1.4 Composition of Mixtures

Essential knowledge statements from the AP Chemistry CED:

- 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.
- Elemental analysis can be used to determine the relative numbers of atoms in a substance and to determine its purity.

Mass of NaCl	Mass of $MgCl_2$	Total Mass of Mixture
2.75 g	3.42 g	6.17 g

1. Answer the following questions about the mixture whose composition is listed in the table above.

   (a) Calculate the percentage of NaCl by mass in this mixture.

   (b) Calculate the percentage of Na by mass in this mixture.

   (c) Calculate the percentage of Cl by mass in this mixture.

2. A sample of a solid labeled as $AgNO_3$ may be impure. A student analyzes the sample, and determines that it contains 68% Ag by mass.

   (a) Calculate the percentage of Ag by mass in a pure sample of $AgNO_3$.

2. (b) Which of the following is more likely to represent the solid sample that was analyzed by the student? Justify your answer.

a mixture of $AgNO_3$ and $AgCl$	a mixture of $AgNO_3$ and $AgBr$

3. A student needs to analyze a mixture that contains $BaCl_2$ and NaCl. The student dissolves a 6.75-g sample of this mixture completely into water and adds an excess amount of $Na_2SO_4(aq)$. A white precipitate of $BaSO_4(s)$ is formed, based on the following chemical equation.

$$BaCl_2(aq) + Na_2SO_4(aq) \rightarrow 2\,NaCl(aq) + BaSO_4(s)$$

The solid precipitate is filtered, dried, and weighed, and its mass is recorded as 2.36 g.

(a) Calculate the number of moles of $BaSO_4(s)$ that is recovered in this experiment.

(b) Calculate the percentage of $BaCl_2$ by mass in this mixture.

4. A mixture of $CaCO_3$ and Na_2CO_3 is found to contain 35.00% Na by mass. Calculate the percentage of Na_2CO_3 by mass in this mixture.

1.5 Atomic Structure and Electron Configuration

Essential knowledge statements from the AP Chemistry CED:

- The atom is composed of negatively charged electrons and a positively charged nucleus that is made of protons and neutrons.
- Coulomb's law is used to calculate the force between two charged particles.

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

- In atoms and ions, the electrons 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 valence electrons. The electron configuration is explained by quantum mechanics, as delineated in the Aufbau principle and exemplified in the periodic table of the elements.
- 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.

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5. The valence electrons of both Na and Mg are located in the 3rd energy level. Which atom, Na or Mg, experiences a greater attractive force between the nucleus and the valence electrons? Justify your answer in terms of Coulomb's law.

6. The valence electron of Na is located in the 3rd energy level, whereas the valence electron of K is located in the 4th energy level. Which atom, Na or K, experiences a greater attractive force between the nucleus and the valence electron? Justify your answer in terms of Coulomb's law.

7. Ionization energy is normally expressed in units of kilojoules per mole, and is defined as the energy required to remove one mole of electrons from one mole of gaseous atoms (or ions) in their ground states. This process is represented by the equation below.

$$X(g) \; + \; \text{ionization energy} \; \rightarrow \; X^+(g) \; + \; e^-$$

Based on your answers to Questions #5 and #6, arrange the atoms Na, Mg, and K in order of increasing ionization energy value.

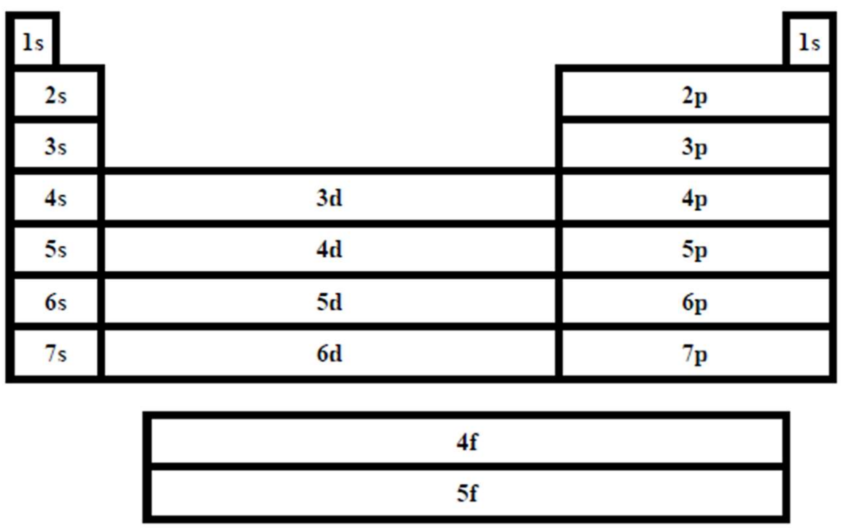
lowest ionization energy value	- - - - - - - ->	highest ionization energy value

