Example Exercise 6.1 Periodic Law

Find the two elements in the fifth row of the periodic table that violate the original periodic law proposed by Mendeleev.

Solution

Mendeleev proposed that elements be arranged according to increasing atomic mass. Beginning with Rb, each of the elements in the fifth row increases in atomic mass until iodine. Although the atomic numbers of Te (52) and I (53) increase, the atomic masses of Te (127.60) and I (126.90) do not. Experimentally, it is I and not Te, with properties similar to those of F, Cl, and Br.

Practice Exercise

Find a pair of elements in the periodic table with atomic numbers less than 20 that are an exception to the original periodic law.

Answer: Ar and K

Concept Exercise

The modern periodic law states that elements are arranged according to increasing (atomic mass/atomic number). (Circle the correct choice.)

Answer: See Appendix G.

Example Exercise 6.2 Groups and Periods of Elements

Select the symbol of the element that fits each of the following descriptions:

(a) the alkali metal in the fourth period
(b) the halogen in the third period
(c) the rare earth with the lowest atomic mass
(d) the metal in Group VIIB/7 and Period 4

Solution

Referring to the periodic table in Figure 6.3, we have

(a) K
(b) Cl
(c) Sc
(d) Mn

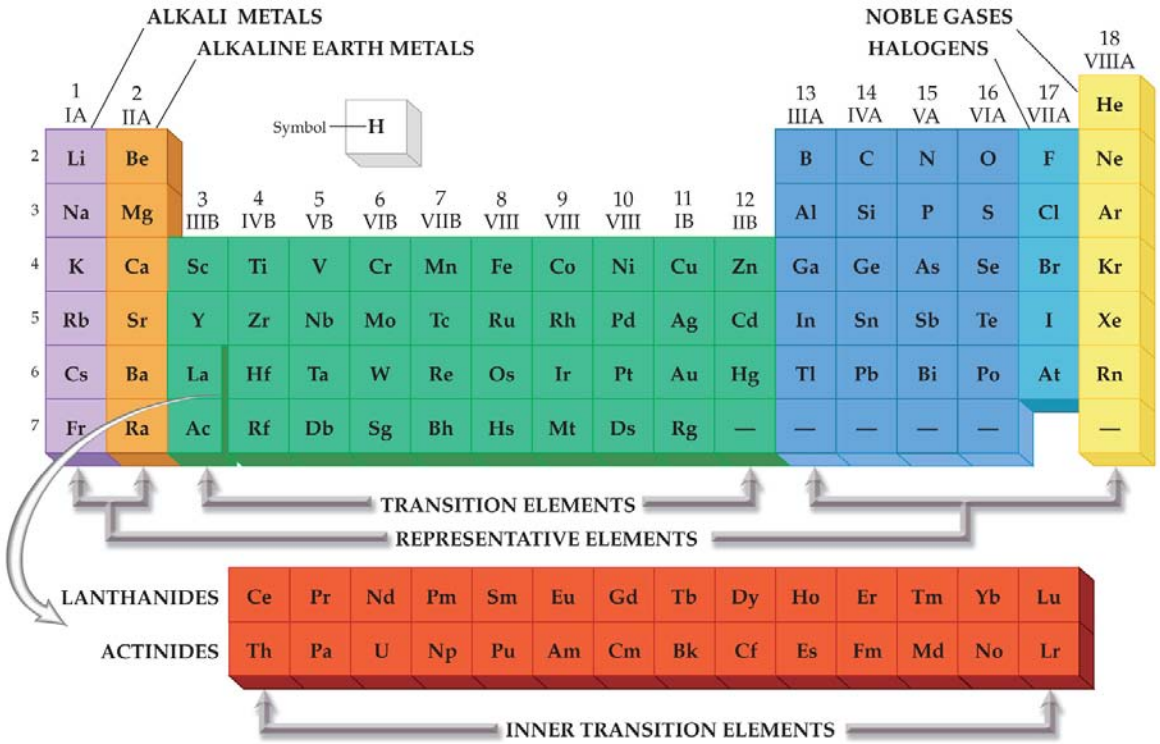

Figure 6.3 Names of Groups and Periods The common names of groups and periods are shown for selected families and series.

