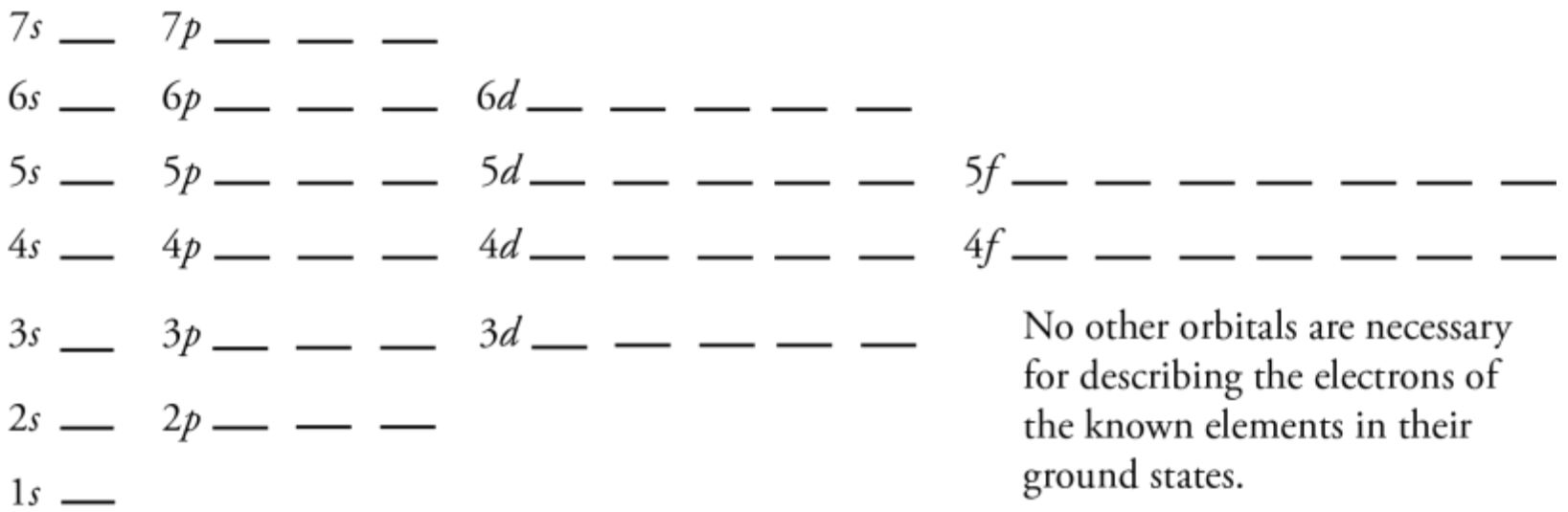
Chapter 4
Modern Atomic Theory

An Introduction to Chemistry

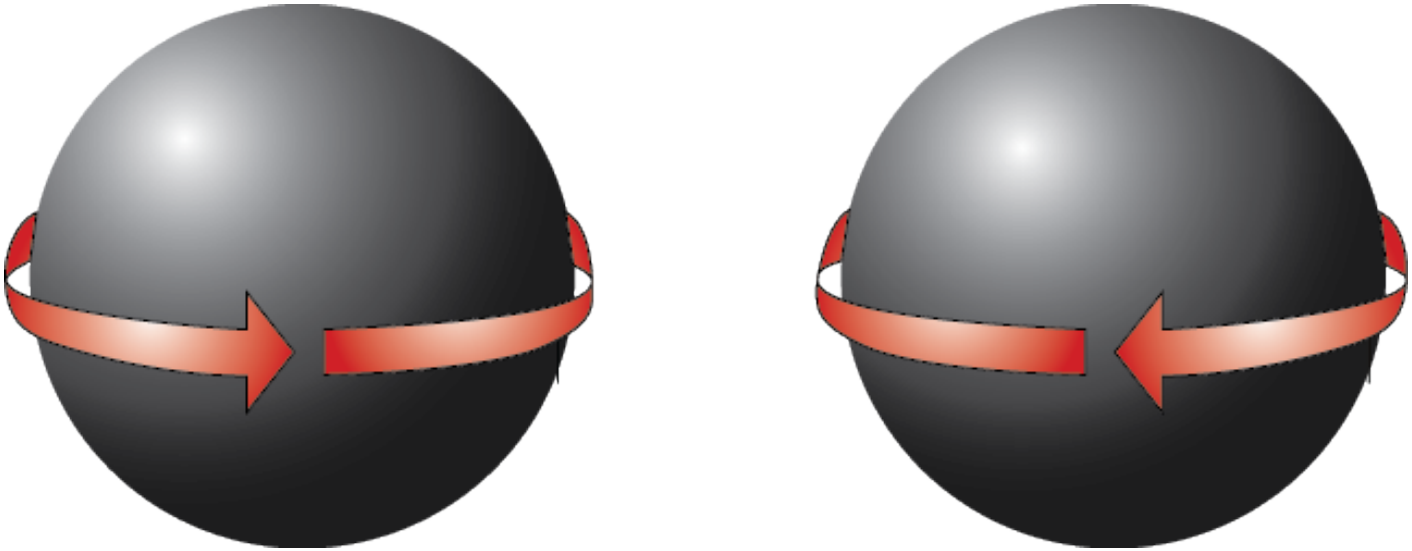
by Mark Bishop

Orbitals for Ground States of Known Elements



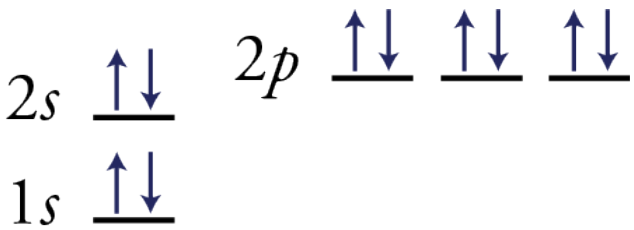
No other orbitals are necessary for describing the electrons of the known elements in their ground states.

