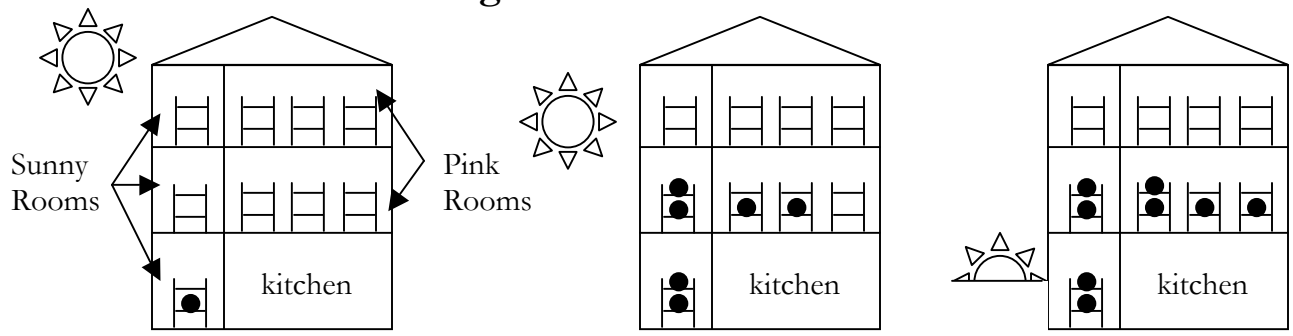
Electron Configurations

What is the electron structure in an atom?

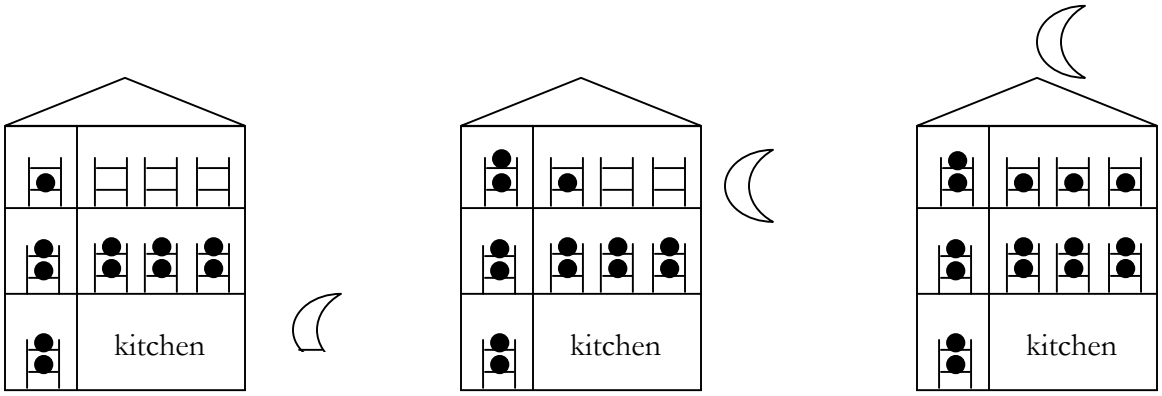
Why?

The electron structure of an atom is very important. Knowing it can help scientists predict bonding in molecules, the charge(s) an atom might have and the physical properties of the element. In order for scientists to study the electron structure in an atom, they give the electrons "addresses". Just like your address might include a 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.

Model 1 – The Boarding House



Time:	1:00 pm	3:00 pm	5:00 pm
Manager's Code:	$1s^1$	$1s^2\ 2s^2\ 2p^2$	$1s^2\ 2s^2\ 2p^4$



Time:	7:00 pm	9:00 pm	11:00 pm
Manager's Code:	$1s^2\ 2s^2\ 2p^6\ 3s^1$	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$

1. Examine the Boarding House diagrams of Model 1. Match each of the symbols below with their meaning.

____a. ● I. bunk bed for boarders

____b.  II. manager's code for the # of boarders in the house

____c. $1s^2\ 2s^2\ 2p^6\ 3s^1$ III. boarder

2. How many boarders were in the boarding house at 5:00 pm?

3. Examine the diagrams in Model 1 and corresponding manager's codes. Use the appropriate symbol to indicate where on the manager's codes each piece of information is found.

