CH 221 Practice Problem Set #3

*This is a **practice problem set** and not the actual graded problem set that you will turn in for credit. Answers to each problem can be found at the end of this assignment.*

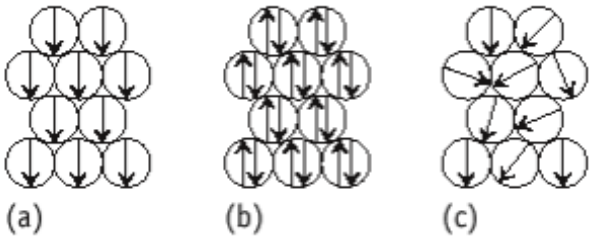
Covering: **Chapter Three** *and* **Chapter Guide Three**
Important Tables and/or Constants: **c = 2.998 x 10^{8} m/s, h = 6.626 x 10^{-34} J s**, the **Electromagnetic Spectrum** *and* **Subshell Filling Order diagrams** o*n page 4 of Problem Set #6*. ***Memorize c and h!***, 1 mol = 6.022 x 10^{23}, "Have No Fear Of Ice Clear Brew" (7 Diatomics)

---

1. Traffic signals are often now made of LEDs (light-emitting diodes). The light from an amber signal has a wavelength of 595 nm, and that from a green signal has wavelength of 500 nm. Which has the higher frequency? Which has the highest energy per photon? Calculate the frequency of amber light.
2. Place the following types of radiation in order of increasing energy per photon:
   a. yellow light from a sodium lamp
   b. x-rays from an instrument in a dentist's office
   c. microwaves in a microwave oven
   d. your favorite FM music station at 91.7 MHz
3. The most prominent line in the spectrum of aluminum is at 396.15 nm. What is the frequency of this line? What is the energy of one photon with this wavelength? Of 1.00 mol of these photons?
4. The energy emitted when an electron moves from a higher energy state to a lower energy state in any atom can be observed as electromagnetic radiation.
   a. Which involves the emission of less energy in the H atom, an electron moving from $n = 4$ to $n = 2$ or an electron moving from $n = 3$ to $n = 2$?
   b. Which involves the emission of more energy in the H atom, an electron moving from $n = 4$ to $n = 1$ or an electron moving from $n = 5$ to $n = 2$? Explain fully.
5. A rifle bullet (mass = 1.50 g) has a velocity of 7.00 x 10^{2} miles per hour. What is the wavelength associated with this bullet? (0.6214 miles = 1 km)
6. a. When $n = 4$, what are the possible values of ℓ?
   b. When ℓ is 2, what are the possible values of m_ℓ?
   c. For a 4*s* orbital, what are the possible values of n, ℓ, and m_ℓ?
   d. For a 4*f* orbital, what are the possible values of n, ℓ, and m_ℓ?
7. Which of the following represent valid sets of quantum numbers? For a set that is invalid, explain briefly why it is not correct.
   a. $n = 3$, $\ell = 3$, $m_\ell = 0$, $m_s = 0$
   b. $n = 2$, $\ell = 1$, $m_\ell = 0$, $m_s = +1/2$
   c. $n = 6$, $\ell = 5$, $m_\ell = -1$, $m_s = -1/2$
   d. $n = 4$, $\ell = 3$, $m_\ell = -4$, $m_s = -1/2$

