TOPIC E PROBLEMS

1) Calculate the following properties of light that has a wavelength of 490 nm.
   a) The frequency
   b) The energy of one photon, in joules
   c) The photon energy in kJ/mol
   d) The number of moles of photons required to supply 10.0 kJ of energy
   e) The total energy of 0.0125 moles of photons
   f) The number of individual photons required to supply 25.0 J of energy.

2) Frequencies of FM radio stations are usually given in megahertz (MHz), where 1 MHz equals 10^6 sec^{-1}. For a radio station that broadcasts at 94.3 MHz, calculate the following:
   a) The frequency in sec^{-1}
   b) The wavelength of the radiation, in meters
   c) The wavelength of the radiation, in nanometers
   d) The photon energy, in joules
   e) The photon energy, in kJ/mol

3) Molecular bromine (Br_2) breaks apart into bromine atoms if it is exposed to light whose energy is 190 kJ/mol.
   a) Calculate the wavelength of this light, in nanometers.
   b) Does this light fall in the visible spectrum? If not, does it fall in the infrared region, or in the ultraviolet region?

4) When an atom absorbs light, does an electron in the atom move from a lower energy level to a higher energy level, or does it move from a higher level to a lower level?

5) Here are two of the allowed energy levels for a lithium atom:

   Level 2: -8.638×10^{-19} J Level 3: -5.678×10^{-19} J

   a) What is ΔE for a lithium atom when an electron moves from level 3 to level 2? Give your answer in joules.
   b) What is ΔE for a lithium atom when an electron moves from level 2 to level 3? Give your answer in joules.
   c) Convert your answer to part a into kJ/mol.
   d) When the electron drops from level 3 to level 2, the atom emits a photon. Calculate the wavelength of this photon, in nanometers.
   e) Can visible light move an electron from level 2 to level 3? Explain your answer.

6) An atom can only undergo one electron transition at a time. However, when we observe the emission spectrum of an element, we see many lines. Explain.

7) Here are three of the allowed energy levels for a calcium atom:

   Level A: -710.3 kJ/mol Level B: -648.4 kJ/mol Level C: -514.2 kJ/mol

   Calculate the wavelengths of the three emission lines that can be produced by electron transitions involving these levels, and list the initial and final level for each emission line.

8) A line in the emission spectrum of neon has a wavelength of 471.5 nm. The final energy level for the corresponding electron transition is -266.7 kJ/mol. What is the initial energy level for this transition?

9) The following electronic transitions and the corresponding wavelengths can be seen in the emission spectrum of potassium:

level 7 → level 6 wavelength = 770.1 nm
level 8 → level 7 wavelength = 1243.6 nm
level 10 → level 8 wavelength = 14,818.5 nm

Using this information, calculate the wavelength that corresponds to the level 10 → level 6 transition in a potassium atom.

10) Calculate the energy of the fourth energy level in:

a) a hydrogen atom b) a C^{5+} ion (note that this is a one-electron ion)

11) Both hydrogen atoms and Be^{3+} ions have an allowed energy level at -7.77 kJ/mol.
a) What is the value of n for this level in the hydrogen atom?
b) What is the value of n for this level in the Be^{3+} ion?

12) a) Calculate the wavelength of the light that is emitted when the electron in a hydrogen atom drops from n = 9 to n = 6.

b) What wavelength would be emitted if this electron were in a B^{4+} ion instead of a hydrogen atom? Calculate the wavelength.

13) The emission spectrum of hydrogen has a line at a wavelength of 2871 nm.
a) Calculate the energy change for the electron transition that corresponds to this line.
b) One of the energy levels involved in this transition has n = 5. What is the value of n for the other energy level?
c) Is the value of n you calculated in part b the initial value, or the final value?

14) 6) The average kinetic energy of an electron in a ground-state helium atom is 2.4 x 10^{3} kJ/mol.

a) What is the corresponding electron velocity?

b) If an experiment is able to measure this velocity with an uncertainty of 10%, what is the minimum uncertainty in the position of the electron for this experiment?

c) The effective radius of a helium atom is 130 pm. Is the uncertainty you calculated in part b a significant fraction of this effective radius?

15) In the Schrödinger equation $\mathcal{H}\psi = E\psi$, what do the symbols E and ψ stand for?

16) What is the difference between a radial node and an angular node?

17) Complete the following table. The first row is completed for you as an example.

Orbital	Value of n	Value of ℓ	Possible values of m_ℓ	Number of nodes	Number of radial nodes	Number of angular nodes
2p	***2***	***1***	***-1, 0, 1***	***1***	***0***	***1***
5d						
	6	1				
				4	1	
			-2, -1, 0, 1, 2	6		
	4					1
					5	3

18) Calculate the energy of the $5p_x$ orbital in a hydrogen atom.

