

Answers

to Selected End-of-Chapter Questions and Problems

Chapter 1

- 1.1. (a) A pure compound in the gas phase; (b) A mixture of blue element atoms and red element atoms: blue atoms are in the gas phase, red spheres are in the solid or liquid phase.
- 1.3. (b)
- 1.5. CH_2O_2
- 1.7. A hypothesis is a tentative explanation of an observation or set of observations; a scientific theory is a concise explanation of a natural phenomenon that has been extensively tested and explains why certain phenomena are always observed.
- 1.9. Dalton's atomic theory explained the small, whole-number, mass ratios in his law of multiple proportions because the compounds contained small, whole-number ratios of atoms of different elements per molecule or formula unit.
- 1.11. Proust's law of definite proportions needed to have corroborating evidence to fully support it. At the time, experiments to prepare a compound of tin with oxygen gave varying compositions. The prepared compounds later turned out to be mixtures of two compounds of tin oxide.
- 1.13. Whereas *theory* in normal conversation means someone's idea or opinion that is open to speculation, a scientific theory is a concise and testable explanation of natural phenomena based on observation and experimentation that can accurately predict the results of future experiments.
- 1.15. A Snickers bar (b) and an uncooked hamburger (d) are heterogeneous mixtures.
- 1.17. Orange juice (d) and tomato juice (e) are heterogeneous mixtures.
- 1.19. Soil particles are not volatile, but water is. Therefore, distillation could be used to separate soil particles from water. However, filtration could also be used and would involve much less energy.
- 1.21. One chemical property of gold is its resistance to corrosion. Gold's physical properties include its density, color, melting temperature, and electrical and thermal conductivity.

- 1.23. We can distinguish between table sugar, water, and oxygen by examining their physical states (sugar is a solid, water is a liquid, and oxygen is a gas) and by their densities, melting points, and boiling points.
- 1.25. Density, melting point, thermal and electrical conductivity, and softness (a–d) are all physical properties while tarnishing and reaction with water (e and f) are both chemical properties.
- 1.27. Extensive properties will change with the size of the sample and therefore cannot be used to identify a substance.
- 1.29. Carbon dioxide is a nonflammable gas (chemical property) and it is denser than air (physical property). Therefore, the fire-extinguishing properties of CO_2 are due to both its physical and chemical properties.
- 1.31. In both liquid and ice, the water molecules touch each other. In ice, however, the water molecules are in a rigid hexagonal arrangement; in liquid, the molecules can move around each other and there is no long-range structure to their arrangement.
- 1.33. The particles in gases have the greatest freedom of motion; those in solids have the least.
- 1.35. The snow, instead of melting, sublimates to water vapor.
- 1.37. Energy is the ability to do work and must be expended to do work.
- 1.39. (a), (b), (c)
- 1.41. 13 times as much
- 1.43. SI units can be easily converted into a larger or smaller unit by multiplying or dividing by multiples of 10. English units are based on other number multiples and thus are more complicated to manipulate.
- 1.45. Scientists prefer the Celsius scale because it is based on the well-documented freezing and boiling points of a pure substance: water.
- 1.47. The absolute temperature scale (Kelvin scale) has no negative temperatures, and its zero value is placed at the lowest possible temperature.
- 1.49. 93.2%
- 1.51. 2.5 mi
- 1.53. 1330 Cal
- 1.55. 4.1×10^{13} km
- 1.57. 2.0 h
- 1.59. 4.03 m/s
- 1.61. 23 g
- 1.63. 19.0 mL
- 1.65. 26.5 g; 0.0265 kg
- 1.67. 58.0 cm^3