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

floor number (arrows)	type of room (circles)	number of boarders (arrows)

4. The Manager of this boarding house has some very strict rules on how beds will be rented out for the night. Examine the diagrams in Model 1 to determine the correct phrase which will complete the Manger's set of rules. Circle the answer that you select.

a) The boarding house will rent out beds on the _____ floor first.
1^{st} 2^{nd} 3^{rd}

b) Boarders are only allowed to double up in a bunk 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

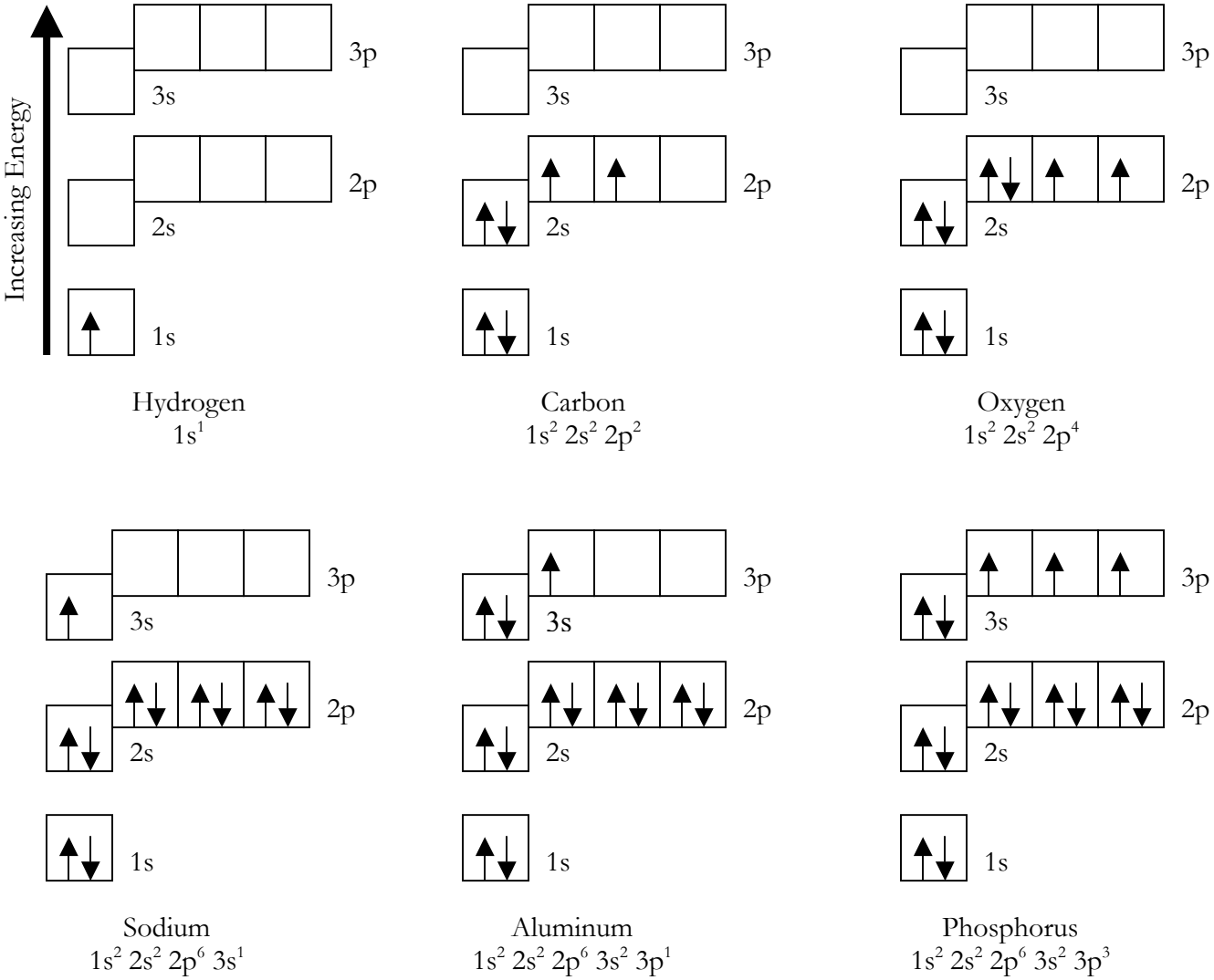
d) The pink room on a floor will be opened for boarders only when _____
all of the lower bunks in the sunny room on that floor are occupied.

all of the bunks in the sunny room on that floor are occupied.

