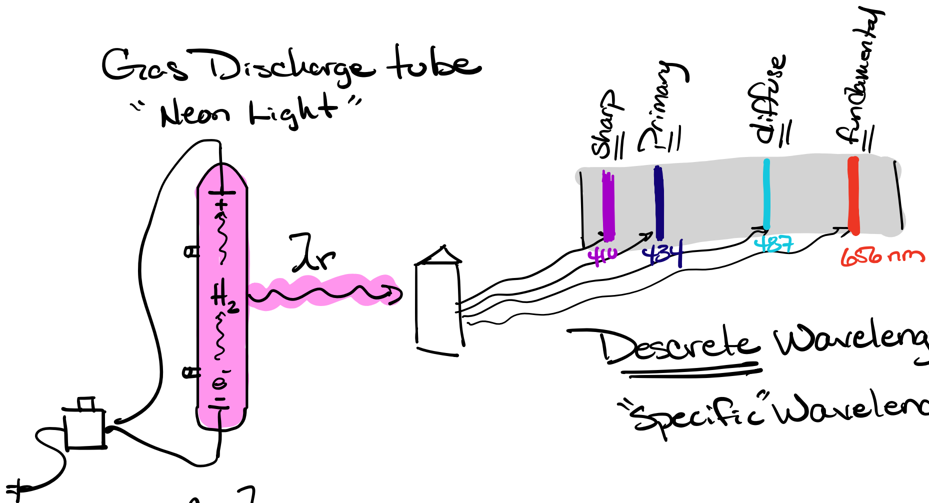
Electron Configuration

Gas Discharge tube
"Neon Light"

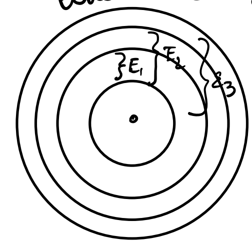


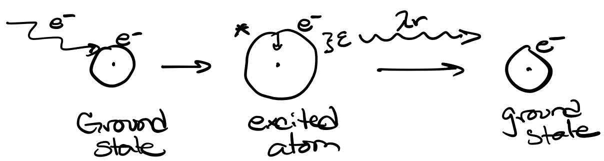
Descrete Wavelengths

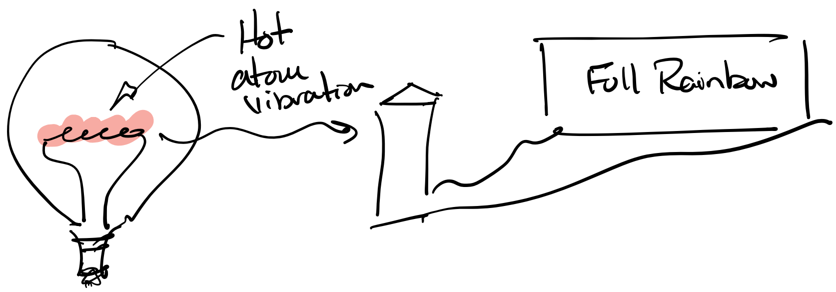
"Specific" Wavelengths

$c = \lambda r$

Locations where e⁻ can go







Black Body Radiation

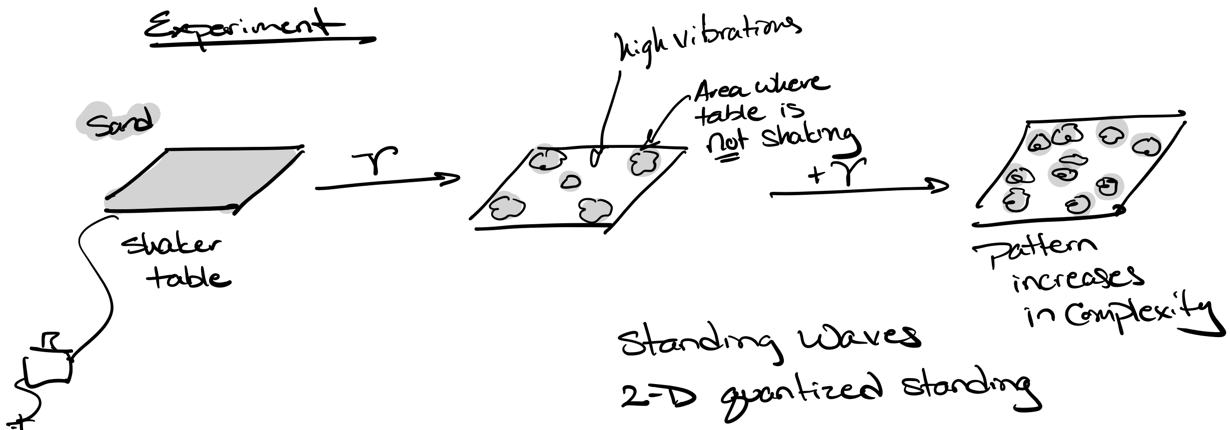
At the smallest levels of matter Newtonian physics brakes down and quantum mechanics takes over.

Quantum simply means descrete allowable amount of energy. Descrete means sepperate or distinct.

Quantum Mechanics is the study of Matter & Energy at the smallest levels. Energy is quantized → only certain allowable energy levels

