

3. Locate where your set of elements should be in Model 1.
- a. Write the last orbital notation in the electron configuration for each element in your set in its respective box.

See Model 1.

- b. What is the relationship between your answer in Question 2 and the “block” of the table where your set of elements is located?

Answers will vary for each team. For Team 1, the element configuration ends with one electron in the s sublevel and the set of elements is found in the first column of the s-block.

4. What is the relationship between the last orbital notation in your set of ground state electron configurations and the row numbers on the left-hand side of the periodic table in Model 1?

Answers will vary for each team. For Team 1, the element configuration ends with an s sublevel in the energy level that matches the row number.



Read This!

Go on a search—send a representative of your group to other tables to find out what they have discovered in Questions 1–4. Add the last orbital notation for their groups of elements to Model 1. Talk to at least one team from each of the “blocks” (*i.e.*, you want to look at a set of elements in the s-block, d-block, p-block, and f-block). It is NOT the goal of this activity to fill in the entire periodic table. You just need a few data points in each section to answer the questions that follow.

5. Count the number of columns in each of the four “blocks” of the table in Model 1. What is the relationship between the “block” size and the number of electrons that will fit in the corresponding atomic sublevel?

An s sublevel can hold 2 electrons—the “s-block” has 2 columns. A d sublevel can hold 10 electrons—the “d-block” has 10 columns. The block size matches the maximum number of electrons the corresponding sublevel can hold.

6. What is the relationship between where an element is located within a “block” of the table in Model 1 and the superscripted (raised, like an exponent) value appearing at the end of the electron configuration for that element?

The superscript number tells you how many columns over the element is within the block.



7. Obtain the Electron Energy Levels handout from your teacher. Put the Electron Energy Levels handout next to Model 1. Start at the bottom of the Electron Energy Levels handout with the 1s energy sublevel and locate the section of the periodic table corresponding to that sublevel. Why are there only two elements in the first row of the periodic table?

The first row of the periodic table contains elements that have ground state electrons in only the first energy level. The first energy level has only one orbital sublevel and can only hold two electrons.

8. Work your way up the Electron Energy Levels diagram, locating as many sublevel sections as you can on Model 1.

- a. Why does the second row of the periodic table not have a “d-block” section?

The second energy level does not have a d subshell, only s and p.

- b. The third energy level in an atom contains a d sublevel. Why then does the “d-block” start in the fourth row of the periodic table?

There is a d sublevel in the third energy level, but it requires the electrons to have energy similar to electrons in the fourth energy level. The 3d orbitals are not filled until after the 4s is filled.



9. For the elements of the “d-block” how is the row number related to the principal energy level for the last orbital notation of their electron configurations?

The highest principal energy levels for the “d-block” elements are equal to the row number minus one.

10. Obtain from your teacher the Periodic Table handout and a pair of scissors. Cut out the sections as instructed and reassemble the periodic table sequentially by atomic number.

Model 2 – Periodic Table (Long Form)

11. Use your group's reconstructed periodic table to label the sections of Model 2.

See Model 2.

12. Compare the periodic table of Model 1 with the periodic table of Model 2. What section of the table was moved?

The "f-block" has been moved into the main table in Model 2.

13. What do the * and # symbols in Model 1 indicate?

The place in the main table where the "f-block" should be inserted to connect it to the other sections.

14. The form of the periodic table seen in Model 2 is called the "long form" of the table. You do not often see this form in books or posters. What are the disadvantages of this form?

Answers will vary. Possible answers include:

- *The long form won't fit on a standard size piece of paper.*
- *The columns become very narrow, making it harder to fit all the necessary information.*
- *Model 2 wastes paper—large unused space in the middle or top of the table.*

15. Explain why the "f-block" does not appear until the 6th row, and why it fits in-between the "s" and "d" blocks. *Hint:* Refer to the Electron Energy Levels handout.

Electrons in the f sublevel have energies that are higher than the "s-block" two levels up. The f sublevels fill after s and before d in the atom.

16. For the elements in the "f-block," how is the row number related to the principal energy level for the last orbital notation of their electron configurations?"

