CHAPTER 2 | Atoms, Ions, and Molecules: Matter Starts Here

2.1. **Collect and Organize**

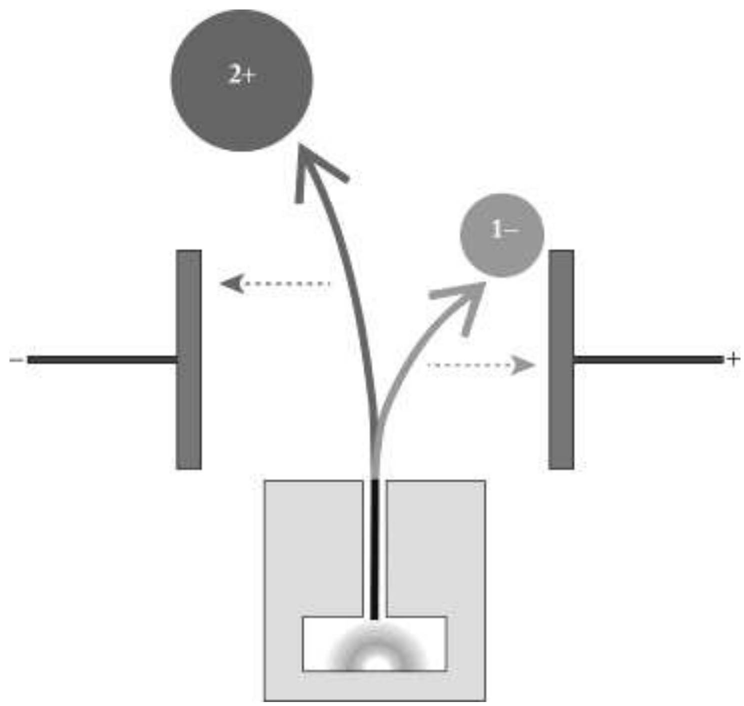
This question asks us to identify alpha and beta particles based on the curved paths taken by each form of radiation, as shown in the figure.

Analyze

Figure P2.1 shows two paths that curve as they exit the sample container and pass through the electrical field. From the diagram, we see that the left plate is negatively charged, while the right plate is positively charged. Alpha particles have a 2+ charge, while beta particles have a 1– charge. Similar electrical charges will repel one another, while opposing electrical charges will be attracted to one another.

Solve

The positively charged alpha particle will be attracted to the negative (left) plate, while the negatively charged beta particle will be attracted to the positive (right) plate.



Think About It

You may have noticed that the beta particle is pulled closer to the positive plate than the alpha particle is to the negative plate. Alpha particles are several thousand times heavier than beta particles, leading to less deflection.

2.2. **Collect and Organize**

This question asks us about the penetrating power of the radiation following the red and green paths in Figure P2.1.

Analyze

Figure P2.1 shows an alpha particle traveling along the red path and a beta particle traveling along the green path. While alpha particles are massive, they do not penetrate deeply into a surface. Beta particles have less ionizing power but can penetrate a surface more deeply than alpha particles.

Solve

Radiation following the red path in Figure P2.1 (alpha particles) does not penetrate solid objects better than the radiation following the green path (beta particles).

Think About It

A sheet of gold foil is sufficiently thick to stop an alpha particle. Despite this low penetrating power, alpha particles have a high ionizing potential and can cause significant damage to living tissue if ingested.

2.3. **Collect and Organize**

This question asks us to look at the connectivity of the atoms of nitrogen (blue spheres) and oxygen (red spheres) to decide which species are represented in the figure.

Analyze

Figure P2.1 shows seven molecules of red and blue spheres. In some cases the spheres are in a group of three; in others they are in a group of two. In all cases, nitrogen and oxygen are present in the molecules; there are no all-red or all-blue molecules. Therefore, the answer will be some mixture of different nitrogen–oxygen species.

Solve

Looking specifically at the molecules made up of three atoms, we see that each contains two oxygen atoms and one nitrogen atom; this must be NO_2. For the two-atom molecules depicted, each is composed of one nitrogen atom and one oxygen atom; this must be written as NO. Therefore, the answer is (c) a mixture of NO_2 and NO.

Think About It

Even though there are 11 red spheres depicted with 7 blue spheres, the answer cannot be (b) N_7O_{11} because that formula implies that all 18 atoms of nitrogen and oxygen are bonded together in one molecule. Answer (a), N_2O_3, does not have the nitrogen-to-oxygen ratio correct, and it indicates that only one type of molecule, composed of two nitrogen and three oxygen atoms, is shown in the figure, whereas two different molecules are actually depicted. Finally, (d)—a mixture of N_2 and O_3—cannot be correct because there are no blue–blue (N_2) or red–red–red (O_3) molecules depicted; all molecules shown contain both nitrogen and oxygen.

2.4. **Collect and Organize**

This question asks us to identify the molecules depicted in the figure, compare the mass of carbon in the compartments, compare the ratio of atoms in the compartments, and evaluate a statement about the pressure of the gases in the compartments. We have to consider not only the specific atoms present in each compartment, but also how the atoms are bonded together to form molecules and the number of each kind of molecule depicted in the compartments.

Analyze

Comparing the compartments in Figure P2.2, we see that the left side contains four molecules made up of one black sphere (carbon) and two red spheres (oxygen). The right side contains four molecules composed of one black sphere and one red sphere.

Solve

The compartments contain the same number of molecules, but different molecules. The left side contains four molecules of CO_2 and the right contains four molecules of CO, so (a) is true.

To compare mass, we count four atoms of carbon on the left side and four atoms of carbon on the right side. Therefore, the masses of the carbon atoms are equal and (b) is also true.

There are eight atoms of oxygen in the left box and four atoms of oxygen in the right box. This ratio is 2:1, so (c) is true, as well.

Finally, if the pressure of a gas is proportional to the number of molecules (particles) in a confined volume, the pressure in each compartment would be the same because they contain equal numbers of molecules, so (d) is also true.

Think About It

We can make many comparisons between two chemical systems, including physical properties such as pressure and mass along with the comparison of ratios of atoms or chemical species present.

2.5. **Collect and Organize**

For this question we need to correlate properties of the elements with their positions in the periodic table. We need to access the definitions of *reactive* and *inert* and know the general regions of the periodic table that have gaseous, metallic, and nonmetallic elements.

Analyze

Reactive means that the species readily combines with other elements to form compounds, and *inert* means that the chemical species does not combine with other species. On the periodic table, metallic elements tend to be on the left side; nonmetallic elements are on the right side. Under standard conditions, the gases tend to be in groups 18 (noble gases) and 17 (the halogens: fluorine and chlorine) along with oxygen, nitrogen, and hydrogen. Of these gases, the noble gases are monatomic, but the others are all diatomic (N_2, O_2, H_2, F_2, Cl_2).

Solve

In the periodic table shown in Figure P2.5, elements Na, Ne, Cl, Au, and Lr are highlighted.

(a) Chlorine (Cl_2) is a reactive, diatomic gas at room temperature (yellow). It is a nonmetal.
(b) Neon (Ne) is a chemically inert gas (red).
(c) Sodium (Na) is a reactive metal (dark blue).

Think About It

Gold and lawrencium are also metals. However, gold is not very reactive (it can be found as an element in nature), and lawrencium is radioactive and synthesized in small amounts, meaning that its chemistry is relatively unexplored.

2.6. **Collect and Organize**

This question asks us to correlate the position of an element in the periodic table with typical charges on the ions for the groups (or families) of elements.

Analyze

The common charges on the elements used in forming compounds are shown in Figure 2.17. That figure will help us to answer which elements in monatomic form give the following charges.

Solve

Highlighted elements in Figure P2.6 are K, Mg, Sc, O, Ag, and I.

(a) Elements in group 1 form 1+ ions, so K will form K^+ (dark blue). Elements in the transition metal series may adopt several different charges, but silver only forms a 1+ ion, so Ag forms Ag^+ (green).
(b) Elements in group 2 form 2+ ions, so Mg forms Mg^{2+} (gray).

(c) Elements in group 3 form 3+ ions, so Sc forms Sc^{3+} (yellow).
(d) Elements in group 17 (the halogens) form 1– ions, so I forms I^{-} (purple).
(e) Elements in group 16 form 2– ions, so O forms O^{2-} (red).

Think About It
Notice that elements on the left side of the periodic table form cations, and the ones on the right tend to form anions. The transition metals tend to form cations, as you can see in Figure 2.17.

2.7. **Collect and Organize**
In this question we have to consider which elements combine with oxygen in a certain ratio to give a neutral compound (i.e., a compound with no overall charge). We must first determine the charge on the unknown element in each molecule. We are then asked to find the element highlighted in the periodic table in Figure P2.7 that corresponds to that charge.

Analyze
Oxygen has a 2– charge when combined with elements to form compounds. To balance out the charge, an element in a 1:1 ratio with O would have to carry a 2+ charge to form a neutral compound. Likewise, an element in 2:1 ratio with O would have to carry a 1+ charge. The other ratios can be found similarly. Once the charges of the unknown elements are determined, we can use the information in Figure 2.17 to identify the element for each oxygen compound.

Solve
The highlighted elements in the periodic table in Figure P2.7 are K, Mg, Ti, and Al.
(a) The ratio of X to O in XO is 1:1; therefore the charge on X is 2+. Elements in group 2 typically have this charge in compounds. Mg (green) will form MgO.
(b) The ratio of X to O in X_2O is 2:1; therefore the charge on X is 1+. Elements in group 1 typically have this charge in compounds. K (red) will form K_2O.
(c) The ratio of X to O in XO_2 is 1:2; therefore the charge on X is 4+. Elements in group 4 typically have this charge in compounds. Ti (yellow) will form TiO_2.
(d) The ratio of X to O in X_2O_3 is 2:3; therefore the charge on X is 3+ (three O ions have a total charge of 6–, so two cations of 3+ charge will form a neutral compound). Elements in group 13 can have this charge in compounds. Al (dark blue) will form Al_2O_3.

Think About It
Elements from across the periodic table, from the alkali metals to the main group elements, combine with oxygen to form compounds.

2.8. **Collect and Organize**
In this question we need to consider which elements combine with oxygen in a certain ratio to give polyatomic anions. We must first find the charge on the element that has combined with oxygen, being sure to take into account the negative charge balance for the anions. We are then asked to find the element highlighted in the periodic table in Figure P2.8 that corresponds to that charge.

Analyze
Oxygen has a 2– charge when combined with elements to form compounds. When the overall charge on the species must be negative, the charge on the cations will not completely balance the charges on the oxygen

anions. The X atom in a species with a 1– charge that has a 1:4 ratio of X to O would have to carry a 7+

charge ($4 \times -2 + 7 = 1-$). Once the charges are known for the elements, we can use the information in Figure 2.17 to identify the particular element for each compound with oxygen.

Solve

The highlighted elements in the periodic table in Figure P2.8 are N, P, S, and Mn.

(a) The ratio of X to O in XO_4^- is 1:4, with an overall charge of 1– on the anion; therefore the charge on X is 7+. Transition metal elements in group 7 could have this charge in compounds. Mn (green) will form MnO_4^-, the permanganate ion.

(b) The ratio of X to O in XO_4^{2-} is 1:4, with an overall charge of 2– on the anion; therefore the charge on X is 6+. Elements in group 16 could have this charge in compounds. S (yellow) will form SO_4^{2-}, the sulfate ion.

(c) The ratio of X to O in XO_4^{3-} is 1:4, with an overall charge of 3– on the anion; therefore the charge on X is 5+. Elements in group 15 could have this charge in compounds. P (red) will form PO_4^{3-}, the phosphate ion.

(d) The ratio of X to O in XO_3^- is 1:3 with an overall charge of 1– on the anion; therefore the charge on X is 5+. Elements in group 15 could have this charge in compounds. N (dark blue) will form NO_3^-, the nitrate ion.

Think About It

The answers for (c) and (d) might initially be thought to be either P or N. In that case for (c), either PO_4^{3-} or NO_4^{3-} would be possible. However, the anion NO_4^{3-} does not exist. Likewise, PO_3^{3-} is not a common ion for phosphorus. (See Table 2.3 for names and chemical formulas for common polyatomic ions.)

2.9. **Collect and Organize**

This question asks us to recall which elements were formed in the fusion processes occurring in giant stars and to correlate the elements' identities with their positions on the periodic table.

Analyze

Giant stars are very hot and are dense enough to pack nuclei together very closely, allowing for fusion reactions between the positively charged helium and hydrogen nuclei. More helium could therefore be produced from the hydrogen nuclei present. We also learned that these processes occurred to produce the elements as heavy as iron on the periodic table.

Solve

All the elements from helium to iron are produced in the fusion fires of giant stars. Therefore, all elements from 1 through 26 on the periodic table would be produced. In Figure P2.4 this includes the elements highlighted in groups 1 (K, dark blue), 4 (Ti, green), and 8 (Fe, yellow). The element shaded in group 12 (red), which is Zn, is too heavy to have been produced in giant stars by fusion.

Think About It

Elements heavier than iron require additional energy to form. Making these elements in stars causes the star to collapse. The heavier elements were made through multiple neutron capture processes accompanied by β decay in these collapsing stars.

2.10. **Collect and Organize**

Using the representations in Figure P2.10, we are asked to answer questions about the type of bonding and relationship between the species depicted.

Analyze

Covalent compounds are formed when two nonmetals interact, while ionic compounds occur when a metal and a nonmetal (or a polyatomic anion). The law of multiple proportions states that elements may combine in different ratios to form distinct chemical compounds. An empirical formula is the ratio of elements in a compound, expressed using the smallest whole numbers possible.

