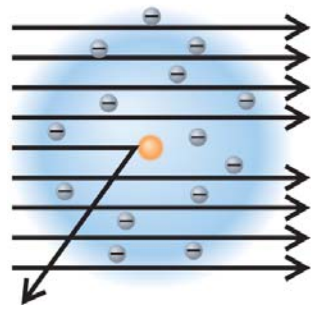
SUMMARY

LO1 The values of the charge and mass of the electron were determined by J. J. Thomson's studies using cathode-ray tubes and by Robert Millikan's oil-drop experiments. Ernest Rutherford's group bombarded thin gold foil with **alpha (α) particles** and discovered that the positive charge and nearly all the mass of an atom are contained in its nucleus. (Section 2.1 (Chapter02-01.xhtml))



LO2 Atoms are composed of negatively charged **electrons** surrounding a **nucleus**, which contains positively charged **protons** and electrically neutral **neutrons**. The number of protons in the nucleus of an element defines its **atomic number (*Z*)**; the number of **nucleons** (protons + neutrons) in the nucleus defines the element's **mass number (*A*)**. The different **isotopes** of an element consist of atoms with the same number of protons per nucleus but different numbers of neutrons. Symbols for subatomic particles and atoms list the symbol for the particle (X) with the value of *A* as a superscript and the value of *Z* as a subscript: $^{A}_{Z}X$. (Section 2.2 (Chapter02-02.xhtml))

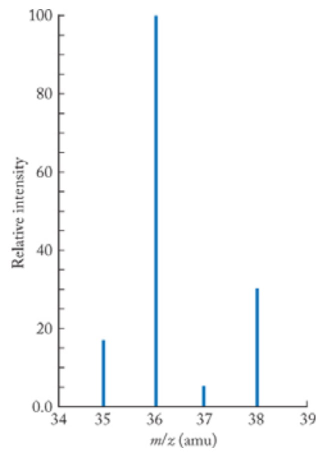
LO3 Elements are arranged in the **periodic table of the elements** in order of increasing atomic number and in a pattern based on their chemical properties, including the charges of the monatomic ions they form. Elements in the same column are in the same **group** and have similar properties. An atom or group of atoms having a net charge is called an ion. If the charge is positive, it is a **cation**; if the charge is negative, it is an **anion**. Elements in groups 1, 2, and 13–18 are **main group** (or **representative**) **elements**. The **transition metals** are in groups 3–12. **Metals** are mostly malleable, ductile solids; they form cations and are good conductors of heat and electricity. **Nonmetals** include elements in all three physical states; they form anions and are poor conductors of heat and electricity. **Metalloids**, or **semimetals**, have the physical properties of metals and chemical properties of nonmetals. (Section 2.3 (Chapter02-03.xhtml))

LO4 To calculate the **average atomic mass** of an element, multiply the mass of each of its stable isotopes by the **natural abundance** of that isotope as a percentage and then sum the products. (Section 2.4

(Chapter02-04.xhtml))

LO5 The **mole (mol)** is the SI base unit for quantity of substances. One mole of a substance consists of an **Avogadro's number** (N_A = 6.0221 × 10^{23}) of particles of the substance. The mass of 1 mole of a substance is its **molar mass (ℳ)**. Avogadro's number and molar mass can be used to convert grams of a substance to moles and to the number of particles or to convert the number of particles to moles and to grams of the substance. (Section 2.5 (Chapter02-05.xhtml))

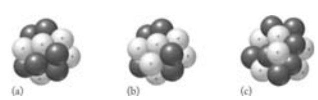
LO6 The **molecular mass** of a compound is the sum of the average atomic mass of each of the atoms in one of its molecules. The formula of an ionic compound defines the simplest combination of its ions that gives a neutral **formula unit** of the compound, which has a corresponding **formula mass**. (Sections 2.4 (Chapter02-04.xhtml) and 2.5 (Chapter02-05.xhtml))



LO7 The *m*/*z* values for the **molecular ion**, **M**$^+$, in the **mass spectrum** of atoms and molecules allow us to determine their molar masses. (Section 2.6 (Chapter02-06.xhtml))

LO8 The relative heights of the *m*/*z* peaks for the molecular ions, $M^{+\cdot}$, in the mass spectrum of an element or a molecule containing the element allow us to find the isotopic abundance of the elements. (Section 2.6 (Chapter02-06.xhtml))

PARTICULATE **PREVIEW WRAP-UP**



Counting the numbers of protons and neutrons in the three nuclei in the figure yields the values in the following table where each mass number (*A*) is the sum of the numbers of protons and neutrons, and each atomic number (*Z*) is equal to the number of protons in that nucleus. Nuclei (b) and (c) have the same atomic number (6), which makes them isotopes of the same element (carbon).

Nucleus	Number of protons	Number of neutrons	A	Z
(a)	5	6	11	5
(b)	6	5	11	6
(c)	6	7	13	6

PROBLEM-SOLVING SUMMARY

Type of Problem	Concepts and Equations	Sample Exercises
Writing symbols of nuclides and ions	Place a superscript for the mass number (*A*) and a subscript for the atomic number (*Z*) to the left of the element symbol. If the particle is a monatomic ion, add its charge as a superscript following the symbol.	**2.1 (Chapter02-02.xhtml#ATOMS2-1), 2.2 (Chapter02-02.xhtml#ATOMS2-2)**
Navigating the periodic table	Use row numbers to identify periods in the periodic table, and use column numbers to identify groups. Groups with special names include the *alkali metals* (group 1), *alkaline earth metals* (group 2), *chalcogens* (group 16), *halogens* (group 17), and *noble gases* (group 18).	**2.3 (Chapter02-03.xhtml#ATOMS2-3)**
Calculating the average atomic mass of an element	Multiply the mass (*m*) of each stable isotope of the element by the natural abundance (*a*) of that isotope; then sum the products: $m_X = a_1m_1 + a_2m_2 + a_3m_3 + \ldots$ (2.2)	**2.4 (Chapter02-04.xhtml#ATOMS2-4), 2.5 (Chapter02-04.xhtml#ATOMS2-5)**
Converting number of particles into number of moles (or vice versa)	Convert number of particles into number of moles by dividing by Avogadro's number. Convert number of moles into number of particles by multiplying by Avogadro's number.	**2.6 (Chapter02-05.xhtml#ATOMS2-6), 2.10 (Chapter02-05.xhtml#ATOMS2-10)**

