ACE Study Resource — CHEM 1311

Syllabus:

To search for your course syllabus, follow these instructions.

1. Visit the following website: https://info.tamiu.edu/
2. Input your course (ex: CHEM 1311) into the "Search" box and make sure you are in the current term (ex: Spring 2022). Click "Search."
3. Scroll down until you find your specific course (ex: CHEM 1311.201) and professor's name.
4. Click on "Syllabus" under your course and the file will automatically download. You are done!

Textbook(s):

Flowers, Paul, et al. *Chemistry: Atoms First*. 2nd ed., E-book, Rice University, 2019.

Key Concepts:

- Introducing Atoms, Molecules, and Ions

  - Matter is composed of exceedingly small particles called atoms. An atom is the smallest unit of an element that can participate in a chemical change.
  - Atoms are neither created nor destroyed during a chemical change but are instead rearranged to yield substances that are different from those present before the change.
  - An atom consists of a small, positively charged nucleus surrounded by electrons. The nucleus contains protons and neutrons.
  - The mass of one atom is usually expressed in atomic mass units (amu), which is referred to as the atomic mass. An amu is defined as exactly half of the mass of a carbon-12 atom and is equal to 1.6605×10^{-24} g.
  - Protons are relatively heavy particles with a charge of 1+ and a mass of 1.0073 amu. Neutrons are relatively heavy particles with no charge and a mass of 1.0087 amu. Electrons are light particles with a charge of 1− and a mass of 0.00055 amu.
  - A convenient amount unit for expressing very large numbers of atoms or molecules is the mole. Experimental measurements have determined the number of entities composing 1 mole of substance to be 6.022×10^{23}, a quantity called Avogadro's number. The mass in grams of 1 mole of substance is its molar mass.
- Electronic Structure and Periodic Properties
  - Light and other forms of electromagnetic radiation move through a vacuum with a constant speed, c, of $2.998 \times 10^8 \ ms^{-1}$. This radiation shows wavelike behavior, which is characterized by a frequency, v, and a wavelength, λ, such that $c = \lambda v$.

- ○ Electromagnetic radiation also demonstrates properties of particles called photons. The energy of a photon is related to the frequency (or alternatively, the wavelength) of the radiation as $E = hv$, where h is Planck's constant.
- ○ When an electron moves from a higher-energy orbit to a more stable one, energy is emitted in the form of a photon. To move an electron from a stable orbit to a more excited one, a photon of energy must be absorbed. Using the Bohr model, we can calculate the energy of an electron and the radius of its orbit in any one-electron system.
- ○ Atomic orbitals describe the areas in an atom where electrons are most likely to be found. An atomic orbital is characterized by three quantum numbers. The principal quantum number, n, can be any positive integer. Orbitals having the same value of n are said to be in the same shell. The secondary (angular momentum) quantum number, l, can have any integer value from 0 to $n - 1$. This quantum number describes the shape or type of the orbital. Orbitals with the same principal quantum number and the same l value belong to the same subshell. The magnetic quantum number, m_l, with $2l + 1$ values ranging from $-l$ to $+l$, describes the orientation of the orbital in space.
- ○ Electrons in the outermost orbitals, called valence electrons, are responsible for most of the chemical behavior of elements. In the periodic table, elements with similar valence electron configurations usually occur within the same group.
- ○ The periodic table can be divided into three categories based on the orbital in which the last electron to be added is placed: main group elements (*s* and *p* orbitals), transition elements (*d* orbitals), and inner transition elements (*f* orbitals).
- ○ Elements in the same group of the periodic table have similar chemical properties. Elements can be classified as metals, metalloids, and nonmetals, or as a main-group elements, transition metals, and inner transition metals. Groups are numbered 1–18 from left to right. The elements in group 1 are known as the alkali metals; those in group 2 are the alkaline earth metals; those in 15 are the pnictogens; those in 16 are the chalcogens; those in 17 are the halogens; and those in 18 are the noble gases.
- ● Chemical Bonding and Molecular Geometry
  - ○ Atoms gain or lose electrons to form ions with particularly stable electron configurations. The charges of cations formed by the representative metals may be determined readily because, with few exceptions, the electronic structures of these ions have either a noble gas configuration or a completely filled electron shell. The charges of anions formed by the nonmetals may also be readily determined because these ions form when nonmetal atoms gain enough electrons to fill their valence shells.
  - ○ Covalent bonds form when electrons are shared between atoms and are attracted by the nuclei of both atoms. In pure covalent bonds, the electrons are shared