Solve

(a) The covalent compounds listed are B, D, E, F, and H.
(b) The ionic compounds depicted are C and G.
(c) C contains both the covalently bonded sulfate anion and an ionic lattice formed from Ba^{2+} and SO_4^{2-}.
(d) The law of multiple proportions is demonstrated by F (N_2O_4) and H (N_2O).
(e) None of these compounds has the same empirical formula.
(f) D – carbon tetrachloride, F – dinitrogen tetroxide, H – dinitrogen monoxide.

Think About It

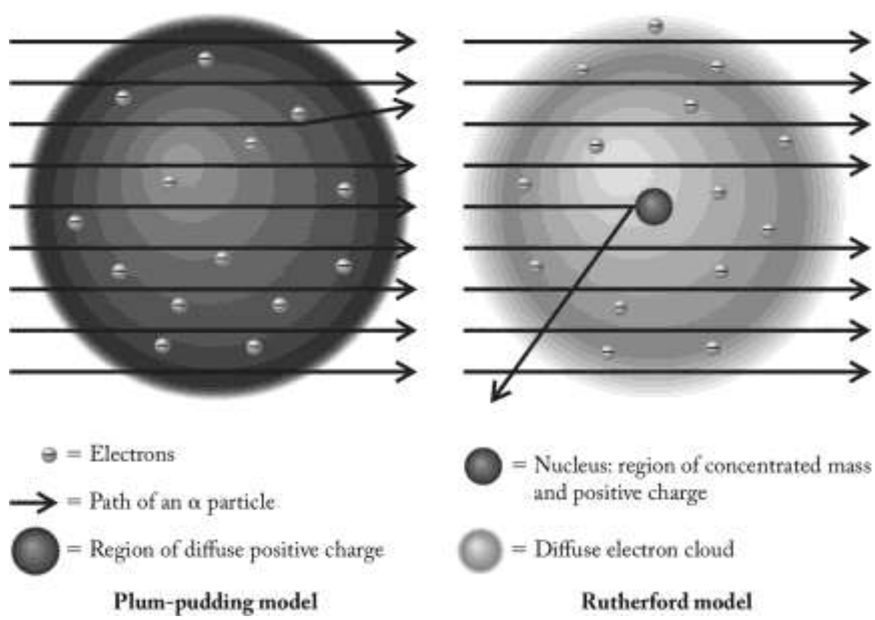
As shown, B exhibits covalent bonding. In solution, HNO_3 acts as a strong acid and is completely ionized to form H^+ and NO_3^- ions. This illustrates the importance of labeling the phase of a chemical species when writing equations in Chapter 3!

2.11. **Collect and Organize**

In this question we are asked to explain how Rutherford's gold-foil experiment changed the plum-pudding model of the atom.

Analyze

The plum-pudding model of the atom viewed the electrons as small particles in a diffuse, positively charged "pudding." In Rutherford's experiment, most of the α particles (positively charged particles) directed at the gold foil went straight through, but a few of them bounced back toward the source of the α particles.



Solve

From his experiments, Rutherford concluded that the positive charge in the atom could not be spread out (the pudding) in the atom, but must result from a concentration of charge in the center of the atom (the nucleus). Most of the α particles were deflected only slightly or passed directly through the gold foil, so he reasoned that the nucleus must be small compared to the size of the entire atom. The negatively charged electrons do not deflect the α particles, and Rutherford reasoned that the electrons took up the remainder of the space of the atom outside the nucleus.

Think About It

The nucleus is about 10^{-15} m in diameter, whereas the atom is about 10^{-10} m. This size difference has often been compared to "a fly in a cathedral."

2.12. **Collect and Organize**

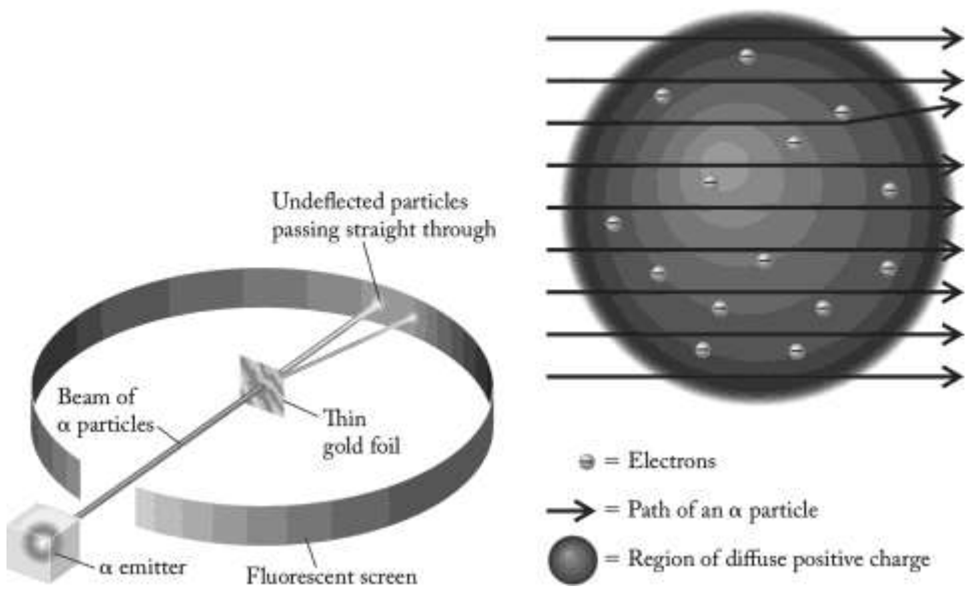
We are asked to consider what Rutherford's gold-foil experiments would have shown if the plum-pudding model had been valid.

Analyze

The plum-pudding model of the atom viewed the electrons as small particles in a diffuse, positively charged "pudding."

Solve

Had the plum-pudding model been valid, the α particles would have encountered only a diffuse positive charge when entering the atom, and they would have been only slightly deflected from their straight-line path.



Think About It

Because the positive charge in the atom was viewed as diffuse, no α particles would have bounced back toward their source in an experiment confirming the plum-pudding model. The key result of Rutherford's experiment was that a few α particles came directly back toward the α source. This indicated a highly dense nucleus of positive charge.

2.13. **Collect and Organize**

In this question we are to explain how J. J. Thomson discovered that cathode rays were not pure energy, but actually particles.

Analyze

Thomson's experiment directed the cathode ray through a magnetic field, and he discovered that the ray was deflected.

Solve

When Thomson observed cathode rays being deflected by a magnetic field, he reasoned that the rays were streams of charged particles because only moving charged particles would interact with a magnetic field. Pure energy rays would not.

Think About It

Thomson's discovery of the electron in cathode rays did not completely eliminate the use of the term *cathode ray*. CRTs (cathode-ray tubes) are the traditional (not LCD) television and computer screens.

2.14. **Collect and Organize**

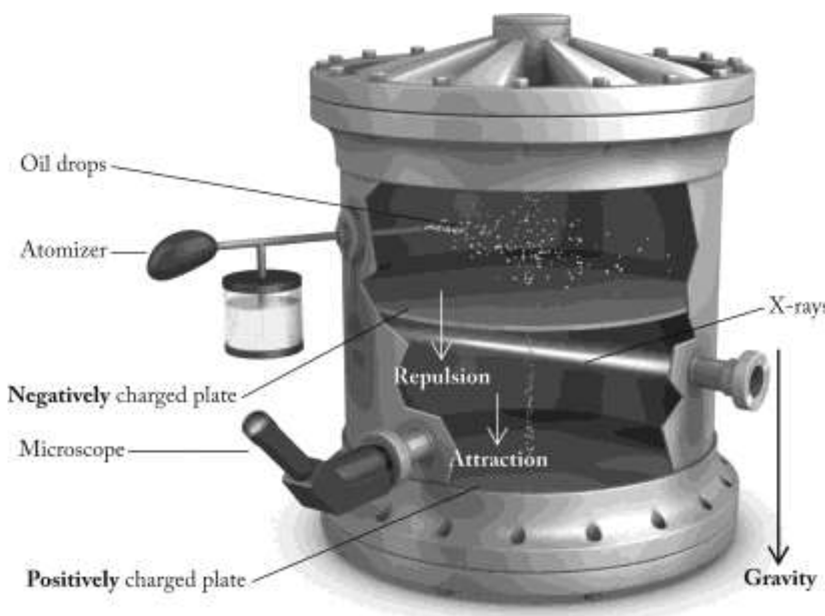
We are asked to comment on what Millikan would have observed during the oil-drop experiment if the charged plates on his apparatus were reversed.

Analyze

It will be helpful to remind yourself of Millikan's experimental setup, as shown in Figure 2.3. Recall that the oil drops in this experiment acquired a negative charge. Similar charges repel one another, whereas dissimilar charges attract one another.

Solve

Millikan's oil-drop experiment relied on the force of repulsion between the negatively charged oil droplets and the negatively charged plate and the force of attraction between the negatively charged oil droplets and the positively charged plate to counteract the force of gravity. If the plates were reversed, these forces would be summed instead of canceling, and the droplets would fall more quickly than by gravity alone (depicted) rather than appearing to hover.



Think About It
Millikan knew that electrons were negatively charged particles from J. J. Thomson's cathode-ray tube experiment. Knowing this, he was able to design an apparatus in which the forces of gravity and Coulombic attraction/repulsion would cancel.

2.15. **Collect and Organize**
We need to define *weighted average* for this question.

Analyze
An average is a number that expresses the middle of the data (in this case of various masses of atoms or isotopes).

Solve
A *weighted average* takes into account the proportion of each value in the group of values to be averaged. For example, the average of 2 and 5 is $(2 + 5)/2 = 3.5$, while the weighted average of 2, 2, 2, and 5 would be computed as $(2 + 2 + 2 + 5)/4 = 2.75$. This average shows the heavier weighting toward the "2" values.

Think About It
Because isotopes for any element are not equally present but have a range of natural abundances, all the masses of the elements in the periodic table are calculated weighted averages.

2.16. **Collect and Organize**
In this question we relate the percentage of natural abundance to the average atomic mass of an element.

Analyze
The natural abundance of an isotope of an element indicates how common that isotope is in nature (on Earth).

Solve
Isotopic abundances are used to compute the *weighted-average* atomic mass. The known isotopic abundances must be considered since the dominance of one isotope will contribute most to the average mass.

Think About It
A higher abundance of one isotope over another indicates its greater nuclear stability.

2.17. **Collect and Organize**
In this question we are asked to describe what is redundant about the expression

$${}^{A}_{Z}\mathrm{X}$$

Analyze
In this symbolism, Z is the atomic number (equal to the number of protons in the nucleus), A is the mass number (equal to the number of protons and neutrons in the nucleus), and X is the element symbol for the nuclide.

Solve
The element symbol and the atomic number provide the same information. Any change to the number of protons will change the identity of the element.

Think About It
Many chemists do not bother to write the atomic number and simply rely on the symbol to provide this information. This expression would look more like

$${}^{A}\mathrm{X}$$

2.18. **Collect and Organize**

In this question we are asked to describe how the number of protons and neutrons is related to the atomic number and the mass number for a nuclide.

Analyze

The mass number is given by the symbol *A*, while the atomic number is given by the symbol *Z*.

Solve

The atomic number is equal to the number of protons in the nucleus, while the mass number for a nuclide is equal to the number of protons and neutrons in the nucleus.

Think About It

Each element has a unique atomic number, and the periodic table is organized by increasing atomic number. The mass number may vary for isotopes of the same element.

2.19. **Collect and Organize**

For each element in this question, we must look at the relationship of the neutrons, protons, and electrons. We need to determine what the element's atomic number is from the periodic table and, from the mass number given for the isotope, compute the number of neutrons in that isotope.

Analyze

An isotope is given by the symbol ${}^{A}_{Z}X$, where X is the element symbol from the periodic table, *Z* is the atomic number (the number of protons in the nucleus), and *A* is the mass number (the number of protons and neutrons in the nucleus). Often, *Z* is omitted because the element symbol gives us the same information about the identity of the element. To determine the number of neutrons in the nucleus for each of the named isotopes, we subtract *Z* (number of protons) from *A* (mass number). If the elements are neutral (no charge), the number of electrons equals the number of protons in the nucleus.

Solve

	Atom	Mass number	Number of protons = atomic number	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

Think About It

Isotopes of an element contain the same number of protons but a different number of neutrons. Thus, isotopes have different masses.

2.20. **Collect and Organize**

For each element in this question, we must look at the relationship of the neutrons, protons, and electrons. We need to determine what the element's atomic number is from the periodic table and, from the mass number given for the isotope, compute the number of neutrons in that isotope.

Analyze

An isotope is given by the symbol ${}^{A}_{Z}\text{X}$, where X is the element symbol from the periodic table, *Z* is the atomic number (the number of protons in the nucleus), and *A* is the mass number (the number of protons and neutrons in the nucleus). Often, *Z* is omitted because the element symbol gives us the same information about the identity of the element. To determine the number of neutrons in the nucleus for each of the named isotopes, we subtract *Z* (number of protons) from *A* (mass number). If the elements are neutral (no charge), the number of electrons equals the number of protons in the nucleus.

