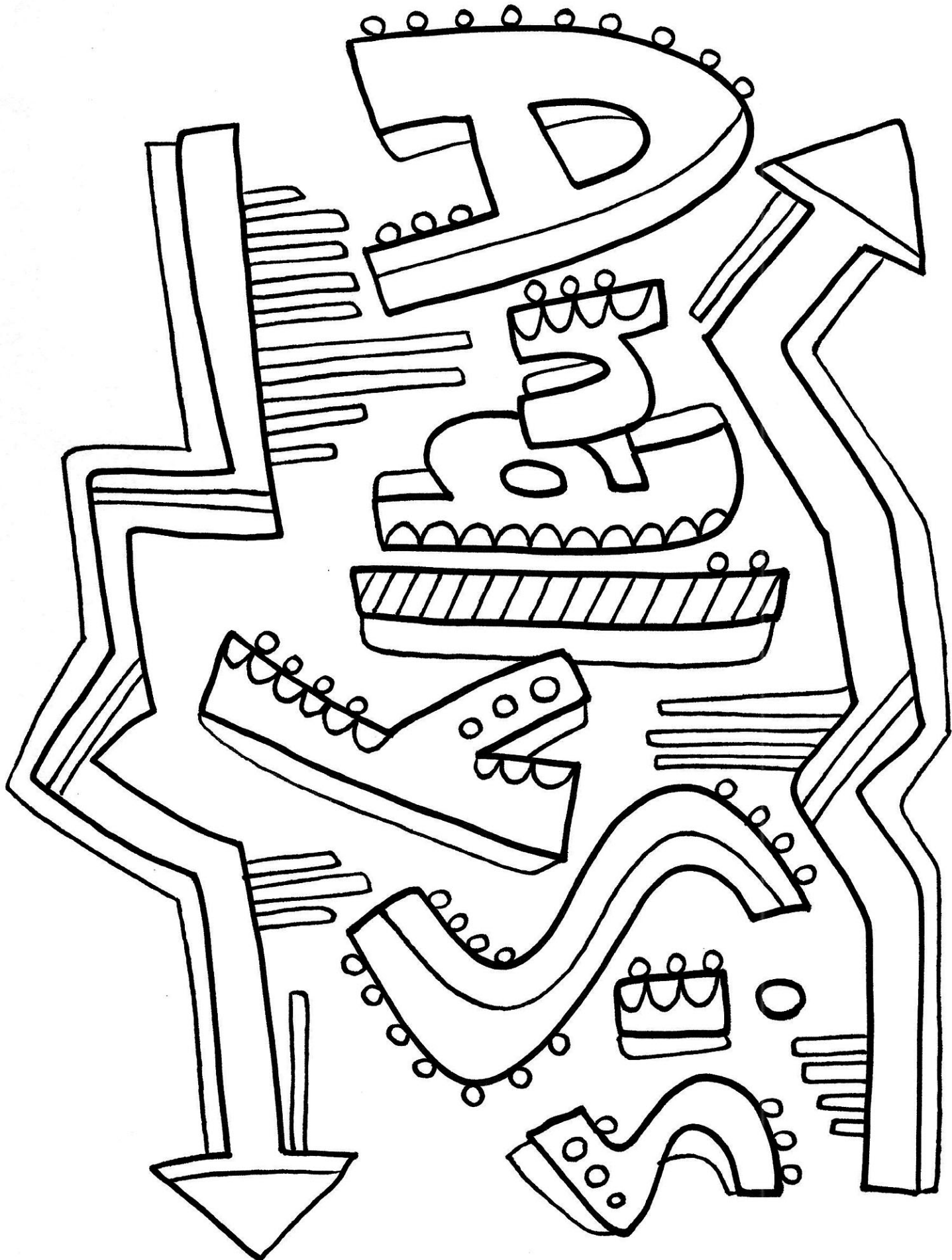
- 4) A sample of sodium bromide, NaBr, has a mass percentage of sodium of 22.34%.
- If the sample of sodium bromide were contaminated with sodium chloride, NaCl, would the mass percentage of Na in the sample be higher or lower than the pure sample? Justify your claim.
 - If the sample of sodium bromide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

- 5) A mixture consisting only of lithium chloride, LiCl, lithium carbonate, Li_2CO_3 , and lithium nitrate, LiNO_3 , was analyzed. The elemental analysis of the mixture revealed the following:

Element	% composition
Li	14.19 %
Cl	10.56 %
C	6.198 %
O	59.06%
N	10.01 %

Calculate the mass percentage of each compound in the mixture.

- 6) 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 78.44 g of carbon dioxide, CO_2 , and 32.12 g of water, H_2O .
- Calculate the empirical formula of the hydrocarbon.
 - The molar mass of the compound was found to be 252.48 g/mol. What is the molecular formula of the hydrocarbon?
 - What percentage (by mass) of the original sample was the hydrocarbon?



TOPIC: 1.5 ATOMIC STRUCTURE AND ELECTRON CONFIGURATION

ENDURING UNDERSTANDING:

SAP-1	Atoms and molecules can be identified by their electron distribution and energy
-------	---

LEARNING OBJECTIVE:

SAP-1.A	Represent the electron configuration of an element or ions of an element using the Aufbau principle.
---------	--

ESSENTIAL KNOWLEDGE:

SAP-1.A.1	The atom is composed of negatively charged electrons and a positively charged nucleus that is made of protons and neutrons.
SAP-1.A.2	Coulomb's law is used to calculate the force between two charged particles.
SAP-1.A.3	In atoms and ions, the electron can be thought of as being in "shells (energy levels)" and "subshells (sublevels)," as described by the electron configuration. Inner electrons are called core electrons, and outer electrons are called valance electrons. The electron configuration is explained by quantum mechanics, as delineated in the Aufbau principle and exemplified in the periodic table of the elements.
SAP-1.A.4	The relative energy required to remove an electron from different subshells of an atom or ion or from the same subshell in different atoms or ions (ionization energy) can be estimated through a qualitative application of Coulomb's law. This energy is related to the distance from the nucleus and the effective (shield) charge of the nucleus.

EQUATION(S):

Force due to Coulomb's law	$F \propto \frac{q_1 q_2}{r^2}$
----------------------------	---------------------------------

NOTES:

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.

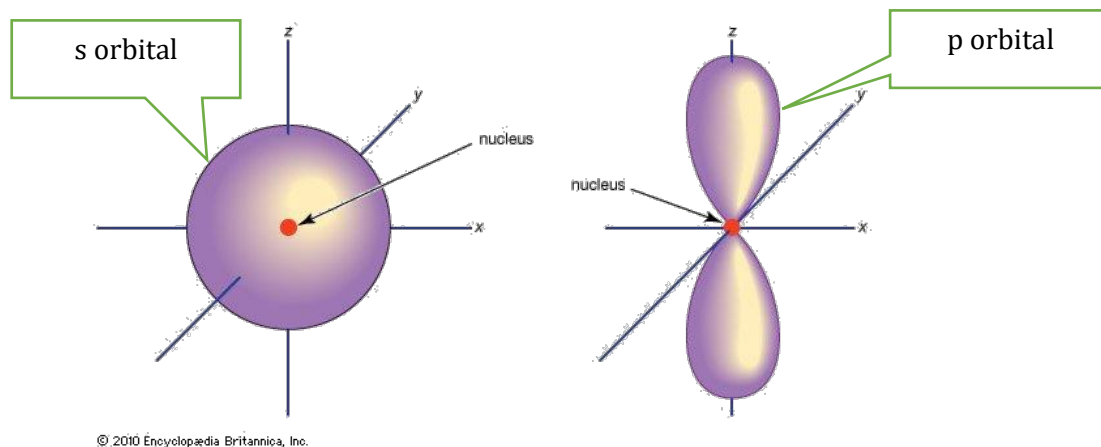
Electron Configurations are a way of describing the arrangement of electrons within an atom and are predicted by the Quantum Mechanical Model of the atom. By solving the **Schrödinger equation** we obtain 4 quantum numbers that (n, l, m_l, m_s) which describe probable location of the electrons around the nucleus of an atom. The inner electrons are called core electrons. The outer electrons are called valence electrons.

	Name	Simple Description	Values	Notes
n	Principle quantum #	Distance from nucleus	1, 2, ... n	Corresponds to the row on the periodic table for s and p. (n-1 for d, n-2 for f etc.)
l	Angular quantum #	Shape of orbital, the most likely place to find the electrons.	0, 1, 2... n-1	0 = s = o shape 1 = p = 8 shape 2 = d 3 = f
m _l	Magnetic quantum #	Orientation of orbital	-l...-1, 0, +1... l	s = 1 orientation p = 3 orientations (x, y, z) d = 5 orientations (1,2,3,4,5) f = 7 orientations (1,2,3,4,5,6,7)
m _s	Spin quantum #	Spin of electron (wave)	+1/2, -1/2	Only two electrons fit into each orbital, often describe as "up" and "down"

THE ASSIGNMENT OF QUANTUM NUMBERS TO ELECTRONS IN SUBSHELLS OF AN ATOM WILL NOT BE ASSESSED ON THE AP EXAM.

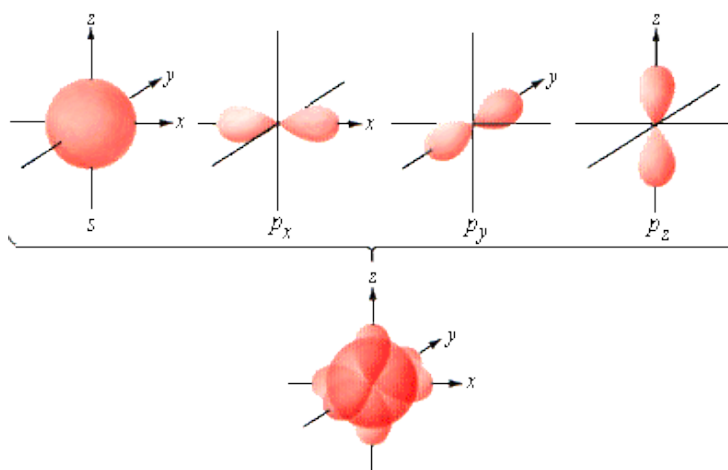
ORBITALS

There are four different cloud-shapes that describe the space that the electrons are most likely to occupy, called orbitals. They are described using 4 letters, s , p , d and f . The s shaped cloud is a sphere around the nucleus. The p shaped cloud looks like two balloons tied together.



<https://socratic.org/chemistry/the-electron-configuration-of-atoms/arrangement-of-electrons-in-orbitals-spd-and-f>

The p orbital can be arranged in three orientations around the nucleus. This picture shows the s orbital and the three different p orbitals apart and together. Since the orbitals are electron clouds, they can overlap.

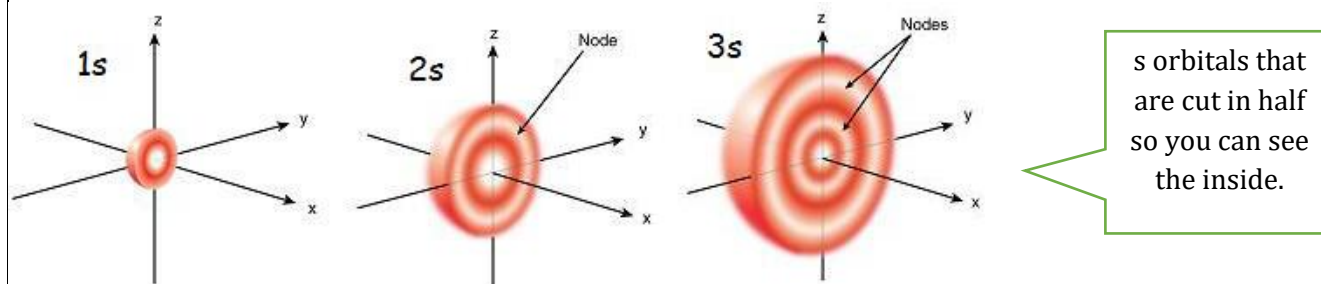


Each orbital can fit 2 electrons, each with a different spin, so the picture shows the potential location for 8 total electrons.

<https://archives.library.illinois.edu/ercc/University%20Archives/1505050/Rogers/Text5/Tx53/tx53.html>

ENERGY LEVELS

Different distances from the nucleus are called **energy levels**.

