J, Wait

Big Idea 1: Atoms and Elements

The chemical elements are fundamental building materials of matter, and all matter can be understood in terms of arrangements of atoms. These atoms retain their identity in chemical reactions.

When all else fails, remember that all elements are composed of atoms. Atoms cannot be broken down in chemical reactions and are themselves composed of protons, neutrons, and electrons. The protons and neutrons live in the nucleus and contribute to the mass of the atom. Electrons live in different orbitals outside of the nucleus and the orbitals are at different energy levels depending on the attractive forces between the protons and electrons, which are in contrast to the repulsive forces the electron feels for each other.

LO 1.1 The student can justify the observation that the ratio of the masses of the constituent elements in any pure sample of that compound is always identical on the basis of the atomic molecular theory.

This LO is describing the law of definite composition and also may include the ability to write a proper formula for a compound.

Example:

In the substance, iron (II) sulfate, which element is in the greatest percentage by mass?

$FeSO_4$ $\frac{55.85}{(55.85+32.07+4(16.00))} = 37\%\ Fe$ $\frac{32.07}{151.92} = 21\%\ S$ $\frac{64}{151.92} = \boxed{42\%\ O}$

LO 1.2 The student is able to select and apply mathematical routines to mass data to identify or infer the composition of pure substances and/or mixtures.

This describes the ability to use mass data and percent composition or the mole concept to determine the identity of a substance or mixture of substances. Balanced chemical equations may also be used.

Example:

A compound is found to contain 36.5% Na, 25.4% S, and 38.1% O. Find its empirical formula.

$\frac{36.5\ g\ Na}{22.99\ g/mol} = \frac{1.59\ mol\ Na}{0.792}$ $\frac{25.4\ g\ S}{32.07\ g/mol} = \frac{0.792\ mol\ S}{0.792}$ $\frac{38.1\ g\ O}{16.00\ g/mol} = \frac{2.38\ mol\ O}{0.792} =$

LO 1.3 The student is able to select and apply mathematical relationships to mass data in order to justify a claim regarding the identity and/or estimated purity of a substance.

Purity of a substance has to do with percent composition as well.

Example:

The mass percent of iron in iron(III) sulfide is 53.7 percent. A chemist analyzes a sample of iron sulfide that has a mass percent of 60% iron, which of the following errors could account for the impurity?

↑ Fe percent in FeS only

a) $FeCl_2$
[✓ b) FeS]
c) $FeSO_4$
d) $FePO_4$

LO 1.4 The student is able to connect the number of particles, moles, mass, and volume of substances to one another, both qualitatively and quantitatively.

The is a stoichiometry and chemical formula LO.

Example:

How many moles in 25 grams of methanol, CH_3OH?

$CH_3OH = 12.01 + 4(1.01) + 16.00 = 32.05\ g/mol$ $\frac{25g}{32.05\ g/mol} = \boxed{0.78\ mol}$

LO 1.5 The student is able to explain the distribution of electrons in an atom or ion based upon data.

This is a PES data analysis LO. It may also refer to absorption or emission spectra as well. Basically simple spectroscopy/

Example:

Which of the following electron configurations matches the element carbon, z=6?

a) $1s^22s^22p^63s^2$
b) $1s^22s^22p^6$
[✓ c) $1s^22s^22p^2$]
d) $1s^22s^23s^2$

$z = 6 \rightarrow 6e^-$

LO 1.6 The student is able to analyze data relating to electron energies for patterns and relationships.

This is the link between PES and the periodic table, or the arrangement of electrons in an atom that is based off data.

Example:

Which of the following groups of elements is correctly arranged in order of increasing first ionization energy?

