Discussion Questions

These questions are designed to be considered by groups of students in class. Often these questions work well for introducing a particular topic in class.

1. You may have noticed that when water boils, you can see bubbles that rise to the surface of the water. What is inside these bubbles? Explain.
   a. air
   b. hydrogen and oxygen gas
   c. oxygen gas
   d. water vapor
   e. carbon dioxide gas

2. Which of the following is true about an individual atom?
   a. An individual atom should be considered a solid.
   b. An individual atom should be considered a liquid.
   c. An individual atom should be considered a gas.
   d. The state of the atom depends on which element it is.
   e. An individual atom cannot be considered a solid, liquid, or gas.
   Justify your choice, and for those you did not choose, explain why they are incorrect.

3. How would you go about finding the number of “chalk molecules” it takes to write your name on the board? Explain what you would need to do and provide a sample calculation.

4. These questions concern the work of J. J. Thomson:
   a. From what you know of Thomson’s work, which particles do you think he would believe are most important in the formation of compounds (chemical changes) and why?
   b. Of the remaining two subatomic particles, which do you place second in importance for forming compounds and why?
   c. Propose three models that explain Thomson’s findings and evaluate them. Include Thomson’s findings.

5. Heat is applied to an ice cube in a closed container until only steam is present. Draw a representation of this process, assuming you can see it at an extremely high level of magnification. What happens to the size of the molecules? What happens to the total mass of the sample?

6. You have a chemical in a sealed glass container filled with air. The setup is sitting on a balance, as shown. The chemical is ignited by means of a magnifying glass focusing sunlight on the reactant. After the chemical has completely burned, which of the following is true? Explain your answer.
   a. The balance will read less than 250.0 g.
   b. The balance will read 250.0 g.
   c. The balance will read greater than 250.0 g.
   d. Cannot be determined without knowing the identity of the chemical.

7. The vitamin niacin (nicotinic acid, C₆H₅NO₂) can be isolated from a variety of natural sources such as liver, yeast, milk, and whole grain. It also can be synthesized from commercially available materials. From a nutritional point of view, which source of nicotinic acid is best for use in a multivitamin tablet? Why?

8. One of the best indications of a useful theory is that it raises more questions for further experimentation than it originally answered. Is this true of Dalton’s atomic theory? Give examples.

9. Dalton assumed that all atoms of the same element are identical in all their properties. Explain why this assumption is not valid.

10. How does Dalton’s atomic theory account for each of the following?
    a. the law of conservation of mass
    b. the law of definite proportion
    c. the law of multiple proportions

11. What refinements had to be made in Dalton’s atomic theory to account for Gay-Lussac’s results on the combining volumes of gases?

12. Which (if any) of the following can be determined by knowing the number of protons in a neutral element? Explain your answer.
    a. the number of neutrons in the neutral element
    b. the number of electrons in the neutral element
    c. the name of the element

13. The average mass of a carbon atom is 12.011. Assuming you were able to pick up only one carbon atom, the chance that you would randomly get one with a mass of 12.011 is
    a. 0%.
    b. 0.011%.
    c. about 12%.
    d. 12.011%.
    e. greater than 50%.
    f. None of these is true.
    Explain.
14. Which of the following explain how an ion is formed? Explain your answer.
   a. adding or subtracting protons to/from an atom
   b. adding or subtracting neutrons to/from an atom
   c. adding or subtracting electrons to/from an atom

15. The formula of water is \( \text{H}_2\text{O} \). Which of the following is indicated by this formula? Explain your answer.
   a. the mass of hydrogen is twice that of oxygen in each molecule
   b. there are two hydrogen atoms and one oxygen atom per water molecule
   c. the mass of oxygen is twice that of hydrogen in each molecule
   d. there are two oxygen atoms and one hydrogen atom per water molecule

16. Why do we call \( \text{Ba(NO}_3)_2 \) barium nitrate, but we call \( \text{Fe(NO}_3)_2 \) iron(II) nitrate?

17. Why is calcium dichloride not the correct systematic name for \( \text{CaCl}_2 \)?

**Exercises**

A blue exercise number indicates that the answer to that exercise appears at the back of this book and a solution appears in the Solutions Guide.