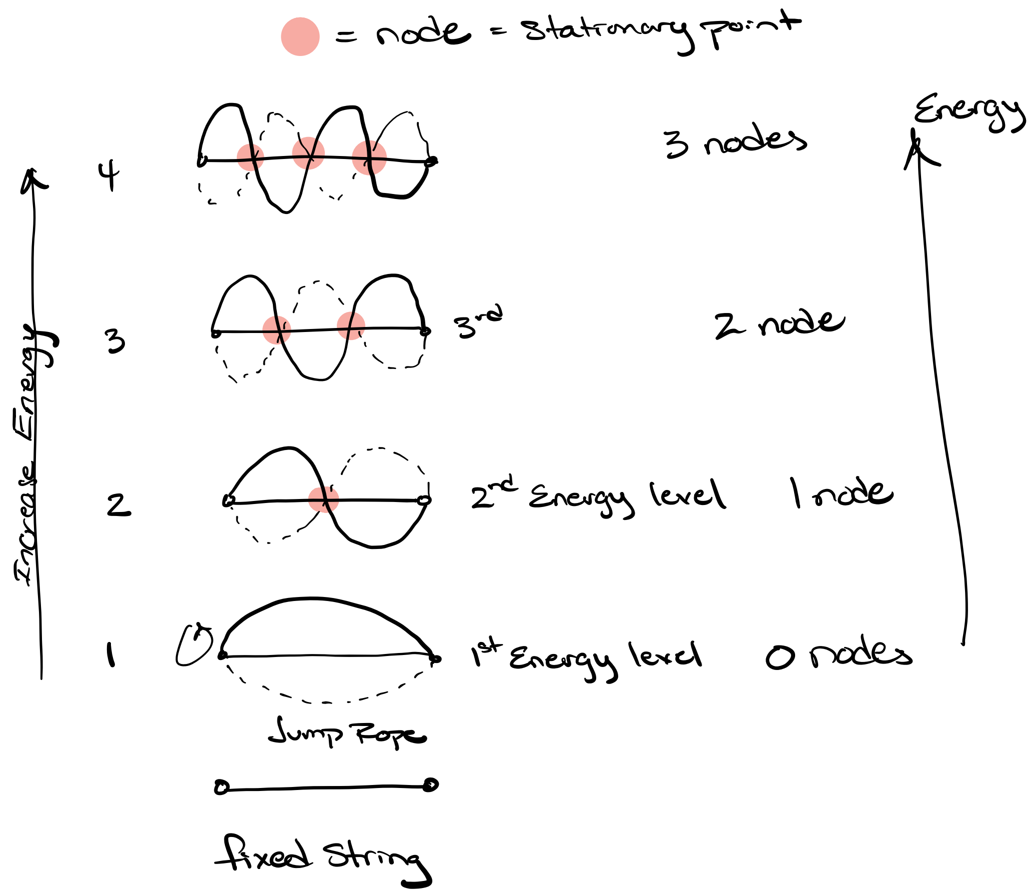
Structure within atom → e^- structure

<u>Experiment</u>



Standing Waves
2-D quantized standing waves

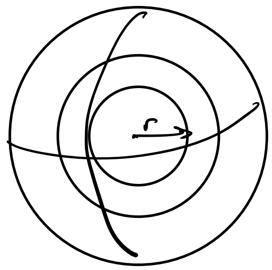
Quantum Energy levels 2D



nodes can only be integer values

Integer Value = Quantized

Fixed allowable energy



Energy level ~ distance from nucleus
- sublevels
  - orbitals
    - spin

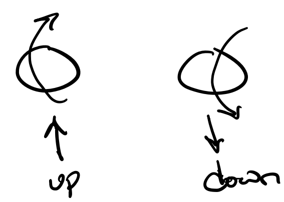
4 variables ⇒ 4 Quantum #

$\underline{n}$ principle Quantum number = principle energy level

$\underline{\ell}$ Azimuthal Quantum number = Sublevels
(Orbital angular momentum)

$\underline{m_\ell}$ Magnetic Quantum number = Orbital
(A 3D shape)

$\underline{m_s}$ Spin Quantum number =



Allowable Quantum number Values

n = 1, 2, 3, 4, ... Integer Value

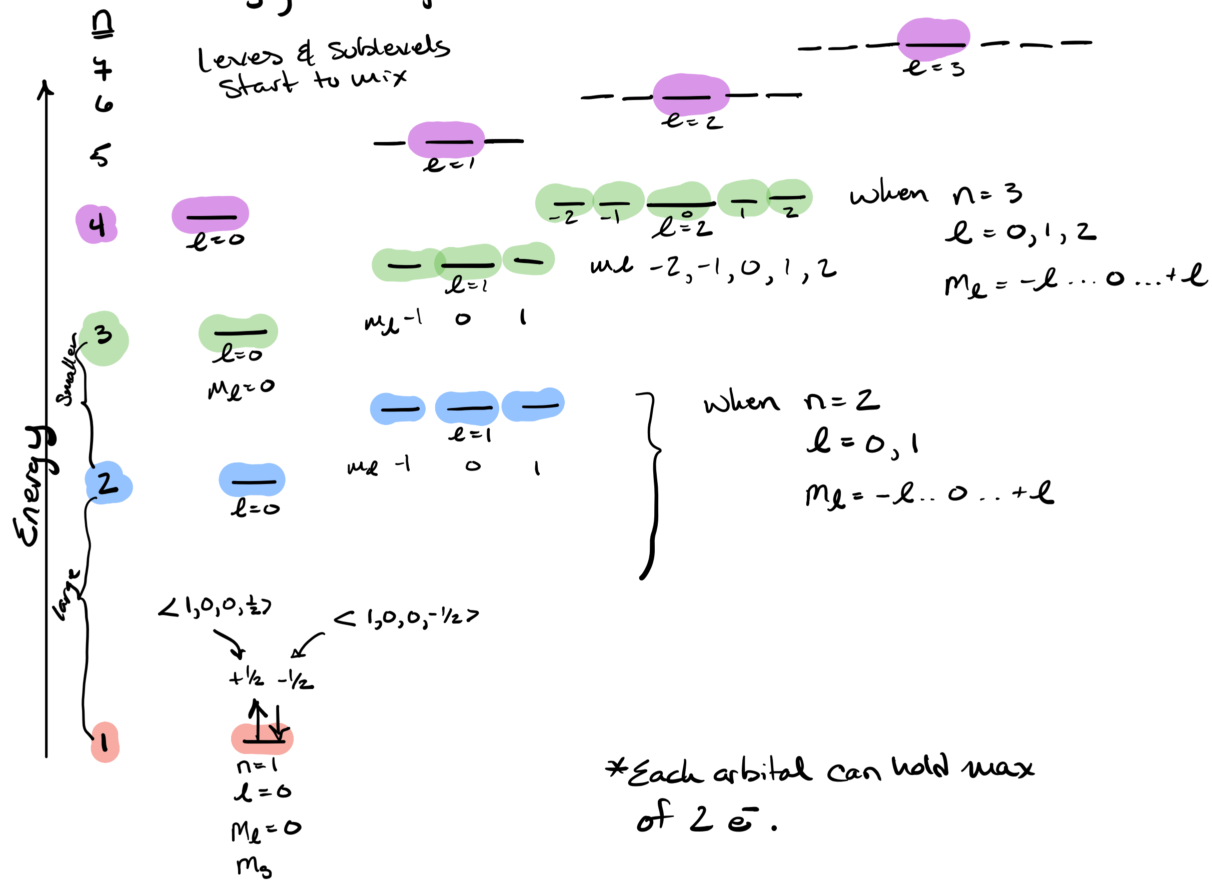
ℓ = 0, 1, 2, upto $n-1$

m_ℓ = Integer Values $-\ell, \ldots\ 0\ \ldots, +\ell$

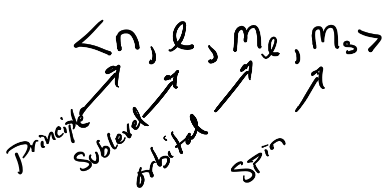
m_s = $+\frac{1}{2}$ (up) or $-\frac{1}{2}$ (down) Spin values

