CHEMISTRY 338

Semester 1 Study Guide – Version 1.00

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I. Introduction to Chemistry

Types of Observations	Qualitative: Looking at attributes Quantitative: Looking at the number of things
Scientific method	1. *Observe* an aspect of something. 2. Make a *Hypothesis* that is consistent with the observation. 3. Make *Predictions* from the hypothesis. 4. Do *Experiments* to see if your hypothesis is correct. 5. Draw *Conclusions* from your experiments about your hypothesis.
Measurement/Units	Mass: *g* (gram) Length: *m* (meter) Volume: cm^3 (cubic centimeter), *L* (liter) Temperature: °*C*, °*F*, *K*
Accuracy and Precision	Accuracy is how well the results match the accepted value. Precision is how well the results match each other.
Percentage error	$\%\ \text{error} = \frac{\lvert \text{Value accepted} - \text{Value observed} \rvert}{\text{Value Accepted}} \cdot 100$ This is a measurement of accuracy.
Sig Figs	These digits in a number represent the degree of accuracy of that number. Every non-zero digit in the number is significant. **Rules for Determining Sig Figs:** 1. All non-zero digits are significant. 2. Zeros to the left of non-zero digits are never significant For example, the number 007 has one sig fig, and .000045 has two sig figs. 3. Zeros between non-zero digits are always significant. For example, .10005 has five sig figs. 4. Zeros to the right of non-zero digits are significant only if a decimal point is shown. For example, 600 has one sig fig, but 600. has three sig figs.
Sig Figs in arithmetic	When adding or subtracting numbers, round the answer off to the same column as the *least* precise measurement used in the calculation. For example, 1.2 + 3.456 ≈ 4.6 because 1.2 is the least precise measurement in the calculation. When multiplying or dividing, the answer must be rounded off to the same number of *sig figs* as the least accurate measurement used in the calculation. For example, 1.0 * 2.88991010 ≈ 2.9 because 1.0 has 2 sig figs, while 2.88991010 has 9 sig figs. Therefore, round it to 2 sig figs.
Scientific notation	A number in scientific notation looks like this: $1.23 \cdot 10^2$ The number before the decimal point must be 1, 2, 3 … 9. It cannot be zero or greater than or equal to 10.

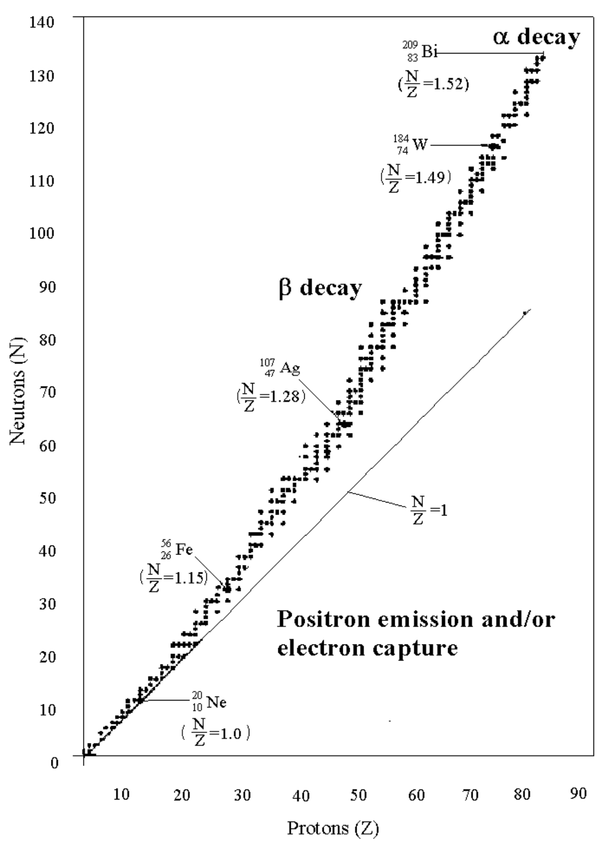
Physical and Chemical changes	*Physical changes* are those changes that do not result in the production of a new substance. If you melt a block of ice, you still have H_2O at the end of the change. Changes of state, like melting or condensing, are physical changes. *Chemical changes* are changes that result in the production of another substance.
Classification of matter	There are three types of matter: elements, compounds, and mixtures. An *element* is a pure substance, made up exclusively of one type of atom. A *compound* is formed when two or more elements chemically combine to form a new substance with new properties. It is *homogeneous*, meaning that all of the molecules in it are identical to each other. Compounds are pure substances. A *mixture* is formed when elements and/or compounds mix together with no chemical bonding. They are *heterogeneous*, meaning that they are not even throughout, and the individual properties of the mixed chemicals are still retained. Mixtures are not pure substances.
Indications of chemical reaction	Some indications are change of color, change of temperature, change of odor, and other changes, such as rusting, etc.
Density measurement	Density is Mass divided by Volume. To get one of these, solve for it, and plug in the other two values.
Dimensional analysis	Rules: All units must cancel out except the numerator in the last fraction. It is the same as Factor-Label. Each separate fraction must be equal to 1; i.e. the numerator and denominator of the fraction are equal or equivalent. To review this method, go to this website: http://www.dalesplace.net/factor.htm