The Bohr Model of the Hydrogen Atom (1913)

- Electrons travel in orbits around the nucleus. Only orbits of certain radii, corresponding to certain specific energy values, are permitted for the electron.
- An electron absorbs energy when it moves farther away from the nucleus from a lower energy level to a higher energy level.
- An electron releases energy when it moves closer to the nucleus from a higher energy level to a lower energy level.
- The letter "n" refers to the principal quantum number or the electronic energy level. The lowest energy level (n = 1) for a hydrogen atom is called the ground state. The higher energy levels (n = 2 or higher) are called excited states.

The Bohr model of the hydrogen atom is a primitive, inaccurate model. Today we do not think of electrons as moving in orbits around the nucleus. Instead, we use the term atomic orbital, which is a mathematical function used to indicate the probability of finding an electron. We can visualize atomic orbitals as "electron clouds."

The **electron configuration** is the distribution of the electrons in an atom or an ion among the various orbitals. There are patterns on the periodic table that help you write the electron configuration of an atom or an ion.



8. Fill in the missing information in the table below.

Element Symbol	Atomic Number	Complete Electron Configuration	Noble Gas Abbreviated Electron Configuration
O	8	$1s^2 2s^2 2p^4$	[He] $2s^2 2p^4$
			[Ne] $3s^2 3p^1$
Ca		$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$	
	26		
As			
Cd			

An orbital diagram is another way to represent the electron configuration. Each box represents an orbital. Each electron is represented by an arrow. Electrons that have opposite spins are represented by a pair of arrows pointing in opposite directions. Electrons are paired when they occupy the same orbital. An unpaired electron is an electron in an orbital without another electron of opposite spin.

9. Fill in the missing information in the table below.

Element Symbol	Atomic Number	Orbital Diagram for the Electron Configuration
Be	4	[↑↓] [↑↓] [ ][ ][ ] [ ] $1s$ $2s$ $2p$ $3s$
N	7	[ ] [ ] [ ][ ][ ] [ ] $1s$ $2s$ $2p$ $3s$
O	8	[ ] [ ] [ ][ ][ ] [ ] $1s$ $2s$ $2p$ $3s$
Na	11	[ ] [ ] [ ][ ][ ] [ ] $1s$ $2s$ $2p$ $3s$

The **ground state** electron configuration refers to the arrangement of the electrons in the lowest available energy levels. An **excited state** electron configuration refers to a situation in which at least one of the electrons has moved up to a higher energy level.

10. Circle all of the following that represent an excited state electron configuration.

$1s^22s^22p^63s^23p^1$ $1s^22s^22p^53s^1$ $1s^22s^22p^63s^23p^64s^1$

$1s^22s^12p^2$ $1s^22s^22p^63s^23p^4$ $1s^22s^22p^63s^13p^1$

Electron Configurations of Ions

- When electrons are removed from an atom to form a cation, they are always removed first from the occupied orbitals having the largest principal quantum number n (energy level).
- When electrons are added to an atom to form an anion, they are added to the empty or partially filled orbital that has the lowest value of n.
- When an atom of a transition metal (e.g., elements #21 – #30 and #39 – #48) loses electrons to become a cation, *the electrons are first removed from the valence s orbitals*. If additional electrons are lost, they are removed from the valence *d* orbitals.

11. Write the ground state electron configuration for each of the following ions.

Ca^{2+} ________________________________ Fe^{2+} ________________________________

O^{2-} ________________________________ Fe^{3+} ________________________________

1.6 Photoelectron Spectroscopy

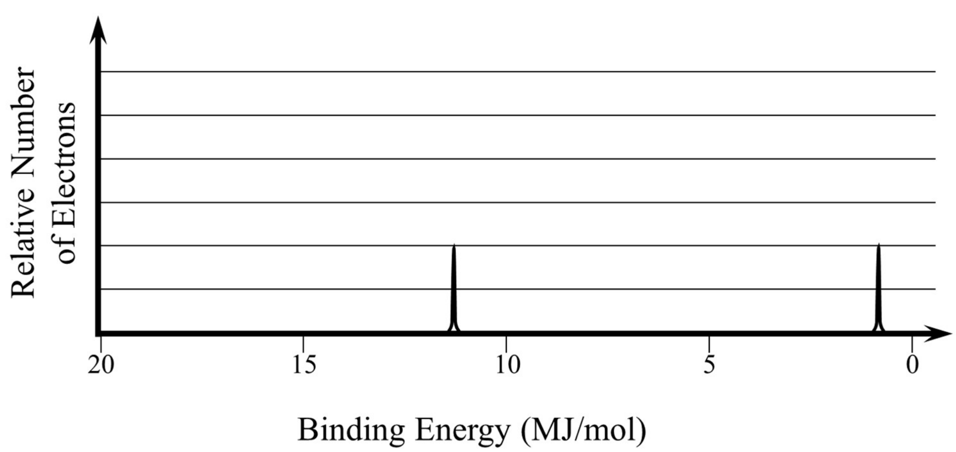
Essential knowledge statements from the AP Chemistry CED:

- 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.