**Development of the Atomic Theory**

18. Explain the law of conservation of mass, the law of definite proportion, and the law of multiple proportions.

19. A reaction of 1 L of chlorine gas (\( \text{Cl}_2 \)) with 5 L of fluorine gas (\( \text{F}_2 \)) yields 2 L of a gaseous product. All gas volumes are at the same temperature and pressure. What is the formula of the gaseous product?

20. When mixtures of gaseous \( \text{H}_2 \) and gaseous \( \text{Cl}_2 \) react, a product forms that has the same properties regardless of the relative amounts of \( \text{H}_2 \) and \( \text{Cl}_2 \) used.
   a. How is this result interpreted in terms of the law of definite proportion?
   b. When a volume of \( \text{H}_2 \) reacts with an equal volume of \( \text{Cl}_2 \) at the same temperature and pressure, what volume of product having the formula \( \text{HCl} \) is formed?

21. Observations of the reaction between nitrogen gas and hydrogen gas show us that 1 volume of nitrogen reacts with 3 volumes of hydrogen to make 2 volumes of gaseous product, as shown below:

   ![Reaction between nitrogen and hydrogen]

Determine the formula of the product and justify your answer.

22. The three most stable oxides of carbon are carbon monoxide (\( \text{CO} \)), carbon dioxide (\( \text{CO}_2 \)), and carbon suboxide (\( \text{C}_3\text{O}_2 \)). The molecules can be represented as

   ![Representation of carbon compounds]

Explain how these molecules illustrate the law of multiple proportions.

23. Hydrazine, ammonia, and hydrogen azide all contain only nitrogen and hydrogen. The mass of hydrogen that combines with 1.00 g of nitrogen for each compound is \( 1.44 \times 10^{-1} \) g, \( 2.16 \times 10^{-1} \) g, and \( 2.40 \times 10^{-2} \) g, respectively. Show how these data illustrate the law of multiple proportions.

24. Consider 80.0-g samples of two different compounds consisting of only carbon and oxygen. One of the compounds consists of 21.8 g of carbon, and the other has 34.3 g of carbon. Determine the ratio in whole numbers of the masses of carbon that combine with 1.00 g of oxygen between the two compounds.

25. Early tables of atomic weights (masses) were generated by measuring the mass of a substance that reacts with 1.00 g of oxygen. Given the following data and taking the atomic mass of hydrogen as 1.00, generate a table of relative atomic masses for oxygen, sodium, and magnesium.

<table>
<thead>
<tr>
<th>Element</th>
<th>Mass That Combines with 1.00 g Oxygen</th>
<th>Assumed Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen</td>
<td>0.126 g</td>
<td>HO</td>
</tr>
<tr>
<td>Sodium</td>
<td>2.875 g</td>
<td>NaO</td>
</tr>
<tr>
<td>Magnesium</td>
<td>1.500 g</td>
<td>MgO</td>
</tr>
</tbody>
</table>

How do your values compare with those in the periodic table? How do you account for any differences?

**The Nature of the Atom**

26. What evidence led to the conclusion that cathode rays had a negative charge? Is there a difference between a cathode ray and a \( \beta \) particle?

27. From the information in this chapter on the mass of the proton, the mass of the electron, and the sizes of the nucleus and the atom, calculate the densities of a hydrogen nucleus and a hydrogen atom.

28. A chemistry instructor makes the following claim: “Consider that if the nucleus were the size of a grape, the electrons would be about 1 mile away on average.” Is this claim reasonably accurate? Provide mathematical support.

29. A chemist in a galaxy far, far away performed the Millikan oil drop experiment and got the following results for the charge on various drops. What is the charge of the electron in zirkombs?

