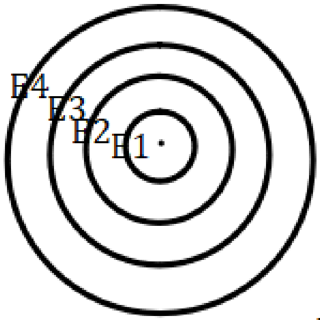
Electrons, Energy, & the Electromagnetic Spectrum Notes

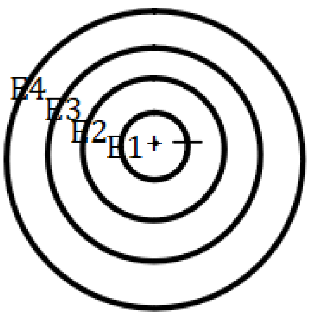


paths, shells, orbits, rings = ______________________________

As the name "energy level" implies, there is a specific amount of energy associated with each energy level.

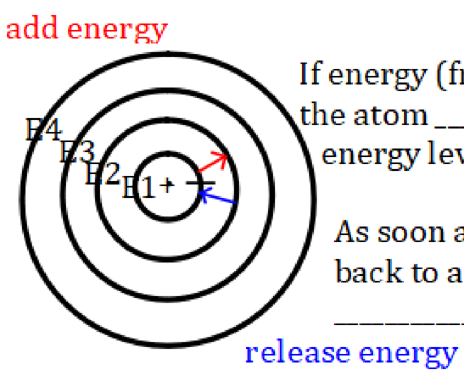
Bohr said that electrons could change paths (energy levels) if energy is _____________ or _____________.

electrons are in their lowest energy state = _________________________



_________________ Principle says that electrons will occupy the location that requires the least amount of energy first.

Electron will be located in E1 because E1 is closest to the nucleus. Nucleus is positive & it attracts negative electrons, so amount of energy needed is minimal.



If energy (from an outside source) is added to the atom… the atom _________________ energy and electron moves to a ____________ energy level. The electron is now in the ____________ state.

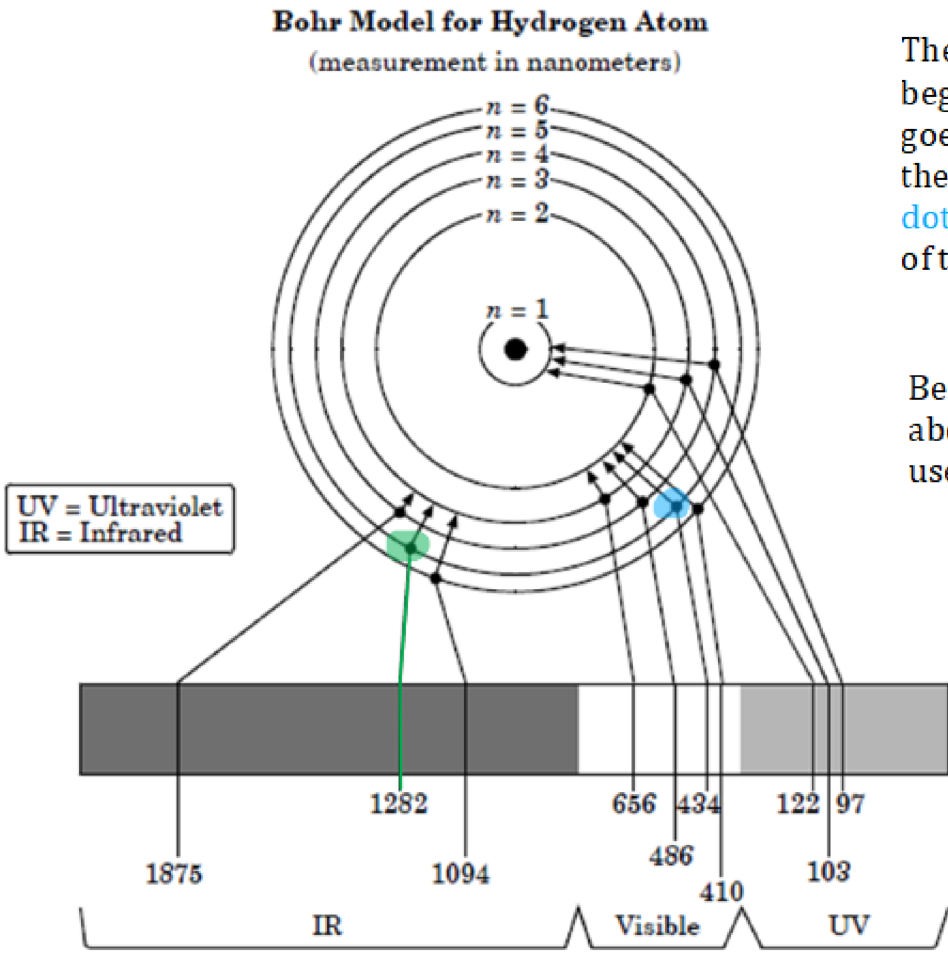
As soon as the electron jumps to a higher level, it immediately falls back to a lower energy level. When the electron falls, energy is _________________.