Example Exercise 6.2 Groups and Periods of Elements

Continued

Practice Exercise

Select the symbol of the element that fits each of the following descriptions:

(a) the alkaline earth metal in the sixth period
(b) the noble gas in the third period
(c) the actinide with the highest atomic mass
(d) the semimetal in Group IIIA/13

Answers: (a) Ba; (b) Ar; (c) Lr; (d) B

Concept Exercise

What is the group number for each of the following families of elements?

(a) alkali metals
(b) alkaline earth metals
(c) halogens
(d) noble gases

Answer: See Appendix G.

Example Exercise 6.3 Periodic Table Predictions

Based on the general trends in the periodic table, predict which element in each of the following pairs has the smaller atomic radius:

(a) Na or K (b) P or N
(c) Ca or Ni (d) Si or S

Solution

The general trend in atomic radii decreases up a group and across a period from left to right. Referring to the periodic table,

(a) Na is above K in Group IA/1; the atomic radius of Na is smaller.
(b) N is above P in Group VA/15; the atomic radius of N is smaller.
(c) Ni is to the right of Ca in Period 4; the atomic radius of Ni is smaller.
(d) S is to the right of Si in Period 3; the atomic radius of S is smaller.

Practice Exercise

Based on the general trends in the periodic table, predict which element in each of the following pairs has the most metallic character:

(a) Sn or Pb (b) Ag or Sr
(c) Al or B (d) Br or As

Answers: (a) Pb; (b) Sr; (c) Al; (d) As

Concept Exercise

Which period represents the smallest atomic radius? Which group represents the most metallic character?

Answer: See Appendix G.

Example Exercise 6.4 Predicting Physical Properties

Predict the missing value (?) for each physical property listed below. The (a) atomic radius, (b) density, and (c) melting point are given for two of three alkaline earth metals in Group IIA/2.

ELEMENT	ATOMIC RADIUS	DENSITY AT 20 °C	MELTING POINT
Ca	0.197 nm	1.54 g/mL	(?) °C
Sr	0.215 nm	(?) g/mL	769 °C
Ba	(?) nm	3.65 g/mL	725 °C

Solution

We can estimate a value for the physical property of an element by observing the trend in values for other elements within the same group.

(a) To determine the atomic radius value for Ba, we first find the increase from Ca to Sr; that is, 0.215 nm – 0.197 nm = 0.018 nm. We then add the difference (0.018 nm) to the atomic radius of Sr and obtain 0.215 nm + 0.018 nm = 0.233 nm. We assumed that the atomic radius increased the same amount from Sr to Ba as it did from Ca to Ba. (The *Handbook of Chemistry and Physics* value is 0.217 *nm*.)

(b) Notice that Sr lies between Ca and Ba in Group IIA/2. Thus, we can estimate that the density of Sr lies midway between Ca and Ba. To find the density of Sr, we calculate the average value for Ca and Ba; that is, (1.54 g/mL + 3.65 g/mL)/2 = 2.60 g/mL. (The literature value is 2.63 *g/mL*.)

(c) From the general trend, we can predict that the melting point of Ca is greater than that of Sr. To determine the value, let's find the increase in melting point from Ba to Sr. It is 769 °C – 725 °C = 44 °C. Now we add 44 °C to the value of Sr: 769 °C + 44 °C = 813 °C. Therefore we predict the melting point of Ca as 813 °C. (The literature value is *839 °C*.)

Example Exercise 6.4 Predicting Physical Properties

Continued

Practice Exercise

Predict the missing value (?) for each physical property listed below. The (a) atomic radius, (b) density, and (c) melting point are given for two of the metals in Group VIII/10.

ELEMENT	ATOMIC RADIUS	DENSITY AT 20 °C	MELTING POINT
Ni	0.125 nm	8.91 g/cm^3	(?) °C
Pd	0.138 nm	(?) g/cm^3	1554 °C
Pt	(?) nm	21.5 g/cm^3	1772 °C

Answers: (a) 0.151 nm; (b) 15.2 g/cm^3; (c) 1336 °C

Concept Exercise

Given the atomic radius (0.186 nm), density (0.97 g/mL), and melting point (98 ° C) for sodium, estimate the corresponding values of lithium.

Answer: See Appendix G.

Example Exercise 6.5 Predicting Chemical Properties

Metallic sodium reacts with chlorine gas to give sodium chloride, NaCl. Predict the products formed when (a) lithium and (b) potassium react with chlorine gas.