II. Atomic Theory and Structure

Dalton's atomic theory	1. All matter is made of atoms. Atoms are indivisible and indestructible. 2. All atoms of a given element are identical in mass and properties. 3. Different atoms are different elements. 4. Compounds are formed by a combination of two or more different kinds of atoms. 5. A chemical reaction is a rearrangement of atoms and form new compounds.
Modern atomic theory	Modern atomic theory is a little more than Dalton's atomic theory. Now, we know that there are different kinds of atoms (differing by their masses) within elements that are known as *isotopes*. In addition, atoms can be destroyed via nuclear reactions but not by chemical reactions.
Laws	Law of definite proportions: Proportion by mass of the elements is always constant. For example, in a small cup of water, the ratio between hydrogen and oxygen atoms is 2 to 1, and in a big tank of water, it is still 2 to 1. Law of multiple proportions: the same elements that make up one compound could also make up another compound. Conservation of mass: the mass of the results of a chemical reaction is the same as the mass before the reaction.
Experiments	*Cathode-Ray Tube:* The cathode-ray tube consisted of a glass cylinder an anode and a cathode, a power supply and two silver conducting wires. The cathode was the negatively charged side of the tube. The anode was the positively charged side. When some air was pumped out, the electricity passed through the tube. This proved that electrons exist.

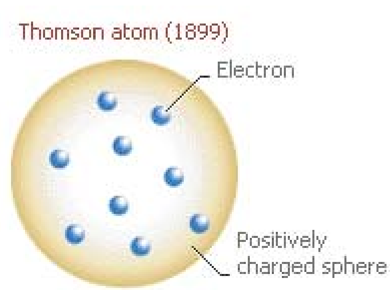
	Gold Foil: When a thin sheet of gold foil was bombarded with alpha particles, most of them penetrated the gold foil, others were deflected slightly, while some of them even bounced back the way they came from. This proved that atoms are mostly empty space.
Structure of atoms	Atoms have a dense nucleus made of protons and neutrons with electron shells surrounding the nucleus.
Atomic number	This is the number of protons an atom has.
Mass number	This is the number of protons plus the number of neutrons an atom has.
Isotopes	The notation of an isotope looks like this: ${}^{14}_{6}C$, which is Carbon-14. The top number, 14, symbolizes the mass number of the isotope, while the bottom number, 6, symbolizes the atomic number of the isotope. The *Average atomic mass* of an atom is the average of the masses of all the isotopes times the relative percent abundance. (This is not clear, so it is explained later.) The *relative percent abundance* is the abundance of an isotope in nature compared to the abundance of the element in nature. For example, 98.9% of all the carbon in the world is Carbon-12, so Carbon-12's relative percent abundance is 98.9%. We will now calculate the average atomic mass of an imaginary element. Let us say that element *X* has 2 isotopes: *X*-5 and *X*-6. *X*-5's percent abundance is 80%, and *X*-6's percent abundance is 20%. The average atomic mass would be 5 (mass of *X*-5) times 0.8 (abundance of *X*-5) plus 6 (mass of *X*-6) times 0.2 (abundance of *X*-6).