Converting mass of a substance into number of moles (or vice versa)	Convert mass of the substance to number of moles by dividing by the molar mass ($\mathcal{M}$) of the substance. Convert number of moles of the substance to mass by multiplying by the molar mass ($\mathcal{M}$) of the substance.	**2.8 (Chapter02-05.xhtml#ATOMS2-8), 2.9 (Chapter02-05.xhtml#ATOMS2-9), 2.10 (Chapter02-05.xhtml#ATOMS2-10)**
Calculating the molar mass of a compound	Sum the molar masses of the elements in the compound's formula, with each element multiplied by the number of atoms of that element in one molecule or formula unit of the compound.	**2.7 (Chapter02-05.xhtml#ATOMS2-7), 2.10 (Chapter02-05.xhtml#ATOMS2-10)**
Determining molecular mass by mass spectrometry	Identify the molecular ion, $M^{+\cdot}$, the peak with the largest value of *m*/*z*.	**2.11 (Chapter02-06.xhtml#ATOMS2-11)**
Calculating isotopic abundances from mass spectra	Use the peak heights (ion counts) of molecular-ion peaks to calculate the natural abundances of the isotopes: $\% \, ^{A}X = \frac{\text{peak height of } ^{A}X}{\text{sum of intensities of all } ^{A}X} \times 100$	**2.12 (Chapter02-06.xhtml#ATOMS2-12)**

VISUAL PROBLEMS

(Answers to boldface end-of-chapter questions and problems are in the back of the book.)

2.1. Atoms of which one of the highlighted elements in Figure P2.1 have the fewest protons per nucleus? Which element is this?

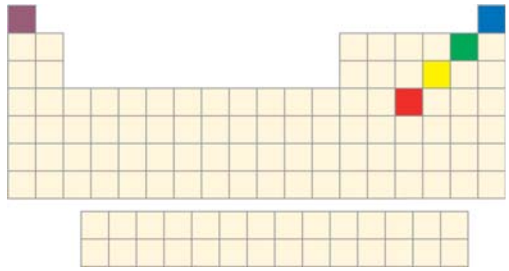


FIGURE P2.1

2.2. Atoms of which one of the highlighted elements in Figure P2.1 have, on average, the greatest number of neutrons?

2.3. Which one of the highlighted elements in Figure P2.1 has a stable isotope with no neutrons in its nucleus?

2.4. Which of the highlighted elements in Figure P2.4 has no stable isotopes?

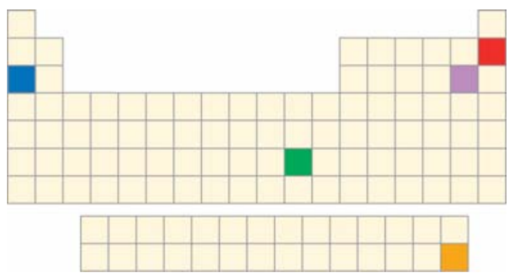


FIGURE P2.4

2.5. Which of the highlighted elements in Figure P2.4 is (a) a transition metal; (b) an alkali metal; (c) a halogen?

2.6. Which of the highlighted elements in Figure P2.4 is (a) a nonmetal; (b) a chemically inert gas; (c) a metal?

2.7. Alpha and beta particles emitted by a sample of pitchblende escape through a narrow channel in the shielding surrounding the sample and into an electric field as shown in Figure P2.7. Identify which colored arrow corresponds to each of the two forms of radiation.

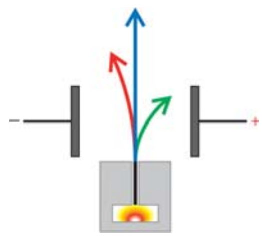


FIGURE P2.7

2.8. Which subatomic particle would curve in the same direction as the green arrow in Figure P2.7?

*2.9. Dichloromethane (CH_2Cl_2, 84.93 g/mol) and cyclohexane (C_6H_{12}, 84.15 g/mol) have nearly the same molar masses. Which compound produced the mass spectrum shown in Figure P2.9? Explain your selection.

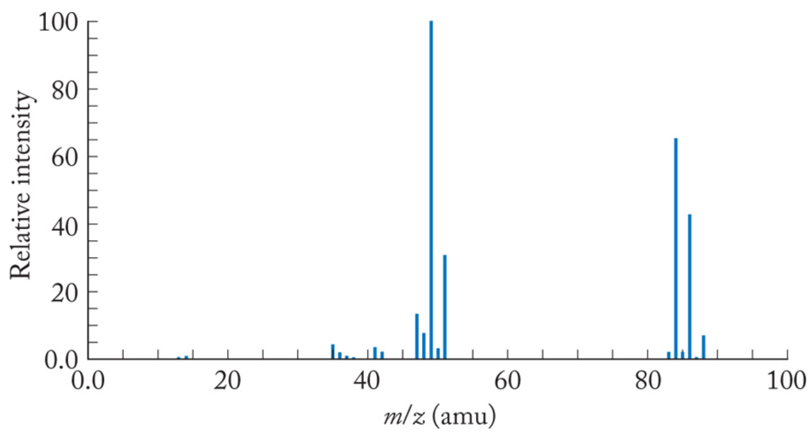


FIGURE P2.9

2.10. Krypton has six stable isotopes. How many neutrons are there in the most abundant isotope of krypton based on the mass spectrum in Figure P2.10?

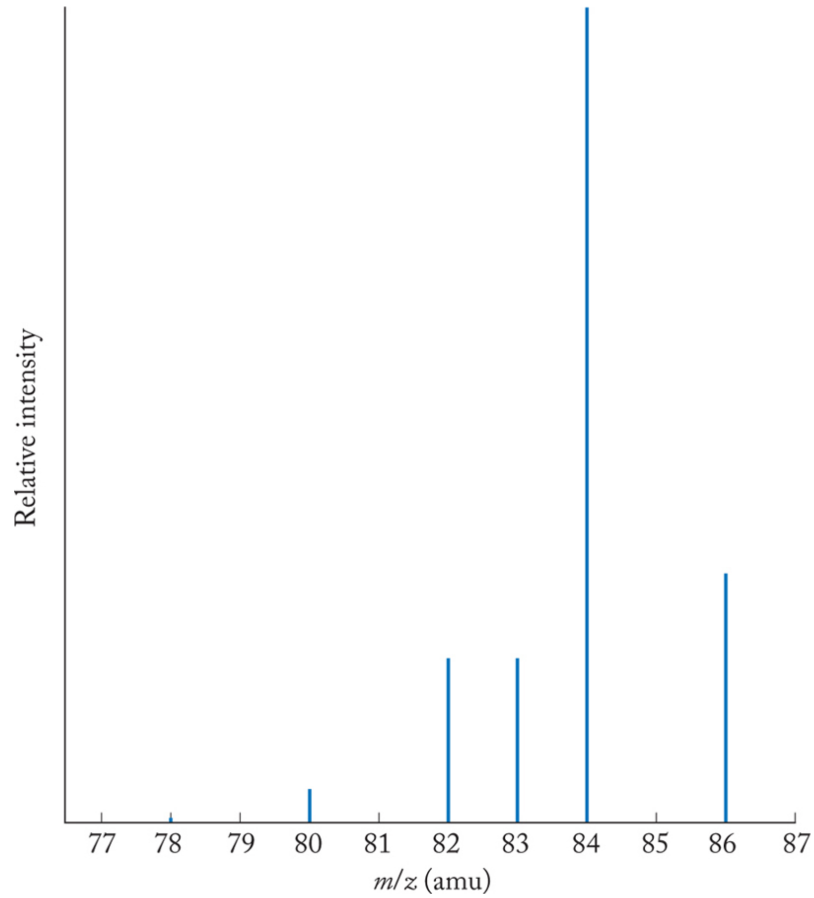


FIGURE P2.10

2.11. Which of the highlighted elements in Figure P2.11 forms monatomic ions with a charge of (a) 1+; (b) 2+; (c) 3+; (d) 1−; (e) 2−?