- 1.69. 73.8 mL
- 1.71. 5.1 g/cm^3
- 1.73. Yes
- 1.75. 109 g; 3.85 oz
- 1.77. (a), (c), (d), (f)
- 1.79. (a) 9.2×10^2 ; (b) 1.293×10^{20} ; (c) 1.53×10^{-23} ; (d) 3.73×10^{-6}
- 1.81. -269.0°C
- 1.83. 54.1°F ; 285.4 K
- 1.85. -89.2°C ; 183.9 K
- 1.87. The T_c for $\text{YBa}_2\text{Cu}_3\text{O}_7$ is already expressed in kelvins, $T_c = 93.0 \text{ K}$. The T_c of Nb_3Ge converted to K is 23.2 K. The T_c of $\text{HgBa}_2\text{CaCu}_2\text{O}_6$ converted to K is 127.0 K. The superconductor with the highest T_c is $\text{HgBa}_2\text{CaCu}_2\text{O}_6$.
- 1.89. The Grubbs' test can be used to test for only one outlier in a data set.
- 1.91. Mean \pm standard deviation (s) is slightly greater because the 95% confidence interval for 7 data points is
- $$\text{Mean} \pm \left(\frac{t \cdot s}{\sqrt{n}} \right) = \pm \left(\frac{2.447 \cdot s}{2.646} \right) = \pm 0.9249 s$$
- 1.93. (a) The mean and standard deviation values (all in μm) are 0.5106 ± 0.0047 for Manufacturer 1; 0.5134 ± 0.0009 for Manufacturer 2; $0.5012, 0.0008$ for Manufacturer 3; (b) The 95% confidence intervals are 0.5106 ± 0.0058 for Manufacturer 1, 0.5134 ± 0.0011 for Manufacturer 2, and 0.5012 ± 0.0010 for Manufacturer 3. To three significant figures, the 95% confidence interval for Manufacturer 3's data includes 0.500; (c) Manufacturer 3 is both precise and accurate; Manufacturer 2 is precise but not accurate.
- 1.95. This point is an outlier.
- 1.97. 0.031 mg/L
- 1.99. Mixtures (a) and (b) react so that neither sodium nor chlorine is left over.
- 1.101. Day 11
- 1.103. 16 times more administered than prescribed
- 1.105. (a) Can't tell from the data given. All readings end in an even number which may mean that the minimum detectable change in temperature is 0.2°C ; (b) It is not likely that any of them would give an accurate reading to the nearest 0.1°C .
- 1.107. $3.246 \times 10^4 \text{ mi/h}$

Chapter 2

- 2.1. Purple (H, hydrogen)

- 2.3. Purple (H, hydrogen)
- 2.5. (a) Green (Au, gold); (b) Blue (Na, sodium); (c) Lilac (Cl, chlorine)
- 2.7. Red arrow, alpha; green arrow, beta
- 2.9. Dichloromethane: the differences in mass between the peaks near 50 amu and 85 amu correspond to the masses of stable Cl isotopes: 35 and 37 amu.
- 2.11. (a) Blue (K) and green (Ag); (b) Grey (Mg); (c) Yellow (Sc); (d) Purple (I); (e) Red (O)
- 2.13. The plum-pudding model could not explain the infrequent, large-angle deflections of alpha particles that Rutherford's students observed. However, these deflections could be explained by the particles' colliding with tiny, dense atomic nuclei that took up little of the volume of gold atoms, but that contained all of the positive charge and most of the atoms' mass (Rutherford's model).
- 2.15. The fact that cathode rays were deflected by a magnetic field indicated that the rays were streams of charged particles.
- 2.17. Through the alpha decay of uranium and other radioactive nuclides.
- 2.19. Absorption of an α particle by a gold atom would have transmuted the gold atom into an atom of thallium.
- 2.21. Greater than 1
- 2.23. Hydrogen (^1H)
- 2.25.

	Atom	Mass Number	Atomic Number = Number of Protons	Number of Neutrons = Mass Number - Atomic Number	Number of Electrons = Number of Protons
(a)	^{14}C	14	6	8	6
(b)	^{59}Fe	59	26	33	26
(c)	^{90}Sr	90	38	52	38
(d)	^{210}Pb	210	82	128	82

- 2.27. The neutron-to-proton ratio for each of these elements is (a) ^4He , $2/2 = 1.00$, (b) ^{23}Na , $12/11 = 1.09$, (c) ^{59}Co , $32/27 = 1.19$, (d) ^{197}Au , $118/79 = 1.49$. As the atomic number (Z) increases, the neutron-to-proton ratio increases.
- 2.29.