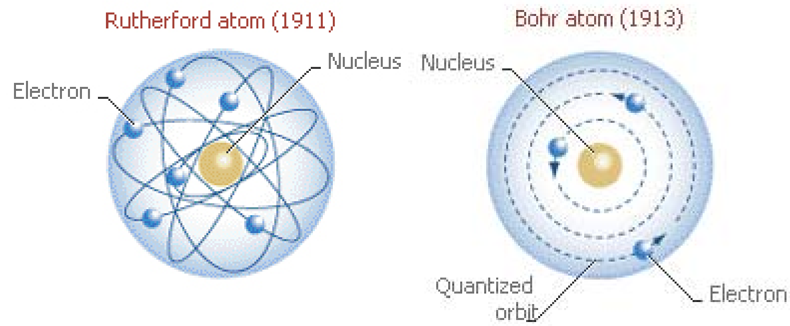
II. Nuclear Chemistry

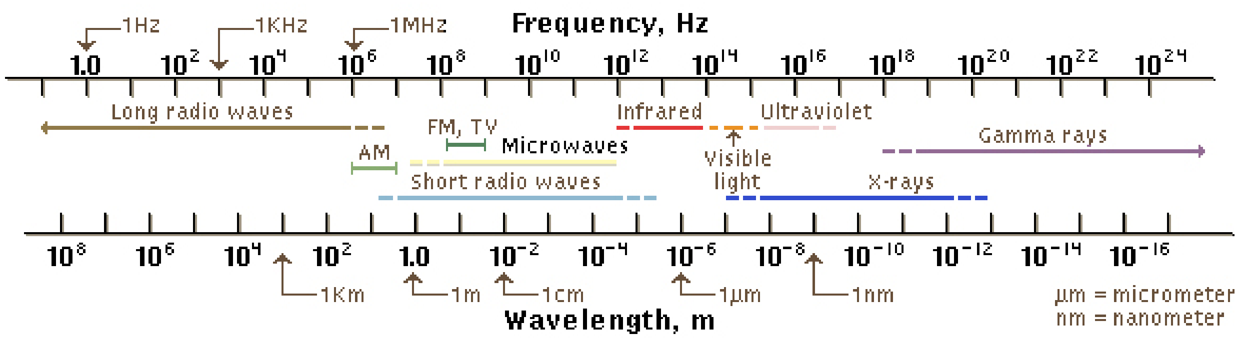
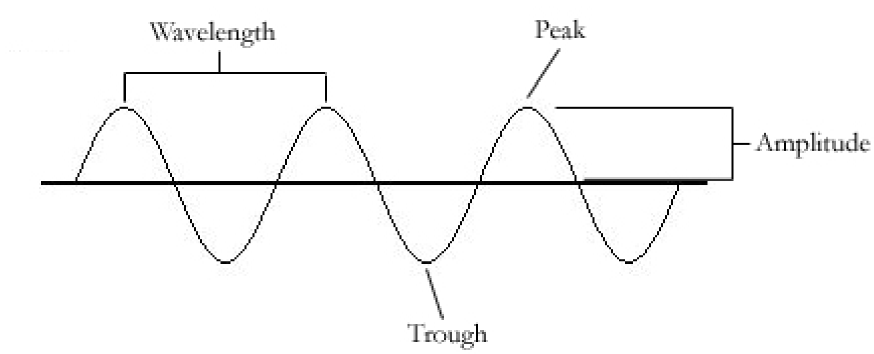
Band of stability	 The only stable isotopes are found in the line made of dots.
Types of nuclear reaction	There are five types of nuclear reaction:

	1. Alpha emission: Release of ${}^{4}_{2}\alpha$ from the nucleus. The atom loses 2 protons and 2 neutrons. 2. Beta emission: Emission of an electron (beta particle) from the nucleus. The atom gains a proton and loses a neutron. 3. Positron emission: Emission of a positron from the nucleus. The atom gains a neutron but loses a proton. 4. Electron capture: The atom captures an electron, gaining a neutron but losing a proton. Same as positron emission. 5. Gamma emission: Occurs when the nucleus is excited. It does not do anything to the mass of the atom. i.e. Alpha (α) emission: ${}^{238}_{92}\mathrm{U} \rightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$. Beta (β) decay: ${}^{234}_{90}\mathrm{Th} \rightarrow {}^{0}_{-1}\beta + {}^{234}_{91}\mathrm{Pa}$.
When emissions occur	Alpha emission: Number of protons is greater than 83. Beta emission: Number of neutrons divided by the number of protons is too big. Positron emission/Electron capture: Number of neutrons divided by the number of protons is too small. Gamma emission: when the nucleus is excited.
Balancing nuclear reactions	Example: ${}^{238}_{92}\mathrm{U} \rightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$. Notice that the sum of the mass numbers on both sides are the same (238 = 234 + 4) and the sum of the atomic numbers on both sides are also the same (92 = 90 + 2). This must be true, or the nuclear reaction is not balanced.
Properties of radiation	There are both harmful and non-harmful types of radiation. The non-harmful types include visible and infrared light. Nuclear radiation, however, is harmful. It breaks chemical bonds and may cause breakage of nuclei too. Other properties: α-decay is the most harmful when exposed to, but its particles are too big to pass through skin. It will be stopped by paper. β-decay is less harmful than α-decay, but is smaller, so it can pass through paper but is stopped by sheets of aluminum foil. γ-decay is probably the most dangerous. Its particles are so small they can cause some serious damage. It can only be stopped by a thick sheet of lead. It will pass through both paper and aluminum foil.

