Preface
The second in-class midterm is scheduled for Wednesday. Similar in style to the first exam, the questions will vary in type, and in many cases draw heavily on your practice with problems and development of problem-solving skills. The topics of the questions will be chosen from among the learning goals (vide infra) for our study of Chapters 4-7 in Burdge & Overby, *Chemistry: Atoms First*:

Calculations of partial charges, dipole moments, and percent ionic character will not appear on the exam, although you should know what these terms mean. See also the note below on molecular structures in Ch.7.

Assumed knowledge: Proper treatment of significant figures in calculations; prefixes used with SI units: kilo- (k) $10^3$, centi- (c) $10^{-2}$, milli- (m) $10^{-3}$, micro (µ) $10^{-6}$, nano- (n) $10^{-9}$, pico- (p) $10^{-12}$. Ability to use the periodic table to derive electron configurations. Names and formulas for all elements, diatomic molecules, polyatomic ions, associated acids, and other molecules from the Mandatory Chemical Vocabulary handout. Note that you need to know the correct charges for all ions.

Remember to keep practicing and developing the use of the periodic table as an invaluable tool for retrieval of a wealth of chemical information.

Learning Goals

Exam questions are intended to assess your attainment of a set of learning goals for each chapter (listed below). In some cases, these learning goals are fairly specific; others are more open-ended, and a variety of questions can arise. However, if you have followed closely each class session, read the chapters actively and carefully, completed the online homework and suggested end-of-chapter questions and problems, then you have had practice with all the relevant subject material.

Chapter 7 - Molecular Geometry and Bonding Theories
- Know the five basic geometries and how they lead to eleven molecular structures
  (Note that for this exam, we will limit questions on molecular structures to those arising from SN = 2, 3, and 4 only)
- Know what an electron domain is and how to count electron domains in a Lewis structure
  (steric number SN = count of electron domains)
- Be sure you know the distinction between electron domain geometry and molecular geometry
- Use the VSEPR model to predict the electron geometry, molecular geometry, and approximate bond angles around a central atom
- Determine if a molecule is polar, and if so, in what direction the dipole will be

Chapter 6 - Representing Molecules
- Understand the basis of the octet rule and the basics of Lewis structures
- Draw valid Lewis structures for molecular compounds and polyatomic ions
- Understand how bond length and bond energy are related to molecular structure
Ch. 6 learning goals (cont’d.)
- Understand the concept of electronegativity (EN) and relate $\Delta$EN to polarity of a bond
  - Be able to represent bond polarity using the notation for partial charges ($\delta^+ / \delta^-$ labels for the atoms) or the bond dipole vector notation, and know the meaning of these; also be able to interpret electrostatic surface potential representations of molecules (e.g. Fig. 6.3, p.187).
- Know the general periodic trends in EN and describe the basis for these trends
  - Recognize the role of EN in assessing Lewis structures using formal charge; it is also helpful to know the top 4 or so most electronegative elements, in order: F > O > N ≈ Cl
- Be able to draw appropriate resonance forms, where possible, for Lewis structures
- Recognize equivalent and nonequivalent resonance structures
- Be able to assign formal charge to any/all atoms of a Lewis structure
- Use formal charge to evaluate alternative skeletal structures and relative contributions of resonance structures

Chapter 5 - Ionic and Covalent Compounds
- Know what Lewis symbols are and be able to write Lewis symbols for the elements (and monatomic ions)
- Predict what ions will form for main group elements
- Predict formulas for ionic compounds
- Name ionic compounds from formula, and given name, write formula
- Understand what a molecule is and what a molecular formula denotes
- Name binary molecular compounds and determine the formula from the name
- Use and understand percent composition by mass
- Define and understand the concepts of mole and molar mass; apply to compounds
- Calculate formula mass from chemical formula
- Convert between mass, moles, and numbers of molecules or ions
- Determine an empirical formula from percent composition data
- Determine a molecular formula from empirical formula and molar mass

Chapter 4 - Periodic Trends of the Elements
- Identify valence and core electrons
- Define effective nuclear charge ($Z_{\text{eff}}$), atomic radius, ionization energy, and electron affinity
- Be able to write the chemical equations corresponding to ionization energy and electron affinity
- Understand the periodicity of $Z_{\text{eff}}$ and its underlying relation to the periodic trends (listed next)
- Understand the general periodic trends for atomic radius, ionization energy, and electron affinity
- Understand what atomic radius is
- Determine electron configurations of ions
  - Note in particular that the configurations of a number of Period 4 transition metal cations do not conform to a “last in, first out” method of generating configuration by removing electrons from the neutral atom
- Understand the relationship between atomic and ionic radius
Exam format and sample questions