Electron Spin



Pauli Exclusion Principle

- *No two electrons in an atom can have the same unique set of four quantum numbers.*
- The first quantum number describes the principal energy level. For example, the quantum number 2 identifies the second principal energy level.

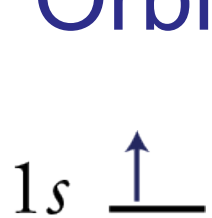


- The first two quantum numbers together describe a sublevel. For example, 2,1 describes the 2p sublevel.
- The first three quantum numbers describe an orbital. For example, 2,1,1 describes one of the 2p orbitals.
- It takes all four quantum numbers to describe an electron. For example, 2,1,1,+1/2 describes an electron in a 2p orbital.

Pauli Exclusion Principle

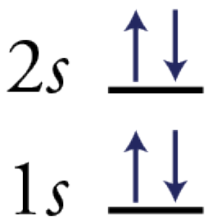
- No two electrons in an atom can be in the same principal energy level, the same sublevel, the same orbital, and with the same spin.
- This means that electrons in the same orbital must have opposite spin.
- Because there are only two possible spins, each orbital, no matter what its size, can have a maximum of two electrons.

Orbital Diagrams



H

He



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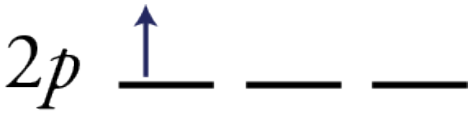
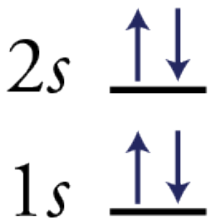
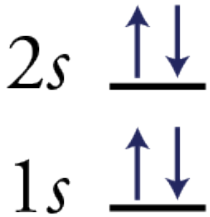
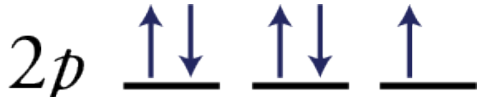


