Name _____

<u>Laws of Multiple and Definite Proportions and Conservation of Mass</u> Classwork:

1. Exactly twice as much oxygen is required to react with 1 gram of hydrogen to form hydrogen peroxide as compared to the amount needed to react with 1 gram of hydrogen to form water.

a) Does the data above support the law of multiple proportions or that of definite proportions? Justify your answer.

b) Both water and hydrogen peroxide are pure substances. Does the % by mass of hydrogen and oxygen in each vary with the size of the sample? Justify your answer.

2. A student purchases hydrogen peroxide from two different suppliers and then analyzed the % oxygen by mass in each. The data is below:

<u>Supplier</u>	<u>% by mass oxygen in sample</u>	
А	90%	
В	93%	

a) Considering that the formula for hydrogen peroxide is H_2O_2 , how would you prove that neither of these samples is pure hydrogen peroxide?

b) What are materials called that are not pure?

c) Assuming the other substance present is water (H_2O), which sample contains a greater % of hydrogen peroxide? Justify your answer.

3. Iron can form different oxides. Using the data below:

Oxide of iron	<u>% by mass iron</u>
A	77.73%
В	69.94%

a) Using calculations, demonstrate how this data supports the law of multiple proportions.

b) Both oxide consist of iron cations and oxide anions. Which oxide contains the iron ion with the higher + charge? Justify your answer.

c) How many oxide anions are present in a 48 gram sample of oxide B?

1. A mixture of table salt (NaCl) and water has a total mass of 345 grams. Upon analysis, it was determined that 48 grams of oxygen were present in the sample.

a) How many grams of each of the following MUST also be in the sample.

- i) hydrogen
- ii) sodium
- iii) chloride

b) What law (multiple proportions or definite proportions) was applied in part "a" above? Justify your answer.

2. Which scientific laws are illustrated by the observations below? In each case, justify your answer.

a) When 10 grams of calcium oxide decomposes, 7.14 grams of calcium are produced along with 2.86 grams of oxygen gas.

b) The mass of oxygen that reacts with 1 gram of hydrogen to make water is always half the mass of the amount of sulfur required to react with 1 gram of hydrogen to make hydrogen sulfide gas.

c) When carbon and oxygen react, carbon monoxide (CO) and carbon dioxide (CO_2) are formed.

3. An entrepreneur says they have discovered a vein of pure CuO in a particular region of the rocky mountains.

a) How would you propose verifying that her claim is true - that the CuO is in fact pure? Support your proposal by citing expected results from your experiment if the sample were pure vs. impure.

b) What law (definite composition or multiple proportions) was applied in your proposal?

c) If the sample were pure, how many grams of copper could be excavated from a 400 gram sample of rock?

4. Propane and propyne are both compounds that consist of carbon and hydrogen. Using the data below, justify with calculations how this demonstrates the law of multiple proportions:

Compound	<u>g of carbon reacted</u>	<u>g of H₂ gas reacted</u>
Propane	5.25	1.167
Propyne	1.50	0.167

Atomic Masses

Classwork:

- 1. Scientists first tried to define one atomic mass unit as the mass of a hydrogen atom and then as the mass of 1/16 of an oxygen atom.
 - a. What discovery prompted scientists to define the unified atomic mass unit (u) in a more specific way? Explain.
 - b. How is the unified atomic mass unit "u" defined now?
- 2. The mass reported on the periodic table for chlorine is 35.45 u.
 - a. Why, when a sample of chlorine gas is examined with a mass spectrometer, there is no peak in the spectrum with a mass of 35.45 u?
 - b. Explain how a mass spectrometer determines the mass of the particles sampled.
- 3. Silicon is a metalloid used in the computer industry. It consists of three isotopes:
 - Si 28 (27.9769) Si – 29 (28.9765) Si – 30 (29.9794)
 - a. Which isotope is most abundant? Explain your reasoning.
 - b. If 3.09% of all silicon atoms in a sample are Si-30, what are the abundances of the other two isotopes?
 - c. Draw the mass spectra for silicon below, clearly indicating the following:
 - i) Proper axis
 - ii) Most abundant isotope with an intensity of 100
 - iii) Proper relative intensity of other peaks
 - d. How many Si-28 atoms are present in a 2.00 gram sample of pure silicon?
- 4. Below is the mass spectra of zirconium (Zr).



- a. How is the "y" axis labeled differently than the spectra you sketched in #3c?
- b. Determine the average atomic mass of Zr justify with calculations.

