Big Idea #1

Properties of Matter
LO 1.1: 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.
Ratio of Masses in a Pure Sample

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1) A 4.5 gram sample of which of the following would have the greatest mass percent of oxygen?
A. Na₂O (molar mass = 62 g/mol)
B. Li₂O (molar mass = 30 g/mol)
C. MgO (molar mass = 40 g/mol)
D. SrO (molar mass = 104 g/mol)

Answer:
A. \( \frac{16}{62} \times 100 = 26\% \)
B. \( \frac{16}{30} \times 100 = 53\% \)
C. \( \frac{16}{40} \times 100 = 40\% \)
D. \( \frac{16}{104} \times 100 = 15\% \)
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LO 1.1: 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.
Composition of Pure Substances and/or Mixtures

- Percent mass can be used to determine the composition of a substance
- % mass can also be used to find the empirical formula
- The empirical formula is the simplest formula of a substance
- It is a ratio between the moles of each element in the substance
- Quick steps to solve!
  - % to mass, mass to moles, divide by the smallest and multiply 'til whole!
- The molecular formula is the actual formula of a substance
- It is a whole number multiple of the empirical formula

LO 1.2: Select and apply mathematical routines to mass data to identify or infer the composition of pure substances and/or mixtures.
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- It is a whole number multiple of the empirical formula.

LO 1.2: Select and apply mathematical routines to mass data to identify or infer the composition of pure substances and/or mixtures.

Question:
A compound is determined to contain 14g nitrogen and 32g of oxygen. The empirical formula of the compound is

a. NO
b. N₂O
c. NO₂
d. NO₃
e. N₂O₅
Composition of Pure Substances

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Answer:
The correct answer is “c”, NO₂. 14g of nitrogen would be 1 mol of nitrogen (14g / 14g mol⁻¹) while 32g of oxygen would be 2 mol of oxygen (32g / 16g mol⁻¹). Therefore, the empirical formula should have a ratio of 2 oxygens for every 1 nitrogen, NO₂.

LO 1.2: Select and apply mathematical routines to mass data to identify or infer the composition of pure substances and/or mixtures.
Identifying Purity of a Substance

- Impurities in a substance can change the percent composition by mass.
- If more of a certain element is added from an impurity, then the percent mass of that element will increase and vice versa.
- When heating a hydrate, the substance is heated several times to ensure the water is driven off.
- Then you are simply left with the pure substance and no excess water.

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.
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3) The mass percent of oxygen in pure glucose, $C_6H_{12}O_6$, is 53.3 percent. A chemist analyzes a sample of glucose that contains impurities and determines that the mass percent of oxygen is 49.7 percent. Which of the follow impurities could account for the low mass percent of oxygen in the sample?
   a. n-eicosane ($C_{20}H_{42}$)
   b. ribose $C_5H_{10}O_5$
   c. fructose, $C_6H_{12}O_6$
   d. sucrose $C_{12}H_{22}O_{11}$

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- d. sucrose C$_{12}$H$_{22}$O$_{11}$

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.
Mole Calculations

- 1 mole = $6.02 \times 10^{23}$ representative particles
- 1 mole = molar mass of a substance
- 1 mole = 22.4 L of a gas at STP

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.
Mole Calculations

How many moles of carbon are in 88 grams of propane, C\textsubscript{3}H\textsubscript{8}? 

A. 2.0  
B. 16.0  
C. 6.0  
D. 96.0

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A. 2.0  
B. 16.0  
C. 6.0  
D. 96.0  

Answer: C  
Propane has a molar mass of 44, therefore there are 2 moles of propane \( \frac{88 \text{ g}}{44 \text{ g/mol}} \).  
There are 3 moles of carbon in 1 mole of propane, so \( 2 \times 3 = 6 \) moles of C.

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.
Electronic Structure of the Atom: Electron Configurations

Electrons occupy orbitals whose energy level depends on the nuclear charge and average distance to the nucleus.

