CH 221 Fall 2023:

Problem Set #6

Instructions

Step One (all sections):

- **Learn the material** for Problem Set #6 by **reading Chapter 6** of the textbook and/or by watching the videos found on our website (https://mhchem.org/221)
- **Try the problems** for Problem Set #6 found on the next pages on your own first. Use separate paper and write out your answers, showing all of your work. If you write the answers on the problem set itself, you will receive fewer points. Include your name on your problem set!

Step Two:

Section 01 and H1: We will go over Problem Set #6 during recitation. ***Self correct all problems*** of your problem set before turning it in at the end of recitation.

- *Section 01:* due **Monday, December 4 at 1:10 PM**
- *Section H1:* due **Wednesday, December 6 at 1:10 PM**

Section W1: **Watch the recitation video** for Problem Set #6:

http://mhchem.org/w/c.htm

- **Self correct *all* of the problems** while viewing the video. Mark correct problems with a star (or other similar mark), and correct all incorrect problems (show the correct answer and the steps required to achieve it.)
- **Submit Problem Set #6 via email (mike.russell@mhcc.edu) as a single PDF file** (use CamScanner (https://camscanner.com), CombinePDF (https://combinepdf.com), etc.) **by 11:59 PM Wednesday, December 6.**

If you have any questions regarding this assignment, please email (mike.russell@mhcc.edu) the instructor! Good luck on this assignment!

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** Complete problem set on separate pieces of paper showing all work, circling final answers, etc.*
** Self correct your work before turning it in to the instructor.*

Covering: **Chapter Six** *and* **Chapter Guide Six**
Important Tables and/or Constants: **c = 2.998 x 10^8 m/s, h = 6.626 x 10^{-34} J s**, the **Electromagnetic Spectrum** *and* **Subshell Filling Order diagrams** *on page 4 of Problem Set #6*. ***Memorize c and h!***

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1. Consider the electromagnetic spectrum:
    a. What color of light has photons of greater energy, yellow or blue?
    b. Which color of light has the greater frequency, blue or green?
    c. Place the following types of radiation in order of increasing energy per photon.
        i. radar signals (RADAR = RAdio Detection And Recognition)
        ii. radiation within a microwave oven
        iii. gamma rays from a nuclear reaction
        iv. red light from a neon sign
        v. ultraviolet radiation from a sun lamp
2. The most prominent line in the spectrum of magnesium is 285.2 nm; other lines are found at 383.8 and 518.4 nm. In which regions of the electromagnetic spectrum are these lines found? Which is the most energetic line? What is the frequency and energy (in both Joules per photon and kJ per mol) of the wavelength of the most energetic line?
3. Consider only transitions involving the n = 1 through n = 4 energy levels for the hydrogen atom:
    a. How many emission lines are possible?
    b. Photons of the lowest energy are emitted in a transition from the level with n = ___ to a level with n = ___.
    c. The emission line having the shortest wavelength corresponds to a transition from the level with n = ___ to the level with n = ___.
4. A beam of electrons (m = 9.11 x 10^{-31} kg/electron) has an average speed of 1.3 x 10^8 m s^{-1}. What is the wavelength of electrons having this average speed? *(Note to physics fans: no relativity in this problem!)*
5. Answer the following questions:
    a. When $n = 4$, $\ell = 2$ and $m_l = -1$, to what orbital type does this refer? (Use the subshell label, such as 1*s*.)
    b. How many orbitals occur in the n = 5 electron shell? How many subshells? What are the letter labels of the subshells?
    c. If a subshell is labeled *f*, how many orbitals occur in the subshell? What are the values of m_l?
6. Explain briefly why each of the following is not a possible set of quantum numbers for an electron in an atom. In each case, change the incorrect value(s) to make the set valid.
    a. $n = 2, \ell = 2, m_l = 0, m_s = +1/2$
    b. $n = 2, \ell = 1, m_l = -1, m_s = 0$
    c. $n = 3, \ell = 1, m_l = +2, m_s = +1/2$