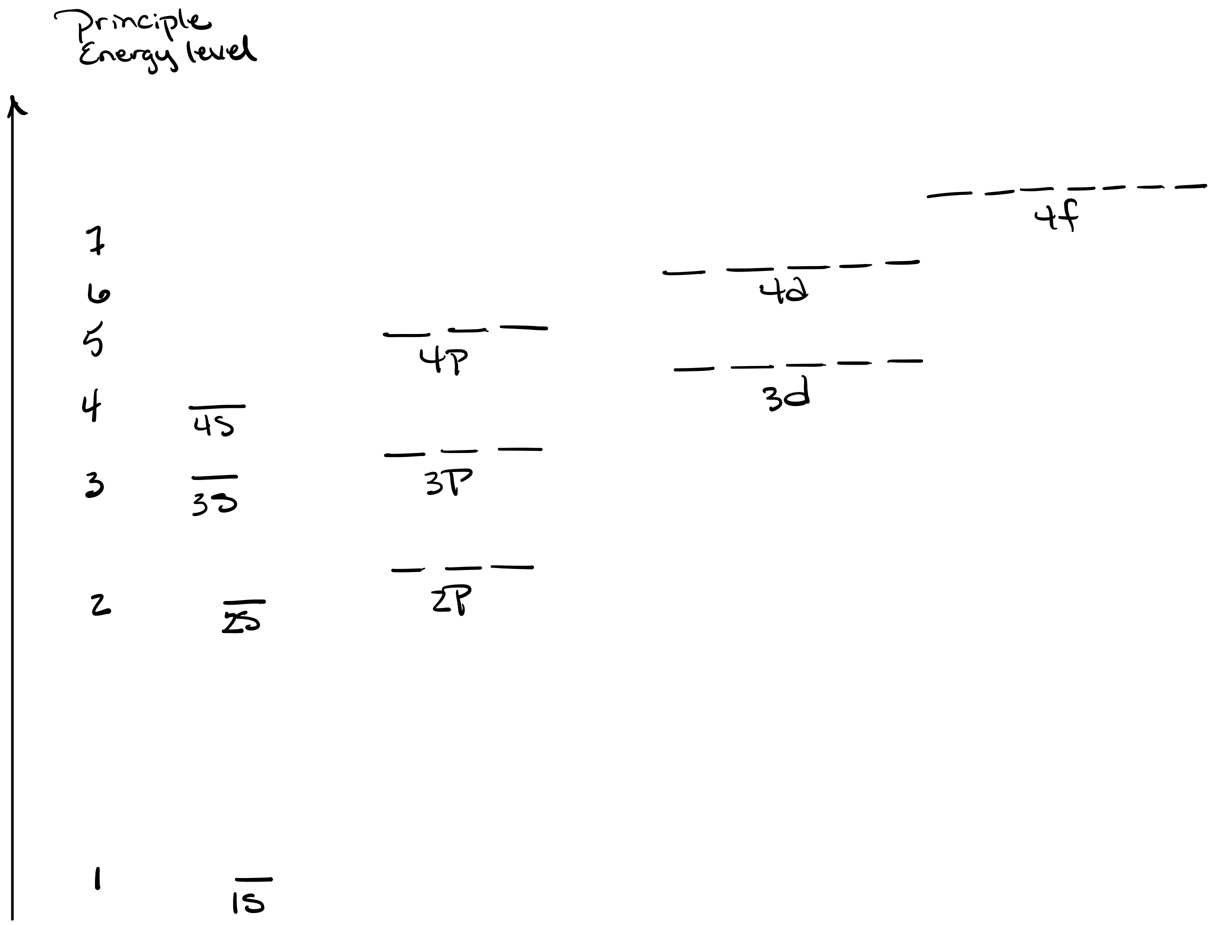
* No two e^- may have the same 4 quantum numbers in an atom. Every e^- is unique.

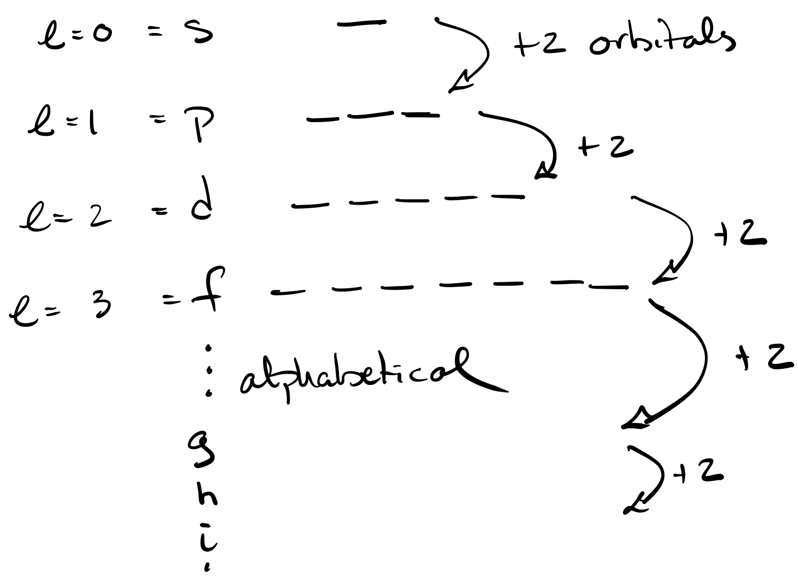
Energy Diagram



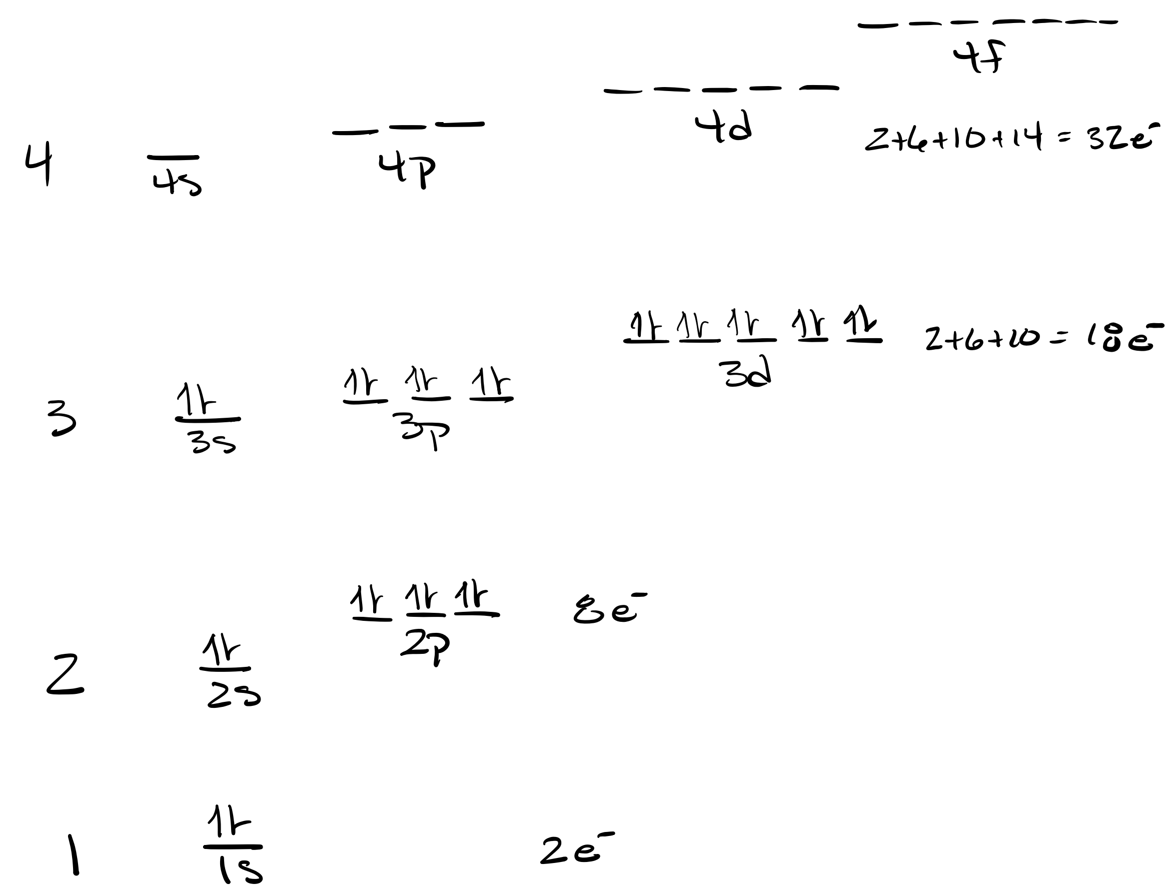
*Each arbital can hold max of 2 e^-.