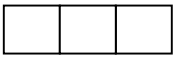
the sunny room on that floor is open.

5. Provide the Manager's Code and a Boarding House diagram when there are 12 boarders present.

Model 2 – Ground State Orbital Diagrams & Electron Configurations



6. Examine the orbital diagrams and electron configurations of Model 2. Match each of the symbols below with their meaning.

____a.		I. single electron
____b.		II. pair of electrons with opposite spin
____c.		III. atomic orbital (region of space where an electron is likely to be found)
____d.		IV. sublevel (several orbitals of equivalent energy)
____e.	$1s^2\ 2s^2\ 2p^4$	V. electron configuration

7. a) In the orbital diagram for oxygen in Model 2, how many electrons are present?

   b) Explain how you know that your answer to part a) is the *correct* number of electrons for an oxygen atom.

8. Examine the orbital diagrams and electron configurations in Model 2. Use the appropriate symbol to indicate where on the manager's codes each piece of information is found.

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

sublevel (circle)	number of electrons (arrow)

Read This!

The lowest energy arrangement of electrons in an atom is called the **ground state.**

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. Ground state electron configurations can be predicted by a strict set of rules known as the **Rules of Aufbau** (meaning filling up). Examine the diagrams in Model 2 to determine the correct phrase which will complete each rule. Circle the correct answer.

    a) Based on where a single electron is placed, the lowest 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.

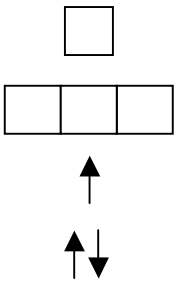
    c) Electrons can begin to occupy sublevels with the next highest integer designation (e.g., 2 vs. 1, 3 vs. 2) only after _____ on the sublevel below are occupied.
    half of the orbitals. at least one of the orbitals all of the orbitals

11. **The Pauli Exclusion Principle** describes the restriction on the placement of electrons into the same orbital. The Pauli Exclusion Principles can be expressed as: "If two electrons occupy the same orbital they must have _____(circle the correct answer).
    the same spin opposite spins

12. **Hund's Rules** describes how electrons are distributed among orbitals of the same sublevel when there is more than one way to distribute them. Hund's Rules consist of two important ideas. Based on the model, circle the correct answer.
    a) Electrons will only pair up in an orbital when _____.
    there is an even number of electrons in the sublevel. all orbitals in the 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 from the Boarding House model:
    a)



_____

_____

_____

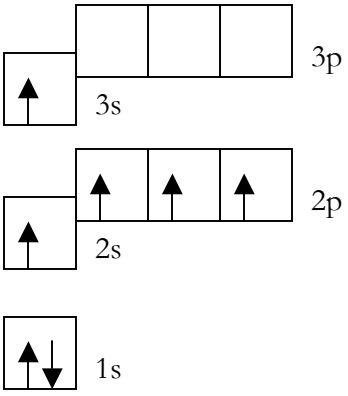
_____

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

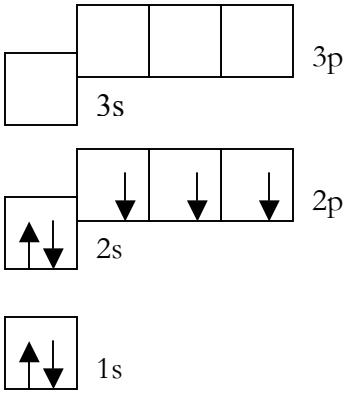
b) What characteristic of electrons is not well represented by the Boarding House model?

c) How could the Boarding House Model be modified to better represent the relative energies of *s* and *p* sublevels?

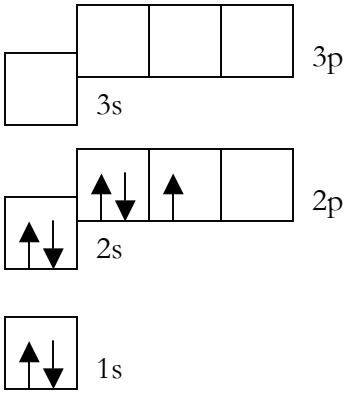
14. Below are three answers generated by students in response to the prompt: "Provide an orbital energy level diagrams for the ground state of a nitrogen atom." In each case, indicate whether the answer is right or wrong, and if it is wrong, indicate what the error is.



a.

