

AP Chemistry Problem Set Chapter 7

Name _____

Due: Monday, December 11th, 2006

30 points – 5 points for completion, 3 random essay problems will be graded, each worth 5 points. Each multiple choice must be answered (1 point each). Staple this sheet to the front of your essay responses.

Multiple Choice. Please indicate your multiple choice answers below.

1. **D** 2. **A** 3. **C** 4. **E** 5. **D**
 6. **A** 7. **E** 8. **C** 9. **D** 10. **E**

(A) 1s _____ 2s \uparrow _____
(B) 1s $\downarrow\uparrow$ _____ 2s $\downarrow\uparrow$ _____
(C) 1s $\downarrow\uparrow$ _____ 2s $\downarrow\uparrow$ _____ 2p \uparrow _____ \uparrow _____ _____
(D) 1s $\downarrow\uparrow$ _____ 2s $\downarrow\uparrow$ _____ 2p $\downarrow\uparrow$ _____ $\downarrow\uparrow$ _____ $\downarrow\uparrow$ _____
(E) [Ar] 4s $\downarrow\uparrow$ _____ 3d $\downarrow\uparrow$ _____ \uparrow _____ \uparrow _____ \uparrow _____ \uparrow _____

1. Represents an atom that is chemically unreactive. – **D – 1999 (75%)**
 2. Represents an atom in an excited state. – **A – 1999 (78%)**
 3. Represents an atom that has four valence electrons. – **C – 1999 (55%)**
 4. Represents an atom of a transition metal. – **E – 1999 (83%)**
 5. Represents a common ion of an alkaline earth element. – **D**
6. Which of the following represents the ground state electron configuration for the Mn³⁺ ion? **A – 1984 (32%)**
(A) 1s² 2s² 2p⁶ 3s² 3p⁶ 3d⁴ (B) 1s² 2s² 2p⁶ 3s² 3p⁶ 3d³ 4s² (C) 1s² 2s² 2p⁶ 3s² 3p⁶ 3d² 4s²
 (D) 1s² 2s² 2p⁶ 3s² 3p⁶ 3d⁸ 4s² (E) 1s² 2s² 2p⁶ 3s² 3p⁶ 3d³ 4s¹
7. One of the outermost electrons in a strontium atom in the ground state can be described by which of the following sets of four quantum numbers? **E – 1984 (41%)**
 (A) 5, 2, 0, ½ (B) 5, 1, 1, ½ (C) 5, 1, 0, ½ (D) 5, 0, 1, ½ **(E) 5, 0, 0, ½**

Ionization Energies for element X (kJ mol ⁻¹)				
First	Second	Third	Fourth	Five
580	1815	2740	11600	14800

8. The ionization energies for element X are listed in the table above. On the basis of the data, element X is most likely to be:
 (A) Na (B) Mg **(C) Al – 1999 (35%)** (D) Si (E) P
9. In the periodic table, as the atomic number increases from 11 to 17, what happens to the atomic radius?
 (A) It remains constant. (B) It increases only. (C) It increases, then decreases.
(D) It decreases only. – 1999 (62%) (E) It decreases, then increases.
10. The electron configuration: 1s² 2s² 2p⁶ 3s² 3p⁶ corresponds to the electron configuration of:
 (A) S²⁻ (B) Ca²⁺ (C) Cl⁻ (D) K⁺ **(E) all of these**

Essays:

1. (1999 - #2)

Answer the following questions regarding light and its interactions with molecules, atoms, and ions.

(a) The longest wavelength of light with enough energy to break the Cl-Cl bond in $\text{Cl}_2(g)$ is 495 nm.

(i) Calculate the frequency, in s^{-1} , of the light. **$6.06 \times 10^{14} \text{ sec}^{-1}$**

(ii) Calculate the energy, in J, of a photon of the light. **$4.02 \times 10^{-19} \text{ J}$**

(iii) Calculate the minimum energy, in kJ mol^{-1} , of the Cl-Cl bond. **242 kJ/mol**

(b) A certain line in the spectrum of atomic hydrogen is associated with the electronic transition in the H atom from the sixth energy level ($n = 6$) to the second energy level ($n = 2$).

(i) Indicate whether the H atom emits energy or whether it absorbs energy during the transition. Justify your answer.