IV. Electrons in atoms; Quanta

Models of the atom	Dalton: The atom is a small solid sphere, much like a billiard ball. Thomson: Plum-Pudding model – Atom is made up of a positively charged matrix made neutral by negatively charged electrons.  Rutherford: Planetary Model – The atom has a very dense positively charged nucleus orbited by electrons. Neutrons do not exist yet.

<table>
<tr><td></td><td>

Bohr: Electrons travel in quantized orbits, meaning that they travel only in certain distances from the nucleus. The nucleus is made of protons and neutrons.</td></tr>
<tr><td colspan="2">Electromagnetic spectrum

</td></tr>
<tr><td>Light and quanta</td><td>Light is made up of waves and particles. The waves are ‘quantized’, meaning that they can only be produced in whole or half amounts. A quantum is a small bundle of energy.</td></tr>
<tr><td>Waves</td><td>

A wave’s frequency is how many wavelengths pass a certain point in a given time. The larger the frequency, the shorter the wavelength, and vice versa. The unit of cycles/second that measures frequency is the hertz.</td></tr>
<tr><td>Speed of light</td><td>The speed of light is approximately $3.0 \cdot 10^8$ meters per second or 186,000 miles per second.</td></tr>
<tr><td>Planck’s constant</td><td>This relates the energy in one photon (or quantum) of electromagnetic radiation to the frequency of that radiation. It is equal to approximately $6.626176 \cdot 10^{-34}$ joule-seconds.</td></tr>
</table>

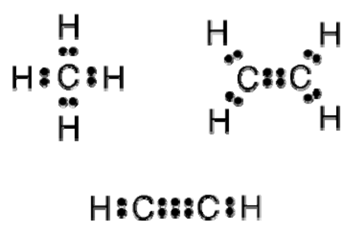
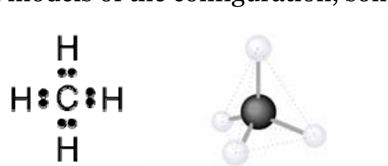
Atomic spectra	This is caused by electrons being excited, jumping to a higher energy state, and then moving back down, releasing energy. When the electron jumps from any level to the first electron level, it releases ultraviolet light. When an electron jumps from any higher level to the third level, it releases infrared light. When the electron jumps from a level to the second level: 3rd to 2nd level → release of red light 4th to 2nd level → release of green light 5th to 2nd level → release of blue light etc.
Atomic orbitals	An orbital is a region of space in which you can expect to find electrons of specific energy. Each orbital 'contains' two electrons. In the first energy level, we find one *s* orbital. In the second energy level, we find one *s* orbital and three *p* orbitals. In the third energy level, we find 1 *s*, 3 *p*, and 5 *d* orbitals. In the fourth energy level, we find *f* orbitals.
Electron configurations	$1s^2 2s^1$ The 1 before the first *s* and the 2 between the *s*'s represent the energy level. Therefore, the first *s* is in the first energy level, and the second *s* is in the second energy level. The superscript 2 and 1 represent the number of electrons found in the orbital, which is in this case 1*s* and 2*s*. Each orbital has 2 spaces for electrons. One of these spaces has positive spin, while the other one has negative spin. If an atom has more than two electrons, the electrons begin filling orbitals in the next subshell with one electron each until all the orbitals in the subshell have one electron. The electrons that are left then go back and fill each orbital in the subshell with a second electron with opposite spin. They follow this order because it takes less energy to add an electron to an empty orbital than to complete a pair of electrons in an orbital. The electrons fill all the subshells in a shell, then go on to the next shell. The *d* orbitals require more energy to fill, so electrons actually fill in 4*s* before they fill in 3d. Also, the *f* orbitals require even more energy to fill, so 6*s* is filled before 4*f* is filled.
Exceptions to configurations	Cr is $[Ar]4s^1 3d^5$. Cu is $[Ar]4s^1 3d^{10}$. Mo is $[Kr]5s^1 4d^5$. Ag is $[Kr]5s^1 4d^{10}$. Au is $[Xe]6s^1 4f^{14} 5d^{10}$.
Orbital box diagrams	Go to http://wine1.sb.fsu.edu/chm1045/notes/Struct/EConfig/Struct08.htm. This also has a little bit on electron configurations.
Pauli exclusion principle	No more than 2 electrons can occupy an orbital. When two electrons occupy the same orbital, they have different spins.
Hund's rule	Try to maximize the number of unpaired electrons. I.e. when there are 3 electrons in a set of 3 *p* orbitals, put each electron in a different orbital.