8. What is the maximum number of orbitals that can be identified by each of the following sets of quantum numbers? When "none" is the correct answer, explain your reasoning.
   a. $n = 3$, $\ell = 0$, $m_\ell = -1$
   b. $n = 5$, $\ell = 1$
   c. $n = 7$, $\ell = 5$
   d. $n = 4$, $\ell = 2$, $m_\ell = -2$, $m_s = -1/2$
9. How many nodal surfaces (planar *and* spherical) are associated with each of the following atomic orbitals?
   a. 5*f*
   b. 1*p*
   c. 4*s*
10. Answer the following questions:
   a. The quantum number *n* describes the _____ of an atomic orbital.
   b. The shape of an atomic orbital is given by the quantum number _____.
   c. A photon of green light has _____ (less or more) energy than a photon of orange light.
   d. The maximum number of orbitals that may be associated with the set of quantum numbers $n = 4$ and $\ell = 3$ is _____.
   e. The maximum number of orbitals that may be associated with the quantum number set $n = 3$, $\ell = 2$, and $m_\ell = -2$ is _____.
   f. Sketch a *d*, *s* and *p* orbital.
   g. When $n = 5$, the possible values of ℓ are _____.
   h. The number of orbitals in the $n = 4$ shell is _____.
   i. The maximum number of orbitals that may be associated with the quantum number set $n = 3$, $\ell = 3$, $m_\ell = -2$ and $m_s = -1/2$ is _____.
   j. The maximum number of orbitals that may be associated with the quantum number set $n = 6$, $\ell = 0$, $m_\ell = 0$ and $m_s = +1/2$ is _____.
11. Write the electron configurations for P and Mg using *spdf* notation and orbital box diagrams.
12. Depict the electron configuration for each of the following atoms using *spdf* and/or noble gas notations.
   a. Arsenic, As. A deficiency of As can impair growth in animals even though larger amounts are poisonous.
   b. Krypton, Kr. It ranks seventh in abundance of the gases in the earth's atmosphere.
   c. Vanadium, V, an element found in some brown and red algae and some toadstools
13. Using orbital box diagrams and noble gas notation, depict the electron configurations of the following: (a) V, (b) V^{2+}, and (c) V^{5+}. Are any of the ions paramagnetic?
14. Arrange the following elements in order of increasing size: Al, B, C, K, and Na.
15. Name the element corresponding to each characteristic below.
   a. the element with the electron configuration $1s^2 2s^2 2p^6 3s^2 3p^3$
   b. the alkaline earth element with the smallest atomic radius
   c. the element with the largest ionization energy in Group 5A
   d. the element whose 2+ ion has the configuration [Kr]$4d^5$
   e. the element with the most negative electron affinity in Group 7A
   f. the element whose electron configuration is [Ar]$3d^{10}4s^2$

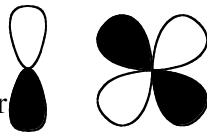
16. Give the symbol, including the correct charge, for each of the following ions:
    a. barium ion b. titanium(IV) ion c. phosphate ion d. hydrogen carbonate ion
    e. sulfide ion f. perchlorate ion g. cobalt(II) ion h. sulfate ion
17. When a potassium atom becomes a monatomic ion, how many electrons does it lose or gain? What noble gas atom is *isoelectronic* (i.e. has the same number of electrons) as a potassium ion?
18. For each of the following compounds, give the formula, charge, and the number of each ion that makes up the compound:
    a. K_2S b. $CoSO_4$ c. $KMnO_4$ d. $(NH_4)_3PO_4$ e. $Ca(ClO)_2$
19. Cobalt forms Co^{2+} and Co^{3+} ions. Write the formulas for the two cobalt oxides formed by these transition metal ions.
20. Which of the following are correct formulas for ionic compounds? For those that are not, give the correct formula.
    a. $AlCl_2$ b. KF_2 c. Ga_2O_3 d. MgS
21. Name each of the following ionic compounds:
    a. K_2S b. $CoSO_4$ c. $(NH_4)_3PO_4$ d. $Ca(ClO)_2$
22. Give the formula for each of the following ionic compounds:
    a. ammonium carbonate
    b. calcium iodide
    c. copper(II) bromide
    d. aluminum phosphate
    e. silver(I) acetate
23. Sodium ion, Na^+, forms ionic compounds with fluoride, F^-, and iodide, I^-. The radii of these ions are as follows: Na^+ = 116 pm; F^- = 119 pm; and I^- = 206 pm. In which ionic compound, NaF or NaI, are the forces of attraction between cation and anion stronger? Explain your answer.
24. Name each of the following binary, nonionic compounds:
    a. NF_3 b. HI c. BI_3 d. PF_5
25. Give the formula for each of the following compounds:
    a. sulfur dichloride
    b. dinitrogen pentaoxide
    c. silicon tetrachloride
    d. diboron trioxide
26. 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?



27. *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**

28. 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.