equally. In polar covalent bonds, the electrons are shared unequally, as one atom exerts a stronger force of attraction on the electrons than the other.

- ○ The ability of an atom to attract a pair of electrons in a chemical bond is called its electronegativity. The difference in electronegativity between two atoms determines how polar a bond will be.
- ○ In a diatomic molecule with two identical atoms, there is no difference in electronegativity, so the bond is nonpolar or pure covalent. When the electronegativity difference is very large, as is the case between metals and nonmetals, the bonding is characterized as ionic.
- ○ VSEPR theory predicts the three-dimensional arrangement of atoms in a molecule. It states that valence electrons will assume an electron-pair geometry that minimizes repulsions between areas of high electron density (bonds and/or lone pairs).
- ○ A dipole moment measures a separation of charge. For one bond, the bond dipole moment is determined by the difference in electronegativity between the two atoms. For a molecule, the overall dipole moment is determined by both the individual bond moments and how these dipoles are arranged in the molecular structure. Polar molecules (those with an appreciable dipole moment) interact with electric fields, whereas nonpolar molecules do not.
- ● Advanced Theories of Bonding
  - ○ When orbitals overlap along an axis containing the nuclei, they form a σ bond. When they overlap in a fashion that creates a node along this axis, they form a π bond. Dipole moments can be used to determine partial separations of charges between atoms.
  - ○ We can use hybrid orbitals, which are mathematical combinations of some or all of the valence atomic orbitals, to describe the electron density around covalently bonded atoms. These hybrid orbitals either form sigma (σ) bonds directed toward other atoms of the molecule or contain lone pairs of electrons. We can determine the type of hybridization around a central atom from the geometry of the regions of electron density about it.
  - ○ Molecular orbital theory describes the behavior of electrons in a molecule in terms of combinations of the atomic wave functions. Bonding molecular orbitals are formed by in-phase combinations of atomic wave functions, and electrons in these orbitals stabilize a molecule. Antibonding molecular orbitals result from out-of-phase combinations of atomic wave functions and electrons in these orbitals make a molecule less stable.
- ● Stoichiometry of Chemical Reactions
  - ○ Formulas for the substances undergoing the change (reactants) and substances generated by the change (products) are separated by an arrow and preceded by integer coefficients indicating their relative numbers. Balanced equations are

those whose coefficients result in equal numbers of atoms for each element in the reactants and products.

- ○ Precipitation reactions involve the formation of one or more insoluble products. Acid-base reactions involve the transfer of hydrogen ions between reactants. Redox reactions involve a change in oxidation number for one or more reactant elements. Writing balanced equations for some redox reactions that occur in aqueous solutions is simplified by using a systematic approach called the half-reaction method.
- ○ Coefficients from the equations are used to derive stoichiometric factors that may be used for solving reactant and product masses, molar amounts, and other quantitative properties.

Tips and Strategies:

- Practice problems found in the textbook and within the professor's lecture slides.
- Review the properties of the periodic table of elements, such as where alkali metals are located, how many valence electrons the elements have and why, etc.
- Study vocabulary by copying information on flashcards or highlighting information in the textbook.
  - ○ Familiarize yourself with the vocabulary by using the terms in a sentence or problem
- Review your previous exam/quiz questions, focusing on the questions that were incorrect.
- Attend SI or tutoring sessions to review content and ask for further studying strategies/tips.
- Attempt to study 1-2 textbook chapters a day leading up to an exam.
- Study for 30-50 minutes followed by short periods of rest (10-15 minutes).
- Make notes of your texts and organizing an outline of steps to follow to solve for problems.

