3.1 Developing a Modern Model of the Atom

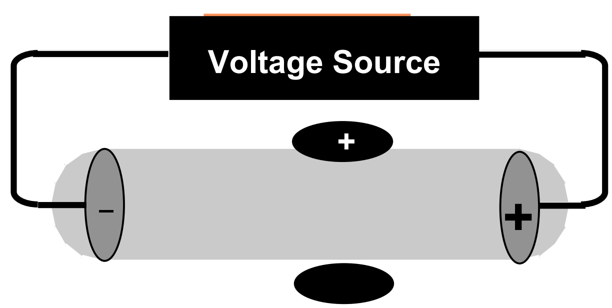
Dalton's Theory:

explained: law of conservation of mass
law of constant composition

limitations:

Technological Advance: cathode ray tube (CRT)

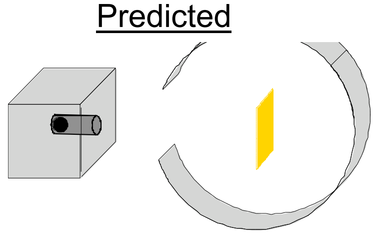
Thomson's Theory:



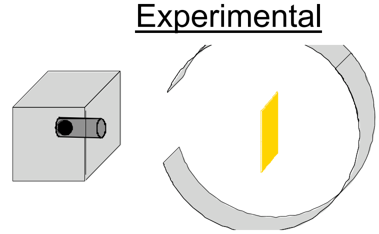
Discovery: discovered certain elements are radioactive, emitting positively charged alpha-particles

Rutherford:

Predicted



Experimental



Rutherford con't:

→ proposed the "nuclear model"

↓

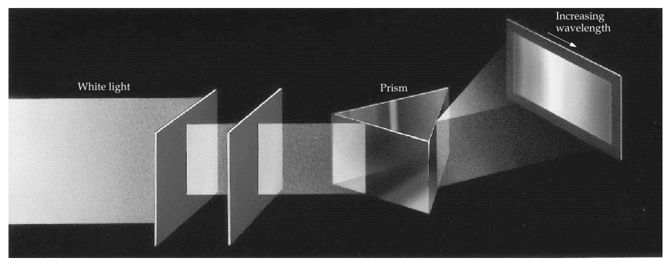
atom contains positively
charged core *(nucleus)*
surround by empty space
containing negative electrons

PROBLEMS: ❶

❷

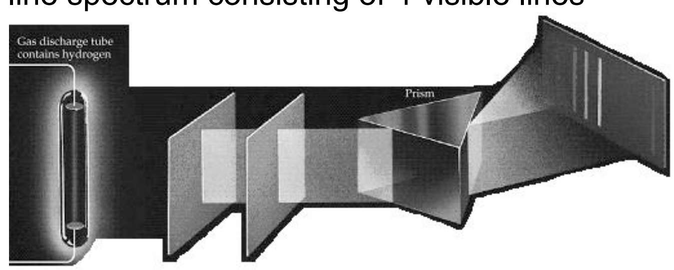
❸ contradicted 19th century physics:

→ it was thought that an electron should give off a ______________________



Continuous light spectrum

Experimental Observation: hydrogen gas emits a line spectrum consisting of 4 visible lines



Bohr Model: →

→

Assumptions: ❶

❷

❸

a) can move to a _______orbit by _____________ a specific quantity of energy

b) can move to a _______ orbit if _______ energy

<u>Assumptions based on</u>:

a) Planck →

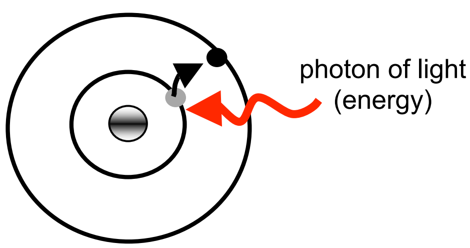
b) Einstein →

Bohr → energy from coloured lines of H-spectrum due to e⁻ moving between energy levels, called a **<u>transition</u>**

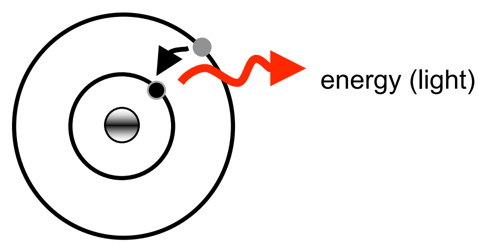
<u>ground state</u> ⇒

<u>excited state</u> ⇒

→ when dropping back down towards ground state the e⁻ emits light at a particular wavelength