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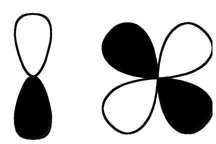
7. What is the maximum number of orbitals that can be identified by each of the following sets of quantum numbers?
   a. $n = 4, \ell = 3$
   b. $n = 4$
   c. $n = 2, \ell = 2$
   d. $n = 3, \ell = 1, m_l = -1$
8. State which of the following are incorrect designations for orbitals according to the quantum theory: 3*p*, 4*s*, 2*f*, and 1*p*. Briefly explain your answers.
9. How many nodal surfaces (planar *and* spherical) are associated with each of the following atomic orbitals?
   a. 4*f*
   b. 2*p*
   c. 6*s*
10. Answer the following questions:
    a. The quantum number n describes the _____ of an atomic orbital and the quantum number ℓ describes its _____.
    b. When $n = 3$, the possible values of ℓ are _____.
    c. What type of subshell corresponds to $l = 3$?
    d. For a 4*d* orbital, the value of n is ___, the value of ℓ is ___, and a possible value of m_l is ___.
    e. For each of the orbitals shown in the diagram on the right, give the letter designation for the orbital, the value of ℓ, and the number of planar nodal surfaces.



    f. An atomic orbital with three planar nodal surfaces is ______(letter).
    g. Which of the following orbitals cannot exist according to modern quantum theory? 2*s*, 3*p*, 2*d*, 3*f*, 5*p*, 6*p*
    h. Which of the following is *not* a valid set of quantum numbers?
       i. $n = 3, \ell = 2, m_l = 1$
       ii. $n = 2, \ell = 1, m_l = 2$
       iii. $n = 4, \ell = 3, m_l = 0$
    i. What is the maximum number of orbitals that can be associated with each of the following sets of quantum numbers?
       i. $n = 2$ and $\ell = 1$
       ii. $n = 3$
       iii. $n = 3$ and $\ell = 3$
       iv. $n = 2, \ell = 1, m_l = 0$
    j. Place the following subshells in order (from lowest to highest energy) using the $n + l$ rule: **1s 2s 2p 3s 3p 3d 4s 4p 4d 4f 5s 5p 5d 6s 6p**

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11. In principle, which of the following can be determined?
    a. The energy of a high-speed electron in the H atom with high precision and accuracy
    b. The position of a high-speed electron with high precision and accuracy
    c. At the same time, both the position and the energy of a high-speed electron with high precision and accuracy.
12. Write the electron configuration for neutral Mg and Ar using both *spdf* notation and orbital box diagrams.
13. Using *spdf* and noble gas notations, write electron configurations for neutral atoms of the following elements:
    a. Strontium, Sr. This element is named for a town in Scotland.
    b. Zirconium, Zr. The metal is exceptionally resistant to corrosion and so has important industrial applications. Moon rocks show a surprisingly high zirconium content compared with rocks on earth.
    c. Rhodium, Rh. This metal is used in jewelry and in catalysts in industry.
    d. Tin, Sn. The metal was used in the ancient world. Alloys of tin (solder, bronze, pewter) are important.
14. Using orbital box diagrams, depict an electron configuration for each of the following ions:
    a. Na^+
    b. Al^{3+}
    c. Ge^{2+}
    d. F^-
15. Explain each answer briefly:
    a. Arrange the following elements in order of increasing size: Ca, Rb, P, Ge, Sr
    b. Which has the largest first ionization energy: O, S, or Se?
    c. Which has the most negative electron affinity: Se, Cl or Br?
    d. Which has the largest radius: O^{2-}, F^{-1} or F?
    e. Which is most paramagnetic: Fe^{3+} or Cr^{3+}? Explain.
16. The diagrams on the right represent a small section of a solid. Each circle represents an atom and an arrow represents an electron.
    a. Which represents a diamagnetic solid, which is a paramagnetic solid, and which is a ferromagnetic solid?
    b. Which is most strongly attracted to a magnetic field? Which is least attracted?

(a) (b) (c)

17. *Briefly* describe the notable achievements of the following individuals in relation to quantum theory: **Maxwell, Planck, Einstein, Bohr, de Broglie, Schrödinger, Heisenberg, Dirac, Pauli, Hund**

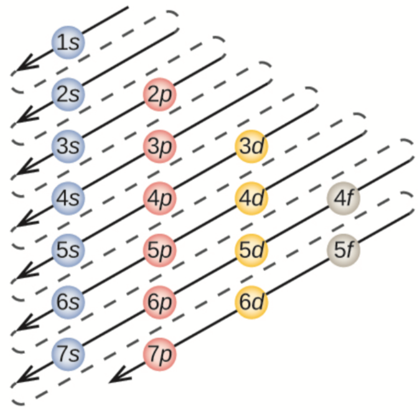

Figure 6.27 The arrow leads through each subshell in the appropriate filling order for electron configurations. This chart is straightforward to construct. Simply make a column for all the *s* orbitals with each *n* shell on a separate row. Repeat for *p*, *d*, and *f*. Be sure to only include orbitals allowed by the quantum numbers (no 1*p* or 2*d*, and so forth). Finally, draw diagonal lines from top to bottom as shown.