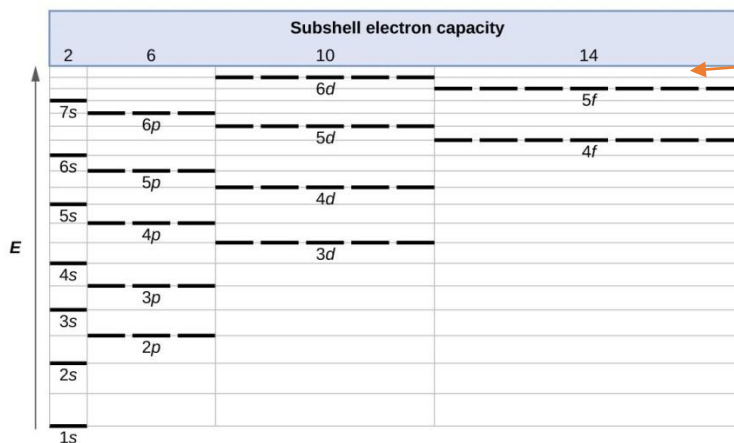


<https://socratic.org/chemistry/the-electron-configuration-of-atoms/arrangement-of-electrons-in-orbitals-spd-and-f>

Each energy level has different shapes possible.

Energy Level (principle quantum number)	Possible Shapes (orbitals)	Number of electrons
1	s (2 electrons)	2
2	s (2 electrons) p (6 electrons)	8
3	s (2 electrons) p (6 electrons) d (10 electrons)	18
4	s (2 electrons) p (6 electrons) d (10 electrons) f (14 electrons)	32

Electron configurations describe the model of the atom by showing shells (energy levels) and subshells (sublevels).



Total number
each subshell
can hold

<https://courses.lumenlearning.com/chemistryformajors/chapter/electronic-structure-of-atoms-electron-configurations/>

Each dark line shows a subshell that can hold up to 2 electrons. Electrons occupy the subshells starting with the lowest energy levels first. The “lowest” energy orbitals are the closest to the nucleus. They would require the greatest energy to remove them. Remember atoms have negatively charged electrons and a positively charged nucleus.

COULOMB’S LAW:

$$F \propto \frac{q_1 q_2}{r^2}$$

This tells us that 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 why it takes more energy to remove electrons that are closest to the nucleus.

In addition to the distance, the electrons that are on the valence shell, the outermost electrons, experience less of the nuclear pull because the electrons that are in the core of the atom block, or **shield**, the attraction of the nucleus from the valence electrons.

RULES FOR ELECTRON CONFIGURATIONS:

1. Aufbau principle which means "to build up," in other words 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.

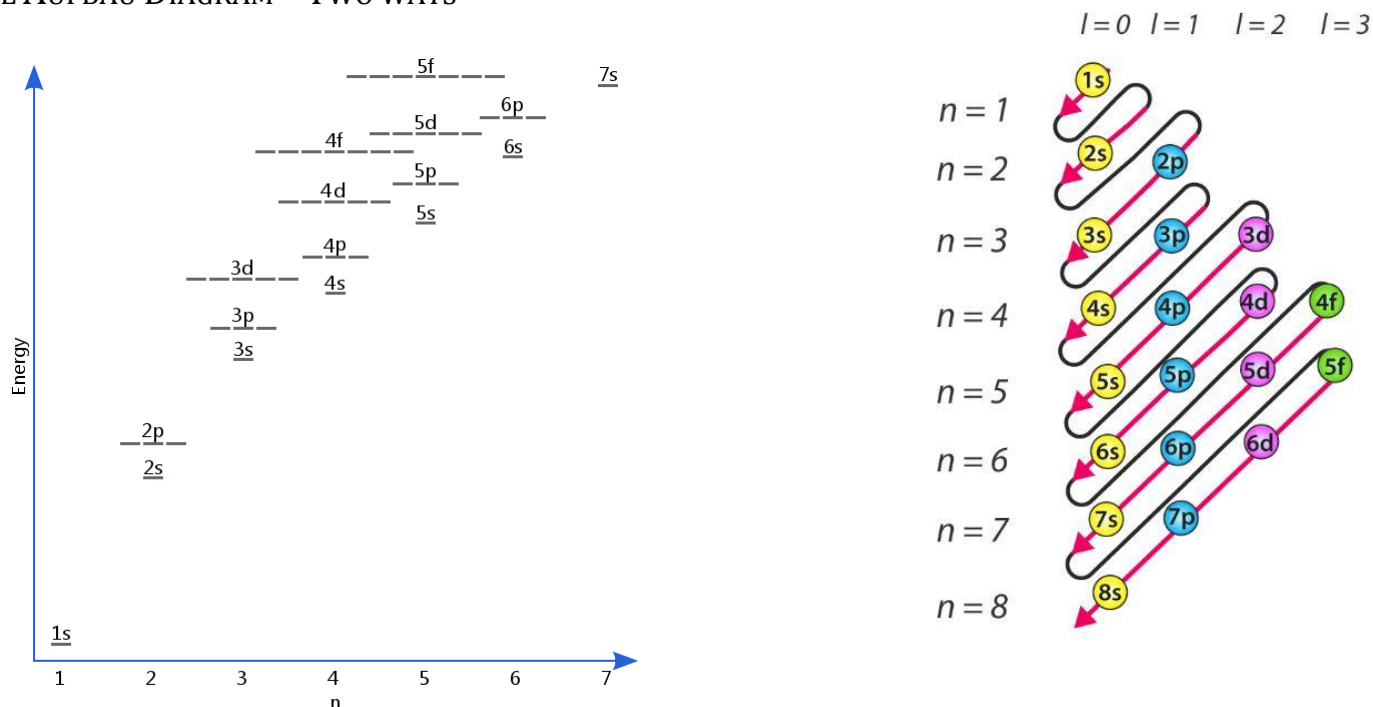
You can use the periodic table to help you with the electron configuration.

Electron Configurations in the Periodic Table

by: Sarah Faizi

<https://dashboard.dublinschools.net/lessons/?id=aaa4c826cb729596b7ca88766a73f063&v=1>

THE AUFBAU DIAGRAM – TWO WAYS

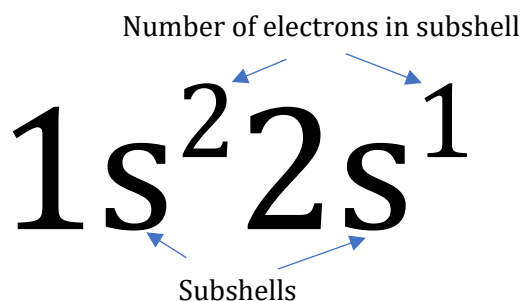


<https://www.chemicool.com/definition/aufbau-principle.html>

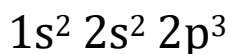
<https://byjus.com/chemistry/aufbau-principle/>

HOW TO WRITE THE ELECTRON CONFIGURATION

Key Idea: Electrons occupy the lowest energy orbitals (closest to the nucleus) first.



The electron configuration for nitrogen would be as follows:



- The numbers in front (1 or 2) means the energy level or the row.
- The letters (*s* or *p*) is talking about the shape of the orbitals. (This is the shape of the electron cloud- either a sphere for *s* or the 8-shape for *p*)
- The smaller numbers at the top (the superscripts ^{2 2 3}) tell you about the number of electrons in that type of orbital.

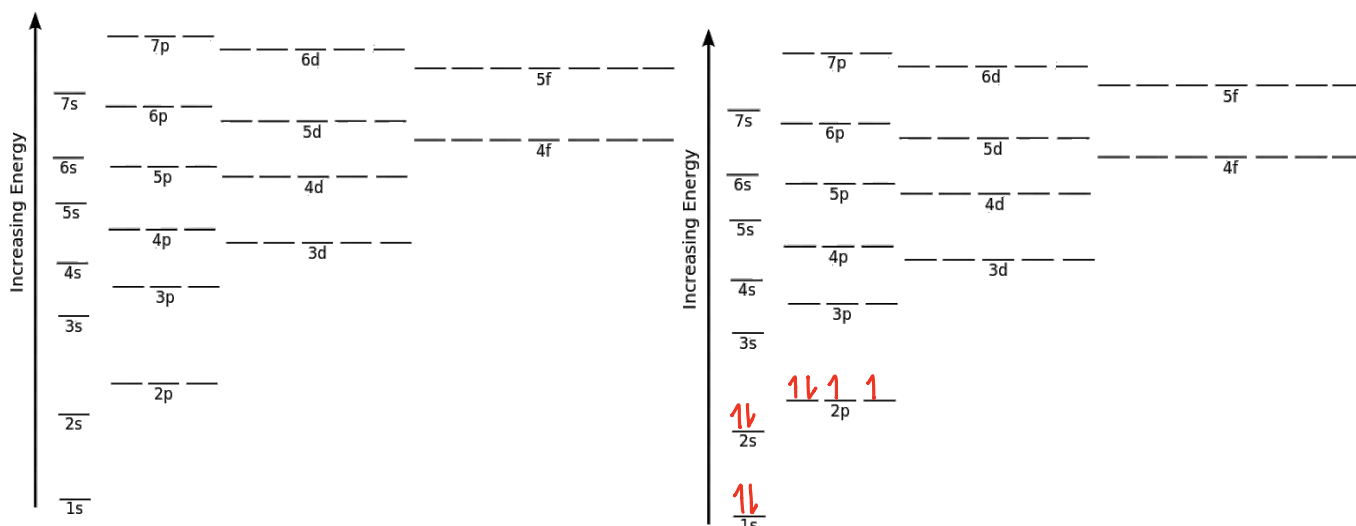
HOW TO COMPLETE AN ORBITAL DIAGRAM

Orbital diagrams are very similar to electron configurations. However, they show the electrons as arrows and provide additional insight into the interactions between the electrons in shared orbitals.

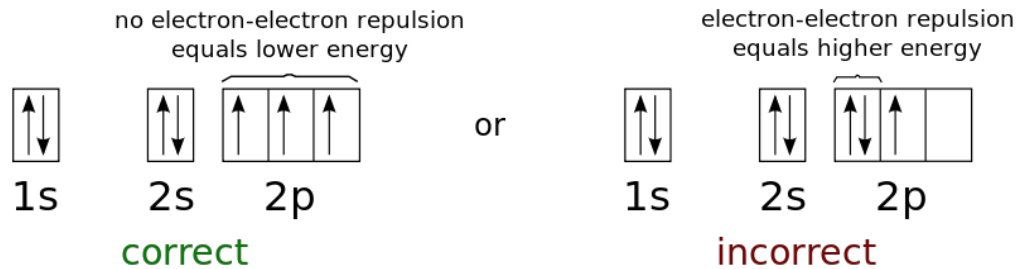
We will start by filling in a vertical orbital diagram, but they are often simply horizontal.

- 1) Electrons are shown as arrows. ($\uparrow\downarrow$)
- 2) Always start with an UP ($\uparrow$) arrow.
- 3) Always start by filling the lowest energy level lines first. (Pay close attention to this!)
- 4) Only put one or two arrows in each box, never more.
- 5) If you have to put two arrows in a box they have to face opposite directions, this shows they have different spins. (This is the Pauli Exclusion Principle)
- 6) When you have three (or more) lines in the same subshell, you put one arrow in each box before you make them share a line. (This is Hund's Rule)

Example: Oxygen = $8e^-$



You can see the linear form of an orbital diagram below. There are two ways to arrange the electrons for nitrogen, but only one follows Hund's Rule and minimizes the electron-electron repulsions.



https://en.m.wikibooks.org/wiki/File:Orbital_diagram_nitrogen_-_Hund%27s_Rule.svg

NOBLE GAS/SHORT-CUT ELECTRON CONFIGURATIONS

As you can imagine, electron configurations can become very long and tedious to write. There is a shorter way to show an electron configuration, however, you must be able to write both electron configurations the long way and the short-cut way.

To write an electron configuration using the short-cut method you start by locating the noble gas preceding your element. The noble gases are the elements in group 8A on the periodic table. They are known for being unreactive. They are unreactive because they have filled valence shells. The fact that the noble gases are unreactive is why they are chosen for the noble gas short-hand electron configurations.

1	2											3	4	5	6	7	0
		H										He					
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac															

Noble gases

<https://www.onlinemathlearning.com/noble-gases.html>

The noble gas short-hand takes the noble gas before the element and then continues on from there.

The complete electron configuration for Calcium is: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$.

The short-hand noble gas configuration for Calcium would be: $[\text{Ar}]^{18} 4s^2$

Writing $[\text{Ar}]^{18}$ is the same as writing $1s^2 2s^2 2p^6 3s^2 3p^6$.

I DO:

Write the ground state electron configuration for Arsenic.

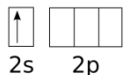
WE DO:

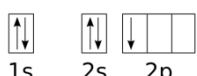
Write the electron configuration for Calcium ion, Ca^{2+} .

