

Chem 130 – First Exam Key

Name _____

On the following pages you will find eight questions covering various topics ranging from nomenclature to periodic properties, and electromagnetic radiation to Lewis structures. Read each question carefully and consider how you might approach the problem before you put pen or pencil to paper. If you aren't sure how to start a question, move to another problem; working on a new question may suggest an approach to that more troublesome problem. For problems requiring a written response, be sure that your answer is written in complete sentences and that it directly and clearly answers the question. For questions asking for an explanation of a periodic trend, it is insufficient to simply say "the hardness of atoms increase to the right and to the top of the periodic table." Instead, your answer must include an explanation for why this trend exists.

Partial credit is willingly given on all problems so be sure to answer all questions!

Question 1 ____/15 Question 5 ____/11

Question 2 ____/6 Question 6 ____/11

Question 3 ____/12 Question 7 ____/12

Question 4 ____/15 Question 8 ____/18

Total ____/100

Potentially useful equations and constants:

$$c = \lambda\nu \quad E = h\nu \quad KE = h\nu - BE \quad \frac{1}{\lambda} = 1.09737 \times 10^{-2} \text{ nm} \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \quad V = \frac{kq_1q_2}{d}$$

$$c = 2.998 \times 10^8 \text{ m/s} \quad h = 6.626 \times 10^{-34} \text{ Js} \quad N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$$

Problem 1. For each of the following, provide one example of an element satisfying the stated condition. *Do not include lanthanides and actinides in your answers, and do not use any element more than once!*

- can form a monatomic ion with a charge of -1: **H, F, Cl, Br, I, At**
- has a covalent radius that is smaller than that for boron: **C, N, O, F, Ne, H, He**
- is in the fifth period: **Rb → Xe**
- has an electron configuration of $ns^2(n-1)d^{10}np^3$: **N, P, As, Sb, Bi**
- forms a +2 ion with a noble gas electron configuration: **Be, Mg, Ca, Sr, Ba, Ra**
- is in the p-block: **B → Ne, Al → Ar, Ga → Kr, In → Xe, Tl → Rn**
- forms monatomic ions with charges of +2 and +3: **Ti, V, Cr, Mn, Fe, Co**
- has exactly two electrons in a d-orbital: **Ti, Zr, Hf, Rf**
- has one unpaired electron: **H → Fr, Sc → Ac, Cu → Au, B → Tl, F → At**
- has a first ionization energy that is larger than that for fluorine: **Ne, He**
- has an electron with the quantum numbers $n = 4$ and $l = 2$: **Y to end of table (4d)**
- has exactly four valence electrons: **C → Pb and Ti → Rf**
- is a semi-metal (also known as metalloid): **B, Si, Ge, As, Sb, Te, Po, At**
- cannot expand its valence shell beyond an octet: **H, He, Li, Be, B, C, N, O, F, Ne**
- has only three peaks in its photoelectron spectrum: **B, C, N, O, F, Ne**

Problem 2. Fill in the missing spaces in the following table:

Formula	Name	Covalent or Ionic?
Ag_2CO_3	silver carbonate	ionic
$\text{Co}(\text{ClO}_4)_2$	cobalt (II) perchlorate	ionic
P_4S_{10}	tetraphosphorous decasulfide	covalent

Problem 3. Consider the following two photons.

Photon 1: wavelength is 250 nm

Photon 2: frequency is $5.0 \times 10^{14} \text{ s}^{-1}$

Which photon has the greater energy and what is that energy in kJ?

Frequency is directly proportional to energy ($E = h\nu$). To compare the two photons, convert the wavelength to a frequency using the equation $c = \lambda\nu$; thus 250 nm is $1.199 \times 10^{15} \text{ s}^{-1}$ and Photon 1 has the greater energy. You also could compare wavelengths (600 nm for Photon 2) or calculate energies ($7.95 \times 10^{-19} \text{ J}$ for Photon 1 and $3.3 \times 10^{-19} \text{ J}$ for Photon 2).

Will this photon have sufficient energy to eject a 4s electron from potassium, for which the ionization energy is 420 kJ/mol? Be sure to clearly justify your answer.

Given a photon's frequency, its energy is given by $E = h\nu$; thus, for a frequency of $1.199 \times 10^{15} \text{ s}^{-1}$ the energy is $7.946 \times 10^{-19} \text{ J}$ for one photon. For a mole of photons the energy is 47850 J, or 478.5 kJ, which is greater than 420 kJ/mol. The photon's energy is sufficient to ionize a 4s electron from potassium. You also could calculate the energy needed to eject a single 4s electron, which is $6.97 \times 10^{-19} \text{ J}$.