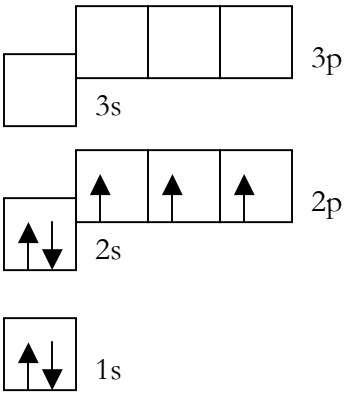


b.

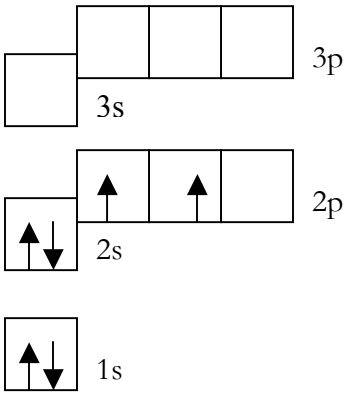


c.

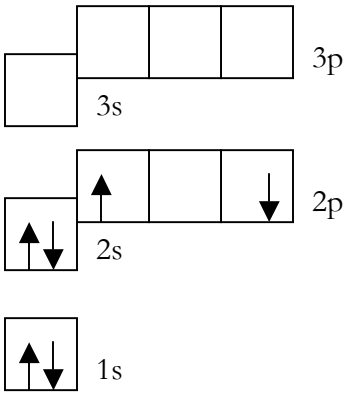
15. Below are three answers generated by students in response to the prompt: "Provide an orbital energy level diagrams for the ground state of a carbon atom." In each case, indicate whether the answer is right or wrong, and if it is wrong, indicate what the error is.



a.



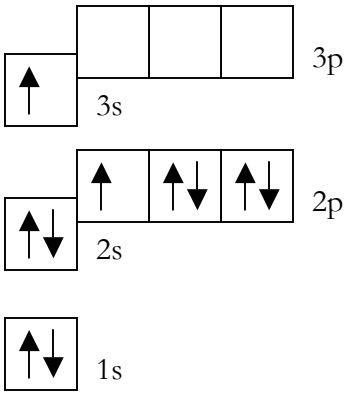
b.



c.

Extension Questions:

Model 3 – Excited State Orbital Diagram for an Atom of Element X



16. a) Based on Model 3, how many electrons are there in 1 atom of element X?

b) Provide the electron configuration that corresponds to the orbital diagram in Model 3.

c) Explain how you know (other than from the title!) that the orbital diagram in Model 3 is *not* a ground state orbital diagram.

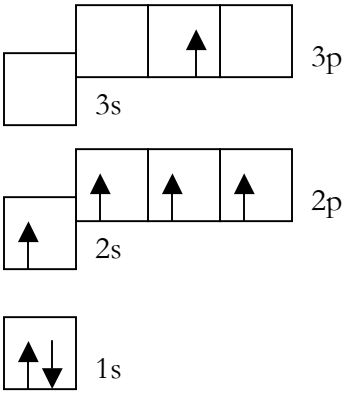
d) Is the arrangement of electrons in the orbital diagram in Model 3 higher in energy or lower in energy than the ground state electron configuration of element X? Explain your reasoning.

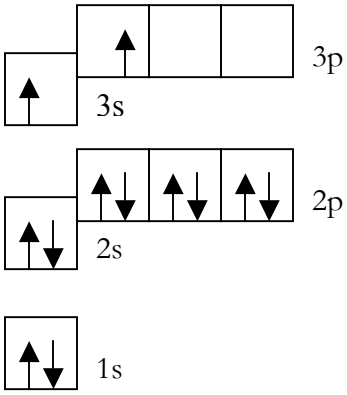
e) Identify element X and provide its ground state electron configuration.

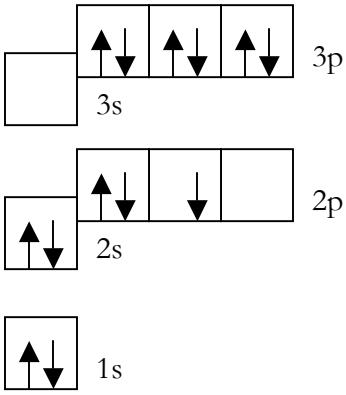
Read This!

An **excited state electron configuration** is *any* electron configuration for an atom that contains the correct total number of electrons but is *not* the ground state electron configuration.

