

- neutrons have roughly the same mass, which is about 1840 times greater than the mass of an electron.
- The atomic number of an element is the number of protons in the nucleus of an atom of the element; it determines the identity of an element. The mass number is the sum of the number of protons and the number of neutrons in the nucleus. Isotopes are atoms of the same element that have the same number of protons but different numbers of neutrons.
  - Chemical formulas combine the symbols for the constituent elements with whole-number subscripts to show the type and number of atoms contained in the smallest unit of a compound. The molecular formula conveys the specific number and types of atoms combined in each

molecule of a compound. The empirical formula shows the simplest ratios of the atoms in a molecule.

- Chemical compounds are either molecular compounds (in which the smallest units are discrete, individual molecules) or ionic compounds (in which positive and negative ions are held together by mutual attraction). Ionic compounds are made up of cations and anions, formed when atoms lose electrons and gain electrons, respectively.
- The names of many inorganic compounds can be deduced from a set of simple rules. The formulas can be written from the names of the compounds.
- The simplest type of organic compounds is the hydrocarbons.

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## QUESTIONS AND PROBLEMS

### Structure of the Atom

#### Review Questions

- Define these terms: (a)  $\alpha$  particle, (b)  $\beta$  particle, (c)  $\gamma$  ray, (d) X ray.
- List the types of radiation that are known to be emitted by radioactive elements.
- Compare the properties of:  $\alpha$  particles, cathode rays, protons, neutrons, and electrons. What is meant by the term "fundamental particle"?
- Describe the contributions of these scientists to our knowledge of atomic structure: J. J. Thomson, R. A. Millikan, Ernest Rutherford, James Chadwick.
- A sample of a radioactive element is found to be losing mass gradually. Explain what is happening to the sample.

- Describe the experimental basis for believing that the nucleus occupies a very small fraction of the volume of the atom.

#### Problems

- The diameter of a neutral helium atom is about  $1 \times 10^2$  pm. Suppose that we could line up helium atoms side by side in contact with one another. Approximately how many atoms would it take to make the distance from end to end 1 cm?
- Roughly speaking, the radius of an atom is about 10,000 times greater than that of its nucleus. If an atom were magnified so that the radius of its nucleus became 10 cm, what would be the radius of the atom in miles? (1 mi = 1609 m.)

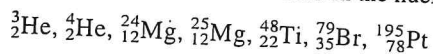
## Atomic Number, Mass Number, and Isotopes

### Review Questions

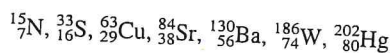
- 2.9 Define these terms: (a) atomic number, (b) mass number. Why does a knowledge of atomic number enable us to deduce the number of electrons present in an atom?
- 2.10 Why do all atoms of an element have the same atomic number, although they may have different mass numbers? What do we call atoms of the same element with different mass numbers? Explain the meaning of each term in the symbol  ${}^A_ZX$ .

### Problems

- 2.11 What is the mass number of an iron atom that has 28 neutrons?
- 2.12 Calculate the number of neutrons of  ${}^{239}\text{Pu}$ .
- 2.13 For each of these species, determine the number of protons and the number of neutrons in the nucleus:



- 2.14 Indicate the number of protons, neutrons, and electrons in each of these species:



- 2.15 Write the appropriate symbol for each of these isotopes: (a)  $Z = 11, A = 23$ ; (b)  $Z = 28, A = 64$ .
- 2.16 Write the appropriate symbol for each of these isotopes: (a)  $Z = 74, A = 186$ ; (b)  $Z = 80, A = 201$ .

## The Periodic Table

### Review Questions

- 2.17 What is the periodic table, and what is its significance in the study of chemistry? What are groups and periods in the periodic table?
- 2.18 Give two differences between a metal and a nonmetal.
- 2.19 Write the names and symbols for four elements in each of these categories: (a) nonmetal, (b) metal, (c) metalloid.
- 2.20 Define, with two examples, these terms: (a) alkali metals, (b) alkaline earth metals, (c) halogens, (d) noble gases.