Electron configurations & orbital diagrams indicate the arrangement of electrons with the lowest energy (most stable):

- Electrons occupy lowest available energy levels
- A maximum of two electrons may occupy an energy level
- Each must have opposite spin (±½)
- In orbitals of equal energy, electrons maximize parallel unpaired spins

<table>
<thead>
<tr>
<th>At #</th>
<th>Electron Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1⁺s</td>
</tr>
<tr>
<td>2</td>
<td>1⁺s²</td>
</tr>
<tr>
<td>3</td>
<td>1⁺s²2⁺s³</td>
</tr>
<tr>
<td>4</td>
<td>1⁺s²2⁺s³</td>
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<td>5</td>
<td>1⁺s²2⁺s³2⁺p</td>
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<td>6</td>
<td>1⁺s²2⁺s³2⁺p²</td>
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<tr>
<td>7</td>
<td>1⁺s²2⁺s³2⁺p²</td>
</tr>
<tr>
<td>8</td>
<td>1⁺s²2⁺s³2⁺p³</td>
</tr>
<tr>
<td>9</td>
<td>1⁺s²2⁺s³2⁺p³</td>
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<tr>
<td>10</td>
<td>1⁺s²2⁺s³2⁺p³ ([Ne]3⁺s¹)</td>
</tr>
<tr>
<td>11</td>
<td>1⁺s²2⁺s³2⁺p³3⁺s¹ ([Ne]3⁺s¹)</td>
</tr>
<tr>
<td>12</td>
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LO 1.5: The student is able to explain the distribution of electrons in an atom or ion based upon data.
Electronic Structure of the Atom:

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- Electron configurations & orbital diagrams indicate the arrangement of electrons with the lowest energy (most stable):
  - Electrons occupy lowest available energy levels.
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  - Each must have opposite spin ($\pm \frac{1}{2}$).
  - In orbitals of equal energy, electrons maximize parallel unpaired spins.

LO 1.5: The student is able to explain the distribution of electrons in an atom or ion based upon data.
Which of the following electron configurations and orbital diagrams represents Si, element #14?

(a) \[1s^2 2s^2 2p^6 3s^2 3p^2\]  
(b) \[1s^2 2s^2 2p^6 3s^2 3p^3\]  
(c) \[1s^2 2s^2 2p^6 3s^2 3p^2\]  
(d) \[1s^2 2s^2 2p^6 3s^2 3p^2\]

Answer: C. The 11th & 12th electrons occupy the 3s orbital, and the last two electrons occupy the 3p orbitals, and to maximize the unpaired parallel spins, they must individually occupy different 3p orbitals.

LO 1.5: The student is able to explain the distribution of electrons in an atom or ion based upon data.
Electronic Structure of the Atom: 1\textsuperscript{st} Ionization Energy

- 1\textsuperscript{st} Ionization Energy (IE) indicates the strength of the coulombic attraction of the outermost, easiest to remove, electron to the nucleus:

\[ X(g) + \text{IE} \rightarrow X^+(g) + e^- \]

- 1\textsuperscript{st} IE generally increases across a period and decreases down a group

- IE generally increases as #protons increases in same energy level

- IE decreases as e\textsuperscript{-} in higher energy level: increased shielding, e\textsuperscript{-} farther from nucleus

LO 1.6: The student is able to analyze data relating to electron energies for patterns and relationships.
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IE generally increases as the number of protons increases in the same energy level.

IE decreases as the electron in a higher energy level is removed: increased shielding, electron farther from the nucleus.

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Electronic Structure of the Atom: Photoelectron Spectroscopy (PES)

- PES uses high-energy (X-ray) photon to excite random $e^{-}$ from atom
- KE of ejected electron indicates binding energy (coulombic attraction) to nucleus:
  \[ BE = \hbar \omega_{\text{photon}} - KE \]
- Direct measurement of energy and number of each electron
- Lower energy levels have higher BE
- Signal size proportional to number of $e^{-}$ in energy level
- Elements with more protons have stronger coulombic attraction, higher BE at each energy level

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.
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Which element could be represented by the complete PES spectrum above?

A. Li  B. B  C. N  D. O  E. Ne
Electronic Structure of the Atom:

Photoelectron Spectroscopy (PES)

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Which element could be represented by the complete PES spectrum above?

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Answer: C. The first peak at about 60 (units are MJ/mol) represents the two 1s electrons, the second peak is the two 2s electrons, and the third peak represents three 2p electrons.
Electronic Structure of the Atom: Higher Ionization Energies

- 2\textsuperscript{nd} & subsequent IE's increase as coulombic attraction of remaining e\textsuperscript{−}'s to nucleus increases
- \( X^+ + \text{IE} \rightarrow X^{2+} + e^- \)
- \( X^{2+} + \text{IE} \rightarrow X^{3+} + e^- \)
- Large jump in IE when removing less-shielded core electrons

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8)

<table>
<thead>
<tr>
<th>Ionization Energies for element X (kJ mol(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>1086</td>
</tr>
</tbody>
</table>

The ionization energies for element X are listed in the table above. On the basis of the data, element X is most likely to be

A. Li  B. Be  C. B  D. C  E. P

Answer: D. There is a large increase in IE from IE\(_4\) to IE\(_5\), indicating that the element has 4 valence electrons and is in group IVA. Carbon is the only listed element in group IVA.