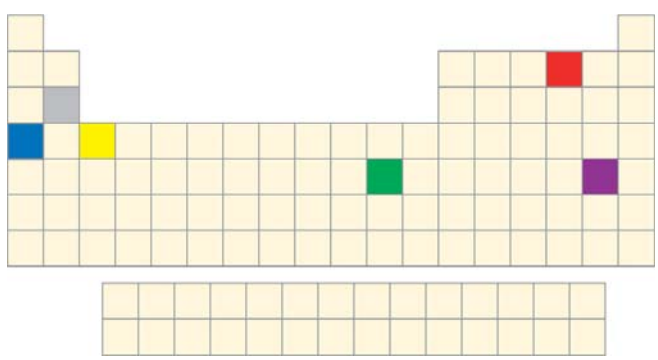


FIGURE P2.11

2.12. Use representations [A] through [I] in Figure P2.12 to answer questions a–f. (The atomic color palette is inside the back cover.)

a. Based on the ratio of cations to anions in representations [A] and [I], which compound is potassium iodide and which is potassium oxide?

b. Order the nuclei from the fewest neutrons to the most neutrons.
c. Which representations depict isotopes?
d. What is the mass of the molecule in representation [E]?
e. Which would contain more molecules, 100 g of [C] or 100 g of [G]?
f. Which would contain more sulfur atoms, 100 g of [C] or 100 g of [G]?

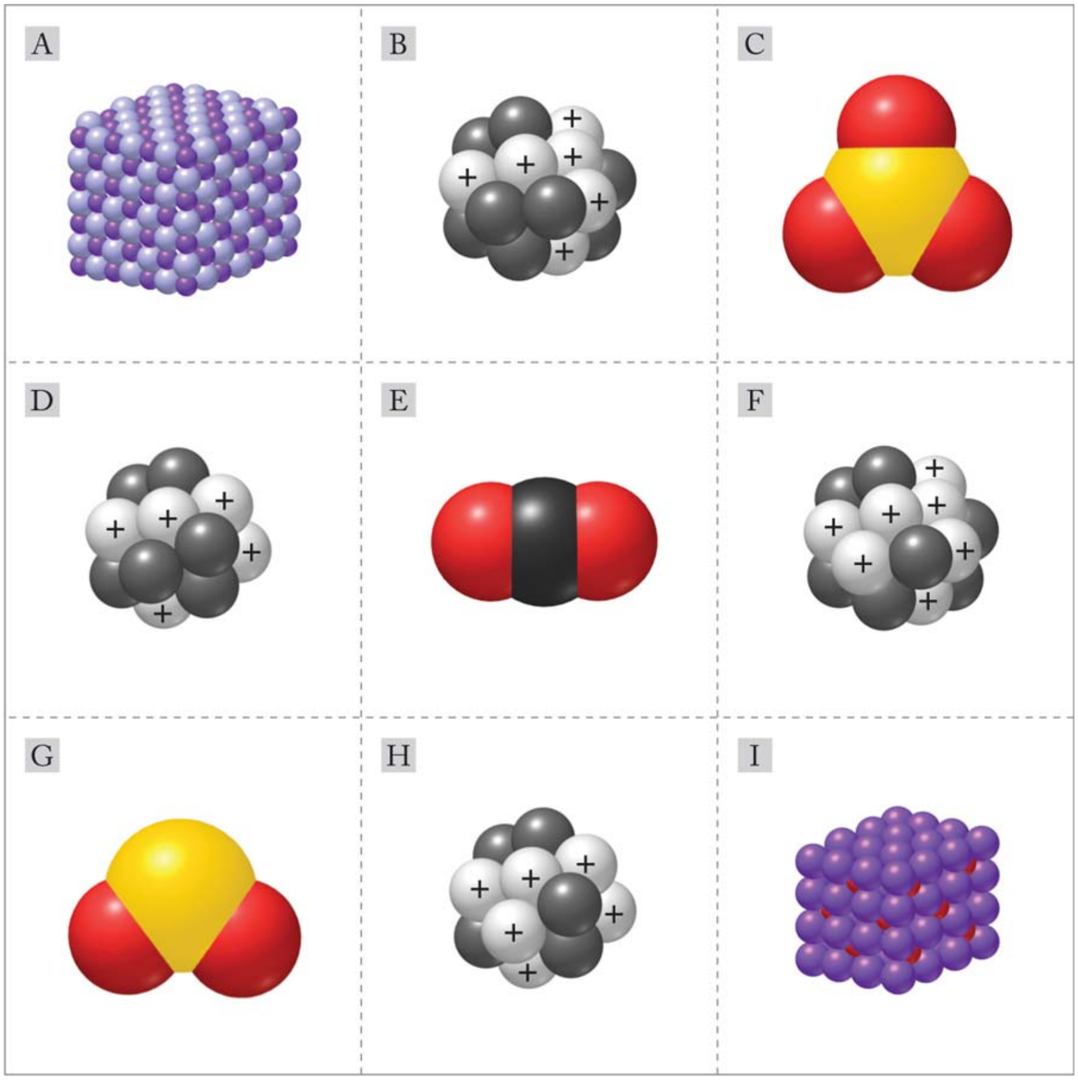


FIGURE P2.12

QUESTIONS AND PROBLEMS

The Rutherford Model of Atomic Structure

Concept Review

2.13. Explain how the results of the gold-foil experiment led Rutherford to dismiss the plum-pudding model of the atom and create his own model based on a nucleus surrounded by electrons.

2.14. Had the plum-pudding model been valid, how would the results of the gold-foil experiment have differed from what Geiger and Marsden actually observed?

2.15. What properties of cathode rays led Thomson to conclude that they were not rays of energy but rather particles with an electric charge?

2.16. Describe two ways in which α particles and β particles differ.

***2.17.** **Helium in Pitchblende** The element helium was first discovered on Earth in a sample of pitchblende, an ore of radioactive uranium oxide. How did helium get in the ore?