Solve

	Atom	Mass number	Number of protons = atomic number	Number of neutrons = mass number − atomic number	Number of electrons = number of protons
(a)	^{11}B	11	5	6	5
(b)	^{19}F	19	9	10	9
(c)	^{131}I	131	53	78	53
(d)	^{222}Rn	222	86	136	86

Think About It

Notice that, as the atom gets more massive, the ratio of neutrons to protons gets larger. For fluorine the ratio is 10/9 = 1.1, but for radon the ratio is 136/86 = 1.6. We will see later that, as the nucleus adds more protons, it needs more neutrons as "glue" to keep the nucleus stable.

2.21. **Collect and Organize**

This question asks us to consider the ratio of neutrons to protons in an element where we are given the fact that the mass number is more than twice the atomic number.

Analyze

We can find the number of neutrons for an isotope by relating the number of protons to the mass number. From that result we can then determine the neutron-to-proton ratio.

Solve

We are given an isotope in which the mass number is more than twice the number of protons. With *m* being the mass number and *p* the number of protons, we can express this relationship as

$$m > 2p$$

The mass number is also equal to the number of protons plus the number of neutrons (*n*):

$$m = p + n$$

Combining these expressions

$$p + n > 2p$$

and solving for *n* gives

$$n > 2p - p$$

$$n > p$$

Therefore, the number of neutrons in this isotope is greater than the number of protons, and the neutron-to-proton ratio is greater than 1.

Think About It

We would not have had to express the relationships between the nuclear particles mathematically if the isotope had a mass number equal to twice the number of protons. In that case, the number of neutrons would have to be exactly the same as the number of protons, giving a neutron-to-proton ratio of 1 to 1.

2.22. **Collect and Organize**

The mass number for each of the isotopes in the pairs given is the number of protons and neutrons in the nucleus. The atomic number on the periodic table gives the number of protons in the nucleus. From that information we can determine the number of neutrons and the number of protons for each isotope.

Analyze

In each case, we subtract the atomic number for the element from the mass number shown for the particular isotope. This gives the number of neutrons for that isotope. From that information, we can then decide which is more abundant in each nucleus: protons or neutrons.

Solve

(a) Iodine's atomic number is 53. Iodine-127 therefore has 74 neutrons and iodine-131 has 78 neutrons. Both of these isotopes have the same number of protons (they are the same element!), and iodine-131 has more neutrons in this pair.

(b) Rhenium's atomic number is 75; it has 75 protons and rhenium-188 has 113 neutrons in its nucleus. Tungsten has 74 protons, and tungsten-188 will have 114 neutrons in its nucleus. Therefore, ^{188}Re has more protons, and ^{188}W has more neutrons.

(c) Nitrogen's atomic number is 7; it has 7 protons and nitrogen-14 has 7 neutrons in its nucleus. Carbon has 6 protons, and carbon-14 has 8 neutrons in its nucleus. Therefore, ^{14}N has more protons, and ^{14}C has more neutrons.

Think About It

When two elements have the same mass number, they must have different numbers of neutrons in their nuclei. How many neutrons would ^{14}C have? In this case carbon would have 8 neutrons along with the 6 protons in its nucleus.

2.23. **Collect and Organize**

For each element in this question, we must look at the relationship of the neutrons, protons, and electrons. We need to determine what the element's atomic number is from the periodic table and, from the mass number given for the isotope, compute the number of neutrons in that isotope.

Analyze

An isotope is given by the symbol $^{A}_{Z}\mathrm{X}$, where X is the element symbol from the periodic table, Z is the atomic number (the number of protons in the nucleus), and A is the mass number (the number of protons and neutrons in the nucleus). Often, Z is omitted because the element symbol gives us the same information about the identity of the element. To determine the number of neutrons in the nucleus for each of the named isotopes, we subtract Z (number of protons) from A (mass number). If the elements are neutral (no charge), the number of electrons equals the number of protons in the nucleus.

Solve

(a) From the symbol provided (^{16}O), we know that oxygen's atomic number is 8 and the mass number for this nuclide is 16. For a charge-neutral species, we can deduce that the number of electrons is equal to the number of protons, 8.

(b) The element with 26 protons is iron (Fe). The mass number for this nuclide is the sum of the number of protons and neutrons, 26 + 30 = 56. For a charge-neutral species, we can deduce that the number of electrons is equal to the number of protons, 26. The symbol for this nuclide is ^{56}Fe.

(c) For a charge-neutral species, we can deduce that the number of protons is equal to the number of electrons, 50. The element with 50 protons is tin (Sn). The number of neutrons for this nuclide is equal to the difference between the mass number and the number of protons, 118 − 50 = 68. The symbol for this nuclide is ^{118}Sn.

(d) For a charge-neutral species, we can deduce that the number of electrons is equal to the number of protons, 79. The number of neutrons for this nuclide is equal to the difference between the mass number and the number of protons, 197 − 79 = 118. The element with 79 protons is gold (Au). The symbol for this nuclide is ^{197}Au.

Summarizing this information in the table below:

Symbol	^{16}O	^{56}Fe	^{118}Sn	^{197}Au
Number of protons	8	26	50	79
Number of neutrons	8	30	68	118
Number of electrons	8	26	50	79
Mass number	16	56	118	197

Think About It

When two elements have the same mass number, they must have different numbers, of neutrons in their nuclei. How many neutrons would ^{18}O have? In this case oxygen would have 10 neutrons along with the 8 protons in its nucleus.

2.24. ### Collect and Organize

To fill in the table, we have to consider how the numbers of nuclear particles relate to each other. We also need to recall how the symbols for the isotopes are written. In looking at the table, it is apparent that in some cases we have to work backward from the number of electrons or protons and the mass number for the element symbol.

Analyze

An isotope is given by the symbol $^{A}_{Z}X$, where X is the element symbol from the periodic table, *Z* is the atomic number (the number of protons in the nucleus), and *A* is the mass number (the number of protons and neutrons in the nucleus). We can determine the number of neutrons in the nucleus for the isotopes by subtracting *Z* (number of protons) from *A* (mass number). If the elements are neutral (no charge), the number of electrons equals the number of protons in the nucleus.

Solve

Symbol	^{27}Al	^{98}Mo	^{143}Nd	^{238}U
Number of protons	13	42	60	92
Number of neutrons	14	56	83	146
Number of electrons	13	42	60	92
Mass number	27	98	143	238

Think About It

Because the nuclear particles are all related to each other, we can work from the isotope symbol to find the number of protons, neutrons, and electrons for a particular isotope, or we can work from the mass number and the number of electrons or protons to determine the number of neutrons and write the element symbol.

2.25. **Collect and Organize**

We have to consider the concept of weighted-average atomic mass to answer this question.

Analyze

We are asked to compare two isotopes and their weighted-average mass. If the lighter isotope is more abundant, then the average atomic mass will be less than the average if both isotopes are equally abundant. If the heavier isotope is more abundant, the average atomic mass will be greater than the simple average of the two isotopes. We are given the mass number for the isotopes as part of the isotope symbol, and we will take that as the mass of that isotope in atomic mass units.

Solve

(a) The simple-average atomic mass for ^{10}B and ^{11}B would be 10.5 amu. The actual weighted-average mass (10.81 amu) is greater than this; ^{11}B is more abundant.
(b) The simple-average atomic mass for ^{6}Li and ^{7}Li would be 6.5 amu. The actual weighted-average mass (6.941 amu) is greater than this; ^{7}Li is more abundant.
(c) The simple-average atomic mass for ^{14}N and ^{15}N would be 14.5 amu. The actual weighted-average mass (14.01 amu) is less than this; ^{14}N is more abundant.
(d) The simple-average atomic mass for ^{20}Ne and ^{22}Ne would be 21 amu. The actual weighted-average mass (20.18 amu) is less than this; ^{20}Ne is more abundant.
Therefore, for both (a) and (b) the heavier isotope is more abundant.

Think About It

This is a quick question to answer for elements like boron, lithium, nitrogen, and neon that have only two isotopes dominating their abundance. It is a little harder to answer the same question for elements with more than two stable isotopes in relatively high abundances.

2.26. **Collect and Organize**

In this question we are provided with the mass and abundance of one of the naturally occurring isotopes of copper as well as the average atomic mass of copper. From this information, and knowing that copper is composed of only two isotopes, we may calculate the mass of the other isotope.

Analyze

To calculate the average atomic mass, we have to consider the relative abundances according to the following formula:

$$m_x = a_1m_1 + a_2m_2 + a_3m_3 + \ldots$$

where a_n refers to the abundance of isotope n and m_n refers to the mass of isotope n. If the relative abundances are given as percentages, the value we use for a_n in the formula is the percentage divided by 100. Since there are only two isotopes, the abundance of the second isotope is determined by subtracting the abundance of the first isotope from 1.

Solve

For the average atomic mass of copper

$$m_{\mathrm{Cu}} = a_1m_1 + a_2m_2 = a_1m_1 + (1 - a_1)m_2$$

We may ignore the mass of each isotope and simply look at the relationship between a_1 and a_2:

$$a_2 = 1 - a_1 = 1 - 0.6917 = 0.3083 \text{ or } 30.83\%$$

Think About It

Because copper-63 is more abundant than copper-65, we expect that the average atomic mass for copper would be below the simple average of 64 amu. We can confirm our solution by calculating the weighted average and comparing this to the average atomic mass of copper.

$$m_{\mathrm{Cu}} = a_1m_1 + a_2m_2 = 0.6917(62.9296 \text{ amu}) + 0.3083(64.9278 \text{ amu}) = 63.55 \text{ amu}$$

The weighted average is equal to the given average atomic mass for copper, 63.546 amu.

2.27. **Collect and Organize**

Here we are asked to find out if the weighted-average atomic mass of magnesium on Mars is the same as here on Earth. For this we have to work backward from the exact masses and abundances of MgO measured by the *Sojourner* robot to the weighted-average mass of magnesium.

Analyze

To find the mass of magnesium in each isotope of MgO, we need to subtract the mass of oxygen-16, given as 15.9949 amu, from the exact masses of the MgO isotopes. Because the oxygen is assumed not to be present in any other isotope, the percent abundances given must be the same as the percent abundances for the magnesium isotopes for the Mars rocks. From this we can calculate the weighted average from the masses of the Mg isotopes and their corresponding abundances.

Solve

The mass of Mg in each of the isotopes is the exact mass given minus the exact mass for oxygen-16. The weighted mass is the sum of the exact masses of Mg isotopes multiplied by their abundances (percentage divided by 100). The results of these calculations follow:

Exact mass of MgO (amu)	Mass of Mg in MgO isotope (amu)	Abundance	Weighted mass of Mg isotope (amu)
39.9872	23.9893	0.7870	18.88
40.9886	24.9937	0.1013	2.532
41.9846	25.9897	0.1117	2.903

Average atomic mass of Mg in Mars MgO samples = 18.88 + 2.532 + 2.903 amu = 24.32 amu.

The average mass of Mg on Mars is about the same as here on Earth.

Think About It

There would be no reason why the mass of Mg on Mars should not be close to the same value as on Earth; the magnesium on both planets arrived in the solar system via the same ancient stardust.

2.28. **Collect and Organize**

In this problem, we are asked to consider the differences in the number of neutrons for the six isotopes of platinum and to calculate the weighted-average atomic mass for platinum.

Analyze

Recall that the mass number for an isotope is located to the top left of the element symbol and is equal to the number of protons and neutrons in that nuclide. Platinum is element number 78, meaning that all isotopes of platinum contain 78 protons. To find the number of neutrons in each isotope, we subtract 78 from the mass number. To calculate the average atomic mass, we have to consider the relative abundances according to the following formula:

$$m_x = a_1m_1 + a_2m_2 + a_3m_3 + \ldots$$

where a_n refers to the abundance of isotope n and m_n refers to the mass of isotope n. If the relative abundances are given as percentages, the value we use for a_n in the formula is the percentage divided by 100.

Solve

(a) The number of neutrons in each isotope may be calculated as below:

Symbol	^{190}Pt	^{192}Pt	^{194}Pt	^{195}Pt	^{196}Pt	^{198}Pt
Mass number	190	192	194	195	196	198
Atomic number	78	78	78	78	78	78
Number of neutrons	112	114	116	117	118	120

(b) The weighted-average atomic mass is:

$$M_{\mathrm{Pt}} = 0.00014(189.96\text{ amu}) + 0.00782(191.96\text{ amu}) + 0.32967(193.96\text{ amu}) +$$
$$0.33832(194.97\text{ amu}) + 0.25242(195.97\text{ amu}) + 0.07163(197.97\text{ amu}) = 195.08\text{ amu}$$

This value is identical to that given on the inside cover.

Think About It

Even though the isotopes ^{194}Pt, ^{195}Pt, and ^{196}Pt make up approximately 92% of the average sample of platinum, it is important to account for all isotopes in the weighted average.

2.29. **Collect and Organize**

In this problem, we again use the concept of weighted-average atomic mass, but in this case we are asked to work backward from the average mass to find the exact mass of the ^{48}Ti isotope.

Analyze

We can use the formula for finding the weighted-average atomic mass, but this time our unknown quantity is one of the isotope masses. In this case,

$$m_{\mathrm{Ti}} = a_{^{46}\mathrm{Ti}}\, m_{^{46}\mathrm{Ti}} + a_{^{47}\mathrm{Ti}}\, m_{^{47}\mathrm{Ti}} + a_{^{48}\mathrm{Ti}}\, m_{^{48}\mathrm{Ti}} + a_{^{49}\mathrm{Ti}}\, m_{^{49}\mathrm{Ti}} + a_{^{50}\mathrm{Ti}}\, m_{^{50}\mathrm{Ti}}$$

Solve

$$47.87\text{ amu} = (0.0825 \times 45.95263\text{ amu}) + (0.0744 \times 46.9518\text{ amu}) +$$
$$(0.7372 \times m_{^{48}\mathrm{Ti}}) + (0.0541 \times 48.94787\text{ amu}) + (0.0518 \times 49.9448\text{ amu})$$

$$m_{^{48}\mathrm{Ti}} = 47.95\text{ amu}$$

Think About It

This answer makes sense since the exact mass of ^{48}Ti should be close to 48 amu.