The energy is released as __________________________________ (EM). The type of EM radiation depends on the difference in energy between the energy levels.

Bohr Model Diagram Interpretation

What form of EM radiation is released when an electron in a hydrogen atom falls from the 5th energy level to the 3rd energy level?

[When a question asks about the hydrogen atom and the type of EM radiation emitted, you should use the top diagram on p. 8 of your reference tables.]



There are only two lines that begin at n = 5. The green dot goes from n = 5 to the end of the arrow at n = 3. The blue dot goes from n = 5 to the end of the arrow at n = 2.

Because the problem asked about n = 5 to n = 3, we will use the green dot.

The line with the green dot corresponds to _______ nm, which falls into the ___________________________ type of EM radiation.

The drawback to Bohr's model and calculations was that ____.

<u>Light Calculation Notes</u>

If we know the difference in energy between the two energy levels involved, we can determine the type of EM radiation for other elements besides hydrogen.

Here's how the type of EM radiation can be determined…

The amount of **<u>energy</u>** released when an electron falls from a higher to a lower energy level is **<u>directly proportional to</u>** its **<u>frequency</u>**.

The calculation follows the equation: $\boxed{E = h \cdot \nu}$

E = Energy (unit is J)
h = Planck's Constant (6.626×10^{-34} J·s)
ν = frequency (unit is Hz or $^{1}/_{second}$)

EXAMPLE 1: A particle of EM radiation has an energy of 1.15×10^{-14} J. What is its frequency?

1.15×10^{-14} J = 6.626×10^{-34} J·s · ν

ν = 1.74×10^{19} Hz

The type of electromagnetic radiation can be determined if one knows the wavelength. The **wavelength** is **inversely proportional to** the **frequency**.

The calculation follows the equation: $\boxed{c = \lambda \cdot \nu}$

c = speed of light (3.00×10^8 m/s)
λ = wavelength (unit is m)
ν = frequency (unit is Hz or $^1/_s$)

EXAMPLE 2: What is the wavelength of the same particle from EXAMPLE 1?

$3.00 \times 10^8 \text{ m/s} = \lambda \cdot 1.74 \times 10^{19} \text{ Hz}$
$\lambda = 1.72 \times 10^{-11}$ m

EXAMPLE 3: What type of electromagnetic radiation is the particle from EXAMPLE 1?

answer for wavelength is 10^{-11} so use EM Spectrum chart below to determine that it is x-rays

Problems for you to try on your own…
[Hint: Pay attention to the units that are given and what they measure!]

1.) A particle of EM radiation has a frequency of 4.80×10^{14} Hz.

(A) How much energy does this particle have?

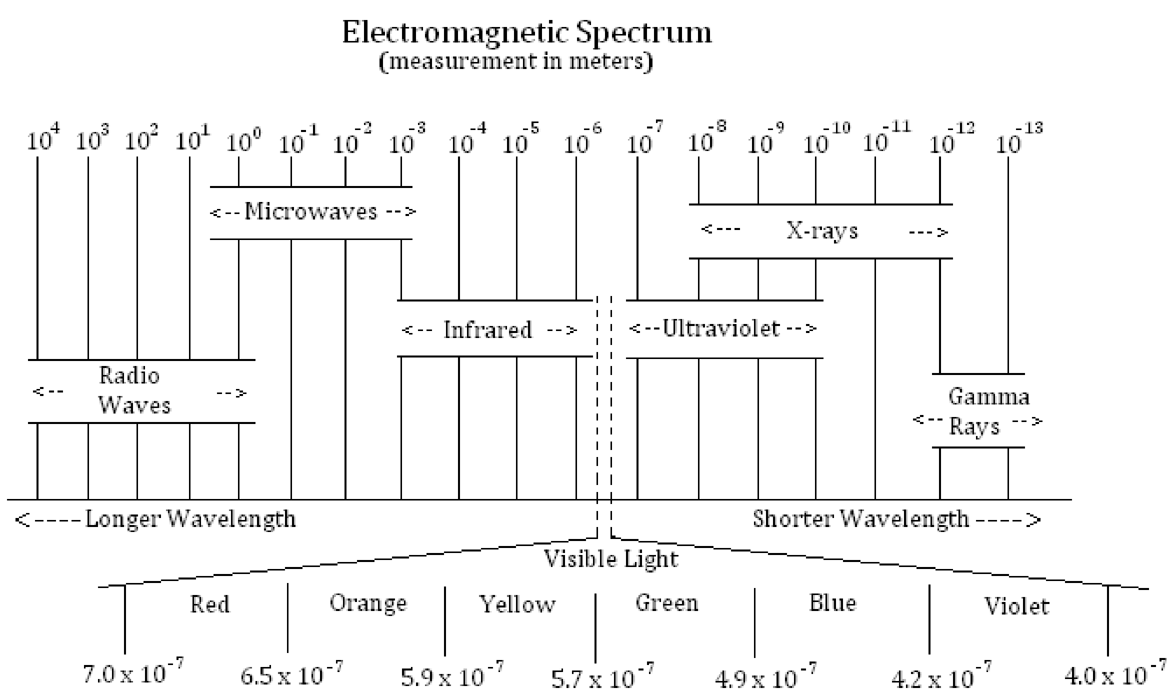
(B) What is the wavelength of this particle?