Symbol	^{23}Na	^{89}Y	^{118}Sn	^{197}Au
Number of protons	11	39	50	79
Number of neutrons	12	50	68	118

Number of electrons	11	39	50	79
Mass number	23	89	118	197

2.31.

Symbol	$^{37}\text{Cl}^-$	$^{23}\text{Na}^+$	$^{81}\text{Br}^-$	$^{226}\text{Ra}^{2+}$
Number of protons	17	11	35	88
Number of neutrons	20	12	46	138
Number of electrons	18	10	36	86
Mass number	37	23	81	226

- 2.33. Group 2, RO; group 3, R₂O₃; group 4, RO₂
- 2.35. Mendeleev based his groups on chemical reactivity. No compounds of the noble gases existed to indicate their presence in nature.
- 2.37. C, N, and O
- 2.39. (a) Palladium (Pd); (b) Rhodium (Rh); (c) Platinum (Pt)
- 2.41. Three (Na, Mg, and Al)
- 2.43. A *weighted average* takes into account the proportion of each value in the group of values to be averaged.
- 2.45. $(m_X + m_Y)/2$
- 2.47. Platinum must have other isotopes with masses greater than and less than 195. The abundances of the heavier and lighter isotopes must be roughly the same so that their weighted average atomic mass is 195.08 amu.
- 2.49. ^{40}Ar
- 2.51. (a) ^{11}B ; (b) ^7Li ; (c) ^{14}N
- 2.53. 63.55 amu
- 2.55. Yes
- 2.57. 47.948 amu
- 2.59. (a) CaF₂, 78.074 amu; (b) Na₂S, 78.045 amu; (c) Cr₂O₃, 151.989 amu
- 2.61. (a) 1; (b) 3; (c) 6; (d) 6
- 2.63. (e) CH₄ < (d) NH₃ < (a) CO < (c) CO₂ < (b) Cl₂
- 2.65. A dozen is too small a unit to express the very large number of atoms, ions, or molecules present in laboratory quantities such as a mole.
- 2.67. No
- 2.69. (a) 7.3×10^{-10} mol Ne; (b) 7.0×10^{-11} mol CH₄; (c) 4.2×10^{-12} mol O₃; (d) 8.1×10^{-15} mol NO₂
- 2.71. (a) 1 mol; (b) 2 mol; (c) 1 mol; (d) 3 mol
- 2.73. 10.3 g