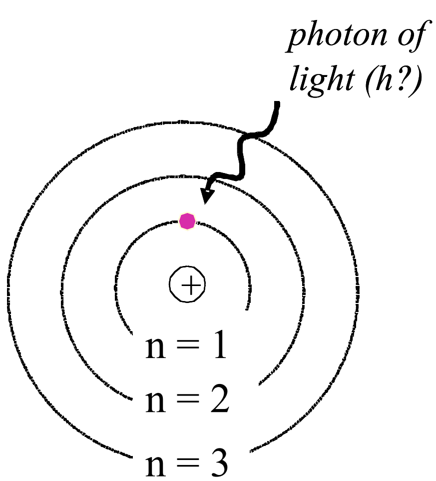


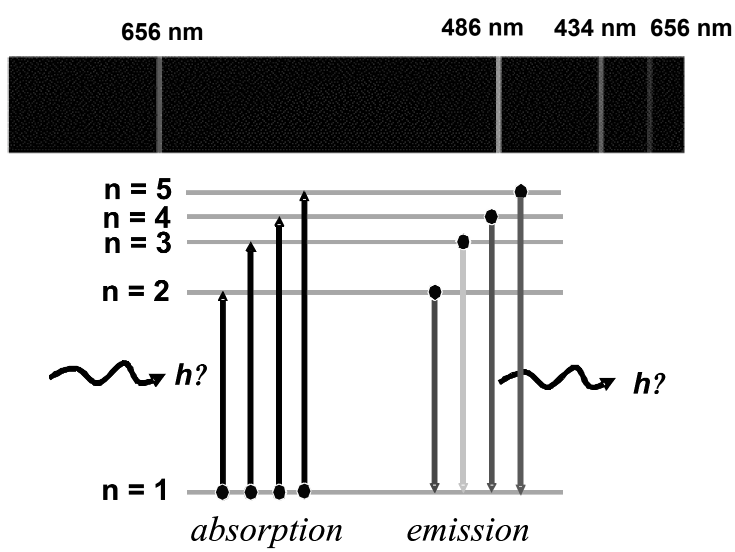
e⁻ _________ a quantum of energy



e⁻ **<u>loses</u>** a quantum of energy

Explaining hydrogen spectrum:



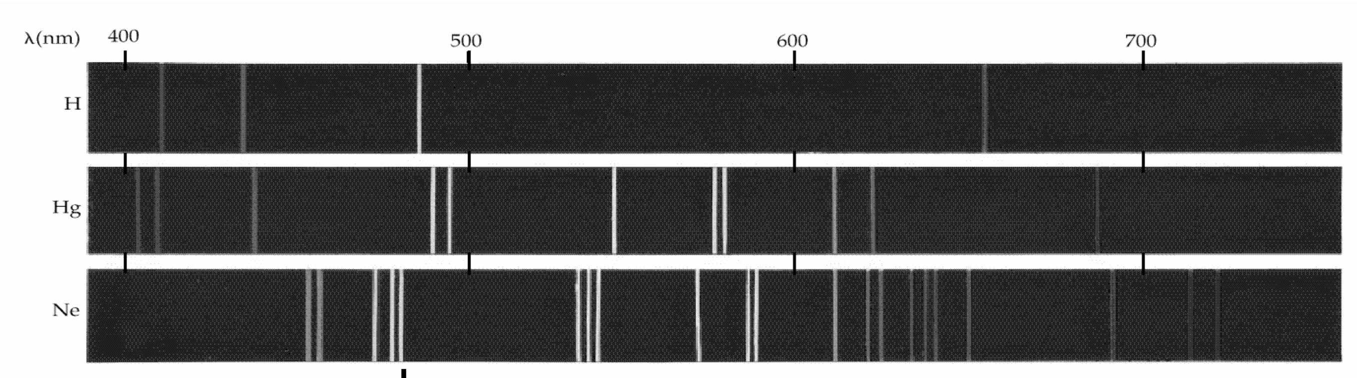


BIG PROBLEM:

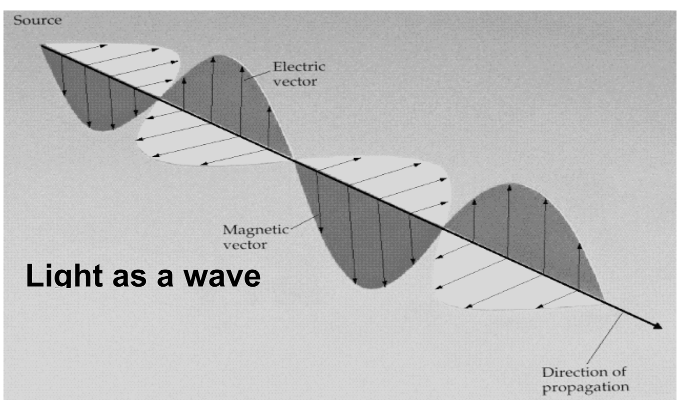
3.2 The Quantum Mechanical Model of the Atom

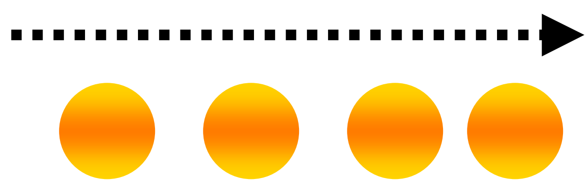
*** Bohr's model could only explain _______________ ***

→ atoms with many e⁻ had many spectral lines close together:



→ not only does light behave like a particle sometimes, but particles behave like waves! **WAVE-PARTICLE DUALITY**





Light as a particle
(a stream of photons)

Quantum model of the atom

→ devised by ___________________ to mathematically describe the wave-like properties of atoms

→

Heisenberg Uncertainty principle

⇒

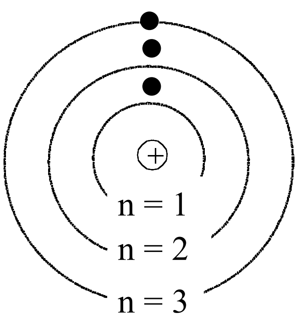
example: if you know an electron's precise position and path around the nucleus, as you would by determining its orbit, you cannot know with certainty of its ________________

similarly, if you know its precise velocity, you cannot know with certainty its _____________

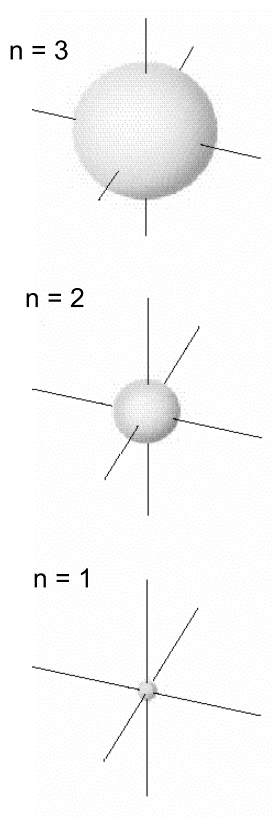
Instead of finding an electron in an orbit, quantum mechanics uses the concept of an ___________

Orbital ⇒

Bohr's Orbits



Quantum Orbitals



Orbits	Orbitals

Quantum Numbers

ground state ⇒

quantum numbers ⇒
There are 4 quantum numbers:

B)
C)
D)

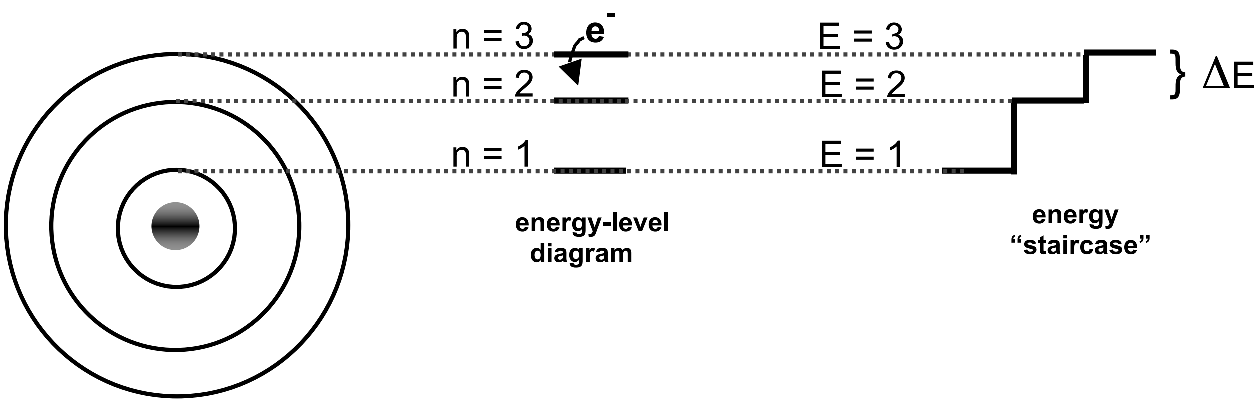
A) Principal Quantum Number (n)