19) a) How many 2p orbitals are there?
b) How many 5f orbitals are there?

20) Draw a picture of each of the following orbitals.
a) 1s b) 2p c) 3d

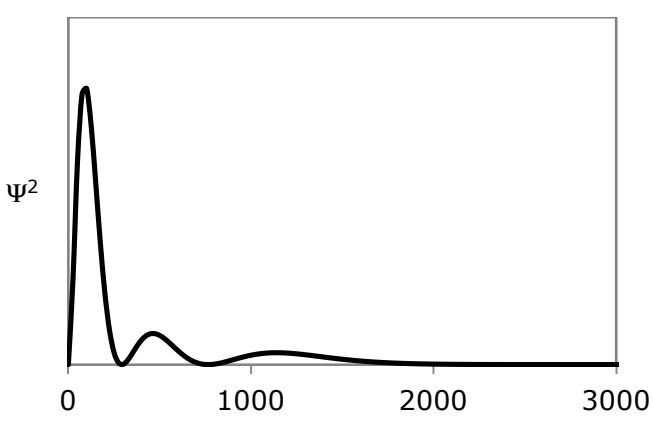
21)
a) How does a 1s orbital differ from a 2s orbital?
b) How does a 2s orbital differ from a 2p orbital?
c) How does a $2p_x$ orbital differ from a $2p_y$ orbital?
d) How does a 3p orbital differ from a 4d orbital?

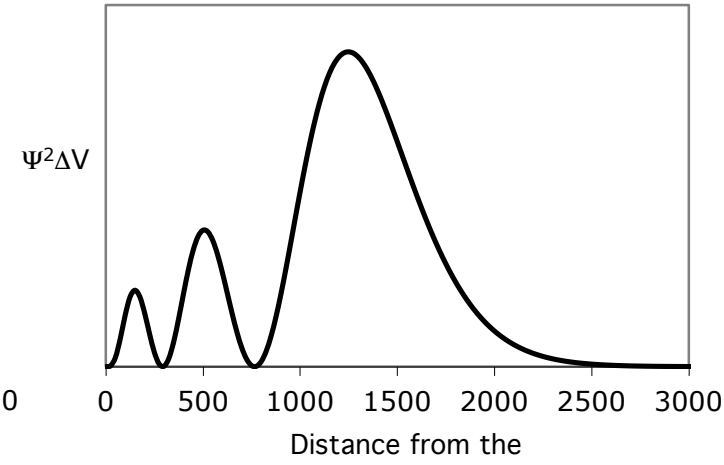
22)
a) How many different orbitals have n = 7? Explain your answer briefly.
b) How many different orbitals have n = 9 and ℓ = 7? Explain your answer briefly.
c) How many different orbitals have n = 8, ℓ = 5, and m_ℓ = -3? Explain your answer br.
d) How many different orbitals have n = 6 and m_ℓ = 2? Explain your answer briefly.
e) How many different orbitals have ℓ = 1 and m_ℓ = 0? Explain your answer briefly.

23) What are the possible values of m_ℓ and m_s for a 4f electron?1

24) Explain why it is impossible for an orbital to have n = 3 and ℓ = 3. (Hint: think about what these numbers are telling you about nodes.)

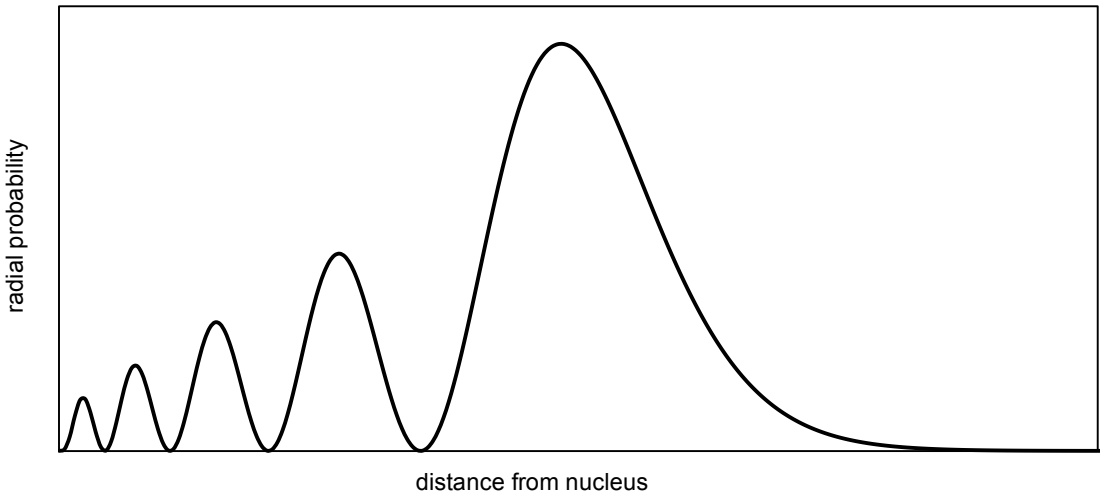
25) The two graphs below show the electron density and radial probability for an atomic orbital. (Both graphs show the same orbital.) Use the graphs to answer questions a through e below.