2.18. How might using a thicker piece of gold foil have affected the scattering pattern of α particles observed by Rutherford's students?

***2.19.** What would have happened to the gold atoms in Rutherford's experiment if their nuclei had absorbed α particles?

*2.20. In addition to gold foil, Geiger and Marsden tried silver and aluminum foils in their experiment. Why might foils of these metals have deflected fewer α particles than gold foil?

Nuclides and Their Symbols

Concept Review

2.21. If the mass number of a nuclide is more than twice the atomic number, is the neutron-to-proton ratio less than, greater than, or equal to 1?

2.22. How are the mass number and atomic number of a nuclide related to the number of neutrons and protons in each of its nuclei?

2.23. Nearly all stable nuclides have at least as many neutrons as protons in their nuclei. Which very common nuclide is an exception?

2.24. Explain the inherent redundancy in the nuclide symbol ${}^{A}_{Z}X$.

Problems

2.25. How many protons, neutrons, and electrons are in the following atoms? (a) ^{14}C; (b) ^{59}Fe; (c) ^{90}Sr; (d) ^{210}Pb

2.26. How many protons, neutrons, and electrons are there in the following atoms? (a) ^{11}B; (b) ^{19}F; (c) ^{131}I; (d) ^{222}Rn

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2.27. Calculate the *ratio* of neutrons to protons in the following stable atomic nuclei: (a) ^{4}He; (b) ^{23}Na; (c) ^{59}Co; and (d) ^{197}Au. Each of these elements exists naturally as a single isotope. What trend do you observe for the neutron-to-proton ratio as *Z* increases?

2.28. Calculate the *ratio* of neutrons to protons in the following group 15 nuclei: (a) ^{14}N; (b) ^{31}P; (c) ^{75}As; (d) ^{121}Sb; and (e) ^{123}Sb. How does the ratio change with increasing atomic number?

2.29. Fill in the missing information about atoms of the four nuclides in the following table.

Symbol	^{23}Na	?	?	?
Number of Protons	?	39	?	79
Number of Neutrons	?	50	?	?
Number of Electrons	?	?	50	?
Mass Number	?	?	118	197

2.30. Fill in the missing information about atoms of the four nuclides in the following table.

Symbol	^{27}Al	?	?	?
Number of Protons	?	42	?	92
Number of Neutrons	?	56	?	?
Number of Electrons	?	?	60	?
Mass Number	?	?	143	238

2.31. Fill in the missing information about the monatomic ions in the following table.

Symbol	$^{37}Cl^-$	?	?	?
Number of Protons	?	11	?	88
Number of Neutrons	?	12	46	?
Number of Electrons	?	10	36	86
Mass Number	?	?	81	226

2.32. Fill in the missing information about the monatomic ions in the following table.

Symbol	$^{137}Ba^{2+}$	?	?	?
Number of Protons	?	30	?	40
Number of Neutrons	?	34	16	?
Number of Electrons	?	28	18	36

Mass Number	?	?	32	90

Navigating the Periodic Table

Concept Review

2.33. Mendeleev arranged the elements on the left side of his periodic table based on the formulas of the binary compounds they formed with oxygen, and he used the formulas as column labels. For example, group 1 in a modern periodic table was labeled "R_2O" in Mendeleev's table, where "R" represented one of the elements in the group. What labels did Mendeleev use for groups 2, 3, and 4 from the modern periodic table?

2.34. Mendeleev arranged the elements on the right side of his periodic table based on the formulas of the binary compounds they formed with hydrogen and used these formulas as column labels. Which groups in the modern periodic table were labeled "HR," "H_2R," and "H_3R," where "R" represented one of the elements in the group?

2.35. Mendeleev left empty spaces in his periodic table for elements he suspected existed but had yet to be discovered. However, he left no spaces for the noble gases (group 18 in the modern periodic table). Suggest a reason why he left no spaces for them.

2.36. Describe how the charges of the monatomic ions that elements form change as group number increases in a particular row of the periodic table and how ion charges change as the row number increases in a particular group.

Problems

2.37. **TNT** Molecules of the explosive TNT contain atoms of hydrogen and second-row elements in groups 14, 15, and 16. Which three elements are they?

2.38. **Phosgene** Phosgene was used as a chemical weapon during World War I. Despite the name, phosgene molecules contain no atoms of phosphorus. Instead, they contain atoms of carbon and the group 16 element in the second row of the periodic table and the group 17 element in the third row. What are the identities and atomic numbers of the two elements?

2.39. **Catalytic Converters** The catalytic converters used to remove pollutants from automobile exhaust contain compounds of several fairly expensive elements, including those described in the following list. Which elements are they?

a. The group 10 transition metal in the fifth row of the periodic table

b. The transition metal whose symbol is to the left of your answer to part a

c. The transition metal whose symbol is directly below your answer to part a

2.40. **Swimming Pool Chemistry** Compounds containing chlorine have long been used to disinfect the water in swimming pools, but in recent years a compound of a less corrosive halogen has become a popular alternative disinfectant. What is the name of this fourth-row element?

2.41. How many metallic elements are there in the third row of the periodic table?

2.42. Which third-row element in the periodic table has chemical properties of a nonmetal but physical properties of a metal?

The Masses of Atoms, Ions, and Molecules

Concept Review

2.43. What is meant by a *weighted average*?

2.44. Explain how percent natural abundances are used to calculate average atomic masses.

2.45. A hypothetical element consists of two isotopes (X and Y) with masses m_X and m_Y. If the natural abundance of the X isotope is exactly 50%, what is the average atomic mass of the element?

2.46. In calculating the formula masses of binary ionic compounds, we use the average masses of neutral atoms, not ions. Why?

***2.47.** The average mass of platinum is 195.08 amu, yet the natural abundance of ^{195}Pt is only 33.8%. Propose an explanation for this observation.

*2.48. The average atomic mass of europium (Eu, 151.96 amu), measured to five significant figures, is only 0.04 amu different from a whole number. Can we conclude that there is only one stable isotope of europium? Why or why not?

Problems

***2.49.** The argon in nature consists of three isotopes: ^{36}Ar, ^{38}Ar, and ^{40}Ar. Which one is the most abundant?

2.50. Manganese has only one stable isotope. How many neutrons are in each of its atoms?

2.51. Boron, lithium, and nitrogen each have two stable isotopes. Use the average atomic masses of the elements to determine which isotope in each of the following pairs of stable isotopes is the more abundant. (a) ^{10}B or ^{11}B; (b) ^{6}Li or ^{7}Li; (c) ^{14}N or ^{15}N

2.52. Rubidium, gallium, and vanadium each have two stable isotopes. Use the average atomic masses of the elements to determine which isotope in each of the following pairs of stable isotopes is the more abundant. (a) ^{85}Rb or ^{87}Rb; (b) ^{69}Ga or ^{71}Ga; (c) ^{50}V or ^{51}V

2.53. Copper in nature is a mixture of 69.17% copper-63 (62.9296 amu) and 30.83% copper-65 (64.9278 amu). Use this information to calculate the average atomic mass of copper.