LO 1.8: The student is able to explain the distribution of electrons using Coulomb’s law to analyze measured energies.
Electronic Structure of the Atom:

1\textsuperscript{st} Ionization Energy Irregularities

- 1\textsuperscript{st} Ionization Energy (IE) decreases from Be to B and Mg to Al
- Electron in 2p or 3p shielded by 2s\textsuperscript{2} or 3s\textsuperscript{2} electrons, decreasing coulombic attraction despite additional proton in nucleus.
- Same effect seen in 3d\textsuperscript{10}-4p, 4d\textsuperscript{10}-5p and 5d\textsuperscript{10}-6p
- 1\textsuperscript{st} Ionization Energy decreases from N to O and P to S
- np\textsuperscript{4} contains first paired p electrons, e\textsuperscript{-}-e\textsuperscript{-} repulsion decreases coulombic attraction despite additional proton

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Given the photoelectron spectra above for phosphorus, P, and sulfur, S, which of the following best explains why the 2p peak for S is further to the left than the 2p peak for P, but the 3p peak for S is further to the right than the 3p peak for P?

A. S has a greater effective nuclear charge than P, and the 3p sublevel in S has greater electron repulsions than in P.
B. S has a greater effective nuclear charge than P, and the 3p sublevel is more heavily shielded in S than in P.
C. S has a greater number of electrons than P, so the third energy level is further from the nucleus in S than in P.
D. S has a greater number of electrons than P, so the Coulombic attraction between the electron cloud and the nucleus is greater in S than in P.
1st Ionization Energy Irregularities

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D. S has a greater number of electrons than P, so the Coulombic attraction between the electron cloud and the nucleus is greater in S than in P.

Answer: A. S has one more proton than P, so a higher effective nuclear charge. However, due to the 3p⁵ configuration of S, it experiences e– e– repulsion due to the paired 3p electrons that are not present in the 3p⁵ configuration of P. This reduces the coulombic attraction of the 3p electrons of S to the nucleus, so it has a lower binding energy (BE).
Predictions with Periodic Trends

The following explains these trends:

- Electrons attracted to the protons in the nucleus of an atom
  - So the closer an electron is to a nucleus, the more strongly it is attracted (Coulomb’s law)
  - The more protons in a nucleus (effective nuclear force), the more strong it attracts electrons
- Electrons are repelled by other electrons in an atom. If valence electrons are shielded from nucleus by other electrons, you will have less attraction of the nucleus (again Coulomb’s law-greater the atomic radius, the greater the distance)

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

Coulomb’s Law – Gives the electric force between two point charges.

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

- **Inverse Square Law**
- \( k = \) Coulomb’s Constant = \( 9.0 \times 10^9 \) Nm\(^2\)/C\(^2\)
- \( q_1, q_2 = \) charge on mass 1
- \( r = \) the distance between the two charges
The electric force is much stronger than the gravitational force.
The following explains these trends:

- Electrons attracted to the protons in the nucleus of an atom follow Coulomb's law.
- The more protons in a nucleus (effective nuclear force), the more strongly it attracts electrons.
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**Question:**

Given the atomic radius and first ionization energy of sodium in the chart below, which pair of values would be the most likely values for magnesium?

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<td>Sodium</td>
<td>495.8</td>
<td>180</td>
</tr>
<tr>
<td>Magnesium</td>
<td></td>
<td></td>
</tr>
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</table>

- a. 737.7 kJ/mol, 150 pm
- b. 737.7 kJ/mol, 200 pm
- c. 290.4 kJ/mol, 150 pm
- d. 290.4 kJ/mol, 200 pm

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Chemical Reactivity

Using Trends

- Nonmetals have higher electronegativities than metals --&gt; causes the formation of ionic solids

- Compounds formed between nonmetals are molecular
  - Usually gases, liquids, or volatile solids at room temperature

- Elements in the 3rd period and below can accommodate a larger number of bonds

- The first element in a group (upper most element of a group) forms pi bonds more easily (most significant in 2nd row, non-metals)
  - Accounts for stronger bonds in molecules containing these elements
  - Major factor in determining the structures of compounds formed from these elements

- Elements in periods 3-6 tend to form only single bonds

- Reactivity tends to increase as you go down a group for metals and up a group for non-metals.

