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**Worksheet 5: Last of Quantum Stuff, Bonding**

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**Orbitals and quantum numbers: 7.59, 7.61, 7.63, 7.65**

**Electron configurations and magnetism: 8.43, 8.45, 8.47, 8.49, 8.51, 8.65, 8.67, 8.93**

**Trends: 8.57, 8.61, 8.63, 8.69, 8.71, 8.73, 8.75, 8.79, 8.81, 8.83**

**Other problems: 8.53, 8.99**

- List the following orbitals in order of increasing energy (assume a multielectron atom).
  - $n = 3, l = 2$
  - $n = 5, l = 4$
  - $n = 3, l = 0$
  - $n = 4, l = 1, m_l = -1$
- Give the allowable combinations of quantum numbers for each of the following electrons:
  - a 4s electron
  - a 3p electron
  - a 5f electron
  - a 5d electron
- Give the electron configurations (not shorthand) of  ${}_3\text{Li}$ ,  ${}_3\text{Li}^+$ ,  ${}_2\text{He}$ ,  ${}_9\text{F}^-$ ,  ${}_{10}\text{Ne}$ ,  ${}_{11}\text{Na}^+$ ,  ${}_{12}\text{Mg}^{2+}$ , and  ${}_{13}\text{Al}^{3+}$ . For which of these species can the electron configuration be abbreviated to read  $[\text{He}]2s^1$ ?
- According to Hund's rule, how many unpaired electrons are there in the following ground-state atoms and ions?
  - ${}_7\text{N}$
  - ${}_8\text{O}$
  - ${}_{15}\text{P}^{3-}$
  - ${}_{11}\text{Na}^+$
- Identify the atom with electron configuration  $[\text{Ar}]4s^13d^5$ . How many unpaired electrons are there in the ground state of this atom?
- Write the electron configurations of the following species:
  - ${}_{11}\text{Na}$
  - ${}_{17}\text{Cl}$
  - ${}_{25}\text{Mn}$
  - ${}_{25}\text{Mn}^{2+}$
- Which of the following electron configurations represent an excited state?
  - $[\text{He}]2s^12p^5$
  - $[\text{Kr}]5s^24d^{10}5p^1$
  - $[\text{Ar}]4s^23d^{10}4p^5$
  - $[\text{Ne}]3s^23p^24s^1$
- How many unpaired electrons are there in the ground-state  ${}_{33}\text{As}$ ,  ${}_{52}\text{Te}$ ,  ${}_{50}\text{Sn}$ , and  ${}_{32}\text{Ge}$  atoms?
- How many unpaired electrons are there in the ground-state  ${}_{22}\text{Ti}$ ,  ${}_{24}\text{Cr}$ ,  ${}_{29}\text{Cu}$ , and  ${}_{30}\text{Zn}$  atoms?
- Which orbital in each of the following pairs is highest in energy?
  - 5p or 5d
  - 4s or 3p
  - 6s or 4d
- According to the aufbau principle, which orbital is filled immediately after each of the following in a multi-electron atom?
  - 4s
  - 3d
  - 5f
  - 5p
- Give the expected ground-state electron configurations for the following elements:
  - ${}_{22}\text{Ti}$
  - ${}_{44}\text{Ru}$
  - ${}_{50}\text{Sn}$
  - ${}_{38}\text{Sr}$
  - ${}_{34}\text{Se}$
- Draw orbital-box diagrams for the following atoms. Use the abbreviation of the preceding noble gas to represent inner electrons:
  - ${}_{37}\text{Rb}$
  - ${}_{74}\text{W}$
  - ${}_{32}\text{Ge}$
  - ${}_{40}\text{Zr}$

