QUESTIONS AND PROBLEMS

The Rutherford Model of Atomic Structure

CONCEPT REVIEW

2.9. 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.
2.10. 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?
2.11. What properties of cathode rays led Thomson to conclude that they were not pure energy, but rather particles with an electric charge?
*2.12. Alpha particles, with a charge of 2+ and a mass of 4 amu, are actually helium nuclei. The element helium was first discovered in a sample of pitchblende, an ore of radioactive uranium oxide. How did helium get in the ore?

Isotopes; Average Atomic Mass

CONCEPT REVIEW

2.13. What is meant by a *weighted average*?
2.14. Explain how percent natural abundances are related to average atomic masses.

PROBLEMS

2.15. If the mass number of an isotope is more than twice the atomic number, is the neutron-to-proton ratio less than, greater than, or equal to 1?
2.16. In each of the following pairs of isotopes, which isotope has more protons and which has more neutrons? (a) ^{127}I or ^{131}I; (b) ^{188}Re or ^{188}W; (c) ^{14}N or ^{14}C

2.17. Boron, lithium, nitrogen, and neon each have two stable isotopes. In which of the following pairs of isotopes is the heavier isotope more abundant?
a. ^{10}B or ^{11}B (average atomic mass, 10.81 amu)
b. ^{6}Li or ^{7}Li (average atomic mass, 6.941 amu)
c. ^{14}N or ^{15}N (average atomic mass, 14.01 amu)
d. ^{20}Ne or ^{22}Ne (average atomic mass, 20.18 amu)
2.18. Naturally occurring copper contains a mixture of 69.17% copper-63 (62.9296 amu) and 30.83% copper-65 (64.9278 amu). What is the average atomic mass of copper?

2.19. Naturally occurring chlorine consists of two isotopes: 75.78% ^{35}Cl, and 24.22% ^{37}Cl. Calculate the average atomic mass of chlorine.
2.20. Naturally occurring sulfur consists of four isotopes: ^{32}S (31.97207 amu, 95.04%); ^{33}S (32.97146 amu, 0.75%); ^{34}S (33.96787 amu, 4.20%); and ^{36}S (35.96708 amu, 0.01%). Calculate the average atomic mass of sulfur in atomic mass units.

2.21. Chemistry of Mars The 1997 mission to Mars included a small robot, the Sojourner, which analyzed the composition of Martian rocks. Magnesium oxide from a boulder dubbed “Barnacle Bill” was analyzed and found to have the following isotopic composition:

Mass (amu)	Natural Abundance (%)
39.9872	78.70
40.9886	10.13
41.9846	11.17

If essentially all of the oxygen in the Martian MgO sample is oxygen-16 (which has an exact mass of 15.9948 amu), is the average atomic mass of magnesium on Mars the same as on Earth (24.31 amu)?

2.22. Using the following table of abundances and masses of the three naturally occurring argon isotopes, calculate the mass of ^{40}Ar.

Symbol	Mass (amu)	Natural Abundance (%)
^{36}Ar	35.96755	0.337
^{38}Ar	37.96272	0.063
^{40}Ar	?	99.60
Average	39.948	

2.23. From the following table of abundances and masses of five naturally occurring titanium isotopes, calculate the mass of ^{48}Ti.

Symbol	Mass (amu)	Natural Abundance (%)
^{46}Ti	45.95263	8.25
^{47}Ti	46.9518	7.44
^{48}Ti	?	73.72
^{49}Ti	48.94787	5.41
^{50}Ti	49.9448	5.18
Average	47.87	

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

a. How many neutrons are there in each isotope?

b. The natural abundances of the four isotopes 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 on the inside front cover.

The Periodic Table of the Elements

CONCEPT REVIEW

2.25. Mendeleev ordered the elements in his version of the periodic table on the basis of their atomic masses instead of their atomic numbers. Why?