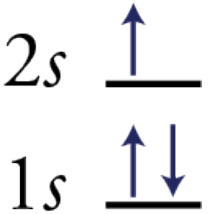


N

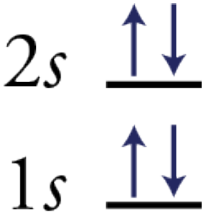


F

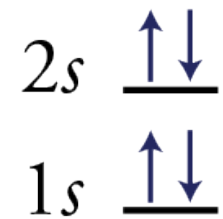




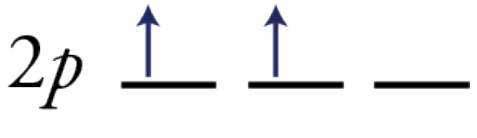
Li

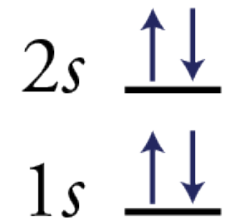


Be

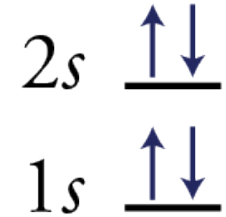


C

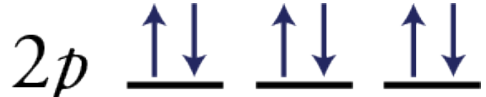




O



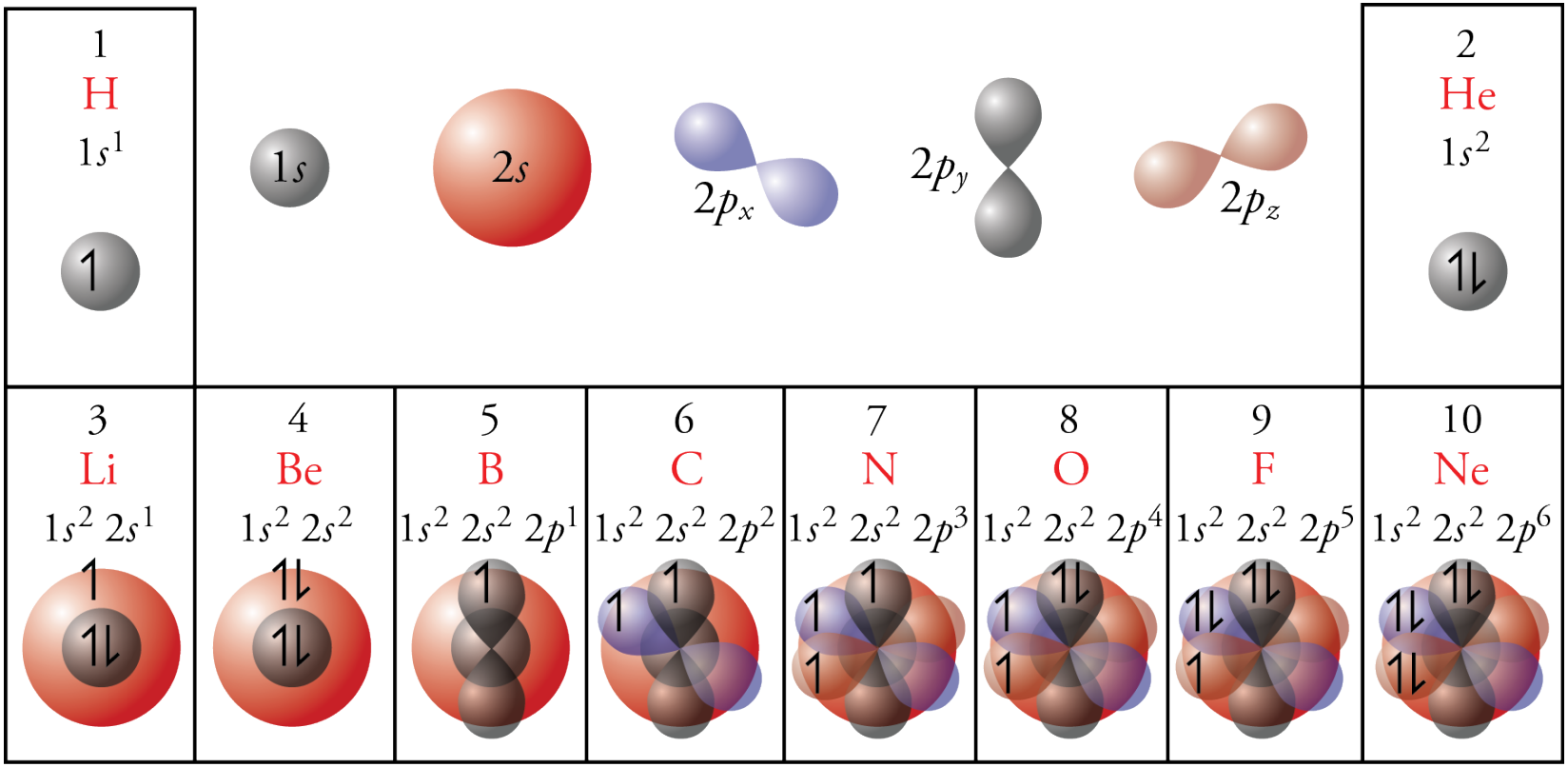
Ne



Drawing Orbital Diagrams

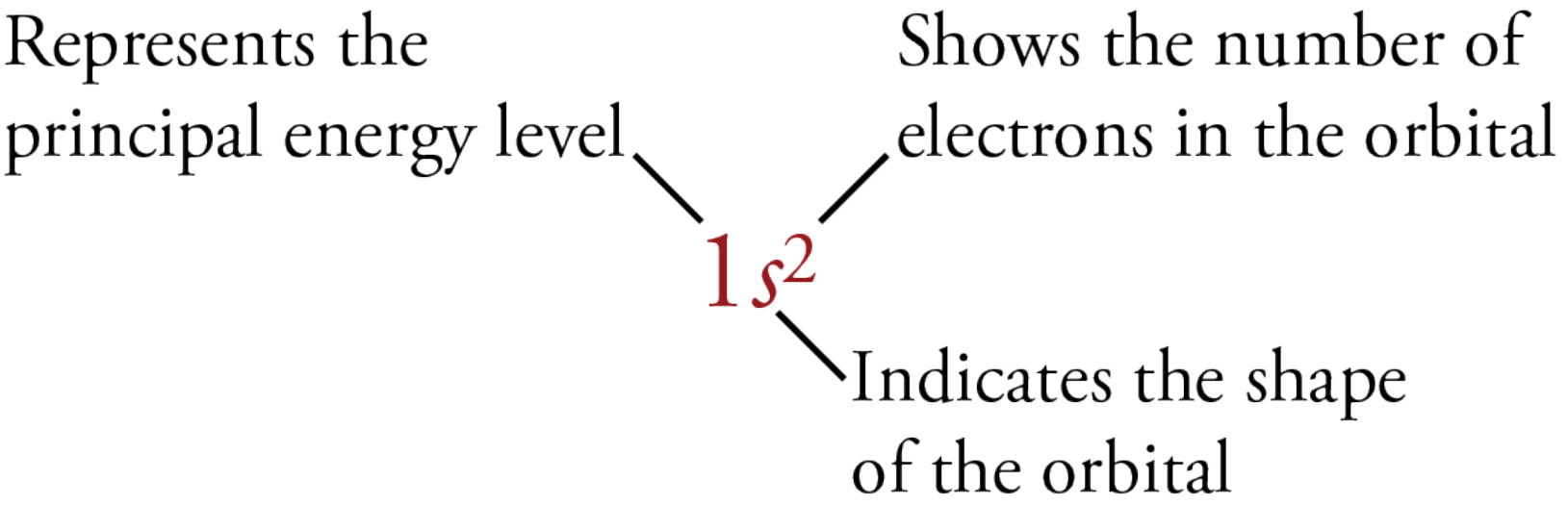
- For each sublevel with at least one electron, draw one line for each *s* sublevel, three lines for each *p* sublevel, five lines for each *d* sublevel, and seven lines for each *f* sublevel.
- Label each sublevel.
- Move up the page to indicate the order in which the orbitals are filled. For the first 18 elements, the order of filling is 1*s* 2*s* 2*p* 3*s* 3*p*. A more complete order of filling will be described soon.
- For orbitals containing two electrons, draw one arrow up and one arrow down to indicate the electrons' opposite spin.
- When adding electrons to orbitals of the same energy, follow Hund's Rule.

Second Period Electron Configurations



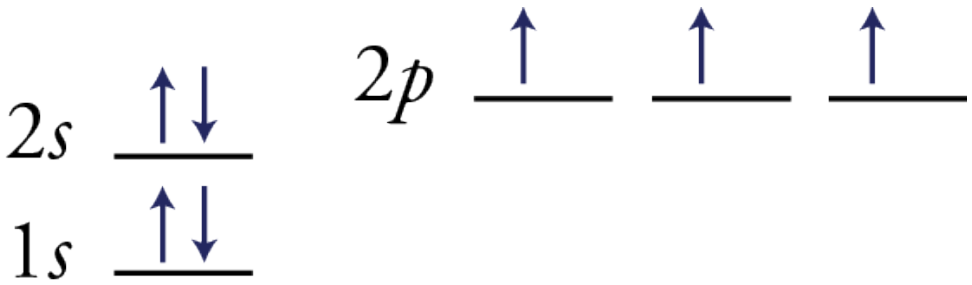
Electron Configurations

- The information in orbital diagrams is often described in a shorthand notation called an ***electron configuration***.



Ways to Describe Electrons in Atoms

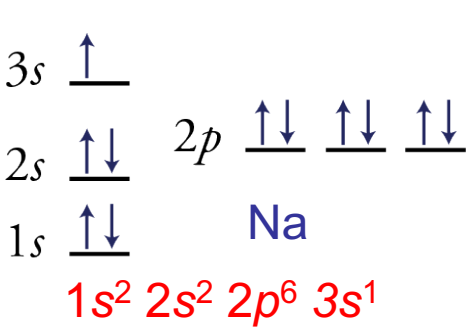
- The following is an orbital diagram for a nitrogen atom.



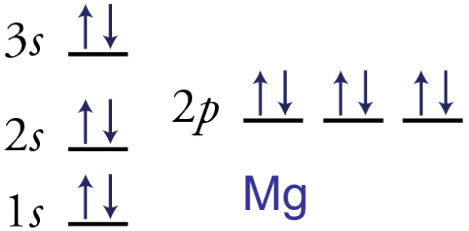
- The following is the electron configuration for nitrogen.

$$1s^2\ 2s^2\ 2p^3$$

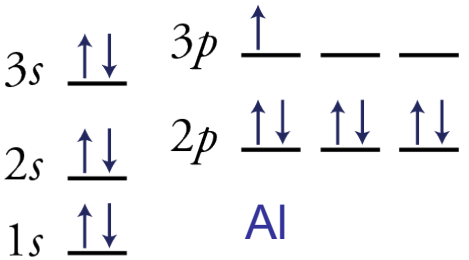
Orbital Diagrams



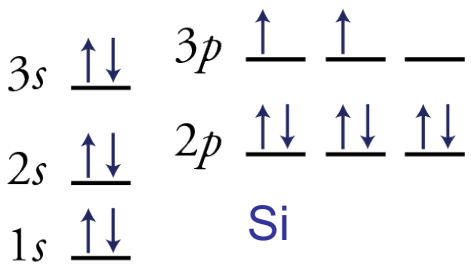
$1s^2\ 2s^2\ 2p^6\ 3s^1$



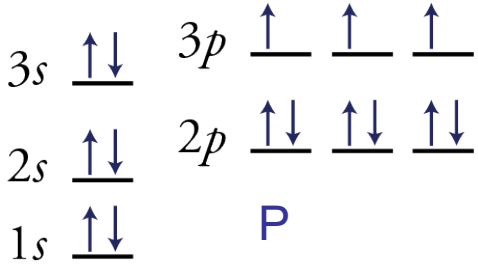
$1s^2\ 2s^2\ 2p^6\ 3s^2$



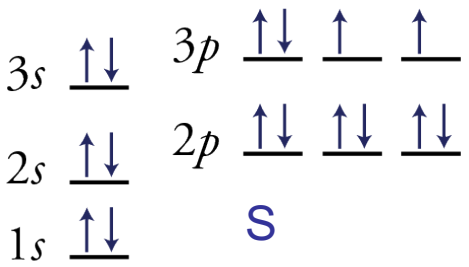
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$



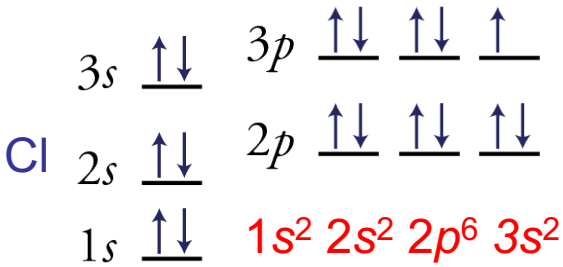
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$