14. Given the subshells 1s, 2s, 2p, 3s, 3p, and 3d, identify those that meet the following descriptions:
- has  $l = 2$
  - can have  $m_l = -1$
  - is empty in a nitrogen atom
  - is full in a carbon atom
  - contains the outermost electrons in a beryllium atom
  - can contain two electrons, both with spin  $m_s = +\frac{1}{2}$
15. Write the condensed electron configurations for the following atoms, using the appropriate noble-gas core abbreviations:
- ${}_{55}\text{Cs}$
  - ${}_{28}\text{Ni}$
  - ${}_{48}\text{Cd}$
  - ${}_{82}\text{Pb}$
16. Identify the specific element that corresponds to each of the following electron configurations:
- $1s^2 2s^2 2p^6 3s^2$
  - $[\text{Ne}]3s^2 3p^1$
  - $[\text{Ar}]4s^1 3d^5$
  - $[\text{Kr}]5s^2 4d^{10} 5p^4$
17. Write the quantum numbers describing the highest-energy electrons in a ground-state atom of  ${}_{53}\text{I}$ .
18. Order the following atoms according to increasing atomic radius:  ${}_{16}\text{S}$ ,  ${}_{9}\text{F}$ ,  ${}_{8}\text{O}$
19. Give a set of quantum numbers representing an electron of highest energy for:
- ${}_{18}\text{Ar}$
  - ${}_{24}\text{Cr}$
  - ${}_{65}\text{Tb}$
  - ${}_{12}\text{Mg}^{2+}$
  - ${}_{16}\text{S}^{2-}$
  - ${}_{26}\text{Fe}^{3+}$
20. Give the full electronic configuration and the shorthand electronic configuration for each of the following. Predict if the atom would be paramagnetic or diamagnetic.
- ${}_{42}\text{Mo}$
  - ${}_{47}\text{Ag}$
  - ${}_{52}\text{Te}$
  - ${}_{79}\text{Au}$
  - ${}_{84}\text{Po}$
21. For each of the atoms above, give the number of inner electrons and give a set of quantum numbers representing the electron of highest energy.
22. Write the electron configuration for the following ions. Give the *element* that is isoelectronic with the ion for the ions in parts a-c.
- ${}_{37}\text{Rb}^{1+}$
  - ${}_{15}\text{P}^{3-}$
  - ${}_{53}\text{I}^{1-}$
  - ${}_{22}\text{Ti}^{2+}$
  - ${}_{29}\text{Cu}^{1+}$
23. Arrange the following sets in order of *decreasing* atomic size.
- ${}_{32}\text{Ge}$ ,  ${}_{82}\text{Pb}$ , and  ${}_{50}\text{Sn}$
  - ${}_{50}\text{Sn}$ ,  ${}_{52}\text{Te}$ , and  ${}_{38}\text{Sr}$
  - ${}_{9}\text{F}$ ,  ${}_{10}\text{Ne}$ , and  ${}_{11}\text{Na}$
  - ${}_{4}\text{Be}$ ,  ${}_{12}\text{Mg}$ , and  ${}_{11}\text{Na}$
24. Arrange the following sets in order of *decreasing* first ionization energies.
- ${}_{11}\text{Na}$ ,  ${}_{3}\text{Li}$ , and  ${}_{19}\text{K}$
  - ${}_{4}\text{Be}$ ,  ${}_{9}\text{F}$  and  ${}_{6}\text{C}$
  - ${}_{17}\text{Cl}$ ,  ${}_{18}\text{Ar}$ , and  ${}_{11}\text{Na}$
  - ${}_{17}\text{Cl}$ ,  ${}_{35}\text{Br}$ , and  ${}_{34}\text{Se}$
25. Which element would you expect to have the lowest *third* ionization energy in the following sets and why?
- ${}_{11}\text{Na}$ ,  ${}_{12}\text{Mg}$ , and  ${}_{13}\text{Al}$
  - ${}_{19}\text{K}$ ,  ${}_{20}\text{Ca}$  and  ${}_{21}\text{Sc}$
  - ${}_{3}\text{Li}$ ,  ${}_{13}\text{Al}$ , and  ${}_{5}\text{B}$
26. Circle the species in the following group which are isoelectronic
- ${}_{30}\text{Zn}^{2+}$        ${}_{18}\text{Ar}$        ${}_{21}\text{Sc}^{3+}$        ${}_{16}\text{S}$        ${}_{15}\text{P}^{3-}$
27. Arrange the isoelectronic species in the previous question in order of increasing size.
28. Rank the following ions in each set in order of *decreasing* size.
- ${}_{34}\text{Se}^{2-}$ ,  ${}_{16}\text{S}^{2-}$  and  ${}_{8}\text{O}^{2-}$
  - ${}_{52}\text{Te}^{2-}$ ,  ${}_{55}\text{Cs}^{+1}$ , and  ${}_{53}\text{I}^{1-}$
  - ${}_{38}\text{Sr}^{+2}$ ,  ${}_{56}\text{Ba}^{+2}$ , and  ${}_{55}\text{Cs}^{+1}$

29. Write the symbol for an element which can have its highest energy electrons with the following quantum addresses. You need to give only one if there are many. If no element has the following quantum numbers, specify why.