L.O. 1.10: Students can justify with evidence the arrangement of the periodic table and can apply periodic properties to chemical reactivity
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  - The first element in a group (uppermost element of a group) forms π bonds more easily (most significant in 2nd row, nonmetals).
  - Accounts for stronger bonds in molecules containing these elements.
  - Accounts for the major factor in determining the structures of compounds formed from these elements.
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L.O. 1.10: Students can justify with evidence the arrangement of the periodic table and can apply periodic properties to chemical reactivity.

Of the elements below, __________ reacts the most quickly with water.

A) sodium
B) barium
C) calcium
D) cesium
E) magnesium
Chemical Reactivity

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Chemical Properties within a Group and across a Period

- Group 1 metals more reactive than group 2 metals
- Reactivity increases as you go down a group
- Metals on left form basic oxides
  - Ex. \( \text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{NaOH} \)
- Nonmetals on right form acidic oxides
  - Ex. \( \text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4 \)
- Elements in the middle, like Al, Ga, etc can behave amphotERICally
- If SiO\(_2\) can be a ceramic then SnO\(_2\) may be as well since both in the same group

LO 1.11: Analyze data, based on periodicity & properties of binary compounds, to identify patterns & generate hypotheses related to molecular design of compounds
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LO 1.11: Analyze data, based on periodicity & properties of binary compounds, to identify patterns & generate hypotheses related to molecular design of compounds

Question:
Which of the following groups from the periodic table would be the easiest to oxidize?
- a. Halogens
- b. Transition metals
- c. Transuranic
- d. Alkali metals
- e. Alkali earth metals

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Click reveals answer and explanation.
Chemical Properties within a Group and across a Period

- Group 1 metals more reactive than group 2 metals
- Reactivity increases as you go down a group
- Metals on left form basic oxides
  - Ex. $\text{Na}_2\text{O} + \text{H}_2\text{O} \rightarrow 2\text{NaOH}$
- Nonmetals on right form acidic oxides
  - Ex. $\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$
- Elements in the middle, like Al, Ga, etc. can behave amphoterically
  - If SiO$_2$ can be a ceramic then SnO$_2$ may be as well since both in the same group

**Question:**
Which of the following groups from the periodic table would be the easiest to oxidize?
- a. Halogens
- b. Transition metals
- c. Transuranic
- d. Alkali metals
- e. Alkali earth metals

**Answer:**
The correct answer is **d**. Oxidation involves the loss of electrons, so the group of elements that has the lowest ionization energy would be the easiest to oxidize. The alkali metals have the lowest ionization energy due to the low number of protons compared to the energy level of their lone valence electron.
Classic Shell Model of Atom vs Quantum Mechanical Model

Shell Model - Bohr

Developed by Schrodinger and the position of an electron is now represented by a wave equation
- Most probable place of finding an electron is called an ORBITAL (90% probability)
- Each orbital can only hold 2 electrons with opposing spins (S, P, D & F orbitals)

Evidence for this theory:
- Work of DeBroglie and Planck that electron had wavelike characteristics
- Heisenberg Uncertainty Principle - impossible to predict exact location of electron- contradicted Bohr
- This new evidence caused the Shell Theory to be replaced by the Quantum Mechanical Model of the atom

LO 1.12: Explain why data suggests (or not) the need to refine a model from a classical shell model with the quantum mechanical model
Shell Model is consistent with Ionization Energy Data

The patterns shown by the IE graph can be explained by Coulomb’s law:
- As atomic number increases, would expect the ionization energy to constantly increase.
- Graph shows that this is NOT observed. WHY NOT?
- The data implies that a shell becomes full at the end of each period.
- Therefore the next electron added must be in a new shell farther away from the nucleus.
- This is supported by the fact that the ionization energy drops despite the addition positive charge in the nucleus.

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.
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Mass spectrometry showed that elements have isotopes:

- This contradicted Dalton’s early model of the atom which stated that all atoms of an element are identical.
- 3 Br\(_2\) & two Br isotopes shown in diagram.
- The average atomic mass of the element can be estimated from mass spectroscopy.