2.26. Why did Mendeleev not include the noble gases in his version of the periodic table?

PROBLEMS

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

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

2.29. Fill in the missing information in the following table of four neutral atoms:

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 in the following table of four neutral atoms:

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 in the following table of ions:

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 in the following table of ions:

Symbol:	$^{137}Ba^{2+}$	?	?	?
Number of protons:	?	30	?	40
Number of neutrons:	?	34	16	?
Number of electrons:	?	28	18	36
Mass number:	?	?	32	90

2.33. Which element is most likely to form a cation with a 2+ charge? (a) S; (b) P; (c) Be; (d) Al
2.34. Which element is most likely to form an anion with a 2– charge? (a) S; (b) P; (c) Be; (d) Al

2.35. Which species contains the greatest number of electrons? (a) F; (b) O^{2-}; (c) S^{2-}; (d) Cl
2.36. Which species contains the smallest number of electrons? (a) F; (b) O^{2-}; (c) S^{2-}; (d) Cl

2.37. Which ion has the same number of electrons as an atom of argon? (a) S^{2-}; (b) P^{3-}; (c) Be^{2+}; (d) Ca^{2+}
2.38. Which ion has the same number of electrons as an atom of krypton? (a) Se^{2-}; (b) As^{3-}; (c) Ca^{2+}; (d) K^+

2.39. Which element is a nonmetal? (a) Si; (b) Br; (c) Ca; (d) Ru
2.40. Which element is a metalloid? (a) Si; (b) Br; (c) Ca; (d) Ru

Trends in Compound Formation

CONCEPT REVIEW

2.41. Cations in Blood and Urine Reports from standard blood and urine tests indicate the amounts of sodium, potassium, calcium, and magnesium cations present. Chloride ion is the most abundant anion in both blood and urine; urine also contains some sulfate ion. Write formulas for the chlorides and sulfates of the four cations.
2.42. Explain why the law of constant composition is classified a scientific *law*, whereas Dalton's view of the atomic structure of matter is classified a scientific *theory*.
2.43. How does Dalton's atomic theory of matter explain the fact that when water is decomposed into hydrogen and oxygen gas, the volume of hydrogen is always twice that of oxygen?
2.44. Pollutants in Automobile Exhaust In the internal combustion engines that power most automobiles, nitrogen and oxygen may combine to form NO. When NO in automobile exhaust is released into the atmosphere, it reacts with more oxygen, forming NO_2, a key ingredient in smog. How do these reactions illustrate Dalton's law of multiple proportions?

PROBLEMS

2.45. Cobalt forms two sulfides: CoS and Co_2S_3. Predict the ratio of the two masses of sulfur that combine with a fixed mass of cobalt to form CoS and Co_2S_3.

2.46. Lead forms two oxides: PbO and PbO_2. Predict the ratio of the two masses of oxygen that combine with a fixed mass of lead to form PbO and PbO_2.

2.47. When 5.0 grams of sulfur is combined with 5.0 grams of oxygen, 10.0 grams of sulfur dioxide is formed. What mass of oxygen would be required to convert 5.0 grams of sulfur into sulfur trioxide?

*2.48. Nitrogen monoxide (NO) is 46.7% nitrogen by mass. Use the law of multiple proportions to calculate the mass percentage of nitrogen in nitrogen dioxide (NO_2).

2.49. Seawater The most abundant anion in seawater is the chloride ion. Write the formulas for the chlorides and sulfates of the most abundant cations in seawater: sodium, magnesium, calcium, potassium, and strontium.

2.50. The most abundant cation in seawater is the sodium ion. The evaporation of seawater gives a mixture of ionic compounds containing sodium combined with chloride, sulfate, carbonate, bicarbonate, bromide, fluoride, and tetrahydroxyborate, $B(OH)_4^-$. Write the chemical formulas of all these compounds.