1. Elemental oxygen is typically found in nature as O₂ gas. There are three stable isotopes of oxygen atoms (O-16, O-17, and O-18). Below is the mass spectrum of oxygen gas.



- a. What does this spectra show regarding the relative abundances of these three isotopes? Justify your conclusions.
- b. What is currently wrong with the "y" axis on this graph? What would be the masses of the other peaks on this chart and identify the composition of each peak.
- 2. Below can be found the mass spectrum of a pure element.



- a. Using a ruler, determine the % abundance of each isotope.
- b. Calculate the average atomic mass and identify the element.
- 3. Silver consists of two stable isotopes, one with a mass of 106.90509 and an abundance of 51.84%. What is the abundance and mass of the other isotope?

4. HCl gas can be made from reacting hydrogen and chlorine gas. Chlorine has two stable isotopes: CI-35 and CI-37. Assuming H is almost entirely H-1:

- a. Determine the relative abundance of each isotope of chlorine
- b. Sketch the mass spectra for HCl clearly showing:
 - i) The proper labels of each axis
 - ii) All possible peaks at appropriate and labeled intensities

Bohr and Rutherford Model of the Atom

Classwork:

- 1. The atomic model has evolved significantly since Daltons original atomic theory.
 - a. What two discoveries compelled revision of elements of Dalton's atomic theory? Explain how.
 - b. How is the Rutherford model different than the plum pudding model and what experimental evidence supported his model?
 - c. How did the Bohr model explain the existence of spectra lines?
- 2. When lithium is vaporized and energized, a spectral line with wavelength of roughly 698 nm is produced.
 - a. Is this more or less energetic than light with a wavelength of 650 nm? Explain.
 - b. How much energy is emitted by the photon of light with wavelength of 698 nm? How much energy would be emitted by a mole of these photons?
 - c. Which electronic transition within a lithium atom would emit more energy $(2 \rightarrow 1 \text{ or } 3 \rightarrow 2)$? Justify your answer.
- 3. Photoelectron spectroscopy (PES) provides support for the notion than electrons are found only at discrete distances from the nucleus.
 - a. Describe how PES works.
 - b. Describe what determines:
 - i) Intensity of electron signal
 - ii) Binding energy of a particular peak
- 4. Below are modified PES spectra for helium, neon, and krypton.



- a. Explain how helium (despite having two electrons) demonstrates only 1 peak and how this supports the Bohr model of the atom.
- b. The PES spectra for neon indicates there are how many discrete orbits where electrons could exist? For Kr?
- c. Were the number of orbits greater or less than Bohr had predicted?
- d. What is the binding energy of the peak in the neon spectra that is produced by the removal of electrons in the orbit closest to the nucleus? Justify your reasoning.

- 1. Rutherford determined that the protons were densely packed together in the nucleus instead of spread out as in the plum pudding model.
 - a. How is the number of protons related to the atomic number of an atom?
 - b. What specific evidence was there for the Rutherford nucleus?
- 2. The Bohr model was postulated as a way to explain spectral line observations. Explain how the Bohr model explained the following:
 - a. Why we see emission spectra instead of a continuous spectra when atoms are energized?
 - b. Why spectral lines are not all the same color or frequency?
- 3. The difference in energy between Bohr orbits N=1 and N= 3 in a hydrogen atom is 1.93×10^{-18} Joules.
 - a. What wavelength (in nm) of light would need to be absorbed to promote an electron transition from N=1 to N=3?
 - What is the difference between the ground and excited state of an electron and which (N=1 or N=3) represents the excited state? Explain your reasoning.
- 4. The PES spectra for carbon shows three distinct peaks. See below:



Binding energy

- a. How many electrons does carbon have?
- b. Explain why there is not a distinct peak for each electron and how this supports the Bohr model of the atom.
- c. The existence of the three peaks in the PES spectra of carbn, along with other observations such as the existence of hyperfine spectral lines all pointed to:

Choose one and justify your reasoning:

1) A more complex atom with a greater number of allowed locations for electrons

2) A simpler atom with fewer allowed locations of electrons than Bohr postulated.

3) Electrons having an infinite number of possible locations around the nucleus.