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

\[
\text{Average Atomic Mass} = \frac{\sum (\text{mass of isotope} \times \% \text{ natural abundance})}{100}
\]
Mass Spectrometry - evidence for isotopes

Mass spectrometry showed that elements have isotopes.

- This contradicted Dalton’s early model of the atom which stated that all atoms of an element are identical.
- For example, Br has two isotopes shown in the diagram.
- The average atomic mass of the element can be estimated from mass spectrometry.

Question:

Both Zr and Nb have similar average atomic masses. Above is the mass spectrum of a sample that was believed to have both Zr and Nb. Which of the following statements would be the best explanation for deciding that the sample contained only Zr?

a. Both elements will form ions with many different charges.
b. Zr has 2 unpaired electrons while Nb has 3.
c. Zr has a lower first ionization energy than Nb.
d. Nb has only one stable isotope with a mass of 93 amu.
Mass Spectrometry - evidence for isotopes

Mass spectrometry showed that elements have isotopes.

This contradicted Dalton's early model of the atom which stated that all atoms of an element are identical.

3 Br

2

& two Br isotopes shown in diagram.

The average atomic mass of the element can be estimated from mass spectroscopy.

Answer:
The correct answer is “d” Nb has only one stable isotope with a mass of 93 amu. While all of the statements are true only answer d would indicate that Nb is missing from the sample. If Nb’s stable isotope has a mass of 93 amu we would expect some peak at that mass in the mass spectrum. Since there were no atoms measured with that mass, we can conclude that there is no Nb in the sample.

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b. Zr has 2 unpaired electrons while Nb has 3.
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Using Spectroscopy to measure properties associated with vibrational or electronic motions of molecules

**IR Radiation** - detects different types of bonds by analyzing molecular vibrations

**UV or X-Ray Radiation**
- Photoelectron Spectroscopy (PES)
- Causes electron transitions
- Transitions provide info on electron configurations

LO: 1.15 Justify the selection of a particular type of spectroscopy to measure properties associated with vibrational or electronic motions of molecules
Using Spectroscopy to measure properties associated with vibrational or electronic motions of molecules

- **IR Radiation**
  - Detects different types of bonds by analyzing molecular vibrations

- **UV or X-Ray Radiation**
  - Photoelectron Spectroscopy (PES)
  - Causes electron transitions
  - Transitions provide info on electron configurations

**LO: 1.15** Justify the selection of a particular type of spectroscopy to measure properties associated with vibrational or electronic motions of molecules

Which one of the following contains a transition paired correctly with an area of high absorption in the electromagnetic spectrum?

- (a) Electronic transition, microwaves
- (b) Electronic transition, infrared radiation
- (c) Molecular rotation, infrared radiation
- (d) Molecular vibration, infrared radiation
Using Spectroscopy to measure properties associated with vibrational or electronic motions of molecules

- IR Radiation: detects different types of bonds by analyzing molecular vibrations.
- UV or X-Ray Radiation:
  - Photoelectron Spectroscopy (PES): causes electron transitions, providing information on electron configurations.

LO: 1.15 Justify the selection of a particular type of spectroscopy to measure properties associated with vibrational or electronic motions of molecules.

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- b. Electronic transition, infrared radiation
- c. Molecular rotation, infrared radiation
- d. Molecular vibration, infrared radiation

**Source**
Beer-Lambert Law - used to measure the concentration of colored solutions

\[ A = abc \]

\( A \) = absorbance  
\( a \) = molar absorptivity (constant for material being tested)  
\( b \) = path length (cuvette = 1 cm)  
\( c \) = concentration

- Taken at fixed wavelength

LO1.16: Design and/or interpret the results of an experiment regarding the absorption of light to determine the concentration of an absorbing species in solution
Question:

Using the absorbance vs. concentration graph given above. A student is trying to determine the concentration of an unknown substance. If the student measures the absorbance to be 0.4 what would be the concentration of the unknown?

a. 0.04  
b. 0.28  
c. 0.40  
d. 0.42  
e. 0.56
Using the absorbance vs. concentration graph given above. A student is trying to determine the concentration of an unknown substance. If the student measures the absorbance to be 0.4 what would be the concentration of the unknown?