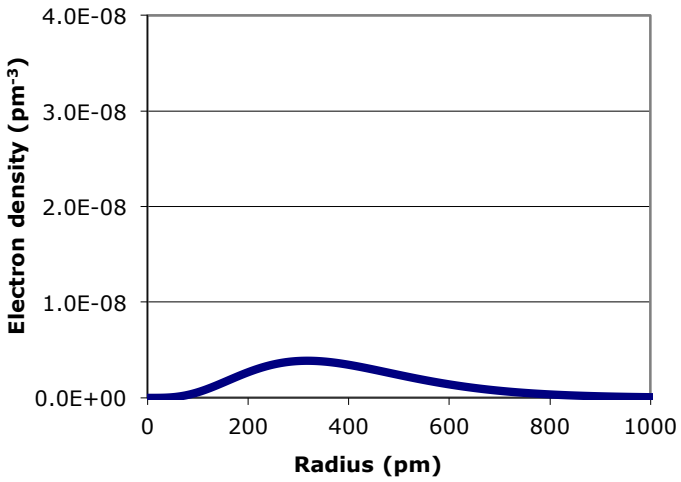
a) Which graph is the electron density plot?
b) What is the most probable distance between the electron and the nucleus for this orbital? (You will need to estimate it from one of the graphs.)
c) How many radial nodes does this orbital have? How can you tell?
d) Does this orbital have any angular nodes? How can you tell?
e) If n = 4 for this orbital, what orbital is it?

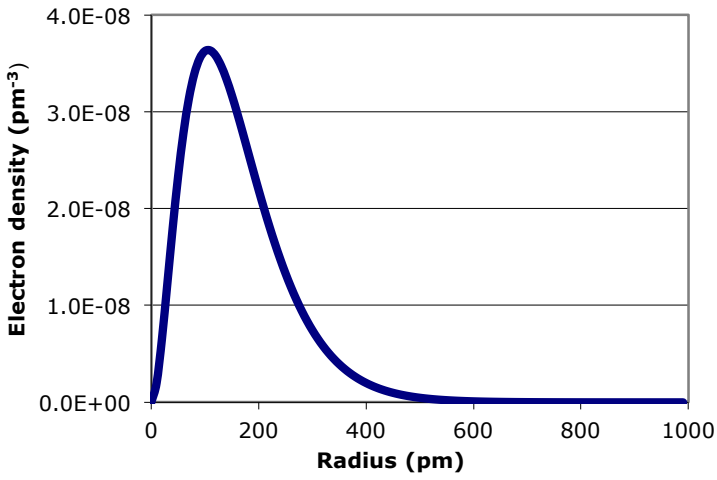
26) The radial probability plot below is for a p orbital. What type of p orbital is it (2p, 3p, 4p, etc.)? Explain your reasoning.



27) One of the electron density graphs below is for a 2p orbital and one is for a 3d orbital.

a) Which one is which? Explain your answer.
b) Explain why both of these graphs show just one "hump" (i.e. there is no place where the graph goes to zero).
c) Explain why both of these graphs start at the origin.
d) Give two examples of orbitals whose electron density plots would <u>not</u> start at the origin, and explain your answer.





28) A <u>partial</u> energy diagram for lithium (Li) is shown below. Answer questions a through d, using the information on this diagram and your understanding of emission spectra. *This is a review problem.*

ionized state	———————	0 kJ/mol
4p	———————	-83 kJ/mol
3p	———————	-150 kJ/mol
2p	———————	-342 kJ/mol
2s	———————	-520 kJ/mol

a) Calculate ΔE for the 2p → 2s transition in lithium, in kJ/mol.
b) Calculate the wavelength of light emitted during the 2p → 2s transition, in nm.
c) When the outer electron undergoes a 5p → 2s transition, the atom emits 256nm light. Calculate the energy of the 5p orbital, in kJ/mol.