(C) What specific type of electromagnetic radiation does this particle represent?

2.) A particle of electromagnetic radiation has 2.39×10^{-13} Joules of energy.

(A) What is the wavelength of this particle?

(B) What type of electromagnetic radiation does this particle represent?



Example Questions:

1. Which has a longer wavelength - microwaves or x-rays?

2. Which has higher frequency - radio waves or ultraviolet?

3. Which has more energy - gamma rays or visible light?

WAVE-PARTICLE DUALITY

When energy is added to an atom, the electron jumps to a higher energy level as it absorbs energy. It takes a certain amount of energy to accomplish this task and it is different between every energy level in every different element. That bundle (or packet) of energy is called a ________________________. This emission of energy in finite amounts gives rise to the idea that light can act like a particle. A particle of EM radiation carrying a quantum of energy is called a ______________________.

As energy continues to be added to the atom, the electron(s) move back and forth, gaining and losing energy as they change energy levels. This idea that the electron moves back and forth between energy levels suggests that light acts like a wave.

________________________ suggested that light had properties of both particles and waves. This idea is called the ____ of light.

LIGHT CALCULATIONS & PROPERTIES OF LIGHT WORKSHEET

1.) Look at the EM spectrum to answer this question.
As you move across the visible light spectrum from red to violet…
(A) Does the wavelength increase or decrease?
(B) Does the frequency increase or decrease?
(C) Does the energy increase or decrease?

2.) A beam of microwaves has a frequency of 1.0×10^{9} Hz. A radar beam has a frequency of 5.0×10^{11} Hz. Which type (microwave or radar)…
(A) has a longer wavelength?
(B) is closer to visible light on the EM spectrum?
(C) is closer to x-rays in frequency value?

3.) What is the frequency of an EM radiation wave if its wavelength is 3.6×10^{-9} meters?

4.) A beam of EM radiation has a wavelength of 4.257×10^{-7} cm. What is its frequency?

5.) A photon of light has a wavelength of 3.20×10^{5} meters. Find…

(A) the frequency

(B) the energy

(C) the region of the EM spectrum/type of radiation

6.) A photon has an energy of 4.00×10^{-19} J. Find…

(A) the frequency

(B) the wavelength

(C) the region of the EM spectrum/type of radiation

7.) A bright line spectrum contains a line with a wavelength of 518 nm. Determine…

(A) the wavelength in meters

(B) the frequency

(C) the energy

(D) the color

*8.) Cobalt-60 is an artificial radioisotope that is produced in a nuclear reactor for use as a gamma ray source in the treatment of certain types of cancer. If the wavelength of the gamma radiation from a cobalt-60 source is 1.00×10^{-3} nm, calculate the energy of a photon of this radiation.

9.) Which has a longer wavelength, orange or violet light?
10.) Which has a higher energy, x-rays or gamma rays?
11.) Which has a lower frequency, radio waves or green light?
12.) Which has the shortest wavelength, violet or ultraviolet light?
13.) Which has lower energy, infrared light or x-rays?

14.) ______________ formed a theory to explain the structure of an atom by revising physical theories.
15.) As the energy level increases, the amount of energy an electron will possess ______________.
16.) Electrons give off energy in finite amounts called ___________ when returning to the ground state.
17.) When this energy is released in the form of light it is called a ______________.
18.) Bohr chose the element ______________ to prove his theory.