The highest principal energy levels for the "f-block" elements are equal to the row number minus two.





17. Write the last orbital notation in the electron configurations for the elements located at A, B, C, and D in the table below. You should not have to “count” electrons to do this if you understand the structure of the periodic table.

1																				
2																				
3																				
4	A																			
5																			C	
6			*				B													
7			#																	

*																				D
#																				

A $4s^1$

B $5d^5$

C $5p^4$

D $4f^{11}$

Model 3 – Use of the Periodic Table for Electron Energy Levels

1																					→ $1s^2$
2																					→ $2s^2 2p^6$
3																					→ ?
4																					→ V
5																					Sn
6			*																		
7			#				Sg														

*																				
#																				

18. Now that you understand how the structure of the periodic table relates to electron sublevels, you can use it as a “cheat sheet” for the order of filling of electrons in the sublevels of the atom. The following steps will help you write the ground state electron configuration for vanadium, V.

- a. Use your finger to trace a line across the top row of the periodic table in Model 3. Explain why the two boxes in that row represent $1s^2$.

The first two electrons in the atom will fill the 1s orbital.

- b. Trace a line across row two of the periodic table. Explain why this row represents $2s^22p^6$.

The next orbitals to fill after 1s are 2s and 2p. There are 8 boxes (electrons) in the second row of the table, so these levels are completely filled.

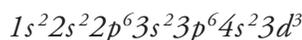
- c. Trace a line across row three of the periodic table. Record the sublevels and number of electrons that will be filled by the time you reach the end of this line.



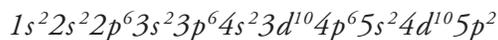
- d. Trace a line across row four ending at vanadium, V, and record the sublevels and number of electrons that are filled to reach that point.



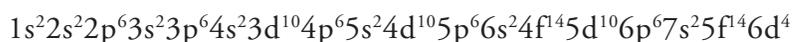
- e. Combine the steps above to write the full ground state electron configuration for vanadium (V).



19. Using only a periodic table, write the full ground state electron configuration for an atom of tin (Sn).



20. The electron configuration for an unknown element is:



- a. Identify the element and write its symbol in its proper location of Model 3.

See Model 3—the element is seaborgium, Sg.

- b. Describe two different methods that could be used to identify this element.

1. *Count the electrons.*

2. *Locate the “6d⁴” box in the periodic table.*

3. *Use the tracing method described in Question 18.*

Extension Questions

Model 4 – Predicted versus True Configuration

	Predicted Configuration	True Configuration (Supported by scientific evidence)
Cr	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^4$	$1s^2 2s^2 2p^6 3s^2 3p^6 \textcircled{4s^1} 3d^5$
Cu	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^9$	$1s^2 2s^2 2p^6 3s^2 3p^6 \textcircled{4s^1} 3d^{10}$
Ce	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^2$	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^1 \textcircled{5d^1}$

21. For each of the elements in Model 4, circle the portion of the true electron configuration that differs from the predicted configuration.

See Model 4.

22. Construct a possible explanation for why the true configurations would be a lower potential energy state for the elements in Model 4. *Hint:* What types of atomic interactions cause a lower potential energy or higher potential energy? How far apart in energy are electrons in the higher energy levels?

Putting two electrons in an orbital increases potential energy because of the repulsion of electrons. If another sublevel is close in energy, it might be a lower energy state to move an electron to a higher energy orbital and keep it unpaired. This could explain the difference found for Cr.

Higher energy orbitals, such as d and f, overlap other energy levels. The amount of energy they overlap by may change as the number of protons increases. This may make it advantageous for an electron to go into a d or f orbital instead of staying in s.

Teacher Resources – Cracking the Periodic Table Code

Learning Objective

1. Predict the ground state electron configuration for an atom of any element using only the periodic table as a guide.

Prerequisites

1. Students should know the maximum number of electrons that can occupy each of the atomic sublevels (s, p, d, and f).
2. Students should be able to write a ground state electron configuration using an Electron Energy Levels “cheat sheet” and the Aufbau principle.