Quantum Model of the Atom and Electron Configurations Classwork

- 1. One of the problems with the Bohr model was understanding why the orbits of the electrons do not decay into the nucleus:
 - a. Why would we expect the orbits of the electrons to decay?
 - b. What evidence existed that they do not decay?
 - c. How did de-Broglie explain the stability of the Bohr orbits and explain why this prompted the development of the quantum model of the atom?
- 2. The quantum model postulates the quantum state of an electron as being described by four quantum numbers. Which quantum number (principal, azimuthal, magnetic, or spin) provides information related to the following?
 - a. Specific orientation of an orbital
 - b. Main energy level of an electron
 - c. Specific orbital an electron occupies (s,p,d,or f)
- 3. Both the Bohr and Quantum model predicted 8 electrons could fit in the second main energy level.
 - a. Describe how the quantum model differs from the Bohr model in how these electrons are arranged in this second main energy level.
 - b. Go to the following website and describe how the quantum model explains the following:

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

- i. Why boron's lowest energy peak has a lower intensity then the higher energy peak at a binding energy of 1.36?
- ii. Why calcium's highest energy PES peak has the same intensity of the it's lowest energy PES peak?
- 4. Criticize the following statements:
 - a. The aufbau principle dictates that the 3d orbital can fit a maximum of 10 electrons.
 - b. The pauli exclusion principle dictates that electrons will fill orbitals of lowest energy first.
- 5. Go to the following website and answer the following:

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

- a. Which orbitals and how many electrons are present in the following peaks of the spectra in aluminum:
 - i. Peak with binding energy of 151

- ii. Peak with binding energy of 7.19
- iii. Peak with binding energy of 0.58
- b. Examine the PES spectra for sulfur and determine what evidence exists to support the quantum model assertion that all 3 orientations of the p orbital are degenerate ie they are of the same energy.
- Write the correct electron configuration for the following:
 a. Ti
 b. Ti²⁺
 c. N³⁻
 d. Zn
- 7. What is the difference between core and valence electrons and which are shown in a shorthand electron configuration?
- 8. Describe Hund's rule and how it influences the way an orbital diagram is written. Show the shorthand orbital diagram for carbon and how it obeys Hund's rule.
- 9. How many unpaired electrons are in the following:
 a. Sr²⁺
 b. Sn⁴⁺
 c. Sn
 d. I
 e. Fe
- 10. Studies with magnetic properties of elements helped corroborate the quantum model.
 - a. What is the difference between para and dia magnetism?
 - b. Does the quantum model predict the following to be diamagnetic?
 - i. Sr²⁺
 - ii. Fe
 - iii. F⁻
 - iv. Cu

- **1.** The quantum model and the Bohr model differ in a number of ways but also share some similarities.
 - a. Describe two ways in which the quantum model differs from the Bohr model.
 - b. What fundamental elements do both models have in common?
 - c. Explain how the quantum model was able to explain the PES spectra for boron shown below, ie: which orbitals represent which peaks.



- d. What is the aufbau principle and how does the PES spectra of boron above provides empirical evidence for the principle?
- 2. For each of the following orbitals, provide the following information:

The lowest principal energy level in which they can be found. The number of orientations The number of electrons per orbital

- a. s orbital
- b. d orbital
- c. f orbital
- d. p orbital
- **3.** The following questions relate to PES spectra and the electron configurations of Fe and Ga derived from the quantum model:
 - a. How many more peaks would the Ga PES spectra have compared to Fe?
 - b. How much greater should the intensity of the 3d peak in Fe be compared to the 4s peak?
 - c. The peak with the lowest binding energy corresponds to which orbital in the gallium atom?
- **4.** Explain the Pauli exclusion principle and how it limits the number of electrons per orientation:
- **5.** Consider the P atom and the phosphide ion (P^{3-}) :

- a. What is the full electron configuration of P?
- b. Draw the full orbital diagram for P and determine how many unpaired electrons are present:
- c. Would P be attracted to or repelled by a magnetic field? Justify your answer.
- d. Is the phosphide ion isoelectronic with neon? Explain.
- **6.** Examine the following website and answer the questions below:

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

- a. For the element scandium, identify which orbital is responsible for the peaks observed with binding energies of:
 - i. 48.5
 - ii. 0.63
 - iii. 0.77
 - iv. 433
- b. Transition metals, like Sc, lose their 4s electrons before their 3d electrons. What evidence do you see in the PES spectra to support this observation?
- c. Again, using evidence from the PES spectra, describe why Sc is unlikely to lose more than 3 electrons.
- d. Write the correct electron configuration for the Sc^{2+} ion
- 7. Write the proper shorthand orbital diagram for the following:
 - a. Se²⁻
 - b. Zn^{2+}
 - c. In
- **8.** Which of the substances from #7 would be paramagnetic? Justify your answer.