- 2.75. (a) 0.125 mol; 7.53×10^{22} atoms; (b) 0.125 mol; 7.53×10^{22} atoms; (c) 0.250 mol; 1.51×10^{23} atoms; (d) 0.375 mol; 2.26×10^{23} atoms
- 2.77. (a) Both contain the same; (b) N_2O_4 ; (c) CO_2
- 2.79. (a) 3.00 mol; (b) 4.50 mol; (c) 1.50 mol
- 2.81. (a) 64.063 g/mol; (b) 47.997 g/mol; (c) 44.009 g/mol; (d) 108.009 g/mol
- 2.83. (a) 152.148 g/mol; (b) 164.203 g/mol; (c) 148.204 g/mol; (d) 132.161 g/mol
- 2.85. 41.63 mol
- 2.87. 0.25 mol; 10 g
- 2.89. (a) NO; (b) CO_2 ; (c) O_2
- 2.91. 0.752 mol
- 2.93. Diamond
- 2.95. The peak with the largest m/z value in many mass spectra is the molecular ion, M^+ , peak whose mass is the molecular mass of the compound.
- 2.97. Yes
- 2.99. (a) 222 amu; (b) 296 amu; (c) 316 amu; (d) 450 amu
- 2.101. (a) The three peaks are due to the different combinations of isotopes in Cl_2 : $^{35}\text{Cl}_2$ is at 70 amu, $^{35}\text{Cl}^{37}\text{Cl}$ is at 72 amu, and $^{37}\text{Cl}_2$ is at 74 amu; (b) The peak at 70 amu is much more intense than the peak at 74 amu because the ^{35}Cl is much more abundant than ^{37}Cl , so it is more likely that a molecule of Cl_2 will contain two ^{35}Cl isotopes than contain two ^{37}Cl isotopes.
- 2.103. The biggest peak at 34 amu is the molecular ion of H_2^{32}S (nearly 95% of all S atoms are ^{32}S). The peaks at 33 and 32 amu are produced when electron bombardment of H_2^{32}S molecules fragments them, forming ions of H^{32}S and ^{32}S atoms. The source of the small peak at 36 amu is probably the molecular ion of H_2^{34}S (the second most abundant S isotope). The even smaller peak at 35 amu is probably a combination of mostly H^{34}S and a very little H_2^{33}S (this isotope of sulfur has a natural abundance of less than 1%). Molecular and fragment ions of the even less abundant ^{35}S isotope were probably not detected.
- 2.105. 303 g/mol
- 2.107. (a) Electrons; (b) The negatively charged electrons were attracted to the positively charged plate and repelled by the negatively charged plate as they passed through the electric field. (c) If the polarities of the plates were switched, the electron would deflect in the opposite direction.
- 2.109. 10.00% ^{25}Mg and 11.01% ^{26}Mg
- 2.111. 1.2×10^{14}
- 2.113. 615 μg
- 2.115. (a) 0.7580 mol C; (b) 4.565×10^{23} atoms C

Chapter 3

- 3.1. (a) Purple (Na), red (Cr), and orange (Au); (b) Blue (Ne); (c) Orange (Au); (d) Red (Cr); (e) Blue (Ne) and green (Cl)
- 3.3. (a) Green (Cl); (b) Purple (Na), red (Cr), and yellow (Au)
- 3.5. Blue (Rb), green (Sr), and orange (Y)
- 3.7. (c)
- 3.9. (a)
- 3.11. (a) e; (b) a; (c) a
- 3.13. All these forms of light have perpendicular, oscillating electric and magnetic fields that travel together through space.
- 3.15. The lead shield protects the parts of our bodies that might be exposed to X-rays but are not being imaged. Lead is a dense metal and effective absorber of X-rays.
- 3.17. It still emits infrared radiation.
- 3.19. $5.490 \times 10^{14} \text{ s}^{-1}$; yes
- 3.21. (a) 3.32 m; (b) 3.14 m; (c) 3.04 m; (d) 2.79 m
- 3.23. The frequency of the X-rays emitted from (a) copper is higher.
- 3.25. 8.317 min
- 3.27. The absorption spectrum consists of dark lines at wavelengths specific to that element. The emission spectrum has bright lines on a dark background. The wavelengths of the emission and absorption lines are the same.
- 3.29. Because each element shows distinctive and unique absorption and emission lines, the bright emission lines observed for the pure elements could be matched to the many dark absorption lines in the spectrum of sunlight. This approach can be used to deduce the sun's elemental composition.
- 3.31. The quantum is the smallest indivisible quantity of radiant energy that can be absorbed or emitted.
- 3.33. No
- 3.35. $6.62 \times 10^{-19} \text{ J}$
- 3.37. (b) The door elevations have discrete values. There are none in between those on adjacent floors.
- 3.39. $7.71 \times 10^{-19} \text{ J}$
- 3.41. No
- 3.43. Potassium; $8.04 \times 10^5 \text{ m/s}$
- 3.45. $3.17 \times 10^{18} \text{ photons/s}$
- 3.47. The Balmer equation is equivalent to the Rydberg if $n_1 = 2$.
- 3.49. It is the difference between n levels that determines emission energy.