Principle
Energy level
7
6
5
4
3
2
1
4f
4d
4p
3d
4s
3p
3s
2p
2s
1s


l=0 = s
l=1 = p
l=2 = d
l=3 = f
alphabetical
g
h
i
+2 orbitals
+2
+2
+2
+2

Each orbital can hold $2e^-$



n = periods in periodic Table

atomic # = # protons
for neutral element = # e^-

	1 (1A)	2 (2A)	3 (3B)	4 (4B)	5 (5B)	6 (6B)	7 (7B)	8 (8B)	9 (8B)	10 (8B)	11 (1B)	12 (2B)	13 (3A)	14 (4A)	15 (5A)	16 (6A)	17 (7A)	18 (8A)
1	1 H Hydrogen 1.008																	2 He Helium 4.003
2	3 Li Lithium 6.941	4 Be Beryllium 9.012	←				? gap					→	5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
3	11 Na Sodium 22.99	12 Mg Magnesium 24.30											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95
4	19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.87	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.84	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.41	31 Ga Gallium 69.72	32 Ge Germanium 72.64	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80
5	37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3
6	55 Cs Cesium 132.9	56 Ba Barium 137.3		72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.8	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
7	87 Fr Francium (223)	88 Ra Radium (226)		104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (281)	111 Rg Roentgenium (272)	112 Cn Copernicium (285)	113 Nh Nihonium (284)	114 Fl Flerovium (289)	115 Mc Moscovium (288)	116 Lv Livermorium (289)	117 Ts Tennessine	118 Og Oganesson

Lanthanides 6	57 La Lanthanum 138.9	58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (145)	62 Sm Samarium 150.4	63 Eu Europium 152.0	64 Gd Gadolinium 157.2	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 Lu Lutetium 175.0
Actinides 7	89 Ac Actinium (227)	90 Th Thorium 232.0	91 Pa Protactinium 231.0	92 U Uranium 238.0	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

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Values rounded to four significant figures

① Aufbau Principle

e^- fill lowest energy first

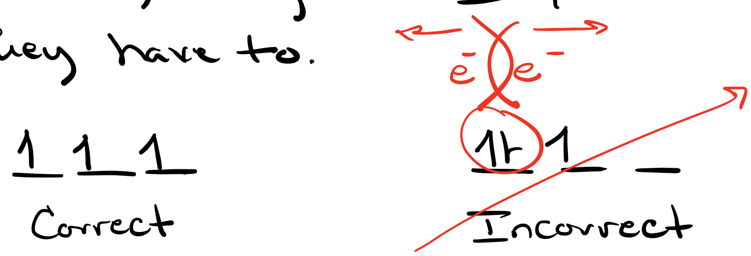
⟹ bottom up

② Pauli Exclusion principle

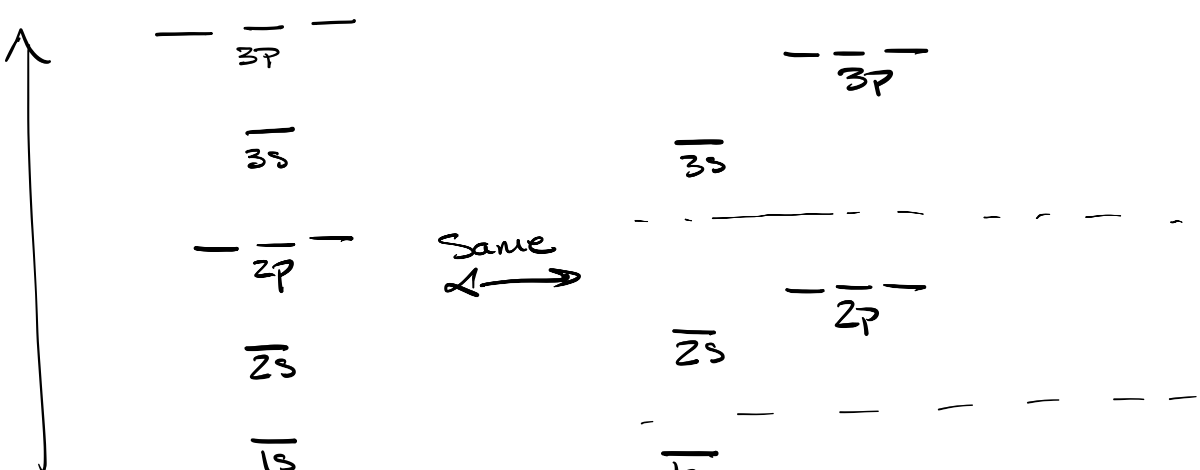
Each orbital can hold only $2e^-$

③ Hunds Rule

when e^- have option of equal energy orbitals, they will not pair unless they have to.