   - \( 2.56 \times 10^{-12} \) zirkombs
   - \( 2.84 \times 10^{-12} \) zirkombs
   - \( 3.84 \times 10^{-12} \) zirkombs
   - \( 6.40 \times 10^{-13} \) zirkombs
30. Do the proton and the neutron have exactly the same mass? How do the masses of the proton and the neutron compare with the mass of the electron? Which particles make the greatest contribution to the mass of an atom? Which particles make the greatest contribution to the chemical properties of an atom?

31. Consider Ernest Rutherford’s α-particle bombardment experiment illustrated in Fig. 2.11. How did the results of this experiment lead Rutherford away from the plum pudding model of the atom to propose the nuclear model of the atom?

**Elements, Ions, and the Periodic Table**

32. Distinguish between the following terms.
   a. molecule versus ion
   b. covalent bonding versus ionic bonding
   c. molecule versus compound
   d. anion versus cation

33. What is the distinction between atomic number and mass number? Between mass number and atomic mass?

34. a. Classify the following elements as metals or nonmetals.
   - Mg, Si, Rn
   - Ti, Ge, Eu
   - Au, B, Am
   - Bi, At, Br

   b. The distinction between metals and nonmetals is really not a clear one. Some elements, called metalloids, are intermediate in their properties. Which of these elements would you reclassify as metalloids? What other elements in the periodic table would you expect to be metalloids?

35. a. List the noble gas elements. Which of the noble gases has only radioactive isotopes? (This situation is indicated on most periodic tables by parentheses around the mass of the element. See inside front cover.)
   b. Which lanthanide element and which transition element have only radioactive isotopes?

36. Consider the elements of the carbon family: C, Si, Ge, Sn, and Pb. What is the trend in metallic character as one goes down a group in the periodic table? What is the trend in metallic character going from left to right across a period in the periodic table?

37. Identify the elements that correspond to the following atomic numbers. Label each as either a noble gas, a halogen, an alkali metal, an alkaline earth metal, a transition metal, a lanthanide metal, or an actinide metal.
   a. 17  c. 2
   b. 4   f. 92
   c. 63  g. 55
   d. 72

38. The number of protons in an atom determines the identity of the atom. What does the number and arrangement of the electrons in an atom determine? What does the number of neutrons in an atom determine?

39. For lighter, stable isotopes, the ratio of the mass number to the atomic number is close to a certain value. What is the value? What happens to the value of the mass number to atomic number ratio as stable isotopes become heavier?

40. For each of the following sets of elements, label each as either noble gases, halogens, alkali metals, alkaline earth metals, or transition metals.
   a. Ti, Fe, Ag
   b. Mg, Sr, Ba
   c. Li, K, Rb
   d. Ne, Kr, Xe
   e. F, Br, I

41. What number of protons and neutrons are contained in the nucleus of each of the following atoms? Assuming each atom is uncharged, what number of electrons are present?
   a. 230U  d. 208Pb
   b. 56Al  e. 34Rb
   c. 56Fe  f. 46Ca

42. Write the atomic symbol (3X) for each of the isotopes described below.
   a. number of protons = 27, number of neutrons = 31
   b. the isotope of boron with mass number 10
   c. Z = 12, A = 23
   d. atomic number 53, number of neutrons = 79
   e. Z = 9, number of neutrons = 10
   f. number of protons = 29, mass number 65

43. How many protons, neutrons, and electrons are in each of the following atoms or ions?
   a. 25Mg  d. 33Co3+
   b. 24Mg2+  e. 34Co2+
   c. 33Co  f. 35Se
   g. 32Se2−
   h. 61Ni
   i. 59Ni2+

44. Complete the following table.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Number of Protons in Nucleus</th>
<th>Number of Neutrons in Nucleus</th>
<th>Number of Electrons</th>
<th>Net Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>238Au</td>
<td>92</td>
<td>146</td>
<td>92</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>20</td>
<td>20</td>
<td>2+</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>28</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>58Fe</td>
<td>26</td>
<td>32</td>
<td>36</td>
<td>2−</td>
</tr>
<tr>
<td></td>
<td>15</td>
<td>16</td>
<td>15</td>
<td>3−</td>
</tr>
</tbody>
</table>

45. What is the symbol for an ion with 63 protons, 60 electrons, and 88 neutrons? If an ion contains 50 protons, 68 neutrons, and 48 electrons, what is its symbol?