Photoelectron spectroscopy (PES) is an experimental technique that involves the ionization of a sample by using a high-energy source of light (usually ultraviolet or X-ray). The energy is absorbed by the sample, causing all of the electrons to be removed from the atom. We can use PES to determine the following information.

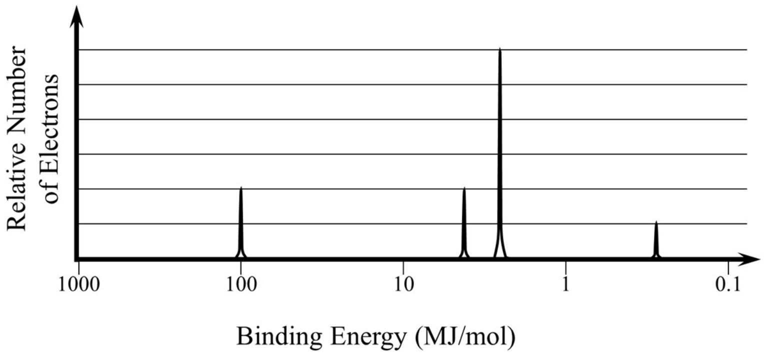
- The binding energy for each subshell
- The number of electrons in each subshell

The relative number of electrons is shown on the y-axis. The binding energy is shown on the x-axis. The appearance of the x-axis for a typical photoelectron spectrum looks a little strange at first. It is sometimes presented as a logarithmic scale. The highest binding energy values are located on the left, and the lowest binding energy values are located on the right. An example of a photoelectron spectrum (PES) for a pure sample of an element is shown below.



12. On the PES diagram above, there are two peaks. Draw a circle around the peak that represents the electrons that are located closer to the atomic nucleus. Justify your answer in terms of Coulomb's law.

The binding energy value in a PES diagram represents the energy required to remove the electrons from a particular subshell. Coulomb's law tells us that the electrons that are located closer to the nucleus should have a stronger attractive force to the nucleus. Therefore the core electrons that are located closer to the nucleus should have a higher binding energy (i.e., require more energy to remove) than the valence electrons in the outermost shell.

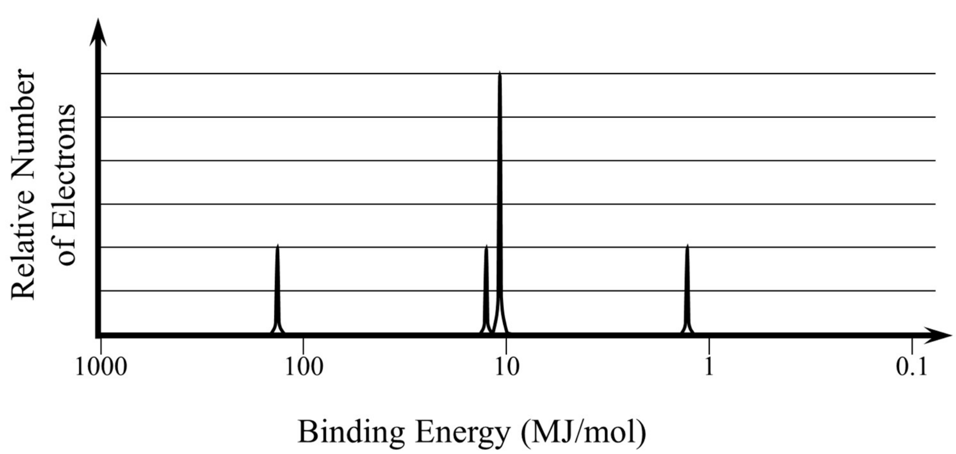


Identity of Element:

13. On the PES diagram above, label each peak as one of the following: 1*s*, 2*s*, 2*p*, or 3*s*. Identify the element that is represented by this PES diagram.

