Introduction to the Atom

Key Terms:

abbreviated electron configuration - combines the inert, noble *core* electrons with the remaining, *outermost* electrons, which are commonly called valence electrons.
angular momentum number (ℓ) - indicates the shape of the orbital; e.g., for s ℓ = 0, for p ℓ = 1, for d ℓ = 2, and for f ℓ = 3.
anion - an atom with more electrons than protons (negatively charged).
atomic mass - the weighted average of the masses of the naturally occurring isotopes**.**
atomic number - indicates how many protons are found in the nucleus of an atom.
aufbau principle - tells us the order the orbitals are filled. Aufbau is a German word meaning "to build-up". Just like building a house we need to start at the bottom floor – when that is completely finished we begin on the next floor. Thus, electrons are added to the lowest energy orbital first and then we work our way up in relative energy
cation - an atom that has more protons than electrons (this ion has a positive charge).
electron - a negatively charged particle that resides outside of the nucleus within orbitals**.**
electron configuration - the arrangement of electrons in an atom (think of this as finding a home for each electron).
elemental identity – an element's unique identity is deduced from the number of protons found in the nucleus.
ground-state electron configuration - the lowest energy arrangement of electrons.
Hund's rule - states orbitals of equal energy are occupied by one electron before any orbital is occupied by a second electron.
ion – an atom with a different number of electrons than protons (charge is written in upper right hand corner of element).
isotopes - atoms with the same number of protons but different number of neutrons.
magnetic quantum number (***m***) - indicates the orientation of an orbital around the nucleus (values are $-\ell$ to $+\ell$).
mass number - the sum of the protons and neutrons.
noble core electrons - have the same electron configuration, often termed isoelectronic, as a noble element.
orbit - a mathematically defined pathway; for example, how the earth orbits the sun (using classical Newtonian physics we can predict where the earth will be on the orbit at some time t and where it was at some time t).
orbital - a three-dimensional region or shape *and* you can expect to find an electron inside this shape approximately 90% of the time (it may help to think of this shape as a boundary surface; the electron is more likely to be inside this boundary shape rather than outside the boundary).
Pauli exclusion principle - simply translates to only two electrons per orbital with opposite spin.
principle quantum number (*n*) - indicates the principle energy level occupied by the electron; n = 1, 2, 3... (as n increases the electron's energy and its average distance from the nucleus increases).
proton - a positively charged particle that resides within the nucleus.
neutron - a particle that resides within the nucleus that has no charge (helps hold the protons together within the nucleus and sometimes referred to as the "nuclear glue").
spin quantum number - has only two possible values; +1/2 (up) or -1/2 (down).
strong nuclear force – an attractive force that occurs at the subatomic level; e.g., two protons attracted to each other within a nucleus.

valence electrons - the outermost electrons. It is often very important to quickly ascertain the number of valence electrons that an atom possesses; after all, these are the electrons that will be involved in bond making and bond breaking.

Review Questions Chapter One:

1) What is the atomic number for the following elements:

a) Carbon
b) Nitrogen
c) Sulfur
d) Calcium

2) How many protons, neutrons, and electrons are present in the following atoms?

a) ^{200}Hg
______P^+
______N°
______e^-

b) ^{41}K
______P^+
______N°
______e^-

c) $^{109}Ag^{1+}$
______P^+
______N°
______e^-

d) $^{227}Ra^{2+}$
______P^+
______N°
______e^-

e) $^{142}Ce^{4+}$
______P^+
______N°
______e^-

f) $^{81}Br^{-1}$
______P^+
______N°
______e^-

3) Write the complete chemical symbol for the ion with 34 protons, 37 neutrons, and 36 electrons.

4) Calculate the atomic mass of copper if there are two naturally occurring isotopes; 69.15% of copper-63, which has an atomic mass of 62.929601amu, and 30.85% of copper-65, which has a mass of 64.927794amu.

5) Given the following data calculate the atomic mass for magnesium:

Isotope	Mass (amu)	Natural Abundance
Magnesium-24	23.985	78.99%
Magnesium-25	24.986	10.00%
Magnesium-26	25.983	11.01%

6) Imagine your teacher discovers a new element called "X" in the lab that contains 210 protons (element symbol $_{210}X$). A sample of 10 atoms of this new element contains the following data:

3 atoms have 250 neutrons
5 atoms have 300 neutrons
2 atom has 350 neutrons

Please calculate the atomic mass of this new element assuming that a proton and a neutron weigh 1amu and the mass of the electrons is negligible.

Answers Chapter One:

1) What is the atomic number of the following elements:

a) Carbon 6
b) Nitrogen 7
c) Sulfur 16
d) Calcium 20

2) How many protons, neutrons, and electrons are present in the following atoms?

a) ^{200}Hg 80 P^+, 120 N°, 80 e^-
b) ^{41}K 19 P^+, 22 N°, 19 e^-
c) $^{109}Ag^{1+}$ 47 P^+, 62 N°, 46 e^-
d) $^{227}Ra^{2+}$ 88 P^+, 139 N°, 86 e^-
e) $^{142}Ce^{4+}$ 58 P^+, 84 N°, 54 e^-

f) $^{81}Br^{-1}$ <u>35</u> P^+
<u>46</u> N°
<u>36</u> e^-

3) Write the complete chemical symbol for the ion with 34 protons, 37 neutrons, and 36 electrons.

$$^{71}Se^{-2}$$

4) Calculate the atomic mass of copper if there are two naturally occurring isotopes; 69.15% of copper-63, which has an atomic mass of 62.929601amu, and 30.85% of copper-65, which has a mass of 64.927794amu.

0.6915x62.929601amu + .3085x64.927794amu = <u>63.55amu</u>

5) Given the following data calculate the atomic mass for magnesium:

Isotope	Mass (amu)	Natural Abundance
Magnesium-24	23.985	78.99%
Magnesium-25	24.986	10.00%
Magnesium-26	25.983	11.01%

23.985x.7899 + 24.986x.1000 + 25.983x.1101 = <u>24.31amu</u>

6) Imagine you discover a new element called "X" in the lab that contains 210 protons (element symbol $_{210}X$). A sample of 10 atoms of this new element contains the following data:

3 atoms have 250 neutrons
5 atoms have 300 neutrons
2 atom has 350 neutrons

Please calculate the atomic mass of this new element assuming that a proton and a neutron weigh 1amu and the mass of the electrons is negligible.

3 atoms of the 10 atom sample is 30% and 250 neutrons plus the 210 protons equals 460amu
5 atoms of the 10 atom sample is 50% and 300 neutrons plus the 210 protons equals 510amu
2 atoms of the 10 atom sample is 20% and 350 neutrons plus the 210 protons equals 560amu

Thus, 460x.3 + 510x.5 + 560x.2 = <u>505amu</u>

Review Questions Chapter Two:

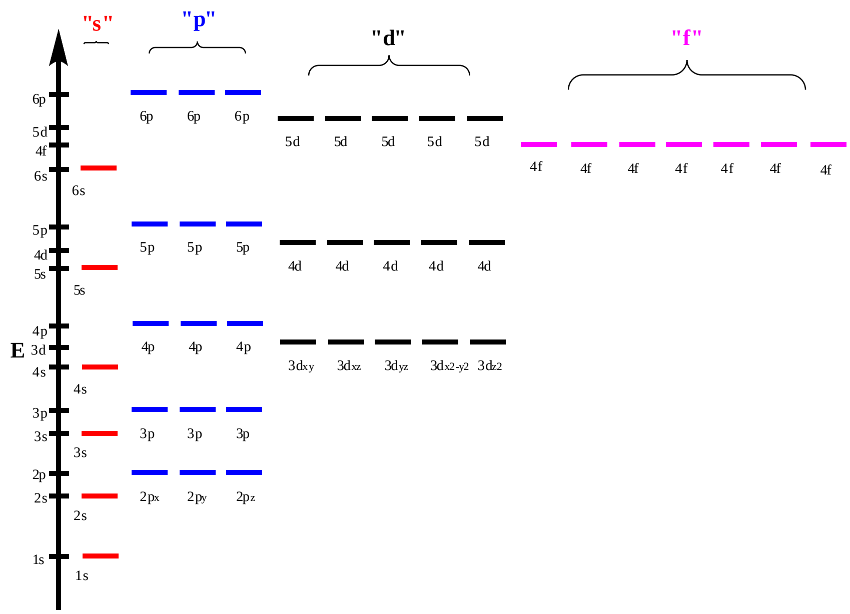
1) What is the difference between an orbit and an orbital?
2) Please reproduce the full electron configuration diagram template (starting at the 1s and finishing at the 6p).
3) What does each line abstractly represent on the electron configuration diagram?

4) Please draw the 1s, 2s, and 3s orbital.
5) Please draw the three 2p orbitals.
6) Please draw the five 3d orbitals.

Answers Chapter Two:

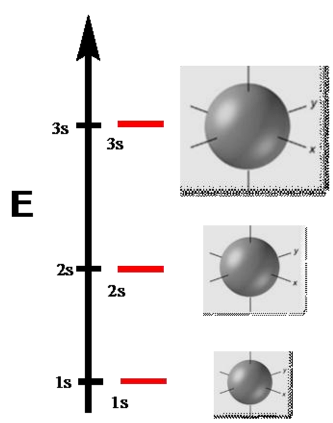
1) An orbit is a mathematically defined pathway; for example, how the earth orbits the sun (using classical Newtonian physics we can predict where the earth will be on the orbit at some time t and where it was at some time t). An orbital is a three-dimensional region or shape *and* you can expect to find an electron inside this shape approximately 90% of the time (it may help to think of this shape as a boundary surface; the electron is more likely to be inside this boundary shape rather than outside the boundary).

2) The full electron configuration diagram template:



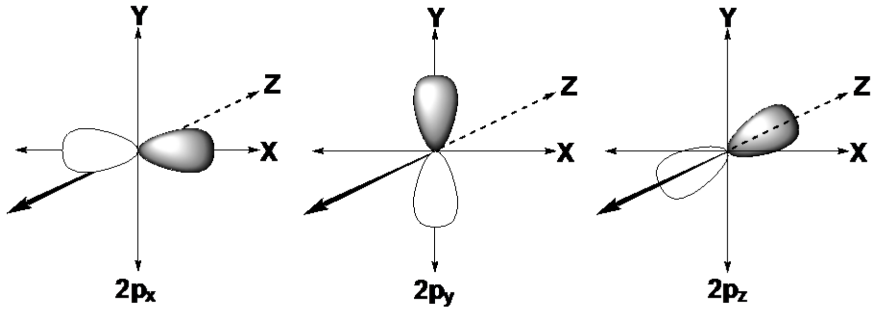
3) Each line on the electron configuration diagram abstractly represents an orbital.

4) The 1s, 2s, and 3s orbital:

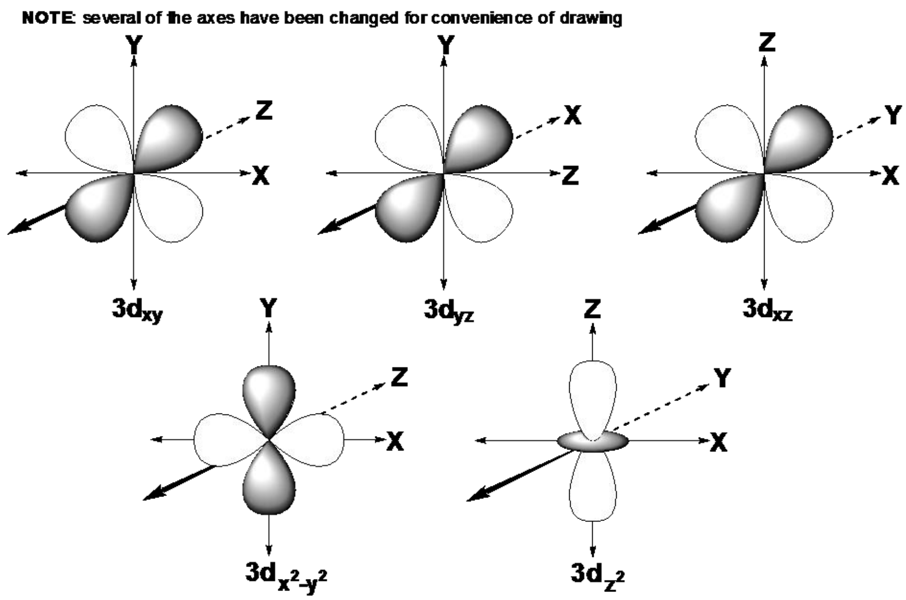


Note: the atomic radius increases as principle quantum number increases.

5) The three 2p orbitals:



6) The five 3d orbitals:



Questions Chapter Three:

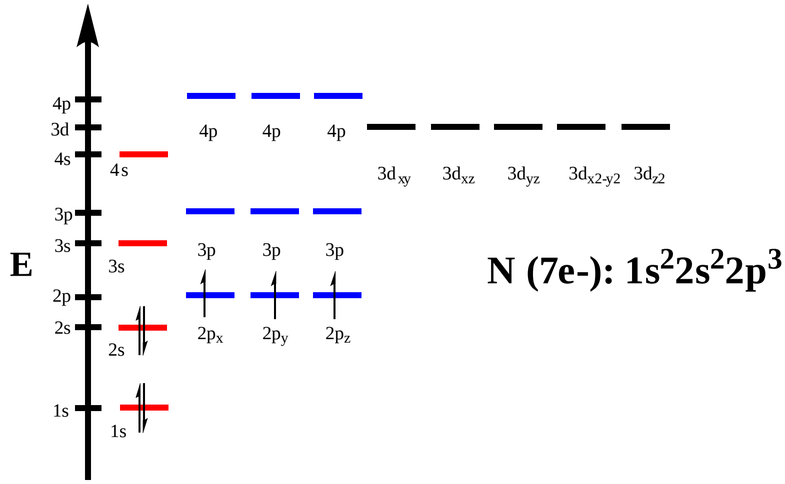
1) What does each half-arrow abstractly represent on the electron configuration diagram?
2) Briefly define the three rules that allow one to draw the ground-state electron configuration diagram.
3) Draw the electron configuration diagram and write the electron configuration for nitrogen.
4) Draw the electron configuration diagram and write the electron configuration for silicon.
5) Draw the electron configuration diagram and write the electron configuration for N^{-3}.
6) Draw the electron configuration diagram and write the electron configuration for Rb^{+1}.

Answers Chapter Three:

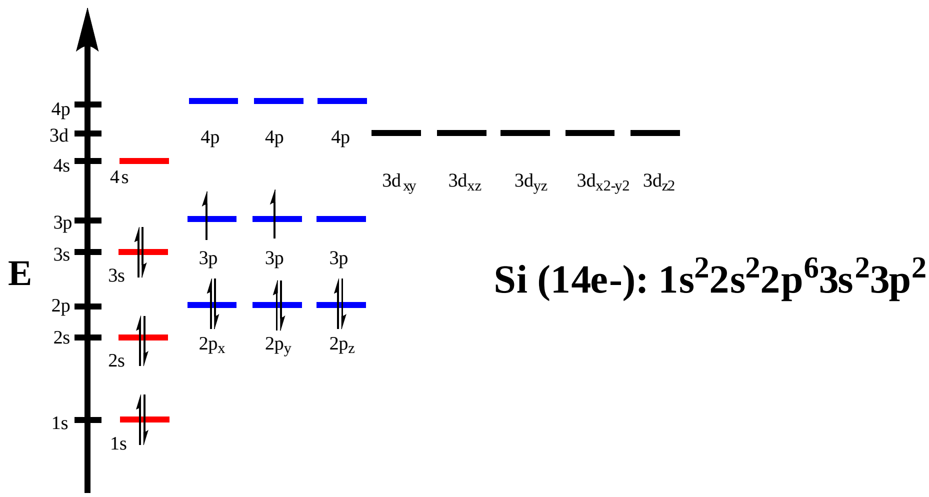
1) Each half-arrow on the electron configuration diagram abstractly represents an electron.
2) Summary of the Electron-Configuration Diagram Rules:
    1. Aufbau - Fill the orbitals in order of increasing energy levels.
    2. Pauli - Only put two electrons in an orbital and make sure that their spins are opposite.

3. Hund - Fill the orbitals one at a time across an energy level before pairing electrons.

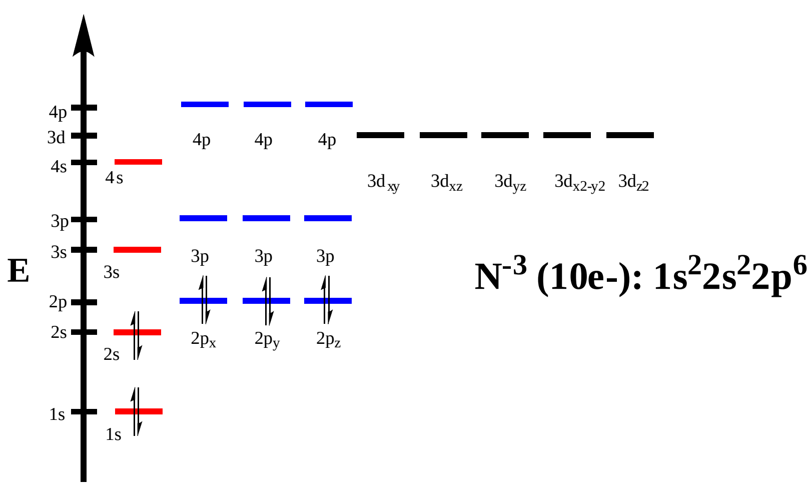
3) The electron configuration diagram and electron configuration for nitrogen:



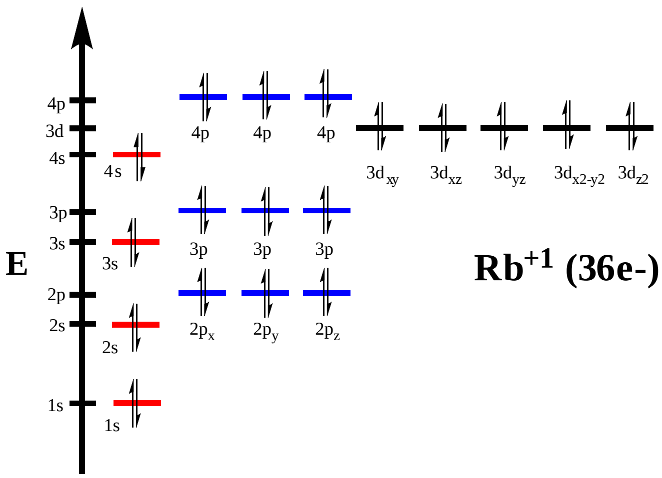
4) The electron configuration diagram and electron configuration for silicon:



5) The electron configuration diagram and electron configuration for N^{-3}:



6) The electron configuration diagram and electron configuration for Rb^{+1}:



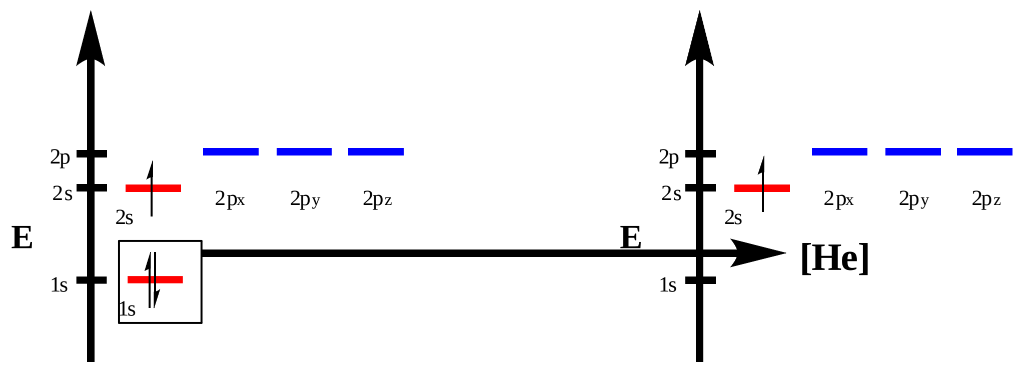
Rb^{+1} (36e-): $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6$

Questions Chapter Four

1) Draw and write the abbreviated electron configuration for lithium.
2) Draw and write the abbreviated electron configuration for aluminum.
3) Draw and write the abbreviated electron configuration for scandium.
4) Draw and write the abbreviated electron configuration for Si^{+2}.
5) Draw and write the abbreviated electron configuration for N^{-1}.

Answers Chapter Four

1) The abbreviated electron configuration for lithium:

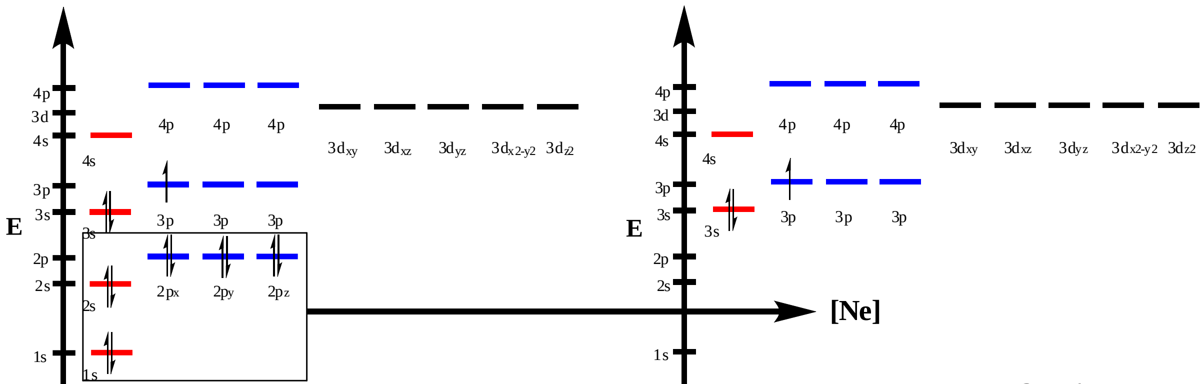


Li (3e-): $1s^2 2s^1$

Li (3e-): [He]$2s^1$

1 valence e–

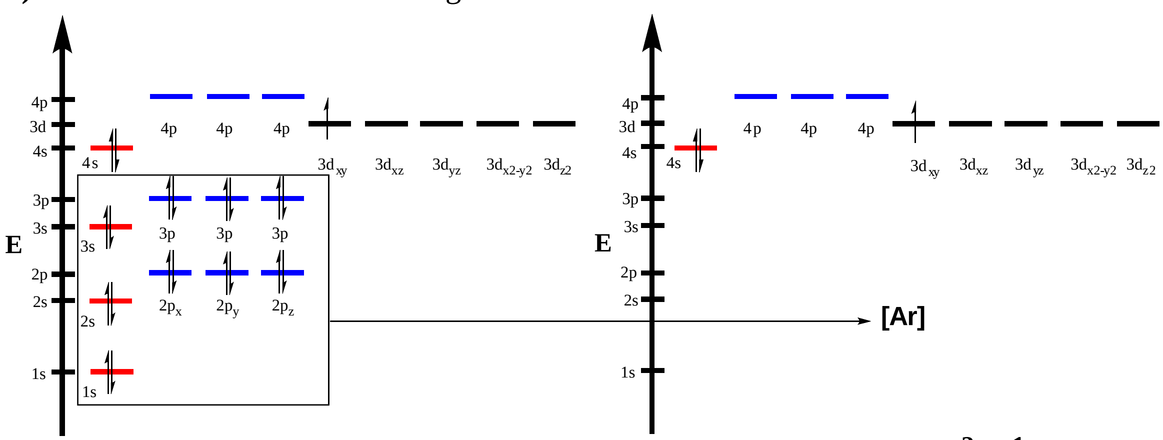
2) The abbreviated electron configuration for aluminum:



Al (13e-): $1s^22s^22p^63s^23p^1$ **Al (13e-): [Ne]$3s^23p^1$**

<u>3 valence e⁻</u>

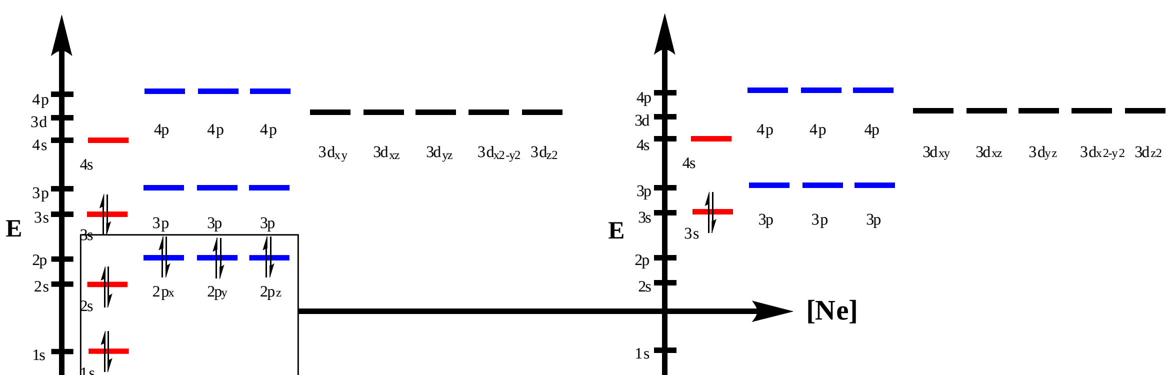
3) The abbreviated electron configuration for scandium:



Sc (21e-): $1s^22s^22p^63s^23p^64s^23d^1$ **Sc (21e-): [Ar]$4s^23d^1$**

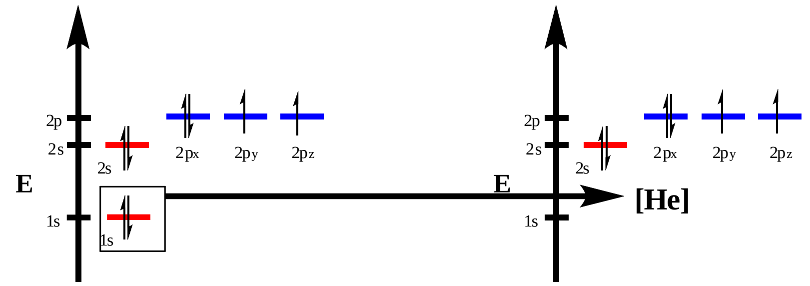
<u>3 valence e⁻</u>

4) The abbreviated electron configuration for Si^{+2}:



Si^{+2} (12e-): $1s^22s^22p^63s^2$ **Si^{+2} (12e-): [Ne]$3s^2$**

5) The abbreviated electron configuration for N^{-1}:



N^{-1} (8e-): $1s^22s^22p^4$ **N^{-1} (8e-): [He]$\underbrace{2s^22p^4}$**

6 valence e⁻

Questions Chapter Five

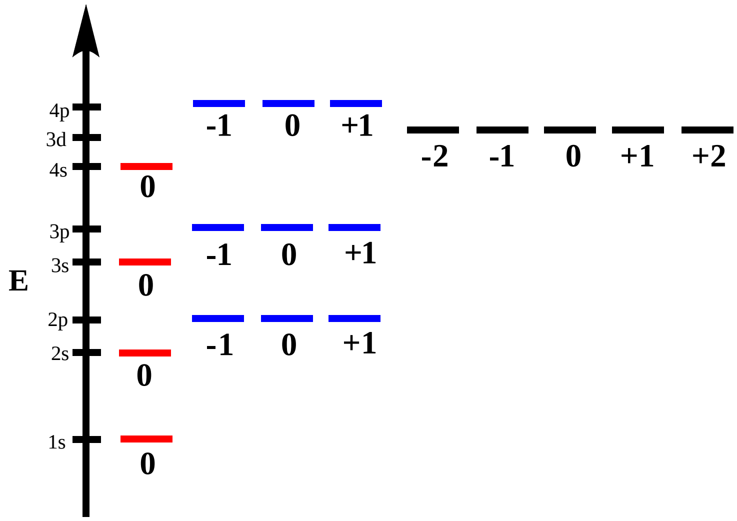
1) Please list and define the four quantum numbers.
2) Please assign the four quantum numbers (n, ℓ, m, s) to the last electron of a neutral atom of carbon.
3) Please assign the four quantum numbers (n, ℓ, m, s) to the last electron of fluoride (F^{-1}).
4) Please assign the four quantum numbers (n, ℓ, m, s) to the last electron of the common ion of calcium (Ca^{+2}).
5) Please assign the four quantum numbers (n, ℓ, m, s) to the last electron of a neutral atom of nickel.

Answers Chapter Five

1) We can assign four QUANTUM NUMBERS to each electron; which will tell us the energy level it is located, what type of orbital shape it is located in, if there are more than one degenerate energy orbital then it will indicate on which axis, and spin (up or down).
   a) Principal Quantum Number (n) - indicates the principle energy level occupied by the electron; n = 1, 2, 3... (as n increases the electron's energy and its average distance from the nucleus increases).
   b) Angular Momentum Quantum Number (ℓ) - indicates the shape of the orbital.

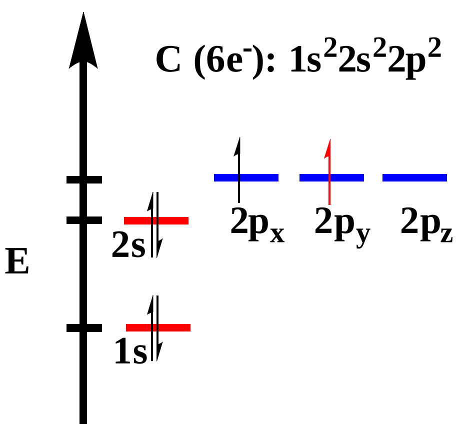
ℓ	**Orbital Shape**
0	s
1	p
2	d
3	f

c) Magnetic quantum number (*m*) - indicates the orientation of an orbital around the nucleus (values are –ℓ to +ℓ)



d) Spin quantum number (*s*) - has only two possible values (+1/2, -1/2)

2) The four quantum numbers (*n*, *ℓ*, *m*, *s*) for the last electron of a neutral atom of carbon:



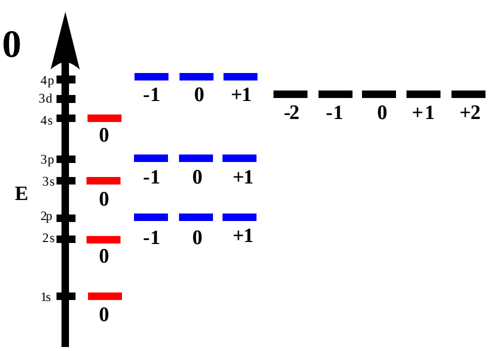
2, 1, 0, +1/2

n = 2, second energy level

ℓ = 1

ℓ	Orbital Shape
0	s
1	p
2	d
3	f

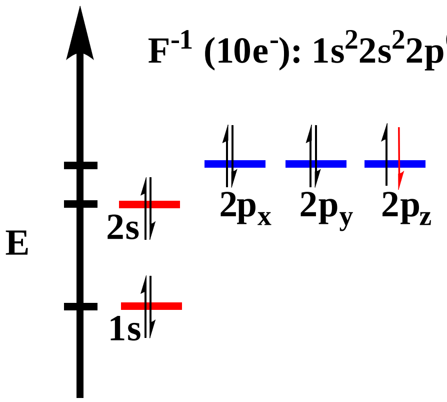
m **= 0**



s **= +1/2**, arrow pointing up

3) The four quantum numbers (*n*, *ℓ*, *m*, *s*) for the last electron of fluoride (F^{-1}):