2.51. Which of these compounds consist of molecules and which consist of ions? (a) CH_3COOH; (b) $SrCl_2$; (c) $MgCO_3$; (d) H_2SO_4

2.52. Which of these compounds consist of molecules, and which consist of ions? (a) LiOH; (b) $Ba(NO_3)_2$; (c) HNO_3; (d) $CH_3(CH_2)_3OH$

Naming Compounds and Writing Formulas

CONCEPT REVIEW

2.53. Consider a mythical element X, which forms only two oxoanions: XO_2^{2-} and XO_3^{2-}. Which of the two has a name that ends in *-ite*?

2.54. Concerning the oxoanions in Problem 2.53, would the name of either of them require a prefix such as *hypo*- or *per*-? Explain why or why not.

2.55. What is the role of Roman numerals in the names of the compounds formed by transition metals?

2.56. Why do the names of the ionic compounds formed by the alkali metals and by the alkaline earth metals not include Roman numerals?

PROBLEMS

2.57. Toxicity of Nitrogen Oxides Nitrogen oxides form naturally during the combustion of nitrogen-containing compounds such as coal, diesel fuel, and green plants. Small quantities of all except N_2O (laughing gas) are irritating to eyes, skin, and the respiratory tract. Name the binary compounds of nitrogen and oxygen: (a) NO_3; (b) N_2O_5; (c) N_2O_4; (d) NO_2; (e) N_2O_3; (f) NO; (g) N_2O; (h) N_4O.

2.58. More than a dozen binary compounds containing sulfur and oxygen have been identified. Give the chemical formulas for the following six:

a. sulfur monoxide	d. disulfur monoxide
b. sulfur dioxide	e. hexasulfur monoxide
c. sulfur trioxide	f. heptasulfur dioxide

2.59. Predict the formula and give the name of the binary ionic compound containing the following:

a. sodium and sulfur	c. aluminum and oxygen
b. strontium and chlorine	d. lithium and hydrogen

2.60. Predict the formula and give the name of the binary ionic compound containing the following:

a. potassium and bromine	c. lithium and nitrogen
b. calcium and hydrogen	d. aluminum and chlorine

2.61. Give the chemical names of the cobalt oxides that have the following formulas: (a) CoO; (b) Co_2O_3; (c) CoO_2.

2.62. Give the formula of each of the following copper minerals:
a. cuprite, copper(I) oxide
b. chalcocite, copper(I) sulfide
c. covellite, copper(II) sulfide

2.63. Give the formula and charge of the oxoanion in each of the following compounds:
a. sodium hypobromite
b. potassium sulfate
c. lithium iodate
d. magnesium nitrite

*2.64. Give the formula and charge of the oxoanion in each of the following compounds:
a. potassium tellurite
b. sodium arsenate
c. calcium selenite
d. potassium chlorate

2.65. Give chemical names of the following ionic compounds: (a) $NiCO_3$; (b) NaCN; (c) $LiHCO_3$; (d) $Ca(ClO)_2$.

2.66. Give chemical names of the following ionic compounds: (a) $Mg(ClO_4)_2$; (b) NH_4NO_3; (c) $Cu(CH_3COO)_2$; (d) K_2SO_4.

2.67. Give the name or chemical formula of each of the following acids: (a) HF; (b) $HBrO_3$; (c) phosphoric acid; (d) nitrous acid.

2.68. Give the name or chemical formula of each of the following acids: (a) HBr; (b) HIO_4; (c) selenous acid; (d) hydrocyanic acid.