Assessment Questions

1. Using only a periodic table, identify which set of electron sublevels is NOT organized from lowest energy to highest energy.
 - a. 2s, 2p, 3s, 3p, 3d, 4s
 - b. 1s, 2s, 2p, 3s, 3p, 4s
 - c. 2s, 2p, 3s, 3p, 4s, 3d
 - d. 5s, 4d, 5p, 6s, 4f, 5d
2. Which element would have $4f^4$ as the last entry of its electron configuration?
 - a. Cr
 - b. Nd
 - c. W
 - d. Se
3. Write the expected ground state electron configuration for atoms of the element hafnium (Hf).

Assessment Target Responses

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

Teacher Tips

- By the end of this activity, students should not need any charts, cheat-sheets or memory tricks to remember the order of filling for electrons in an atom. This of course assumes that the order of filling is followed for all atoms. You may wish to point out some atoms that have anomalous behavior, such as chromium, copper, lanthanum, and cerium. These exceptions are briefly addressed in the *Extension Questions* of this activity.
- Each group of students must be assigned a set of elements from the periodic table with electron configuration that are representative of that section of the table. Cards have been prepared that have the electron configurations of each element written out in long form. Alternatively, you could have students write ground state configurations for assigned groups of elements as preparation for this activity.

- Here are suggested sets of elements to assign groups. You must use at least the first four sets of elements to cover all of the sections of the periodic table.

Team 1	Group IA—H, Li, Na, K, Rb, Cs (Alkali Metals)
Team 2*	Group VIIIB—Fe, Co, Ni, Ru, Rh, Pd
Team 3	f-block sample—Sm, Tb, Ho, Pu, Bk, Es
Team 4	Group VIIA—F, Cl, Br, I, At (Halogens)
Team 5	Group IIA—Be, Mg, Ca, Sr, Ba (Alkaline Earth Metals)
Team 6	Group VA—N, P, As, Sb, Bi (Pnictogens)
Team 7*	Groups IVB-VB—Ti, V, Cr, Zr, Nb, Mo
Team 8	f-block sample—Er, Tm, Yb, Fm, Md, No
Team 9	Group VIIIA—Ne, Ar, Kr, Xe, Rn (Noble Gases)

*Several of the elements in these sets have anomalous electron configurations. The configurations that the students predict (and are listed on the attached cards) will not match the true electron configurations for those elements. It is very difficult to find a set of transition elements that will illustrate the order of filling and not include any anomalies.

- Students will need two extra handouts for this activity—The Electron Energy Levels handout and the Periodic Table handout with cutting instructions. One copy per team should be sufficient.
- After Question 4 in the activity, students will need to move around the room and get data from other teams. Instruct the students to keep at least one person at the table to talk to other teams as they come by.

Handout 1. Templates of Element Sets with Electron Configurations

(One set per team)

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Team 1. Alkali Metals—Predicted Electron Configurations

H $1s^1$	Li $1s^2 2s^1$
Na $1s^2 2s^2 2p^6 3s^1$	K $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
Rb $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^1$	Cs $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^1$

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Team 2. Transition Metals—Predicted Electron Configurations

Fe $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$	Co $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^7$
Ni $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$	Ru $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^6$
Rh $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^7$	Pd $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^8$

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Team 3. Rare Earth Elements—Predicted Electron Configurations

Sm $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^6$	Tb $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^9$
Ho $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^{11}$	Pu $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^{14} 5d^{10} 6p^6 7s^2 5f^6$
Bk $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^{14} 5d^{10} 6p^6 7s^2 5f^9$	Es $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^{14} 5d^{10} 6p^6 7s^2 5f^{11}$

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Team 4. Halogens—Predicted Electron Configurations

F $1s^2 2s^2 \underline{2p^5}$	Cl $1s^2 2s^2 2p^6 3s^2 \underline{3p^5}$
Br $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} \underline{4p^5}$	I $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} \underline{5p^5}$
At $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^{14} 5d^{10} \underline{6p^5}$	