2.30. **Collect and Organize**

In this problem, we again use the concept of weighted-average atomic mass, but in this case we are asked to work backward from the average mass to find the exact mass of the ^{40}Ar isotope.

Analyze

We can use the formula for finding the weighted-average atomic mass, only this time our unknown quantity is one of the isotope masses. In this case,

$$m_{\mathrm{Ar}} = a_{^{36}\mathrm{Ar}} m_{^{36}\mathrm{Ar}} + a_{^{38}\mathrm{Ar}} m_{^{38}\mathrm{Ar}} + a_{^{40}\mathrm{Ar}} m_{^{40}\mathrm{Ar}}$$

Solve

$$39.948\text{ amu} = (0.00337 \times 35.96755\text{ amu}) + (0.00063 \times 37.96272\text{ amu}) + (0.9960 \times m_{^{40}\mathrm{Ar}})$$

$$m_{^{40}\mathrm{Ar}} = 39.96\text{ amu}$$

Think About It

Since the abundance of argon-40 is very high, the average atomic mass is very close to that of the exact mass calculated for argon-40.

2.31. **Collect and Organize**

We are asked why Mendeleev arranged his periodic table based on atomic masses instead of atomic numbers.

Analyze

Mendeleev announced his periodic table in 1869. At this point, atoms were considered to be indivisible, and electrons, neutrons, and (especially) protons (which distinguish one element from another today) were not yet discovered.

Solve

Mendeleev knew only the masses of the elements when he arranged the elements into his periodic table. At the time, there was no idea that an element distinguished itself from another element by the number of protons in its nucleus.

Think About It

Mendeleev, however, also looked for patterns in chemical reactivity and physical properties to arrange the known elements in his periodic table. Remarkably, he left open spots in his periodic table for yet-undiscovered elements.

2.32. **Collect and Organize**

We are asked why the noble gases were not included by Mendeleev in his periodic table.

Analyze

The noble gases are characterized by their remarkable unreactivity. Unreactive elements can be quite unnoticeable because they do not form compounds with other elements.

Solve

The noble gases were not discovered until after Mendeleev put together his periodic table. He also could not have predicted the existence of the noble gases at the time since (a) none of them were isolated and characterized based on their reactivity (or lack thereof) and (b) he arranged the elements in order of increasing mass, not atomic number. If he had been aware of atomic numbers as characteristic of the elements, he would have noticed that the atomic numbers for the noble gases were a missing column in his table.

Think About It

The noble gases are monatomic, colorless and odorless, and have a remarkably narrow liquid range (their boiling points and melting points are close together).

2.33. **Collect and Organize**

In this question, we are provided with the label that Mendeleev used to describe the alkali metals (group 1) of the periodic table. Using his system, we are asked to predict the correct labels for groups 2, 3, and 4.

Analyze

Mendeleev labeled the left side of the periodic table using the formulas for their oxides. Since alkali metals adopt a 1+ charge, and the oxide anion bears a 2− charge, the label for group 1 is R_2O. Elements of groups 2, 3, and 4 adopt charges of 2+, 3+, and 4+, respectively.

Solve

Using Mendeleev's system, group 2 should be labeled RO, group 3 should be labeled R_2O_3, and group 4 should be labeled RO_2.

Think About It

The oxides were a good choice to use as a label since the formula for these ionic compounds depends on the group number. Lithium and sodium are both members of group 1, and both oxides have the same general formula, Li_2O and Na_2O.

2.34. **Collect and Organize**

In this question, we are provided with the labels that Mendeleev used to describe the elements of the right side of the periodic table. We are asked to identify which groups are described by the labels HR, H_2R, and H_3R.

Analyze

It helps to think of these labels as ionic compounds in which hydrogen is present as H^+. In HR the R must bear a 1– charge, in H_2R the R must bear a 2– charge, and in H_3R the R must bear a 3– charge.

Solve

The elements of group 17 adopt a 1– charge when forming ionic compounds and so should be labeled HR in this system. The elements of group 16 adopt a 2– charge when forming ionic compounds and so should be labeled H_2R in this system. The elements of group 15 adopt a 3– charge when forming ionic compounds and so should be labelled H_3R in this system.

Think About It

A good way to check our response is to use actual examples and see if they match the labels H_3R, H_2R, and HR. The binary compounds for the second period elements of groups 15, 16, and 17 are H_3N (ammonia, often written NH_3), H_2O (water), and HF (hydrogen fluoride). These compounds are reasonable, so we can be confident in our answer above.

2.35. **Collect and Organize**

We need to refer to the periodic table to determine the group that typically forms cations with charges of 2+.

Analyze

According to the periodic table, the elements of group 2 often combine with nonmetals to form salts in which the cation has a charge of 2+. To answer the question we need only match up the elements that are in group 2.

Solve

Only (c) Be is likely to form Be^{2+}.

Think About It

The only other element that is likely to form a cation in the question is (d) Al because it is a metal. Both (a) S and (b) P are nonmetals and are more likely to form anions.

2.36. **Collect and Organize**

We need to refer to the periodic table to determine the group that typically forms anions with charges of 2–.

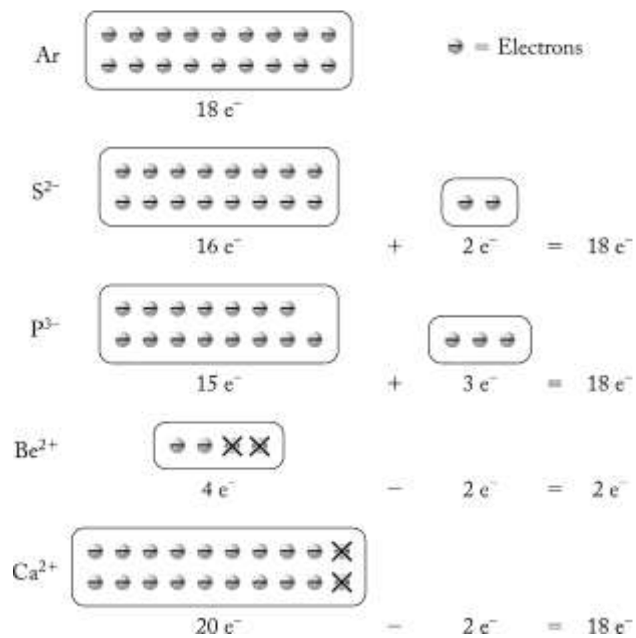
Analyze
According to the periodic table, the elements of group 16 often combine with metals to form salts in which the anion has a charge of 2–. To answer the question we need only match up the elements that belong to group 16.

Solve
Only (a) S is likely to form S^{2-}.

Think About It
The only other nonmetal on the list (one likely to form an anion) is (b) P. Because it belongs to group 15, however, it is more likely to form an anion with a charge of 3–, not 2–. Both (d) Al and (c) Be are metals, so they are more likely to form cations.

2.37. **Collect and Organize**
We need to refer to the periodic table to determine the atomic number of the element or ion and then count up the electrons for each species. Here we are looking for species that have the same number of electrons as an argon atom.

Analyze
According to the periodic table, argon has 18 electrons. From the periodic table and by adding or subtracting electrons as necessary to make anions and cations as needed, we see that S^{2-} has 18 electrons, P^{3-} has 18 electrons, Be^{2+} has 2 electrons, and Ca^{2+} has 18 electrons.



Solve
The species with the same number of electrons as Ar are (a) S^{2-}, (b) P^{3-}, and (d) Ca^{2+}.

Think About It
These species are *isoelectronic* with each other, meaning that they have the same number of electrons.

2.38. **Collect and Organize**

We need to refer to the periodic table to determine the atomic number of the element or ion and then count up the electrons for each species. Here we are looking for species that have the same number of electrons as a krypton atom.

Analyze

According to the periodic table, krypton has 36 electrons. From the periodic table and by adding or subtracting electrons as necessary to make anions and cations as needed, we see that Se^{2-} has 36 electrons, As^{3-} has 36 electrons, Ca^{2+} has 18 electrons, and K^{+} has 18 electrons.

Solve

The species with the same number of electrons as Kr are (a) Se^{2-} and (b) As^{3-}.

Think About It

Two other species in this series are also *isoelectronic* with each other: (c) Ca^{2+} and (d) K^{+}, with 18 electrons each.

2.39. **Collect and Organize**

We need to refer to the periodic table to determine if each element is classified as a metal, a nonmetal, or a metalloid.

Analyze

Nonmetals are to the right side of the stair-step line on the periodic table, metals are on the left side, and metalloids (semimetals) are between the two.

Solve

(a) and (b) are metals, (c) is a metalloid, and both (d) and (e) are nonmetals.

Think About It

Aluminum (b) may appear as though it should be a metalloid because of its location on the stair step, but it exhibits metallic properties, so it is best characterized as a metal.

2.40. **Collect and Organize**

We need to refer to the periodic table to determine if each element is classified as a metal, a nonmetal, or a metalloid.

Analyze

Nonmetals are to the right side of the stair-step line on the periodic table, metals are on the left side, and metalloids (semimetals) are between the two.

Solve

(a) and (b) are metals, (c) is a metalloid, and both (d) and (e) are nonmetals.

Think About It

The metalloids are located between the metals and the nonmetals in the periodic table. These elements are useful in making semiconducting materials for computer chips and solid-state electronic devices.

2.41. **Collect and Organize**

We are asked to match the provided elements from the fourth period with the correct group name.

Analyze
The alkali metals are group 1, the alkaline earth metals are group 2, the halogens are group 17, and the noble gases are group 18. The transition metals run from group 3 to group 12.

Solve
(a) Bromine (Br) is a halogen – group 17.
(b) Calcium (Ca) is an alkaline earth metal – group 2.
(c) Potassium (K) is an alkali metal – group 1.
(d) Krypton (Kr) is a noble gas – group 18.
(e) Vanadium (V) is a transition metal – group 5.

Think About It
The fourth-period elements from scandium (Sc) to zinc (Zn) are all transition metals.

2.42. **Collect and Organize**
We are asked to determine which element from the second period belongs to each of the listed groups.

Analyze
The alkali metals are group 1, the alkaline earth metals are group 2, the halogens are group 17, and the noble gases are group 18.

Solve
(a) The second-row halogen is fluorine (F).
(b) The second-row alkali metal is lithium (Li).
(c) The second-row alkaline earth metal is beryllium (Be).
(d) The second-row noble gas is neon (Ne).

Think About It
The term "second row" refers to the row of the periodic table, not the row of each group. Even though beryllium is the lightest member of the alkaline earth metals, it is located in the second row.

2.43. **Collect and Organize**
We must refer to the periodic table and identify the elements of groups 14, 15, and 16 that are located in the second row of the periodic table.

Analyze
Groups 14, 15, and 16 are located to the right of the transition metals.

Solve
The second-row elements of groups 14, 15, and 16 are carbon (C), nitrogen (N), and oxygen (O), respectively.

Think About It
The acronym TNT stands for trinitrotoluene. In Chapter 13, we will see more examples of organic compounds similar to this explosive molecule.

2.44. **Collect and Organize**
We must refer to the periodic table and identify the name and atomic number for the second-period element located in group 16 and the third-period element located in group 17.

Analyze
The atomic number (Z) is equal to the number of protons in the nucleus of an element.

Solve
The second-row element of group 16 is oxygen (O) with $Z = 8$. The third-row element of group 17 is chlorine (Cl) with $Z = 17$.

Think About It
The empirical formula for phosgene is $COCl_2$.

2.45. **Collect and Organize**
We are asked to identify some transition metals based on their location in the periodic table.

Analyze
The first row of the transition metals is actually the fourth row of the periodic table.

Solve
(a) The element in the fifth period and group 10 of the periodic table is palladium, Pd.
(b) The transition metal to the left of Pd (i.e., in the fifth period and group 9) is rhodium, Rh.
(c) The transition metal directly below Pd (i.e., in the sixth period and group 10) is platinum, Pt.

Think About It
Palladium and platinum have similar properties as a result of being in the same group of the periodic table.

2.46. **Collect and Organize**
We are asked to identify the fourth-row halogen.

Analyze
The halogens are another name for group 17 of the periodic table.

Solve
The element located in the fourth row and group 17 is bromine, Br.

Think About It
Chlorine, bromine, and iodine are all used as disinfectants in various applications. You may have encountered a brown disinfectant solution containing iodine in a hospital.

2.47. **Collect and Organize**
We are asked how Dalton's atomic theory applies to the decomposition of water into hydrogen and oxygen.

Analyze
Dalton's atomic theory states that the ratio of atoms of different elements in a compound is always in small whole numbers.

Solve
Dalton's atomic theory states that, because atoms are indivisible, the ratios of the atoms (elements) in a compound will occur as whole-number ratios. Thus, the ratio of hydrogen gas to oxygen gas is 2:1, a whole-number ratio, because the atoms in water are in the ratio of 2:1.

Think About It

Another way of thinking about this part of Dalton's atomic theory is that a compound cannot have a fraction of an atom in its formula.