Subset of Energy diagram



Saves Space

	1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1	1 H Hydrogen 1.008																	2 He Helium 4.003
2	3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
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	19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.87	23 V Vanadium 50.94	24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.84	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.41	31 Ga Gallium 69.72	32 Ge Germanium 72.64	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80
	37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3
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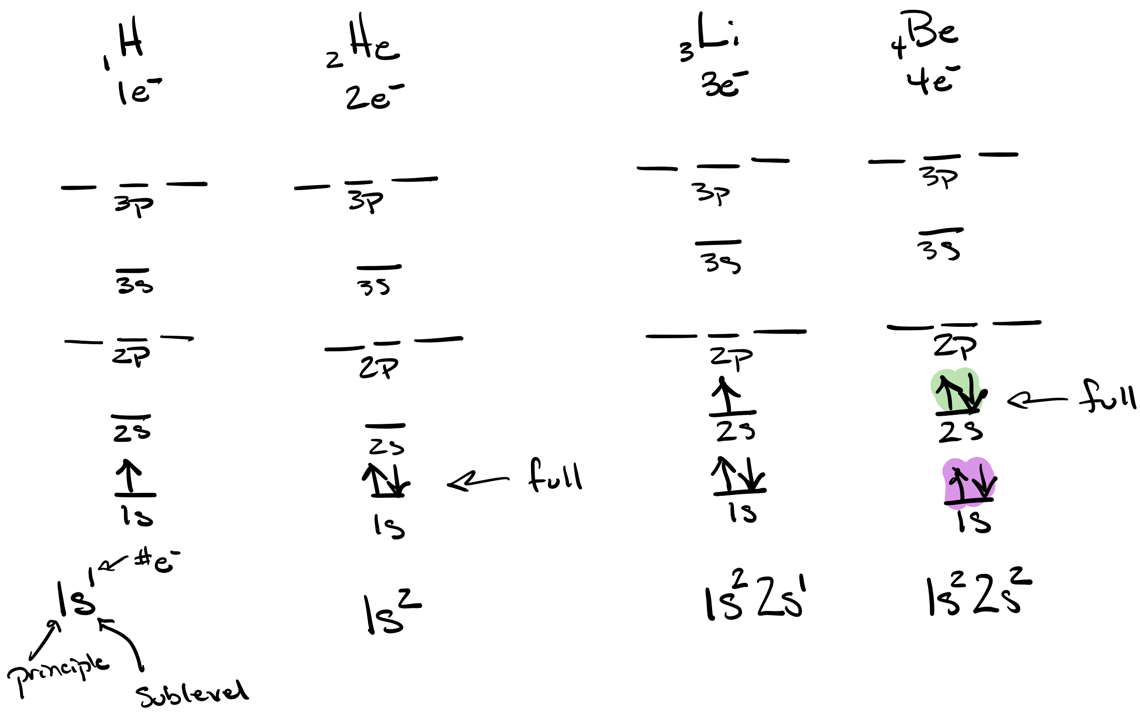
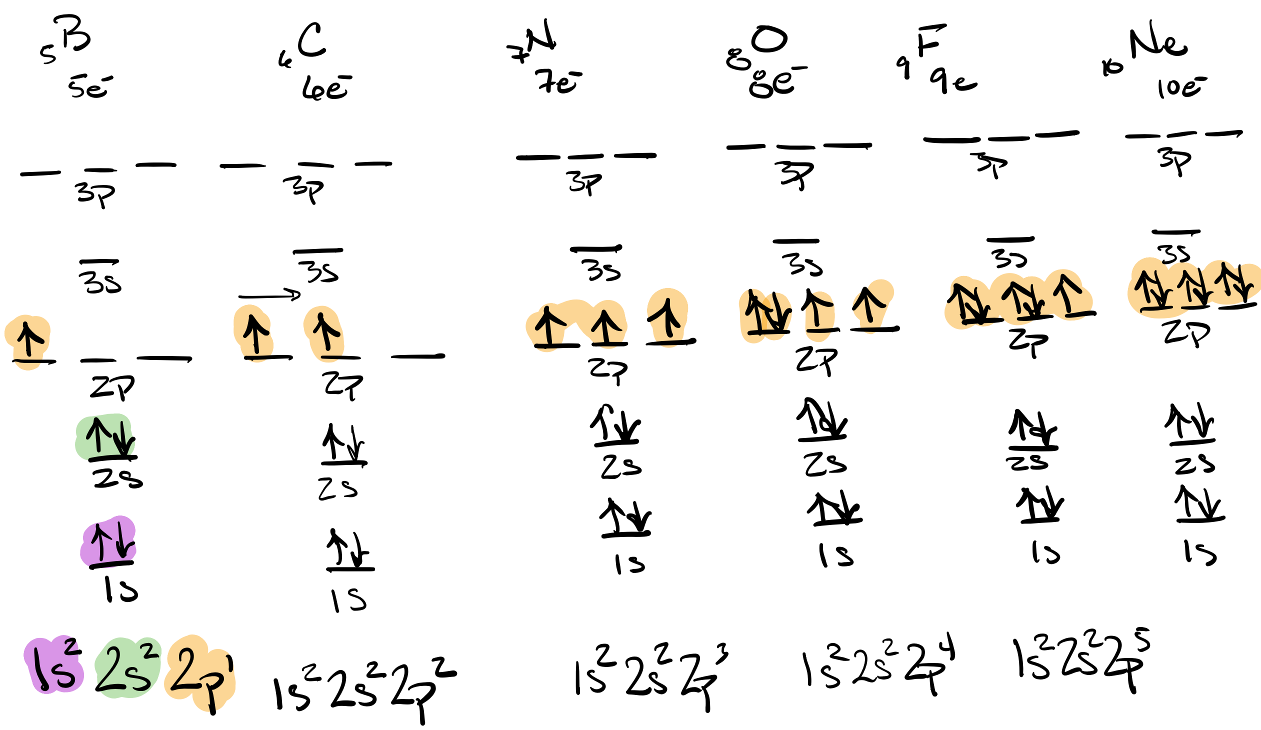

₁H
1e⁻
₂He
2e⁻
₃Li
3e⁻
₄Be
4e⁻
3p
3s
2p
2s
1s
full
1s¹
#e⁻
principle
sublevel
1s²
1s² 2s¹
1s² 2s²

$1s^{\#e^-}$


₅B
5e⁻
₆C
6e⁻
₇N
7e⁻
₈O
8e⁻
₉F
9e
₁₀Ne
10e⁻
3p
3s
2p
2s
1s
1s² 2s² 2p¹
1s² 2s² 2p²
1s² 2s² 2p³
1s² 2s² 2p⁴
1s² 2s² 2p⁵

s-block: ↑↓ / 2e⁻ = 2 elements

p-block: ↑↓ ↑↓ ↑↓ / 6e⁻ = 6 elements

d-block: ↑↓ ↑↓ ↑↓ ↑↓ ↑↓

	1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
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f-block: ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ ↑↓ / 14e⁻

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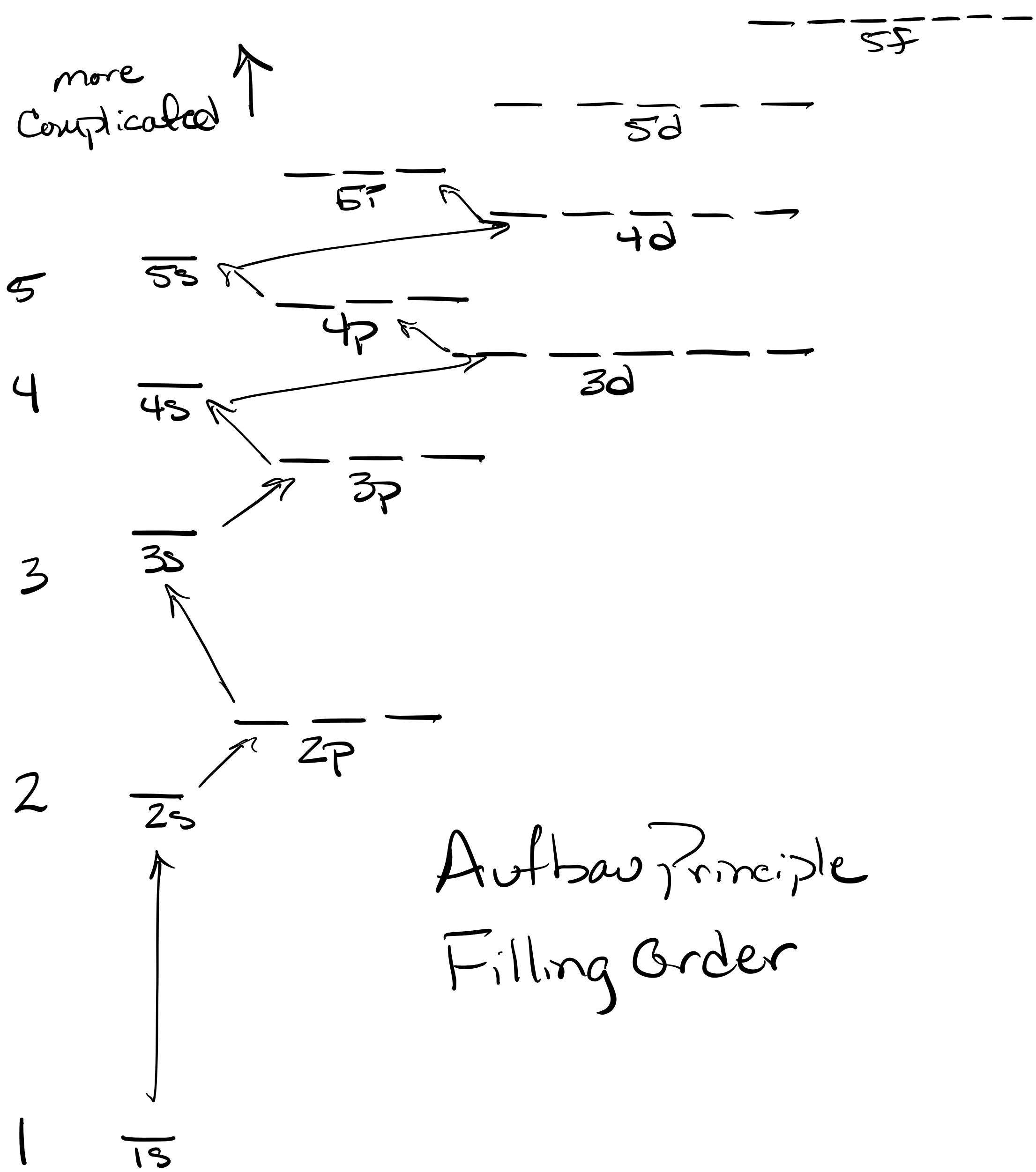