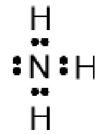
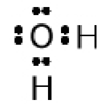
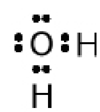
V. Periodicity

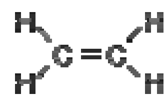
Names of families	The first family is called the *alkali metals*. The second family is called the *alkaline earth metals*. The 7th family (second from the right) is called the *halogens*. The 8th family (rightmost one) is called the n*oble gases*.
Trends on the periodic table	From left to right: ionization energy increases, electronegativity increases, and atomic radius decreases. From top to bottom: Atomic radius increases, electronegativity decreases, and

	ionization energy decreases. Also, metallic character increases when you go from right to left and top to bottom.

VI. Bonding

Properties	Ionic compounds: Formula based, very high melting and boiling points, solids at room temperature, soluble in water Covalent compounds: Molecule based, liquids and gases at room temperature, weak forces between molecules, low melting points, does not conduct electricity
Electron dot structures	It shows the valence electrons of an atom. How to find it: 1. Count the valence electrons. Add them together; this is how many electrons you need to have in the final structure. 2. Assemble the bonding framework (draw the atoms by each other in the way you think they are arranged) 3. Place the electrons on the structure, making sure you follow the octet rule and its exceptions. Example: 
Covalent bonds	These are formed when two atoms share electrons. The formula for a covalent bond is represented with a dash — in dot structures. There can be double and triple covalent bonds as well.
Coordinate covalent bonds	This is when the shared electrons are not evenly shared between the two atoms; for example in CO, Carbon donates 2 electrons, but Oxygen donates 4.
Octet rule	In forming compounds, atoms need to achieve the electron configuration of a noble gas: they must have 8 electrons around them. Exceptions: Hydrogen needs only 2, Boron needs 6, and Beryllium needs 4.
VSEPR theory	*Valence Shell Electron Pair Repulsion*. The whole concept revolves around the idea that the electrons in a molecule repel each other and will try and get as far away from each other as possible. Therefore, in models of the configuration, some angles are:  It is a central Carbon with 4 Hydrogens attached to it, so its shape is *tetrahedral* and its bond angle is 109.5°.

	 This is a central nitrogen with 3 hydrogens attached to it. It has 3 shared and 1 unshared electron pairs. Its shape is *trigonal pyramidal* (or just pyramidal). Its angle is 109.5° (actually it is 107°, but we said it was 109.5° in class).  This is a *bent* shape because it has 2 shared and 2 unshared electron pairs. Its degree angle is 105°.  This is a *linear* shape because it is straight. Its angle is 180°. Another shape (not shown here) is *trigonal planar*. It is a central atom with three shared pairs of electrons and no unshared pairs. Its angle is 120°.
Polarity	A molecule is *polar* if its polar bonds (if it has any) do not cancel each other out. A bond is polar if the difference in electronegativity (look on the periodic table to find out electronegativity) is 0.4 or greater. 'Canceling out' occurs when there are no unshared electron pairs. Let us look at two examples: H_2O and H_2Be (the second may not exist, but it is a good example ☺) H_2O has 2 shared and 2 unshared electron pairs, like shown:  Since it has unshared electron pairs, and the O-H bond is polar, the molecule is polar. H_2Be looks like **H : Be : H**. Since it has no unshared electron pairs, even though the Be-H bond is polar, they cancel out and the molecule is not polar. In a polar bond, the electrons are closer to the atom that is more electronegative. The more electronegative atom is designated δ^-, or delta-negative, and the less electronegative atom is designated δ^+, or delta-positive.
Intermolecular attractions	There are a few kinds of molecular attractions. The weakest are called *van der Waals* forces. They include *dispersion forces* and *dipole interactions*. *Dispersion forces* are the weakest of all attractions, and are caused by the motion of electrons. The more electrons a chemical has, the stronger the dispersion forces are. Chemicals such as fluorine and chlorine have weak dispersion forces, so they are gases at room temperature. However, other chemicals such as bromine have quite strong dispersion forces because they have lots of electrons. Therefore, bromine is a liquid at room temperature. Iodine has even more electrons, so it is a solid at room temperature. *Dipole interactions* occur when polar molecules are attracted to each other. A δ^+ atom on one molecule may be weakly attracted to a δ^- atom on another molecule. In