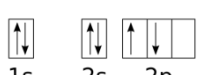
YOU DO:

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 scandium, Sc.
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.

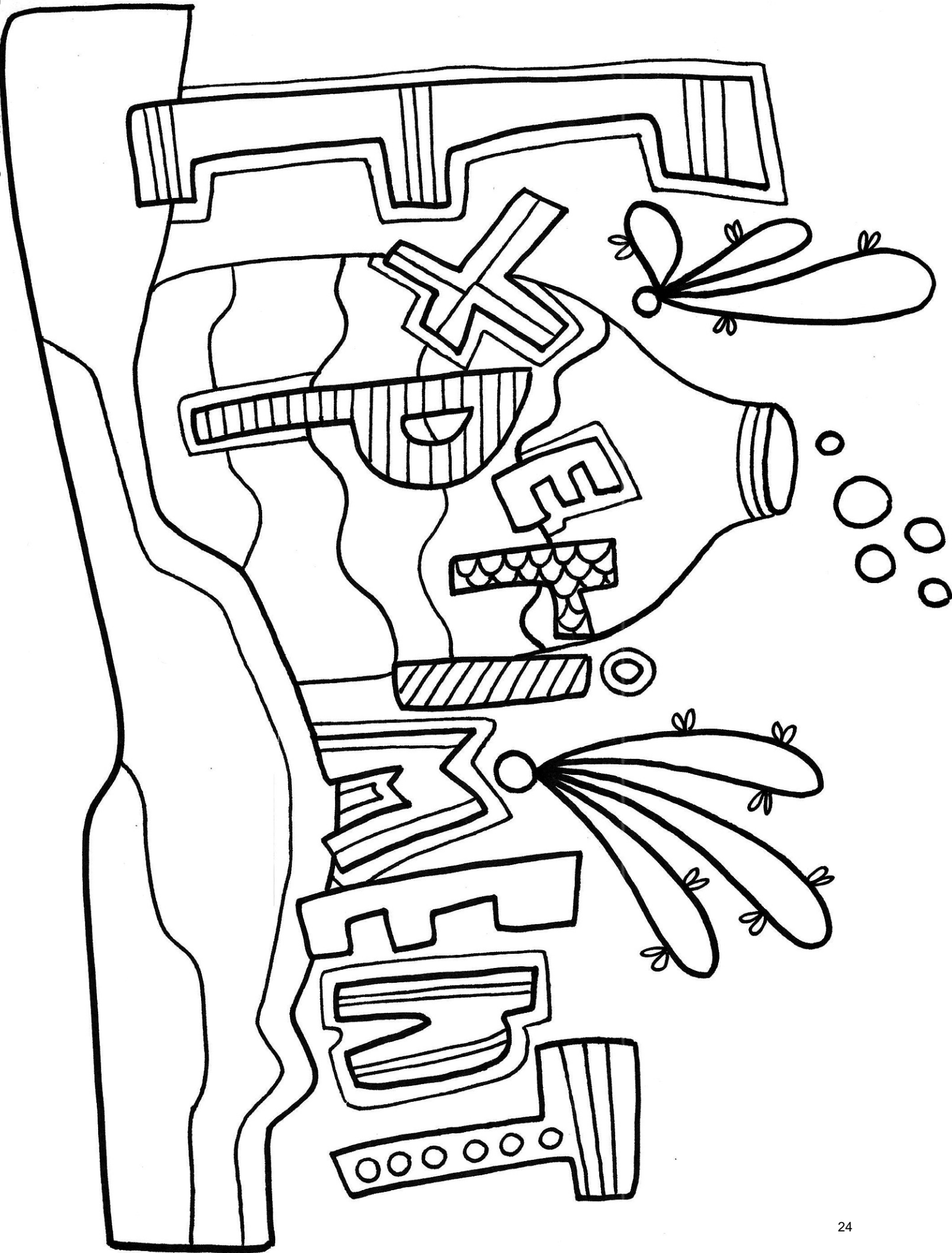
a. 
1s 2s

b. 
1s 2s 2p

c. 
1s 2s 2p

d. 
1s 2s 2p
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. Write an electron configuration for an excited state of sodium in which one of the 2p electrons jumps up to the 3p orbital.

<https://commons.wikimedia.org/w/index.php?curid=16713146>



TOPIC: 1.6 PHOTOELECTRON SPECTROSCOPY

ENDURING UNDERSTANDING:

SAP-1 Atoms and molecules can be identified by their electron distribution and energy.

LEARNING OBJECTIVE:

SAP-1.B Explain the relationship between the photoelectron spectrum of an atom or ion and:
 a. The electron configuration of the species
 b. The interactions between the electrons and the nucleus.

ESSENTIAL KNOWLEDGE:

SAP-1.B.1 The energies of the electrons in a given shell can be measured experimentally with photoelectron spectroscopy (PES). The position of each peak in the PES spectrum is related to the energy required to remove an electron from the corresponding subshell, and the height of each peak is (ideally) proportional to the number of electrons in that subshell.

EQUATION(S):

N/A

NOTES:

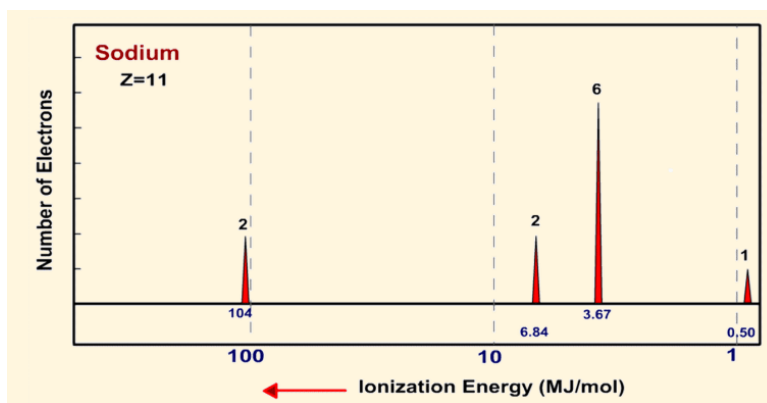
Photoelectron spectroscopy (PES) is an experimental technique that measures the relative energies of electrons in atoms or molecules. It works by ejecting electrons from the materials using high energy electromagnetic radiation (like UV or x-rays) and then measuring the kinetic energy of those electrons. This process can be described as photoionization.

PES graphs show the relative number of electrons and their corresponding binding energy. 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.

The PES graphs directly correspond to the electron configuration.

The PES for sodium is below. The graphs are often set up so that the x axis gives the largest values first. The graphs are scaled so that they can show many orders of magnitude. ALWAYS read the axis! The highest value for the ionization energy (binding energy) will be the innermost electrons. On this graph they are the peak on the left. We know that there are 2 electrons in the 1s orbital so we can use the height of that peak to estimate the others. Often the graph is not labeled with the number of electrons in each peak.

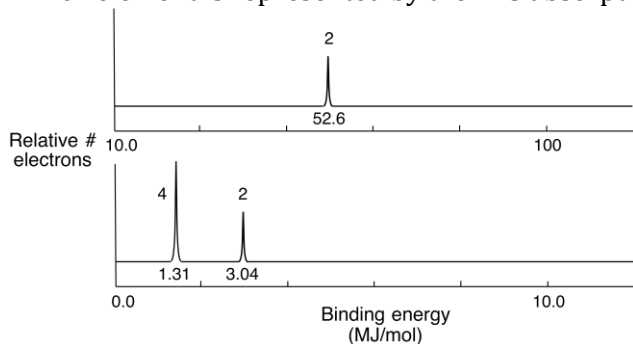
The electron configuration for sodium is $1s^2 2s^2 2p^6 3s^1$, notice that this corresponds to the peaks given. This provides additional evidence for the quantum mechanical model of the atom as the $2s^2 2p^6$ peaks have different energy values.



<https://chemicalthinking.xyz/pem/pem.html>

I DO:

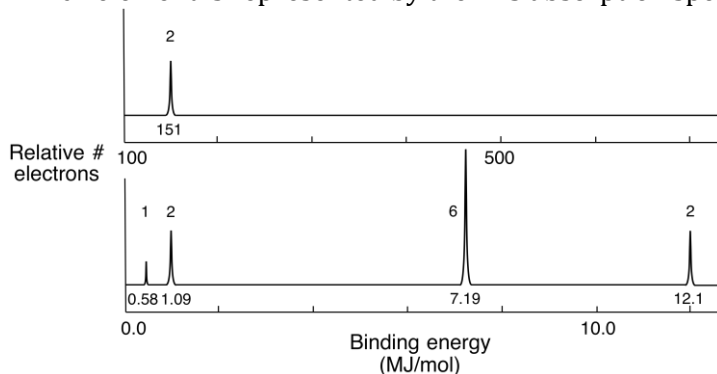
Which element is represented by the PES absorption spectra shown?



<https://khanacademy.org/science/chemistry/electronic-structure-of-atoms/electron-configurations-jay-sal/a/photoelectron-spectroscopy>

WE DO:

Which element is represented by the PES absorption spectra shown?

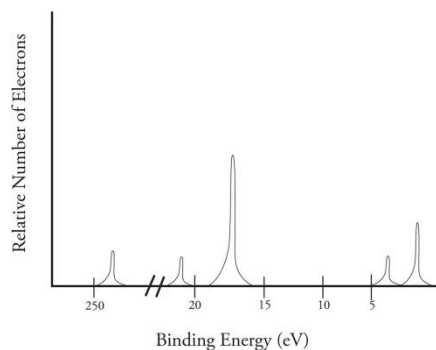


<https://khanacademy.org/science/chemistry/electronic-structure-of-atoms/electron-configurations-jay-sal/a/photoelectron-spectroscopy>

YOU DO:

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

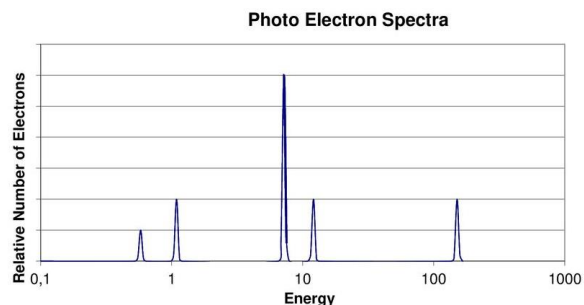
https://schoolbag.info/chemistry/ap_chemistry/8.html



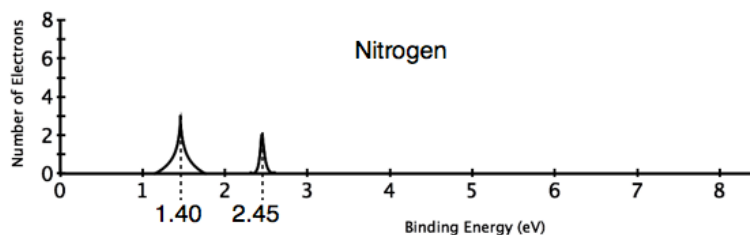
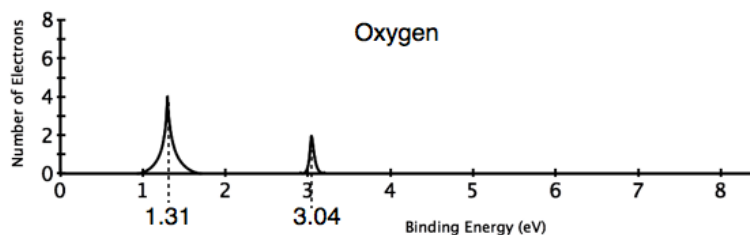
- 2) Inspect the PES spectra provided.

<https://slideplayer.com/slide/15177715/>

- Identify the element shown
- Write the electron configuration
- Predict the charge this element will form as an ion



3) Below are the PES spectra for the valence electrons for oxygen and nitrogen.