### Problems

- 2.21 Elements whose names end with “-ium” are usually metals; sodium is one example. Identify a nonmetal whose name also ends with “-ium.”
- 2.22 Describe the changes in properties (from metals to nonmetals or from nonmetals to metals) as we move (a) down a periodic group and (b) across the periodic table.
- 2.23 Consult a handbook of chemical and physical data (ask your instructor where you can locate a copy of

the handbook) to find (a) two metals less dense than water, (b) two metals more dense than mercury, (c) the densest known solid metallic element, (d) the densest known solid nonmetallic element.

- 2.24 Group these elements in pairs that you would expect to show similar chemical properties: K, F, P, Na, Cl, and N.

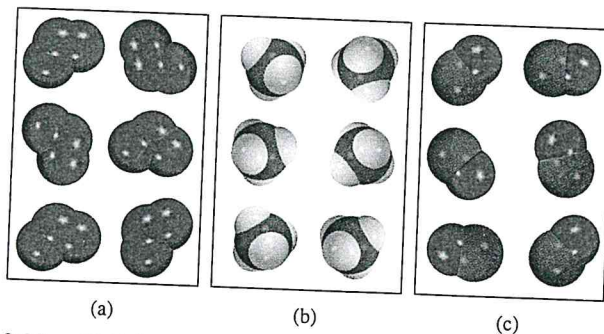
## Molecules and Ions

### Review Questions

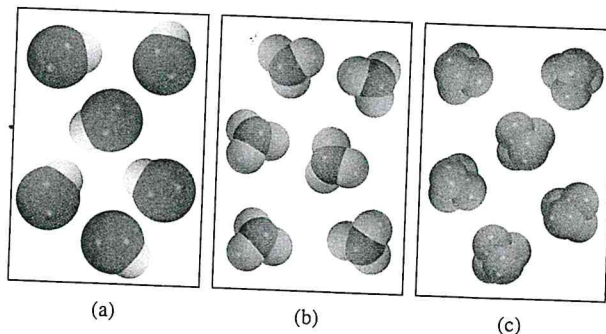
- 2.25 What is the difference between an atom and a molecule?
- 2.26 What are allotropes? Give an example. How are allotropes different from isotopes?
- 2.27 Describe the two commonly used molecular models.
- 2.28 Give an example of each of the following: (a) a monatomic cation, (b) a monatomic anion, (c) a polyatomic cation, (d) a polyatomic anion.

### Problems

- 2.29 Which of the following diagrams represent diatomic molecules, polyatomic molecules, molecules that are not compounds, molecules that are compounds, or an elemental form of the substance?



- 2.30 Which of the following diagrams represent diatomic molecules, polyatomic molecules, molecules that are not compounds, molecules that are compounds, or an elemental form of the substance?



- 2.31 Identify the following as elements or compounds:  $\text{NH}_3$ ,  $\text{N}_2$ ,  $\text{S}_8$ ,  $\text{NO}$ ,  $\text{CO}$ ,  $\text{CO}_2$ ,  $\text{H}_2$ ,  $\text{SO}_2$ .

- 2.32 Give two examples of each of the following: (a) a diatomic molecule containing atoms of the same element, (b) a diatomic molecule containing atoms of different elements, (c) a polyatomic molecule containing atoms of the same element, (d) a polyatomic molecule containing atoms of different elements.
- 2.33 Give the number of protons and electrons in each of the following common ions:  $\text{Na}^+$ ,  $\text{Ca}^{2+}$ ,  $\text{Al}^{3+}$ ,  $\text{Fe}^{2+}$ ,  $\text{I}^-$ ,  $\text{F}^-$ ,  $\text{S}^{2-}$ ,  $\text{O}^{2-}$ ,  $\text{N}^{3-}$ .
- 2.34 Give the number of protons and electrons in each of the following common ions:  $\text{K}^+$ ,  $\text{Mg}^{2+}$ ,  $\text{Fe}^{3+}$ ,  $\text{Br}^-$ ,  $\text{Mn}^{2+}$ ,  $\text{C}^{4-}$ ,  $\text{Cu}^{2+}$ .