•

•

•

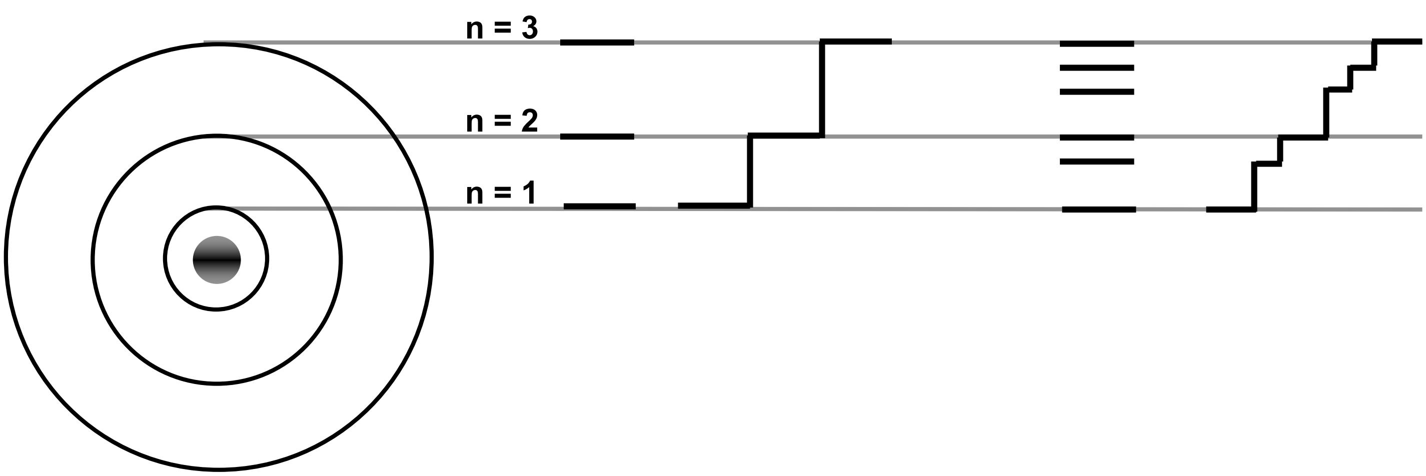
•



B) Secondary Quantum Number ( ) ( )

•

•



→ refers to the shape of the orbital, given a letter to describe shape:

_ = 2
_ = 3

→

Putting it together:

n	_ (n-1)	shape
1		
2		
3		
4		

We will use both the principal (n) and secondary (_) quantum numbers to name a particular orbital.

e.g.