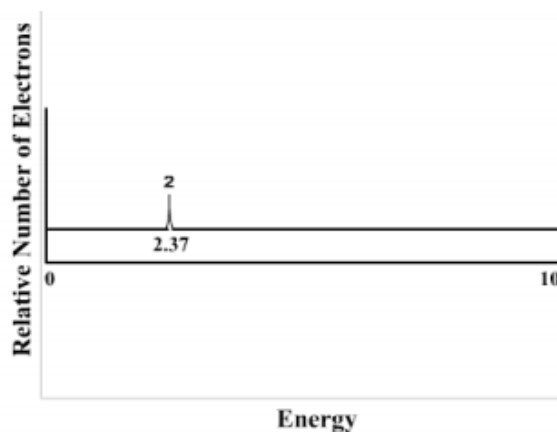
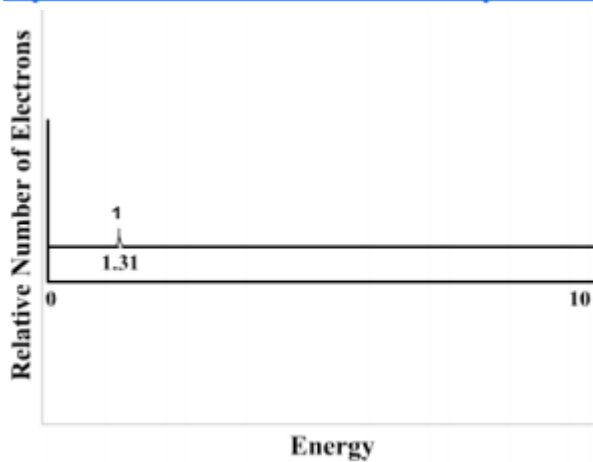


<http://www.learnapchemistry.com/potd/problem.php?pc=5881a1ba31d56308ba187d6c6496a8af>

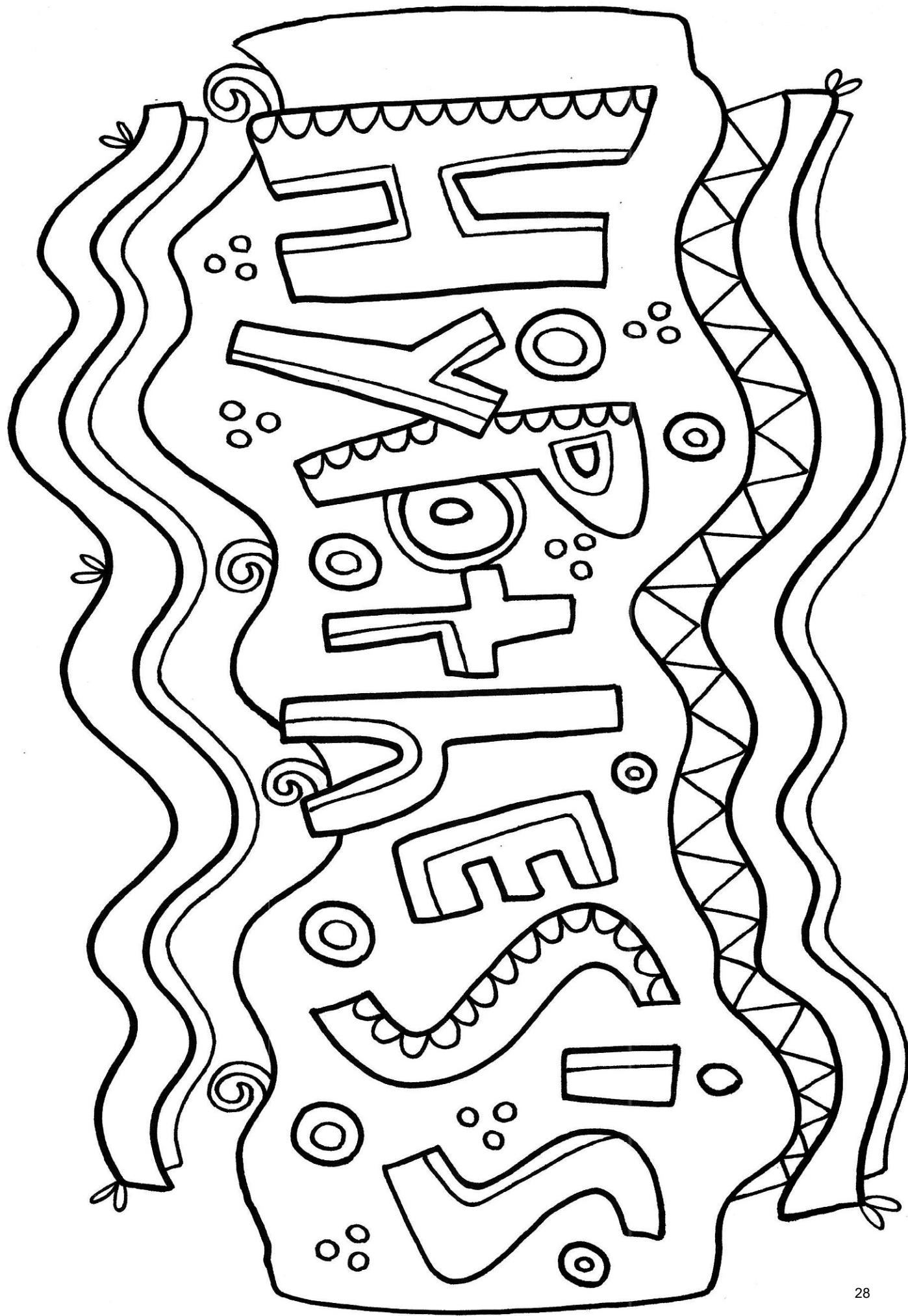
- Write a complete electron configuration for both elements.
- Identify and label the 2s peak on each spectra.
- Explain the difference in energy for the 2s peaks.
- Write/Draw a valence electron orbital diagram for each element.
- Based on the orbital diagram, propose an explanation for the difference in energy for the 2p peaks.

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

<http://www.chem.arizona.edu/chemt/Flash/photoelectron.html>



- Label each graph as Hydrogen or Helium
- Explain the difference in the intensity (height) of the peaks.
- Explain the difference in the energy of the peaks.



TOPIC: 1.7 PERIODIC TRENDS

ENDURING UNDERSTANDING:

SAP-2 The periodic table shows patterns in electronic structure and trends in atomic properties.

LEARNING OBJECTIVE:

SAP-2.A Explain the relationship between trends in atomic properties of elements and electronic structure and periodicity.

ESSENTIAL KNOWLEDGE:

SAP-2.A.1 The organization of the periodic table is based on the recurring properties of the elements and explained by the pattern of electron configurations and the presence of completely or partially filled shells (and subshells) of electrons in atoms.

WRITING THE ELECTRON CONFIGURATION OF ELEMENTS THAT ARE EXCEPTIONS TO THE AUFBAU PRINCIPLE WILL NOT BE ASSESSED ON THE AP EXAM.

Rationale: The mere rote recall of the exceptions does not match the goals of the curriculum revision.

SAP-2.A.2 Trends in atomic properties within the periodic table (periodicity) can be qualitatively understood through the position of the element in the periodic table, Coulomb's law, the shell model, and the concept of shielding/effective nuclear charge. These properties include: a. Ionization energy b. Atomic and ionic radii c. Electron affinity d. Electronegativity.

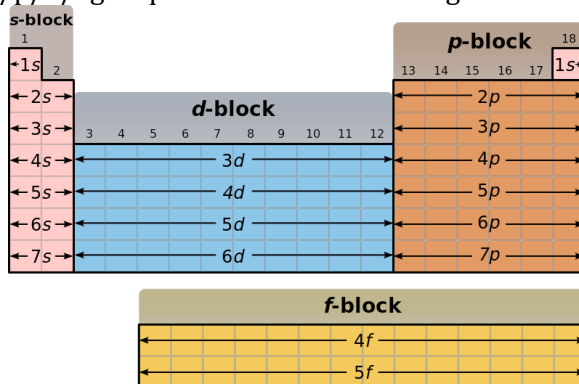
SAP-2.A.3 The periodicity (in SAP-2.A.2) is useful to predict /estimate values of properties in the absence of data.

EQUATION(S):

N/A

NOTES:

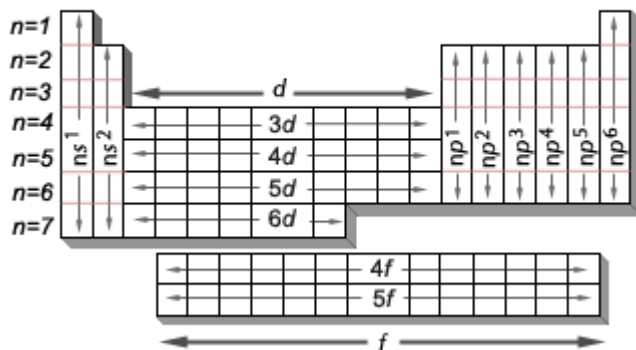
The periodic table is arranged in order from lowest atomic number (# of protons) to highest. The blocks of the periodic table correspond to the s/p/d/f groups for the electron configuration.



<https://socratic.org/questions/what-is-the-electron-configuration-for-francium>

Elements that have the same valence electron configuration tend to have similar chemical properties.

Periodic Table of the Elements



http://nobel.scas.bcit.ca/wiki/index.php/File:Ptable_econfig.gif#filelinks

Most, if not all, periodic trends can be explained by the arrangement of the electrons and the number of protons in the atoms.

1 H 1s ↑									2 He 1s ↑↓
3 Li 2s ↑ 1s ↑↓	4 Be 2s ↑↓ 1s ↑↓	5 B 2p ↑ — — 2s ↑↓ 1s ↑↓	6 C 2p ↑ ↑ — 2s ↑↓ 1s ↑↓	7 N 2p ↑ ↑ ↑ 2s ↑↓ 1s ↑↓	8 O 2p ↑↓ ↑ ↑ 2s ↑↓ 1s ↑↓	9 F 2p ↑↓ ↑↓ ↑ 2s ↑↓ 1s ↑↓	10 Ne 2p ↑↓ ↑↓ ↑↓ 2s ↑↓ 1s ↑↓		
11 Na 3s ↑ 2p ↑↓ ↑↓ ↑↓ 2s ↑↓ 1s ↑↓	12 Mg 3s ↑↓ 2p ↑↓ ↑↓ ↑↓ 2s ↑↓ 1s ↑↓	13 Al 3p ↑ — — 3s ↑↓ 2p ↑↓ ↑↓ ↑↓ 2s ↑↓ 1s ↑↓	14 Si 3p ↑ ↑ — 3s ↑↓ 2p ↑↓ ↑↓ ↑↓ 2s ↑↓ 1s ↑↓	15 P 3p ↑ ↑ ↑ 3s ↑↓ 2p ↑↓ ↑↓ ↑↓ 2s ↑↓ 1s ↑↓	16 S 3p ↑↓ ↑ ↑ 3s ↑↓ 2p ↑↓ ↑↓ ↑↓ 2s ↑↓ 1s ↑↓	17 Cl 3p ↑↓ ↑↓ ↑ 3s ↑↓ 2p ↑↓ ↑↓ ↑↓ 2s ↑↓ 1s ↑↓	18 Ar 3p ↑↓ ↑↓ ↑↓ 3s ↑↓ 2p ↑↓ ↑↓ ↑↓ 2s ↑↓ 1s ↑↓		

[https://chem.libretexts.org/Under_Construction/Purgatory/Essential_Chemistry_\(Curriki\)/Unit_1%3A_Atomic_and_Molecular_Structure/1.4%3A_Electron_Configuration_and_Orbital_Diagrams](https://chem.libretexts.org/Under_Construction/Purgatory/Essential_Chemistry_(Curriki)/Unit_1%3A_Atomic_and_Molecular_Structure/1.4%3A_Electron_Configuration_and_Orbital_Diagrams)

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

Coulombic Attraction is the electrostatic attraction between two charged particles. Often when discussing periodic trends the charged particles are the nucleus (specifically the total number of protons) and the electrons. Often we are referring to the outermost electrons, the valence electrons.

Coulomb's law states that the attraction between two charged particles is proportional to the magnitude of the charge and inversely proportional to the distance between them. To make this simpler, the larger the charge, the more attractive forces between the particles. The further away the particles are from each other, the weaker the attraction.

PERIODIC TRENDS

Key Terms:

COULOMBIC ATTRACTION/ ELECTROSTATIC INTERACTIONS

The positive-negative attraction which takes place when you have two charged particles in close proximity.

- Increases with increase in charge
- Increases with decrease in distance between particles

EFFECTIVE NUCLEAR CHARGE AND ELECTRON SHIELDING

The **effective nuclear charge** is the net positive **charge** experienced by valence electrons. It can be approximated by the equation: $Z_{\text{eff}} = Z - S$, where Z is the atomic number and S is the number of electrons in orbitals that are closer to the nucleus.

A) FIRST IONIZATION ENERGY

The energy required to remove the outermost (highest energy) electron from the gas from of a neutral atom in its ground state.

First Ionization energy **decreases** as you move down a group. Electrons are further from the nucleus and therefore have a lower Coulombic attraction. Additionally, the inner shells of electrons **shield** or block the protons force of attraction, so that outermost electrons do not feel as much of the nuclear force. This results in the outer electrons being even easier to remove.