2.48. **Collect and Organize**

In this question we use NO and NO_2 to illustrate the law of multiple proportions.

Analyze

The law of multiple proportions states that, if more than one compound is formed from two elements, the ratios of the masses of the two elements in each compound will be whole-number ratios.

Solve

Comparing NO to NO_2, we find that the mass of oxygen present in NO_2 will be twice that found in NO for a given amount of nitrogen.

Think About It

Because NO and NO_2 have different ratios of nitrogen and oxygen in their molecules, we expect that they will have different chemical and physical properties.

2.49. **Collect and Organize**

We are asked to describe the types of elements that form ionic and molecular compounds.

Analyze

Molecular compounds are held together by the sharing of electrons (covalent interactions) between atoms. Ionic compounds are held together by an electrostatic attraction between cations and anions. These differences in bonding may be attributed to the types of elements that comprise each compound.

Solve

In a molecular compound, two nonmetals share electrons in a covalent fashion. In an ionic compound, electrons are transferred between a metal and a nonmetal to form discrete cations and anions.

Think About It

Both types of bonding involve the sharing of electrons, but if a metal is involved, the compound is likely to be ionic rather than molecular.

2.50. **Collect and Organize**

We are asked how the properties of covalent compounds (also called molecular compounds) differ from those of ionic compounds.

Analyze

Ionic and molecular compounds differ with respect to the types of bonds holding them together.

Solve

Molecular compounds are formed when electrons are shared between two or more nonmetal atoms. Properties of these molecular compounds depend on the ratio of nonmetal atoms, as shown by John Dalton. Ionic compounds are formed when electrons are transferred from a metal atom (or atoms) to a nonmetal atom (or atoms). Because the number of electrons lost or gained to form ions may be predicted based on location in the periodic table, the formula unit for an ionic compound is more easily determined.

Think About It

The physical properties of ionic and molecular solids will be discussed in greater detail later in the text. For now, it will suffice to understand that the sharing of electrons in a covalent bond and the electrostatic attraction between ions represent two extreme cases.

2.51. **Collect and Organize**

This question asks how the masses of cobalt and sulfur in two different compounds are related. To answer this question, we apply Dalton's law of multiple proportions.

Analyze

The law of multiple proportions states that, if more than one compound is formed from two elements, the ratios of the masses of the two elements in each compound will be whole-number ratios. In this problem we consider the mass of sulfur that would combine with a certain mass of cobalt to form CoS and Co_2S_3. We need only look at the ratio of the two elements in the compounds to answer this.

Solve

Because the ratio of Co to S in CoS is 1:1 and the ratio is 2:3 in Co_2S_3, applying Dalton's law of multiple proportions means that, if we compare the mass of sulfur needed to react with one gram of cobalt to form CoS in one reaction to the amount of sulfur needed to form Co_2S_3 in a second reaction, we would find the mass of sulfur required in the second reaction to be 1.5 times that needed for the first reaction. Adjusting that to a whole-number ratio would give us a 2:3 ratio for Co to S for the second compound.

Think About It

Notice here that the masses of the elements are compared, not the actual number of atoms in the molecules themselves; that idea came later. Dalton's link is with the indivisible atom, which means that the mass ratios also must be in whole-number ratios when making comparisons between different compounds containing the same elements.

2.52. **Collect and Organize**

This question asks how the masses of two elements in compounds of lead and oxygen are related. To answer this question, we apply Dalton's law of multiple proportions.

Analyze

The law of multiple proportions states that, if more than one compound is formed from two elements, the ratios of the masses of the two elements in each compound will be whole-number ratios. In this problem we consider the mass of oxygen that would combine with a certain mass of lead to form PbO and PbO_2. We need only look at the ratio of the two elements in the compounds to answer this.

Solve

Because the ratio of Pb to O in PbO is 1:1 and the ratio is 1:2 in PbO_2, applying Dalton's law of multiple proportions means that, if we compare the mass of oxygen needed to react with one gram of lead to form PbO in one experiment to the amount of oxygen needed to form PbO_2 in a second experiment, we would find the mass of oxygen required in the second experiment to be twice that needed for the first experiment. The ratio of oxygen masses to form PbO, compared to PbO_2, is 1:2.

Think About It

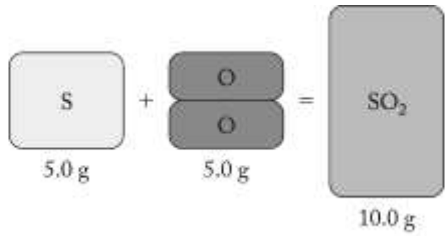
In writing the chemical formulas you can see that the formula for compounds reflects Dalton's theory because the elements appear in whole-number ratios.

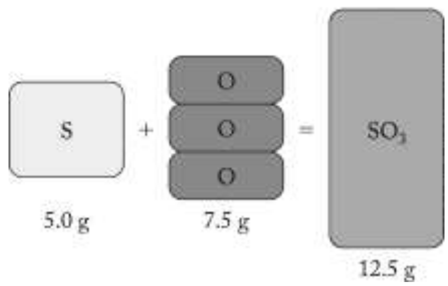
2.53. **Collect and Organize**

Given the mass ratio of sulfur to oxygen needed to make SO_2, we are asked in this problem to use Dalton's law of multiple proportions to determine the amount of oxygen required to prepare SO_3 from a given mass of sulfur.

Analyze

The masses of elements in compounds of the same elements occur in whole-number ratios when compared to each other. If 5 g of sulfur combines with 5 g of oxygen to give SO_2 (a 1:2 ratio), we can use that mass ratio to determine the mass of oxygen to combine with 5 g of sulfur to give SO_3 (a 1:3 ratio).





Solve

By comparing the mass ratios (1:2 versus 1:3), we see that we need half again as much of oxygen to make SO_3 compared to SO_2. Therefore, we will need $5.0 \times 1.5 = 7.5$ g of oxygen to react with 5.0 g of sulfur to make SO_3.

Think About It

This amount of oxygen makes sense because it is still less than twice the amount of oxygen (10 g), which would create a 1:4 ratio of S:O, giving a formula of SO_4.

2.54. **Collect and Organize**

In this problem we compare the percentage of nitrogen in two compounds of nitrogen and oxygen. We first have to examine the amount of oxygen in one compound and relate it to the oxygen in the other compound, then find the percentage of nitrogen in the second compound.

Analyze

We can conveniently use 100 grams as our starting point for the mass of NO. If NO is 46.7% nitrogen, then the remainder of the mass must be oxygen. If NO_2 contains twice the amount of oxygen for the same mass of nitrogen in NO, we can simply multiply the mass of oxygen in NO by 2 to find the mass of oxygen in NO_2. The amount of nitrogen in grams will be the same as in NO. Combining the mass of oxygen and nitrogen in NO_2, we can compute the total mass and, from that, the percentage of nitrogen in NO_2.

Solve

Assuming 100 g of NO, 46.7% by mass of nitrogen means that 46.7 g of N is present. From this, we also know that $100 - 46.7 = 53.3$ g of O is present by mass in NO. Because NO_2 contains twice the mass of O compared to NO, NO_2 contains 53.3 × 2 = 106.6 g of O for every 46.7 g of N. The total mass of O and N in NO_2, therefore, is 106.6 + 46.7 = 153.3 g. The percent nitrogen in NO_2, then, is (46.7 g/153.3 g) × 100 = 30.5%.

Think About It
This problem quantitatively uses Dalton's law of multiple proportions, which eventually led to the concept of ratios of atoms in compounds.

2.55. **Collect and Organize**
An isotope is given by the symbol ${}^{A}_{Z}X^{n}$, where X is the element symbol from the periodic table, *Z* is the atomic number (the number of protons in the nucleus), *A* is the mass number (the number of protons and neutrons in the nucleus), and *n* is the charge on the species.

Analyze
If we are given the number of protons in the nucleus, the element can be identified from the periodic table. The mass number can be determined by adding the protons to the neutrons in the nucleus for the isotope. We can determine the number of neutrons or protons in the nucleus for the isotopes by subtracting *Z* (number of protons) or the number of neutrons from *A* (mass number), respectively. We can account for the charge on the species by adding electrons (to form a negatively charged ion) or by subtracting electrons (to form a positively charged ion).

Solve
(a) From the symbol provided (${}^{37}Cl^{-}$), we know that chlorine's atomic number is 17 and the mass number for this nuclide is 37. For a species with a 1− charge, we can deduce that the number of electrons is one greater than the number of protons, 17 + 1 = 18. The number of neutrons is equal to the difference between the mass number and the number of protons, 35 − 17 = 18.
(b) The element with 11 protons is sodium (Na). The mass number for this nuclide is the sum of the number of protons and neutrons, 11 + 12 = 23. The charge on this ion is equal to the difference between the number of protons and the number of electrons, 11 − 10 = +1. The symbol for this ion is ${}^{23}Na^{+}$.
(c) The number of protons is equal to the difference between the mass number and the number of neutrons, 81 − 46 = 35. The element with 35 protons is bromine (Br). The charge on this ion is equal to the difference between the number of protons and the number of electrons, 35 − 36 = −1. The symbol for this nuclide is ${}^{81}Br^{-}$.
(d) The element with 82 protons is lead (Pb). The number of neutrons is equal to the difference between the mass number and the number of protons, 210 − 82 = 128. The charge on this ion is equal to the difference between the number of protons and the number of electrons, 82 − 80 = +2. The symbol for this nuclide is ${}^{210}Pb^{2+}$.

Summarizing this information in the table below:

Symbol	${}^{37}Cl^{-}$	${}^{23}Na^{+}$	${}^{81}Br^{-}$	${}^{210}Pb^{2+}$
Number of protons	17	11	35	82
Number of neutrons	18	12	46	128
Number of electrons	18	10	36	80
Mass number	35	23	81	210

Think About It

To form a singly charged ion, there has to be one electron more (for a negative charge) or one electron less (for a positive charge) than the number of protons in the nucleus. For a doubly charged ion, we add or take away two electrons.

2.56. **Collect and Organize**

An isotope is given by the symbol ${}^{A}_{Z}X^{n}$, where X is the element symbol from the periodic table, Z is the atomic number (the number of protons in the nucleus), A is the mass number (the number of protons and neutrons in the nucleus), and n is the charge on the species.

Analyze

If we are given the number of protons in the nucleus, the element can be identified from the periodic table. The mass number can be determined by adding the protons to the neutrons in the nucleus for the isotope. We can determine the number of neutrons or protons in the nucleus for the isotopes by subtracting Z (number of protons) or the number of neutrons from A (mass number), respectively. We can account for the charge on the species by adding electrons (to form a negatively charged ion) or by subtracting electrons (to form a positively charged ion).

Solve

(a) From the symbol provided (${}^{137}Cs^{+}$), we know that cesium's atomic number is 55 and the mass number for this nuclide is 137. For a species with a 1+ charge, we can deduce that the number of electrons is one less than the number of protons, 55 – 1 = 54. The number of neutrons is equal to the difference between the mass number and the number of protons, 137 – 55 = 82.

(b) The element with 30 protons is zinc (Zn). The mass number for this nuclide is the sum of the number of protons and neutrons, 30 + 34 = 64. The charge on this ion is equal to the difference between the number of protons and the number of electrons, 30 – 28 = +2. The symbol for this ion is ${}^{64}Zn^{2+}$.

(c) The number of protons is equal to the difference between the mass number and the number of neutrons, 32 – 16 = 16. The element with 16 protons is sulfur (S). The charge on this ion is equal to the difference between the number of protons and the number of electrons, 16 – 18 = –2. The symbol for this nuclide is ${}^{32}S^{2-}$.

(d) The element with 40 protons is zirconium (Zr). The number of neutrons is equal to the difference between the mass number and the number of protons, 90 – 40 = 50. The charge on this ion is equal to the difference between the number of protons and the number of electrons, 40 – 36 = +4. The symbol for this nuclide is ${}^{90}Zr^{4+}$.

Summarizing this information in the table below:

Symbol	${}^{137}Cs^{+}$	${}^{64}Zn^{2+}$	${}^{32}S^{2-}$	${}^{90}Zr^{4+}$
Number of protons	55	30	16	40
Number of neutrons	82	34	16	50
Number of electrons	54	28	18	36
Mass number	137	64	32	90

Think About It

These are all multiply charged ions. For anions, we add electrons; for cations, we remove electrons.

2.57. **Collect and Organize**

In this question we are asked to distinguish between molecular and ionic substances.

Analyze

Ionic substances usually contain a metal (left side of the periodic table) and a nonmetal (right side of the periodic table), whereas covalent substances usually are a combination of nonmetallic elements.

Solve

(a) Both phosphorus and oxygen are nonmetals. This compound consists of molecules.
(b) Strontium is a metal and chlorine is a nonmetal. $SrCl_2$ consists of ions.
(c) Magnesium is a metal, and fluorine is a nonmetal. MgF_2 consists of ions.
(d) All the elements in SO_3 are nonmetals. Sulfur trioxide consists of molecules.

Think About It

The formation of ionic compounds versus the formation of molecular (covalent) compounds can often be predicted by the difference in electronegativity between the bonding elements. Later you will learn the definition of electronegativity (Chapter 8).

2.58. **Collect and Organize**

In this question we are asked to distinguish between molecular (covalent) and ionic substances.

Analyze

Ionic substances usually contain a metal cation (from the left side of the periodic table) and a nonmetal anion (from the right side of the periodic table), whereas molecular substances contain covalent bonds and usually are a combination of nonmetallic elements.

