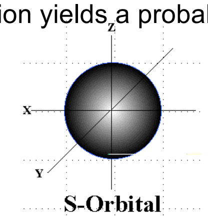
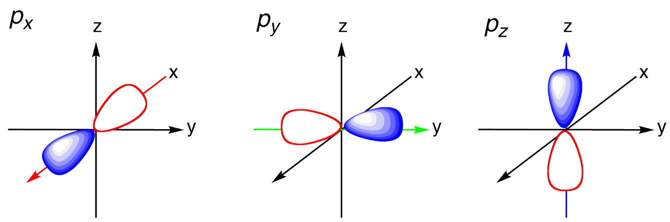
AP Chemistry
Unit 2 Practice Problems Key

1. The principal energy level represents the overall size and energy of an orbital. In QM the first quantum number, "n" symbolizes the principal energy level, it has integer values of 1, 2, 3, . . . The larger the value for "n" the larger the orbital. The equation $E_n = \frac{-2.18\times10^{-18} J}{n^2}$ is used to calculate the energy for a hydrogen atom. The values are negative because the electron's energy is lowered (made more negative) by it's interaction with the nucleus.

2. An orbital is a 3D region of space (a probability distribution map) in which a maximum of two electrons have a high probability of being located. This region of space, an orbital, is determined by Schrödinger's equation.

3. Schrödinger is credited with developing an equation to describe the probable location of an electron. Solving the equation yields a probability of knowing the energy, shape, orientation and spin of an electron in an atom.

4. 



The three p orbitals are aligned along perpendicular axes

5. Both are spherical in shape, but the larger the value for "n" the larger the s-orbital. Also, larger n means greater energy (less negative) for the orbital.

6. Increases. The energy level number is the same as the number of sublevels. For example: first energy level has one sublevel, s. Second had two s and p.

7.

Energy Level (n)	*Number of sublevels*	*Sublevel letter(s)*	*# of e- in each sublevel*	*# of orbitals in each sublevel*	*# of e- in each orbital*
1^{st}	1	s	2	1	2
2^{nd}	2	s,p	2,6	1,3	2
3^{rd}	3	s,p,d	2,6,10	1,3,5	2
4^{th}	4	s,p,d,f	2,6,10,14	1,3,5,7	2

8.

Symbol	Period #	Group #	Group Name	Metal or Nonmetal
s ***I***	5	***17***	Halogen	***nonmetal***
d ***K***	4	1	***alkaline metal***	***metal***
f Be	***2***	***2***	***alkaline earth metal***	***metal***
Ar	3	***18***	noble gas	***nonmetal***

9. $1s^22s^22p^63s^23p^64s^23d^{10}4p^65s^24d^{10}5p^66s^24f^{14}5d^{10}6p^67s^25f^{14}6d^{10}7p$

10. The 1 is the principal energy level, the s is the sublevel (also describes orbital) and the 2 is how many electrons in that orbital.

11. By looking at which group the element is found. For example: groups 1 and 2 are known as the s-block because the s sublevel (also orbital) is filling with electrons. Groups 13-18 are called the p-block, p sublevel filling, etc.

12. The period that the element is on indicates the energy level filling with electrons.

13. Groups 1 and 2 have one and two valence electrons respectively. Groups 13-18, take the group# and subtract 10. Group 13 has 3, 14 has 4, 15 has 5, etc. Transition metals and inner transition metals generally have 2, some exceptions though, groups 6 and 11.

14. Energy level containing valence electrons corresponds to the period the element is on.

15.

Ca	P	I (use noble gas shortcut)	Fe^{2+}
$1s^22s^22p^63s^23p^64s^2$	$1s^22s^22p^63s^23p^3$	$[Kr]:5s^24d^{10}5p^5$	$[Ar]3d^6$ (remember: ionized electrons come 4s before 3d)

16. The noble gas shortcut.

17. a) Pd b) Se c) Ir d) V^{2+} e) Pa f) Cu

18. Na^{+}, Mg^{2+}, Al^{3+} are isoelectronic with Ne and Cl^{-}, S^{2-}, P^{3-} all are isoelectronic with Ar.

19. K^{+}, Ca^{2+}, Sc^{3+} and P^{3-}, S^{2-}, Cl^{-}

20.