46. What is the symbol for an ion with 16 protons, 18 neutrons, and 18 electrons? What is the symbol for an ion that has 16 protons, 16 neutrons, and 18 electrons?

47. Would you expect each of the following atoms to gain or lose electrons when forming ions? What ion is the most likely in each case?
   a. Ra   c. F   e. Br
   b. In   d. Te   f. Rb
48. For each of the following atomic numbers, use the periodic table to write the formula (including the charge) for the simple ion that the element is most likely to form in ionic compounds.

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>34</td>
<td>56</td>
<td>7</td>
<td>35</td>
<td>87</td>
</tr>
<tr>
<td>53</td>
<td>52</td>
<td>51</td>
<td>56</td>
<td>54</td>
<td>55</td>
</tr>
</tbody>
</table>

**Nomenclature**

49. The compounds AlCl₃, CrCl₃, and ICl₃ have similar formulas, yet each follows a different set of rules to name it. Name these compounds, and then compare and contrast the nomenclature rules used in each case.

50. Each of the following compounds has three possible names listed for it. For each compound, what is the correct name and why aren’t the other names used?

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
</tr>
</thead>
<tbody>
<tr>
<td>N₂O: nitrogen oxide, nitrogen(I) oxide, dinitrogen monoxide</td>
<td>Cu₂O: copper oxide, copper(I) oxide, dicopper monoxide</td>
<td>Li₂O: lithium oxide, lithium(I) oxide, dilithium monoxide</td>
<td>Hg₂O</td>
<td>FePO₄, iron(II) phosphide</td>
<td>Mg(C₂H₃O₂)₂, manganese diacetate</td>
</tr>
</tbody>
</table>

51. Name the compounds in parts a–d and write the formulas for the compounds in parts e–h.

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
<th>g</th>
<th>h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hg₂O</td>
<td>FeBr₃</td>
<td>CoS</td>
<td>TiCl₄</td>
<td>BaSO₃</td>
<td>Al₂S₃</td>
<td>K₂Cr₂O₇</td>
<td>KMnO₄</td>
</tr>
</tbody>
</table>

52. Name the compounds in parts a–d and write the formulas for the compounds in parts e–h.

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
<th>g</th>
<th>h</th>
</tr>
</thead>
<tbody>
<tr>
<td>BaSO₃</td>
<td>NaNO₂</td>
<td>KMnO₄</td>
<td>K₂Cr₂O₇</td>
<td>Hg₂O</td>
<td>FePO₄</td>
<td>K₂MnO₄</td>
<td>Al(OH)₃</td>
</tr>
</tbody>
</table>

53. Name each of the following compounds.

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>O</td>
<td>I</td>
<td>Cl</td>
</tr>
</tbody>
</table>

54. Name the following compounds.

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
<th>g</th>
<th>h</th>
<th>i</th>
</tr>
</thead>
<tbody>
<tr>
<td>NaClO₄</td>
<td>Mg₃(PO₄)₂</td>
<td>Al₂(SO₄)₃</td>
<td>SF₂</td>
<td>S₂Cl₂</td>
<td>Hg₂O</td>
<td>CaCO₃</td>
<td>ZnS</td>
<td>NaOH</td>
</tr>
<tr>
<td>f</td>
<td>g</td>
<td>h</td>
<td>i</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

55. Name each of the following compounds.

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>CuI</td>
<td>CuI₂</td>
<td>Co₂O₃</td>
<td>Na₂CO₃</td>
</tr>
</tbody>
</table>

56. Name the following compounds. Assume the potential acids are dissolved in water.

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>c</th>
</tr>
</thead>
<tbody>
<tr>
<td>HClO₄</td>
<td>HCl</td>
<td>KClO₃</td>
</tr>
<tr>
<td>f</td>
<td>d</td>
<td>e</td>
</tr>
</tbody>
</table>