Solve

(a) Magnesium is a metal, and nitrogen is a nonmetal. Mg_3N_2 consists of ions.
(b) Barium is a metal, and sulfur is a nonmetal. BaS consists of ions.
(c) Silver is a metal, and chlorine is a nonmetal. AgCl consists of ions.
(d) Both nitrogen and chlorine are nonmetals. NCl_3 consists of molecules.

Think About It

All of the salts in this problem are binary compounds, consisting of only two elements. It is also possible for compounds to be composed of a metal or nonmetal and a polyatomic ion.

2.59. **Collect and Organize**

We are asked whether the binary compounds formed from each of the listed pairs of elements would contain covalent bonds or ionic bonds.

Analyze

Ionic bonds are typically observed when a metal and a nonmetal are combined. Covalent bonds are typically observed when two nonmetals are combined.

Solve

(a) Cesium is a metal, and fluorine is a nonmetal. These two elements should form ionic bonds.
(b) Nitrogen and chlorine are both nonmetals. These two elements should form covalent bonds.

(c) Carbon and oxygen are both nonmetals. These two elements should form covalent bonds.
(d) Magnesium is a metal, and oxygen is a nonmetal. These two elements should form ionic bonds.

Think About It

Since all of the species in (a) and (d) will form monatomic ions, we can predict the identity of the compound formed: (a) will form CsF, and (d) will form MgO.

2.60. **Collect and Organize**

We are asked whether the binary compounds formed from each of the listed pairs of elements would contain covalent bonds or ionic bonds.

Analyze

Ionic bonds are typically observed when a metal and a nonmetal are combined. Covalent bonds are typically observed when two nonmetals are combined.

Solve

(a) Silver is a metal, and oxygen is a nonmetal. These two elements should form ionic bonds.
(b) Sulfur and oxygen are both nonmetals. These two elements should form covalent bonds.
(c) Carbon and hydrogen are both nonmetals. These two elements should form covalent bonds.
(d) Barium is a metal, and nitrogen is a nonmetal. These two elements should form ionic bonds.

Think About It

Predicting the formula for the covalent (molecular) compound that will be formed when two elements react can be difficult. Examples of binary covalent compounds that might be formed in (b) and (c) are SO_2, SO_3, CH_4, and C_2H_4. Many more similar compounds could be formed, depending on the ratio of elements and reaction conditions.

2.61. **Collect and Organize**

We are asked to determine the total number of atoms in the formula unit for the listed ionic compounds.

Analyze

Subscripts denote the number of atoms in a compound or ion. Subscripts following a polyatomic ion denote the number of polyatomic ions in the compound.

Solve

(a) 4 atoms (b) 5 atoms (c) 4 atoms (d) 5 atoms

Think About It

A formula unit is the simplest repeating unit for an ionic compound. The number of atoms in a formula unit could also be expressed as a ratio for dimensional analysis. For example, (a) could be expressed as

$$\frac{4 \text{ atoms}}{1 \text{ formula unit } LaF_3}$$

2.62. **Collect and Organize**

We are asked to determine the total number of atoms in the formula unit for the listed ionic compounds.

Analyze

Subscripts denote the number of atoms in a compound or ion. Subscripts following a polyatomic ion denote the number of polyatomic ions in the compound.

Solve

(a) 5 atoms (b) 3 atoms (c) 4 atoms (d) 2 atoms

Think About It

It is a good idea to check your formulas by looking for charge balance. For example, in In_2O_3, there are two indium cations with a charge of 3+ each and three oxide anions with a charge of 2– each. The total charges are $2 \times 3+ = 6+$ and $3 \times 2- = 6-$. Since these charges cancel, we can be confident that the ratio is correct, and there must be 5 atoms.

2.63. **Collect and Organize**

For the oxoanions of element X, XO_2^{2-} and XO_3^{2-}, we are to assign one as *-ite.*

Analyze

Compound names that end in *-ite* represent oxoanions that have one fewer oxygen atom than compounds ending in *-ate*.

Solve

Between XO_2^{2-} and XO_3^{2-}, the oxoanion XO_2^{2-} would have a name ending in *-ite.*

Think About It

In Table 2.4 we can see this pattern for oxoanions of chlorine. ClO_3^- is *chlorate* and ClO_2^- is *chlorite*.

2.64. **Collect and Organize**

For the oxoanions in Problem 2.63, XO_2^{2-} and XO_3^{2-}, we consider whether either of them would require *hypo*- or *per*- as a prefix to name them.

Analyze

The prefixes *hypo*- and *per*- apply only when the element forms more than two oxoanions.

Solve

In Problem 2.63, XO_2^{2-} and XO_3^{2-} are the only oxoanions formed with element X; there is no need to add prefixes to distinguish the oxoanions.

Think About It

Because chlorine forms many oxoanions, it requires use of the two prefixes: ClO^- is hypochlorite, ClO_2^- is chlorite, ClO_3^- is chlorate, and ClO_4^- is perchlorate (Table 2.4).

2.65. **Collect and Organize**

When writing names for transition metal compounds, we include Roman numerals in the name. We are asked in this question what purpose these Roman numerals serve.

Analyze

Transition metals often take on more than one oxidation state (or charge).

Solve

Roman numerals are used in the names of compounds of transition elements to indicate the charge on the transition metal cation.

Think About It

The indication of charge on the transition metal cation in the name of the compounds makes it easy to write the formula for a compound. For example, without the (III) in iron(III) chloride, we would not be sure whether to write $FeCl_3$ or $FeCl_2$ because both compounds exist and exhibit different chemical and physical properties.

2.66. **Collect and Organize**

We are to explain why we do not include Roman numerals in the names of salts of the alkali and alkaline earth metals.

Analyze

Alkali metals always form cations with a 1+ charge, and alkaline earth metals form cations with a 2+ charge. They do not typically exhibit multiple charges in compounds.

Solve

The alkali and alkaline earth metal cations do not need to have their charges indicated with Roman numerals in the names of their compounds because they only form cations of one charge.

Think About It

This is also true for salts of Zn and Cd. Although they are placed in the periodic table with the transition metals, they do not typically exhibit any charge other than 2+ in compounds.

2.67. **Collect and Organize**

All the compounds here are oxides of nitrogen. These are all molecular compounds composed of two nonmetallic elements. We name these using the rules for binary compounds.

Analyze

We will use prefixes (Table 2.2) to indicate the number of oxygen atoms in these compounds. The nitrogen atom is always first in the formula, so it is named first. If there is only one nitrogen atom in the formula, we do not need to use the prefix *mono-* for the nitrogen. If there is more than one nitrogen atom, however, we will indicate the number with the appropriate prefix. Also, since *oxide* begins with a vowel, it would be awkward to say *pentaoxide*, so we shorten the double vowel in this part of the chemical name to *pentoxide*.

Solve

(a) NO_3, nitrogen trioxide
(b) N_2O_5, dinitrogen pentoxide
(c) N_2O_4, dinitrogen tetroxide
(d) NO_2, nitrogen dioxide

Think About It

All of these binary compounds of nitrogen and oxygen are uniquely named.

2.68. **Collect and Organize**

All the compounds here are oxides of nitrogen. These are all molecular compounds composed of two nonmetallic elements. We name these using the rules for binary compounds.

Analyze

We will use prefixes (Table 2.2) to indicate the number of oxygen atoms in these compounds. The nitrogen atom is always first in the formula, so it is named first. If there is only one nitrogen atom in the formula, we do not need to use the prefix *mono-* for the nitrogen. If there is more than one nitrogen atom, however, we will indicate the number with the appropriate prefix. Also, since *oxide* begins with a vowel, it would be awkward to say *pentaoxide*, so we shorten the double vowel in this part of the chemical name to *pentoxide*.

Solve

(a) N_2O_3, dinitrogen trioxide
(b) NO, nitrogen monoxide
(c) N_2O, dinitrogen monoxide
(d) N_4O, tetranitrogen monoxide

Think About It

All of these binary compounds have unique properties. It is important to understand and apply the rules of nomenclature to avoid confusion.

2.69. **Collect and Organize**

To predict the formula for the binary ionic compounds formed from the elements listed in the problem, we first have to decide what charges the metal and nonmetal typically have in ionic compounds. To name the compounds, we use the naming rules for ionic compounds.

Analyze

Metallic elements in group 1 of the periodic table (Na and Li) have a 1+ charge in ionic compounds, those in group 2 (Sr) have a 2+ charge, and those in group 13 (Al) have a 3+ charge. Nonmetals in group 16 (S and O) have a 2– charge, and those in group 17 (Cl) have a 1– charge. Hydrogen here has a 1– charge because it is combining with a metal and is thus a hydride. To write the formulas of the neutral salts, the charges of the anion must be balanced with the charges of the cation. In naming binary ionic compounds, the cation is named first as the element, and the anion is named second with the ending *-ide* added.

Solve

(a) sodium (Na^+) and sulfur (S^{2-}): Na_2S, sodium sulfide
(b) strontium (Sr^{2+}) and chlorine (Cl^-): $SrCl_2$, strontium chloride
(c) aluminum (Al^{3+}) and oxygen (O^{2-}): Al_2O_3, aluminum oxide
(d) lithium (Li^+) and hydrogen (H^-): LiH, lithium hydride

Think About It

In naming binary ionic salts of the main group elements, we do not need to indicate the numbers of anions or cations in the formula with prefixes, making the naming of these compounds very direct.

2.70. **Collect and Organize**

To predict the formula for the binary ionic compounds formed from the elements listed in the problem, we first have to decide what charges the metal and nonmetal typically have in ionic compounds. To name the compounds, we use the naming rules for ionic compounds.

Analyze

Metallic elements that belong to group 1 of the periodic table (K and Li) have a 1+ charge in ionic compounds, those in group 2 (Ca) have a 2+ charge, and those in group 13 (Al) have a 3+ charge. Nonmetals belonging to group 15 (N) have a 3– charge, and those in group 17 (Cl and Br) have a 1– charge. Hydrogen here has a 1− charge because it is combining with a metal and is thus a hydride. To write the formulas of the neutral salts, the charges of the anion must be balanced with the charges of the cation. In naming binary ionic compounds, the cation is named first as the element, and the anion is named second with the ending *-ide* added.

Solve

(a) potassium (K^+) and bromine (Br^-): KBr, potassium bromide
(b) calcium (Ca^{2+}) and hydrogen (H^-): CaH_2, calcium hydride
(c) lithium (Li^+) and nitrogen (N^{3-}): Li_3N, lithium nitride
(d) aluminum (Al^{3+}) and chlorine (Cl^-): $AlCl_3$, aluminum chloride

Think About It

In naming binary ionic salts of the main group elements, we do not need to indicate the numbers of anions or cations in the formula with prefixes, making the naming of these compounds very direct.

2.71. **Collect and Organize**

We are asked to determine the chemical name for $Mg(OH)_2$. Before naming the compound, we must classify the compound as ionic or molecular.

Analyze

Magnesium is an alkaline earth metal, and OH^- is a polyatomic anion. We must follow the rules for naming a binary ionic compound.

Solve

Ionic compounds are named starting with the cation, followed by the name of the anion. The hydroxide anion, OH^-, is a polyatomic anion (see Table 2.3) and already has an *-ide* ending. The correct, unambiguous name for this compound is *magnesium hydroxide*, as it can only describe a compound of one magnesium cation and two hydroxide anions.

Think About It

Because magnesium forms a cation with a 2+ charge exclusively, it is not necessary to specify a charge, as we would for a transition metal.

2.72. **Collect and Organize**

We are asked to determine the chemical name for $(NH_4)_2CO_3$. Before naming the compound, we must classify the compound as ionic or molecular. We are also asked to determine the chemical formula for ammonia.

Analyze

NH_4^+ is a polyatomic cation, and CO_3^{2-} is a polyatomic anion. This compound is named using the rules for naming an ionic compound.

Solve

(a) Ionic compounds are named starting with the cation, followed by the name of the anion. The ammonium cation (NH_4^+) has a charge of 1+, while the carbonate anion (CO_3^{2-}) has a charge of 2–. The correct, unambiguous name for this compound is *ammonium carbonate*.

(b) Ammonia is the common name for a molecular compound with the formula NH_3. Despite being a molecular compound, many chemists use the common name for NH_3 rather than referring to it as nitrogen trihydride.

Think About It

Although the carbonate anion does not end in *-ide*, we should not alter the ending. The names of the polyatomic anions in Table 2.3 should be used as is.

2.73. **Collect and Organize**

All the compounds listed are salts of sodium. Some are composed of polyatomic ions, and others are binary salts.

Analyze

For ionic compounds, name the cation as the element first, then name the anion. If the anion is an element, the suffix *-ide* is used; if the anion is a polyatomic oxoanion, we simply add the name of that anion.

Solve

(a) Na_2O, sodium oxide
(b) Na_2S, sodium sulfide
(c) Na_2SO_4, sodium sulfate
(d) $NaNO_3$, sodium nitrate
(e) $NaNO_2$, sodium nitrite

Think About It

All of these names uniquely describe the compounds. Once we are familiar with the names of the polyatomic anions, there is no ambiguity in the identity of the compound when named.

2.74. **Collect and Organize**

All the compounds listed are salts of potassium. Some are composed of polyatomic ions, and others are binary salts.

Analyze

For ionic compounds, name the cation as the element first, then name the anion. If the anion is an element, the suffix *-ide* is used; if the anion is a polyatomic oxoanion, we simply add the name of that anion.