Problem 4. The first ionization energy for Br is less than that for Cl. Consider the following three explanations for this observation, none of which is correct. For each response, provide either a one sentence explanation for why it is incorrect or provide a counter example that proves the response to be incorrect.

These questions are informed by Coulomb's law – ionization energy depends on the nucleus' core charge and the distance between the nucleus and electron

(a) bromine has more protons than chlorine **Br does have more protons than Cl, but the core charge is the same in both cases. A counter example is Ne and F; Ne has more protons and a larger ionization energy.**

(b) chlorine has fewer total electrons than bromine **Cl does have more electrons; however, the number of electrons does not factor into Coulomb's law. A counter example is O and F; O has fewer electrons and a smaller ionization energy.**

(c) bromine has a smaller core charge than chlorine **This statement is not true as both have the same core charge of +7**

In no more than two sentences explain why the first ionization energy for Br is less than that for Cl. Be sure to read the caution on the front of the exam.

The valence electrons in Br are further from the nucleus than for Cl because they are in a shell with $n = 4$ instead of $n = 3$; a greater distance means a smaller ionization energy given the identical core charges.

Problem 5. Arrange the ions Li^+ , F^- , Na^+ , Cl^- , and Br^- in order of size, placing the smallest ion on the left and the largest ion on the right. In two or three sentences, clearly explain your reasoning. Be sure to read the caution on the front of the exam.



A cation is smaller than its associated element because the loss of a valence electron increases the core charge experienced by the remaining valence electrons. An anion is larger than its associated element because an extra electron in the valence shell allows for more repulsion between electrons. Na^+ is larger than Li^+ and Br^- larger than Cl^- , which is larger than F^- because valence electrons in shells with a larger n are further from the nucleus. Na^+ and F^- are isoelectronic, so they have the same valence electrons but different core charges; Na^+ has the larger core charge and, therefore, the smaller radius.

Problem 6. Of the elements – C, N, O, Si, P, S – which has the smallest AVEE? Clearly explain your reasoning in two to four sentences. Be sure to read the caution on the front of the exam.

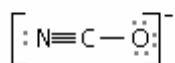
The AVEE is a weighted average of the ionization energies for an element's valence electrons. Ionization energies generally increase to the right of the periodic table due to an increase in core charge and decrease down the periodic table due to the increased distance between the valence electrons and the nucleus. Of the six elements, Si is further to the left and further down the table and, therefore, has the smallest AVEE.

Problem 7. In the Lewis structure for the compound XF_4 , where X is an unknown element, there is a single pair of non-bonding electrons on X . Identify an element that could be X (there are several possible choices). Explain how you arrived at your choice in no more than three sentences.

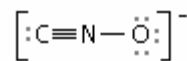
The Lewis structure for XF_4 will have four X-F single bonds (8 total electrons), six lone-pairs of electrons on each of the four fluorines (24 total electrons) and a single lone-pair of electrons on X (2 total electrons). This is a total of 34 electrons. Each fluorine brings 7 valence electrons into the structure, for a total of 28 electrons. This leaves six electrons that must come from X , which places it in the oxygen group. Because X has four bonds and a lone-pair of electrons, it cannot be oxygen as it can take only an octet of electrons. The choices, therefore, are S, Se, Te and Po.

Problem 8. The cyanate ion and the fulminate ion both contain one atom each of carbon, nitrogen and oxygen, and both have a charge of -1. Cyanate's skeletal structure has carbon as a central atom and fulminate has nitrogen as its central atom. Draw the most valid Lewis structure for each ion (do any scratch work below the line and place your two final structures in the space below).

Cyanate



Fulminate



Annotate your structures by providing the formal charges for each atom.

For cyanate, the formal charge on oxygen is -1 and is zero on carbon and nitrogen. For fulminate, the formal charges on oxygen and carbon are -1 and the formal charge on nitrogen is +1.

Metal salts of one of these ions are commonly used as a friction-sensitive explosive in percussion caps. In one or two sentences, indicate which ion is likely to be the explosive and offer an explanation for your choice.

Fulminate is the less stable ion. The negative formal charge on carbon is not favorable, particularly when nitrogen, an element with a higher AVEE, has a positive formal charge. Having more elements with formal charges and the separation of formal charges also suggest that, of the two ions, fulminate is the less stable.

Place all scratch work for this problem here.