First Ionization energy **increases** as you move across a period on the periodic table, from left to right. As you move across the period the atomic radius is smaller and there is an increase in protons in the nucleus. Both factors result in greater Coulombic attraction, which in turn means that it will require more energy to remove the first electron.

<https://wps.pearsoned.com.au/ibcsl/89/22896/5861561.cw/content/index.html>

There are a few places where the ionization doesn't appear to follow a trend. You can see this on the graph between Be and B or between N and O. These are actually for two slightly different reasons.

https://useruploads.socratic.org/N5qKJ5fTLiJK3MXQAifQ_Ionization_Energy_Trend_IK.png

Be and B exception (s^2 to s^2p^1)

Be = $1s^2 2s^2$

B = $1s^2 2s^2 2p^1$

When the first electron is removed from the boron, B, atom, the electron is being removed from the 2p orbital. Since the 2p orbital is further away from the nucleus it takes less energy to remove it even though there are more protons in the atom.

N and O exception (s^2p^3 to s^2p^4)

N = $1s^2 2s^2 2p^3$

O = $1s^2 2s^2 2p^4$

When the first electron is removed from oxygen it takes less energy (despite the increase in protons) than from nitrogen because the electrons in oxygen are sharing the $2p_x$ orbital and therefore have greater electron-electron repulsions making it easier to remove one electron.

The second ionization energy is the energy to remove a second electron from the atom and so on for each successive electron.

By examining the successive ionization energies for an element we can determine how many valence electrons there are in that element. When all of the valence electrons have been removed, you will see a large "jump" in the ionization energy values. This "jump" is due to the fact that the core electrons are closer to and less shielded from the nucleus and therefore it requires more energy to remove them.

For example:

Consider magnesium, Mg, the electron configuration is $1s^2 2s^2 2p^6 3s^2$ and we can see that it has 2 valence electrons.

<https://www.webelements.com/magnesium/atoms.html>

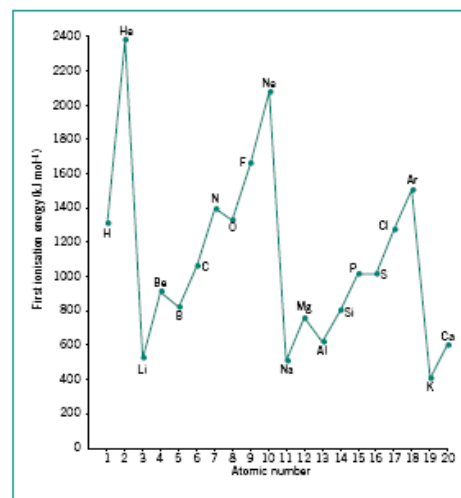
You can see that there is a big jump between the 2nd and 3rd ionization energies and again between the 10th and 11th ionization energies. This shows when electrons are being removed from a shell that is closer to the nucleus.

INCREASING IONIZATION ENERGY

1	H	1.00794
3	Li	6.941
4	Be	9.012182
11	Na	22.98976928
12	Mg	24.304
13	Al	26.9815386
14	Si	28.08558
15	P	30.973762
16	S	32.06
17	Cl	35.453
18	Ar	39.948
19	K	39.0983
20	Ca	40.078
21	Sc	44.955912
22	Ti	47.88
23	V	50.9415
24	Cr	51.9961
25	Mn	54.938045
26	Fe	55.845
27	Co	58.933200
28	Ni	58.6934
29	Cu	63.546
30	Zn	65.38
31	Ga	69.723
32	Ge	72.64
33	As	74.92160
34	Se	78.96
35	Br	79.904
36	Kr	83.80
37	Rb	85.4678
38	Sr	87.62
39	Y	88.90584
40	Zr	91.224
41	Nb	92.90638
42	Mo	95.94
43	Tc	98
44	Ru	101.07
45	Rh	102.90550
46	Pd	106.9076
47	Ag	107.8682
48	Cd	112.411
49	In	114.818
50	Sn	118.710
51	Sb	121.757
52	Te	127.60
53	I	126.90547
54	Xe	131.29
55	Cs	132.90545196
56	Ba	137.327
57	La	138.9048
58	Ce	140.12
59	Pr	140.90765
60	Nd	144.242
61	Pm	144.9126
62	Sm	150.36
63	Eu	151.964
64	Gd	157.25
65	Tb	158.92534
66	Dy	162.50014
67	Ho	164.93032
68	Er	167.259
69	Tm	168.93032
70	Yb	173.05468
71	Lu	174.967
72	Hf	178.49
73	Ta	180.94788
74	W	183.84
75	Re	186.207
76	Os	190.23
77	Ir	192.222
78	Pt	195.083
79	Au	196.966569
80	Hg	200.59
81	Tl	204.3833
82	Pb	207.2
83	Bi	208.980398
84	Po	209
85	At	210
86	Rn	222
87	Fr	223
88	Ra	226
89	Ac	227
90	Th	232.0377
91	Pa	231.036889
92	U	238.02891
93	Np	237.048173
94	Pu	244.06422
95	Am	243.061361
96	Cm	247.070353
97	Bk	247.070353
98	Cf	251.083288
99	Es	252.083288
100	Fm	257.10351
101	Md	258.10351
102	No	259.10351
103	Lr	262.10351

INCREASING IONIZATION ENERGY

5	B	10.811
6	C	12.011
7	N	14.00643
8	O	15.9994
9	F	18.9984032
10	Ne	20.1797
13	Al	26.9815386
14	Si	28.08558
15	P	30.973762
16	S	32.06
17	Cl	35.453
18	Ar	39.948
19	K	39.0983
20	Ca	40.078
21	Sc	44.955912
22	Ti	47.88
23	V	50.9415
24	Cr	51.9961
25	Mn	54.938045
26	Fe	55.845
27	Co	58.933200
28	Ni	58.6934
29	Cu	63.546
30	Zn	65.38
31	Ga	69.723
32	Ge	72.64
33	As	74.92160
34	Se	78.96
35	Br	79.904
36	Kr	83.80
37	Rb	85.4678
38	Sr	87.62
39	Y	88.90584
40	Zr	91.224
41	Nb	92.90638
42	Mo	95.94
43	Tc	98
44	Ru	101.07
45	Rh	102.90550
46	Pd	106.9076
47	Ag	107.8682
48	Cd	112.411
49	In	114.818
50	Sn	118.710
51	Sb	121.757
52	Te	127.60
53	I	126.90547
54	Xe	131.29
55	Cs	132.90545196
56	Ba	137.327
57	La	138.9048
58	Ce	140.12
59	Pr	140.90765
60	Nd	144.242
61	Pm	144.9126
62	Sm	150.36
63	Eu	151.964
64	Gd	157.25
65	Tb	158.92534
66	Dy	162.50014
67	Ho	164.93032
68	Er	167.259
69	Tm	168.93032
70	Yb	173.05468
71	Lu	174.967
72	Hf	178.49
73	Ta	180.94788
74	W	183.84
75	Re	186.207
76	Os	190.23
77	Ir	192.222
78	Pt	195.083
79	Au	196.966569
80	Hg	200.59
81	Tl	204.3833
82	Pb	207.2
83	Bi	208.980398
84	Po	209
85	At	210
86	Rn	222
87	Fr	223
88	Ra	226
89	Ac	227
90	Th	232.0377
91	Pa	231.036889
92	U	238.02891
93	Np	237.048173
94	Pu	244.06422
95	Am	243.061361
96	Cm	247.070353
97	Bk	247.070353
98	Cf	251.083288
99	Es	252.083288
100	Fm	257.10351
101	Md	258.10351
102	No	259.10351
103	Lr	262.10351



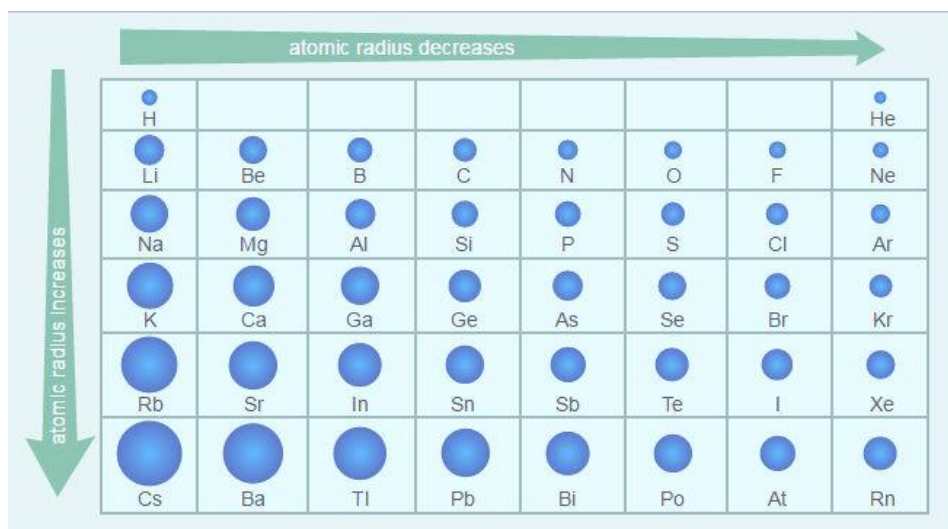
Ionization Energy Number	Enthalpy (kJ/mole)
1 st	738
2 nd	1451
3 rd	7733
4 th	10543
5 th	13636
6 th	18020
7 th	21711
8 th	25658
9 th	31646
10 th	35457
11 th	169988

B) ATOMIC RADIUS

The **atomic radius** of a chemical element is a measure of the size of its **atoms**, usually the mean or typical distance from the center of the nucleus to the boundary of the surrounding cloud of electrons.

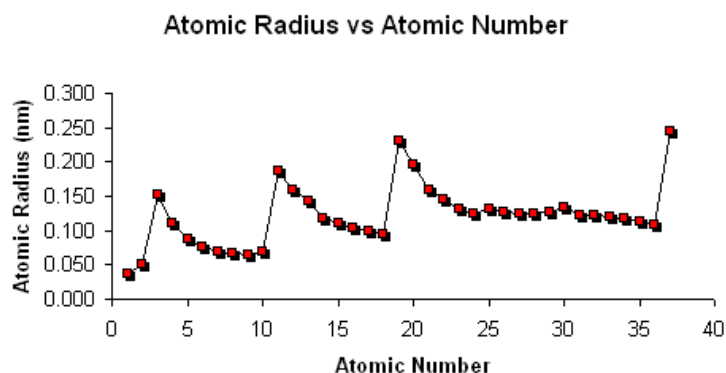
Atomic Radii **increases** as you move down a column as there are more electron shells.

<https://byjus.com/chemistry/atomic-radius-in-periodic-table-in-basic-chemistry/>



Atomic Radii **decreases** as you move across a period on the periodic table, from left to right. Electrons are being added to the same energy level. At the same time, protons are being added to the nucleus. Increasing the number of protons gives a **higher effective nuclear charge**. In other words, there is a stronger force of attraction pulling the electrons closer to the nucleus. This results in a smaller atomic radius, as with greater numbers of protons there is more pull on the electrons.

https://www.geocities.ws/junebug_sophia/atmRad.gif

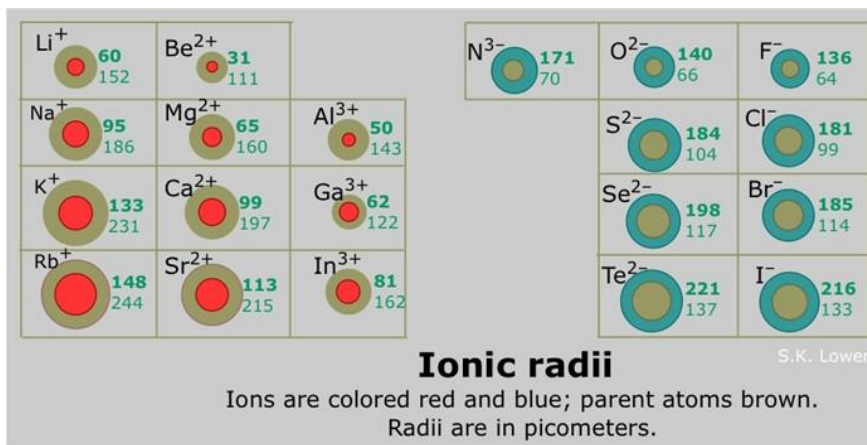


IONIC RADIUS

The trends for ionic radii are similar to those of atomic radii, except that cations and anions are different from each other.

Cations are always smaller than the parent atoms, because they have lost their valence shell. This causes them to be smaller. They also decrease in size because the nuclear attraction is now acting on fewer electrons so they are drawn in toward the nucleus due to the greater attraction. Additionally there are fewer electron-electron repulsions.