Solve

(a) K_3PO_4, potassium phosphate
(b) K_2O, potassium oxide
(c) K_2SO_3, potassium sulfite
(d) KNO_3, potassium nitrate
(e) KNO_2, potassium nitrite

Think About It

All of these names uniquely describe the compounds. Once we are familiar with the names of the polyatomic anions, there is no ambiguity in the identity of the compound when named.

2.75. **Collect and Organize**

We are asked to write the formula of an ionic salt from the name given.

Analyze

We use the rules for naming ionic salts. The first element in the name is the cation in the formula. In binary ionic salts, the anion is the element name with the ending *-ide*. If the ion is a polyatomic ion, the name of that polyatomic anion follows the name of the metal. In all cases when writing the formula, we have to balance the charges of the anion and the cation to give a neutral salt.

Solve

(a) potassium sulfide, K^+ with S^{2-} gives K_2S
(b) potassium selenide, K^+ with Se^{2-} gives K_2Se
(c) rubidium sulfate, Rb^+ with SO_4^{2-} gives Rb_2SO_4
(d) rubidium nitrite, Rb^+ with NO_2^- gives $RbNO_2$
(e) magnesium sulfate, Mg^{2+} with SO_4^{2-} gives $MgSO_4$

Think About It

Most of the anions in these salts are dianions with a 2− charge. When combining with cations with a 1+ charge, we have to balance the charge by having two cations for every anion in the formula.

2.76. **Collect and Organize**

We are asked to write the formula of an ionic salt from the name given.

Analyze

We use the rules for naming ionic salts. The first element in the name is the cation in the formula. In binary ionic salts, the anion is the element name with the ending *-ide*. If the anion is a polyatomic anion, the name of that polyatomic anion follows the name of the metal. In all cases when writing the formula, we have to balance the charges of the anion and cation to give a neutral salt.

Solve

(a) rubidium nitride, Rb^+ with N^{3-} gives Rb_3N
(b) potassium selenite, K^+ with SeO_3^{2-} gives K_2SeO_3
(c) rubidium sulfite, Rb^+ with SO_3^{2-} gives Rb_2SO_3
(d) rubidium nitrate, Rb^+ with NO_3^- gives $RbNO_3$
(e) magnesium sulfite, Mg^{2+} with SO_3^{2-} gives $MgSO_3$

Think About It

Many of the anions in these salts are dianions with a 2− charge. When combining with cations with a 1+ charge, we have to balance the charge by having two cations for every anion in the formula. For the nitride compound, we have to balance the cation with the 3− charge on the nitrogen anion; in this case three rubidium cations are necessary in the formula to give a neutral salt.

2.77. **Collect and Organize**

We are asked to identify the oxoanion from the name of a salt and write its formula.

Analyze

The oxoanions are polyatomic ions. The element other than oxygen appears first in the name, and the ending depends on the number of oxygen atoms in the anion. Oxoanions with *-ate* as an ending have one more oxygen in their structure than those ending in *-ite*. Prefixes such as *per-* and *hypo-* can indicate the largest and smallest number of oxygens, respectively. We can use these rules and the examples in the text for chlorine (Table 2.4) as well as the polyatomic ions listed in Table 2.3 to help us write the formulas for the oxoanions in this question.

Solve

(a) $NaBrO$
(b) K_2SO_4
(c) $LiIO_3$
(d) $Mg(NO_2)_2$

Think About It

The names here do not really help us write the formulas; we have to just remember them. Learning them well for oxoanions containing chlorine can help because we can name the other halogen oxoanions by analogy with chlorine oxoanions.

2.78. **Collect and Organize**

We are asked to identify the oxoanion from the name of a salt and write its formula.

Analyze

The oxoanions are polyatomic ions. The element other than oxygen appears first in the name, and the ending depends on the number of oxygen atoms in the anion. Oxoanions with *-ate* as an ending have one more oxygen in their structure than those ending in *-ite*. Prefixes such as *per-* and *hypo-* can indicate the largest and smallest number of oxygens, respectively. We can use these rules, the examples in the text for chlorine (Table 2.4), and the polyatomic ions listed in Table 2.3 for sulfur and nitrogen to help us write the formulas for the oxoanions in this question.

Solve

(a) K_2TeO_3
(b) Na_3AsO_4
(c) $CaSeO_3$
(d) $KClO_3$

Think About It

Selenium and tellurium oxoanions may be named in analogy to the sulfur oxoanions. Likewise, arsenic oxoanions can be named using the phosphorus oxoanions as a guide.

2.79. **Collect and Organize**

We are asked to identify magnesium nitrite from the four formulas provided.

Analyze

Elemental anions have *-ide* as an ending. Oxoanions with *-ate* as an ending have one more oxygen in their structure than those ending in *-ite*. NO^- is an unusual oxoanion called the nitroxyl anion.

Solve

The names for each of these formulas are

(a) magnesium nitr*ide*

(b) magnesium nitr*ite*

(c) magnesium nitr*ate*

(d) magnesium nitro*xyl*

The correct formula is (b), $Mg(NO_2)_2$.

Think About It

The nitrate anion (NO_3^-) is one you will encounter frequently and is a good choice for an oxoanion to commit to memory. By analogy, we know that the nitrite anion (NO_2^-) must have one fewer oxygen atom.

2.80. **Collect and Organize**

We are asked to identify lithium phosphate from the four formulas provided.

Analyze

Elemental anions have *-ide* as an ending. Oxoanions with *-ate* as an ending have one more oxygen in their structure than those ending in *-ite*.

Solve

The names for each of these formulas are

(a) lithium phosph*ide*

(b) lithium phosph*ite*

(c) lithium phosph*ate*

(d) This compound contains the lithium cation and the phosphate anion (PO_4^{3-}), but the subscripts are not correct.

The correct formula is (c), Li_3PO_4.

Think About It

The biggest clue that the formula for (d) is not correct comes from inspecting the charge balance. Two lithium cations with a charge of 1+ each gives $2 \times 1+ = 2+$ total. The three phosphate anions each bear a charge of 3–, giving $3 \times 3– = 9–$ total. Since the charges do not cancel, the formula cannot be correct.

2.81. **Collect and Organize**

We are asked which of the chemical formulas for the listed ionic compounds is incorrect. We must assume that all of the given chemical names are correct.

Analyze

You may find it helpful to predict the formula for each ionic compound from the chemical name given and compare these with the formula given in the question. In each case, consider the charge based on location in the periodic table or from the list of common polyatomic ions (Table 2.3).

Solve

(a) Calcium forms a cation with a 2+ charge, Ca^{2+}; oxygen forms an anion with a 2– charge, O^{2-}. CaO is correct.

(b) Lithium forms a cation with a 1+ charge, Li^+; sulfate is a polyatomic anion with a 2– charge, SO_4^{2-}. The correct chemical formula would be Li_2SO_4.

(c) Barium forms a cation with a 2+ charge, Ba^{2+}; sulfur forms an anion with a 2– charge, S^{2-}. BaS is correct.

(d) Potassium forms a cation with a 1+ charge, K^+; oxygen forms an anion with a 2– charge, O^{2-}. K_2O is correct.

The only incorrect chemical formula is (b).

Think About It

You may be tempted to use the charge on each ion as the subscript for the other ion. This shortcut would suggest that the chemical formula for barium sulfide is Ba_2S_2, which is incorrect. If the charge on the cation and anion are the same, only one of each ion is required to balance charge.

2.82. **Collect and Organize**

We are asked which of the chemical formulas for the listed ionic compounds is incorrect. We must assume that all of the given chemical names are correct.

Analyze

You may find it helpful to predict the formula for each ionic compound from the chemical name given and compare these with the formula given in the question. In each case, consider the charge based on location in the periodic table or from the list of common polyatomic ions (Table 2.3). One of the listed compounds is a dodecahydrate, meaning that twelve water molecules are coordinated to the ionic compound in the solid state.

Solve

(a) Aluminum forms a cation with a 3+ charge, Al^{3+}; nitrogen forms an anion with a 3– charge, N^{3-}. AlN is correct.

(b) Aluminum forms a cation with a 3+ charge, Al^{3+}; sulfate is a polyatomic anion with a 2– charge, SO_4^{2-}. $Al_2(SO_4)_3$ is correct.

(c) Potassium forms a cation with a 1+ charge, K^+; chlorine forms an anion with a 1– charge, Cl^-. The correct chemical formula would be KCl.

(d) Cesium forms a cation with a 1+ charge, Cs^+; sulfate is a polyatomic anion with a 2– charge, SO_4^{2-}. Cs_2SO_4 is correct.

The only incorrect chemical formula is (c).

Think About It

It is easy to confuse the *monoatomic* nitride anion (N^{3-}) with the *polyatomic* azide anion (N_3^-). Note the difference in charge and the number of atoms in each ion.

2.83. **Collect and Organize**

Following the naming rules for ionic compounds, we are asked to write formulas for the eight combinations of the ions provided.

Analyze

The four cations are sodium (Na^+), potassium (K^+), magnesium (Mg^{2+}), and calcium (Ca^{2+}). The two anions are chloride (Cl^-) and dihydrogen phosphate ($H_2PO_4^-$). The formula for an ionic compound is written with the cation listed first, followed by the anion.

Solve

The eight formulas are

	Na^+ cation	K^+ cation	Mg^{2+} cation	Ca^{2+} cation
Cl^- anion	NaCl	KCl	$MgCl_2$	$CaCl_2$
$H_2PO_4^-$ anion	NaH_2PO_4	KH_2PO_4	$Mg(H_2PO_4)_2$	$Ca(H_2PO_4)_2$

Think About It

Note that two $H_2PO_4^-$ anions are required to balance the 2+ charge for magnesium and calcium. The compound stoichiometry is indicated by the 2 subscript following the parentheses.

2.84. **Collect and Organize**

We are asked to write formulas for a variety of salts of the sodium ion. We have to balance the charge of the sodium ion (1+) with the charges on the anions to obtain the formula of the neutral salt species that are present after the evaporation of the seawater.

Analyze

The sodium cation is written as Na^+. The anions have the following formulas and charges: Cl^-, SO_4^{2-}, CO_3^{2-}, HCO_3^-, Br^-, F^-, $B(OH)_4^-$.

Solve

The formulas for the neutral salts of these anions with sodium cations are NaCl, Na_2SO_4, Na_2CO_3, $NaHCO_3$, NaBr, NaF, and $NaB(OH)_4$.

Think About It

As we will see in studying the solubility of salts in water, all sodium salts are soluble.

2.85. **Collect and Organize**

These compounds all contain a transition metal cation in combination with a polyatomic or elemental anion. These compounds are ionic and follow the naming rules for ionic compounds.

Analyze

For these compounds, we first name the metal cation using the element name, then name the anion, using the suffix *-ide* for binary compounds, or the ion name for polyatomic anions. For transition metals, it is often important to determine the charge of the metal cation and indicate this using Roman numerals. In each case, we should identify the charge on the anion and multiply by the number of anions to determine the total negative charge that must be cancelled out by the cation. Dividing by the number of cations provides the charge on the transition metal.

Solve

(a) Tellurium is a member of group 16 and should bear a 2− charge. This results in a total negative charge of $3 \times 2- = 6-$. The two chromium cations have a total charge of 6+ to cancel this out, so each must bear a 3+ charge. This compound is chromium(III) telluride.

(b) The sulfate anion has a 2− charge, resulting in a total negative charge of $3 \times 2- = 6-$. The two vanadium cations have a total charge of 6+ to cancel this out, so each must bear a 3+ charge. This compound is vanadium(III) sulfate.

(c) The chromate anion has a 2− charge, resulting in a total negative charge of $1 \times 2- = 2-$. The two iron cations have a total charge of 2+ to cancel this out, so each must bear a 1+ charge. This compound is iron(I) chromate.

(d) Oxygen is a member of group 16 and should bear a 2− charge. This results in a total negative charge of $1 \times 2- = 2-$. The manganese cation has a charge of 2+ to cancel this out. This compound is manganese(II) oxide.

Think About It

All of the transition metal cations in this problem may adopt more than one charge. It is important to distinguish between iron(I) chromate (Fe_2CrO_4) and iron(III) chromate ($Fe_2(CrO_4)_3$), for example.

2.86. **Collect and Organize**

These compounds all contain a transition metal cation in combination with a polyatomic or elemental anion. These compounds are ionic and follow the naming rules for ionic compounds.

Analyze

For these compounds, we first name the metal cation using the element name, then name the anion, using the suffix -*ide* for binary compounds, or the ion name for polyatomic anions. For transition metals, it is often important to determine the charge of the metal cation, and indicate this using Roman numerals. In each case, we should identify the charge on the anion and multiply by the number of anions to determine the total negative charge that must be cancelled out by the cation. Dividing by the number of cations provides the charge on the transition metal.

Solve

(a) The phosphate anion has a 3− charge, resulting in a total negative charge of $1 \times 3- = 3-$. The iron cation must have a 3+ charge to cancel this out. This compound is iron(III) phosphate.
(b) The sulfate anion has a 2− charge, resulting in a total negative charge of $1 \times 2- = 2-$. The copper cation must have a 2+ charge to cancel this out. This compound is copper(II) sulfate.
(c) This compound is silver carbonate.
(d) This compound is zinc nitrite.

Think About It

Silver and zinc always adopt 1+ and 2+ charges, respectively. Since these charges do not change, we do not include Roman numerals when naming ionic compounds containing these ions.

2.87. **Collect and Organize**

These ionic compounds all contain a transition metal cation in combination with a polyatomic anion.

