Name Mr. Shank Period AP 1, 2, 3

Electrons in Atoms

1. Use only the words in the Word Bank below to fill in the blanks in the following paragraph.

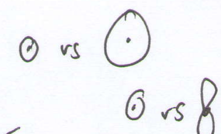
Word Bank

(Niels) Bohr	Probability	Rydberg Equation	Shrodinger Equation
Heisenberg	Certainty	Uncertainty Principle	Orbits
Quantum Numbers	Discrete	Orbitals	Position
	Particle		Wave

The Danish scientist Niels Bohr developed a model of the atom in which electrons traveled around the nucleus in discrete orbits. Electrons jumping between different orbits emitted or absorbed light with wavelengths given by the Rydberg Equation. However, according to the Uncertainty Principle postulated by Heisenberg, the Bohr model of the atom could not be correct, since it predicted the position of electrons in atoms with too much certainty. To account for the wave and particle nature of electrons, orbitals have replaced orbits in the modern model of the atom. These orbitals only give the probability of finding an electron at a given distance and position from the nucleus. The energies, shapes, and orientations of these orbitals are found exactly by solving the Schrodinger Equation but can be described much more easily by looking at their quantum numbers.

2. Give the name and significance of each of the quantum numbers listed below:

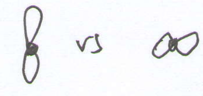
Ex. m_s: **Spin, describes the behavior of the electron in a magnetic field.**



n: principal quantum number, describes size of an orbital; $n > 0$

l: angular momentum quantum number, describes shape of an orbital; $0 \leq l \leq (n-1)$

m_l: magnetic quantum number; describes orientation of an orbital; $m_l = -l, \ldots, +l$



3. Complete the following table:

Orbital	n	l	m_l (all possible values)	Can Hold ___ Total Electrons	Orbital Picture (choose one m_l)
5s	5	0	0	2	
2p	2	1	-1, 0, +1	6	
3d	3	2	-2, -1, 0, +1, +2	10	
7f	7	3	-3, -2, -1, 0, +1, +2, +3	14	

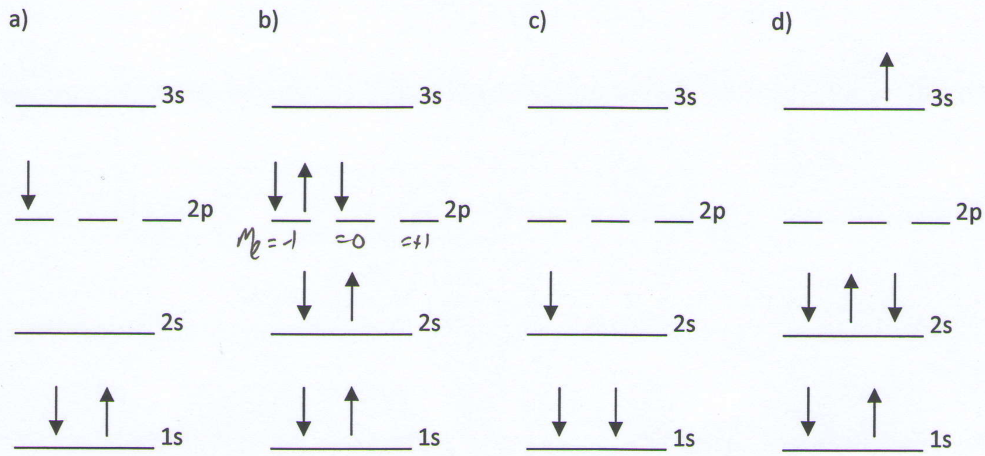
4. Imagine you have to teach a grade-eight student about the Pauli Exclusion Principle. In class, I used the analogy of an apartment building to describe why and how electrons obey the Pauli Exclusion Principle. In teaching your grade-eight student, invent your own analogy for the Pauli Exclusion Principle, and clearly describe, using complete sentences, how your analogy explains the Pauli Exclusion Principle.

Imagine BNDS is planning a school trip to the Great Wall. Each grade of students is a principle quantum number (grade 9 ≡ n=9, grade 10 ≡ n=10, etc.). Each bus the students ride the Wall is an angular momentum quantum number (bus 1 ≡ l=1, etc.), and each row of seats on the bus is a magnetic quantum number (row 2 ≡ m_s = 2, etc.). Boys have spin $m_s = +1/2$, and girls have spin $m_s = -1/2$. By the Pauli Exclusion Principle, no two boys could sit in the same seat, but a boy and a girl could.

5. Define Hund's rule. Be sure to discuss orbital energies.

Put one electron into orbitals with the same energy before putting two electrons into any of the orbitals with the same energy. The first $2l+1$ electrons should have have their spins in the same direction.

6. **Describe why each ground-state energy orbital diagram below is incorrect, and draw the correct diagram using the orbitals and number electrons given.**



Mistakes in energy orbital diagrams above:

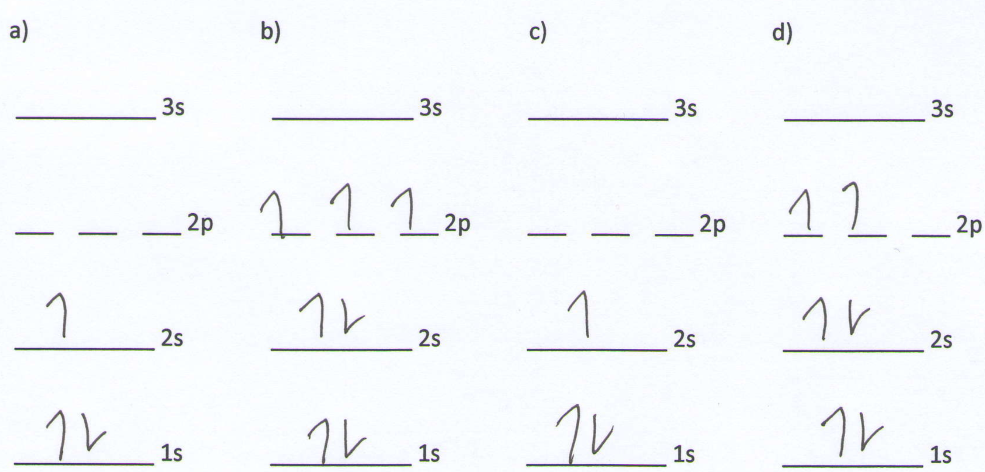
a) Violates Golden Rule (Energy Ordering). 2p electron should be in lower-energy 2s orbital.