True or False
19.) Electrons may regularly occupy spaces between energy levels.
20.) The varying wavelengths on the electromagnetic radiation spectrum travel at different speeds.
21.) Atoms release energy when electrons jump to higher energy levels.

ELECTRON ARRANGEMENT NOTES

Heisenberg Uncertainty Principle:

GENERAL LOCATION -------------------- __________________________________

____

____

SPECIFIC LOCATION -------------------- __________________________________

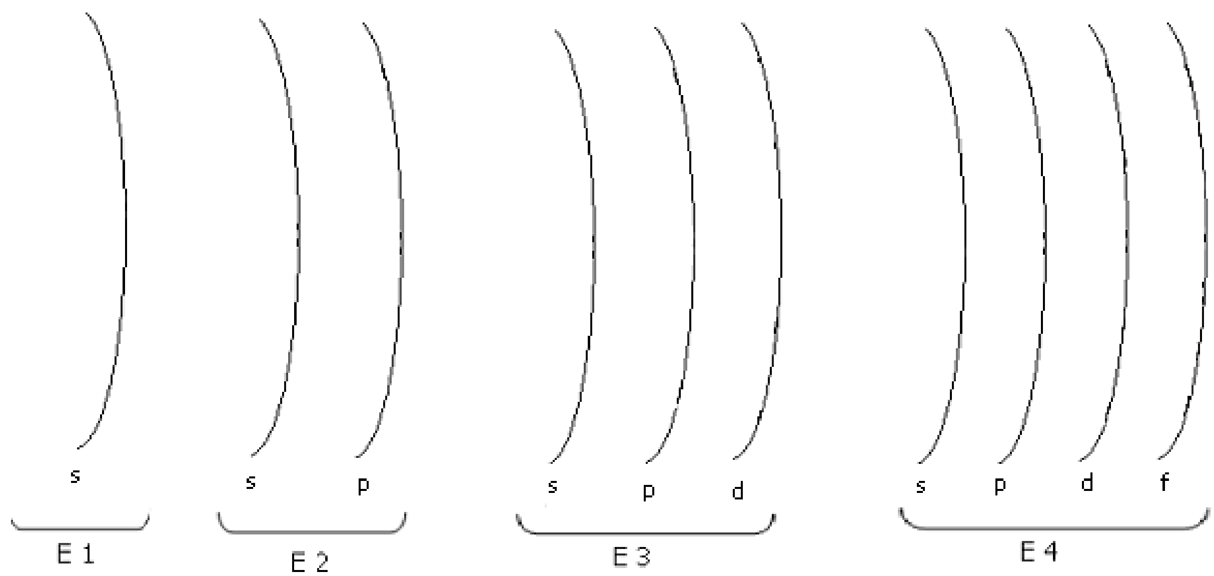
ENERGY LEVELS - divisions of the electron cloud

- numbered consecutively from closest to farthest away from nucleus

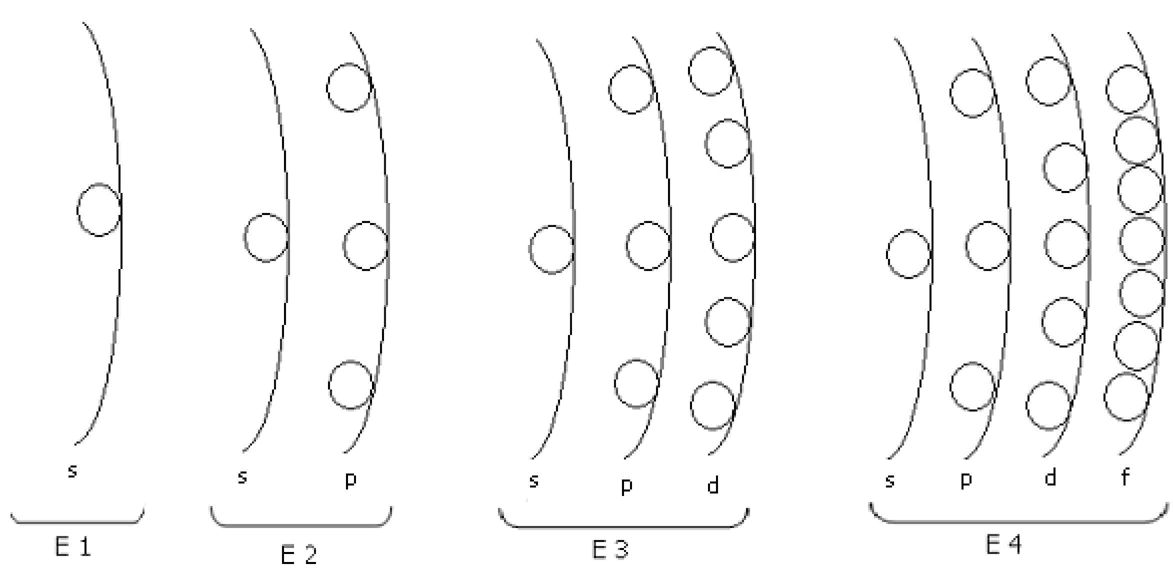
.