Energy is emitted. The $n = 6$ state is at a higher energy than the $n = 2$ state. Going from a high energy state to a low energy state means that energy must be emitted.

(ii) Calculate the wavelength, in nm, of the radiation associated with the spectral line. **411 nm**

(iii) Account for the observation that the amount of energy associated with the same electronic transition ($n = 6$ to $n = 2$) in the He^+ ion is greater than that associated with the corresponding transition in the H atom.

The positive charge holding the electron is greater for He^+ , which has a 2+ nucleus, than for H with its 1+ nucleus. The stronger attraction means that it requires more energy for the electron to move to higher energy levels. Therefore, transitions from high energy states to lower states will be more energetic for He^+ than for H.

2. (1993 - #6 a & b; 2006B - #7 b, c & d)

Account for each of the following in terms of principles of atomic structure, including the number, properties, and arrangements of subatomic particles.

(a) The second ionization energy of sodium is about three times greater than the second ionization energy of magnesium.

Electron configuration of Na and Mg

Octet / Noble gas stability comparison of Na and Mg

Energy difference explanation between Na and Mg

Size difference explanation between Na and Mg

Shielding/effective nuclear charge discussion

(b) The difference between the atomic radii of Na and K is relatively large compared to the difference between the atomic radii of Rb and Cs.

Correct direction and explanation of the following:

shielding differences

energy differences

of proton/ # of electron differences

(c) Atomic size decreases from Na to Cl in the periodic table.

Across the periodic table from Na to Cl, the number of electrons in the s- and p- orbitals of the valence shell increases, as does the number of protons in the nucleus. The added electrons only partially shield the added protons, resulting in an increased effective nuclear charge. This results in a greater attraction for the electrons, drawing them closer to the nucleus, making the atom smaller.

(d) The first ionization energy of K is less than that of Na.

Both Na and K have an s^1 valence-shell electron configuration (Na: $[\text{Ne}] 3s^1$; K: $[\text{Ar}] 4s^1$). The K atom valence electron has a higher n quantum number, placing it farther from the nucleus than the Na atom valence electron. The greater distance results in less attraction to the nucleus. Because its valence electron is less attracted to its nucleus, the K atom has the lower ionization energy.

(e) Each element displays a unique gas-phase emission spectrum.

Each element has a unique set of quantized energy states for its electrons (because of its unique nuclear charge and unique electron configuration). As the electrons of an element absorb quanta of energy, they change to higher energy states (are excited) – during de-excitation, energy is released as EM radiation as the electrons cascade to lower energy states. Each photon of the EM radiation is associated with a specific wavelength ($\lambda = hc/E$), a flux of which produces the lines of the emission spectrum.

3. (2000 - #7 a, b & c; 2005 - #7 c)

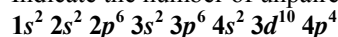
Answer the following questions about the element selenium, Se (atomic number 34).

(a) Samples of natural selenium contain six stable isotopes. In terms of atomic structure, explain what these isotopes have in common, and how they differ.

The isotopes have the same number (34) of protons, but a different number of neutrons.

(b) Write the complete electron configuration (e.g., $1s^2 2s^2 \dots$ etc.) for a selenium atom in the ground state.

Indicate the number of unpaired electrons in the ground-state atom, and explain your reasoning.



Since there are three different 4p orbitals, there must be two unpaired electrons. There must be some explanation of Hund's rule, and an orbital diagram.

(c) In terms of atomic structure, explain why the first ionization energy of selenium is

(i) less than that of bromine (atomic number 35), and

The ionized electrons in both Se and Br are in the same energy level, but Br has more protons than Se, so the attraction to the nucleus is greater.

(ii) greater than that of tellurium (atomic number 52).

The electron removed from a Te atom is in a 5p orbital, while the electron removed from an Se atom is in a 4p orbital. The 5p orbital is at a higher energy than the 4p orbital, thus the removal of an electron in a 5p orbital requires less energy.

(d) As shown in the table below, the first ionization energies of Si, P, and Cl show a trend.

Element	First Ionization Energy (kJ mol ⁻¹)
Si	786
P	1,012
Cl	1,251

(i) For each of the three elements, identify the quantum level (e.g., $n = 1$, $n = 2$, etc.) of the valence electrons in the atom.