29) Write ground-state electron configurations for the following atoms and ions. You may use inert gas abbreviations (for example, [Ne]$3s^1$ instead of $1s^2 2s^2 2p^6 3s^1$).

a) Rb b) Rb^+ c) S d) S^{2-} e) Cd f) Cd^{2+}
g) Co h) Co^{2+} i) Co^{3+}

30)

a) Which has the higher energy in a hydrogen atom, the 3s orbital or the $3p_x$ orbital?
b) Which has the higher energy in a phosphorus atom, the 3s orbital or the $3p_x$ orbital?
c) Which has the higher energy in a hydrogen atom, the 4s or the $3d_{xy}$ orbital?
d) Which has the higher energy in a Mn atom, the 4s or the $3d_{xy}$ orbital?
e) Which has the higher energy in a Mn^{2+} ion, the 4s or the $3d_{xy}$ orbital?

31) Which of the following configurations are ground states, which are excited states, and which are impossible configurations for an uncharged lithium atom?

a) $1s^3$ b) $1s^2 1p^1$ c) $1s^2 2s^1$ d) $1s^2 2p^1$ e) $1s^2 87f^1$

32) One possible electron configuration for an oxygen atom is [He]$2s^2 2p^4$. Which of the following orbital energy diagrams represent the ground state, which represent excited states, and which represent impossible arrangements for the 2p electrons in an uncharged oxygen atom?

a)
b)
c)
d)
e)
f)

33) Draw orbital energy diagrams for the 3d and 4s orbitals in the ground states of the following atoms. Do not show any other orbitals (but include arrows for the electrons).

i) a) Mn b) Ni c) Mn^{2+}

34) Which ground-state atoms in period 4 (elements 19 through 36) have…

i) a) no unpaired electrons? b) two unpaired electrons?

35) Draw an orbital energy diagram for the following configurations.

a) An atom that has the configuration $1s^2 2s^2 2p^4$ and is diamagnetic.
b) An atom that has the configuration $1s^2 2s^2 2p^4$ and is paramagnetic.

36) Which of the following configurations must be paramagnetic, which could be paramagnetic, and which cannot possibly be paramagnetic (i.e. they must be diamagnetic)?

i) a) [Ne]3s b) [Ne]$3s^2$ c) [Ne]$3s^2 3p$ d) [Ne]$3s^2 3p^2$

37)

a) How many electrons have n = 4 in a ground-state atom of technetium (Tc)?
b) How many electrons have $\ell = 1$ in a ground-state atom of arsenic (As)?
c) How many electrons have $m_\ell = 1$ in a ground-state atom of krypton (Kr)?
d) How many electrons have $m_s = -½$ in a ground-state atom of radium (Ra)?
e) What is the maximum number of electrons that could have $m_\ell = 2$ in a ground-state atom of iron?
f) What is the minimum number of electrons that could have $m_s = ½$ in a ground-state atom of oxygen?

38) Explain each of the following observations. Explanations such as "Ca is larger than Mg because atoms get larger as you down a column of the periodic table" are not acceptable; you must tell me why this trend occurs.

a) The atomic radius of Na is larger than the atomic radius of Mg.
b) The atomic radius of K is larger than the atomic radius of Na.
c) The ionic radius of S2– is larger than the ionic radius of Cl–.
d) The ionic radius of Zr3+ is larger than the ionic radius of Zr4+.

39) Arrange the elements Al, Ga, Ne, and S in order of increasing ionization energy (i.e. from lowest to highest). You should not need to look up the ionization energies to answer this question.

40) The list below shows the ionization energies for elements 36 through 40, in kJ/mol:

Element 36: 1351 Element 37: 403 Element 38: 549
Element 39: 600 Element 40: 640

a) Explain why the ionization energies increase as you go from element 37 to element 40.
b) Explain why the ionization energy drops dramatically as you go from element 36 to element 37.
c) Would you expect the ionization energy of element 35 to be lower than 1351 kJ/mol, or higher than 1351 kJ/mol?

41) An element in period 3 (elements 10 through 18) has the following ionization energies. Identify the element. Note: IE 1 is the energy required to remove the first electron, IE 2 is the energy required to remove the second electron, etc.

IE 1 = 787 kJ/mol IE 2 = 1577 kJ/mol IE 3 = 3232 kJ/mol
IE 4 = 4356 kJ/mol IE 5 = 16,091 kJ/mol IE 6 = 19,805 kJ/mol

42) The ionization energy of chlorine is 1251 kJ/mol. Based on this value, which of the following conclusions is reasonable? Select the correct statement, and fill in the blank with the correct orbital name.

a) The energy of the ____ orbital(s) in chlorine is 1251 kJ/mol.
b) The energy of the ____ orbital(s) in chlorine is –1251 kJ/mol.