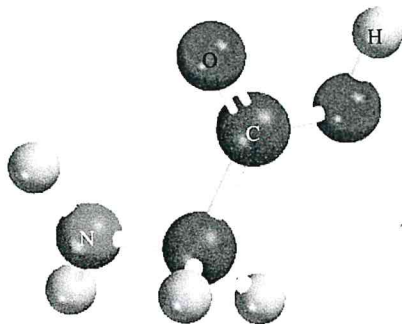
## Chemical Formulas

### Review Questions

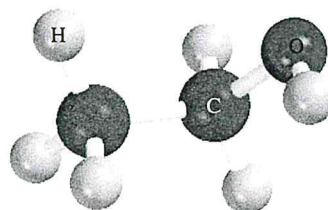
- 2.35 What does a chemical formula represent? What is the ratio of the atoms in the following molecular formulas? (a)  $\text{NO}$ , (b)  $\text{NCl}_3$ , (c)  $\text{N}_2\text{O}_4$ , (d)  $\text{P}_4\text{O}_6$
- 2.36 Define molecular formula and empirical formula. What are the similarities and differences between the empirical formula and molecular formula of a compound?
- 2.37 Give an example of a case in which two molecules have different molecular formulas but the same empirical formula.
- 2.38 What does  $\text{P}_4$  signify? How does it differ from  $4\text{P}$ ?
- 2.39 What is an ionic compound? How is electrical neutrality maintained in an ionic compound?
- 2.40 Explain why the chemical formulas of ionic compounds are usually the same as their empirical formulas.

### Problems

- 2.41 What are the empirical formulas of the following compounds? (a)  $\text{C}_2\text{N}_2$ , (b)  $\text{C}_6\text{H}_6$ , (c)  $\text{C}_9\text{H}_{20}$ , (d)  $\text{P}_4\text{O}_{10}$ , (e)  $\text{B}_2\text{H}_6$
- 2.42 What are the empirical formulas of the following compounds? (a)  $\text{Al}_2\text{Br}_6$ , (b)  $\text{Na}_2\text{S}_2\text{O}_4$ , (c)  $\text{N}_2\text{O}_5$ , (d)  $\text{K}_2\text{Cr}_2\text{O}_7$
- 2.43 Write the molecular formula of glycine, an amino acid present in proteins. The color codes are: black (carbon), blue (nitrogen), red (oxygen), and gray (hydrogen).



- 2.44 Write the molecular formula of ethanol. The color codes are: black (carbon), red (oxygen), and gray (hydrogen).



- 2.45 Which of the following compounds are likely to be ionic? Which are likely to be molecular?  $\text{SiCl}_4$ ,  $\text{LiF}$ ,  $\text{BaCl}_2$ ,  $\text{B}_2\text{H}_6$ ,  $\text{KCl}$ ,  $\text{C}_2\text{H}_4$
- 2.46 Which of the following compounds are likely to be ionic? Which are likely to be molecular?  $\text{CH}_4$ ,  $\text{NaBr}$ ,  $\text{BaF}_2$ ,  $\text{CCl}_4$ ,  $\text{ICl}$ ,  $\text{CsCl}$ ,  $\text{NF}_3$