Solution

Since Li and K are in the same group as Na (Group IA/1), we can predict that the products are similar to NaCl. Thus,

(a) lithium metal should react with chlorine gas to give LiCl.

(b) potassium metal should react with chlorine gas to give KCl.

Practice Exercise

The chemical formulas for the oxides of potassium, calcium, gallium, and germanium are, respectively, K_2O, CaO, Ga_2O_3, and GeO_2. Refer to the periodic table and predict the chemical formula for each of the following compounds:

(a) rubidium oxide (b) strontium oxide

(c) indium oxide (d) lead oxide

Answers: (a) Rb_2O; (b) SrO; (c) In_2O_3; (d) PbO_2

Concept Exercise

Predict which of the following metals has chemical properties most similar to zinc: Fe, Cu, or Cd.

Answer: See Appendix G.

Example Exercise 6.6 Energy Sublevels and the Periodic Table

State the highest energy sublevel in each of the following elements:

(a) H (b) S

(c) Ni (d) U

Solution

Refer to the periodic table and determine the energy sublevel based on the period and block of the elements.

(a) Hydrogen has only one electron; thus, H is filling a 1*s* sublevel.

(b) Sulfur is in the third period and is a *p* block element; S is filling a 3*p* sublevel.

(c) Nickel is in the first series of *d* block elements; Ni is filling a 3*d* sublevel.

(d) Uranium is in the second series of *f* block elements; U is filling a 5*f* sublevel.

Practice Exercise

State the energy sublevel being filled in each of the following series of elements:

(a) Cs – Ba (b) Y – Cd

(c) In – Xe (d) Ce – Lu

Answers: (a) 6*s*; (b) 4*d*; (c) 5*p*; (d) 4*f*

Concept Exercise

Refer to the periodic table and state the highest energy sublevel in a silver atom.

Answer: See Appendix G.

Example Exercise 6.7 Electron Configuration and the Periodic Table

Refer to a periodic table and write the predicted electron configuration for each of the following elements by counting the number of electrons in each block:

(a) P (b) Co

Solution

Now that you understand blocks of elements in the periodic table, you can predict the order of sublevels according to increasing energy.

(a) Phosphorus is the third element in the 3*p* sublevel. The electron configuration for P is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$, or [Ne] $3s^2\ 3p^3$.

(b) Cobalt is the seventh element in the 3*d* sublevel. The electron configuration for Co is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^7$ or [Ar] $4s^2\ 3d^7$.

Practice Exercise

Refer to a periodic table and write the predicted electron configuration for each of the following elements.

(a) Zn (b) Se

Answers:

(a) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3s^6\ 4s^2\ 3d^{10}$ or [Ar] $4s^2\ 3d^{10}$

(b) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3s^6\ 4s^2\ 3d^{10}$ or [Ar] $4s^2\ 3d^{10}\ 4p^4$

Concept Exercise

Refer to the periodic table and predict the number of 5*d* electrons in a Pt atom.

Answer: See Appendix G.

Example Exercise 6.8 Valence Electrons and the Periodic Table

Refer to the periodic table and predict the number of valence electrons for an atom of each of the following representative elements:

(a) Na (b) Al
(c) S (d) Xe

Solution

Find the element in the periodic table, note the group number, and indicate the number of valence electrons.

(a) Since sodium is in Group IA/1, Na has 1 valence electron.
(b) Aluminum is in Group IIIA/13, and so Al has 3 valence electrons.
(c) Sulfur is in Group VIA/16, and so S has 6 valence electrons.
(d) Xenon is in Group VIIIA/18, and so Xe has 8 valence electrons.

Practice Exercise

Refer to the periodic table and state the number of valence electrons for any element in each of the following groups:

(a) Group IIA (b) Group VA
(c) Group 14 (d) Group 17

Answers: (a) 2; (b) 5; (c) 4; (d) 7

Concept Exercise

Why are predictions for the number of valence electrons only for representative elements?

Answer: See Appendix G.

Example Exercise 6.9 Electron Dot Formulas

Draw the electron dot formula for each of the following elements:

(a) Si (b) Xe

Solution

Let's find the group number of the element in the periodic table and note the number of valence electrons. We write the symbol of the element and place the same number of dots around the symbol as there are valence electrons. In these examples, Si has 4 valence electrons and Xe has 8. The electron dot formulas are as follows:

(a) Si

(b) Xe

Practice Exercise

Draw the electron dot formula for each of the following elements:

(a) K (b) I

Answers:

(a) K

(b) I

Concept Exercise

Propose two ways of drawing the electron dot formula for Mg.