2.54. Sulfur in nature is a mixture of four isotopes: ^{32}S (31.9721 amu, 95.04%); ^{33}S (32.9715 amu, 0.75%); ^{34}S (33.9679 amu, 4.20%); and ^{36}S (35.9671 amu, 0.01%). Use this information to calculate the average atomic mass of sulfur.

2.55. **Chemistry of Mars** Chemical analyses conducted by the first Mars rover robotic vehicle in its 1997 mission produced the magnesium isotope data shown in the table that follows. Is the average atomic mass of magnesium in this Martian sample the same as on Earth (24.31 amu)?

Isotope	Mass (amu)	Natural Abundance (%)
^{24}Mg	23.9850	78.70
^{25}Mg	24.9858	10.13
^{26}Mg	25.9826	11.17

2.56. The natural abundances of the four isotopes of strontium are 0.56% ^{84}Sr (83.9134 amu), 9.86% ^{86}Sr (85.9094 amu), 7.00% ^{87}Sr (86.9089 amu), and 82.58% ^{88}Sr (87.9056 amu). Calculate the average atomic mass of strontium and compare it to the value in the periodic table inside the front cover.

2.57. Use the data in the following table of abundances and masses of the five stable titanium isotopes to calculate the atomic mass of ^{48}Ti.

Isotope	Mass (amu)	Natural Abundance (%)
^{46}Ti	45.9526	8.25
^{47}Ti	46.9518	7.44
^{48}Ti	?	73.72
^{49}Ti	48.94787	5.41
^{50}Ti	49.94479	5.18
Average	47.867	

2.58. Use the following table of abundances and masses of the stable isotopes of zirconium to calculate the atomic mass of ^{92}Zr.

Symbol	Mass (amu)	Natural Abundance (%)
^{90}Zr	89.905	51.45
^{91}Zr	90.906	11.22
^{92}Zr	?	17.15
^{94}Zr	93.906	17.38
^{96}Zr	95.908	2.80
Average	91.224	

2.59. What are the masses of the formula units of each of the following ionic compounds? (a) CaF_2; (b) Na_2S; (c) Cr_2O_3

2.60. What are the masses of the formula units of each of the following ionic compounds? (a) KCl; (b) MgO; (c) Al_2O_3

2.61. How many carbon atoms are there in one molecule of each of the following compounds? (a) CH_4; (b) C_3H_8; (c) C_6H_6; (d) $C_6H_{12}O_6$

2.62. How many hydrogen atoms are there in each of the molecules in Problem 2.61?

2.63. Rank the following compounds based on increasing molecular mass. (a) CO; (b) Cl_2; (c) CO_2; (d) NH_3; (e) CH_4

2.64. Rank the following compounds based on decreasing molecular mass. (a) H_2; (b) Br_2; (c) NO_2; (d) C_2H_2; (e) BF_3

Moles and Molar Masses

Concept Review

2.65. In principle, we could use the more familiar unit *dozen* in place of mole when expressing the quantities of particles (atoms, ions, or molecules). What would be the disadvantage in doing so?

2.66. In what way is the molar mass of an ionic compound the same as its formula mass, and in what ways are they different?

2.67. Do equal masses of two isotopes of an element contain the same number of atoms?

2.68. The natural abundances of the isotopes of an element are given in % by mass. Does the same percentage apply to the percent natural abundance by moles?

Problems

2.69. Earth's atmosphere contains many volatile substances that are present in trace amounts. The following quantities of trace gases were found in a 1.0 mL sample of air. Calculate the number of moles of each gas in the sample.

a. 4.4×10^{14} atoms of Ne

b. 4.2×10^{13} molecules of CH_4

c. 2.5×10^{12} molecules of O_3

d. 4.9×10^{9} molecules of NO_2

2.70. The following quantities of trace gases were found in a 1.0 mL sample of air. Calculate the number of moles of each compound in the sample.

a. 1.4×10^{13} molecules of H_2

b. 1.5×10^{14} atoms of He

c. 7.7×10^{12} molecules of N_2O

d. 3.0×10^{12} molecules of CO

2.71. How many moles of iron are there in 1 mole of the following compounds? (a) FeO; (b) Fe_2O_3; (c) $Fe(OH)_3$; (d) Fe_3O_4

2.72. How many moles of Na^+ ions are there in 1 mole of the following compounds? (a) NaCl; (b) Na_2SO_4; (c) Na_3PO_4; (d) $NaNO_3$

2.73. What is the mass of 0.122 mol of $MgCO_3$?

2.74. What is the volume of 1.00 mol of benzene (C_6H_6) at 20°C? The density of benzene at 20°C is 0.879 g/mL.

2.75. How many moles of titanium and how many atoms of titanium are there in 0.125 mole of each of the following? (a) ilmenite, $FeTiO_3$; (b) $TiCl_4$; (c) Ti_2O_3; (d) Ti_3O_5

2.76. How many moles of iron and how many atoms of iron are there in 2.5 moles of each of the following? (a) wolframite, $FeWO_4$; (b) pyrite, FeS_2; (c) magnetite, Fe_3O_4; (d) hematite, Fe_2O_3

2.77. Which substance in each of the following pairs of quantities contains more moles of oxygen?

a. 1 mol Al_2O_3 or 1 mol Fe_2O_3

b. 1 mol SiO_2 or 1 mol N_2O_4

c. 3 mol CO or 2 mol CO_2

2.78. Which substance in each of the following pairs of quantities contains more moles of oxygen?

a. 2 mol N_2O or 1 mol N_2O_5

b. 1 mol NO or 1 mol $Ca(NO_3)_2$

c. 2 mol NO_2 or 1 mol $NaNO_2$

2.79. **Elemental Composition of Minerals** Aluminum, silicon, and oxygen form minerals known as aluminosilicates. How many moles of aluminum are in 1.50 moles of the following?

a. pyrophyllite, $Al_2Si_4O_{10}(OH)_2$

b. mica, $KAl_3Si_3O_{10}(OH)_2$

c. albite, $NaAlSi_3O_8$

2.80. **Radioactive Minerals** The uranium used for nuclear fuel exists in nature in several minerals. Calculate how many moles of uranium are in 1 mole of the following.

a. carnotite, $K_2(UO_2)_2(VO_4)_2$

b. uranophane, $CaU_2Si_2O_{11}$

c. autunite, $Ca(UO_2)_2(PO_4)_2$

2.81. Calculate the molar masses of the following gases. (a) SO_2; (b) O_3; (c) CO_2; (d) N_2O_5

2.82. Determine the molar masses of the following minerals.

a. rhodonite, $MnSiO_3$

b. scheelite, $CaWO_4$

c. ilmenite, $FeTiO_3$

d. magnesite, $MgCO_3$

2.83. **Flavors** Calculate the molar masses of the following common flavors in food.