Aufbau Principle
Filling Order

Filling Order

Period	1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1	(1s) 1 H Hydrogen 1.008																	2 He Helium 4.003
2	(2s) 3 Li Lithium 6.941	4 Be Beryllium 9.012											(2p) 5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
3	(3s) 11 Na Sodium 22.99	12 Mg Magnesium 24.30											(3p) 13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95
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6	(6s) 55 Cs Cesium 132.9	56 Ba Barium 137.3		(5d) 72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.8	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.6	(6p) 81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
7	(7s) 87 Fr Francium (223)	88 Ra Radium (226)		(6d) 104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (281)	111 Rg Roentgenium (272)	112 Cn Copernicium (285)	(7p) 113 Nh Nihonium (284)	114 Fl Flerovium (289)	115 Mc Moscovium (288)	116 Lv Livermorium (289)	117 Ts Tennessine	118 Og Oganesson

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Table Predicts filling order

1s
2s 2p
3s 3p 3d
4s 4p 4d 4f
5s 5p 5d 5f 5g
6s 6p 6d 6f 6g 6h
7s 7p 7d 7f 7g 7h 7i

1s 2s 2p 3s 3p 4s 3d 4p 5s 4d 5p 6s 4f 5d 6p 7s . . .

Name____________________________

Section____________ Date_______

Electronic Configuration Worksheet

Scientists have learned from experiment that electrons *in atoms* occupy specific energy levels. These energy levels form an orderly pattern, and once this pattern is understood, it is rather simple to figure out, for any element, where the electrons are, i.e., which energy levels they occupy. Once we know this electron arrangement (also called the electronic configuration), we can predict a great deal about how these electrons will behave in chemical reactions. And this is the basis for chemistry--a fundamental understanding of the nature of atoms so that we can begin to understand and predict what they do.

Look at the diagram on the next page. It shows major, or principal energy levels. These are numbered consecutively 1, 2, 3, ...; the first 7 are shown on the diagram. It also shows that each of these levels is split into sublevels. The first principal energy level consists of a single sublevel; the second one has two sublevels, and so on. For levels 5, 6 and 7, not all the sublevels are shown. The sublevels are designated by letters: s, p, d, f, g, h, i, ... (the reason for choosing these letters is historical.)

Notice that as energy increases, the levels become more and more closely spaced. Although the exact spacing changes from element to element, the same general pattern exists for all elements--a large gap between levels one and two, a smaller gap between levels two and three, and so on.

Exercise:

Complete the list of sublevels For principal energy level 4:

4_s_, 4_p_, 4_d_, 4_f_.

List the sublevels for principal energy level 6: _6s_, ___, ___, ___, ___, ___

What sort of experiment indicates the existence of discrete energy levels?

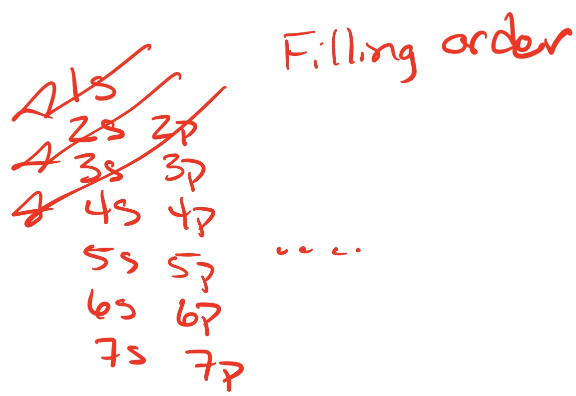
Gas discharge tube

The energy levels and sublevels by themselves do not tell the whole story. Because the spacing between energy levels becomes smaller and smaller as energy increases, the sublevels of different principal energy levels overlap each other. Note on the diagram on the next page that the 3d sublevel, for instance, is higher in energy than the 4s.

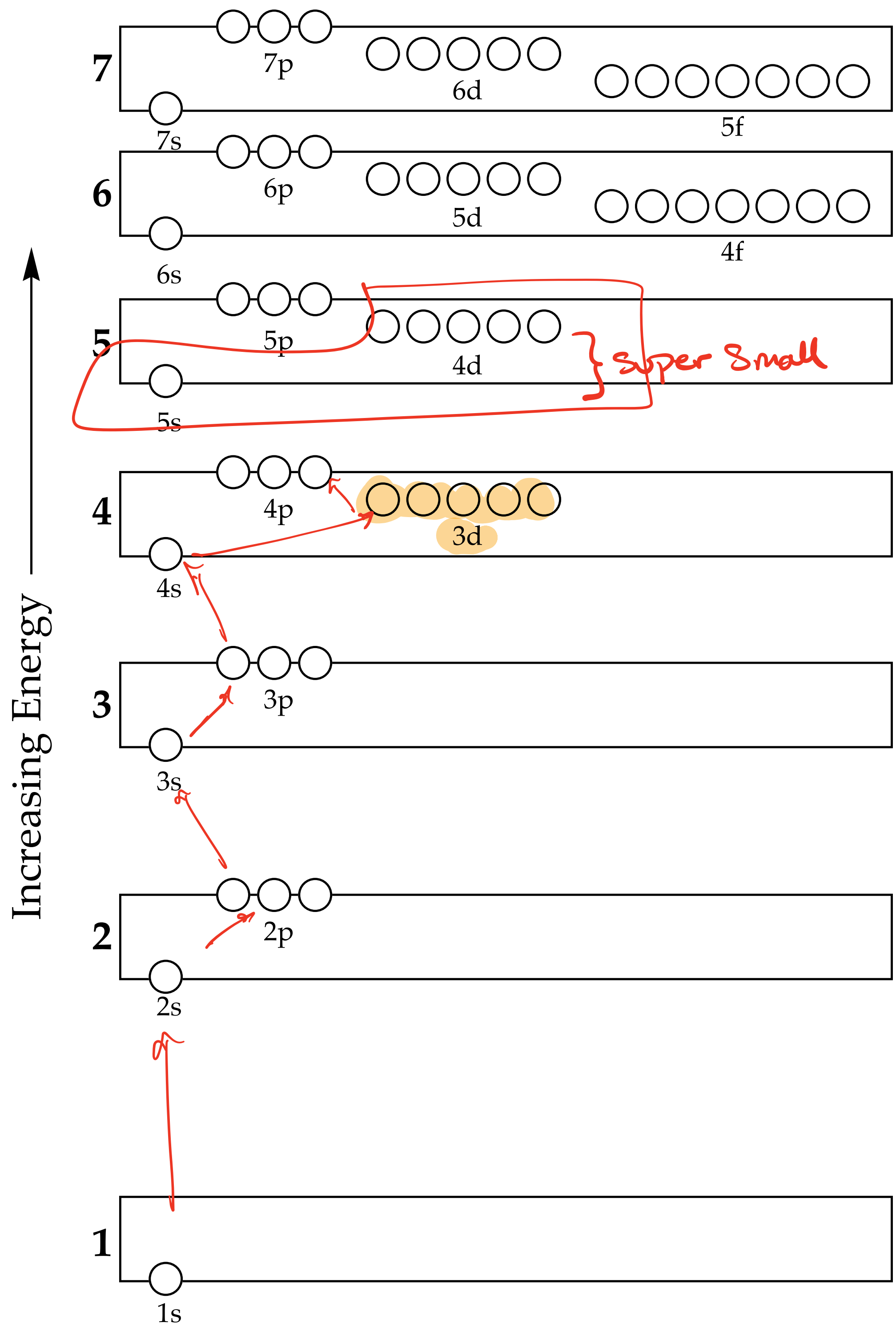
One way to learn the order of the sublevels is simply to remember the arrangement on the diagram on the next page. Another is to remember the arrangement shown in Figure 11-14 on p. 467.