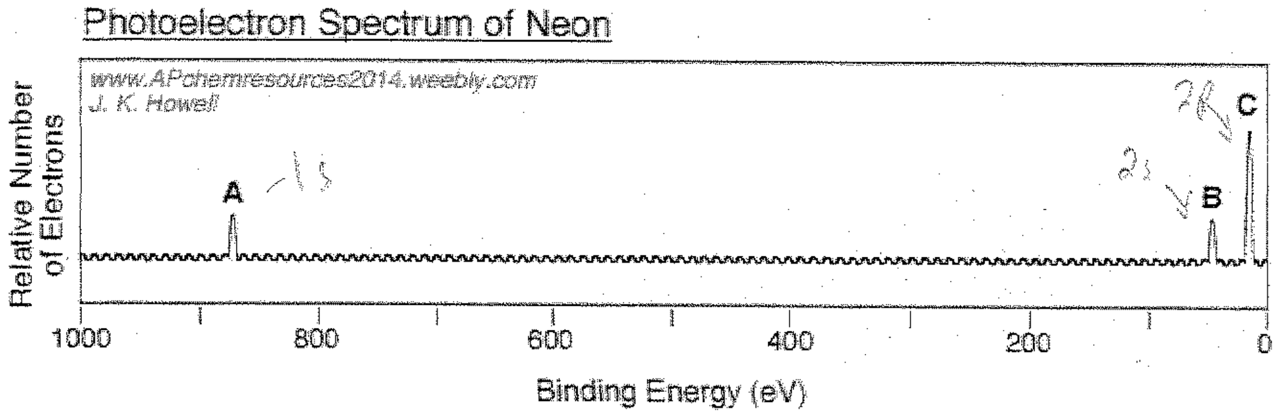
a) F<N<B<Li
b) F<N<Li<B
[✓ c) Li<B<N<F]
d) N<Li<F<B

IE ↑ as →

LO 1.7 The student is able to describe the electronic structure of the atom, using PES data, ionization energy data, and/or Coulomb's Law to construct explanations of how the energies of electrons within shells in atoms vary.

Students need to know how electrons can be arranged in an atom, including the main energy levels, orbitals, and how many electrons are in each orbital. This is influenced by Coulomb's law and it is important for the students to know that opposite charges attract and like charges repel and how that manifests in data.

Example:



Peaks A, B, and C represent the binding energies of electrons in which subshells of neon?

[✓ a. 1s, 2s, 2p]

b. 2p, 2s, 1s

c. 1s, 1s, 1s

d. 2s, 2p, 2p

LO 1.8 The student is able to explain the distribution of electrons using Coulomb's Law to analyze measured energies.

Measured energy would be ionization energy, electron affinity, or bond energy. A good question here would ask about the difference between first and second ionization energies in certain elements.

Example:

The electron affinity values for some elements are listed in the table below.

He = -19.7 eV	Li = 0.618 eV	C = 1.26 eV	O = 1.46 eV
Na = 0.547 eV	Al = 0.432 eV	X = 1.4 eV	Cl = 3.612 eV

What is the identity of element X?

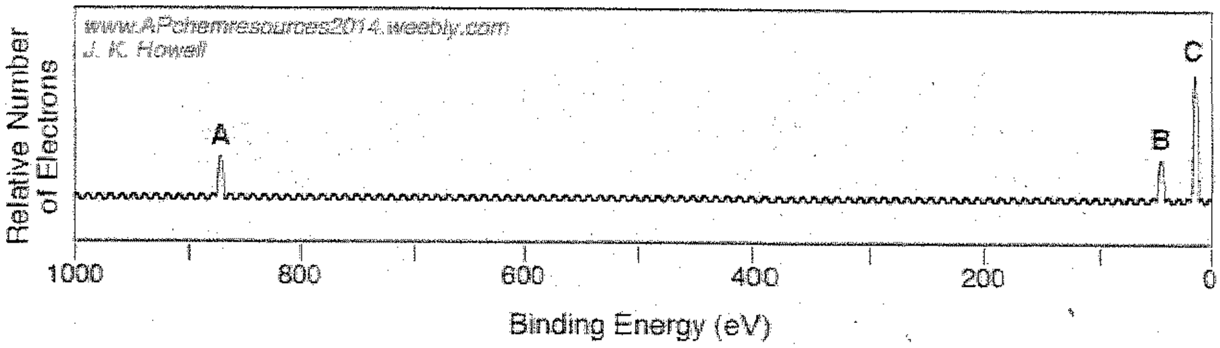
in between C and O

a) B

[✓ b) N]

c) S

d) F


Photoelectron Spectrum of Neon

Which of the following statements best accounts for peak A being far to the left of peaks B and C:

a. the electron configuration of neon is $1s^22s^22p^6$
b. neon has 8 electrons located in its valence shell
[✓ c. core electrons of an atom experience a much higher effective nuclear charge than valence electrons]
d. peaks B and C show first ionization energies of electrons in neon, whereas peak A shows the second ionization energy of neon

√ only one that applied to what question asks

LO 1.9 The student is able to predict and/or justify trends in atomic properties based on location on the periodic table and/or the shell model.