Anions, on the other hand, are always larger than the parent atom. Electrons are added to the same valence shell; however, there are greater electron-electron repulsions so the ion increases in size.



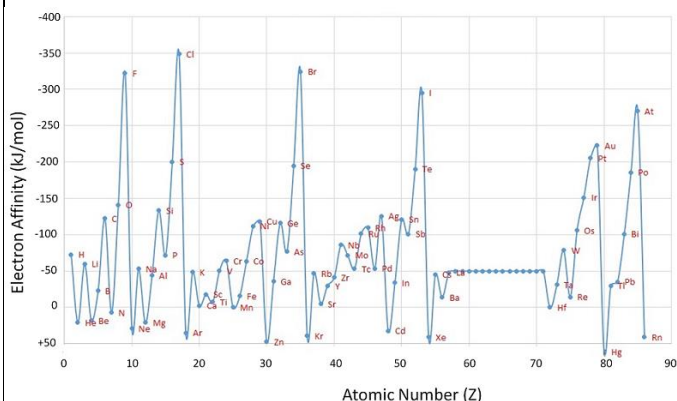
<https://slideplayer.com/slide/8861824/>

C) ELECTRON AFFINITY

Electron affinity is the amount of energy involved when an electron is accepted by a gaseous atom to form a negative ion. In other words, the neutral atom's likelihood of gaining an electron. The values tend to be negative to show the energy is released as electrons are added to the atoms.

In general, the electron affinity increases from left to right on the periodic table. This is caused by the filling of the valence shell of the atom; a Group 17 atom releases more energy than a Group 1 atom when it gains an electron, this indicates that it is more stable.

[https://chem.libretexts.org/Bookshelves/Physical_and_Theoretical_Chemistry_Textbook_Maps/Supplemental_Modules_\(Physical_and_Theoretical_Chemistry\)/Physical Properties of Matter/Atomic and Molecular Properties/Electron Affinity](https://chem.libretexts.org/Bookshelves/Physical_and_Theoretical_Chemistry_Textbook_Maps/Supplemental_Modules_(Physical_and_Theoretical_Chemistry)/Physical_Properties_of_Matter/Atomic_and_Molecular_Properties/Electron_Affinity)



D) ELECTRONEGATIVITY

Electronegativity is a measure of the ability of an atom (or group of atoms) to attract shared electrons.

Electronegativity **decreases** as you move down a column as there is a greater distance from the nucleus and because there is also more electron shielding.

Electronegativity **increases** as you move across a period on the periodic table, from left to right. This is because the atomic radius is decreasing while the number of protons (and effective nuclear charge) is increasing.

Fluorine is the most electronegative element.

INCREASING ELECTRON AFFINITY

1 H (1.51361) 1.00794																							2 He (0.4801) 4.003								
3 Li (0.6035) 6.941	4 Be (0.9005) 9.012																					10 Ne (1.6818) 20.183									
5 Na (0.5781) 22.990	6 Mg (0.7377) 24.305																					18 Ar (0.9808) 39.948									
7 K (0.8219) 39.098	8 Ca (0.9314) 40.078	9 Sc (1.0000) 44.956	10 Ti (1.0500) 47.88	11 V (1.1395) 50.942	12 Cr (1.1995) 51.996	13 Mn (1.2938) 54.938	14 Fe (1.4016) 55.845	15 Co (1.4553) 58.933	16 Ni (1.4912) 58.693	17 Cu (1.551) 63.546	18 Zn (1.551) 65.38	19 Ga (1.623) 69.723	20 Ge (1.623) 72.61	21 As (1.712) 74.922	22 Se (1.712) 78.96	23 Br (1.712) 79.904	24 Kr (1.712) 83.80	25 Rb (1.712) 85.468	26 Sr (1.712) 87.62	27 Y (1.712) 88.906	28 Zr (1.712) 91.224	29 Nb (1.712) 92.906	30 Mo (1.712) 95.94								
31 Ga (0.8219) 69.723	32 Ge (0.9314) 72.61	33 As (1.0000) 74.922	34 Se (1.0500) 78.96	35 Br (1.1395) 79.904	36 Kr (1.1995) 83.80	37 Rb (1.2938) 85.468	38 Sr (1.4016) 87.62	39 Y (1.4553) 88.906	40 Zr (1.4912) 91.224	41 Nb (1.551) 92.906	42 Mo (1.551) 95.94	43 Tc (1.551) 98.906	44 Ru (1.551) 101.07	45 Rh (1.551) 102.905	46 Pd (1.551) 106.42	47 Ag (1.551) 107.868	48 Cd (1.551) 112.411	49 In (1.551) 114.818	50 Sn (1.551) 118.710	51 Sb (1.551) 121.760	52 Te (1.551) 127.60	53 I (1.551) 126.905	54 Xe (1.551) 131.29								
55 Cs (0.8219) 132.905	56 Ba (0.9314) 137.327	57 La (1.0000) 138.905	58 Ce (1.0500) 140.12	59 Pr (1.1395) 140.908	60 Nd (1.1995) 144.24	61 Pm (1.2938) 144.913	62 Sm (1.4016) 150.36	63 Eu (1.4553) 151.964	64 Gd (1.4912) 157.25	65 Tb (1.551) 158.925	66 Dy (1.551) 162.50	67 Ho (1.551) 164.930	68 Er (1.551) 167.259	69 Tm (1.551) 168.933	70 Yb (1.551) 173.054	71 Lu (1.551) 174.967	72 Hf (1.551) 178.49	73 Ta (1.551) 180.948	74 W (1.551) 183.84	75 Re (1.551) 186.207	76 Os (1.551) 190.23	77 Ir (1.551) 192.225	78 Pt (1.551) 195.084	79 Au (1.551) 196.967	80 Hg (1.551) 200.59	81 Tl (1.551) 204.383	82 Pb (1.551) 207.2	83 Bi (1.551) 208.980	84 Po (1.551) 209	85 At (1.551) 210	86 Rn (1.551) 222
87 Fr (0.8219)	88 Ra (0.9314)	89 Ac (1.0000)	90 Th (1.0500)	91 Pa (1.1395)	92 U (1.1995)	93 Np (1.2938)	94 Pu (1.4016)	95 Am (1.4553)	96 Cm (1.4912)	97 Bk (1.551)	98 Cf (1.551)	99 Es (1.551)	100 Fm (1.551)	101 Md (1.551)	102 No (1.551)	103 Lr (1.551)	104 Rf (1.551)	105 Db (1.551)	106 Sg (1.551)	107 Bh (1.551)	108 Hs (1.551)	109 Mt (1.551)	110 Ds (1.551)	111 Rg (1.551)	112 Cn (1.551)	113 Nh (1.551)	114 Fl (1.551)	115 Mc (1.551)	116 Lv (1.551)	117 Ts (1.551)	118 Og (1.551)

INCREASING ELECTRON AFFINITY

A trend of decreasing electron affinity when moving down the groups in the periodic table might be expected. The additional electron will be entering an orbital farther away from the nucleus. Since this electron is farther from the nucleus it is less attracted to the nucleus and would release less energy when added. However, a clear counterexample to this trend can be found in Group 2, and inspecting the entire periodic table, it turns out that the proposed trend only applies to Group 1 atoms.

INCREASING ELECTRONEGATIVITY

1 H 1.01794																	2 He 1.00000
3 Li 0.9776	4 Be 1.577															6 C 2.55	7 N 3.04
9 F 3.98	8 O 3.44															14 Si 1.90	15 P 2.19
11 Na 0.9339	12 Mg 1.31	13 Al 1.61	16 S 2.58	17 Cl 3.16	18 Ar 1.90											31 Ga 1.61	32 Ge 2.01
19 K 0.8219	20 Ca 0.9991	21 Sc 1.36	22 Ti 1.54	23 V 1.63	24 Cr 1.66	25 Mn 1.55	26 Fe 1.83	27 Co 1.88	28 Ni 1.91	29 Cu 1.90	30 Zn 1.65	31 Ga 1.61	32 Ge 2.01	33 As 2.18	34 Se 2.55	35 Br 2.96	
37 Rb 0.8219	38 Sr 0.95	39 Y 1.22	40 Zr 1.39	41 Nb 1.46	42 Mo 1.68	43 Tc 1.70	44 Ru 1.86	45 Rh 1.88	46 Pd 1.88	47 Ag 1.93	48 Cd 1.69	49 In 1.78	50 Sn 1.79	51 Sb 1.92	52 Te 1.90	53 I 2.5	
55 Cs 0.79	56 Ba 0.854	57 La 1.10	58 Ce 1.04	59 Pr 1.05	60 Nd 1.05	61 Pm 1.13	62 Sm 1.06	63 Eu 1.00	64 Gd 1.05	65 Tb 1.07	66 Dy 1.05	67 Ho 1.03	68 Er 1.00	69 Tm 1.00	70 Yb 1.00	71 Lu 1.00	
87 Fr 0.7	88 Ra 0.9	89 Ac 1.0	90 Th 1.3	91 Pa 1.3	92 U 1.3	93 Np 1.3	94 Pu 1.3	95 Am 1.3	96 Cm 1.3	97 Bk 1.3	98 Cf 1.3	99 Es 1.3	100 Fm 1.3	101 Md 1.3	102 No 1.3	103 Lr 1.3	

INCREASING ELECTRONEGATIVITY

Example	Difference in electronegativity	Type of Bond
H-H	No difference – Electrons are shared equally	Nonpolar covalent bond
H-Br	Slight difference in values – Electrons are shared unequally	Polar covalent bond
NaCl	Large difference in values – Electrons are not shared, they are transferred	Ionic Bond

IDO:

For each of the following pairs of elements

Na or Li

F and O

Choose the atom with:

- Higher first ionization energy
- Larger atomic radius
- Higher electronegativity

1																		2																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
H 1.00794																		He 4.002602																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
3				4														5				6				7				8				9				10																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
Li 6.941				Be 9.012182														B 10.811				C 12.0107				N 14.00644				O 15.9994				F 18.9984032				Ne 20.1797																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
11				12														13				14				15				16				17				18																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
Na 22.989770				Mg 24.3050														Al 26.981538				Si 28.0855				P 30.973761				S 32.066				Cl 35.4527				Ar 39.948																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					
19																		20																		21																		22																		23																		24																		25																		26																		27																		28																		29																		30																		31																		32																		33																		34																		35																		36																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
K 39.0983																		Ca 40.078																		Sc 44.955910																		Ti 47.867																		V 50.9415																		Cr 51.9961																		Mn 54.938049																		Fe 55.845																		Co 58.933200																		Ni 58.6934																		Cu 63.546																		Zn 65.39																		Ga 69.723																		Ge 72.61																		As 74.92160																		Se 78.96																		Br 79.904																		Kr 83.80																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																									
37				38				39				40				41				42				43				44				45				46				47				48				49				50				51				52				53				54				55																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																			
Rb 85.4678				Sr 87.62				Y 88.90585				Zr 91.224				Nb 92.90638				Mo 95.94				Tc (98)				Ru 101.07				Rh 102.90550				Pd 106.42				Ag 107.8682				Cd 112.411				In 114.818				Sn 118.710				Sb 121.760				Te 127.60				I 126.90447				Xe 131.29																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
55				56				57				72				73				74				75				76				77				78				79				80				81				82				83				84				85				86																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
Cs 132.90545				Ba 137.327				La 138.9055				Hf 178.49				Ta 180.9479				W 183.84				Re 186.207				Os 190.23				Ir 192.217				Pt 195.078				Au 196.96655				Hg 200.59				Tl 204.3833				Pb 207.2				Bi 208.98038				Po (209)				At (210)				Rn (222)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																							
87				88				89				104				105				106				107				108				109				110				111				112																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																															

58 Ce 140.116	59 Pr 140.90765	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.92534	66 Dy 162.50	67 Ho 164.93032	68 Er 167.26	69 Tm 168.93421	70 Yb 173.04	71 Lu 174.967
90 Th 232.0381	91 Pa 231.03688	92 U 238.0289	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

WE DO:

Rank the following from smallest to largest atomic/ionic radius.

- Na⁺, Na, Na⁻
- C, N, O
- Cl, Ar, K
- Be, Mg, Ca

1																		2																	
H 1.00794																		He 4.002602																	
3																		4																	
Li 6.941																		Be 9.012182																	
11																		12																	
Na 22.989770																		Mg 24.3050																	
19																		20																	
K 39.0983																		Ca 40.078																	
21																		22																	
Sc 44.955910																		Ti 47.867																	
23																		24																	
V 50.9415																		Cr 51.9961																	
25																		26																	
Mn 54.938049																		Fe 55.845																	
27																		28																	
Co 58.933200																		Ni 58.6934																	
29																		30																	
Cu 63.546																		Zn 65.39																	
31																		32																	
Ga 69.723																		Ge 72.61																	
33																		34																	
As 74.92160																		Se 78.96																	
35																		36																	
Br 79.904																		Kr 83.80																	
37																		38																	
Rb 85.4678																		Sr 87.62																	
39																		40																	
Y 88.90585																		Zr 91.224																	
41																		42																	
Nb 92.90638																		Mo 95.94																	
43																		44																	
Tc (98)																		Ru 101.07																	
45																		46																	
Rh 102.90550																		Pd 106.42																	
47																		48																	
Ag 107.8682																		Cd 112.411																	
49																		50																	
In 114.818																		Sn 118.710																	
51																		52																	
Sb 121.760																		Te 127.60																	
53																		54																	
I 126.90447																		Xe 131.29																	
55																		56																	
Cs 132.90545																		Ba 137.327																	
57																		58																	
La 138.9055																		Hf 178.49																	
59																		60																	
Pr 140.90768																		Ta 180.9479																	
61																		62																	
Nd 144.242																		W 183.84																	
63																		64																	
Pm (145)																		Re 186.207																	
65																		66																	
Sm 150.36																		Os 190.23																	
67																		68																	
Eu 151.964																		Ir 192.217																	
69																		70																	
Gd 157.25																		Pt 195.078																	
71																		72																	
Tb 158.925																		Au 196.96655																	
73																		74																	
Dy 162.50																		Hg 200.59																	
75																		76																	
Ho 164.93032																		Tl 204.3833																	
77																		78																	
Er 167.259																		Pb 207.2																	
79																		79																	
Tm 168.9328																		Bi 208.98038																	
81																		82																	
Yb 173.045																		Po (209)																	
83																		84																	
Lu 174.967																		At (210)																	
85																		86																	
Hf 178.49																		Rn (222)																	
87																		88																	
Ta 180.9479																																			
89																		90																	
Nb 92.90638																																			
91																		92																	
Mo 95.94																																			
93																		94																	
Tc (98)																																			
95																		96																	
Ru 101.07																																			
97																		98																	
Rh 102.90550																																			
99																		100																	
Pd 106.42																																			
101																		102																	
Ag 107.8682																																			
103																		104																	
Cd 112.411																																			
105																		106																	
In 114.818																																			
107																		108																	
Sn 118.710																																			
109																		110																	
Sb 121.760																																			
111																		112																	
Te 127.60																																			
113																		114																	
I 126.90447																																			
115																		116																	
Xe 131.29																																			
117																		118																	
Cs 132.90545																																			
119																		120																	
Ba 137.327																																			
121																		122																	
La 138.9055																																			
123																		124																	
Pr 140.90768																																			
125																		126																	
Nd 144.242																																			
127																		128																	
Pm (145)																																			
129																		130																	
Sm 150.36																																			
131																		132																	
Eu 151.964																																			
133																		134																	
Gd 157.25																																			
135																		136																	
Tb 162.50																																			
137																		138																	
Dy 164.93032																																			
139																		140																	
Ho 167.259																																			
141																		142																	
Er 168.9328																																			
143																		144																	
Tm 168.9328																																			
145																		146																	
Yb 173.045																																			
147																		148																	
Lu 174.967																																			
149																		150																	
151																		152																	
153																		154																	
155																		156																	
157																		158																	
159																		160																	
161																		162																	
163																		164																	
165																		166																	
167																		168																	
169																		170																	
171																		172																	
173																		174																	
175																		176																	
177																		178																	
179																		180																	
181																		182																	
183																		184																	
185																		186																	
187																		188																	
189																		190																	
191																		192																	
193																		194																	
195																		196																	
197																		198																	
199																		200																	
201																		202																	
203																		204																	
205																		206																	
207																		208																	
209																		210																	
211																		212																	
213																		214																	
215																		216																	
217																		218																	
219																		220																	
221																		222																	
223																		224																	
225																		226																	
227																		228																	
229																		230																	
231																		232																	
233																		234																	
235																		236																	
237																		238																	
239																		240																	
241																		242																	
243																		244																	
245																		246																	
247																		248																	
249																		250																	
251																		252																	
253																		254																	
255																		256																	
257																		258																	
259																		260																	
261																		262																	
263																		264																	
265																		266																	
267																		268																	
269																		270																	
271																		272																	
273																		274																	
275																		276																	
277																		278																	
279																		280																	
281																		282																	
283																		284																	
285																		286																	
287																		288																	
289																		290																	
291																		292																	
293																		294																	
295																		296																	
297																		298																	
299																		300																	
301																		302																	
303																		304																	
305																		306																	
307																		308																	
309																		310																	
311																		312																	
313																		314																	
315																		316																	
317																		318																	
319																		320																	
321																		322																	
323																		324																	
325																		326																	
327																		328																	
329																		330																	
331																		332																	
333																		334																	
335																		336																	
337																		338																	
339																		340																	
341																		342																	
343																		344																	
345																		346																	
347																		348																	
349																		350																	
351																		352																	
353																		354																	
355																		356																	
357																		358																	
359																		360																	
361																		362																	
363																		364																	
365																		366																	
367																		368																	
369																		370																	
371																		372																	
373																		374																	
375																		376																	
377																		378																	
379																		380																	
381																		382																	
383																		384																	
385																		386																	
387																		388																	
389																		390																	
391																		392																	
393																		394																	
395																		396																	
397																		398																	
399																		400																	

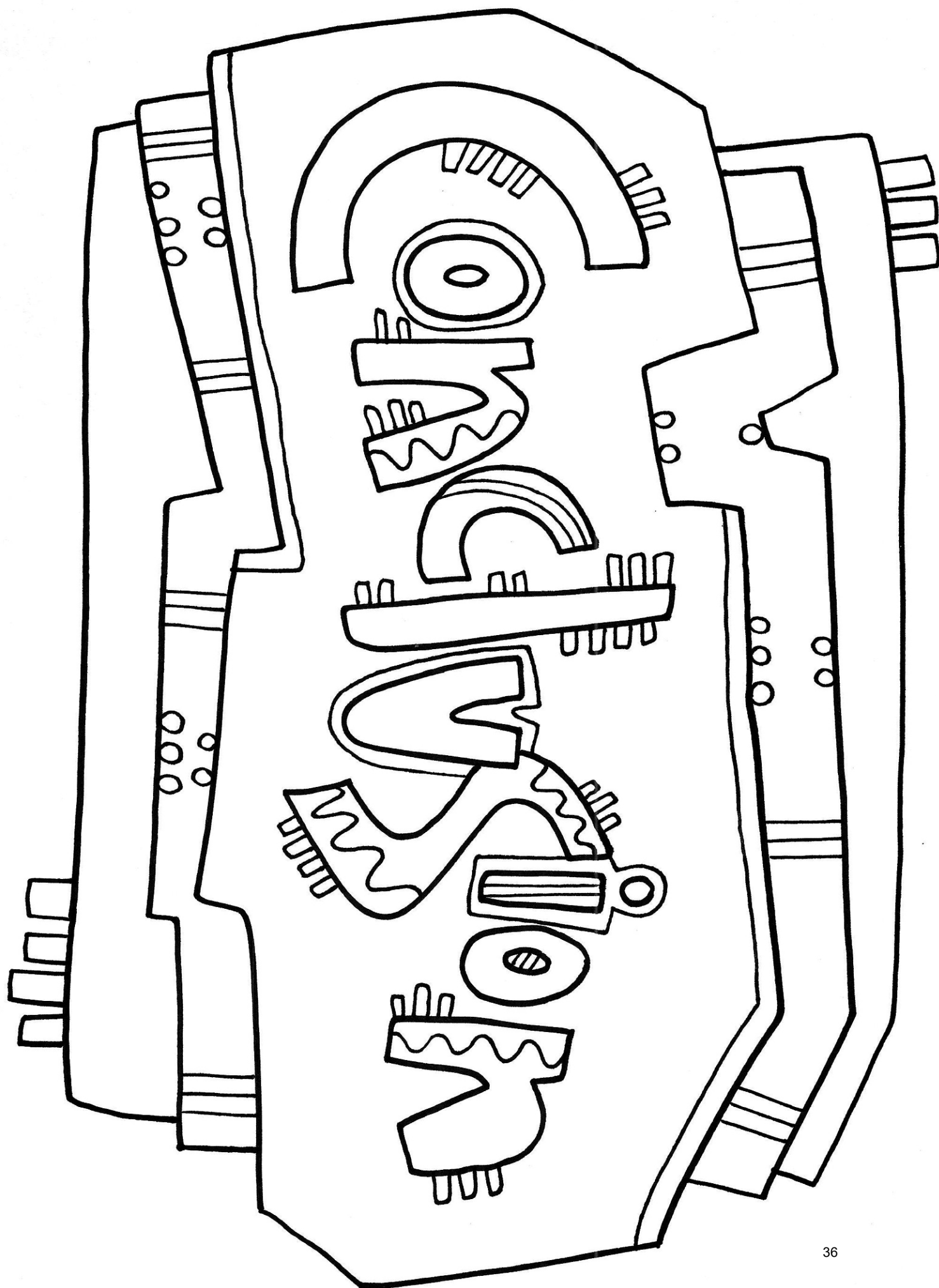
58 Ce 140.116	59 Pr 140.90765	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.92534	66 Dy 162.50	67 Ho 164.93032	68 Er 167.26	69 Tm 168.93421	70 Yb 173.04	71 Lu 174.967
90 Th 232.0381	91 Pa 231.03688	92 U 238.0289	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

YOU DO:

- On the basis of their position on the periodic table determine which element in the pair would have a larger atomic radius
 - P or S
 - Cl or Br
 - Sr or Sc
- Based on the successive ionization energies for the following element "X", predict the formula that would be formed when "X" reacts with chlorine, Cl.

Ionization Energy Number	Enthalpy (kJ/mole)
1 st	577
2 nd	1820
3 rd	2740
4 th	11600
5 th	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 isoelectric (have the same number of electrons).
- $$\text{K}_{(\text{g})} \rightarrow \text{K}^{+}_{(\text{g})} + \text{e}^{-}$$
- $$\text{Ca}^{+}_{(\text{g})} \rightarrow \text{Ca}^{2+}_{(\text{g})} + \text{e}^{-}$$
- 4) Element X has an electron configuration of $1s^2 2s^2 2p^6 3s^1$, while element Z has an electron configuration of $1s^2 2s^2 2p^5$.
- Which element would have greater first ionization energy?
 - Which element would have a larger radius?
 - Which element would have higher electronegativity?
 - Which element would form an ion that has a larger radius?
 - Which element would release more energy when it gains an electron?
- 5) Predict two elements that would have properties similar to:
- Chlorine
 - Sodium
 - Calcium
- 6) Nitrogen is in column 5A of the periodic table, which is called the pnictogens. When nitrogen reacts with iodine it forms nitrogen triiodide, NI_3 , which is a contact explosive that explodes with a snap releasing clouds of purple iodine vapor. Select another pnictogen and predict the formula of the compound that would be formed with a reaction with bromine.
- 7) Based on the given electron configurations, group together the elements that would have similar chemical properties.
- $1s^2 2s^2 2p^6 3s^1$
 - $1s^2 2s^2 2p^6 3s^2 3p^4 4s^2$
 - $1s^2 2s^2 2p^5$
 - $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 4p^5 5s^2$
 - $1s^2 2s^1$
 - $1s^2 2s^2 2p^6 3s^2 3p^5$



TOPIC: 1.8 VALENCE ELECTRONS AND IONIC COMPOUNDS

ENDURING UNDERSTANDING:

SPQ-2	The periodic table shows patterns in electronic structure and trends in atomic properties.
-------	--

LEARNING OBJECTIVE:

SPQ-2.B	Explain the relationship between trends in the reactivity of elements and periodicity.
---------	--

ESSENTIAL KNOWLEDGE:

SPQ-2.B.1	The likelihood that two elements will form a chemical bond is determined by the interactions between the valence electrons and nuclei of elements.
-----------	--

SPQ – 2.B.2	Elements in the same column of the periodic table tend to form analogous compounds
-------------	--

SPQ – 2.B.3	Typical charges of atoms in ionic compounds are governed by their location on the periodic table and the number of valence electrons.
-------------	---

EQUATION(S):

N/A

NOTES:

An ionic bond always involves the transfer of electrons 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. This loss or gain of electrons leads to the formation of positive or negative ions. Ionic compounds are held together by an electrostatic force.