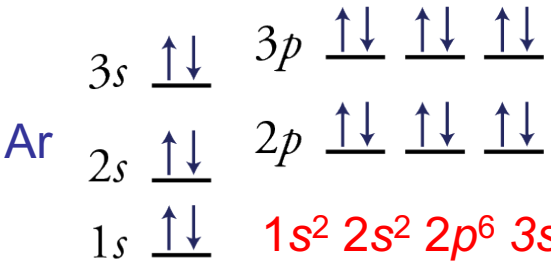
$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$



$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$



$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

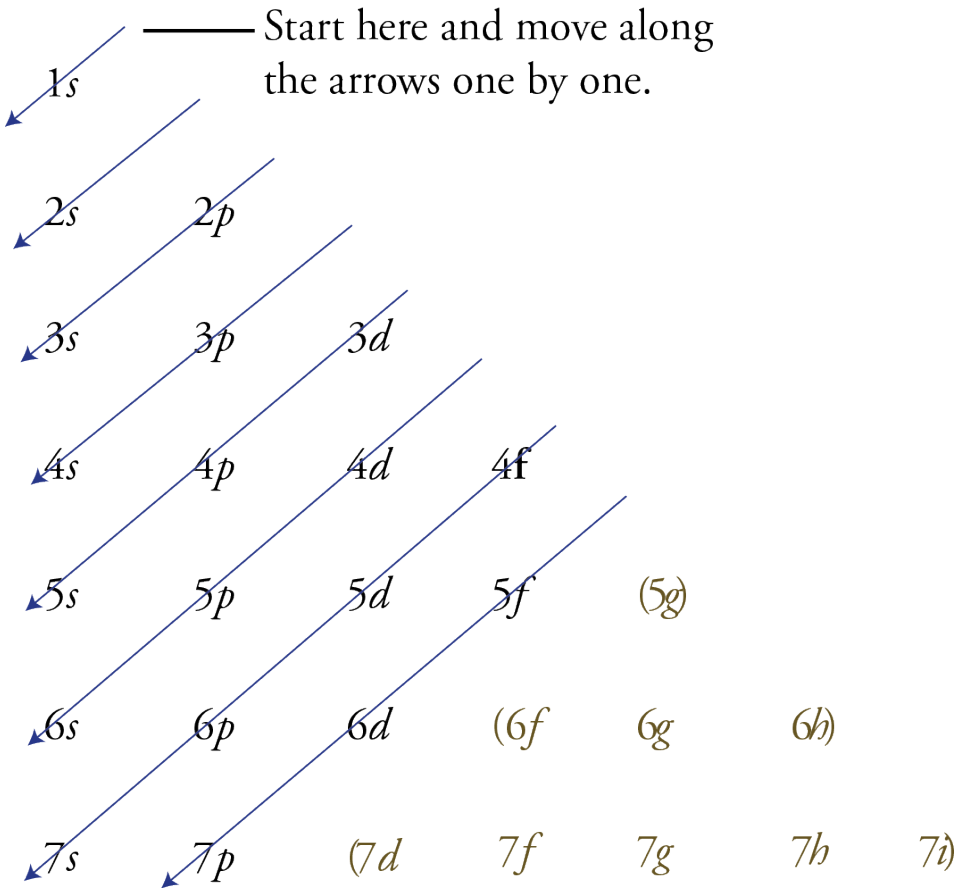


$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

Writing Electron Configurations

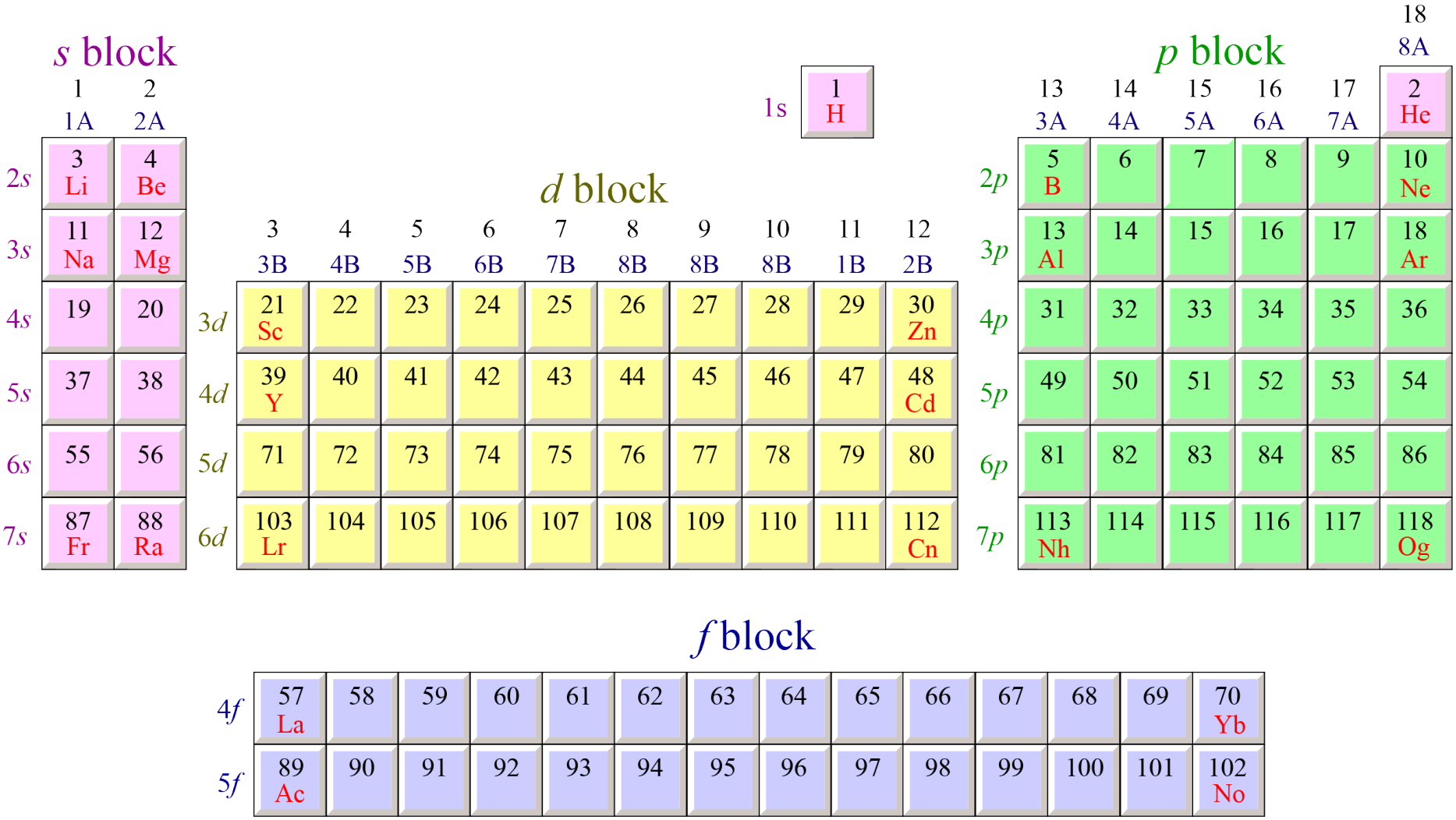
- Determine the number of electrons in the atom from its atomic number.
- Add electrons to the sublevels in the correct order of filling.
- Add a maximum of two electrons to each *s* sublevel, 6 to each *p* sublevel, 10 to each *d* sublevel, and 14 to each *f* sublevel.