Sc^{3+}	Ag^{+}	Ru^{3+}	Zn^{2+}
[Ar]	***[Kr]4d^{10}***	***[Kr]4d^{5}***	***[Ar]3d^{10}***

21.

Z=35	${}^{40}_{19}K^{+1}$	metal in group 14, period 5	Ne	${}^{16}_{8}O^{-2}$
[Ar] $4s^2 3d^{10} 4p^5$	[Ar]	[Kr]$5s^2 4d^{10} 5p^2$	[He]$2s^2 2p^6$	[Ne]

22. Pb:[Xe]$6s^2 4f^{14} 5d^{10} 6p^2$ Sb:[Kr] $5s^2 4d^{10} 5p^3$

23.

[Ar]$4s^2$	P^{3-}	Cu	[Xe]$6s^2 4f^{14} 5d^{10} 6p^3$	N
Ca :	:P: (8 dots)	Cu •	•Bi: (5 dots)	•N: (5 dots)

24. $IE = E_{photon} - KE$ $\qquad IE = 143.4\ MJ/mol - 114.8\ MJ/mol = 28.6\ MJ/mol$

25. x-axis represents the ionization energy of the electron, which is the energy required to remove an electron from an atom. The y-axis represents the relative number of electrons. BTW the energy has a positive sign indicating that the electron absorbs energy to become ionized.

26. PES
   a) This PES shows two energy levels. The energy level closest to the nucleus requires the greatest ionization energy, at 19.3 MJ/mol, it makes sense because Coulomb's law shows that the closer the charges the greater the energy required to separate them. This peak illustrates the 1s shell. The other two peaks at 1.36 and 0.80 are closely spaced indicating sublevels in the same energy level, 2s.
   b) Electrons being ionized from same energy level or shell
   c) B
   d) $1s^2$ then $2s^2$ and finally $2p^1$
   e) $2p^1$ electron as it is farthest from the nucleus, therefore; according to Coulomb's Law requires less energy to ionize.
   f) $1s^2 2s^2 2p^1$
   g) •B:

27. a)

Relative Size	Increase	Decrease
Atoms from top to bottom	***x***	
Cations from top to bottom	***x***	
Anions from top to bottom	***x***	
Atoms from left to right		***x***
Cations from left to right		***x***
Anions from left to right		***x***
Isoelectric ions from low Z to high Z		***x***
Size of cation compared to atom		***x***
Size of anion compared to atom	***x***	

b) cations lose an energy level, therefore; are smaller
c) Anions add electrons, which increases electron-electron repulsion.

28. Silicon. Generally speaking, as valence electrons are removed, the remaining electrons experience a greater force of attraction from the nucleus. The first two ionization energies refer to the two electrons being removed from the 3p, then the two electrons from the 3s (closer to nucleus) and the fifth electron would be on the second energy level, even closer to the nucleus, again Coulomb's law shows that the energy needed to remove electrons from n=2 would be very high.

29. a) refer to figure 7.6, in text. b) refer to figure 7.10, c) refer to figure 7.12.

30.

Atomic Radius	
Period Pattern left to right	***decreases***
Anomaly group numbers	***no anomalies***
Ionization Energy	
Period Pattern left to right	***increases***
Anomaly group numbers	***columns 13 and 16***
Electron Affinity	
Period Pattern left to right	***decreases***
Anomaly group numbers	***columns 2, 15 and 18***

31. IE is the energy required to remove an electron from an atom to create a cation. It is positive because the electron/atom must gain energy to be removed. Electron affinity is the energy change when an atom gains an electron to become a negative ion. Usually negative, but not always. An atom releases energy if it gains an electron. The greater the attraction between an atom and the added electron, the more negative the electron affinity.