Electrons will occupy the location with the <u>lowest</u> amount of energy.

SUBLEVELS - divisions of energy levels
- designated by letters (s, p, d, f)
- number of sublevels in an energy level = # of the energy level



ORBITALS - divisions of sublevels
- number of orbitals in an energy level =
- “s” sublevel has 1 orbital; “p” sublevel has 3 orbitals; “d” sublevel has 5 orbitals; “f” sublevel has 7 orbitals

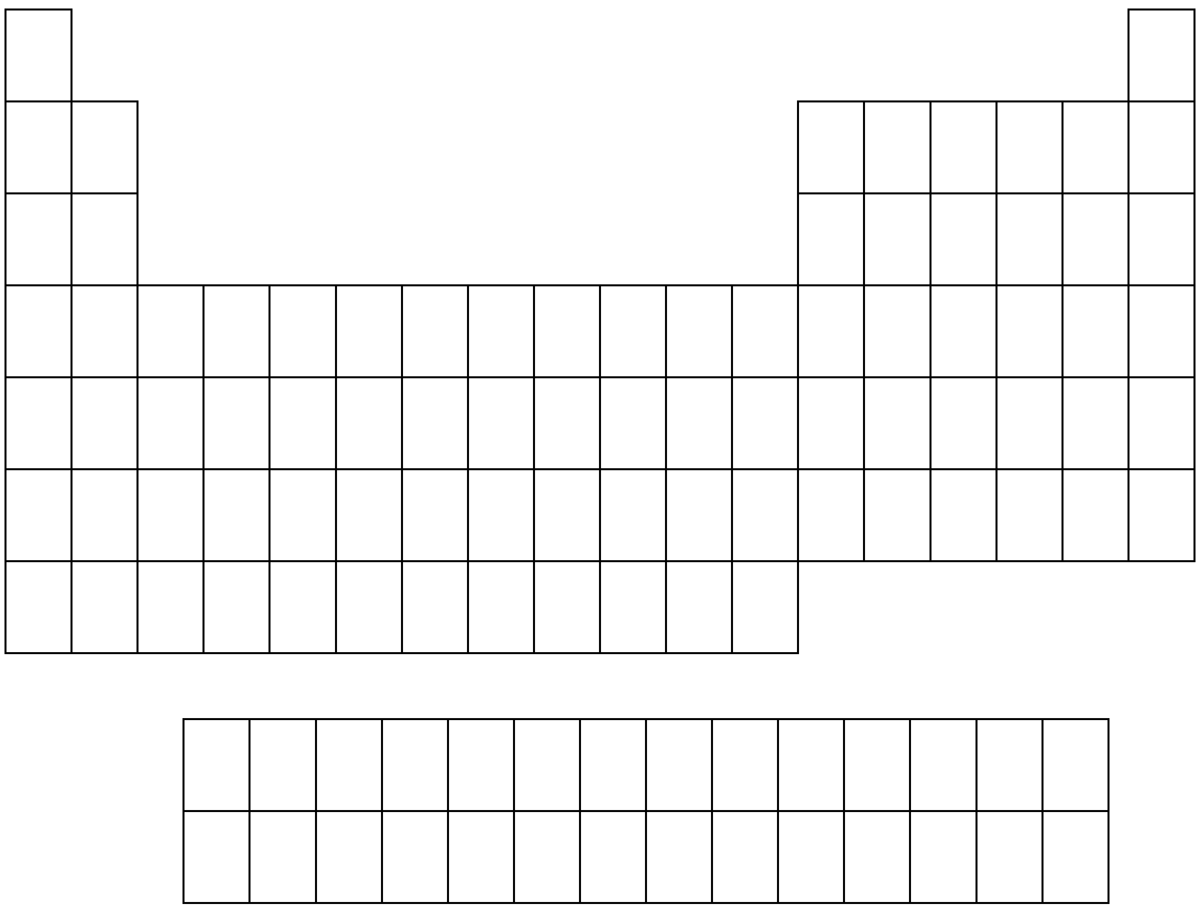


How many electrons can each of these orbitals hold?

How many electrons can an energy level hold?

How many electrons can each sublevel hold?
"s" = ___ e- "p" = ___ e- "d" = ___ e- "f" = ___ e-

What is the order in which the sublevels fill with electrons? Use the PERIODIC TABLE.