a. vanillin, $C_8H_8O_3$

b. oil of cloves, $C_{10}H_{12}O_2$

c. anise oil, $C_{10}H_{12}O$

d. oil of cinnamon, C_9H_8O

2.84. **Sweeteners** Calculate the molar masses of the following common sweeteners.

a. sucrose, $C_{12}H_{22}O_{11}$

b. saccharin, $C_7H_5O_3NS$

c. aspartame, $C_{14}H_{18}N_2O_5$

d. fructose, $C_6H_{12}O_6$

2.85. How many moles of carbon are there in 500.0 grams of carbon?

2.86. How many moles of gold are there in 2.00 ounces of gold?

2.87. How many moles of Ca^{2+} ions are in 0.25 mol $CaTiO_3$? What is the mass in grams of the Ca^{2+} ions?

2.88. How many moles of O^{2-} ions are in 0.55 mol Al_2O_3? What is the mass in grams of the O^{2-} ions?

2.89. Suppose pairs of balloons are filled with 10.0 g of the following pairs of gases. Which balloon in each pair has the greater number of particles? (a) CO_2 or NO; (b) CO_2 or SO_2; (c) O_2 or Ar

2.90. If you had equal masses of the substances in the following pairs of compounds, which of the two would contain the greater number of ions? (a) NaBr or KCl; (b) NaCl or $MgCl_2$; (c) $CrCl_3$ or Na_2S

2.91. How many moles of SiO_2 are there in a quartz crystal (SiO_2) that has a mass of 45.2 g?

2.92. How many moles of NaCl are there in a crystal of halite that has a mass of 6.82 g?

2.93. The density of uranium (U; 19.05 g/cm^3) is more than five times as great as that of diamond (C; 3.514 g/cm^3). If you have a cube (1 cm on a side) of each element, which cube contains more atoms?

*2.94. Aluminum (d = 2.70 g/cm^3) and strontium (d = 2.64 g/cm^3) have nearly the same density. If we manufacture two cubes, each containing 1 mol of one element or the other, which cube will be smaller? What are the dimensions of this cube?

Mass Spectrometry

Concept Review

2.95. How does mass spectrometry provide information on the molecular mass of a compound?

2.96. How are isotopic abundances reflected in the mass spectrum of HBr?

2.97. Would you expect the mass spectra of CO_2 and C_3H_8 to have molecular ions with the same mass (to the nearest amu)?

*2.98. Would you expect the mass spectra of CO_2 and C_3H_8 to be the same?

Problems

2.99. **Screening for Explosives** Many of the explosive materials of concern to airport security contain nitrogen and oxygen. Calculate the masses of the molecular ions formed by (a) $C_3H_6N_6O_6$, (b) $C_4H_8N_8O_8$, (c) $C_5H_8N_4O_{12}$, and (d) $C_{14}H_6N_6O_{12}$.

*2.100. **Landfill Gas** Mass spectrometry has proven useful in analyzing the gases emitted from landfills. The principal component is methane (CH_4), but small amounts of dimethylsulfide (C_2H_6S) and dichloroethene ($C_2H_2Cl_2$) are often present, too. Calculate the masses of the molecular ions formed by these three compounds in a mass spectrometer.

2.101. The mass spectrum of chlorine, Cl_2, is shown in Figure P2.101. The natural abundances of its two stable isotopes are 75.78% ^{35}Cl and 24.22% ^{37}Cl.

a. Why are there peaks in the mass spectrum at 70, 72, and 74 amu?

b. Why is the peak at 70 amu so much taller than the peak at 74 amu?

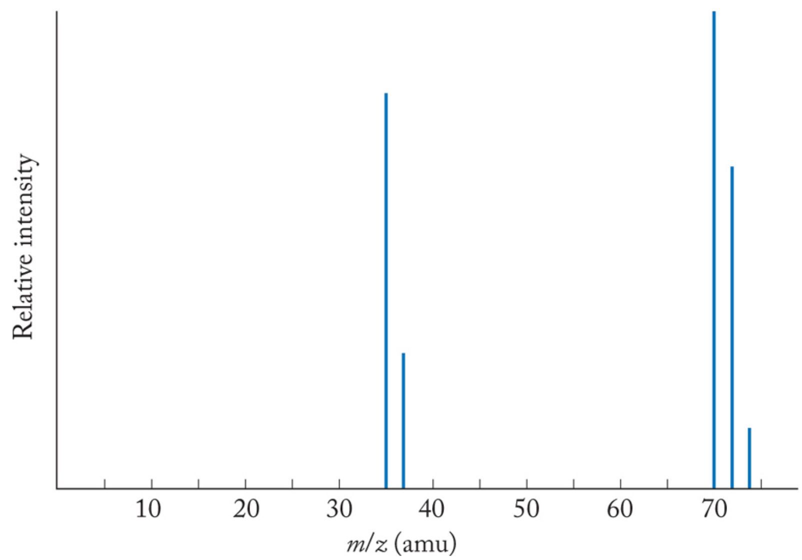

FIGURE P2.101

2.102. The mass spectrum of bromine, Br_2, is shown in Figure P2.102. The natural abundances of its two stable isotopes are 50.69% ^{79}Br and 49.31% ^{81}Br.

a. Why are there peaks in the mass spectrum at 158, 160, and 162 amu?

*b. How do we know that bromine doesn't have a third isotope, ^{80}Br?

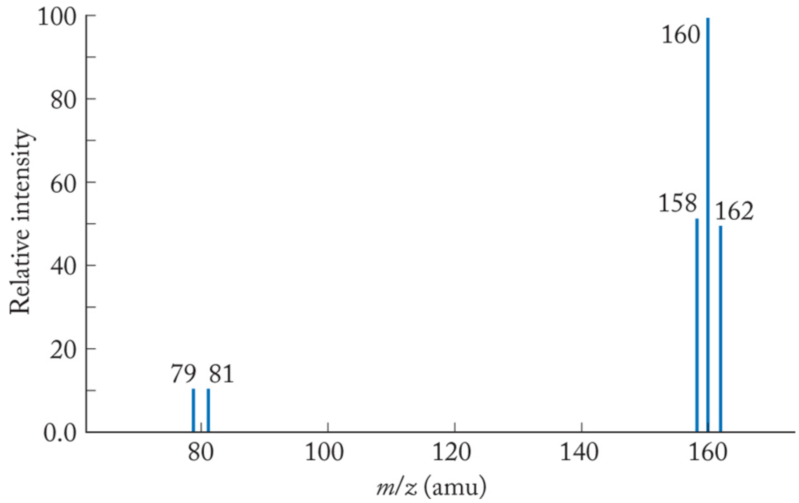

FIGURE P2.102

***2.103.** **Sewer Gas** Hydrogen sulfide, H_2S, is a foul-smelling and toxic gas that may be present in wastewater sewers. Although the human nose detects H_2S in low concentrations, prolonged exposure to H_2S deadens our sense of smell, making it particularly dangerous to sewer workers who work in poorly ventilated areas. Sulfur in nature is a mixture of four isotopes: ^{32}S (94.93%), ^{33}S (0.76%), ^{34}S (4.29%), and ^{35}S (0.02%). Explain how the relative intensities of the peaks in the mass spectrum of H_2S (Figure P2.103) reflect the natural abundance of sulfur isotopes and the sequential loss of H atoms from molecules of H_2S.