17. Each of the three orbital diagrams shown below describes an excited state of an atom of a different element. In each case: provide the corresponding electron configuration (a), identify the element (b), and then provide the ground state electron configuration for an atom of that element (c).







a._____ a._____ a._____

b._____ b._____ b._____

c._____ c._____ c._____

18. For each of the *excited state* electron configurations given below, identify the corresponding element and then provide *two more* possible excited state configurations.

a) $1s^2\ 2s^1\ 2p^2$
b) $1s^2\ 2s^2\ 2p^2\ 3s^2\ 3p^1$
c) $1s^2\ 2p^2$

Teacher Resources

Learning Objectives:

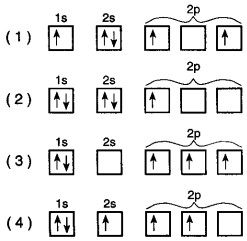
1. Construct orbital diagram and electron configurations for the first 18 elements.
2. Derive the Rules of Aufbau, Pauli Exclusion Principle, and Hund's Rules.
3. Deduce if an orbital diagram is constructed correctly.

Prerequisites:

1. Students should be able to determine the number of electrons in an atom.
2. Students should have had an introduction to orbitals, including the number and shapes of s, p, d and f orbitals.
3. Students should know that electrons can have two different "spins".

Assessment Questions:

1. Which orbital diagram represents a boron atom in the ground state?



2. Based on the charge of an electron, why would electrons prefer to be in different orbitals of the same sublevel if possible?

3. Match the definition to the correct 'rule'.

_____A.	Rules of Aufbau	I.	Electrons in orbitals must have opposite spins.
_____B.	Pauli Exclusion Principle	II.	Electrons are placed in individual orbitals before they are paired up.
_____C.	Hund's Rules	III.	Electrons will fill into the lowest available energy level.

Assessment Target Responses:

1. *2*
2. *The electrons have a negative charge so they will strongly repell each other.*
3. *III a*
   I b
   II c

Teacher Tips:

- This activity is only an introduction to electron configurations. It does not go into detail about d or f orbitals and the degree of overlap in energy. Instruction beyond this activity will be necessary for any elements beyond the third row of the periodic table, but those ideas should be easily assimilated once students are given a full energy level sequence to use as a reference.
- A great follow-up activity to this one is Cracking the PT Code which shows students how the periodic table structure relates to the sequence of filling for electron configurations.

Target Responses:

1. Examine the Boarding House diagrams of Model 1. Match each of the symbols below with their meaning.

III. a.
II. b.
I c.

2. How many boarders were in the boarding house at 5:00 pm? *8*

3. Examine the diagrams in Model 1 and corresponding manager's codes. Use the appropriate symbol to indicate where on the manager's codes each piece of information is found.

floor number (arrows) | type of room (circles) | number of boarders (arrows)

4. The Manager of this boarding house has some very strict rules on how beds will be rented out for the night. Examine the diagrams in Model 1 to determine the correct phrase which will complete the Manger's set of rules. Circle the answer that you select.

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 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 the Manager's Code and a Boarding House diagram when there are 12 boarders present.
Floors on the lowest level are rented out first.

All bottom bunks must be occupied before bunks may be doubled up.

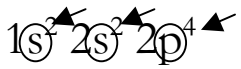
A new room (if available) on the floor will open when all of the bunks on that floor are occupied.

6. Examine the orbital diagrams and electron configurations of Model 2. Match each of the symbols below with their meaning.
__III__a.
__I_ b.
_II___c.
_IV__d.
_V__e.

7. a) In the orbital diagram for oxygen in Model 2, how many electrons are present?
8 electrons are present

b) Explain how you know that your answer to part a) is the *correct* number of electrons for an oxygen atom.
The atomic number on the periodic table is 8.

8. Examine the orbital diagrams and electron configurations in Model 2. Use the appropriate symbol to indicate where on the manager's codes each piece of information is found.



sublevel	number of electrons
(circle)	(arrow)

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.

The s level is located lower than the p level.

10. Ground state electron configurations can be predicted by a strict set of rules known as the **Rules of Aufbau** (meaning filling up). Examine the diagrams in Model 2 to determine the correct phrase which will complete each rule. Circle the correct answer.

a) Based on where a single electron is placed, the lowest 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.