2.69. Name these compounds: (a) Na_2O; (b) Na_2S; (c) Na_2SO_4; (d) $NaNO_3$; (e) $NaNO_2$.

2.70. Name these compounds: (a) K_3PO_4; (b) K_2O; (c) K_2SO_3; (d) KNO_3; (e) KNO_2.

2.71. Write the chemical formulas of these compounds:
a. potassium sulfide
b. potassium selenide
c. rubidium sulfate
d. rubidium nitrite
e. magnesium sulfate

2.72. Write the chemical formulas of these compounds:
a. rubidium nitride
b. potassium selenite
c. rubidium sulfite
d. rubidium nitrate
e. magnesium sulfite

2.73. Name these compounds: (a) MnS; (b) V_3N_2; (c) $Cr_2(SO_4)_3$; (d) $Co(NO_3)_2$; (e) Fe_2O_3.

2.74. Name these compounds: (a) RuS; (b) $PdCl_2$; (c) Ag_2O; (d) WO_3; (e) PtO_2.

2.75. Which compound is sodium sulfite? (a) Na_2S; (b) Na_2SO_3; (c) Na_2SO_4; (d) NaHS

2.76. Which compound is calcium nitrate? (a) Ca_3N_2; (b) Ca_2NO_3; (c) $Ca_2(NO_3)_2$; (d) $Ca(NO_3)_2$

2.77. Which element is a halogen? (a) N_2; (b) Cl_2; (c) Xe; (d) H_2

2.78. Which element is a noble gas? (a) N_2; (b) Cl_2; (c) Xe; (d) I_2

2.79. Which element is an alkali metal? (a) Na; (b) Cl_2; (c) Xe; (d) Br_2

2.80. Which element is an alkaline earth metal? (a) Na; (b) Ca; (c) Xe; (d) H_2

Nucleosynthesis

CONCEPT REVIEW

2.81. Write brief (one-sentence) definitions of *chemistry* and *cosmology*, and then give as many examples as you can of how the two sciences are related.

2.82. In the history of the universe, which of these particles formed first and which formed last? (a) deuteron; (b) neutron; (c) proton; (d) quark

2.83. Chemists don't include quarks in the category of subatomic particles—can you think of a reason why?

2.84. Why did early nucleosynthesis last such a short time?

2.85. In the current cosmological model, the volume of the universe is increasing with time. How might this expansion affect the density of the universe?

2.86. Components of Solar Wind Most of the ions that flow out from the sun in the solar wind are hydrogen ions. The ions of which element should be next most abundant?

2.87. Nucleosynthesis in Giant Stars A star needs a core temperature of about 10^7 K for hydrogen fusion to occur. Core temperatures above 10^8 K are needed for helium fusion. Why does helium fusion require much higher - temperatures?

2.88. Why was the triple-alpha process unlikely to happen in a rapidly cooling universe soon after the Big Bang?

***2.89.** It takes nearly twice the energy to remove an electron from a helium atom as it does to remove an electron from a hydrogen atom. Propose an explanation for this.

2.90. Origins of the Elements Our sun contains carbon even though its core is not hot or dense enough to sustain carbon synthesis through the triple-alpha process. Where could the carbon have come from?

2.91. Early nucleosynthesis produced a universe that was more than 99% hydrogen and helium with less than 1% lithium. Why were the other elements not formed?

2.92. What is the effect of b decay on the ratio of neutrons to protons in a nucleus?

PROBLEMS

2.93. What nuclide is produced in the core of a giant star by each of the following fusion reactions?

a. ${}^{12}_{6}\mathrm{C} + {}^{4}_{2}\alpha \rightarrow$ b. ${}^{20}_{10}\mathrm{Ne} + {}^{4}_{2}\alpha \rightarrow$ c. ${}^{32}_{16}\mathrm{S} + {}^{4}_{2}\alpha \rightarrow$

2.94. What nuclide is produced in the core of a giant star by each of the following fusion reactions?

a. ${}^{28}_{14}\mathrm{Si} + {}^{4}_{2}\alpha \rightarrow$ b. ${}^{40}_{20}\mathrm{Ca} + {}^{4}_{2}\alpha \rightarrow$ c. ${}^{24}_{12}\mathrm{Mg} + {}^{4}_{2}\alpha \rightarrow$