57. Write formulas for the following compounds.

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
<th>g</th>
<th>h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulfur dioxide</td>
<td>Sulfur trioxide</td>
<td>Sodium sulfite</td>
<td>Potassium hydrogen sulfite</td>
<td>Lithium nitride</td>
<td>Chromium(III) carbonate</td>
<td>Lead(II) oxide</td>
<td>tin(IV) fluoride</td>
</tr>
</tbody>
</table>

58. Write formulas for the following compounds.

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
<th>g</th>
<th>h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium oxide</td>
<td>Sodium peroxide</td>
<td>Potassium cyanide</td>
<td>Copper(II) nitrate</td>
<td>Silicon tetrachloride</td>
<td>Lead(II) oxide</td>
<td>Lead(IV) oxide</td>
<td>Copper(I) chloride</td>
</tr>
</tbody>
</table>

59. The common names and formulas for several substances are given below. What are the systematic names for these substances?

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
<th>g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sugar of lead</td>
<td>Blue vitriol</td>
<td>Quicklime</td>
<td>Galena</td>
<td>Epsom salts</td>
<td>Gypsum</td>
<td>Quicklime</td>
</tr>
</tbody>
</table>

60. Each of the following compounds is incorrectly named. What is wrong with each name, and what is the correct name for each compound?

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>f</th>
<th>g</th>
<th>h</th>
</tr>
</thead>
<tbody>
<tr>
<td>FeCl₃</td>
<td>NO₂, nitrogen(IV) oxide</td>
<td>CaO, calcium(II) monoxide</td>
<td>Al₂S₃, dialuminum trisulfide</td>
<td>Mg(C₂H₃O₂)₂, manganese diacetate</td>
<td>FePO₄, iron(II) phosphate</td>
<td>P₂S₅, phosphorus sulfide</td>
<td>Na₂O₂, sodium oxide</td>
</tr>
</tbody>
</table>

61. Name the following acids.

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>HC₂H₃O₂</td>
<td>NH₄NO₂</td>
<td>CO₂S₃</td>
<td>HClO₄</td>
</tr>
</tbody>
</table>

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- **Exercises** 46c
Chapter 2  Atoms, Molecules, and Ions

Additional Exercises

62. Chlorine has two natural isotopes: 
\(^{35}\text{Cl}\) and \(^{37}\text{Cl}\). Hydrogen reacts with chlorine to form the compound HCl. Would a given amount of hydrogen react with different masses of the two chlorine isotopes? Does this conflict with the law of definite proportion? Why or why not?

63. Label the type of bonding for each of the following.
   a. 
   b. 

64. What discoveries were made by J. J. Thomson, Henri Becquerel, and Lord Rutherford? How did Dalton’s model of the atom have to be modified to account for these discoveries?

65. Consider the chemical reaction depicted below. Label as much as you can using the terms atom, molecule, element, compound, ionic, gas, and solid.

66. Section 2.3 describes the postulates of Dalton’s atomic theory. With some modifications, these postulates hold up very well regarding how we view elements, compounds, and chemical reactions today. Answer the following questions concerning Dalton’s atomic theory and the modifications made today.
   a. The atom can be broken down into smaller parts. What are the smaller parts?
   b. How are atoms of hydrogen identical to each other, and how can they be different from each other?
   c. How are atoms of hydrogen different from atoms of helium? How can H atoms be similar to He atoms?
   d. How is water different from hydrogen peroxide (\(\text{H}_2\text{O}_2\)) even though both compounds are composed of only hydrogen and oxygen?
   e. What happens in a chemical reaction, and why is mass conserved in a chemical reaction?

67. A sample of chloroform is found to contain 12.0 g of carbon, 106.4 g of chlorine, and 1.01 g of hydrogen. If a second sample of chloroform is found to contain 30.0 g of carbon, what is the total mass of chloroform in the second sample?

68. In a reaction, 34.0 g of chromium(III) oxide reacts with 12.1 g of aluminum to produce chromium and aluminum oxide. If 23.3 g of chromium is produced, what mass of aluminum oxide is produced?