Order of Orbital Filling

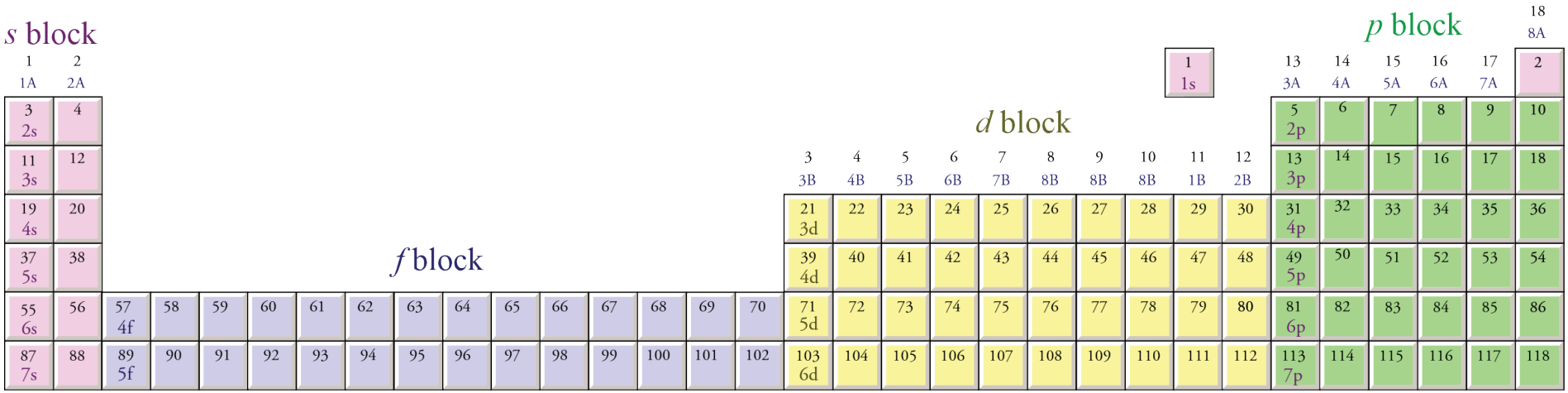


1*s* 2*s* 2*p* 3*s* 3*p* 4*s* 3*d* 4*p* 5*s* 4*d* 5*p* 6*s* 4*f* 5*d* 6*p* 7*s* 5*f* 6*d* 7*p*