b) Violates Hund's Rule. One 2p ($m_\ell = -1$) electron should be placed in $m_\ell = +1$.

c) Violates Pauli Exclusion Principle. One 1s electron should have spin ↑.

d) Violates Pauli Exclusion Principle and Golden Rule (Energy Ordering).

Corrected energy orbital diagrams (fill in yourself):



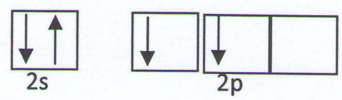
7. Are the following electron orbitals possible? If not, explain why not.

$2d^4$: No. $n = 2$ and $\ell(d) = 2$, but ℓ must be less than n.

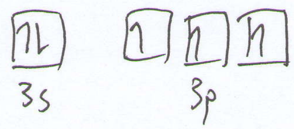
$3p^7$: No. $\ell = 1$, so there are $2\ell + 1 = 2(1) + 1 = 3$ 3p orbitals, which can hold a maximum of 6 electrons.

8. Give the ground-state electron configurations of the following atoms. Draw a box diagram for the **valence** electrons in each atom:

Ex. **C: $1s^2 2s^2 2p^2$** **[He]**

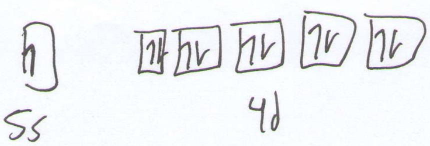


P: $[Ne]3s^2 3p^3$ [Ne]



Ti: $[Ar]4s^2 3d^2$ [Ar]

Ag: $[Kr]5s^1 4d^{10}$ [Kr]



9. Give the ground-state electron configurations of the following ions using the noble gas abbreviations:

Nb^{2-}: $[Kr]5s^2 4d^5$ [from Nb: $[Kr]5s^2 4d^3$]

Cu^+: $[Ar]3d^{10}$ [from Cu: $[Ar]4s^1 3d^{10}$]

Ti^{2-}: $[Ar]4s^2 3d^4$ [from Ti: $[Ar]4s^2 3d^2$]

10. Are the following sets of quantum numbers (n, l, m_l, m_s) possible? Why or why not?

a) (2, 1, -1, 1/2) Yes.

b) (0, 0, 0, -1/2) No. $n > 0$

c) (1, 2, 0, -1/2) No. $l \geq (n-1)$

d) (7, 6, -5, 3/2) No. $m_s = \pm 1/2$

11. List the six possible sets of quantum numbers for the 5p orbital:

(5, 1, -1, +1/2) (5, 1, -1, -1/2)
(5, 1, 0, +1/2) (5, 1, 0, -1/2)
(5, 1, +1, +1/2) (5, 1, +1, -1/2)

12. List five atoms or ions with the electron configuration [Kr] $5s^2 4d^7$.

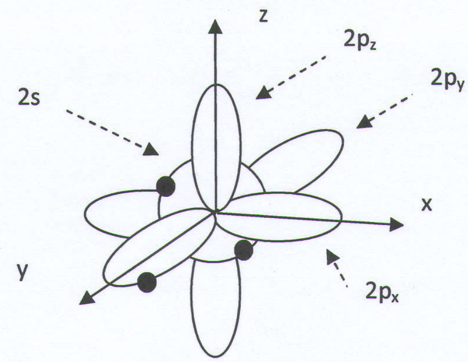
Rh, Ru^-, Tc^{2-}, Mo^{3-}, Nb^{4-}

* Note: the transition metals in this row have strange electron configurations. I will not ask you about them on your test.

13. Draw complete orbital pictures for the following atoms. Include only valence orbitals occupied in the ground state, and place electrons in the appropriate orbitals. Write the electron configuration, and label all orbitals.

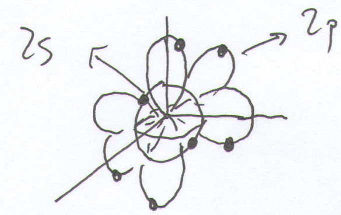
Ex. B: **[He] $2s^22p^1$**

● = electron

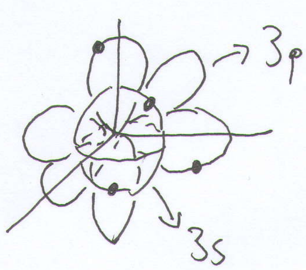


He $1s^2$

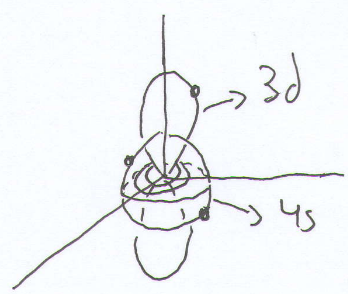
F $[He]\,2s^2 2p^5$



Si $[Ne]\,3s^2 3p^2$



Sc $[Ar]\,4s^2 3d^1$



Note: Not all d orbitals are drawn, for clarity.