69. The isotope of an unknown element, X, has a mass number of 79. The most stable ion of the isotope has 36 electrons and forms a binary compound with sodium having a formula of Na\(_2\)X. Which of the following statements is(are) true? Correct the false statements.
   a. The binary compound formed between X and fluorine will be a covalent compound.
   b. The isotope of X contains 38 protons.
   c. The isotope of X contains 41 neutrons.
   d. The identity of X is strontium, Sr.

70. For each of the following ions, indicate the total number of protons and electrons in the ion. For the positive ions in the list, predict the formula of the simplest compound formed between each positive ion and the oxide ion. For the negative ions in the list, predict the formula of the simplest compound formed between each negative ion and the aluminum ion.
   a. Fe\(^{2+}\)  d. Cs\(^{+}\)  g. Br\(^{-}\)
   b. Fe\(^{3+}\)  e. S\(^{2-}\)  h. N\(^{3-}\)
   c. Ba\(^{2+}\)  f. P\(^{3-}\)

71. An element’s most stable ion forms an ionic compound with bromine, having the formula XBr\(_2\). If the ion of element X has a mass number of 230 and 86 electrons, what is the identity of the element, and how many neutrons does it have?

72. Using the information in Table 2.2, answer the following questions. In an ion with an unknown charge, the total mass of all the electrons was determined to be \(2.55 \times 10^{-26}\) g, while the total mass of its protons was \(5.34 \times 10^{-23}\) g. What is the identity and charge of this ion? What is the symbol and mass number of a neutral atom whose total mass of its electrons is \(3.92 \times 10^{-26}\) g, while its neutrons have a mass of \(9.35 \times 10^{-23}\) g?

73. The two most reactive families of elements are the halogens and the alkali metals. How do they differ in their reactivities?

74. The early alchemists used to do an experiment in which water was boiled for several days in a sealed glass container. Eventually, some solid residue would begin to appear in the bottom of the flask. This result was interpreted to mean that some of the water in the flask had been converted into earth. When Lavoisier repeated this experiment, he found that the water weighed the same before and after heating, and the weight of the flask plus the solid residue equaled the original weight of the flask. Were the alchemists correct? Explain what really happened. (This experiment is described in the article by A. E. Scott in Scientific American, January 1984.)

75. Elements in the same family often form oxianions of the same general formula. The anions are named in a similar fashion. What are the names of the oxianions of selenium and tellurium: \(\text{SeO}_3^{2-}\), \(\text{SeO}_2^{2-}\), \(\text{TeO}_4^{2-}\), \(\text{TeO}_3^{2-}\)?

76. How would you name HBrO\(_3\), KIO\(_3\), NaBrO\(_3\), and HIO\(_5\)? Refer to Table 2.5 and the acid nomenclature discussion in the text.

77. Indium oxide contains 4.784 g of indium for every 1.000 g of oxygen. In 1869, when Mendeleev first presented his version of the periodic table, he proposed the
formula In$_2$O$_3$ for indium oxide. Before that time, it was thought that the formula was InO. What values for the atomic mass of indium are obtained using these two formulas? Assume that oxygen has an atomic mass of 16.00.

78. The designations 1A through 8A used for certain families of the periodic table are helpful for predicting the charges on ions in binary ionic compounds. In these compounds, the metals generally take on a positive charge equal to the family number, and the nonmetals take on a negative charge equal to the family number minus 8. Thus the compound formed from sodium and chlorine contains Na$^+$ and Cl$^-$ ions and has the formula NaCl. Predict the formula and the name of the binary compound formed from the following pairs of elements.

a. Ca and N  
b. K and O  
c. Rb and F  
d. Mg and S  
e. Ba and I  
f. Al and Se  
g. Cs and P  
h. In and Br

79. Consider 100.0-g samples of two different compounds consisting only of carbon and oxygen. One compound contains 27.2 g of carbon, and the other has 42.9 g of carbon. How can these data support the law of multiple proportions if 42.9 is not a multiple of 27.2? Show that these data support the law of multiple proportions.