ELECTRON ARRANGEMENT WORKSHEET

1. What is an electron cloud?
2. Name the three major divisions within an electron cloud with respect to the energy of an electron.
3. What letter represents the principal quantum number?
4. What does the principal quantum number tell about an electron?
5. What formula is used to determine the maximum number of electrons that can occupy any energy level?
6. What is the maximum number of electrons for each of the following?
   (A) 1st energy level (B) 4th energy level (C) n = 3 (D) n = 5

7. Energy levels are divided into ______________.

8. How can we determine the possible number of sublevels in any energy level?

9. Name the four primary sublevels in order of increasing energy.

10. Circle the sublevel that represents the lowest energy in each pair.
    (A) 1s or 2s (B) 2s or 2p (C) 4f or 4d (D) 3d or 4s (E) 7s or 5d
    (F) 6s or 4s (G) 4p or 5p (H) 3s or 3d (I) 2p or 3s

11. Sublevels are divided into ______________.

12. Each orbital can hold up to ______________ electrons.

13. How many orbitals are in each sublevel?
    (A) s ______________ (B) p ______________ (C) d ______________ (D) f ______________

<u>More Electron Arrangement NOTES</u>

<u>HOEL (Highest Occupied Energy Level)</u>: energy level furthest from the nucleus that contains at least one electron

How to determine this using electron configuration?

~ largest non-exponent number

Se $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ \underline{4}s^2\ 3d^{10}\ \underline{4}p^4$ HOEL = 4

Sn $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ \underline{5}s^2\ 4d^{10}\ \underline{5}p^2$ HOEL = 5

Hg $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^6\ \underline{6}s^2\ 4f^{14}\ 5d^{10}$ HOEL = 6

<u>Valence Electrons</u>: electrons in the HOEL

How to determine this using electron configuration?

~ add up exponents of terms in HOEL

Se $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ \underline{4}s^2\ 3d^{10}\ \underline{4}p^4$
HOEL = 4 Valence electrons = 2 + 4 = 6

Sn $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ \underline{5}s^2\ 4d^{10}\ \underline{5}p^2$
HOEL = 5 Valence electrons = 2 + 2 = 4

Hg $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^6\ \underline{6}s^2\ 4f^{14}\ 5d^{10}$
HOEL = 6 Valence electrons = 2

<u>Noble Gas Configuration</u>: shortcut for electron configuration

How is it written?

~ [symbol for noble gas closest to element with lower atomic #]

~ [after brackets] write the rest of the configuration as if you had written the configuration for the noble gas

NOTE: ending of electron configuration and noble gas configuration should be the same

Se $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $4s^2$ $3d^{10}$ $4p^4$
[Ar] $4s^2$ $3d^{10}$ $4p^4$

18 20 30 34

Sn $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $4s^2$ $3d^{10}$ $4p^6$ $5s^2$ $4d^{10}$ $5p^2$

[Kr] $5s^2$ $4d^{10}$ $5p^2$

36 38 48 50

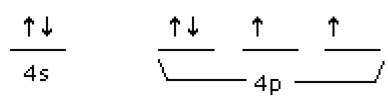
Hg $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $4s^2$ $3d^{10}$ $4p^6$ $5s^2$ $4d^{10}$ $5p^6$ $6s^2$ $4f^{14}$ $5d^{10}$
[Xe] $6s^2$ $4f^{14}$ $5d^{10}$

54 56 70 80

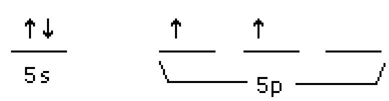
<u>Orbital Notation</u>: drawing of how electrons are arranged in orbitals; will only need to do this for the HOEL

*NOTE: ___ = orbital ↑ or ↓ = electrons

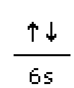
Se $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $4s^2$ $3d^{10}$ $4p^4$



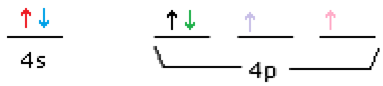
Sn $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $4s^2$ $3d^{10}$ $4p^6$ $5s^2$ $4d^{10}$ $5p^2$

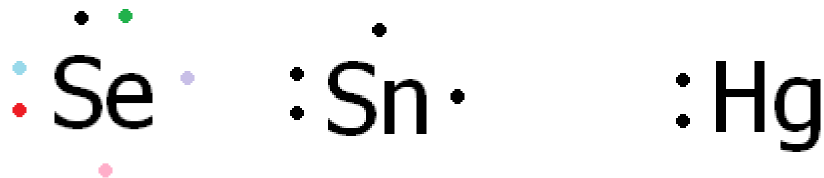


Hg $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $4s^2$ $3d^{10}$ $4p^6$ $5s^2$ $4d^{10}$ $5p^6$ $6s^2$ $4f^{14}$ $5d^{10}$