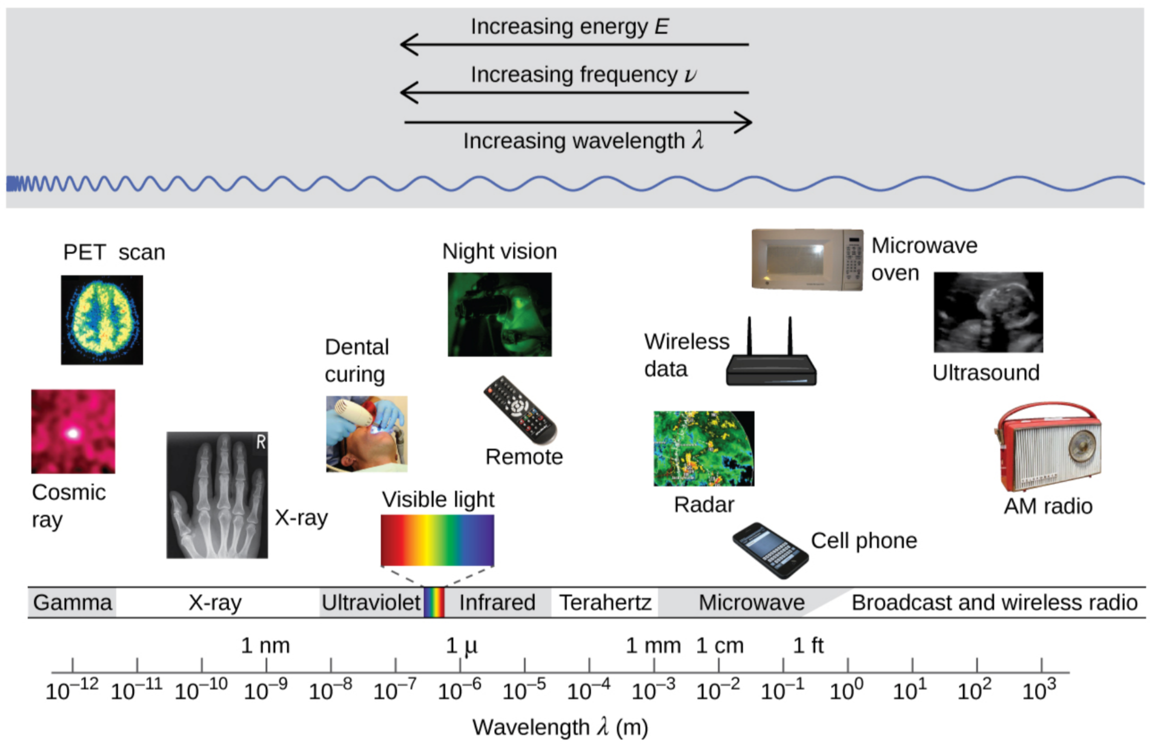

Figure 6.3 Portions of the electromagnetic spectrum are shown in order of decreasing frequency and increasing wavelength. Examples of some applications for various wavelengths include positron emission tomography (PET) scans, X-ray imaging, remote controls, wireless Internet, cellular telephones, and radios. (credit “Cosmic ray": modification of work by NASA; credit “PET scan": modification of work by the National Institute of Health; credit “X-ray": modification of work by Dr. Jochen Lengerke; credit “Dental curing": modification of work by the Department of the Navy; credit “Night vision": modification of work by the Department of the Army; credit “Remote": modification of work by Emilian Robert Vicol; credit “Cell phone": modification of work by Brett Jordan; credit “Microwave oven": modification of work by Billy Mabray; credit “Ultrasound": modification of work by Jane Whitney; credit “AM radio": modification of work by Dave Clausen)

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