80. Identify each of the following elements.

a. a member of the same family as oxygen whose most stable ion contains 54 electrons  
b. a member of the alkali metal family whose most stable ion contains 36 electrons  
c. a noble gas with 18 protons in the nucleus  
d. a halogen with 85 protons and 85 electrons

81. A certain element has only two naturally occurring isotopes: one with 18 neutrons and the other with 20 neutrons. The element forms 1$^-$ charged ions when in ionic compounds. Predict the identity of the element. What number of electrons does the 1$^-$ charged ion have?

ChemWork Problems

These multiconcept problems (and additional ones) are found interactively online with the same type of assistance a student would get from an instructor.

82. Complete the following table.

<table>
<thead>
<tr>
<th>Atom/Ion</th>
<th>Protons</th>
<th>Neutrons</th>
<th>Electrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{120}$Sn</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{25}$Mg$^{2+}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{56}$Fe$^{2+}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{74}$Se</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{13}$Cl</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{65}$Cu</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

83. Which of the following is(are) correct?

a. An electron is heavier than a proton.  
b. The nucleus contains protons, neutrons, and electrons.

c. The correct name for TiO$_2$ is titanium dioxide.

84. What are the formulas of the compounds that correspond to the names given in the following table?

<table>
<thead>
<tr>
<th>Compound Name</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon tetrabromide</td>
<td></td>
</tr>
<tr>
<td>Cobalt(II) phosphate</td>
<td></td>
</tr>
<tr>
<td>Magnesium chloride</td>
<td></td>
</tr>
<tr>
<td>Nickel(II) acetate</td>
<td></td>
</tr>
<tr>
<td>Calcium nitrate</td>
<td></td>
</tr>
</tbody>
</table>

85. What are the names of the compounds that correspond to the formulas given in the following table?

<table>
<thead>
<tr>
<th>Formula</th>
<th>Compound Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co(NO$_2$)$_2$</td>
<td></td>
</tr>
<tr>
<td>AsF$_5$</td>
<td></td>
</tr>
<tr>
<td>LiCN</td>
<td></td>
</tr>
<tr>
<td>K$_2$SO$_3$</td>
<td></td>
</tr>
<tr>
<td>Li$_3$N</td>
<td></td>
</tr>
<tr>
<td>PbCrO$_4$</td>
<td></td>
</tr>
</tbody>
</table>

86. Complete the following table to predict whether the given atom will gain or lose electrons in forming the ion most likely to form when in ionic compounds.

<table>
<thead>
<tr>
<th>Atom</th>
<th>Gain (G) or Lose (L)</th>
<th>Ion Formed</th>
</tr>
</thead>
<tbody>
<tr>
<td>K</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Br</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Se</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

87. Which of the following statements is(are) correct?

a. The symbols for the elements magnesium, aluminum, and xenon are Mn, Al, and Xe, respectively.  
b. The elements P, As, and Bi are in the same family on the periodic table.  
c. All of the following elements are expected to gain electrons to form ions in ionic compounds: Ga, Se, and Br.  
d. The elements Co, Ni, and Hg are all transition elements.  
e. The correct name for TiO$_2$ is titanium dioxide.

88. Which of the following is(are) correct?

a. $^{40}$Ca$^{2+}$ contains 20 protons and 18 electrons.  
b. Rutherford created the cathode-ray tube and was the founder of the charge-to-mass ratio of an electron.
Challenge Problems

88. Reaction of 2.0 L of hydrogen gas with 1.0 L of oxygen gas yields 2.0 L of water vapor. All gases are at the same temperature and pressure. Show how these data support the idea that oxygen gas is a diatomic molecule. Must we consider hydrogen to be a diatomic molecule to explain these results?

89. Each of the statements below is true, but Dalton might have had trouble explaining some of them with his atomic theory. Give explanations for the following statements.
   a. The space-filling models for ethyl alcohol and dimethyl ether are shown below.