2.95. What nuclide is produced in the core of a collapsing giant star by each of the following reactions?

a. ${}^{56}_{26}\mathrm{Fe} + 3\,{}^{1}_{0}\mathrm{n} \rightarrow$ ___ $+ {}^{0}_{-1}\beta$

b. ${}^{118}_{50}\mathrm{Sn} + 3\,{}^{1}_{0}\mathrm{n} \rightarrow$ ___ $+ {}^{0}_{-1}\beta$

c. ${}^{108}_{47}\mathrm{Ag} + {}^{1}_{0}\mathrm{n} \rightarrow$ ___ $+ {}^{0}_{-1}\beta$

2.96. What nuclide is produced in the core of a collapsing giant star by each of the following reactions?

a. ${}^{65}_{29}\mathrm{Cu} + 3\,{}^{1}_{0}\mathrm{n} \rightarrow$ ___ $+ {}^{0}_{-1}\beta$

b. ${}^{68}_{30}\mathrm{Zn} + 2\,{}^{1}_{0}\mathrm{n} \rightarrow$ ___ $+ {}^{0}_{-1}\beta$

c. ${}^{88}_{38}\mathrm{Sr} + {}^{1}_{0}\mathrm{n} \rightarrow$ ___ $+ {}^{0}_{-1}\beta$

2.97. Radioactive ^{137}I decays to ^{137}Xe, which is also radioactive and decays to ^{137}Cs. Do either, or both, of these decay processes involve emission of a b particle?

2.98. Isotopes in Geochemistry The relative abundances of the stable isotopes of the elements are not entirely constant. For example, in some geological samples (soils and rocks) the ratio of ^{87}Sr to ^{86}Sr is affected by the presence of a radioactive isotope of another element, which slowly undergoes b decay to produce more ^{87}Sr. What is this other isotope?

Additional Problems

2.99. In April 1897, J. J. Thomson presented the results of his experiment with cathode-ray tubes (Figure P2.99) 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 these particles today?
b. Why did the beam deflect when passed between electrically charged plates, as shown in Figure P2.99?
c. If the polarity of the plates were switched, how would the position of the light spot on the phosphorescent screen change?
d. If the voltage on the plates were reduced by half, how would the position of the light spot change?

FIGURE P2.99

*2.100. Suppose the electrically charged discs at the end of the cathode-ray tube were replaced with a radioactive source, as shown in Figure P2.100. Also suppose the radioactive material inside the source emits a and b particles, plus rays of energy with no charge. The only way for any of the three kinds of particles or rays to escape the source is through a narrow channel drilled through a block of lead.

a. How many light spots do you expect to see on the phosphorescent screen?
b. What are their positions relative to the electrical plates, and which particle produces which spot?

FIGURE P2.100

***2.101.** Suppose the radioactive material inside the source in the apparatus shown in Figure P2.100 emits protons and a particles, and suppose both kinds of particles have the same velocities.

a. How many light spots do you expect to see on the phosphorescent screen?
b. What are their positions on the screen (above, at, or below the center)? Which particle produces which spot?

2.102. Cosmologists estimate that the matter in the early universe was 75% by mass hydrogen-1 and 25% helium-4 when atoms first formed.

a. Assuming these proportions are correct, what was the ratio of hydrogen to helium *atoms* in the early universe?
b. The ratio of hydrogen to helium atoms in our solar system is slightly less than 10:1. Compare this value with the value you calculated in part a.
c. Propose a hypothesis that accounts for the difference in composition between the solar system and the early - universe.
d. Describe an experiment that would test your hypothesis.

2.103. Sources of Breathable Air Potassium forms three compounds with oxygen: K_2O (potassium oxide), K_2O_2 (potassium peroxide), and KO_2 (potassium superoxide). Potassium is rarely encountered; it reacts violently with water and is very corrosive to human tissue. Potassium superoxide is used in self-contained breathing apparatus as a source of oxygen in mines, submarines, and spacecraft. Potassium peroxide binds carbon dioxide and is used to scrub (remove) toxic CO_2 from the air in submarines. Predict the ratio of the masses of oxygen that combine with a fixed mass of potassium in K_2O, K_2O_2, and KO_2.