	water, the δ⁺ hydrogens are somewhat attracted to δ⁻ oxygens of other water molecules. That makes water a liquid at room temperature. This attraction between the hydrogen and the oxygen molecule is called a *hydrogen bond*, and occurs in hydrogen-containing polar molecules.
Hybridization	This is when several orbitals mix to form equivalent hybrid orbitals. There are three categories of hybridization: sp^3, sp^2, and *sp* hybridization. The process in which one *s*-orbital and three *p*-orbitals overlap to make 4 sp^3 hybrid orbitals is called sp^3 hybridization. This occurs in tetrahedral molecules that are similar to methane, which is CH_4. Carbon has four hybrid sp^3 orbitals, which orbitals overlap a lot with the *s* orbitals of hydrogen. The valence electrons fill in the orbitals to form four *sigma bonds*, which are very strong covalent bonds. The process in which one *s*-orbital and two *p*-orbitals overlap to make 3 sp^2 orbitals is called sp^2 hybridization. In ethene (shown below), the carbon atoms have 3 sp^2 orbitals each. Two of the orbitals make sigma-bonds with the hydrogens, while one of them sigma-bonds with the other carbon. The remaining p-orbitals overlap to form a *pi bond* connecting the carbons together, which are weaker than sigma bonds.  The process in which one *s*-orbital and one *p*-orbital overlap to make two *sp* orbitals is called *sp* hybridization. In acetylene, which looks like $H-C\equiv C-H$, the carbons each have two *sp* orbitals and 2 *p* orbitals. The carbon bonds to the other carbon with sigma bonds. The *p* orbitals form two pi-bonding orbitals that surround the carbons.

VII. Chemical Formulas and Names

Ionic compounds	In these, the charges of the anions (negative ions) and the cations (positive ions) must add to be zero. So, if the cation has a charge of +2 and the anion has a charge of -1, there needs to be 2 of the anion to make the charges add to zero. To write a ionic compound, first write the name of the cation. Nothing needs to be changed in it. Then, write the name of the anion like this: If the anion is an element, write the element with an ending of –ide. Therefore, chlorine would turn into chloride. If the anion is a compound, just write the name of the compound down. Therefore, NaCl will be sodium chloride, and K_2S will be potassium sulfide.
Binary covalent compounds	These are made up of two elements. Covalent bonds occur when two non-metals bond with each other. The subscript in the formula (i.e. 2 in H_2) turns into a prefix in the name. The prefixes are as follows: 1 – mono 2 – di 3 – tri 4 – tetra 5 – penta 6 – hexa 7 – hepta 8 – octa 9 – nono 10 – deca Therefore, SO_3 will be sulfur trioxide, and N_2O_5 will be dinitrogen pentoxide.
Monoatomic/Polyatomic ions	Monoatomic ions are either cations or anions that are made up of only one element. These include Na^+, Cl^-, and Al^{3+}. Polyatomic ions are cations or anions that are made up of more than one element. For example, SO_4^{2-} and NH_4^+ are polyatomic ions.

VIII. Moles

Definition	A *mole* is defined as the amount of a substance containing the same number of molecules, atoms, or formula units as the number of atoms in 12 grams of C-12,

	which is $6.022 \cdot 10^{23}$.
Avogadro's number	$6.022 \cdot 10^{23}$. The number of molecules, atoms, or formula units in a mole.
Calculating things	Use factor-label to calculate the answer. For example: how many atoms are in 5000. g of carbon? $5000.\text{ g} \cdot \frac{1\text{ mol}}{12.011\text{ g}} \cdot \frac{6.022 \times 10^{23}\text{ atoms}}{1\text{ mol}} = 2.507 \times 10^{26}\text{ atoms}$ Remember to follow the rules of factor-labeling. Also remember: When there are, say, 5 moles of H_2O, remember that when you split them into atoms, there are 5 moles of every part, meaning that there are 10 moles of *H* and 5 moles of *O*.

This is the end of the study guide. If you find any errors or have any questions or comments about this study guide, feel free to email me at fenguin@gmail.com. Thanks a lot for reading, and good luck on finals!