## Naming Compounds

### Problems

- 2.47 Name these compounds: (a)  $\text{Na}_2\text{CrO}_4$ , (b)  $\text{K}_2\text{HPO}_4$ , (c)  $\text{HBr}$  (gas), (d)  $\text{HBr}$  (in water), (e)  $\text{Li}_2\text{CO}_3$ , (f)  $\text{K}_2\text{Cr}_2\text{O}_7$ , (g)  $\text{NH}_4\text{NO}_2$ , (h)  $\text{PF}_3$ , (i)  $\text{PF}_5$ , (j)  $\text{P}_4\text{O}_6$ , (k)  $\text{CdI}_2$ , (l)  $\text{SrSO}_4$ , (m)  $\text{Al}(\text{OH})_3$ , (n)  $\text{Na}_2\text{CO}_3 \cdot 10\text{H}_2\text{O}$ .
- 2.48 Name these compounds: (a)  $\text{KClO}$ , (b)  $\text{Ag}_2\text{CO}_3$ , (c)  $\text{FeCl}_2$ , (d)  $\text{KMnO}_4$ , (e)  $\text{CsClO}_3$ , (f)  $\text{HIO}$ , (g)  $\text{FeO}$ , (h)  $\text{Fe}_2\text{O}_3$ , (i)  $\text{TiCl}_4$ , (j)  $\text{NaH}$ , (k)  $\text{Li}_3\text{N}$ , (l)  $\text{Na}_2\text{O}$ , (m)  $\text{Na}_2\text{O}_2$ , (n)  $\text{FeCl}_3 \cdot 6\text{H}_2\text{O}$ .
- 2.49 Write the formulas for these compounds: (a) rubidium nitrite, (b) potassium sulfide, (c) perbromic acid, (d) magnesium phosphate, (e) calcium hydrogen phosphate, (f) boron trichloride, (g) iodine heptafluoride, (h) ammonium sulfate, (i) silver perchlorate, (j) iron(III) chromate, (k) calcium sulfate dihydrate.
- 2.50 Write the formulas for these compounds: (a) copper(I) cyanide, (b) strontium chlorite, (c) perchloric acid, (d) hydroiodic acid, (e) disodium ammonium phosphate, (f) lead(II) carbonate, (g) tin(II) fluoride, (h) tetraphosphorus decasulfide, (i) mercury(II) oxide, (j) mercury(I) iodide, (k) cobalt(II) chloride hexahydrate.

## Additional Problems

- 2.51 One isotope of a metallic element has a mass number of 65 and has 35 neutrons in the nucleus. The cation derived from the isotope has 28 electrons. Write the symbol for this cation.
- 2.52 In which one of these pairs do the two species resemble each other most closely in chemical properties? (a)  ${}^1_1\text{H}$  and  ${}^1_1\text{H}^+$ , (b)  ${}^{14}_7\text{N}$  and  ${}^{14}_7\text{N}^{3-}$ , (c)  ${}^{12}_6\text{C}$  and  ${}^{13}_6\text{C}$ .
- 2.53 This table gives numbers of electrons, protons, and neutrons in atoms or ions of a number of elements.

(a) Which of the species are neutral? (b) Which are negatively charged? (c) Which are positively charged? (d) What are the conventional symbols for all the species?

Atom or Ion of Element	A	B	C	D	E	F	G
Number of electrons	5	10	18	28	36	5	9
Number of protons	5	7	19	30	35	5	9
Number of neutrons	5	7	20	36	46	6	10

2.54 What is wrong or ambiguous about these descriptions? (a) 1 g of hydrogen, (b) four molecules of NaCl.

2.55 These phosphorus sulfides are known:  $P_4S_3$ ,  $P_4S_7$ , and  $P_4S_{10}$ . Do these compounds obey the law of multiple proportions?

2.56 Which of these are elements, which are molecules but not compounds, which are compounds but not molecules, and which are both compounds and molecules? (a)  $SO_2$ , (b)  $S_8$ , (c) Cs, (d)  $N_2O_5$ , (e) O, (f)  $O_2$ , (g)  $O_3$ , (h)  $CH_4$ , (i) KBr, (j) S, (k)  $P_4$ , (l) LiF.