a. 0.04  
b. 0.28  
c. 0.40  
d. 0.42  
e. 0.56

**Answer:**
The correct answer is “b” 0.28. Based on the Beer-Lambert law, for small concentration ranges there is a linear relationship between absorbance and concentration. For an absorbance of 0.4 the corresponding concentration is 0.28.
Law of Conservation of Mass

\[ \text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3 \]

LO1.17: Express the law of conservation of mass quantitatively and qualitatively using symbolic representations and particulate drawings
Law of Conservation of Mass

2 \text{H}_2(g) + \text{O}_2(g) \rightarrow 2\text{H}_2\text{O}(g)

The picture above is a representation of \text{H}_2(g) and \text{O}_2(g) in a sealed container. Which of the following pictures would be the best representation of the products if the reaction below were to run to completion?

Click reveals answer and explanation.
Law of Conservation of Mass

\[ \text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3 \]

The picture above is a representation of \( \text{H}_2(g) \) and \( \text{O}_2(g) \) in a sealed container. Which of the following pictures would be the best representation of the products if the reaction below were to run to completion?

\[ 2\text{H}_2(g) + \text{O}_2(g) \rightarrow 2\text{H}_2\text{O}(g) \]

a. 

b. 

c. 

d. 

e. 

Answer:
The correct answer is “d”. In the balanced chemical equation we need 2 hydrogen atoms for each oxygen atom to form water. We will use up all the hydrogen molecules and have one oxygen molecule left over.
Use Mole Ratio in balanced equation to calculate moles of unknown substance

**Chemical Reactions**

*Using Mole Ratios*

Using the balanced reaction below for the combustion of propane, calculate the number of moles of CO₂ produced if 3.52 g C₃H₈ are burned in excess O₂.

\[ C_3H_8 (g) + 5O_2 (g) \rightarrow 3CO_2 (g) + 4H_2O (g) \]

? moles

**molar mass C₃H₈**

\[
\frac{3 \times 12.01 \text{ g/mol}}{44.11 \text{ g/mol}} = \frac{36.03 \text{ g/mol}}{44.11 \text{ g/mol}}
\]

**mole ratio**

\[
\frac{1 \text{ mole } C_3H_8}{3 \text{ moles } CO_2}
\]

\[
0.0798 \text{ mol } C_3H_8 \times \frac{3 \text{ mol } CO_2}{1 \text{ mole } C_3H_8} = 0.239 \text{ mol } CO_2
\]

**LO1.18:** Apply the conservation of atoms to the rearrangement of atoms in various processes.
Gravimetric Analysis

Buchner Filtration Apparatus

How much lead ($\text{Pb}^{2+}$) in water?

$$\text{Pb}^{2+}(\text{aq}) + 2\text{Cl}^- (\text{aq}) \rightarrow \text{PbCl}_2 (s)$$

- By adding excess Cl$^-$ to the sample, all of the Pb$^{2+}$ will precipitate as PbCl$_2$.
- Solid product is filtered using a Buchner Filter and then dried to remove all water.
- Mass of PbCl$_2$ is then determined.
- This can be used to calculate the original amount of lead in the water.

LO 1.19: Design and/or interpret data from, an experiment that uses gravimetric analysis to determine the concentration of an analyte in a solution.
Gravimetric Analysis

Buchner Filtration

Apparatus

How much lead ($\text{Pb}^{2+}$) in water?

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<table>
<thead>
<tr>
<th>Mass of KI tablet</th>
<th>0.425 g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of thoroughly dried filter paper</td>
<td>1.462 g</td>
</tr>
<tr>
<td>Mass of filter paper + precipitate after first drying</td>
<td>1.775 g</td>
</tr>
<tr>
<td>Mass of filter paper + precipitate after second drying</td>
<td>1.699 g</td>
</tr>
<tr>
<td>Mass of filter paper + precipitate after third drying</td>
<td>1.698 g</td>
</tr>
</tbody>
</table>

1. A student is given the task of determining the $\text{I}^-$ content of tablets that contain KI and an inert, water-soluble sugar as a filler. A tablet is dissolved in 50.0 mL of distilled water, and an excess of $0.20 \, \text{M} \, \text{Pb(NO}_3)_2(\text{aq})$ is added to the solution. A yellow precipitate forms, which is then filtered, washed, and dried. The data from the experiment are shown in the table above.

(a) For the chemical reaction that occurs when the precipitate forms,
   (i) write a balanced, net-ionic equation for the reaction, and
   (ii) explain why the reaction is best represented by a net-ionic equation.