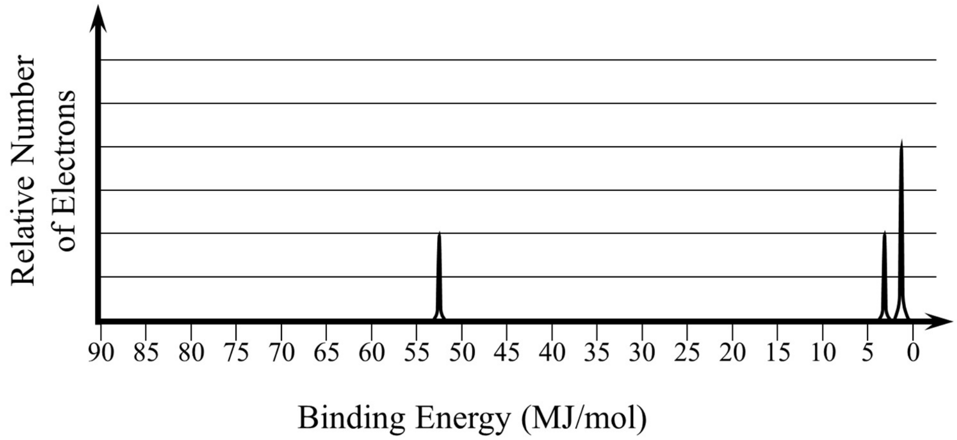
	Binding Energy (MJ/mol)
1*s* electrons in nitrogen (N)	39.6
1*s* electrons in oxygen (O)	52.6

14. The table above shows the binding energy for the 1*s* electrons in a nitrogen atom and the binding energy for the 1*s* electrons in an oxygen atom. Explain the difference in these two values in terms of Coulomb's law and atomic structure.

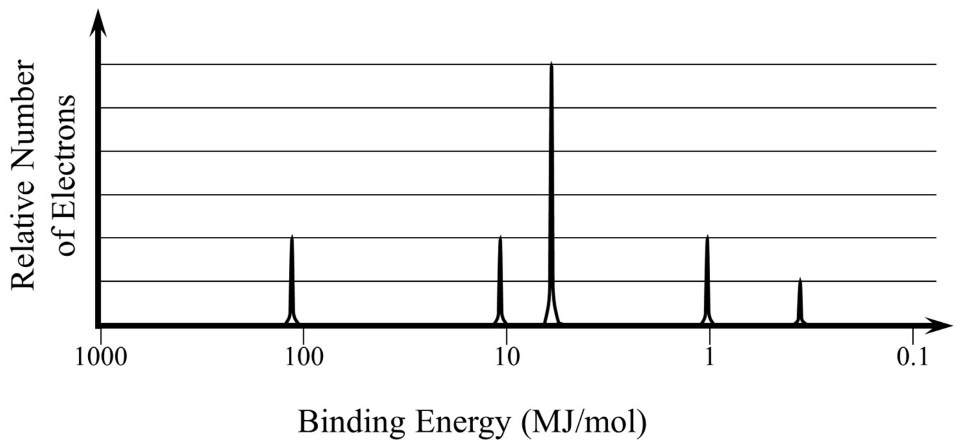


15. A partial photoelectron spectrum of pure phosphorus (P) is shown above. On the spectrum above, draw the missing peak that corresponds to the electrons in the 3*p* sublevel.

16. The photoelectron spectrum diagrams for three different elements are shown below. Identify the element that is represented by each diagram.



Identity of Element:



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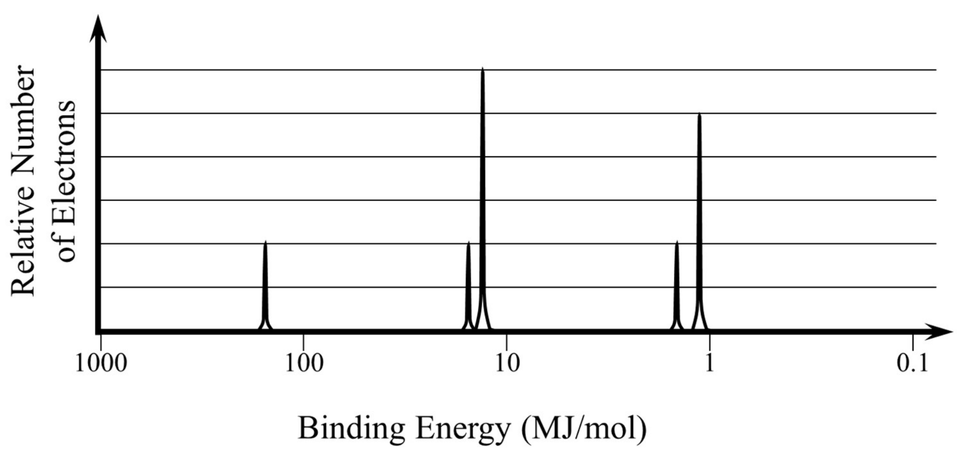

Identity of Element: