Name ________________________ *Chemistry*

DUE DATE _________ Period ______

POGIL: Electron Configurations

Why?

The electron structure of an atom is very important. Scientists use the electronic structure of atoms to predict bonding in molecules, the charge(s) an atom might have, and the physical properties of elements. In order for scientists to describe the electron structure in an atom, they give the electrons "addresses." Just like your address might include your house number, street, city, and state, an electron's "address" has multiple parts. In this activity, you will learn how the electrons fill up the available spaces in an atom and how their "addresses" or configurations are assigned.

Success Criteria

- Explain the rules for electron placement: aufbau Principle, Pauli Exclusion Principle, and Hund's Rule.
- Construct the orbital filling diagrams, electron configurations, and noble gas shortcut configurations for neutral ground-state atoms.
- Identify an element from its ground-state orbital filling diagram, electron configuration, or noble gas shortcut configuration.
- Identify an element from its excited-state orbital filling diagram, electron configuration, or noble gas shortcut configuration.

Vocabulary

- **Energy Level** = fixed energy an electron can have (whole number = 1, 2, 3, 4; written first)
- **Sublevel** = orbitals of the same energy in an energy level (letters = s, p, d, f; written second)
- **Orbital** = region of space where an electron is most likely to be found
- **Electron Spin** = denoted by ↑↓, show direction of magnetic poles for spinning electrons
- **Orbital Filling Diagram** = electron configuration that uses arrows to depict electrons and demonstrates how each orbital is filled for a sublevel
- **Electron Configuration** = arrangement of electrons of an atom in its ground state into the orbitals surrounding the nucleus
- **Ground State** = lowest possible energy of an electron (opposite of Excited State)
- **Noble Gas Shortcut** = using the symbol of a noble gas to represent the stable configuration of electrons instead of writing out a complete electron configuration (ONLY NOBLE GASES!!!)

Hog Hilton Review

1. For the following electron rules, write the Hog Hilton rule that is similar.
    a. Aufbau = Electrons must be placed in the lowest energy orbitals first.

    b. Hund = Each sublevel fills each orbital with one electron before electrons are paired.

    c. Pauli = In order for two electrons to occupy the same orbital, they must have opposing spins.

2. Fill in the following configuration for 27 electrons:

4p ___ ___ ___

3d ___ ___ ___ ___ ___

4s ___

3p ___ ___ ___

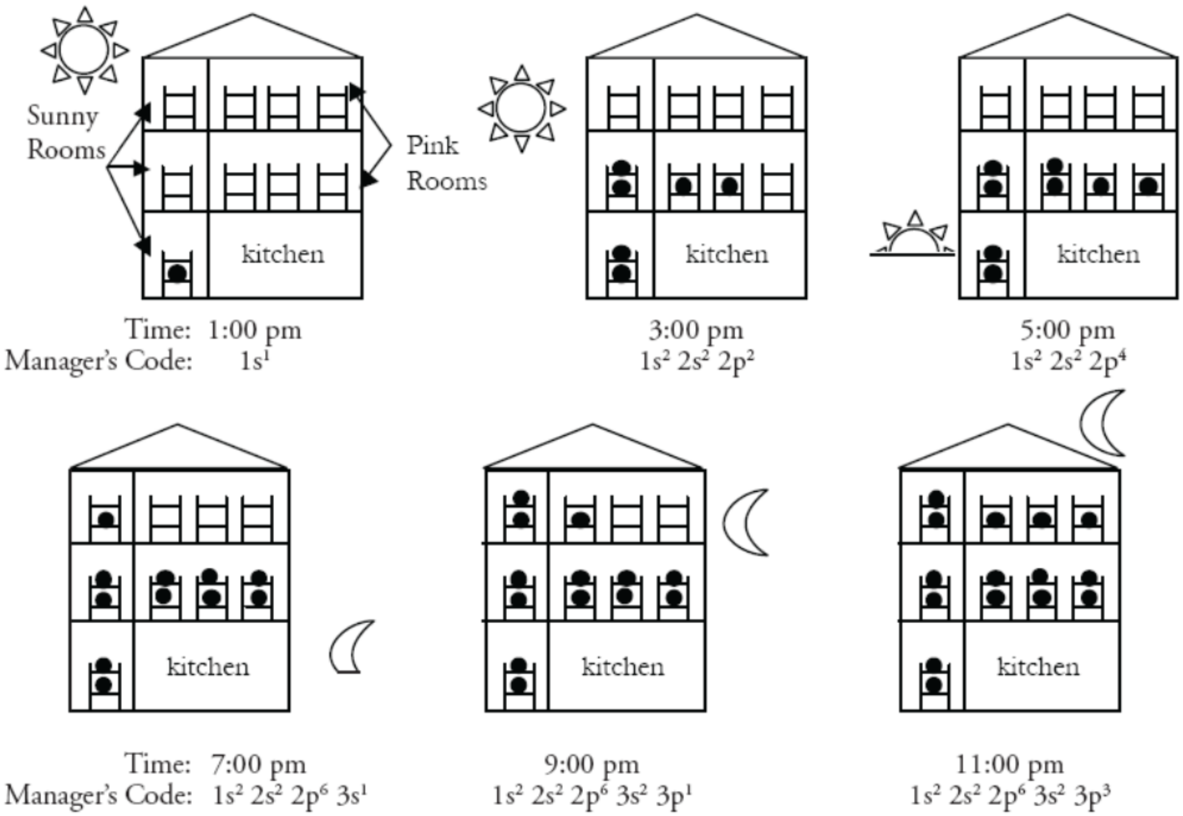
3s ___

2p ___ ___ ___

2s ___

1s ___

Model 1 – The Boarding House



Key Questions

1. Examine the boarding house diagrams in Model 1. Match each symbol below with its most likely meaning.

a.	_____ ●	I. Bunk Bed for Boarders
b.	_____ 	II. Manager's Code for Boarders' Room Assignments
c.	_____ $1s^2\ 2s^2\ 2p^6\ 3s^1$	III. Boarder

2. Refer to Model 1.
   a. How many boarders were in the boarding house at 5:00 pm?

   b. Describe how you determined your answer to part *a*.

3. Examine each diagram in Model 1 and the corresponding manager's code. Using the following manager's code:

$$\mathbf{1\,s^{2}\ \ 2\,s^{2}\ \ 2\,p^{4}}$$

   a. Underline the floor numbers.
   b. Circle the types of rooms.
   c. Draw a box around the numbers of boarders.

4. The manager of the boarding house has some very strict rules on how beds will be rented out for the night. Examine the diagrams in Model 1 and the statements below to determine the phrase that best describes the manager's set of rules. ***Circle*** the correct answer.

   a. The boarding house will rent out beds on the _______ floor first.

      1st 2nd 3rd

   b. Boarders are only allowed to double up in a bunk in a room when ____________________.

      there is an even number of boarders in the room all bottom bunks are occupied

   c. The next floor of rooms will be opened for boarders only when _____________________ on the floor below are occupied.

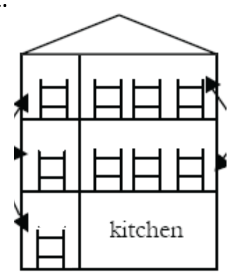
      half of the bunks at least one of the rooms all of the bunks

   d. The pink room on a floor will be opened for boarders only when ____________________.

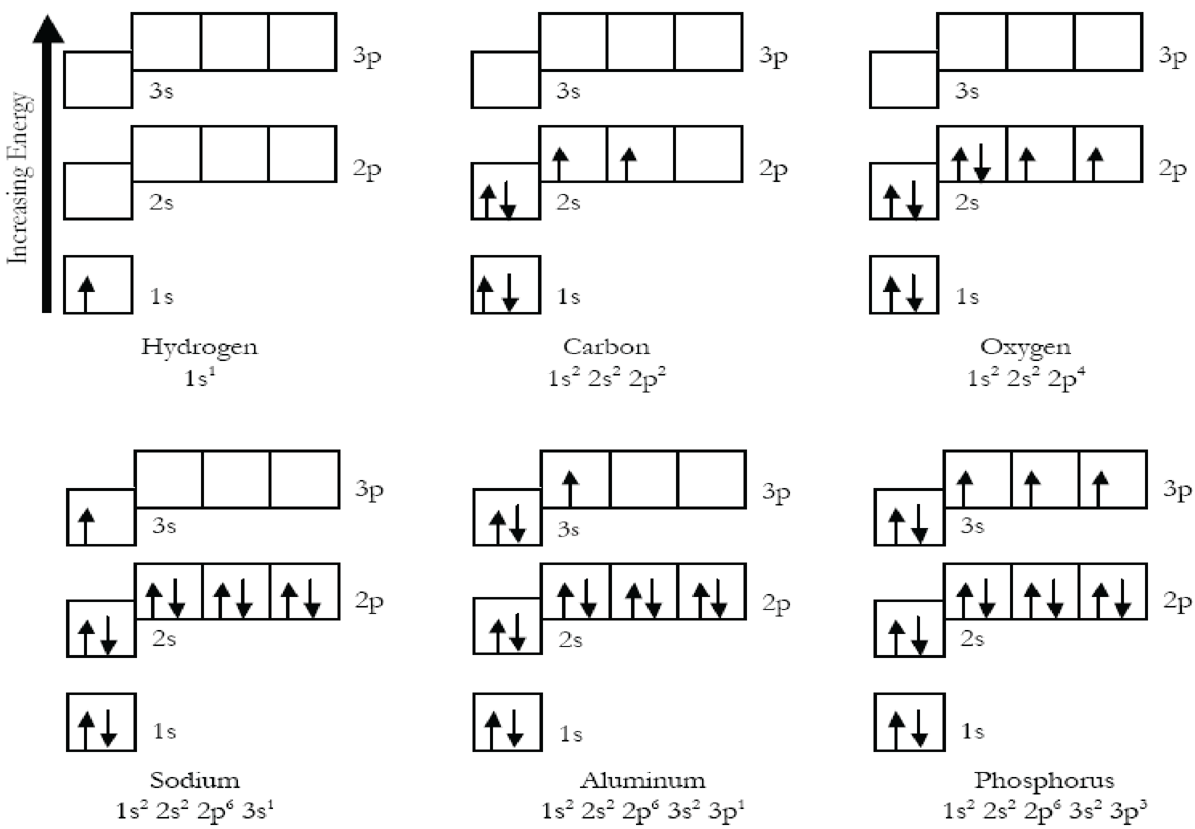
      all of the lower bunks in the sunny room on that floor are occupied
      all of the bunks in the sunny room on that floor are occupied
      the sunny room on that floor is open

5. Provide (a) the manager's code and (b) a boarding house diagram showing 12 boarders present.

   a. Manager's Code = ____________________________ b. Boarding Diagram:



Model 2 – Ground State Orbital Diagrams and Electron Configurations



Key Questions

6. Examine the orbital diagrams and electron configurations in Model 2. Match each symbol below with its meaning.

a.	_____ ☐	I. Single Electron
b.	_____ ↑	II. Pair of Electrons with Opposite Spins
c.	_____ ↑↓	III. Atomic Orbital (region where electron is likely to be found)
d.	_____ ☐☐☐	IV. Sublevel (set of orbitals with the same energy)
e.	_____ $1s^2\ 2s^2\ 2p^4$	V. Electron Configuration

7. Consider the orbital diagram for oxygen in Model 2.
   a. How many electrons are present in the orbital diagram?

   b. Based on its position in the periodic table, explain how you know that your answer to part *a* is the correct number of electrons for oxygen.

8. Examine the orbital diagrams and electron configurations in Model 2. Using the following electron configuration:

   $$1s^2\ 2s^2\ 2p^4$$

   a. Underline the energy levels.
   b. Circle the sublevels.
   c. Draw a box around the numbers of electrons

9. The 2s and 2p sublevels are very close in energy, as are the 3s and 3p sublevels. Explain how the orbital diagram for sodium confirms that the 3s sublevel is lower in energy than the 3p sublevel.

10. The lowest potential energy arrangement of electrons in an atom is called the ground state. Ground state electron configurations can be predicted by a strict set of rules known as the Aufbau principle (“aufbau”means filling up). Examine the diagrams in Model 2 and the statements below to determine the phrase that best describes each rule. ***Circle*** the correct answer.
    a. Based on where a single electron is placed, the lowest potential energy electron in an atom is found in the ________ sublevel.
       1s 2s 3s

    b. Electrons will occupy a p-orbital only after ____________ .
       the previous s-orbital is half full
       the previous s-orbital is completely full
       the previous s-orbital is empty

    c. Electrons can begin to occupy energy levels with the next highest integer designation (e.g., 2 vs. 1, 3 vs. 2) only after __________________ on the energy level below it are occupied.
       half of the orbitals at least one of the orbitals all of the orbitals

11. The Pauli exclusion principle describes the restriction on the placement of electrons into the same orbital. The Pauli exclusion principle can be expressed as: “If two electrons occupy the same orbital, they must have __________________.” ***<u>Circle</u>*** the correct answer.
    the same spin opposite spins

12. Hund's rule describes how electrons are distributed among orbitals of the same sublevel when there is more than one way to distribute them. Hund's rule consists of two important ideas. Based on Model 2, circle the correct answer to each statement.
    a. Electrons will pair up in an orbital only when ___________________
       there is an even number of electrons in the sublevel
       all orbitals in the same sublevel have one electron

    b. When single electrons occupy different orbitals of the same sublevel, ___________________.
       they all have the same spin
       they all have different spins
       their spins are random

13. For each of the symbols below from Model 2, provide the name or description of the analogous component that was used in the boarding house model (Model 1).
    a.

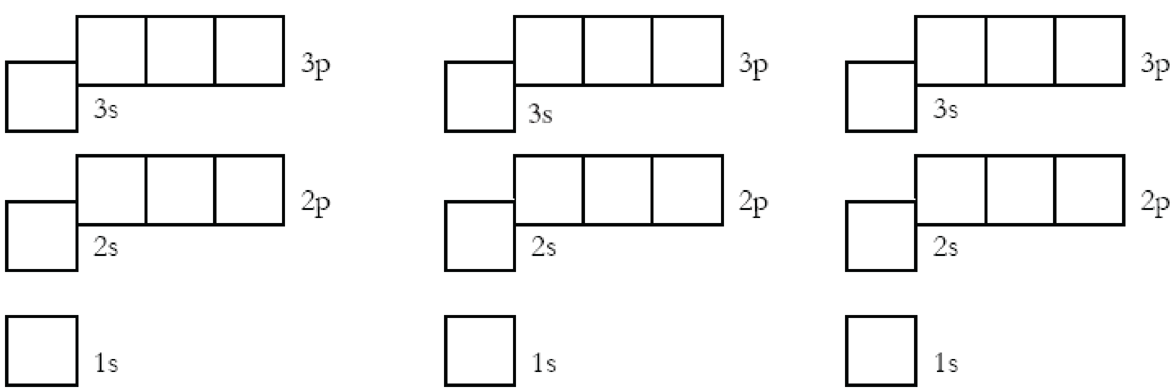
□	
□□□	
↑	
↑↓	
$1s^2\ 2s^2\ 2p^4$	

    b. What characteristic of electrons is not well represented by the boarding house model?

    c. How could the boarding house model be modified to better represent the relative energies of s and p sublevels?

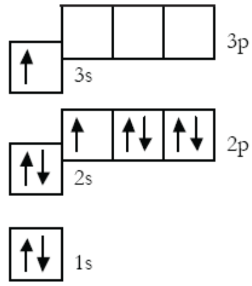
14. Complete the ground state orbital energy level diagrams and write the corresponding electron configurations for:

Sulfur Silicon Neon



Sulfur	Silicon	Neon

MODEL 3 – Excited State of Element X



Key Questions

15. Consider the orbital diagram in Model 3.
    a. How many electrons are there in one atom of element X?

    b. Identify element X and provide its ground state electron configuration. Assume the atom is neutral.

    c. Is the arrangement of electrons in the orbital diagram in Model 3 higher in total potential energy or lower in total potential energy than the ground state electron configuration of element X? Explain your reasoning.

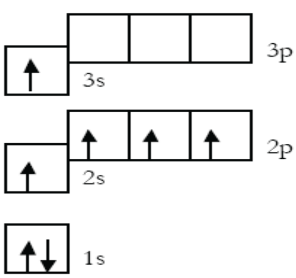
READ THIS!

An excited state electron configuration is any electron configuration for an atom that contains the correct total number of electrons but has a higher total electron potential energy than the ground state electron configuration.

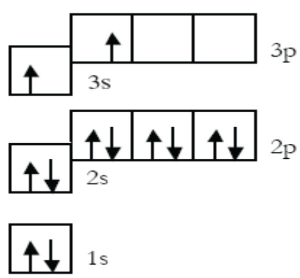
16. Write an electron configuration for element X that shows the atom in a different excited state than the one illustrated in Model 3.

17. Each orbital diagram shown below describes an excited state of an atom of a different element. Use the orbital diagrams to complete the table.

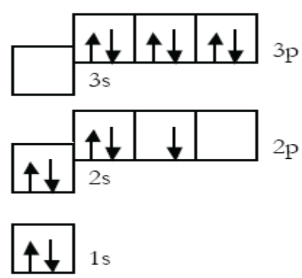
A



B



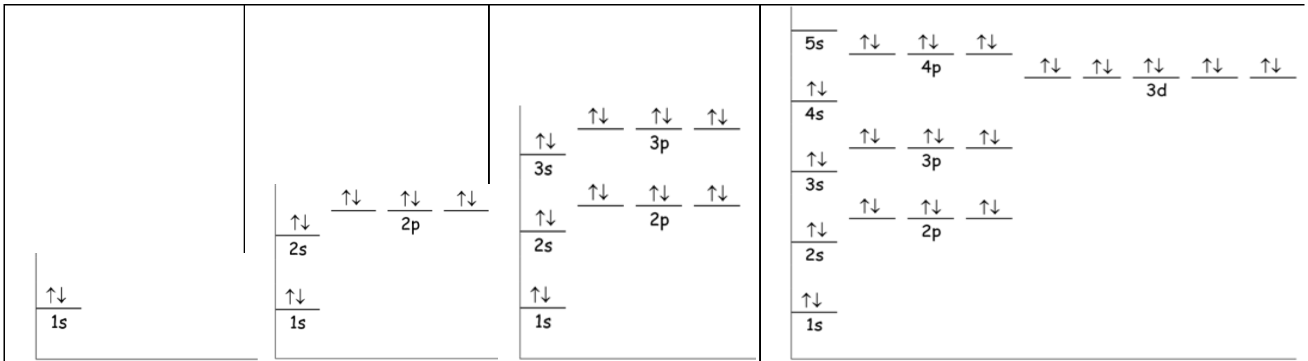
C



	A	B	C
Excited state electron configuration			
Identify the element			
Ground state electron configuration			

MODEL 4 – Noble Gases and Their Stability

Noble gases were named because they are fairly non-reactive. The reason they are non-reactive is that their electron configurations are considered to be stable. They will neither lose nor gain electrons, so their configurations ***never change***.



HELIUM	NEON	ARGON	KRYPTON
2 electrons	**10 electrons**	**18 electrons**	**36 electrons**
$\mathbf{1s^2}$	$\mathbf{1s^2\ 2s^2\ 2p^6}$	$\mathbf{1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6}$	$\mathbf{1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6}$
[He]	**[Ne]**	**[Ar]**	**[Kr]**

18. Compare the electron configurations for neon, argon, and krypton. Do you notice a pattern?

19. Consider the following electron configurations:

ELEMENT	ELECTRONS	ELECTRON CONFIGURATION	NOBLE GAS SHORTCUT
Sodium	11	$1s^2\ 2s^2\ 2p^6\ 3s^1$	$[Ne]\ 3s^1$
Phosphorus	15	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$	$[Ne]\ 3s^2\ 3p^3$
Calcium	20	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$	$[Ar]\ 4s^2$
Bromine	35	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^5$	$[Ar]\ 4s^2\ 3d^{10}\ 4p^5$
Silver	47	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^9$	$[Kr]\ 5s^2\ 4d^9$

a. Comparing the electron configurations for sodium and phosphorus, what does the [Ne] represent?

b. Comparing the electron configurations for calcium and bromine, what does the [Ar] represent?

c. Using silver as your primary example, which would be the proper ***noble gas configuration*** for tin?

Sn = 50 electrons = $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^2$

I. $[Ag]\ 4d^1\ 5p^2$
II. $[Cd]\ 5p^2$
III. $[Kr]\ 5s^2\ 4d^{10}\ 5p^2$
IV. $[In]\ 5p^1$

20. Write the noble gas configurations for the following elements:

ELEMENT	ELECTRONS	ELECTRON CONFIGURATION	NOBLE GAS SHORTCUT
Aluminum	13	$1s^2\ 2s^2\ 2p^6\ 3s^3$	
Cobalt	27	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^7$	
Iodine	53	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^5$	

PRACTICE PROBLEMS

Noble Gas Shortcut Reference

- [He] = $1s^2$
  - 2 electrons; continues at 2s
- [Ne] = [He] $2s^2$ $2p^6$
  - 10 electrons; continues at 3s
- [Ar] = [Ne] $3s^2$ $3p^6$
  - 18 electrons; continues at 4s
- [Kr] = [Ar] $4s^2$ $3d^{10}$ $4p^6$
  - 36 electrons; continues at 5s
- [Xe] = [Kr] $5s^2$ $4d^{10}$ $5p^6$
  - 54 electrons; continues at 6s
- [Rn] = [Xe] $6s^2$ $4f^{14}$ $5d^{10}$ $6p^6$
  - 86 electrons; continues at 7s

Complete the following table:

ELEMENT	ELECTRONS	ORBITAL DIAGRAM & ELECTRON CONFIGURATION	NOBLE GAS SHORTCUT
Nitrogen	7	↑↓ ↑↓ ↑ ↑ ↑ $1s^2$ $2s^2$ $2p^3$	[He] $2s^2$ $2p^3$
Magnesium	12		
Iron	26		
Selenium	34		
Barium	56		
Lead	82		
Uranium	92		