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Team 5. Alkaline Earth Metals—Predicted Electron Configurations

Be $1s^2 \underline{2s^2}$	Mg $1s^2 2s^2 2p^6 \underline{3s^2}$
Ca $1s^2 2s^2 2p^6 3s^2 3p^6 \underline{4s^2}$	Sr $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 \underline{5s^2}$
Ba $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 \underline{6s^2}$	

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Team 6. Pnictogens—Predicted Electron Configurations

N $1s^2 2s^2 \underline{2p^3}$	P $1s^2 2s^2 2p^6 3s^2 \underline{3p^3}$
As $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} \underline{4p^3}$	Sb $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} \underline{5p^3}$
Bi $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 4f^{14} 5d^{10} \underline{6p^3}$	

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Team 7. Transition Metals—Predicted Electron Configurations

Ti $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 \underline{3d^2}$	V $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 \underline{3d^3}$
Cr $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 \underline{3d^4}$	Zr $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 \underline{4d^2}$
Nb $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 \underline{4d^3}$	Mo $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 \underline{4d^4}$

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Team 8. Rare Earth Elements—Predicted Electron Configurations

Er $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 \underline{4f^{12}}$	Tm $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 \underline{4f^{13}}$
Yb $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 \underline{4f^{14}}$	Fm $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 \underline{4f^{14} 5d^{10} 6p^6 7s^2 5f^{12}}$
Md $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 \underline{4f^{14} 5d^{10} 6p^6 7s^2 5f^{13}}$	No $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 \underline{4f^{14} 5d^{10} 6p^6 7s^2 5f^{14}}$

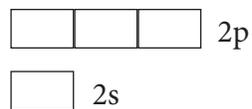
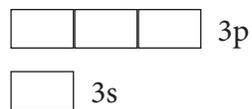
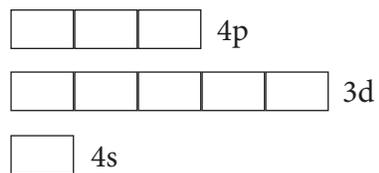
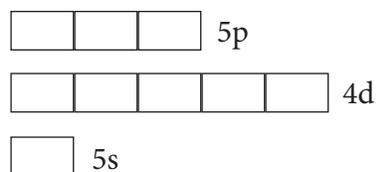
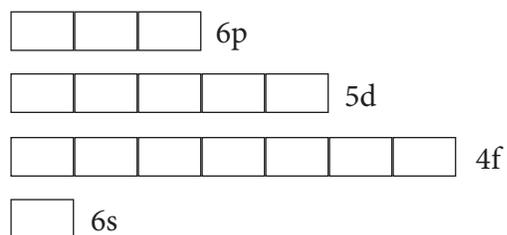
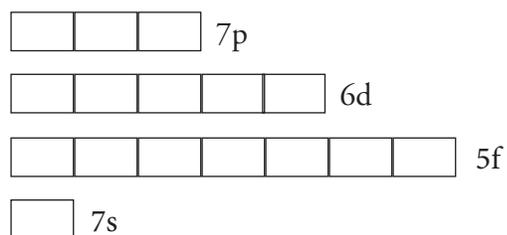
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Team 9. Noble Gases—Predicted Electron Configurations

Ne $1s^2 2s^2 \underline{2p^6}$	Ar $1s^2 2s^2 2p^6 3s^2 \underline{3p^6}$
Kr $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} \underline{4p^6}$	Xe $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} \underline{5p^6}$
Rn $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^6 5s^2 4d^{10} 5p^6 6s^2 \underline{4f^{14} 5d^{10} 6p^6}$	

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Electron Energy Levels



Periodic Table

	s-block																		p-block					
1	1															2								
2	3	4													5	6	7	8	9	10				
3	11	12	d-block										13	14	15	16	17	18						
4	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36						
5	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54						
6	55	56	*71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86						
7	87	88	#103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118						
	f-block																							
	*	57	58	59	60	61	62	63	64	65	66	67	68	69	70									
	#	89	90	91	92	93	94	95	96	97	98	99	100	101	102									

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