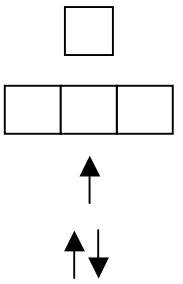
c) Electrons can begin to occupy sublevels with the next highest integer designation (e.g., 2 vs. 1, 3 vs. 2) only after _____ on the sublevel below are occupied.
half of the orbitals. at least one of the orbitals all of the orbitals

11. **The Pauli Exclusion Principle** describes the restriction on the placement of electrons into the same orbital.
The Pauli Exclusion Principles can be expressed as: "If two electrons occupy the same orbital they must have _____(circle the correct answer).
the same spin opposite spins

12. **Hund's Rules** describes how electrons are distributed among orbitals of the same sublevel when there is more than one way to distribute them. Hund's Rules consist of two important ideas. Based on the model, circle the correct answer.
a) Electrons will only pair up in an orbital when _____.
there is an even number of electrons in the sublevel.
all orbitals in the 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 from the Boarding House model:
a)



Bunk beds for boarders

Pink room

One boarder

Two boarders

Managers code

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

b) What characteristic of electrons is not well represented by the Boarding House model?
Two people in the boarding house are the same.
S and P rooms are on the same floor but s and p orbitals don't have the same energy.

c) How could the Boarding House Model be modified to better represent the relative energies of *s* and *p* sublevels?
Place steps going into the p-level to show that it is slightly higher than the s sublevel.

14. Below are three answers generated by students in response to the prompt: "Provide an orbital energy level diagrams for the ground state of a nitrogen atom." In each case, indicate whether the answer is right or wrong, and if it is wrong, indicate what the error is.

a. wrong; electrons are in the third energy levels when the previous orbitals are not full – violation of Aufbau

b. right

c. wrong; Electrons are filling into the same orbital when all orbitals in the sublevel do not have one electron – violation of Hund's Rule

15. Below are three answers generated by students in response to the prompt: "Provide an orbital energy level diagrams for the ground state of a carbon atom." In each case, indicate whether the answer is right or wrong, and if it is wrong, indicate what the error is.

a. wrong; there are too many electrons present

b.right;

c.wrong; one of the electrons has the wrong spin – violation of Hund's Rule.

16. a) Based on Model 3, how many electrons are there in 1 atom of element X?
10 electrons

b) Provide the electron configuration that corresponds to the orbital diagram in Model 3.
$1s^2 2s^2 2p^5 3s^1$

c) Explain how you know (other than from the title!) that the orbital diagram in Model 3 is *not* a ground state orbital diagram.
There is one electron in an energy level that is higher than an energy level that is not full.

d) Is the arrangement of electrons in the orbital diagram in Model 3 higher in energy or lower in energy than the ground state electron configuration of element X? Explain your reasoning.
Higher energy because that electron is shown at a higher energy.

e) Identify element X and provide its ground state electron configuration.
Element X is Neon and its ground state electron configuration is: $1s^2 2s^2 2p^6$

17. Each of the three orbital diagrams shown below describes an excited state of an atom of a different element. In each case: provide the corresponding electron configuration (a), identify the element (b), and then provide the ground state electron configuration for an atom of that element (c).

a.$1s^2 2s^1 2p^3 3p^1$	a. $1s^2 2s^2 2p^6 3s^1 3p^1$	a. $1s^2 2s^2 2p^3 3p^6$
b.nitrogen	b. magnesium	b.aluminum
c. $1s^2 2s^2 2p^3$	c. $1s^2 2s^2 2p^6 3s^2$	c. $1s^2 2s^2 2p^6 3s^2 3p^1$

18. For each of the *excited state* electron configurations given below, identify the corresponding element and then provide *two more* possible excited state configurations.
    a) $1s^2\ 2s^1\ 2p^2$: Boron; $1s^1\ 2s^2\ 2p^2$; $1s^1\ 2s^1\ 2p^3$
    b) $1s^2\ 2s^2\ 2p^2\ 3s^2\ 3p^1$:Fluorine; $1s^2\ 2s^2\ 2p^2\ 3s^1\ 3p^2$; $1s^1 2s^2\ 2p^2\ 3s^2\ 3p^2$
    c) $1s^2\ 2p^2$:Beryllium; $1s^2\ 2s^1$,$2p^1$; $1s^1\ 2s^1\ 2p^2$