Exercise:

Copy the diagram from Figure 11-14 ~~on p. 467 in the space at the right.~~



Electronic Energy Levels



No orbitals higher in energy than the 7p are needed to describe the unexcited electrons in every known element (as of 2003).

The next step is to find out how many electrons can fit into each sublevel. The answer to this question comes from theory, but is verified by experiment. Sublevels are divided into orbitals. An *orbital* is not the same as an *orbit*. An orbit is a well-defined path, like the earth's orbit around the sun. An orbital is a mathematically defined volume of space in an atom, molecule or ion, within which an electron can be found some specified percentage of the time. Electrons in orbitals in a given sublevel have the same energy.

Exercise:

Fill in the answers (number and diagram) for f, g, and h sublevels, below:

s sublevels have 1 orbital __

p sublevels have 3 orbitals __ __ __ +2 each time

d sublevels have 5 orbitals __ __ __ __ __

f sublevels have 7 orbitals __ __ __ __ __ __ __

g sublevels have ___ orbitals

h sublevels have ___ orbitals

Experiments have shown us that ***each orbital may hold a maximum of 2 electrons***. When two electrons occupy a single orbital, their spins are aligned in opposite directions: ↑↓

Thus an orbital may have no electrons (empty): __; one electron: ↑ , or two electrons: ↑↓.

Exercise:

For each of the following sublevels, indicate a diagram for the maximum number of electrons:

orbital			how many electrons?
2p	↑↓ ↑↓ ↑↓	3×2 (orbitals × e⁻)	6 electrons
2s	__	1×2	___ electrons
4p	__ __ __	3×2	___ electrons
3d	__ __ __ __ __	5×2	___ electrons
5f			___ electrons
6s			___ electrons
5g			___ electrons
6f			___ electrons

What is the maximum number of electrons in principal energy level 1 _________, principal energy level 2 _________, principal energy level 3 _________?

s: __ 1×2

s + p: 1×2 + 3×2

s + p + d

We have now looked at the basic rules for energy levels, sublevels, and orbitals. Now we will use this information to find the arrangement of electrons of different elements. These arrangements are called *orbital diagrams*.

Some guidelines:

1. The energy sequence of the sublevels is the same for all elements.
2. Electrons go into the lowest energy orbital that has room available. This is the "Pauli Exclusion Principle."
3. The maximum number of electrons in an orbital is 2.

We list the first few elements and their sublevels. Electrons fill orbitals from the bottom up:

	$_1$H	$_2$He	$_3$Li	$_4$Be	$_5$B
2p	__ __ __	__ __ __	__ __ __	__ __ __	↑ __ __
2s	__	__	↑	↑↓	↑↓
1s	↑	↑↓	↑↓	↑↓	↑↓

The fifth electron in boron (B) could go into any one of the three 2p orbitals. But when we come to carbon (C), we have two distinct choices for the sixth electron:

Hund's Rule

	This? $_6$C	or this? $_6$C
2p	↑ ↑ __	↑↓ __ __
2s	↑↓	↑↓
1s	↑↓	↑↓

The answer again comes from experiment, and gives us Guideline #4:

4. Electrons will occupy orbitals of equal energy singly before pairing up. This statement is known as Hund's Rule of Maximum Multiplicity, or, more simply, as "Hund's Rule."

Exercise:

Fill in the electrons of the second row elements from N through Ne:

	$_6$C	$_7$N	$_8$O	$_9$F	$_{10}$Ne
2p	__ __ __	__ __ __	__ __ __	__ __ __	__ __ __
2s	__	__	__	__	__
1s	__	__	__	__	__

(The 2p electrons in carbon can occupy any two of the 2p orbitals.)

Exercise:

Fill in the electrons for the third-row elements:

	$_{11}Na$	$_{12}Mg$	$_{13}Al$	$_{14}Si$	
3p	— — —	— — —	— — —	— — —	3p
3s	—	—	—	—	3s
2p	— — —	— — —	— — —	— — —	2p
2s	—	—	—	—	2s
1s	—	—	—	—	1s

	$_{15}P$	$_{16}S$	$_{17}Cl$	$_{18}Ar$	
3p	— — —	— — —	— — —	— — —	3p
3s	—	—	—	—	3s
2p	— — —	— — —	— — —	— — —	2p
2s	—	—	—	—	2s
1s	—	—	—	—	1s

In addition to the orbital diagrams the electron arrangement can be written in shorter form called *electron configuration*:

H	He	Li	Be	B	and so on.
$1s^1$	$1s^2$	$1s^2 2s^1$	$1s^2 2s^2$	$1s^2 2s^2 2p^1$	

Exercise:

Write the short notation electron configurations for elements 6-18: Carbon — Argon

$_6C$ $1s^2 2s^2 2p^2$

$_7N$ $1s^2 2s^2 2p^3$

⋮

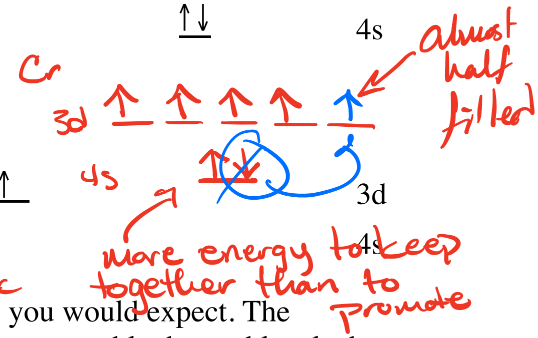
Beginning with K, the fourth period elements fill in the 4s, 3d and 4p sublevels, in that order. In the orbital diagrams below, the first 18 electrons (in the previously filled sublevels) are omitted:

	$_{19}$K	$_{20}$Ca	$_{21}$Sc	$_{22}$Ti	
3d	_ _ _ _ _	_ _ _ _ _	↑ _ _ _ _	↑ ↑ _ _ _	3d
4s	↑	↑↓	↑↓	↑↓	4s

	$_{23}$V	*$_{24}$Cr	$_{25}$Mn	
3d	↑ ↑ ↑ _ _	↑ ↑ ↑ ↑ ↑	↑ ↑ ↑ ↑ ↑	3d
4s	↑↓	↑	↑↓	4s

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$

comes back



Note that Cr is unusual, with configuration $4s^1 3d^5$, and ***not*** $4s^2 3d^4$ as you would expect. The theoretical explanation is that half-filled or fully-filled sublevels are more stable than sublevels that are neither. As the energy levels get closer in energy, starting with the 4s, it takes more energy to pair the electrons in the 4s than it does to promote one to the 3d level. Why is this true? It is true because there is stability gained (energy kick-back) in producing a half-filled or fully-filled 3d sublevel. Therefore an electron will promote from the 4s to the 3d sublevel when the resulting configuration has a half-filled or fully-filled 3d sublevel. All other electron configuration inconsistencies found later in the periodic table can be explained with similar arguments, that the pairing energy is greater than the energy required to promote.