- 3.51. (a)
- 3.53. No
- 3.55. At $n = 7$, the wavelength of the electron's transition ($n = 7$ to $n = 2$) is in the ultraviolet region.
- 3.57. 1875 nm; infrared
- 3.59. No, because for hydrogen the transition is in the ultraviolet region and as Z increases the wavelength will shorten further.
- 3.61. (a) No; (b) Yes
- 3.63. In the de Broglie equation, λ is the wavelength the particle of mass m exhibits as it travels at speed u , where h is Planck's constant. This equation states that (1) any moving particle has wavelike properties because a wavelength can be calculated through the equation, and (2) the wavelength of the particle is inversely related to its momentum (mass multiplied by velocity).
- 3.65. No
- 3.67. (b) and (c)
- 3.69. (a) 10.8 nm; (b) 0.180 nm; (c) 8.2×10^{-28} nm; (d) 3.7×10^{-54} nm
- 3.71. $\Delta x \geq 1.3 \times 10^{-13}$ m
- 3.73. The Bohr model orbit showed the quantized nature of the electron in the atom as a particle moving around the nucleus in concentric orbits. In quantum theory, an orbital is a region of space where the probability of finding the electron is high. The electron is not viewed as a particle but as a wave, and it is not confined to a clearly defined orbit; rather, we refer to the probability of the electron being at various locations around the nucleus.
- 3.75. Three: n , ℓ , and m_ℓ .
- 3.77. (a) 1; (b) 4; (c) 9; (d) 16; (e) 25
- 3.79. 3, 2, 1, 0
- 3.81. (a) $6s$; (b) $3d$; (c) $2p$; (d) $5g$
- 3.83. (a) 2; (b) 2; (c) 10; (d) 2
- 3.85. (b)
- 3.87. Degenerate orbitals have the same energy and are indistinguishable from each other.
- 3.89. Starting with the fourth row elements, the outermost ($n =$ row number) s orbitals fill before the $(n - 1)$ d orbitals do. For example K and Ca atoms contain $4s$ electrons, but no $3d$ electrons.
- 3.91. (c) $3s < (a) 3d < (d) 4p < (b) 7f$
- 3.93. Li^+ : $1s^2$ or $[\text{He}]$; Ca : $[\text{Ar}]4s^2$; F^- : $[\text{He}]2s^22p^6$ or $[\text{Ne}]$; Mg^{2+} : $[\text{He}]2s^22p^6$ or $[\text{Ne}]$; Al^{3+} : $[\text{He}]2s^22p^6$ or $[\text{Ne}]$
- 3.95. K: $[\text{Ar}]4s^1$; K^+ : $[\text{Ar}]$; Ba: $[\text{Xe}]6s^2$; Ti^{4+} : $[\text{Ne}]3s^23p^6$ or $[\text{Ar}]$; Ni: $[\text{Ar}]4s^23d^8$

- 3.97. (b) for Mn; (d) for Mn^{2+}
- 3.99. (a) 3; (b) 2; (c) 0; d) 0
- 3.101. Ti, two unpaired electrons
- 3.103. Cl^- , no unpaired electrons
- 3.105. (a) and (d)
- 3.107. $5p$, yes
- 3.109. Na atoms are larger than Cl atoms because the latter have six more positive charges in their nuclei, which pull the atom's electrons inward more strongly. However, Na^+ ions are much smaller than Na atoms because their $n = 3$ shell is empty. In addition, Cl^- ions are larger than Cl atoms because each ion has one more electron, which means greater electron-electron repulsion and an expanded cloud of electrons around the ion's nucleus.
- 3.111. (a) $\text{Al} > \text{P} > \text{Cl} > \text{Ar}$; (b) $\text{Sn} > \text{Ge} > \text{Si} > \text{C}$; (c) $\text{K} > \text{Na} > \text{Li} > \text{Li}^+$; (d) $\text{Cl}^- > \text{Cl} > \text{F} > \text{Ne}$
- 3.113. (a) As the atomic number increases down a group, electrons are added to higher n levels, leading to a decrease in effective nuclear charge and ionization energy.
(b) As the atomic number increases across a row, the effective nuclear charge increases. This means that the ionization energy increases across a period of elements.
- 3.115. Because less energy would be required to ionize a larger atom, the wavelength of light required would be longer for atoms of higher atomic number than for atoms of lower atomic number in the same group on the periodic table.
- 3.117. (a) $\text{I} < \text{Br} < \text{Cl} < \text{F}$; (b) $\text{Na} < \text{Li} < \text{Mg} < \text{Be}$; (c) $\text{N} < \text{O} < \text{F} < \text{Ne}$
- 3.119. No, sodium has a negative (favorable) electron affinity but is never found as an anion in nature. It is always a cation in salts such as NaCl and Na_2CO_3 .
- 3.121. Electrons are added to shells that are farther from the nucleus with increasing Z . This means electron affinities become weaker, that is, less negative, which means their arithmetic values increase.
- 3.123. (a) $[\text{Xe}]6s^2$; (b) $n = 5, \ell = 2, m_\ell = -2, -1, 0, 1, 2$; (c) No; (d) Yes
- 3.125. (a), (c), and (d)
- 3.127. Yes. It is generally observed that as Z increases so does the IE_2 . However, Ge's second IE_2 is lower than Ga's because to ionize the second electron in Ga, we need to remove an electron from a lower energy $4s$ orbital. Also, Br's IE_2 is lower than Se's because the electron pairing ($4p^4$) in one of the p orbitals for the Br^+ ion lowers its IE_2 slightly.