Symbol of Element	n	l	$m_l$	$m_s$
	4	1	-1	+1/2
	3	1	0	1
	2	0	0	-1/2
	4	3	-2	+1/2
	3	2	+1	-1/2

30. Circle the species which exhibits the property indicated:

- tends to form a positive ion, Fe or P:
- smaller electron affinity, C or Sn:
- larger atomic radius, Ba or Pb:
- larger first ionization energy, Na or Cs:
- Ion is larger than atom, K or I:

31. Order the following elements according to increasing electronegativity: Li, K, and C.

32. Which of the following substances are largely ionic and which are covalent?

- HF
- HI
- $\text{PdCl}_2$
- $\text{BBr}_3$
- NaOH

Key:

1.  $c < a < d < b$

2. a.  $n = 4, l = 0, m_l = 0, m_s = \pm \frac{1}{2}$       b.  $n = 3, l = 1, m_l = 0, \pm 1, m_s = \pm \frac{1}{2}$       c.  $n = 5, l = 3, m_l = 0, \pm 1, \pm 2, \pm 3, m_s = \pm \frac{1}{2}$       d.  $n = 5, l = 2, m_l = 0, \pm 1, \pm 2, m_s = \pm \frac{1}{2}$

3. Li only

4. a. 3, b. 2, c. 0, d. 0

5. Cr, 6

7. a, d

8. 3, 2, 2, 2

9. 2, 6, 1, 0

10. 5d, 4s, 6s

11. 3d, 4p, 6d, 6s

14. a. 3d, b. 2p, 3p, 3d    c. 3s, 3p, 3d    d. 1s, 2s    e. 2s    f. 2p, 3p, 3d

16. a. Mg    b. Al    c. Cr    d. Te

17.  $n = 5, l = 1, m_l = 0 \text{ or } 1 \text{ or } -1, m_s = +\frac{1}{2} \text{ or } -\frac{1}{2}$

18.  $F < O < S$

19.

	n	l	$m_l$	$m_s$
a.	3	1	-1, 0 or +1	+1/2 or -1/2
b.	3	2	-2, -1, 0, 1, or 2	+1/2 or -1/2
c.	4	3	-3,-2,-1,0,1,2 or 3	+1/2 or -1/2
d.	2	1	-1,0, or 1	+1/2 or -1/2
e.	3	1	-1,0,or 1	+1/2 or -1/2
f.	3	2	-2, -1, 0, 1, or 2	+1/2 or -1/2

20. all are paramagnetic

21.

	Inner	n	l	$m_l$	$m_s$
a.	41	4	2	-2, -1, 0, 1, or 2	+1/2 or -1/2
b.	46	4	2	-2, -1, 0, 1, or 2	+1/2 or -1/2
c.	46	5	1	-1, 0, or 1	+1/2 or -1/2
d.	78	5	2	-2, -1, 0, 1, or 2	+1/2 or -1/2
e.	78	6	1	-1, 0, or 1	+1/2 or -1/2

22. a. [Kr] b. [Ar] c. [Xe] d. [Ar]3d<sup>2</sup> e. [Ar]3d<sup>10</sup>

23. a. Pb > Sn > Ge b. Sr > Sn > Te c. Na > F > Ne d. Na > Mg > Be

24. a. Li > Na > K b. F > C > Be c.. Ar > Cl > Na d. Cl > Br > Se

25. a.. Al b. Sc c. Al

26. Ar, Sc<sup>3+</sup>, P<sup>3-</sup>

27. Sc<sup>3+</sup> < Ar < P<sup>3-</sup>

28. a. Se > S > O b. Te > I > Cs c. Cs > Ba > Sr

29. a. any in 4p region, b. none c. Li or Be d. any in 4f region e. any in 3d region

30. a. Fe b. Sn c. Ba d. Na e. I

31. K, Li, C

32. Ionic: c, e, polar covalent: a, b, OH<sup>1-</sup> in e