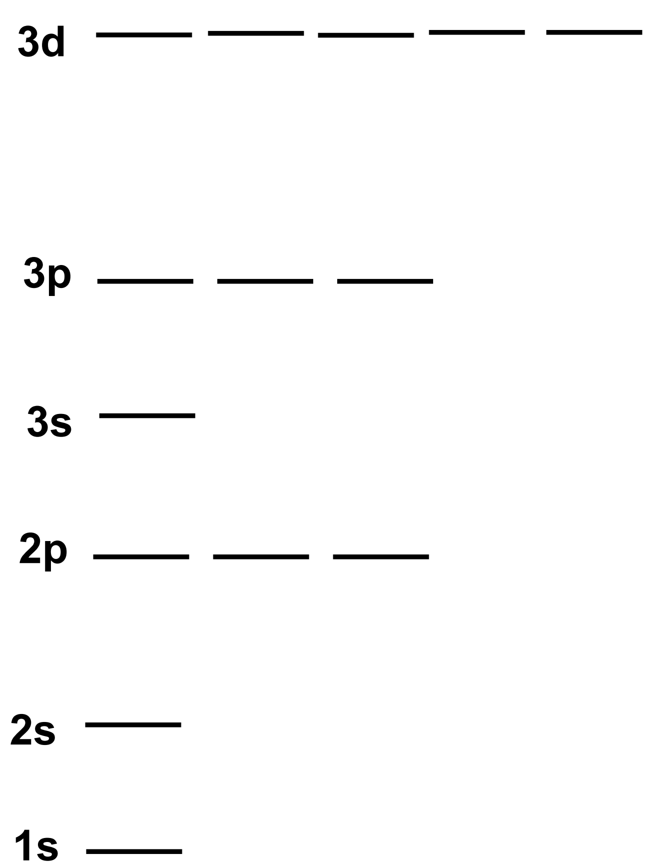
Practice

Primary energy level	Principal Quantum Number (n)	Possible Secondary Quantum Numbers (_)	Number of sublevels per primary level
1			
2			
3			
4			

c) <u>Magnetic Quantum Number (m)</u>

-
-
-

n	(n – 1)	m (- _ → _)
3	2 (d)	-2, -1, 0, +1, +2 ⎬ 3d
	1 (p)	-1, 0, +1 ⎬ 3p
	0 (s)	0 ⎬ 3s
2	1(p)	-1, 0, +1 ⎬ 2p
	0(s)	0 ⎬ 2s
1	0 (s)	0 ⎬ 1s



D) <u>Spin Quantum Number (m_s)</u>

<u>Summary of the four quantum numbers</u>

Quantum Number	Symbol	Allowed Values	Property
principal			

orbital shape			
magnetic			
spin			

Example 1: If n = 3, what are the allowed values for _ and m_, and what is the total number of orbitals in this energy level?

Example 2: What are the possible values for m_ if n = 5 and _ = 1? What kind of orbital is described by these quantum numbers? How many orbitals can be described by these quantum numbers?

p. 136 Practice # 1- 5

SCH 4U Quantum Numbers Practice Problems

1. What are the allowed ratios for _ in each of the following cases?

   a) n = 5 b) n = 1

2. What are the allowed values for m_ for an electron with the following quantum numbers?

   a) _ = 4 b) _ = 0

3. What are the names (i.e. 1s, 3p, 4d), m_ values, and the total number of orbitals described by the following quantum numbers?

   a) n = 2, _ = 0 b) n = 4, _ = 3

4. Determine the n, _, and possible m_ values for an electron in the 2p orbital.

5. Each value of the secondary quantum number is used to determine the possible values of the magnetic quantum number. How many possible values of m_ are there for _ = 1, 2, 3, 4?

6. Which of the following are allowable sets of quantum numbers for an atomic orbital? Explain you answer for those that are <u>NOT</u> allowable.

   a) n = 4, _ = 4, m_ = 0 b) n = 3, _ = 2, m_ = +1

   c) n = 2, _ = 0, m_ = 0 d) n = 5, _ = 5, m_ = -4

7. Identify any values that are incorrect for the following sets of quantum numbers:

   a) n = 1, _ = 1, m_ = 0; name 1*p*

   b) n = 4, _ = 3, m_ = +1; name 4*d*

   c) n = 3, _ = 1, m_ = -2; name *3p*

8. Fill in the missing values in the following sets of quantum numbers.

   a) n = ?, _ = ?, m_ = 0; name 4*p*

   b) n = 2, _ = 1, m_ = 0; name ?

   c) n = 3, _ = 2, m_ = -2; name ?

   d) n = ?, _ = ?, m_ = ?; name 2*s*

3.3 Electron Configurations and Periodic Trends

Electron Configurations –

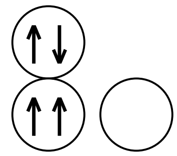
-
-
-

Pauli Exclusion Principle

a)

correct:

incorrect:



b)

(can't have 2 e^- in the same exact space, with the same spin)

Aufbau principle ⇒

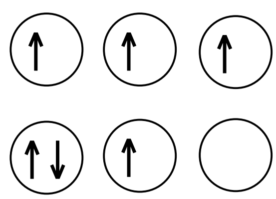
.