   ![Space-filling models](image)

   These two compounds have the same composition by mass (52% carbon, 13% hydrogen, and 35% oxygen), yet the two have different melting points, boiling points, and solubilities in water.
   b. Burning wood leaves an ash that is only a small fraction of the mass of the original wood.
   c. Atoms can be broken down into smaller particles.
   d. One sample of lithium hydride is 87.4% lithium by mass, whereas another sample of lithium hydride is 74.9% lithium by mass. However, the two samples have the same properties.

90. You take three compounds, each consisting of two elements (X, Y, and/or Z) and decompose them to their respective elements. To determine the relative masses of X, Y, and Z, you collect and weigh the elements, obtaining the following data:

<table>
<thead>
<tr>
<th>Elements in Compound</th>
<th>Masses of Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. X and Y</td>
<td>X = 0.4 g, Y = 4.2 g</td>
</tr>
<tr>
<td>2. Y and Z</td>
<td>Y = 1.4 g, Z = 1.0 g</td>
</tr>
<tr>
<td>3. X and Y</td>
<td>X = 2.0 g, Y = 7.0 g</td>
</tr>
</tbody>
</table>

   a. What are the assumptions needed to solve this problem?
   b. What are the relative masses of X, Y, and Z?

91. Two elements, R and Q, combine to form two binary compounds. In the first compound, 14.0 g of R combines with 3.00 g of Q. In the second compound, 7.00 g of R combines with 4.50 g of Q. Show that these data are in accord with the law of multiple proportions. If the formula of the second compound is RQ, what is the formula of the first compound?

92. A single molecule has a mass of $7.31 \times 10^{-23}$ g. Provide an example of a real molecule that can have this mass.

93. A combustion reaction involves the reaction of a substance with oxygen gas. The complete combustion of any hydrocarbon (binary compound of carbon and hydrogen) produces carbon dioxide and water as the only products. Octane is a hydrocarbon found in gasoline. Complete combustion of octane produces 8 L of carbon dioxide for every 9 L of water vapor (both measured at the same temperature and pressure). What is the ratio of carbon atoms to hydrogen atoms in a molecule of octane?

94. You have two distinct gaseous compounds made from element X and element Y. The mass percents are as follows:

<table>
<thead>
<tr>
<th>Compound</th>
<th>X %</th>
<th>Y %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compound I</td>
<td>30.43</td>
<td>69.57</td>
</tr>
<tr>
<td>Compound II</td>
<td>63.64</td>
<td>36.36</td>
</tr>
</tbody>
</table>

   In their natural standard states, element X and element Y exist as gases. (Monatomic? Diatomic? Triatomic? That is for you to determine.) When you react "gas X" with "gas Y" to make the products, you get the following data (all at standard pressure and temperature):

   1 volume "gas X" + 2 volumes "gas Y" $\rightarrow$ 2 volumes compound I
   2 volumes "gas X" + 1 volume "gas Y" $\rightarrow$ 2 volumes compound II

   Assume the simplest possible formulas for reactants and products in these chemical equations. Then determine the relative atomic masses of element X and element Y.

Marathon Problem

95. You have gone back in time and are working with Dalton on a table of relative masses. Following are his data:

   - 0.602 g gas A reacts with 0.295 g gas B
   - 0.172 g gas B reacts with 0.401 g gas C
   - 0.320 g gas A reacts with 0.374 g gas C

   a. Assuming simplest formulas (AB, BC, and AC), construct a table of relative masses for Dalton.
   b. Knowing some history of chemistry, you tell Dalton that if he determines the volumes of the gases reacted at constant temperature and pressure, he need not assume simplest formulas. You collect the following data:

<table>
<thead>
<tr>
<th>Data</th>
<th>Equation</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 volumes gas A + 1 volume gas B $\rightarrow$ 4 volumes product</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 volume gas B + 4 volumes gas C $\rightarrow$ 4 volumes product</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 volumes gas A + 2 volumes gas C $\rightarrow$ 6 volumes product</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

   Write the simplest balanced equations, and find the actual relative masses of the elements. Explain your reasoning.