Answer: See Appendix G.

Example Exercise 6.10 Ionization Energy and the Periodic Table

Based on the general trends in the periodic table, predict which element in each of the following pairs has the higher ionization energy:

(a) Li or Na (b) O or F

Solution

Let's refer to a periodic table and apply the general trends in ionization energy, which increases up a group and across a period.

Li is above Na in Group IA/1, and so Li has the higher ionization energy.

F is right of O in Period 2, and so F has the higher ionization energy.

Practice Exercise

Based on the general trends in the periodic table, predict which element in each of the following pairs has the higher ionization energy:

(a) Na or Mg (b) O or S

Answers: (a) Mg; (b) O

Concept Exercise

Which group in the periodic table has the highest ionization energy?

Answer: See Appendix G.

Example Exercise 6.11 Ionic Charge and the Periodic Table

Predict the ionic charge for each of the following ions based on the group number of the element in the periodic table:

(a) Al ion (b) S ion

Solution

We refer to the periodic table to find the group number of the element.

(a) Aluminum is in Group IIIA/13. The metal atom loses 3 e^-, and so the ionic charge is 3+, that is, Al^{3+}.

(b) Sulfur is in Group VIA/16. The nonmetal atom gains 2 e^-, and so the ionic charge is 2–, that is, S^{2-}.

Practice Exercise

Predict the ionic charge for each of the following ions based on the group number of the element in the periodic table:

(a) Mg ion (b) Br ion

Answers: (a) Mg^{2+}; (b) Br^-

Concept Exercise

Predict the common ionic charge for Group IA/1 elements, for Group IIA/2 elements and for Group VIIA/17 elements.

Answer: See Appendix G.

Example Exercise 6.12 Predicting Isoelectronic Ions

Refer to the periodic table and predict which of the following ions are isoelectronic with the noble gas argon:

(a) K^+ (b) Br^-

(c) Ca^{2+} (d) O^{2-}

Solution

We refer to the periodic table to find the atomic number of the element.

(a) K^+ has 18 electrons (19–1); it is isoelectronic with argon (18 e^-).

(b) Br^- has 36 electrons (35+1); it is isoelectronic with krypton (36 e^-).

(c) Ca^{2+} has 18 electrons (20–2); it is isoelectronic with argon (18 e^-).

(d) O^{2-} has 10 electrons (8+2); it is isoelectronic with neon (10 e^-).

Practice Exercise

Refer to the periodic table and predict which of the following ions are isoelectronic with the noble gas xenon:

(a) Cs^+ (b) Cl^-

(c) La^{3+} (d) Se^{2-}

Answers: (a) Cs^+ is isoelectronic with xenon; (b) Cl^- is isoelectronic with argon; (c) La^{3+} are isoelectronic with xenon; (d) Se^{2-} is isoelectronic with krypton

Concept Exercise

Predict the next ion in the isoelectronic series: Se^{2-}, Br^-, Kr, Rb^+, Sr^{2+}.

Answer: See Appendix G.

Example Exercise 6.13 Electron Configuration of Ions

Refer to the periodic table and write the predicted electron configuration for each of the following ions using core notation:

(a) Fe^{3+} (b) Se^{2-}

Solution

We refer to the periodic table to recall the blocks of elements so that we can write the electron configuration for the element.

(a) The electron configuration for an Fe atom is [Ar] $4s^2\ 3d^6$. The core electron configuration for an Fe^{3+} ion is [Ar] $3d^5$.

(b) The electron configuration for a Se atom is [Ar] $4s^2\ 3d^{10}\ 4p^4$. The electron configuration for a Se^{2-} ion is [Ar] $4s^2\ 3d^{10}\ 4p^6$ or simply [Kr].

Practice Exercise

Refer to the periodic table and write the predicted electron configuration for each of the following ions using core notation:

(a) Cd^{2+} (b) p^{3-}

Answers: (a) [Kr] $4d^{10}$; (b) [Ne] $3s^2\ 3p^6$, or [Ar].

Concept Exercise

What is the electron configuration for radon gas using core notation?

Answer: See Appendix G.