-

Hund's rule ⇒

correct: *2p*

incorrect: *2p*

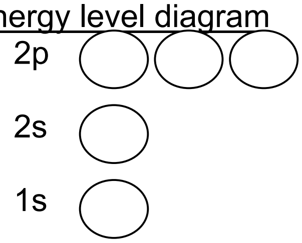


example 1:

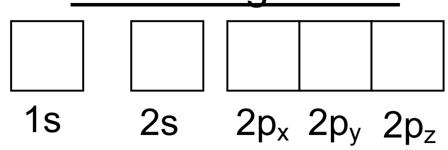
$^{16}_{8}O$

a) 8 e^- need to be placed
b) O is in Period 2, ∴2 main energy levels to fill

Energy level diagram



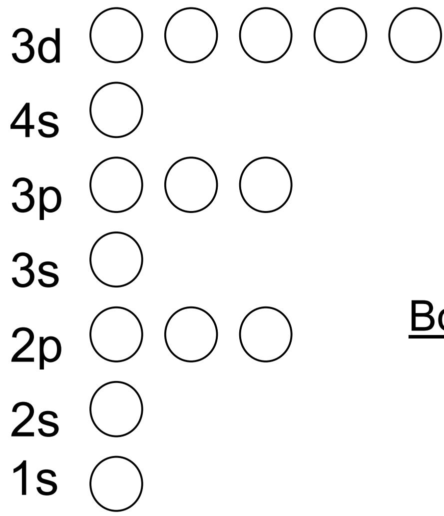
Box configuration



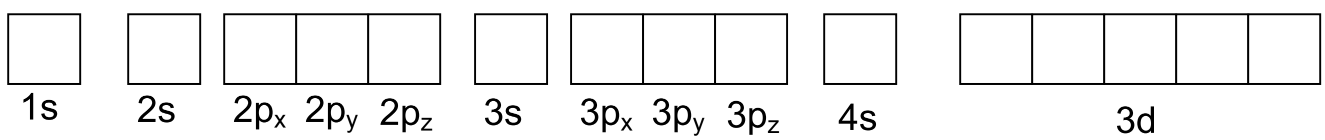
electron configuration:

example 2: $^{56}_{26}Fe$

a) 26 e^- need to placed
b) Fe is in Period 4, ∴ 4 main energy levels to fill

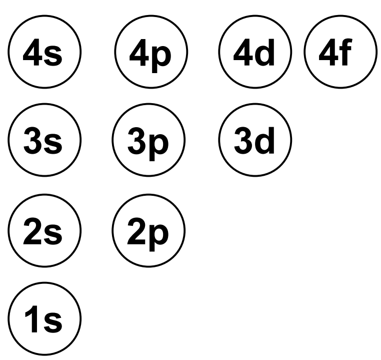


<u>Box configuration and electron configuration</u>



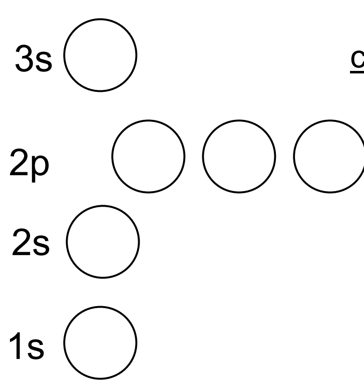
SUMMARY:

1.

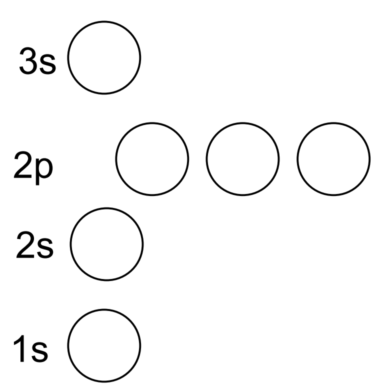


2.

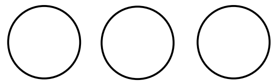
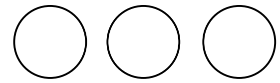
<u>incorrect</u>:



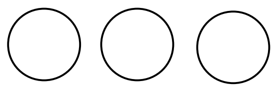
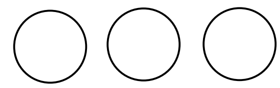
<u>correct:</u>



3.