The shell model implies that this has to do with the number of layers of electrons and the row on the periodic table or perhaps the number of valence electrons and the column number on the periodic table.

Example:

Which of the following would have a lower first ionization energy than sodium?

[✓ a) K]
b) Mg
c) C
d) He

IE ↓ as ↓ column

LO 1.10 Students can justify with evidence the arrangement of the periodic table and can apply periodic properties to chemical reactivity.

Periodic properties and chemical reactivity describes the way that elements bond, like metals vs. nonmetals and the charges of ions.

Example:

Which of the following is the most reactive nonmetal?

a) I
b) Br
c) Cl
[✓ d) F]

nonmetal reactivity ↑ as ↑ column

LO 1.11 The student can analyze data, based on periodicity and the properties of binary compounds, to identify patterns and generate hypotheses related to the molecular design of compounds for which data are not supplied.

This is the different types of bonding and the relation to electronegativity difference. Ionic bonding, metallic bonding, and molecular compounds would apply here.

Example:

Which of the following groups would form ionic compounds with the halogens?

a) Noble gases
b) Halcogens (oxygen family)
[✓ c)] Alkali metals
d) Metalloids

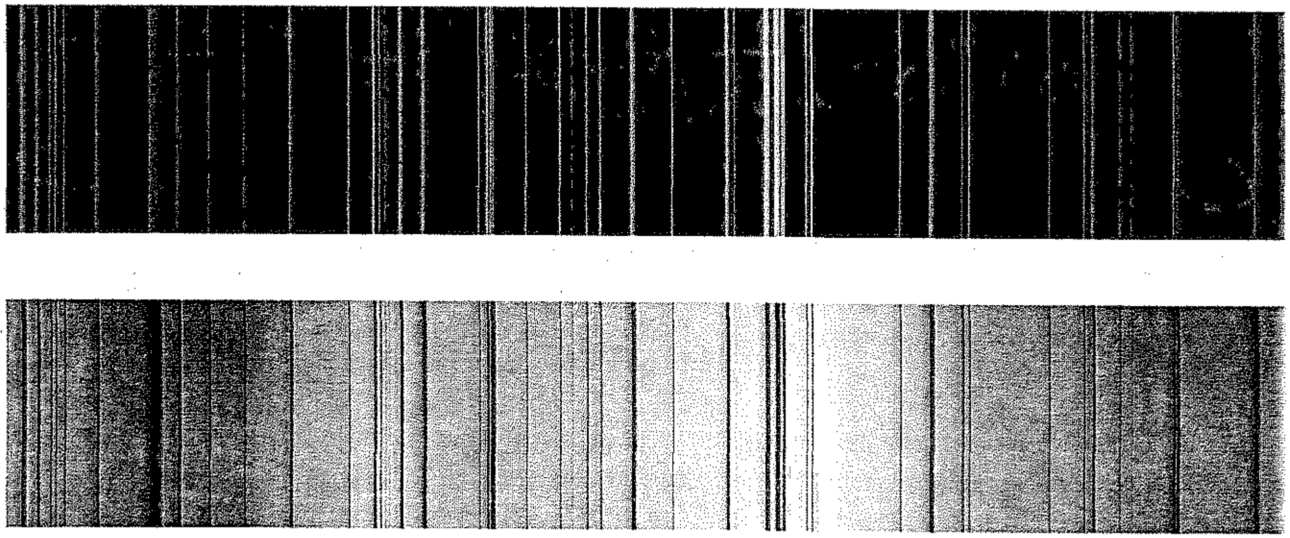
metals form ionic compounds

LO 1.12 The student is able to explain why a given set of data suggests, or does not suggest, the need to refine the atomic model from a classical shell model with the quantum mechanical model.