The exam will consist of somewhere between 12 – 15 questions (3½-4 pages) of various formats: multiple-choice, true-or-false, problems involving calculations and short-answer questions. See below for the information that will be provided. The sample questions have appeared on previous exams and are meant to be representative of the kinds of questions to be expected, not necessarily the weight or distribution of topics that will appear on the actual exam. Note that the questions provided here by no means touch on all the learning goals. Some questions may be quite similar to those below, others may touch on topics not addressed by any of the samples given.

Potentially useful information:

Physical constants, conversion factors:
Avogadro’s number: \( N_A = 6.022 \times 10^{23} \)
Planck’s constant: \( h = 6.626 \times 10^{-34} \text{ J} \cdot \text{s} \)
Speed of light: \( c = 2.998 \times 10^8 \text{ m s}^{-1} \)
Atomic charge units: \( 1.6022 \times 10^{-19} \text{ C} \)
Dipole moments: \( 1 \text{ D} = 3.336 \times 10^{-30} \text{ C} \cdot \text{m} \)

Equations:
Coulomb’s law: \( PE_{\text{elec}} \propto q_1 q_2 / r \)
Relations for EM radiation: \( c = \lambda \nu; E = h \nu \)
Sample exam questions

4A. (a) For each of the following, predict electron configurations.

(i) Ca$^{+}$
(ii) Se$^{2-}$
(iii) Cu$^{2+}$

4B. Order the following atoms by increasing effective nuclear charge, $Z_{eff}$: Al, Ca, Cl, Na, Si

4C. Select the atom or ion in each pair that has the larger radius

(a) Na or Na$^{+}$
(b) B or Al
(c) Al or N
(d) O$^{2-}$ or F$^{-}$
(e) Cl$^{-}$ or Ca$^{2+}$

4D. Which of these groups of elements is arranged correctly in order of increasing ionization energy?

(a) C, Si, Li, Ne.
(b) Ne, Si, C, Li.
(c) Li, Si, C, Ne.
(d) Ne, C, Si, Li

4D. Choose the atom with the smallest electron affinity from the following, and write the corresponding chemical equation:

(a) Al
(b) O
(c) Br
(d) Cs
(e) P

4E. For each of the following bonds, indicate the partial charges carried by each atom. In addition, explain how you would order the bonds according to polarity (least to most polar).

(a) F $\cdots$ Cl
(b) Si $\cdots$ Cl
(c) S $\cdots$ Cl

5A. Write the chemical formula for ammonium sulfate and calculate its formula mass. Is this a molecular or ionic compound?

5B. Classify the following as molecular or ionic compounds.

(a) potassium nitrate
(b) N$_2$O
(c) hydrogen sulfide

5C. Give the name and predict the formula of an ionic compound that would form between:

(a) aluminum and oxygen
(b) calcium and fluorine
(c) sodium and sulfur
5D. Analysis of a sample of an oxide of an undetermined element X yields a mass composition of 8 g X and 12 g O.
(a) If X and O are the only elements present, what would the mass composition of a 25-g sample be? State any laws or principles you are using to arrive at your answer and note briefly how you are applying them in this case.

(b) If the chemical formula of this compound is determined to be XO₃, what is the identity of the element X? Show clearly how you arrive at your answer.

5E. Analysis of a compound consisting of carbon, hydrogen, and oxygen only was found to have 60.00% C, 13.33% H, and 26.67% O by mass. Find the empirical formula for this compound.

6A. Draw Lewis structures for each of the following:
(a) H₂O⁺
(b) CN⁻
(c) Cl₂CO
6B. (a) Draw the Lewis structure for the species OCN$^-$ (carbon central), including any resonance form(s). Include any non-zero formal charge assignments.

(b) Do the same for part (a) for the species ONC$^-$ (nitrogen central). What do your formal charge assignments indicate about which skeletal structure, O-C-N, or O-N-C, is more likely? State the reason for your answer.

7A. For each of the following molecules, (a) determine its molecular geometry (provide the name of the shape and a sketch of the molecular structure, and (b) determine whether or not the molecule is polar. Be sure to explain and/or show how you arrive at your conclusion.

(i) NF$_3$  
(ii) BF$_3$  
(iii) SF$_4$