<u>incorrect</u>:  <u>correct:</u> 

4.

incorrect:  correct: 

<u>Condensed electron configuration:</u>

-

uses the noble gas preceding in square brackets

eg. Si –

p. 145 practice # 6-9

Electron configurations and Orbital Diagrams for Period 4
Look at periodic table for Cu and Cr

Different from others
Cr –

Cu –

s,p orbitals

D block are called transition metals

F block are called the inner transition metals

Patterns involving Group Numbers and Period Numbers

3 patterns:

1.

2.

3.

p. 150 practice # 10-13

Read p.150-157 independently

SCH 4U Electron Configuration Practice #1

1. Practice questions 6 and 7 (text pg. 194)

2. Without looking at the periodic table, identify the group number, period number, and block of an atom that has the following electron configurations.

   a) $[Ne]3s^1$ b) $[He]2s^2$ c) $[Kr]5s^24d^{10}5p^5$

3. Use the *aufbau* principle to write complete electron configurations for the atom of the element that fits the following descriptions.

   a) group 2 (IIA) element in period 4

   b) group 12 (IIB) element in period 4

   c) group 16 (VI) element in period 2

4. Identify all the possible elements that have the following valence electron configurations.

   a) s^2d^1 b) s^2p^3 c) s^2p^6

5. For each of the following elements below, use the *aufbau* principle to write the full and condensed electron configurations.

   a) potassium b) nickel c) lead

   d) calcium ion e)chloride ion

6. Explain what each number and letter means in the following notation: $3p^6$

7. Fill in the numerical value(s) that correctly complete(s) each of the following statements.

   a) A 5f subshell holds a maximum of ____ electrons.

   b) A 4s orbital holds a maximum of ____ electrons.

   c) The maximum number of electrons in the third electron shell is ____.

   d) The forth shell contains ____ subshells, ____ orbitals, and a maximum of ____ electrons

SCH 4U Electron Configuration Practice #2

1. Give full **and** abbreviated (noble gas core) electronic configurations for the following.

a) Br FULL ______________________________

NOBLE GAS CORE ______________________________

b) Cr FULL ______________________________

NOBLE GAS CORE ______________________________

c) Fe FULL ______________________________

NOBLE GAS CORE ______________________________

d) S^{2-} FULL ______________________________

NOBLE GAS CORE ______________________________

2. For each of the following sets of orbitals, indicate which orbital is higher in energy.

a) 1s, 2s _________ b) 2p, 3p _________

c) 4s, $3d_{yz}$ _________ d) $3p_x$, $3p_y$, $3p_z$ _________

3. Indicate the block (s, p or d) in which each of the following elements found.

	BLOCK		BLOCK
a) Sc	______	b) P	______
c) Fr	______	d) Ni	______
e) As	______		

4. An **atom** has two electrons with principal quantum number n = 1, eight electrons with principal quantum number n = 2 and seven electrons with principal quantum number n = 3. From these data, supply the following values (if insufficient information is given, say so)

a) the mass number. _________

b) the atomic number. _________

c) the electron configuration. ___________________________

5. Identify the element from the electron configurations of **atoms** shown below.

a) [Ne] $3s^2 3p^2$ _________

b) [Ar] $4s^2 3d^7$ _________

c) [Xe] $6s^2$ _________

6. State which atom or ion is represented by the following sets of atomic numbers and electronic configurations. (4)

	Atomic #	Electronic Configuration	
a)	8	$1s^2\ 2s^2\ 2p^4$	________
b)	11	$1s^2\ 2s^2\ 2p^6$	________
c)	14	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$	________
d)	22	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^2$	________

7. Of the following species (Sc, Ca^{2+}, Cl, S^{2-}, Ti^{3+}), which are isoelectronic?

8. Identify the element that is composed of atoms whose **last** electron;

a) enters and fills the 4s sub-shell ________

b) enters but does not fill the 4s sub-shell ________

c) is the first to enter the 2p sub-shell ________

d) is the next to the last to enter the 4p sub-shell ________

e) is the second to enter the 4d sub-shell ________

9. Identify two positive **and** two negative ions that are isoelectronic with neon.

Two Positive ions ________ ________

Two Negative ions ________ ________

10. Using the electrons in boxes notation complete the electronic configurations of the following elements.

1s	2s	2p	3s	3p	3d	4s	4p	Element
☐	☐		☐		☐	☐		V
☐	☐		☐		☐	☐		Ar
☐	☐		☐		☐	☐		Zn

11. State the number of **unpaired** electrons in each of the electronic configurations in question 11.

V ________ Ar ________ Zn ________