Chapter 8

Electron Configurations and Periodicity

Concept Check 8.1

Imagine a world in which the Pauli principle is "No more than one electron can occupy an atomic orbital, irrespective of its spin." How many elements would there be in the second row of the periodic table, assuming that nothing else is different about this world?

Solution

The second period elements are those in which the 2*s* and 2*p* orbitals fill. Each orbital can hold only one electron, so all four orbitals will be filled after four electrons. Therefore, the second period will have four elements.

Concept Check 8.2

Two elements in Period 3 are adjacent to one another in the periodic table. The ground-state atom of one element has only *s* electrons in its valence shell; the other one has at least one *p* electron in its valence shell. Identify the elements.

Solution

The *s* orbital fills in the first two elements of the period (Groups IA and IIA); then, the *p* orbital starts to fill (Group IIIA). Thus, the first element is in Group IIA (Mg) and the next element is in Group IIIA (Al).

Concept Check 8.3

Given the following information for element E, identify the element's group in the periodic table: The electron affinity of E is positive (that is, it does not form a stable negative ion). The first ionization energy of E is less than the second ionization energy, which in turn is very much less than its third ionization energy.

Solution

From the information given, the element must be in Group IIA. These elements have positive electron affinities and also have large third ionization energies.

Concept Check 8.4

What is the name of the element that is a metalloid with an acidic oxide of formula R_2O_5?

Solution

A metalloid is an element near the staircase line in the periodic table (the green elements in the periodic table on the inside front cover of the book). The formula R_2O_5 suggests a period VA element. There are two metalloids in Group VA, arsenic and antimony. That this is an acidic oxide indicates that this metalloid has considerable nonmetal character. So of the two metalloids, the one nearer the top of the column, arsenic, seems most likely. This is in agreement with the text, which notes that arsenic(V) is acidic, whereas antimony(V) oxide is amphoteric.

Conceptual Problem 8.25

Suppose that the Pauli exclusion principle were "No more than two electrons can have the same four quantum numbers." What would be the electron configurations of the ground states for the first six elements of the periodic table, assuming that, except for the Pauli principle, the usual building-up principle holds?

Solution

This statement of the Pauli principle implies that there can be two electrons with the same spin in a given orbital. Because an electron can have either one of two spins, any one orbital can hold a maximum of four electrons. The first six elements of the periodic table would have the following electronic configurations:

(1) $1s^1$
(2) $1s^2$
(3) $1s^3$
(4) $1s^4$

(5) $1s^4 2s^1$
(6) $1s^4 2s^2$

Conceptual Problem 8.26

Imagine a world in which all quantum numbers, except the *l* quantum number, are as they are in the real world. In this imaginary world, *l* begins with l and goes up to *n* (the value of the principal quantum number). Assume that the orbitals fill in the order by *n*, then *l*; that is, the first orbital to fill is for $n = 1$, $l = 1$; the next orbital to fill is for $n = 2$, $l = 1$, and so forth. How many elements would there be in the first period of the periodic table?

Solution

The first period of the periodic table would have the following allowed quantum numbers: $n = 1$; $l = 1$; $m_l = 0, +1, -1$; $m_s = +1/2, -1/2$. There are six different possible combinations. Therefore, there would be six elements in the first period.

Conceptual Problem 8.27

Two elements in Period 5 are adjacent to one another in the periodic table. The ground-state atom of one element has only *s* electrons in its valence shell; the other has at least one *d* electron in an unfilled shell. Identify the elements.

Solution

The elements are in Group IIA (only *s* electrons) and IIIB (*d* electrons). They are also in Period 5. Therefore, the elements are strontium (Sr) and yttrium (Y).

Conceptual Problem 8.28

Two elements are in the same column of the periodic table, one above the other. The ground-state atom of one element has two *s* electrons in its outer shell, and no *d* electrons anywhere in its configuration. The other element has *d* electrons in its configuration. Identify the elements.

Solution

The elements are in Group IIA. They must also be in Periods 4 (no *d* electrons) and 5 (*d* electrons). Therefore, the elements are calcium (Ca) and strontium (Sr).

Conceptual Problem 8.29

You travel to an alternate universe where the atomic orbitals are different from those on earth, but all other aspects of the atoms are the same. In this universe, you find that the first (lowest energy) orbital is filled with three electrons and the second orbital can hold a maximum of nine electrons. You discover an element *Z* that has five electrons in its atom. Would you expect *Z* to be more likely to form a cation or an anion? Indicate a possible charge on this ion.

Solution

Keeping in mind that a filled orbital is usually a stable configuration for an atom, an element in this universe with five electrons would probably lose the two electrons in the second orbital and form a cation with a charge of positive two. The other possible option is for the atom to gain seven additional electrons to fill the second orbital; however, this is unlikely given that the nuclear charge would be relatively small and electron-electron repulsions in such an atom would be large.

Conceptual Problem 8.30

Would you expect to find an element having both a very large (positive) first ionization energy and an electron affinity that is much less than zero (large but negative)? Explain.

Solution

Keep in mind that the ionization energy of an atom provides a measure of how strongly an electron is attracted to that atom. The electron affinity of an atom provides a measure of how strongly attracted an additional electron is to the atom. Both electron affinity and ionization energy provide information about the strength of the attraction between electrons and a particular nucleus. An element that forms an anion easily has an electron affinity much less than zero, and a very large first ionization energy. Examples are the elements on the upper right of the periodic table, like fluorine, with an electron affinity of -328 kJ/mol and a first ionization energy of 1681 kJ/mol.

Conceptual Problem 8.31

Two elements are in the same group, one following the other. One is a metalloid, the other is a metal. Both form oxides of the formula RO_2; the first is acidic, the next is amphoteric. Identify the two elements.

Solution

The elements that form oxides of the form RO_2 are in Groups IVA and VIA. However, there are no metals in Group VIA. Therefore, the elements are in Group IVA. The metalloid is germanium (Ge), and the metal is tin (Sn). GeO_2 is the acidic oxide, and SnO_2 is the amphoteric oxide.

Conceptual Problem 8.32

A metalloid has an acidic oxide of the formula R_2O_3. The element has no oxide of the formula R_2O_5. What is the name of the element?

Solution

Oxides of Groups IIIA and VA have oxides of the form R_2O_3. However, Group VA oxides can also be of the form R_2O_5, so the element is in group IIIA. It is also acidic. Therefore, it must be boron oxide, B_2O_3.