This may refer to the atomic emission spectra for elements above hydrogen, which leads to the refinement of the Bohr Model. It may also describe the historical data that leads to the refinement of Dalton, or Thomson, or Rutherford as well.

Example:

Describe why the atomic emission spectrum of any element is the perfect opposite of the atomic absorption spectrum for that element. e^- absorb same energy as the emit when excited



LO 1.13 Given information about a particular model of the atom, the student is able to determine if the model is consistent with specified evidence.

This is really general, but could be applied by analysis of multiple sources of data and making inferences with the data.

much higher

E_1	E_2	E_3	E_4	E_5	E_6	E_7	E_8
1012	1900	2910	4960	6270	22,200	25,400	29,900

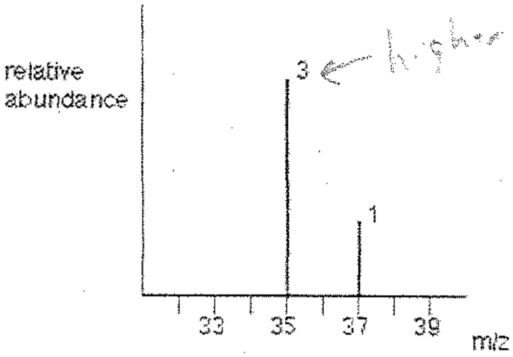
Based on the table of ionization energy above, what is the identity of the 3rd row element?

5 valence e^-

a) Mg
b) Al
[✓ c) P]
d) Cl

LO 1.14 The student is able to use data from mass spectrometry to identify the elements and the masses of individual atoms of a specific element.

This is mass spectroscopy, and the data refers to the fact that a mass spectrometer gives data about the mass of the atoms and fragments of molecules that pass through. It also gives information about abundance of isotopes of certain elements.



higher relative abundance

Above is the mass spectra of an element on the periodic table. According to the data, what can you say about the element, Chlorine?

[✓ a) There are 2 isotopes of chlorine, Cl-35 and Cl-37, and the more abundant isotope is Cl-35]
b) There are 4 isotopes of chlorine, Cl-35 and Cl-37, and the more abundant isotope is Cl-35
c) There are 4 isotopes of chlorine, Cl-35 and Cl-37, and the more abundant isotope is Cl-37
d) There are 2 isotopes of chlorine, Cl-35 and Cl-37, and the more abundant isotope is Cl-37

LO 1.15 The student can justify the selection of a particular type of spectroscopy to measure properties associated with vibrational or electronic motions of molecules.

Vibrational motion is IR spectroscopy, while electron transitions is UV-Vis spectroscopy. This might be a relation between energy of light and the wavelength.

Example:

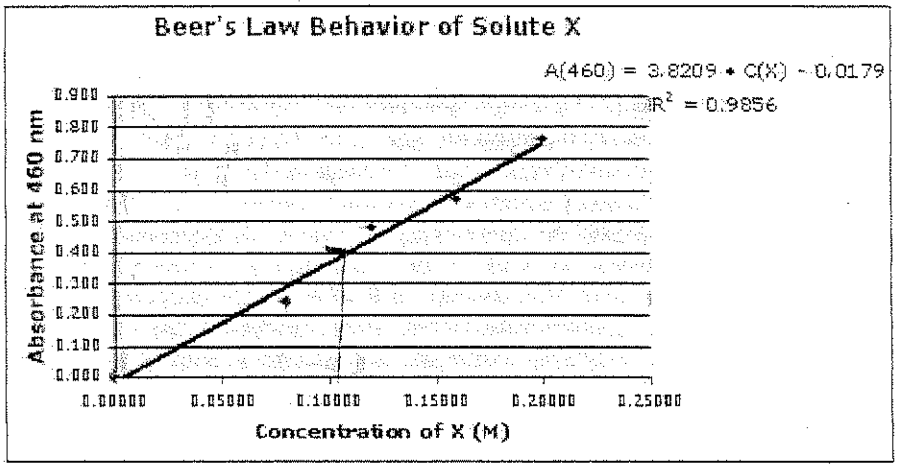
Which of the following contains a transition paired correctly with an area of the EM spectrum?

a) Vibrational motion, UV
[✓ b) Electron transitions, UV-Vis]
c) Molecular rotation, Vis
d) Vibrational motion, X-rays

LO 1.16 The student can design and/or interpret the results of an experiment regarding the absorption of light to determine the concentration of an absorbing species in a solution.