Order of Filling from the Periodic Table



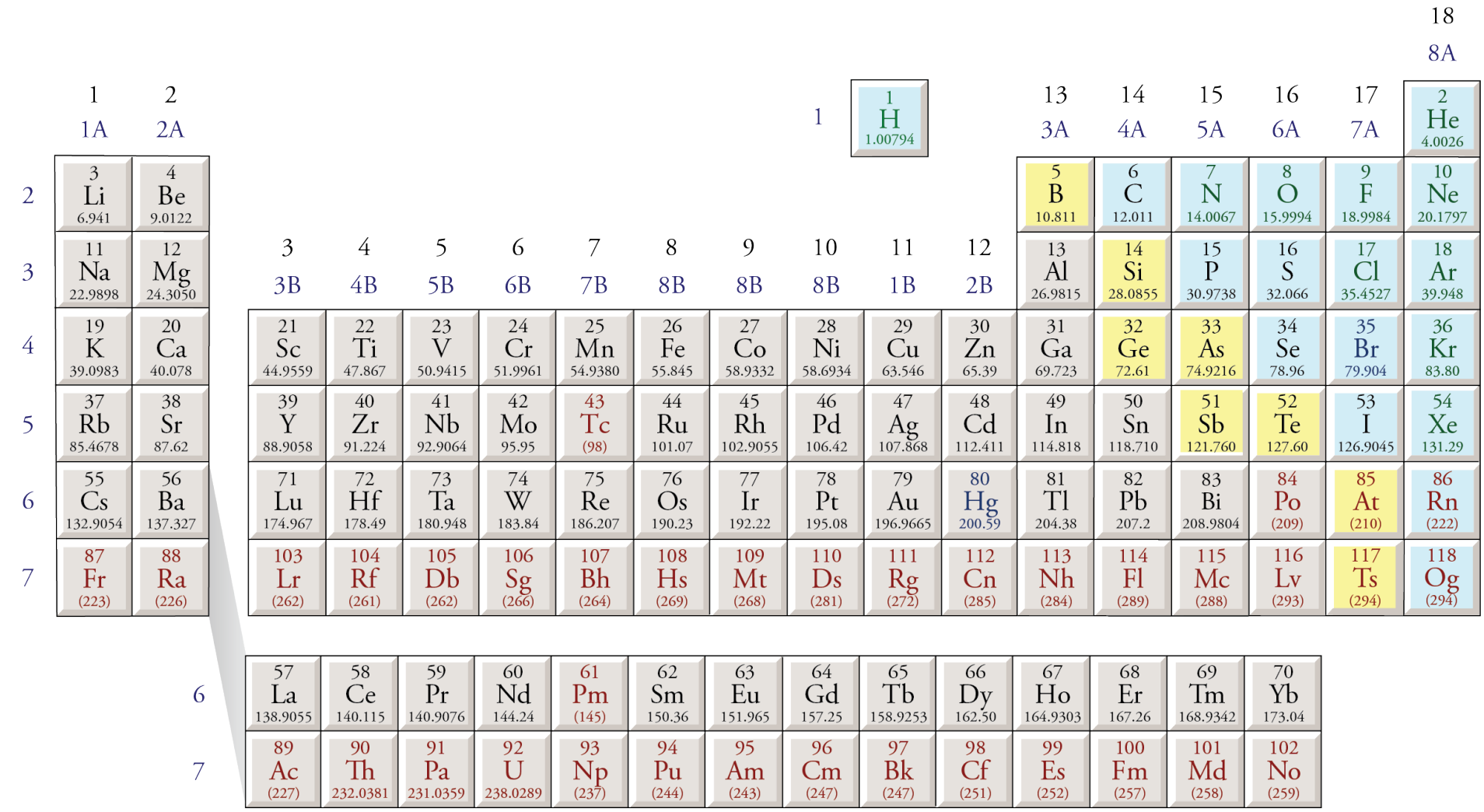
Long Periodic Table



Exercise 4.2 and 11.1

Write the complete electron configuration and draw an orbital diagram for antimony, Sb.

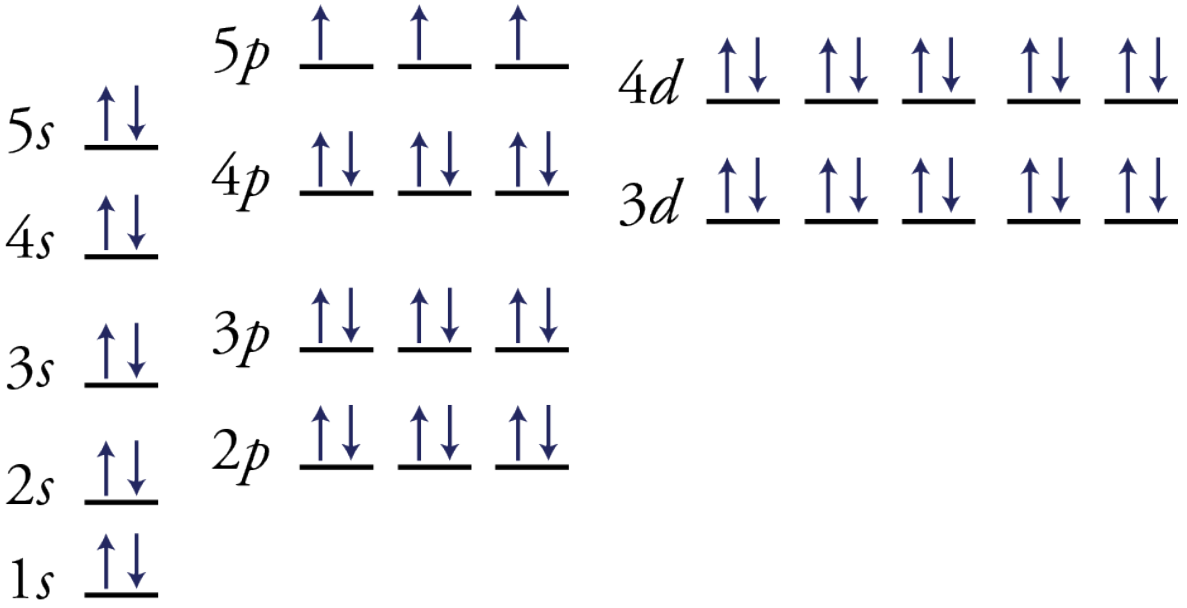
Periodic Table



Exercise 4.2 and 11.1

Write the complete electron configuration and draw an orbital diagram for antimony, Sb.