2.57 Why is magnesium chloride ( $MgCl_2$ ) not called magnesium(II) chloride?

2.58 Some compounds are better known by their common names than by their systematic chemical names. Consult a handbook, a dictionary, or your instructor for the chemical formulas of these substances: (a) dry ice, (b) table salt, (c) laughing gas, (d) marble (chalk, limestone), (e) quicklime, (f) slaked lime, (g) baking soda, (h) milk of magnesia.

2.59 Fill in the blanks in this table:

Symbol		${}^{54}_{26}Fe^{2+}$			
Protons	5			79	86
Neutrons	6		16	117	136
Electrons	5		18	79	
Net charge			-3		0

2.60 (a) Which elements are most likely to form ionic compounds? (b) Which metallic elements are most likely to form cations with different charges?

2.61 Many ionic compounds contain either aluminum (a Group 3A metal) or a metal from Group 1A or Group 2A and a nonmetal—oxygen, nitrogen, or a halogen (Group 7A). Write the chemical formulas and names of all the binary compounds that can result from such combinations.

2.62 Which of these symbols provides more information about the atom:  ${}^{23}Na$  or  ${}_{11}Na$ ? Explain.

2.63 Write the chemical formulas and names of acids that contain Group 7A elements. Do the same for elements in Groups 3A, 4A, 5A, and 6A.

2.64 Of the 114-elements known, only two are liquids at room temperature ( $25^\circ C$ ). What are they? (*Hint*: One element is a familiar metal and the other element is in Group 7A.)

2.65 Group the following elements in pairs that you would expect to show similar chemical properties: K, F, P, Na, Cl, and N.

2.66 List the elements that exist as gases at room temperature. (*Hint*: All except one element can be found in Groups 5A, 6A, 7A, and 8A.)

2.67 The Group 1B metals, Cu, Ag, and Au, are called coinage metals. What chemical properties make them specially suitable for making coins and jewels?

2.68 The elements in Group 8A of the periodic table are called noble gases. Can you guess the meaning of "noble" in this context?

2.69 The formula for calcium oxide is CaO. What are the formulas for magnesium oxide and strontium oxide?

2.70 A common mineral of barium is barytes, or barium sulfate ( $BaSO_4$ ). Because elements in the same periodic group have similar chemical properties, we might expect to find some radium sulfate ( $RaSO_4$ ) mixed with barytes because radium is the last member of Group 2A. However, the only source of radium compounds in nature is in uranium minerals. Why?

2.71 Fluorine reacts with hydrogen (H) and with deuterium (D) to form hydrogen fluoride (HF) and deuterium fluoride (DF) [deuterium ( ${}^2H$ ) is an isotope of hydrogen]. Would a given amount of fluorine react with different masses of the two hydrogen isotopes? Does this violate the law of definite proportions? Explain.

2.72 Predict the formula and name of a binary compound formed from these elements: (a) Na and H, (b) B and O, (c) Na and S, (d) Al and F, (e) F and O, (f) Sr and Cl.

2.73 Fill the blanks in the following table.

Cation	Anion	Formula	Name
			Magnesium bicarbonate
		$SrCl_2$	
$Fe^{3+}$	$NO_2^-$		
			Manganese(II) chlorate
		$SnBr_4$	
$Co^{2+}$	$PO_4^{3-}$		
$Hg_2^{2+}$	$I^-$		
		$Cu_2CO_3$	
			Lithium nitride
$Al^{3+}$	$S^{2-}$		

- 2.74 Identify each of the following elements: (a) a halogen whose anion contains 36 electrons, (b) a radioactive noble gas with 86 protons, (c) a Group 6A

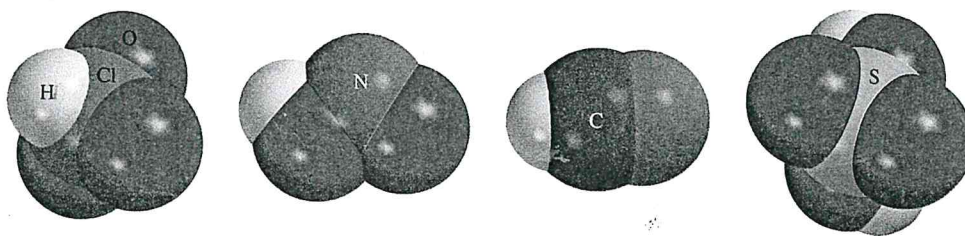
element whose anion contains 36 electrons, (d) an alkali metal cation that contains 36 electrons, (e) a Group 4A cation that contains 80 electrons.