<u>Dot Diagrams</u>: symbol represents nucleus and non-valence (“inner-shell”) electrons; dots around symbol represent valence electrons





<u>QUANTUM NUMBERS NOTES</u>

~ describe one specific electron

~ 1st quantum number = PRINCIPAL QUANTUM NUMBER

- ~ abbreviated "n"
- ~ tells the energy level the electron is located in
- ~ n = number of the energy level
- ~ 1st energy level: n = 1, 4th energy level: n = 4, etc.

~ 2nd quantum number = ANGULAR MOMENTUM QUANTUM NUMBER

- ~ abbreviated " ℓ "
- ~ tells the sublevel the electron is located in
- ~ tells shape of orbital
- ~ "s" sublevel: ℓ = 0, "p" sublevel: ℓ = 1, "d" sublevel: ℓ = 2, "f" sublevel: ℓ = 3

~ 3rd quantum number = MAGNETIC QUANTUM NUMBER

- ~ abbreviated "m"
- ~ tells which orbital the electron is in
- ~ tells orientation of orbital around nucleus
- ~ m = - ℓ .. + ℓ

~ 4th quantum number = SPIN QUANTUM NUMBER

- ~ abbreviated " s "
- ~ tells which electron is being described
- ~ tells which way electron is spinning
- ~ s = $-^1/_2$ or $+^1/_2$

Pauli Exclusion Principle:

EXAMPLE QUESTIONS:

1.) What are the 4 quantum numbers for this electron? __↓__ ____ ____ ____ ____
3 d

2.) If the electron in question 1 was the last electron added, what element would it be?

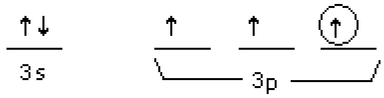
3.) Draw in the electron (and the orbital notation) for the electron with the following quantum numbers.

n = 3 ℓ = 2 m = -1 s = - ½

4.) How many electrons in an atom can have the quantum numbers n = 3 and ℓ = 1?

5.) What are the four quantum numbers for the electron circled in the diagram below?

n = ℓ = m = s =



QUANTUM NUMBERS WORKSHEET

	1s	2s	2p	3s	3p	3d	4s	4p	4d	4f	5s	5p
1.)	_	_	_ _ _	_	_ _ _	_ _ _ _ _ _	_	_ _ _	_ ↑ _ _ _	_ _ _ _ _ _ _ _	_	_ _ _
2.)	_	↑	_ _ _	_	_ _ _	_ _ _ _ _ _	_	_ _ _	_ _ _ _ _ _	_ _ _ _ _ _ _ _	_	_ _ _
3.)	_	_	_ _ ↓	_	_ _ _	_ _ _ _ _ _	_	_ _ _	_ _ _ _ _ _	_ _ _ _ _ _ _ _	_	_ _ _
4.)	_	_	_ _ _	_	_ _ _	_ _ _ _ _ _	_	_ _ _	_ _ _ _ _ _	_ _ _ _ _ _ _ _	_	_ _ _
5.)	_	_	_ _ _	_	_ _ _	_ _ _ _ _ _	_	_ _ _	_ _ _ _ _ _	_ _ _ _ _ _ _ _	_	_ _ _
6.)	_	_	_ _ _	_	_ _ _	_ _ _ _ _ _	_	_ _ _	_ _ _ _ _ _	_ _ _ _ _ _ _ _	_	_ _ _
7.)	_	_	_ _ _	_	_ _ _	_ _ _ _ _ _	_	_ _ _	_ _ _ _ _ _	_ _ _ _ _ _ _ _	_	_ _ _
8.)	_	_	_ _ _	_	_ _ _	_ _ _ _ _ _	_	_ _ _	_ _ _ _ _ _	_ _ _ _ _ _ _ _	_	_ _ _
9.)	_	_	_ _ _	_	_ _ _	_ _ _ _ _ _	_	_ _ _	_ _ _ _ _ _	_ _ _ _ _ _ _ _	_	_ _ _

** Each question below corresponds to the number in the table. **

For 1 – 3, give the four quantum numbers for the electron indicated.

1.) n = ℓ = m = s =

2.) n = ℓ = m = s =

3.) n = ℓ = m = s =

For 4 – 9, draw in the electron with the following sets of quantum numbers.