Resources:

- ACE — Academic Support Tutoring
- ACE — Academic Support My Academic Achievement Plan
- Khan Academy: Chemistry
- OpenStax textbook: https://openstax.org/books/chemistry-atoms-first-2e/pages/1-introduction

Practice and Application:

Below are practice problems to reinforce your knowledge of key course concepts.

*Understanding the Periodic Tables*

Stoichiometry

When carbon dioxide is dissolved in an aqueous solution of sodium hydroxide, the mixture reacts to yield aqueous sodium carbonate and liquid water. Write balanced molecular, complete ionic, and net ionic equations for this process.

1. Identify the reactants and products. Form the chemical equation.

$CO2(aq)+NaOH(aq)\longrightarrow Na2CO3(aq)+H2O(l)(unbalanced)$

2. Balance the equation by changing NaOH's coefficient to 2. This creates the molecular equation.

$CO2(aq)+2NaOH(aq)\longrightarrow Na2CO3(aq)+H2O(l)$
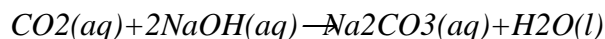
3. Notice that NaOH and Na2CO3 are dissolved ionic compounds. They can be addressed as dissociated ions, forming the ionic equation.

$O2(aq)+2Na+(aq)+2OH-(aq)\longrightarrow 2Na+(aq)+CO32-(aq)+H2O(l)$
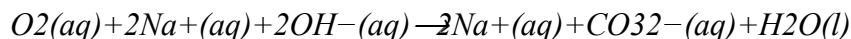
4. Identify the spectator ion(s) [Na+]. Be sure to remove it from both sides, forming the net ionic equation.

$O2(aq)+2Na+(aq)+2OH-(aq)\longrightarrow 2Na+(aq)+CO32-(aq)+H2O(l)$

$CO2(aq)+2OH-(aq)\longrightarrow CO32-(aq)+H2O(l)$
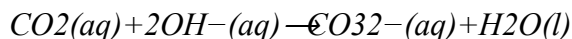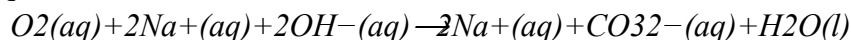
Check Yourself:

Diatomic chlorine and sodium hydroxide (lye) are commodity chemicals produced in large quantities, along with diatomic hydrogen, via the electrolysis of brine, according to the following unbalanced equation:

$NaCl(aq)+H2O(l)\rightarrow NaOH(aq)+H2(g)+Cl2(g)$

Molecular:

$2NaCl(aq)+2H2O(l)\longrightarrow 2NaOH(aq)+H2(g)+Cl2(g)$

Ionic Equation:

$2Na+(aq)+2Cl-(aq)+2H2O(l)\longrightarrow 2Na+(aq)+2OH-(aq)+H2(g)+Cl2(g)$

Net Ionic:

$2Cl-(aq)+2H2O(l)\longrightarrow 2OH-(aq)+H2(g)+Cl2(g)$

Wavelengths

1. FM-95, an FM radio station, broadcasts at a frequency of $9.51 \times\times 10^7$ s^{-1} (95.1 MHz). What is the wavelength of these radio waves in meters?

2. Light with a wavelength of 614.5 nm looks orange. What is the energy, in joules, per photon of this orange light? What is the energy in eV (1 eV = $1.602 \times\times 10^{-19}$ J)?

Check Yourself:
Wavelengths should be the proper unit of measurement and the steps to find them should involve any of the necessary conversions.

Identify Bonding Types
1. Predict which of the following compounds are ionic and which are covalent, based on the location of their constituent atoms in the periodic table:

(a) Cl_2CO

(b) MnO

(c) NCl_3

2. From its position in the periodic table, determine which atom in each pair is more electronegative:

(a) Br or Cl

(b) N or O

(c) S or O

Polarity
1. Which of the following molecules or ions contain polar bonds?

(a) O_3

(b) S_8

(c) O_2^{2-}

(d) NO_3^-