29. 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**

Answers to the Practice Problem Set:

1. Green, green, 5.04×10^{14} Hz
2. FM radio (d) < microwaves (c) < yellow light (a) < X-rays (b)
3. $7.5676 \times 10^{14}\ s^{-1}$, 5.0144×10^{-19} J/photon, 3.02×10^{5} J/mol photons
4. a. $n = 3$ to $n = 2$ b. $n = 4$ to $n = 1$
5. 1.41×10^{-33} m
6. *Answers:*
   a. ℓ can be 0, 1, 2, 3
   b. m_ℓ can be 0, ±1, ±2
   c. $n = 4$, $\ell = 0$, $m_\ell = 0$
   d. $n = 4$, $\ell = 3$, $m_\ell = 0, \pm1, \pm2, \pm3$
7. *Answers:*
   b. and c. are valid sets of quantum numbers
   a. incorrect; when $n = 3$, the maximum value of ℓ is 2; also, m_s = *must* be $+1/2$ or $-1/2$
   d. incorrect; when $\ell = 3$, m_ℓ can only have values of 0, ±1, ±2, or ±3
8. a. none b. 3 c. 11 d. 1
9. a. 3 planar, 1 spherical b. zero planar, zero spherical c. zero planar, three spherical
10. a. size, energy b. ℓ c. more d. 7 e. 1 f. "cloverleaf", "spherical", "figure eight/dumbbell" g. 0, 1, 2, 3, 4 h. 16 i. 0 j. 1
11. P: $1s^2 2s^2 2p^6 3s^2 3p^3$ Mg: $1s^2 2s^2 2p^6 3s^2$
12. a. [Ar]$3d^{10} 4s^2 4p^3$ b. [Ar]$3d^{10} 4s^2 4p^6$ c. [Ar]$3d^3 4s^2$
13. a. [Ar]$3d^3 4s^2$ b. [Ar]$3d^3$ c. [Ar]
14. C < B < Al < Na < K
15. a. P b. Be c. N d. Tc e. Cl f. Zn
16. a. Ba^{2+} b. Ti^{4+} c. PO_4^{3-} d. HCO_3^{-1} e. S^{2-} f. ClO_4^{-1} g. Co^{2+} h. SO_4^{2-}
17. One electron; argon.
18. *Answers:*
    a. 2 K^+ ions, 1 S^{2-} ion
    b. 1 Co^{2+} ion, 1 SO_4^{2-} ion
    c. 1 K^+ ion, 1 MnO_4^- ion
    d. 3 NH_4^+ ions, 1 PO_4^{3-} ion
    e. 1 Ca^{2+} ion, 2 ClO^- ions
19. CoO, Co_2O_3
20. a. incorrect, $AlCl_3$ b. incorrect, KF c. correct d. correct
21. a. potassium sulfide b. cobalt(II) sulfate c. ammonium phosphate d. calcium hypochlorite
22. *Answers:*
    a. $(NH_4)_2CO_3$
    b. CaI_2
    c. $CuBr_2$
    d. $AlPO_4$
    e. $AgCH_3CO_2$
23. NaF stronger, shorter cation-anion distance
24. *Answers:*
    a. nitrogen trifluoride
    b. hydrogen monoiodide
    c. boron triiodide
    d. phosphorus pentafluoride
25. a. SCl_2 b. N_2O_5 c. $SiCl_4$ d. B_2O_3

26. a) b = diamagnetic, c = paramagnetic, a = ferromagnetic b) most attracted to field = a, least attracted = b (no attraction)
27. **Maxwell**: developed EM wave theory (frequency, wavelength, etc.)
Planck: light is quantized, light consists of photons, Planck's constant
Einstein: photoelectric effect, light behaving as "particle"
Bohr: first theory for sharp line spectra, theory works great for H and He^{+1}
de Broglie: matter behaving as waves, de Broglie wave equation
Schrödinger: created quantum mechanics using wave theory, useful but complicated
Heisenberg: Heisenberg uncertainty principle, cannot know energy and position simultaneously (e^{-1})
Dirac: combined relativity and quantum mechanics, spin quantum number comes out naturally
Pauli: Pauli exclusion principle, each electron needs individual set of 4 quantum numbers
Hund: Hund's rule, place each electron in orbital, don't pair unless necessary
28. (a) and (b), but not (c)
29. (a) size, energy and/or shell; shape and/or subshell
(b) 0, 1, 2
(c) *f*
(d) 4; 2; –2
(e)

letter	*p*	*d*	
ℓ value	1	2	
nodal planes		1	2

(f) *f*
(g) 2*d*, 3*f*
(h) $n = 2$, $\ell = 1$, $m_\ell = 2$ is not valid
(i) i. 3 ii. 9 iii. none iv. 1
(j) 1s 2s 2p 3s 3p 4s 3d 4p 5s 4d 5p 6s 4f 5d 6p