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

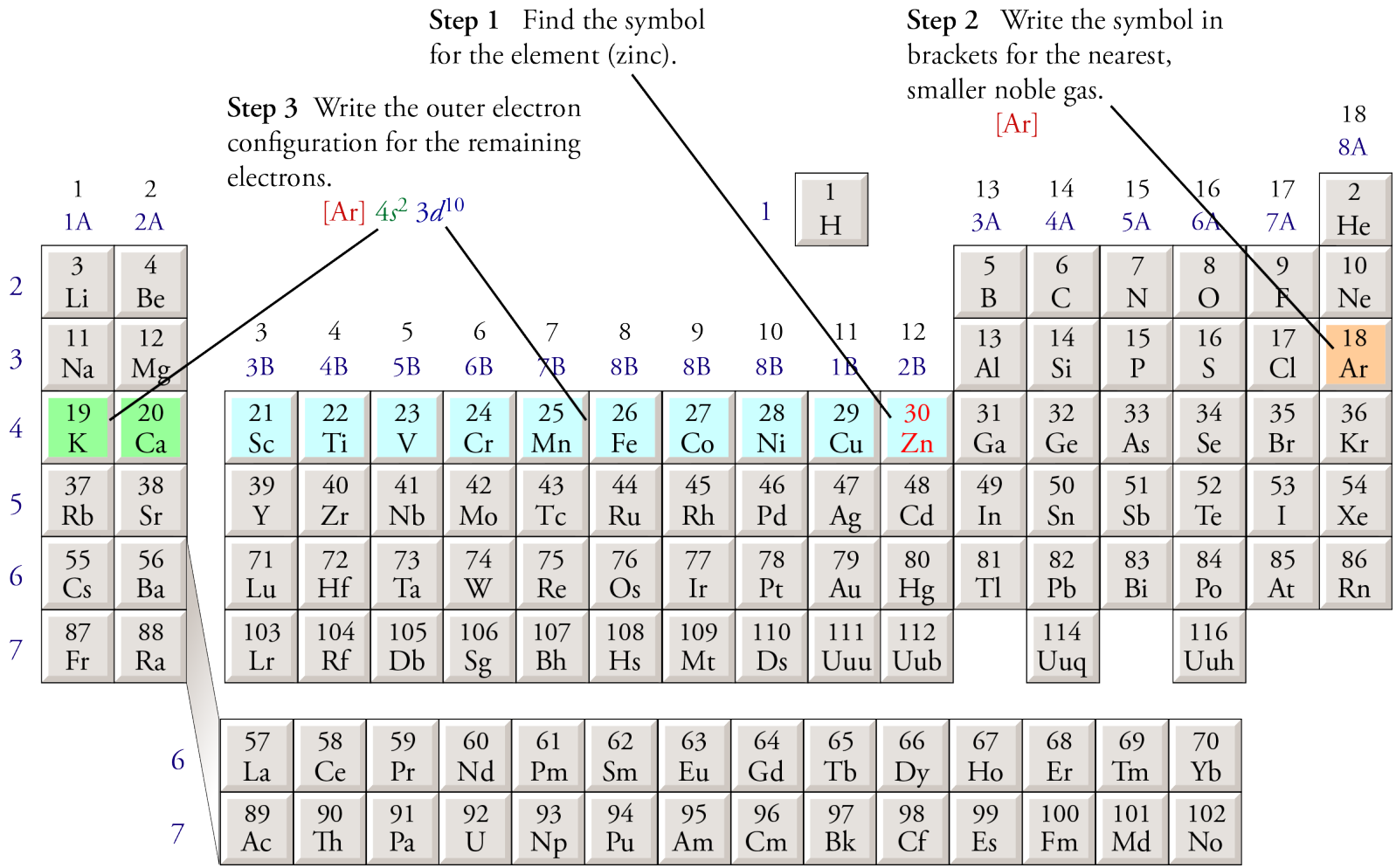


Abbreviated Electron Configurations

- The highest energy electrons are most important for chemical bonding.
- The noble gas configurations of electrons are especially stable and, therefore, not important for chemical bonding.
- We often describe electron configurations to reflect this representing the noble gas electrons with a noble gas symbol in brackets.
- For example, for sodium

$1s^2\ 2s^2\ 2p^6\ 3s^1$ goes to [Ne] $3s^1$

Abbreviated Electron Configuration Steps for Zinc



Exercise 4.3 and 11.2

Write abbreviated electron configurations for (a) rubidium, Rb, (b) bismuth, Bi.

Common Mistakes

- Complete electron configurations – miscounting electrons (Use the periodic table to determine order of filling.)
- Orbital diagrams – forgetting to leave electrons unpaired with the same spin when adding electrons to the *p*, *d*, or *f* sublevels (Hund's Rule)
- Abbreviated electron configurations - forgetting to put $4f^{14}$ after [Xe]

Electron Configuration Tutorials

- Complete electron configurations.

https://preparatorychemistry.com/Comp_Electron_Config_Canvas.html

- Abbreviated electron configurations

https://preparatorychemistry.com/Abb_Electron_Config_Canvas.html