CH301 Fall 2009 Worksheet 3 Answer Key on Electronic Configuations and Periodic Table Trends

1. Write the electron configuration of gallium (Ga) in long notation and in short notation.
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^1$
$[Ar]\ 4s^2\ 3d^{10}\ 4p^1$

2. Write the electron configuration of a divalent vanadium cation (V^{2+}) in long and in short notation.
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^1$
$[Ar]\ 4s^2\ 3d^1$

3. Write the electron configuration of a monovalent iodine anion (I^-) in long and in short notation.
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6 5s^2\ 4d^{10}\ 5p^6$
$[Kr]\ 5s^2\ 4d^{10}\ 5p^6$

4. State in your own words the Pauli exclusion principle. Which of the quantum numbers is it most concerned with?
In a given atom, all of the electrons must be described by a unique set of four quantum numbers (n, l, m_l and m_s). It is most concerned with m_s, since for any value of n, l and m_l, m_s must be different, ensuring that the electrons have opposite spins. So, for our purposes, the Pauli exclusion principle states that any two electrons in the same orbital must have opposite spins.

5. Which ground state element corresponds to the following electron configurations?
   a. $[Rn]\ 5f^{14}\ 6d^3\ 7s^2$
   Dubnium (Db)
   b. $[Ne]\ 3s^2\ 3p^4$
   Sulfur (S)
   c. $[Xe]\ 4f^{14}\ 5d^6\ 6s^2$
   Osmium (Os)
   d. $[Xe]\ 4f^{14}\ 5d^{10}\ 6s^1$
   Gold (Au)

6. In your own words, what does Hund's rule state?
Every orbital in a subshell must have one electron in it before any orbital can have a pair of electrons in it. In other words, we half fill all orbitals before completely filling any of them. (For the record, Hund had 3 rules, but we're only concerned with the 1st one.)

7.In which region of the periodic table do we find most of the exceptions to Aufbau for neutral, ground state elements? What about cations (positively charged ionic species)?
The d block elements, aka the transition metals, and their ions often will "borrow" an electron or two from the nearest s subshell in order to fill or half-fill their d subshell. The p block metal ions, e.g. Pb^{3+}, also have electron configurations that are exceptions to Aufbau, particularly if they are isoelectronic with exception in the d block.

8. Write the electron configuration for silver. Try to give at least one example of an ion that would have an identical electron configuration.
$[Kr]\ 5s^1\ 4d^{10}$
Cd^+, In^{2+} and Sn^{3+} would all have the same electron configuration as Ag.

9. Is the electron configuration for silver a violation of the Aufbau principle? Defend your assertion.
No, silver's electron configuration is not a violation of the Aufbau principle. Silver's experimentally determined electron configuration is $[Kr]\ 5s^1\ 4d^{10}$. The Aufbau principle states that a ground state atom will have its electrons in their lowest energy possible, so if

[Kr] $5s^1$ $4d^{10}$ is what is observed, it is by definition lower in energy than [Kr] $5s^2$ $4d^9$ and thus Aufbau has not been violated.

10. What one adjective describes the following species: Ar, P^{3-}, Cl^-, Ca^{2+}?
Isoelectronic.

11. Arrange the following ions in order of increasing ionic radius
Sr2+ and Ca2+
O-2 and S-2
Sr2+ > Ca2+
Ionic radius increases down a group because electrons are occupying shells with higher principal quantum numbers. All cations are smaller than their parent atoms because they lose electrons and their core is exposed.
O-2 < S-2
Again, ionic radius increases down a group. Anions are larger than their parent atoms. More electrons are added to the valence shell and the repulsive effect of the electrons and repel each other.

12. Define electron affinity in your own words and explain why electron affinity decreases from groups I to II.
Electron affinity corresponds to the energy released when an electron is added to an atom in the gas phase. When a lot of energy is released the atom is said to have a high electron affinity. These atoms are more likely to take in an electron. Group I atoms need 1 electron to complete their s orbital. When an electron is added to group II atoms the electron enters into a p orbital. The complete s orbital is more tightly bound to the nucleus than the p orbital.

13. Explain why a p orbital experiences more shield than an s orbital.
Remember that orbitals are found by squaring the angular wavefunction. An electron in the s orbital penetrates through inner shells and has no nodes. An electron in the p orbital penetrates much less because its angular wavefunction limits how close it can get to the nucleus (it also has a node through the nucleus unlike the s orbital). Also, electrons in the s orbital will shield those in the p orbital from the protons in the nucleus.

14. Calculate the effective nuclear charge for all of the electrons in nitrogen.
The actual nuclear charge of nitrogen is 7 (there are 7 protons in the nucleus).
Electrons in the same shell will experience the same effective nuclear charge
1s electrons: 7-0 = 7 No electrons shield the first row
2s electrons: 7-2 = 5
2p electrons: 7-2 = 5
Electrons in the same row will have the same effective nuclear charge

15. Explain why the first ionization energy decreases from group V to group VI elements (an exception to the trend of increasing ionization energy from left to right).
Filled and half filled shells have additional stability.

16. Rank the following elements in increasing atomic radius and explain the trend: Mg, Cs, F, Br
Cs > Mg > Br > F
Atomic radius decreases from left to right across a period and increases down a group. Down a group the electrons occupy shells that are farther from the nucleus and these electrons are more shielded. Across a period, the number of electrons and protons increase but these electrons are not that shielded since they fill the same shell and experience an increasing ENC.

17. You travel to planet Darwin IV and discover that on this planet three electron spins exist. Which element would have a higher electron affinity, an element with atomic number 17 or an element with atomic number 26?
On a 3 spin world.... (remember we live in a 2 spin world!)
The electron configuration of element 17:
1s3 2s3 2p9 3s2
The electron configuration of element 26:
1s3 2s3 2p9 3s3 3p8
Element 26 only needs one more electron to complete the p subshell, therefore it has a higher electron affinity.

18. Where do you find metals in the periodic table? Which periodic trend dictates the location of metals on the periodic table?
Metals are found in the lower left part of the periodic table. Their ionization energies are low and readily lose electrons.

19. Rank the following in order of increasing ionization energies: He, Ca, Sn, Sn^{+1}
Ca < Sn < Sn+1 < He
In general, ionization energy increases across a period and decreases down a row. The second ionization energy of an element is higher than its first.

20. As the effective nuclear charge increases right and up across the periodic table which trends also increase?
Electron affinity, ionization potential, and electronegativity
All of which increase along with ENC because there is less shielding, therefore the electrons experience a stronger pull towards the nucleus.