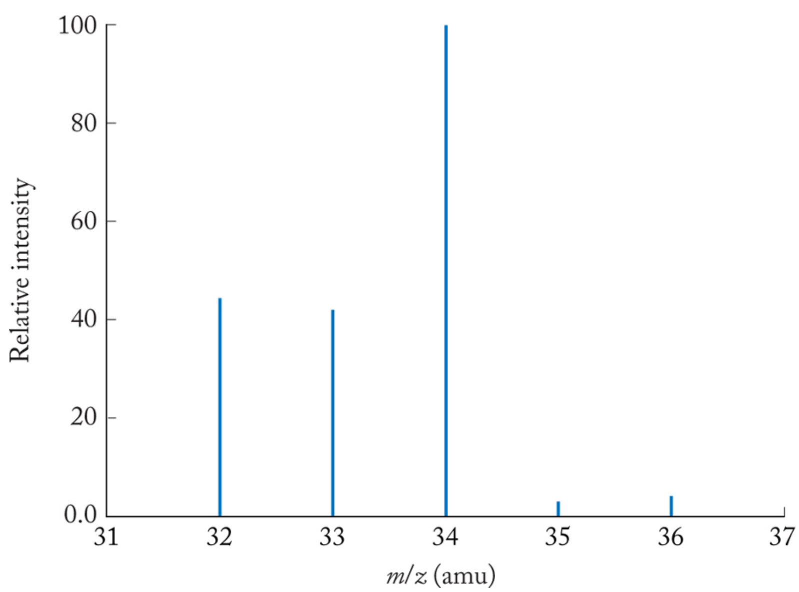

FIGURE P2.103

*2.104. **Bar Code Readers** Arsine, AsH_3, is a hazardous gas used in the manufacture of electronic devices, including the bar code readers used at the checkout counters of many stores. The mass spectrum of arsine is shown in Figure P2.104. Arsenic has only one stable isotope. What are the formulas of the ions responsible for the four peaks in the mass spectrum?

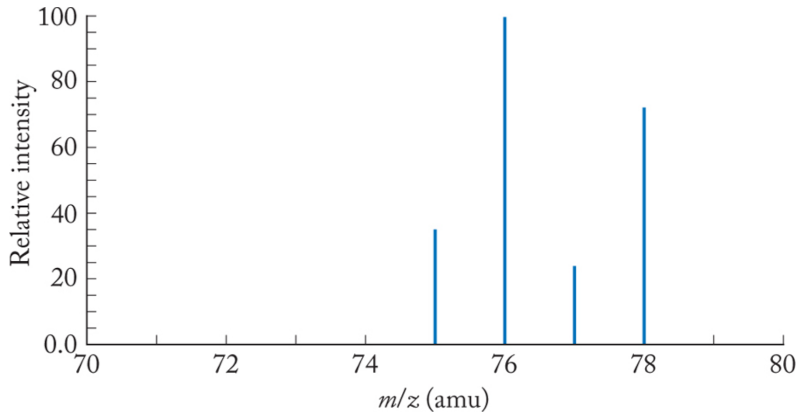

FIGURE P2.104

2.105. **Detecting Illegal Drugs** In July 2015, researchers in Britain reported on a new method for detecting cocaine on fingertips using mass spectrometry. The mass spectrum of cocaine is shown in Figure P2.105. What is the molar mass of cocaine?

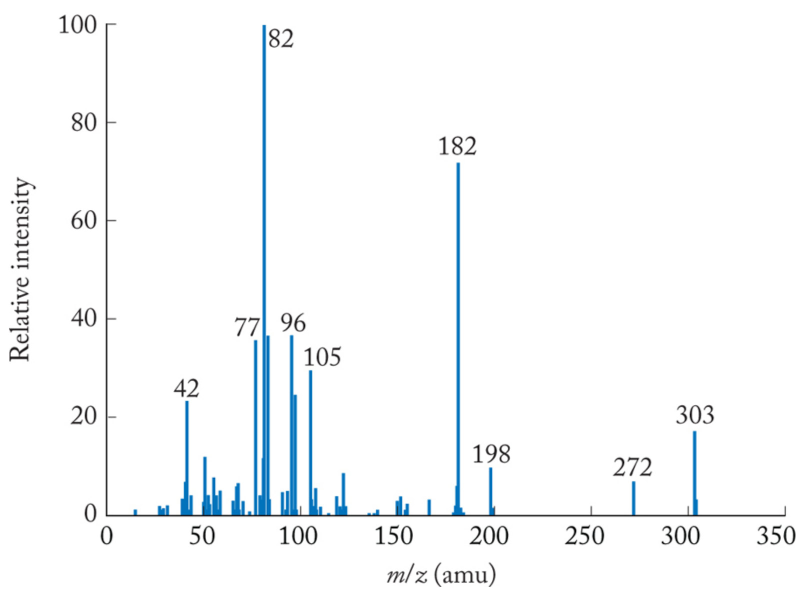

FIGURE P2.105

*2.106. Many main group elements form molecular compounds of general formula $(CH_3)_nM$, where n is a simple whole number. The mass spectrum of the compound where M = Sb is shown in Figure P2.106. The natural abundances of the two stable isotopes of antimony are 57.25% ^{121}Sb and 42.75% ^{123}Sb. What is the value of n in $(CH_3)_nSb$?