The valence electron is located in the $n = 3$ level for all three atoms.

(ii) Explain the reasons for the trend in first ionization energies.

Because the valence electrons in all three elements are shielded by the same number of inner core electrons and the nuclear charge increases going from Si to P to Cl, the valence electrons feel an increasing attraction to the nucleus going from Si to P to Cl. Valence electrons having a greater attraction to the nucleus, as in Cl, will be more difficult to remove, so Cl has the highest ionization energy. P has the second highest ionization energy, and Si has the lowest ionization energy.

4. (2002 - #6 a & b; 2003B - #7 b, c & d)

Use the principles of atomic structure and/or chemical bonding to explain each of the following. In each part, your answer must include references to both substances.

(a) The atomic radius of Li is larger than that of Be.

Both Li and Be have their outer electrons in the same shell (and/or they have the same number of inner core electrons shielding the valence electrons from the nucleus). However, Be has four protons and Li has only three protons. Therefore, the effective nuclear charge experienced (attraction experienced) by the valence (outer) electrons is greater in Be than in Li, so Be has a smaller atomic radius.

(b) The second ionization energy of K is greater than the second ionization energy of Ca.

The second electron removed from a potassium atom comes from the third level (inner core). The second electron removed from a calcium atom comes from the fourth level (valence level). The electrons in the third level are closer to the nucleus so the attraction is much greater than for electrons in the fourth level.

(c) Carbon and lead are in the same group of elements, but carbon is classified as a nonmetal and lead is classified as a metal.

Binary compounds of carbon exhibit covalent character (property of a nonmetallic element), whereas binary compounds of lead exhibit ionic character (property of a metallic element). Oxides of carbon, when dissolved in water, are acidic (property of a nonmetallic element), whereas oxides of lead, when added to water, are basic (property of a metallic element). Carbon is a poor thermal conductor (property of a nonmetallic element), whereas lead is a very good thermal conductor (property of a metallic element).

(d) Compounds containing Kr have been synthesized, but there are no known compounds that contain He.

Helium has a filled shell (the first shell), so does not tend to lose or gain electrons. Therefore, helium does not react. Krypton, while having filled 4s and 4p sublevels, has empty 4d and 4f sublevels. These empty orbitals affect the reactivity of Kr. Note: Also acceptable is a comparison of the ionization energies of helium, and krypton and then the justification for krypton being more reactive.

(e) The first ionization energy of Be is 900 kJ mol^{-1} , but the first ionization energy of B is 800 kJ mol^{-1} .

The electron configuration for Be is $1s^2 2s^2$, whereas the electron configuration for B is $1s^2 2s^2 2p^1$. The first electron removed in boron is in a 2p subshell, which is higher in energy than the 2s subshell, from which the first electron is removed in beryllium. The higher in energy the subshell containing the electron to be removed (ionized), the lower the ionization energy.

5. (2006 - #8)

Suppose that a stable element with atomic number 119, symbol Q, has been discovered.

(a) Write the ground-state electron configuration for Q, showing only the valence-shell electrons.

$8s^1$

(b) Would Q be a metal or a nonmetal? Explain in terms of electron configuration.

It would be a metal (OR an alkali metal). The valence electron would be held only loosely.

(c) On the basis of periodic trends, would Q have the largest atomic radius in its group or would it have the smallest? Explain in terms of electronic structure.

It would have the largest atomic radius in its group because its valence electron is in a higher principal shell.

(d) What would be the most likely charge of the Q ion in stable ionic compounds?

+1

(e) Write a balanced equation that would represent the reaction of Q with water.

$2 \text{ Q(s)} + 2 \text{ H}_2\text{O(l)} \rightarrow 2 \text{ Q}^+(\text{aq}) + 2 \text{ OH}^-(\text{aq}) + \text{ H}_2(\text{g})$

(f) Assume that Q reacts to form a carbonate compound.

(i) Write the formula for the compound formed between Q and the carbonate ion, CO_3^{2-} .

Q_2CO_3

(ii) Predict whether or not the compound would be soluble in water. Explain your reasoning.

It would be soluble in water because all alkali metal carbonates are soluble.