F^{-1} (10e$^-$): $1s^2 2s^2 2p^6$



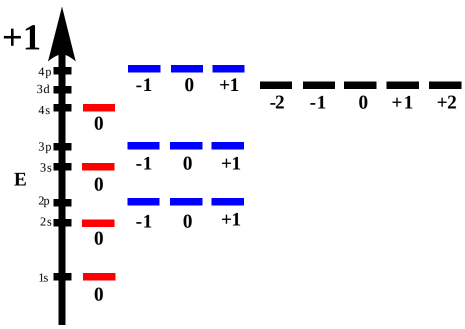
2, 1, +1, - 1/2

n = 2, second energy level

ℓ = 1

ℓ	Orbital Shape
0	s
1	p
2	d
3	f

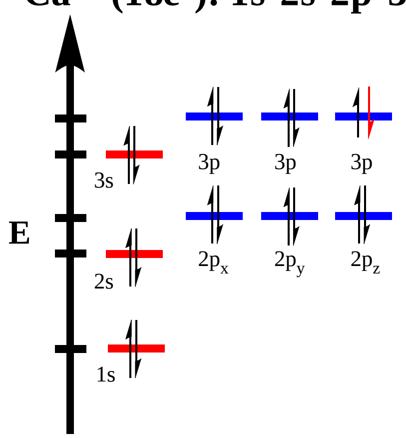
***m* = +1**



***s* = - 1/2**, arrow pointing down

4) The four quantum numbers (*n*, *ℓ*, *m*, *s*) for the last electron of the common ion for calcium (Ca^{+2}):

Ca^{+2} (18e-): $1s^2 2s^2 2p^6 3s^2 3p^6$



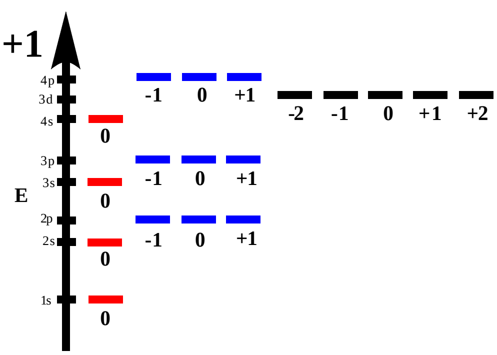
3, 1, +1, - 1/2

n = 3, third energy level

ℓ = 1

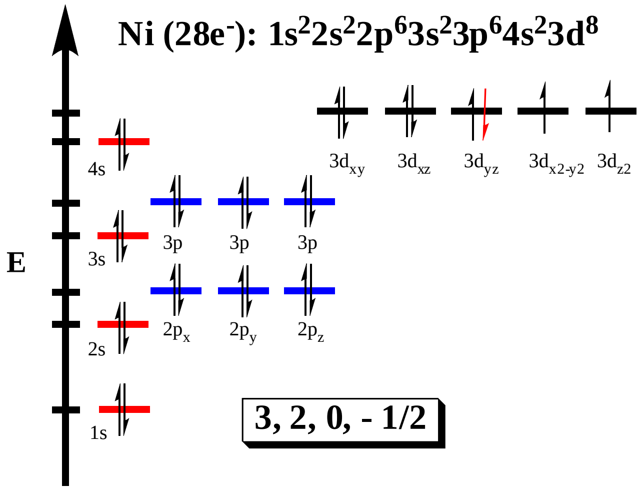
ℓ	Orbital Shape
0	s
1	p
2	d
3	f

***m* = +1**



***s* = - 1/2**, arrow pointing down

5) The four quantum numbers (*n*, *ℓ*, *m*, *s*) for the last electron of a neutral atom of nickel:

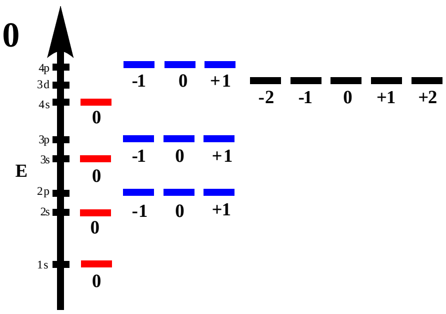


n = 3, third energy level

***ℓ* = 2**

ℓ	Orbital Shape
0	s
1	p
2	d
3	f

***m* = 0**



***s* = - 1/2**, arrow pointing down