(b) Explain the purpose of drying and weighing the filter paper with the precipitate three times.

(c) In the filtrate solution, is $[\text{K}^+]$ greater than, less than, or equal to $[\text{NO}_3^-]$? Justify your answer.

(d) Calculate the number of moles of precipitate that is produced in the experiment.

(e) Calculate the mass percent of $\text{I}^-$ in the tablet.

(f) In another trial, the student dissolves a tablet in 55.0 mL of water instead of 50.0 mL of water. Predict whether the experimentally determined mass percent of $\text{I}^-$ will be greater than, less than, or equal to the amount calculated in part (e). Justify your answer.
Gravimetric Analysis

Buchner Filtration

Apparatus

How much lead (Pb\(^{2+}\)) in water?

\[
Pb^{2+} + 2\text{I}^- \rightarrow Pb\text{I}_2
\]

 By adding excess \(\text{Cl}^-\) to the sample, all of the \(\text{Pb}^{2+}\) will precipitate as \(\text{PbCl}_2\).

 Solid product is filtered using a Buchner Filter and then dried to remove all water.

 Mass of \(\text{PbCl}_2\) is then determined.

 This can be used to calculate the original amount of lead in the water.

Source

LO 1.19: Design and/or interpret data from an experiment that uses gravimetric analysis to determine the concentration of an analyte in a solution.
(d) Calculate the number of moles of precipitate that is produced in the experiment.

\[
1.698 \text{ g} - 1.462 \text{ g} = 0.236 \text{ g Pbi}_2(s)
\]

\[
0.236 \text{ g Pbi}_2 \times \frac{1 \text{ mol Pbi}_2}{461.0 \text{ g Pbi}_2} = 5.12 \times 10^{-4} \text{ mol Pbi}_2
\]

1 point is earned for the correct number of moles of Pbi$_2$(s) precipitate.

(e) Calculate the mass percent of I$^-$(aq) in the tablet.

\[
5.12 \times 10^{-4} \text{ mol Pbi}_2 \times \frac{2 \text{ mol I}^-}{1 \text{ mol Pbi}_2} = 1.02 \times 10^{-3} \text{ mol I}^-
\]

\[
1.02 \times 10^{-3} \text{ mol I}^- \times \frac{126.91 \text{ g I}^-}{1 \text{ mol I}^-} = 0.130 \text{ g I}^- \text{ in one tablet}
\]

\[
\frac{0.130 \text{ g I}^-}{0.425 \text{ g KI tablet}} = 0.306 = 30.6% \text{ I}^- \text{ per KI tablet}
\]

1 point is earned for determining the number of moles of I$^-$ in one tablet.

1 point is earned for calculating the mass percent of I$^-$ in the KI tablet.

(f) In another trial, the student dissolves a tablet in 55.0 mL of water instead of 50.0 mL of water. Predict whether the experimentally determined mass percent of I$^-$ will be greater than, less than, or equal to the amount calculated in part (e). Justify your answer.

The mass percent of I$^-$ will be the same. Pb$^{2+}$(aq) was added in excess, ensuring that essentially no I$^-$ remained in solution. The additional water is removed by filtration and drying, leaving the same mass of dried precipitate.

1 point is earned for correct comparison with a valid justification.
Using titrations to determine concentration of an analyte

At the equivalence point, the stoichiometric molar ratio is reached

LO1.20: Design and/or interpret data from an experiment that uses titration to determine the concentration of an analyte in a solution.
Using titrations to determine concentration of an analyte.

LO1.20: Design and/or interpret data from an experiment that uses titration to determine the concentration of an analyte in a solution.

At the equivalence point, the stoichiometric molar ratio is reached.

a. A  
b. B  
c. C  
d. D  
e. E

The graph below is of the titration of a weak base with hydrochloric acid. Based on the graph which point would represent the pH of the solution at the equivalence point?

Click reveals answer and explanation.
The graph below is of the titration of a weak base with hydrochloric acid. Based on the graph which point would represent the pH of the solution at the equivalence point?

![Titration Graph]

a. A  
b. B  
c. C  
d. D  
e. E

Answer:
The correct answer is “d” D. The equivalence point of a titration is when the moles of acid are equal to the moles of base. On a titration curve it is the middle of the vertical section. For the titration of a week base the pH at the equivalence point will be less than 7 so point D is the correct answer.