- 3.129. (a) Sn^{2+} : $[\text{Kr}]4d^{10}5s^2$; Sn^{4+} : $[\text{Kr}]4d^{10}$; Mg^{2+} : $[\text{He}]2s^22p^6$ or $[\text{Ne}]$; (b) Cadmium has the same electron configuration as Sn^{2+} and neon has the same electron configuration as Mg^{2+} ; (c) Cd^{2+}
- 3.131. (a) Ne, 5.76; Ar, 6.76; (b) The outermost electron in argon is a $3p$ electron, which is mostly shielded by the electrons in the $n = 2$ level (10 electrons) and the $n = 1$ level (2 electrons), whereas the outermost electron in neon is a $2p$ electron, which is shielded only by the electrons in the $n = 1$ level (2 electrons).
- 3.133. Assume that the electrons in p orbitals behave like standing waves. Then the node between the two lobes could be a place where their waves have zero amplitude, but wave amplitudes in the lobes are not zero.

Chapter 4

- 4.1. (e) Al^{3+}
- 4.3. Only the middle structure is a resonance structure of the thiocyanate ion, SCN^- , because its middle atom is carbon.
- 4.5. (d) Cl is slightly more electronegative than Br, so the Cl atom should be redder than the Br atom.
- 4.7. (a) Oxygen is more electronegative than sulfur, so the O atoms at the ends of the molecule should have partial negative charges (depicted by their orange color) and the S atom in the middle should have a partial positive charge.
- 4.9. All three modes are infrared active.
- 4.11. The red curve represents the interaction between potassium and fluoride ions: its minimum is more negative and at a smaller distance between nuclei than the blue curve because of the smaller ionic radius of F^- compared to Cl^- .
- 4.13. The number of valence electrons equals the group number for groups 1–12. Once the d orbitals are filled, they are considered “core” electrons.
- 4.15. There are Coulombic forces of attraction between the ions of opposite charge in ionic compounds. In covalent compounds, chemical bonds are formed through electron sharing.
- 4.17. $-6.94 \times 10^{-18} \text{ J}$
- 4.19. (b) TiO_2
- 4.21. $\text{CsBr} < \text{KBr} < \text{SrBr}_2$
- 4.23. Roman numerals indicate the charge on the transition metal cation.
- 4.25. XO_2^{2-}
- 4.27. (a) NO_3 , nitrogen trioxide; (b) N_2O_5 , dinitrogen pentoxide; (c) N_2O_4 , dinitrogen tetroxide; (d) NO_2 , nitrogen dioxide; (e) N_2O_3 , dinitrogen trioxide; (f) NO , nitrogen monoxide; (g) N_2O , dinitrogen monoxide; (h) N_4O , tetranitrogen monoxide