### SPECIAL PROBLEM

- 2.75 (a) Describe Rutherford's experiment and how it led to the structure of the atom. How was he able to estimate the number of protons in a nucleus from the scattering of the  $\alpha$  particles? (b) Consider the  $^{23}\text{Na}$  atom. Given that the radius and mass of the nucleus are  $3.04 \times 10^{-15}$  m and  $3.82 \times 10^{-23}$  g, respectively, calculate the density of the nucleus in  $\text{g}/\text{cm}^3$ . The radius of a  $^{23}\text{Na}$  atom is 186 pm. Calculate the density of the space occupied by the electrons in the sodium atom. Do your results support Rutherford's model of an atom? [The volume of a sphere is  $(4/3)\pi r^3$ , where  $r$  is the radius.]
- 2.76 On p. 30 it was pointed out that mass and energy are alternate aspects of a single entity called *mass-energy*. The relationship between these two physical quantities is Einstein's famous equation,  $E = mc^2$ , where  $E$  is energy,  $m$  is mass, and  $c$  is the speed of light. In a combustion experiment, it was found that 12.096 g of hydrogen molecules combined with 96.000 g of oxygen molecules to form water and released  $1.715 \times 10^3$  kJ of heat. Calculate the corresponding mass change in this process and comment on whether the law of conservation of mass holds for ordinary chemical processes. (*Hint*: The Einstein equation can be used to calculate the change in mass

as a result of the change in energy.  $1 \text{ J} = 1 \text{ kg m}^2/\text{s}^2$  and  $c = 3.00 \times 10^8 \text{ m/s}$ .)

- 2.77 Draw all possible structural formulas of the following hydrocarbons:  $\text{CH}_4$ ,  $\text{C}_2\text{H}_6$ ,  $\text{C}_3\text{H}_8$ ,  $\text{C}_4\text{H}_{10}$ , and  $\text{C}_5\text{H}_{12}$ .
- 2.78 Ethane and acetylene are two gaseous hydrocarbons. Chemical analyses show that in one sample of ethane, 2.65 g of carbon are combined with 0.665 g of hydrogen, and in one sample of acetylene, 4.56 g of carbon are combined with 0.383 g of hydrogen. (a) Are these results consistent with the law of multiple proportions? (b) Write reasonable molecular formulas for these compounds.
- 2.79 Draw two different structural formulas based on the molecular formula  $\text{C}_2\text{H}_6\text{O}$ . Is the fact that you can have more than one compound with the same molecular formula consistent with Dalton's atomic theory?
- 2.80 A monatomic ion has a charge of +2. The nucleus of the parent atom has a mass number of 55. If the number of neutrons in the nucleus is 1.2 times that of the number of protons, what is the name and symbol of the element?
- 2.81 Name the following acids:



### ANSWERS TO PRACTICE EXERCISES

- 2.1 29 protons, 34 neutrons, and 29 electrons. 2.2  $\text{CHCl}_3$ .  
 2.3  $\text{C}_4\text{H}_5\text{N}_2\text{O}$ . 2.4 (a) Lead(II) oxide, (b) lithium sulfite.  
 2.5 (a)  $\text{Rb}_2\text{SO}_4$ , (b)  $\text{BaH}_2$ . 2.6 (a) Nitrogen trifluoride,

- (b) dichlorine heptoxide. 2.7 (a)  $\text{SF}_4$ , (b)  $\text{N}_2\text{O}_5$ .  
 2.8 (a) Hypobromous acid, (b) hydrogen sulfate ion.