32. N experiences an effective nuclear charge of +5 (Z_{eff}=7-2=5), Be Z_{eff}= +2. The valence e- of N are "feeling" the pull of 5 protons as opposed to 2 e- for Be.

33. Use Coulomb's law. $E \approx \frac{Q_1 Q_2}{r}$ lowest energy is C, then A and B has the highest energy.

34.

a. Atomic radii of Li = 1.34 Å and Na = 1.54 Å.

The valence electron for Li is in the 2s subshell, which is closer to its nucleus than the valence electron for Na, which is in the 3s sublevel.

b. Atomic radii of Al = 1.18 Å and Si = 1.11 Å.

Si has 4 unshielded protons (protons – core electrons), which attract the valence electrons closer to the nucleus than the 3 unshielded protons in Al.

c. First ionization energies for B = 801 kJ/mol and Al = 578 kJ/mol.

The ionized electron for B comes from the second energy level, which is at a lower energy state than the ionized electron from Al, which comes from the third energy level ∴ it takes more energy to ionize.

d. First ionization energies for Si = 786 kJ/mol and P = 1012 kJ/mol.

The ionized electrons for Si and P come from the 3p sublevel, but the attraction between the Si nucleus and the ionized electron is less compared to P because Si is larger than P ∴ it takes more energy to ionize P.

e. First ionization energies for Mg = 738 kJ/mol and Al = 578 kJ/mol.

The ionized electron for Al comes from the 3p sublevel, which is at a higher energy state than the ionized electron for Mg, which comes from the 3s sublevel ∴ it takes less energy to ionize Al.

f. First ionization energies for P = 1012 kJ/mol and S = 1000 kJ/mol.

The ionized electron for S comes from a fully occupied 3p orbital, which is at a higher energy state (greater e-e repulsion) than the ½-filled 3p orbital of P's ionized electron ∴ it takes less energy to ionize S.

g. For Na, the first ionization energy I_1 = 495 kJ/mol and second ionization energy I_2 = 4562 kJ/mol.

I_2 is much larger than I_1 because the second ionized electron comes from the core rather than valence shell.

h. The gap between the first and second ionization energies is greater for Al (I_1 = 578 kJ/mol and I_2 = 1817 kJ/mol) than Si (I_1 = 786 kJ/mol and I_2 = 1577 kJ/mol).

For Al, the first two ionized electron come from different sublevels, which have a greater difference in energy compared to Si, where the first two electrons come from the same energy sublevel.

i. The common ion for magnesium is Mg^{2+}, where I_1 = 738 kJ/mol, I_2 = 1451 kJ/mol and I_3 = 7733 kJ/mol.

The first two electrons have relatively low ionization energies. As a result, they are typically lost during chemical reactions.

j. The electron affinities for Mg > 0 and Na = -53 kJ/mol.

The added electron to Mg must go into a higher energy state (3p) compared Na (3s) $\therefore$ the loss in energy when an electron approaches a nucleus is offset by the electron's higher energy level.

k. The electron affinities for Si = -134 kJ/mol and P = -72 kJ/mol.

The added electron to P must go into an occupied p-orbital with e-e repulsion compared to Si, which has an empty p-orbital $\therefore$ the loss in energy when an electron approaches a nucleus is offset by the e-e repulsion.

l. The electron affinities for S = -200 kJ/mol and Cl = -349 kJ/mol.

Although the added electrons for S and Cl enter occupied p-orbitals, the Cl atom is smaller; therefore the electron can get closer to the Cl nucleus, which releases more energy.

m. The electron affinities for Cl = -349 kJ/mol and Ar > 0.

The added electron to Ar enters the 4s sublevel, whereas the added electron to Cl enters the 3p sublevel $\therefore$ the loss in energy when an electron approaches a nucleus is offset by the higher energy level.