2.104. Stainless Steel The gleaming metallic appearance of the Gateway Arch (Figure P2.104) in St. Louis, Missouri, comes from the stainless steel used in its construction. This steel is made mostly of iron but it also contains 19% by mass chromium and 9% by mass nickel.

a. Stainless steel maintains its metallic sheen because the chromium and nickel in it combine with oxygen from the atmosphere, forming a layer of Cr_2O_3 and NiO that is too thin to detract from the luster of the steel but that protects the metal beneath from further corrosion. What are the names of these two ionic compounds?
b. What are the charges of the cations in Cr_2O_3 and NiO?

FIGURE P2.104

2.105. Bronze Age Historians and archaeologists often apply the term "Bronze Age" to the period in Mediterranean and Middle Eastern history when bronze was the preferred material for making weapons, tools, and other metal objects. Ancient bronze was an alloy prepared by blending molten copper (90%) and tin (10%) by mass. What is the ratio of copper to tin atoms in a piece of bronze with this composition?

*2.106. In his version of the periodic table, Mendeleev arranged elements based on the formulas of the compounds they formed with hydrogen and oxygen. The elements in one of his eight groups formed compounds with these generic formulas: MH_3 and M_2O_5, where M is the symbol of an element in the group. Which Roman numeral did Mendeleev assign to this group?

2.107. In the Mendeleev table in Figure 2.9, there are no symbols for elements with predicted atomic masses of 44, 68, and 72.

a. Which elements are these?
b. Mendeleev anticipated the later discovery of these three elements and gave them tentative names: ekaaluminum, ekaboron, and ekasilicon, reflecting the probability that their properties would resemble those of aluminum, boron, and silicon, respectively. What are the modern names of ekaaluminum, ekaboron, and ekasilicon?

c. When were these elements finally discovered? To answer this question you may wish to consult a reference such as webelements.com.

2.108. Medical and Commercial Compounds Many common compounds have old-fashioned, nonsystematic names or newer commercial names that are widely used. Search for the systematic names and chemical formulas of compounds with these nonsystematic names: (a) magnesia; (b) Epsom salt; (c) K-Dur; (d) lime; (e) baking soda; (f) caustic soda; (g) muriatic acid; (h) zirconia.

***2.109.** The ruby shown in Figure P2.109 has a mass of 12.04 carats (1 carat = 200.0 mg). Rubies are made of a crystalline form of Al_2O_3.

a. What percentage of the mass of the ruby is aluminum?

b. The density of rubies is 4.02 g/cm^3. What is the volume of the ruby?

FIGURE P2.109

2.110. In chemical nomenclature, the prefix *thio*- is used to indicate that a sulfur atom has replaced an oxygen atom in the structure of a molecule or a polyatomic ion.

a. With this rule in mind, write the formula for the thiosulfate ion.

b. What is the formula of sodium thiosulfate?

2.111. There are two stable isotopes of gallium. Their masses are 68.92558 and 70.9247050 amu. If the average atomic mass of gallium is 69.7231 amu, what is the natural abundance of the lighter isotope?

2.112. There are two stable isotopes of bromine. Their masses are 78.9183 and 80.9163 amu. If the average atomic mass of bromine is 79.9091 amu, what is the natural abundance of the heavier isotope?

***2.113.** Start with the information in the previous question, and then do the following:

a. Predict the possible masses of individual molecules of Br_2.

b. Calculate the natural abundance of molecules with each of the masses predicted in part a in a sample of Br_2.

*2.114. 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?

Additional study materials including ChemTours and Diagnostic Quizzes are available at StudySpace at www.wwnorton.com/studyspace.