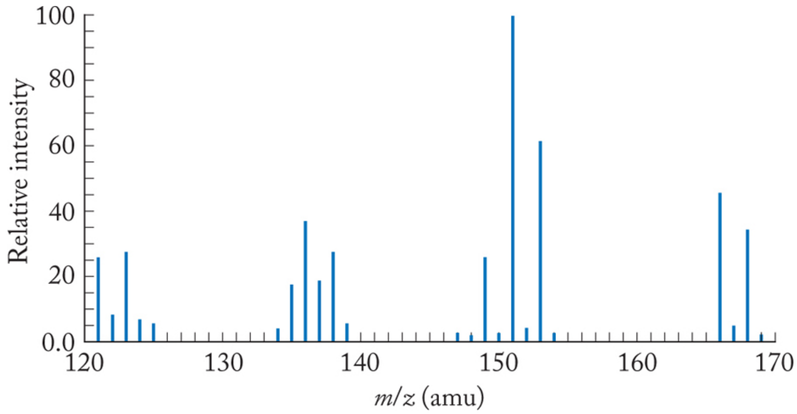

FIGURE P2.106

Additional Problems

2.107. In April 1897, J. J. Thomson presented the results of his experiment with cathode-ray tubes in which he proposed that the rays were actually beams of negatively charged particles, which he called "corpuscles."

a. What is the name we use for the particles today?

b. Why did the beam deflect when passed between electrically charged plates?

c. If the polarity of the plates were switched, how would the position of the light spot on the phosphorescent screen change?

2.108. Strontium has four isotopes: ^{84}Sr, ^{86}Sr, ^{87}Sr, and ^{88}Sr.

a. How many neutrons are there in an atom of each isotope?

b. Use the data in the following table to calculate the natural abundances of ^{87}Sr and ^{88}Sr.

Isotope	Mass (amu)	Natural Abundance (%)
^{84}Sr	83.9134	0.56
^{86}Sr	85.9094	9.86
^{87}Sr	86.9089	?
^{88}Sr	87.9056	?

Average	87.621

2.109. There are three stable isotopes of magnesium. Their masses are 23.9850, 24.9858, and 25.9826 amu. If the average atomic mass of magnesium is 24.3050 amu and the natural abundance of the lightest isotope is 78.99%, what are the natural abundances of the other two isotopes?

2.110. Without consulting a periodic table, give the atomic number (Z) for each of the highlighted elements in Figure P2.110.

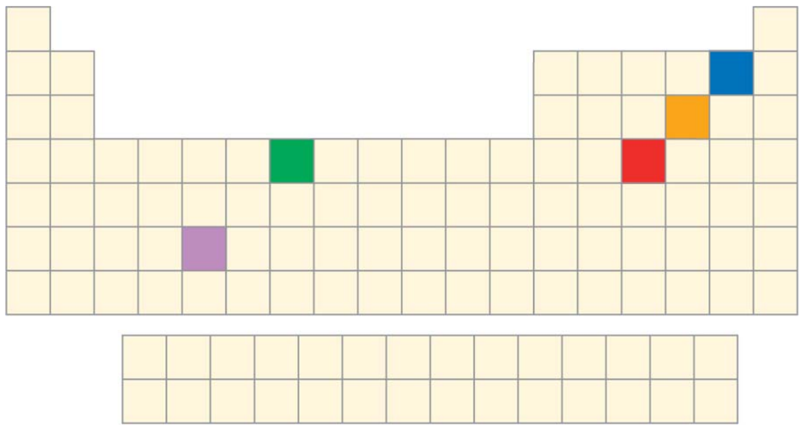

FIGURE P2.110

2.111. **Silver Nanoparticles in Clothing** The antimicrobial properties of silver metal have led to the use of silver nanoparticles in clothing (Figure P2.111) to reduce odors. If a silver nanoparticle with a diameter of 1×10^{-7} m contains 4.8×10^{7} atoms of Ag, how many nanoparticles are in 1.00 g?

FIGURE P2.111

2.112. **HD Television** Some newer television sets utilize nanoparticles of cadmium sulfide (CdS) and cadmium selenide (CdSe), called "quantum dots," to produce the colors on the screen. Different-sized quantum dots lead to different colors.

a. Calculate the formula masses of CdS and CdSe.

b. If a nanoparticle of CdSe contains 2.7×10^{7} atoms of Cd, how many atoms of Se are in the particle?

c. If a nanoparticle of CdS weighs 4.3×10^{-15} g, how many grams of Cd and how many grams of S does it contain?

***2.113.** **Greenhouse Gas Concentrations** Samples of air are collected daily at the Mauna Loa Observatory in Hawaii and analyzed for CO_2 content. During January 2016, the average result of these analyses was 402.5 μmoles (10^{-6} moles) of CO_2 per mole of air. If the average molar mass of the gases in air is 28.8 g/mol, how many μg of CO_2 per gram of air were in these samples?

2.114. **Performance-Enhancing Drugs** Mass spectrometry is used to detect performance-enhancing drugs in body fluids. Included on the list of banned substances for Olympic athletes is tetrahydrogestrinone, a compound that mimics the steroid testosterone and can be used to build muscle. The mass spectrum of tetrahydrogestrinone is shown in Figure P2.114. Identify the molecular ion and show that it has a mass consistent with the formula $C_{21}H_{28}O_2$.

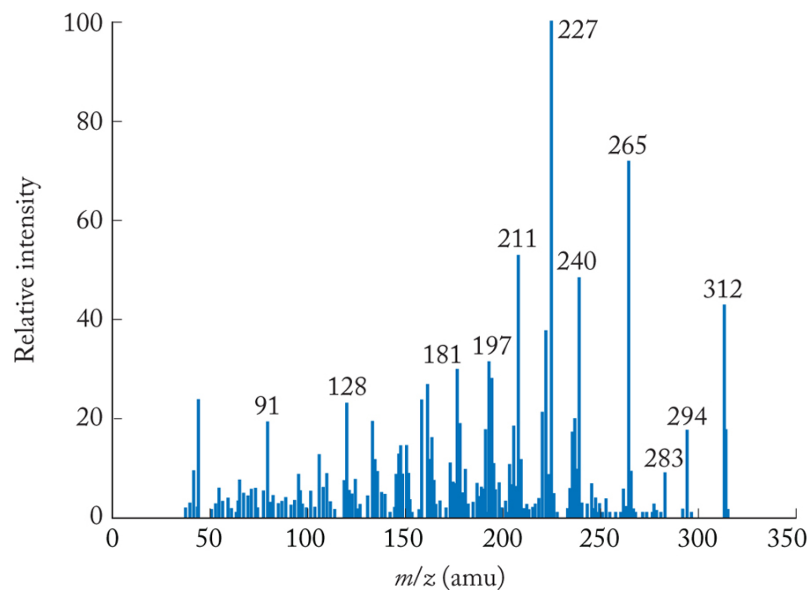

FIGURE P2.114

2.115. **Hope Diamond** The Hope Diamond (Figure P2.115) at the Smithsonian National Museum of Natural History has a mass of 45.52 carats.

a. How many moles of carbon are in the Hope Diamond (1 carat = 200 mg)?

b. How many carbon atoms are in the diamond?

FIGURE P2.115

2.116. Suppose we know the atomic mass of each of the three stable isotopes of an element to six significant figures, and we know the natural abundances of the isotopes to the nearest 0.01%. How well can we know the average atomic mass—that is, how many significant figures should be used to express its value?