4.) n = 3 ℓ = 2 m = 0 $s = +1/2$

5.) n = 3 ℓ = 1 m = + 2 $s = +1/2$

6.) n = 4 ℓ = 1 m = + 1 $s = -1/2$

7.) n = 2 ℓ = 1 m = 0 $s = +1/2$

8.) n = 3 ℓ = 2 m = - 1 $s = -1/2$

9.) n = 2 ℓ = 1 m = - 1 $s = -1/2$

10.) Does an electron with this set of quantum numbers exist in the element calcium?
n = 4 ℓ = 1 m = 0 $s = -1/2$

Determine the element whose outermost electron (last electron added) is being defined by the following quantum numbers.

11.) n = 1 ℓ =0 m = 0 $s = -1/2$

12.) n = 4 ℓ =1 m = 1 $s = -1/2$

13.) n = 3 ℓ =1 m = -1 $s = +1/2$

14.) n = 4 ℓ = 0 m = 0 $s = +1/2$

15.) n = 3 ℓ = 2 m = -2 $s = -1/2$

Unit 4 Review Worksheet

Section I - Problems Given: $E = h \cdot \nu$ $h = 6.626 \times 10^{-34}$ J·s
$c = \lambda \cdot \nu$ $c = 3.00 \times 10^{8}$ m/s

1. What is the frequency of a wave with a wavelength of 3.5×10^{-4} m?
2. What is the energy of a photon with a frequency of 5.41×10^{17} Hz?
3. What type of electromagnetic radiation is described in question 2?

Section II - Electromagnetic Spectrum

4. Label both ends of the spectrum with high/low frequency, high/low energy, and long/short wavelength

radio waves microwaves infrared light ROYGBIV ultraviolet light x-rays gamma rays

5. Which has a higher energy, gamma or x-rays?
6. Which has a shorter wavelength, radio or ultraviolet?
7. Which has a lower frequency, yellow or green light?
8. In the equation $E = h \cdot \nu$, energy and frequency are ___________________ proportional.
9. In the equation $c = \lambda \cdot \nu$, wavelength and frequency are _________________ proportional.
10. The symbol for wavelength is _____.
11. Electrons give off energy in the form of a ___________________ when returning to the ground state.
12. Which scientist proposed the idea that electrons travel around the nucleus in fixed paths?
13. When an electron moves from the ground state to the excited state, energy is ___________________.
14. Bohr chose the element ___________________ to prove his theory.
15. The dual wave-particle nature of electrons describes how the electrons in atoms can behave as ___________________ and ___________________.

Section III - Electrons

16. What is the maximum number of electrons in any orbital?
17. The principal quantum number, n, indicates the ___________________.
18. The maximum number of electrons in an energy level can be determined by the equation ________ That means the maximum number of electrons in the 3rd energy level is ___________________.
19. The number of sublevels in any energy level can be determined by ___________________.
20. The number of orbitals in an energy level can be determined by the equation ___________________. 3rd energy level has _____ orbitals. (_____ = "s" orbital, _____ = "p" orbitals, and _____ = "d" orbitals)
21. List the four sublevels according to increasing energy.
22. The "s" sublevel is shaped like a ___________________ and has _____ orbitals.
23. A "p" sublevel is shaped like a ___________________ and has _____ orbitals.
24. The "d" sublevel has _____ orbitals and the "f" sublevel has _____ orbitals.

Section IV - Electron configuration, noble gas configuration, valence electrons, orbital notations

25. What is the electron configuration for phosphorus?
26. How many total electrons are in a neutral atom of phosphorus?
27. Write the noble gas configuration for phosphorus.
28. What is the highest occupied energy level for phosphorus?
29. What is the atomic number of phosphorus?
30. Draw the orbital notation for the highest occupied energy of phosphorus.

31. Circle the last electron added to phosphorus in #30. What are the four quantum numbers for this electron?
    n = ℓ = m = s =
32. How many electrons are in the highest occupied energy level of phosphorus?
33. How many inner-shell electrons does phosphorus have?
34. In which orbitals are the inner-shell electrons located?
35. Draw the electron dot diagram for phosphorus.

Section V - Quantum numbers (Honors level only)

36. How many electrons can be described by the quantum numbers n = 3 and ℓ = 1?
37. How many electrons in an atom can have the quantum numbers n = 2 and ℓ = 3?
38. How many electrons can have the value n = 3?
39. How many electrons in an atom have the quantum numbers n = 4 and ℓ = 2?
40. Which of the following sets of quantum numbers does NOT represent a possible set of quantum numbers? (There may be more than one correct answer.)

	n	ℓ	m	s
(A)	4	8	-4	½
(B)	6	5	-5	½
(C)	3	2	2	½
(D)	6	0	1	½