In order to maintain neutrality, the number of electrons lost must equal the number of electrons gained. Because the number of electrons lost or gained is based on electron configurations, elements in the same group will form the same $M_nN_{m_n}$ analogous compounds. For example, all group I metals (Lithium – Cesium) will have the following format when combined with any group VII halogen (Fluorine – Astatine): LiF or $LiCl$. Any group II metal, when combined with a group VII halogen would be CaF_2 or $MgCl_2$. Again, these analogous structures are because of the need to maintain neutrality. 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.

Valence Electrons in Each Group

Group																2	
1																2	
1	2											3	4	5	6	7	8
1	2											3	4	5	6	7	8
1	2										3	4	5	6	7	8	
1	2										3	4	5	6	7	8	
1	2										3	4	5	6	7	8	
1	2										3	4	5	6	7	8	

[illegible]

<http://kinga2.weebly.com/unit-3-periodic-table.html>

I DO:

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_2X_2
D) NaX

WE DO:

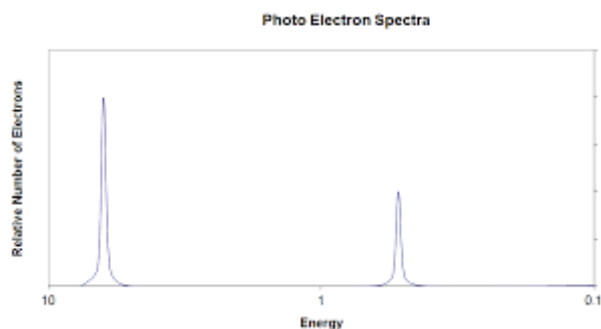
Element 117 was recently discovered and is named Tennessine. Assuming that periodic trends are followed, write the noble gas electron configuration and predict the formula when it forms an ionic compound with Mg.

1 IA H Hydrogen 1.00794																		18 VIIIA He Helium 4.002602																	
3 Li Lithium 6.941		4 Be Beryllium 9.012182																5 B Boron 10.811		6 C Carbon 12.011		7 N Nitrogen 14.00643		8 O Oxygen 15.999		9 F Fluorine 18.998463		10 Ne Neon 20.1797							
11 Na Sodium 22.98976928		12 Mg Magnesium 24.304		13 Al Aluminum 26.9815385		14 Si Silicon 28.0855		15 P Phosphorus 30.973761508		16 S Sulfur 32.06		17 Cl Chlorine 35.45		18 Ar Argon 39.948																					
19 K Potassium 39.0983		20 Ca Calcium 40.078		21 Sc Scandium 44.955912		22 Ti Titanium 47.88		23 V Vanadium 50.9415		24 Cr Chromium 51.9961		25 Mn Manganese 54.938044		26 Fe Iron 55.845		27 Co Cobalt 58.933194		28 Ni Nickel 58.6934		29 Cu Copper 63.546		30 Zn Zinc 65.38		31 Ga Gallium 69.723		32 Ge Germanium 72.630		33 As Arsenic 74.9216		34 Se Selenium 78.96		35 Br Bromine 79.904		36 Kr Krypton 83.798	
37 Rb Rubidium 85.4678		38 Sr Strontium 87.62		39 Y Yttrium 88.90584		40 Zr Zirconium 91.224		41 Nb Niobium 92.90638		42 Mo Molybdenum 95.94		43 Tc Technetium 98		44 Ru Ruthenium 101.07		45 Rh Rhodium 101.07		46 Pd Palladium 106.3675		47 Ag Silver 107.8682		48 Cd Cadmium 112.411		49 In Indium 114.818		50 Sn Tin 118.710		51 Sb Antimony 121.757		52 Te Tellurium 127.6		53 I Iodine 126.90547		54 Xe Xenon 131.29	
55 Cs Cesium 132.90545196		56 Ba Barium 137.327		57-71 Lanthanoids		72 Hf Hafnium 178.49		73 Ta Tantalum 180.94788		74 W Tungsten 183.84		75 Re Rhenium 186.207		76 Os Osmium 190.23		77 Ir Iridium 192.222		78 Pt Platinum 195.084		79 Au Gold 196.966569		80 Hg Mercury 200.59		81 Tl Thallium 204.38		82 Pb Lead 207.2		83 Bi Bismuth 208.9804		84 Po Polonium [209]		85 At Astatine [210]		86 Rn Radon [222]	
87 Fr Francium [223]		88 Ra Radium [226]		89-103 Actinoids		104 Rf Rutherfordium [261]		105 Db Dubnium [262]		106 Sg Seaborgium [266]		107 Bh Bohrium [264]		108 Hs Hassium [277]		109 Mt Meitnerium [268]		110 Ds Darmstadtium [271]		111 Rg Roentgenium [272]		112 Cn Copernicium [285]		113 Nh Nihonium [284]		114 Fl Flerovium [289]		115 Mc Moscovium [288]		116 Lv Livermorium [293]		117 Ts Tennessine [294]		118 Og Oganesson [294]	

57 La Lanthanum 138.90547	58 Ce Cerium 140.12	59 Pr Praseodymium 140.90766	60 Nd Neodymium 144.24	61 Pm Promethium [145]	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.92535	66 Dy Dysprosium 162.50014	67 Ho Holmium 164.93033	68 Er Erbium 167.259	69 Tm Thulium 168.93421	70 Yb Ytterbium 173.05468	71 Lu Lutetium 174.967
89 Ac Actinium [227]	90 Th Thorium 232.0377	91 Pa Protactinium 231.03688	92 U Uranium 238.02891	93 Np Neptunium [237]	94 Pu Plutonium [244]	95 Am Americium [243]	96 Cm Curium [247]	97 Bk Berkelium [247]	98 Cf Californium [251]	99 Es Einsteinium [252]	100 Fm Fermium [257]	101 Md Mendelevium [258]	102 No Nobelium [259]	103 Lr Lawrencium [260]

YOU DO:

- Which of the following has the same number of electrons as Cl⁻¹?
 - F⁻¹
 - S
 - Al³⁺
 - K⁺
- KCl dissolves in water, forming a solution able to conduct electricity. Which of the following would behave similarly?
 - PbCl₂
 - LiK
 - LiCl
 - SrCl₂
- The complete photoelectron spectrum for an element is shown. What oxide compound would it most likely form?
 - XO₂
 - X₂O
 - XO
 - X₂O₂
- Identify the correct electron configuration for the aluminum ion.
 - 1s²2s²2p⁶
 - 1s²2s²2p⁶3s²3p¹
 - 1s²2s²2p⁶3s²3p⁶
 - 1s²2s²2p⁶3s²



AP® CHEMISTRY EQUATIONS AND CONSTANTS, EFFECTIVE 2025

UNIT SYMBOLS	
gram,	g
mole,	mol
liter,	L
meter,	m
second,	s
hertz,	Hz
atmosphere,	atm
millimeter of mercury,	mm Hg
degree Celsius,	°C
Kelvin,	K
joule,	J
volt,	V
coulomb,	C
ampere,	A

UNIT CONVERSIONS
1 hertz = 1 s ⁻¹
1 atm = 760 mm Hg = 760 torr
K = °C + 273.15
1 volt = $\frac{1 \text{ joule}}{1 \text{ coulomb}}$
1 ampere = $\frac{1 \text{ coulomb}}{1 \text{ second}}$

METRIC PREFIXES		
Factor	Prefix	Symbol
10 ⁹	giga	G
10 ⁶	mega	M
10 ³	kilo	k
10 ⁻²	centi	c
10 ⁻³	milli	m
10 ⁻⁶	micro	μ
10 ⁻⁹	nano	n
10 ⁻¹²	pico	p

ATOMIC STRUCTURE

$$E = h\nu$$

$$c = \lambda\nu$$

$$F_{\text{coulombic}} \propto \frac{q_1 q_2}{r^2}$$

E = energy

ν = frequency

λ = wavelength

F = force

q = charge

r = separation

Planck's constant, $h = 6.626 \times 10^{-34}$ J s

Speed of light, $c = 2.998 \times 10^8$ m s⁻¹

Avogadro's number = 6.022×10^{23} mol⁻¹

GASES, LIQUIDS, AND SOLUTIONS

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$PV = nRT$$

$$P_A = P_{\text{total}} \times X_A, \text{ where } X_A = \frac{\text{moles A}}{\text{total moles}}$$

$$P_{\text{total}} = P_A + P_B + P_C + \dots$$

$$n = \frac{m}{M}$$

$$D = \frac{m}{V}$$

$$KE = \frac{1}{2}mv^2$$

$$M = \frac{n_{\text{solute}}}{L_{\text{solution}}}$$

$$A = \epsilon bc$$

P = pressure

V = volume

T = temperature

n = number of moles

X = mole fraction

m = mass

M = molar mass

D = density

KE = kinetic energy

v = velocity

M = molarity

A = absorbance

ϵ = molar absorptivity

b = path length

c = concentration

Gas constant, $R = 8.314$ J mol⁻¹ K⁻¹

= 0.08206 L atm K⁻¹ mol⁻¹

STP = 273.15 K and 1.0 atm

Ideal gas at STP = 22.4 L mol⁻¹

KINETICS

$$[A]_t - [A]_0 = -kt$$

$$\ln[A]_t - \ln[A]_0 = -kt$$

$$\frac{1}{[A]_t} - \frac{1}{[A]_0} = kt$$

$$t_{1/2} = \frac{0.693}{k}$$

k = rate constant
 t = time
 $t_{1/2}$ = half-life

EQUILIBRIUM

$$K_c = \frac{[C]^c [D]^d}{[A]^a [B]^b}, \text{ where } a A + b B \rightleftharpoons c C + d D$$

$$K_p = \frac{(P_C)^c (P_D)^d}{(P_A)^a (P_B)^b}$$

$$K_w = [H_3O^+][OH^-] = 1.0 \times 10^{-14} \text{ at } 25^\circ\text{C}$$

$$pK_w = 14 = \text{pH} + \text{pOH at } 25^\circ\text{C}$$

$$\text{pH} = -\log[H_3O^+], \quad \text{pOH} = -\log[OH^-]$$

$$K_a = \frac{[H_3O^+][A^-]}{[HA]}, \quad K_b = \frac{[OH^-][HB^+]}{[B]}$$

$$pK_a = -\log K_a, \quad pK_b = -\log K_b$$

$$K_w = K_a \times K_b, \quad pK_w = pK_a + pK_b$$

$$\text{pH} = pK_a + \log \frac{[A^-]}{[HA]}$$

Equilibrium Constants

K_c (molar concentrations)
 K_p (gas pressures)
 K_w (water)
 K_a (acid)
 K_b (base)

THERMODYNAMICS/ELECTROCHEMISTRY

$$q = mc\Delta T$$

$$\Delta H^\circ_{\text{reaction}} = \sum \Delta H^\circ_{f \text{ products}} - \sum \Delta H^\circ_{f \text{ reactants}}$$

$$\Delta S^\circ_{\text{reaction}} = \sum S^\circ_{\text{products}} - \sum S^\circ_{\text{reactants}}$$

$$\Delta G^\circ_{\text{reaction}} = \sum \Delta G^\circ_{f \text{ products}} - \sum \Delta G^\circ_{f \text{ reactants}}$$

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

$$= -RT \ln K$$

$$= -nFE^\circ$$

$$I = \frac{q}{t}$$

$$E_{\text{cell}} = E^\circ_{\text{cell}} - \frac{RT}{nF} \ln Q$$

q = heat
 m = mass
 c = specific heat capacity
 T = temperature
 S° = standard entropy
 H° = standard enthalpy
 G° = standard Gibbs free energy
 R = gas constant
 K = equilibrium constant
 n = number of moles of electrons
 E° = standard potential
 I = current (amperes)
 q = charge (coulombs)
 t = time (seconds)
 Q = reaction quotient

Faraday's constant, $F = 96,485 \text{ coulombs} / 1 \text{ mol } e^-$

PERIODIC TABLE OF THE ELEMENTS																																																																																															
1	2		3										4	5	6	7	8	9	10	11	12	13		14	15	16	17	18																																																																			
1 H 1.008	2 He 4.00		3 Li 6.94		4 Be 9.01	5 B 10.81		6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18	11 Na 22.99		12 Mg 24.30	13 Al 26.98		14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95	19 K 39.10		20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.63	33 As 74.92	34 Se 78.97	35 Br 79.90	36 Kr 83.80	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29	55 Cs 132.91	56 Ba 137.33	57–71 *	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po	85 At	86 Rn	87	88	89–103 †	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og
*Lanthanoids																		57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm	62 Sm 150.36	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97																																																															
†Actinoids																		89 Ac	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr																																																															