Exercise:

Continue filling in the orbital diagrams below for Fe to Ge. (NOTE: Cu is an exception, similar to Cr.) Under each orbital diagram on this page, write the short notation for the electron configuration.

	$_{26}$Fe	$_{27}$Co	$_{28}$Ni	*$_{29}$Cu	
3d	_ _ _ _ _	_ _ _ _ _	_ _ _ _ _	_ _ _ _ _	3d
4s	_	_	_	_	4s

	$_{30}$Zn	$_{31}$Ga	$_{32}$Ge	
4p	_ _ _	_ _ _	_ _ _	4p
3d	_ _ _ _ _	_ _ _ _ _	_ _ _ _ _	3d
4s	_	_	_	4s

Now, sharpen your pencil, and in the small space provided on the periodic chart on the next page, write the electronic configuration of the highest filled, or partially filled, energy sublevel for each element up to xenon (element 54).

1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 H $1s^1$																	2 He $1s^2$
3 Li $2s^1$	4 Be $2s^2$											5 B $2p^1$	6 C $2p^2$	7 N	8 O	9 F	10 Ne
11 Na $3s^1$	12 Mg $3s^2$											13 Al $3p^1$	14 Si $3p^2$	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc $3d^1$	22 Ti $3d^2$	23 V	*24 Cr $3d^5$	25 Mn $3d^5$	26 Fe	27 Co	28 Ni	*29 Cu $3d^{10}$	30 Zn $3d^{10}$	31 Ga $4p^1$	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe

Lanthanides															
Actinides															

Which groups are the representative (main group) elements?

Which sublevels are filling as one goes across a row of representative elements?

Which sublevels are filling as one goes across a row of transition elements?

Which sublevel is being filed by the lanthanides?

Which sublevel is being filled by the actinides?

Which sublevel is being filled by elements $_{104}Rf$ and $_{105}Db$?

Because the inner (noble gas core) electrons of an element are not as important as the outer most electrons, chemists often write electron configurations in an abbreviated form. The noble gas core electrons are represented with the noble gas symbol written in brackets followed by the remaining configuration. *Only the noble gases may be used for core representations*. Write the shorthand electronic configurations for the following:

Si: [Ne]$3s^23p^2$ Ag:[Kr] Se:[Ar]

Br:[Ar] Sr:[Kr] Ar: [Ne]

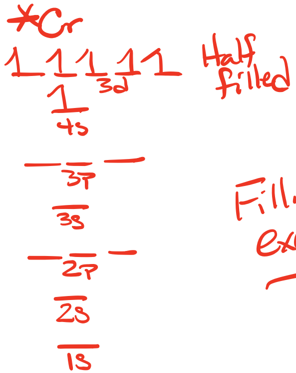
Diamagnetic elements have no unpaired electrons in any orbital; paramagnetic ones have one or more unpaired electrons. Identify which of the following are diamagnetic, and which are paramagnetic (remember that all are one or the other!). Write "dia" or "para":

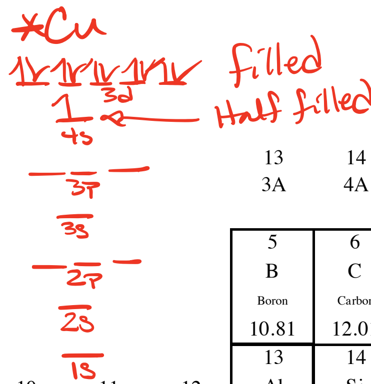
He: B: C: Ne: Ti: Fe: Zn: S: Sn:

↑↓ ↑↓ ↑↓
diamagnetic

↑↓ ↑ ↑
paramagnetic

Filling exceptions





1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
11 Na Sodium 22.99	12 Mg Magnesium 24.30											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.07	17 Cl Chlorine 35.45	18 Ar Argon 39.95
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.87	23 V Vanadium 50.94	* 24 Cr Chromium 52.00	25 Mn Manganese 54.94	26 Fe Iron 55.84	27 Co Cobalt 58.93	28 Ni Nickel 58.69	* 29 Cu Copper 63.55	30 Zn Zinc 65.41	31 Ga Gallium 69.72	32 Ge Germanium 72.64	33 As Arsenic 74.92	34 Se Selenium 78.96	35 Br Bromine 79.90	36 Kr Krypton 83.80
37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.94	43 Tc Technetium (98)	44 Ru Ruthenium 101.1	45 Rh Rhodium 102.9	46 Pd Palladium 106.4	47 Ag Silver 107.9	48 Cd Cadmium 112.4	49 In Indium 114.8	50 Sn Tin 118.7	51 Sb Antimony 121.8	52 Te Tellurium 127.6	53 I Iodine 126.9	54 Xe Xenon 131.3
55 Cs Cesium 132.9	56 Ba Barium 137.3		72 Hf Hafnium 178.5	73 Ta Tantalum 180.9	74 W Tungsten 183.8	75 Re Rhenium 186.2	76 Os Osmium 190.2	77 Ir Iridium 192.2	78 Pt Platinum 195.1	79 Au Gold 197.0	80 Hg Mercury 200.6	81 Tl Thallium 204.4	82 Pb Lead 207.2	83 Bi Bismuth 209.0	84 Po Polonium (209)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226)		104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (281)	111 Rg Roentgenium (272)	112 Cn Copernicium (285)	113 Nh Nihonium (284)	114 Fl Flerovium (289)	115 Mc Moscovium (288)	116 Lv Livermorium (289)	117 Ts Tennessine	118 Og Oganesson

Lanthanides	57 La Lanthanum 138.9	58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (145)	62 Sm Samarium 150.4	63 Eu Europium 152.0	64 Gd Gadolinium 157.2	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 Lu Lutetium 175.0
Actinides	89 Ac Actinium (227)	90 Th Thorium 232.0	91 Pa Protactinium 231.0	92 U Uranium 238.0	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251)	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)	103 Lr Lawrencium (262)

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Values rounded to four significant figures

1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
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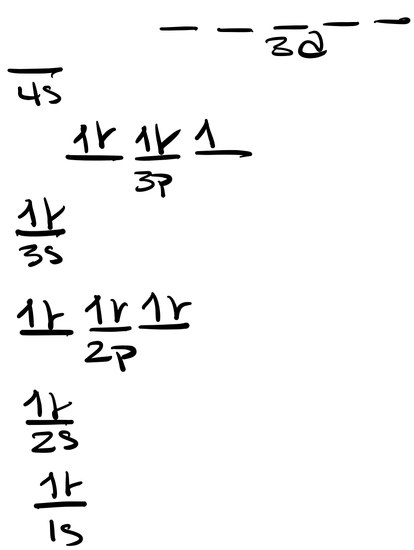
Values rounded to four significant figures

s-block · p-block · d-block · f-block · Main Group Representative · Transition Metals · Inner Transition · 1 · 2 · 3 · 4

Nobel Gas Core Configuration

$_{17}Cl$



$1s^2 2s^2 2p^6 3s^2 3p^5$

$Ne = 1s^2 2s^2 2p^6$

$[Ne] 3s^2 3p^5$

Nobel Gas Short hand

& can only be done with a nobel gas

Br

Core electrons

$[Ar]\ 4s^2 3d^{10} 4p^5$

Nobel Gas Core