Beer's Law!

Example:



A student prepares several sample solutions to create the above calibration curve for a certain solution. If an unknown solution, of the same type, were analyzed and the absorbance was 0.40, what would be the concentration of the solution?

a) 0.050M
[✓ b) 0.12M]
c) 0.35M
d) 0.17M

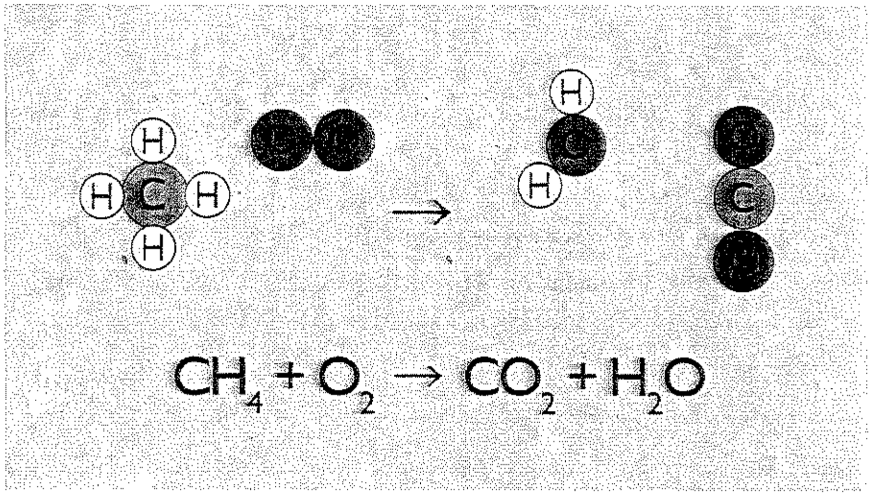
Reading a graph

LO 1.17 The student is able to express the law of conservation of mass quantitatively and qualitatively using symbolic representations and particulate drawings.

This is drawing molecules before and after a chemical reaction to show that the atoms are not created or destroyed.

Example:

The following illustration represents the reaction of methane and oxygen in a combustion reaction.



Not Balanced

What is incorrect about this representation?

- [✓ a)] It appears as if oxygen is generated and hydrogen is destroyed in the reaction
- b) It is not useful to this of molecules as atoms bonded together
- c) The reactants do not match the equation
- d) There needs to be a plus sign in the illustrations

LO 1.18 The student is able to apply conservation of atoms to the rearrangement of atoms in various processes.

Example:

Balance the following chemical reaction: $3HNO_3 + Al(OH)_3 \rightarrow 3H_2O + Al(NO_3)_3$

LO 1.19 The student can design, and/or interpret data from, an experiment that uses gravimetric analysis to determine the concentration of an analyte in a solution.

Students need to be able to use mass measurements in experiments to describe what is happening in an experiment. This could be percent yield, or dehydration of hydrated crystals, etc.

Example: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

The combustion of 0.136 kg of methane in the presence of excess oxygen produces 353 g of carbon dioxide. What is the percent yield?

- A. 38.5 %
- [✓ B. 94.6 %]
- C. 0.946 %

$136g\ CH_4 \times \frac{1mol}{16.05g} \times \frac{1mol\ CO_2}{1mol\ CH_4} \times \frac{44.01g}{1mol\ CO_2} = 373g$

$\frac{353}{373} \times 100 = 95\%$

LO 1.20 The student can design, and/or interpret data from, an experiment that uses titration to determine the concentration of an analyte in a solution.

Titration is an important lab skill for the students.

Example:

How many moles of KOH are needed to neutralize 35.0 mL of 0.115 M HNO_3 solution?

[✓ A. 4.03 x 10^{-3} moles]

B. 4.03 x 10^{1} moles

C. 1.15 x 10^{-1} moles

$$KOH + HNO_3 \rightarrow KNO_3 + H_2O$$

$$0.035 L \times \frac{0.115 mol HNO_3}{L} \times \frac{1 mol KOH}{mol HNO_3} = 0.004025 mol$$