Analyze

In each case, we must determine the total positive and negative charge and ensure that these cancel by including the correct number of each ion.

Solve

(a) Zinc has a charge of 2+, and the dichromate anion has a charge of 2−. Only one of each ion is required to generate a charge-neutral ionic compound. The formula for this compound is $ZnCr_2O_7$.
(b) Iron(III) has a charge of 3+, and the acetate anion has a charge of 1−. This compound must contain three acetate anions for every one iron(III) cation to generate a charge-neutral ionic compound. The formula for this compound is $Fe(CH_3COO)_3$.
(c) Mercury(I) is a polyatomic cation with a charge of 2+, and the peroxide anion has a charge of 2−. Only one of each ion is required to generate a charge-neutral ionic compound. The formula for this compound is Hg_2O_2.
(d) Scandium has a charge of 3+, and the thiocyanate anion has a charge of 1−. This compound must contain three thiocyanate anions for every one scandium cation to generate a charge-neutral ionic compound. The formula for this compound is $Sc(SCN)_3$.

Think About It

Mercury(I) is somewhat unusual when compared with other transition metal cations since it does not exist as Hg^+, but rather as Hg_2^{2+}.

2.88. **Collect and Organize**

These ionic compounds all contain a transition metal cation in combination with a polyatomic anion.

Analyze

In each case, we must determine the total positive and negative charge and ensure that these cancel by including the correct number of each ion.

Solve

(a) Mercury(II) has a charge of 2+, and the hydroxide anion has a charge of 1−. This compound must contain two hydroxide anions for every one mercury(II) cation to generate a charge-neutral ionic compound. The formula for this compound is $Hg(OH)_2$.
(b) Silver has a charge of 1+, and the perchlorate anion has a charge of 1−. Only one of each ion is required to generate a charge-neutral ionic compound. The formula for this compound is $AgClO_4$.
(c) Manganese(IV) has a charge of 4+, and the nitrate anion has a charge of 1−. This compound must contain four nitrate anions for every one manganese(IV) cation to generate a charge-neutral ionic compound. The formula for this compound is $Mn(NO_3)_4$.
(d) Vanadium(V) has a charge of 5+, and the sulfate anion has a charge of 2−. This compound must contain five sulfate anions for every two vanadium(V) cations to generate a charge-neutral ionic compound. The formula for this compound is $V_2(SO_4)_5$.

Think About It

One way to check the formulas you wrote above is to convert them back into a name and check that the name matches that provided in the question. If you are uncertain about a charge, or if a classmate can't convert these formulas to names, double check your solution! As an example, in (d) we see that there are five sulfate anions, each with a charge of 2–, for a total negative charge of 10–. For a charge-neutral complex, the cations must have a total charge of 10+. There are two vanadium cations, each with a charge of 5+. The name for this formula is vanadium(V) sulfate, which matches the name provided in our question.

2.89. **Collect and Organize**

These compounds are all copper compounds combining with a group 16 anion of sulfur or oxygen. We have to consider the charge of these anions as well as the charge of the coppers, as indicated by the Roman numerals in the name.

Analyze

In these compounds, both oxygen and sulfur have a charge of 2− because they belong to group 16 in the periodic table. The number of oxygen or sulfur and copper ions that compose the compounds must balance each other in charge to give neutral species.

Solve

(a) cuprite [copper(I) oxide]: Cu_2O
(b) chalcocite [copper(I) sulfide]: Cu_2S
(c) covellite [copper(II) sulfide]: CuS

Think About It

Copper can be present in nature as a cation with either a 1+ or a 2+ charge.

2.90. **Collect and Organize**

These compounds are all binary ionic compounds of cobalt and oxygen. Because cobalt is a transition metal and thus has more than one available ionic charge, we use the naming rules that incorporate Roman numerals into the name to indicate the charge on the cobalt ion in the compound.

Analyze

In these compounds, oxygen has a charge of 2–. The charge on the cobalt ion must balance out the charge on the oxide ion to give the neutral species listed. In naming these compounds the metal is named first, followed by the charge in Roman numerals in parentheses. The anion is named as a separate word with the ending *-ide*.

Solve

(a) CoO: cobalt ion has a 2+ charge, cobalt(II) oxide
(b) Co_2O_3: cobalt ion has a 3+ charge, cobalt(III) oxide
(c) CoO_2: cobalt ion has a 4+ charge, cobalt(IV) oxide

Think About It

Because the charges of the cations and anions must balance to give a neutral species, we do not have to indicate the number of oxide anions in these compounds; the cation charge dictates the number of oxide ions that must be present in the formula.

2.91. **Collect and Organize**

We need to name each of the compounds according to the rules for naming acids.

Analyze

Binary acids are named by placing *hydro-* in front of the element name other than hydrogen along with replacing the last syllable with *-ic* and adding *acid*. For acids containing oxoanions that end in *-ate*, the acid name becomes *-ic acid*. For acids containing oxoanions that end in *-ite*, the acid name becomes *-ous acid*.

Solve

(a) HF(*aq*), a binary acid, hydrofluoric acid
(b) $HBrO_3$(*aq*), an acid of the bromate anion, bromic acid
(c) HBr(*aq*), a binary acid, hydrobromic acid
(d) HIO_4(*aq*), an acid of the periodate anion, periodic acid

Think About It

Note that the acids are all in aqueous solution. If not dissolved in water, these species should be named as covalent (molecular) compounds!

2.92. **Collect and Organize**

We need to write the formula for each of the compounds according to the rules for naming acids.

Analyze

Binary acids are named by placing *hydro-* in front of the element name other than hydrogen along with replacing the last syllable with *-ic* and adding *acid*. For acids containing oxoanions that end in *-ate*, the acid name becomes *-ic acid*. For acids containing oxoanions that end in *-ite*, the acid name becomes *-ous acid*.

Solve

(a) selenous acid, an acid of the selenite anion, H_2SeO_3(*aq*)
(b) hydrocyanic acid, HCN(*aq*)
(c) phosphoric acid, acid of the phosphate anion, H_3PO_4(*aq*)
(d) nitrous acid, acid of the nitrite anion, HNO_2(*aq*)

Think About It

The rules are somewhat systematic but have to be learned and practiced.

2.93. **Collect and Organize**

We are asked to identify the classes of organic compounds that do not contain heteroatoms.

Analyze

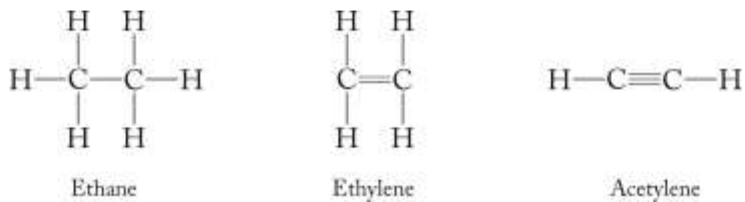
Heteroatoms are nonmetals other than carbon and hydrogen. Refer to Section 2.8 for a discussion of the different classes of organic compounds.

Solve

The organic compounds discussed in Section 2.8 without heteroatoms are the hydrocarbons: alkanes, alkenes, and alkynes.

Think About It

Examples of these three functional groups are drawn below.



Notice that, in each case, only carbon and hydrogen atoms are present, but the number of bonds between carbon atoms changes. In each case, carbon has a total of four bonds.

2.94. **Collect and Organize**

We are asked to identify the classes of organic compounds that contain oxygen atoms.

Analyze

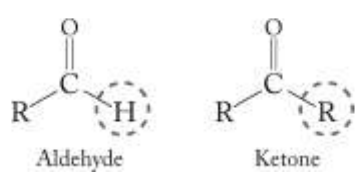
Refer to Section 2.8 for a discussion of the different classes of organic compounds. Several classes of organic compounds contain oxygen atoms, which we can determine by examining the functional groups in Table 2.5.

Solve

The classes of organic molecules that have functional groups containing oxygen atoms are alcohols, ethers, aldehydes, ketones, carboxylic acids, esters, and amides.

Think About It

As shown below, aldehydes and ketones are structurally very similar to one another.



While both groups contain a C=O bond, the carbon atom of a ketone is bound to two other carbon atoms (in the R groups), while the carbon atom of an aldehyde is bound to only one other carbon atom (in an R group) as well as a hydrogen atom. These functional groups are given different names because their properties and reactivity can be quite different.

2.95. **Collect and Organize**

We are asked to identify the classes of organic compounds that contain nitrogen atoms.

Analyze

Refer to Section 2.8 for a discussion of the different classes of organic compounds. Several classes of organic compounds contain oxygen atoms, which we can determine by examining the functional groups in Table 2.5.

Solve

The classes of organic molecules that have functional groups containing nitrogen atoms are amines and amides. Amides contain both a nitrogen and an oxygen atom.

Think About It

Amide functional groups are formed when amino acids bond with one another to generate a polypeptide. Organic functional groups may be found in the organic chemistry laboratory or your own body!

2.96. **Collect and Organize**

We are asked to describe organic compounds as molecular compounds composed of covalent bonds or ionic lattices composed of ionic bonds.

Analyze

Organic compounds are primarily composed of carbon and hydrogen atoms, with some nonmetal heteroatoms. Bonds formed between two nonmetals are covalent (molecular) in nature since electrons are shared more equally between these atoms.

Solve

Organic compounds contain covalent bonds and exist as molecules.

Think About It

Although the bonding in organic compounds is covalent, not all of the electrons in these bonds are shared equally. We will see in Chapter 9 that covalent bonds may be polarized toward one atom in the bond. This unequal sharing of electron density has a profound effect on the chemistry of organic compounds.

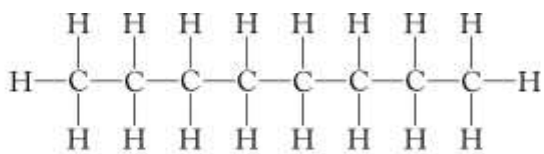
2.97. **Collect and Organize**

We are asked to determine to which class each of the listed organic compounds belongs.

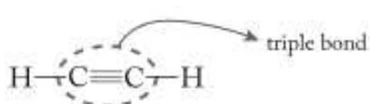
Analyze

Refer to Section 2.8 for a discussion of the different classes of organic compounds. Both of the species described in this problem are hydrocarbons. It may be easier to see the type of C–C bond in each case by drawing the full structure, rather than just looking at the condensed formula. The functional group is circled in each case:

(a)



(b)



Solve

(a) Octane is a hydrocarbon with all C–C (single) bonds. This is an alkane.
(b) Ethyne, or acetylene, is a hydrocarbon with a C≡C bond. This is an alkyne.

Think About It

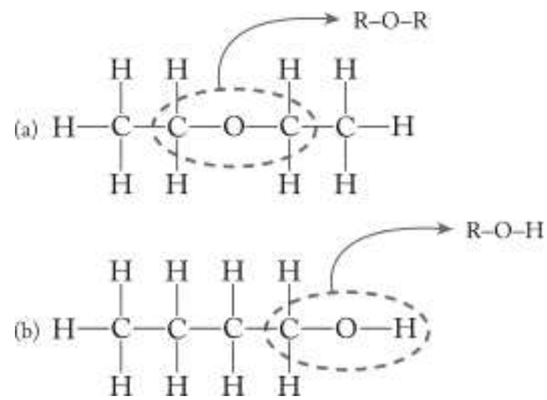
The type of functional group is given by the systematic name for each of these hydrocarbons. Alkanes all end in *-ane*, while alkynes all end in *-yne*.

2.98. **Collect and Organize**

We are asked to determine to which class each of the listed organic compounds belongs.

Analyze

Refer to Section 2.8 for a discussion of the different classes of organic compounds. Both of the species described in this problem contain an oxygen atom. It may be easier to see the functional group in each case by drawing the full structure, rather than just looking at the condensed formula. The functional group is circled in each case:



Solve

(a) Diethyl ether contains a C–O–C unit. This is an ether.
(b) Butanol contains a C–O–H unit. This is an alcohol.

Think About It

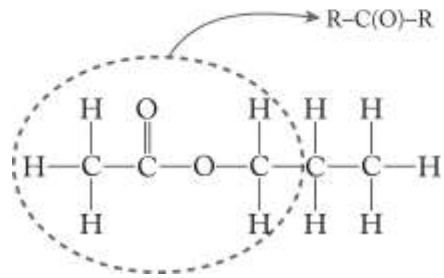
The type of functional group is given by the systematic name for each of these compounds. Ethers all end in the word "*ether*," while alcohols all end in *-ol*.

2.99. **Collect and Organize**

We are asked to determine to which class propyl acetate belongs.

Analyze

Refer to Section 2.8 for a discussion of the different classes of organic compounds. The functional group in propyl acetate is circled below:



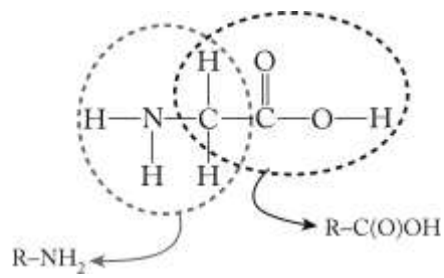
Solve
Propyl acetate contains a R–C(O)–R unit, as we would expect for an ester.

Think About It
Note that the "R" groups in this ester are not identical (one contains a one-carbon chain and one contains a three-carbon chain). Varying the R groups results in different esters with different aromas.

2.100. **Collect and Organize**

We are asked the two functional groups in the amino acid, glycine.

Analyze
Refer to Section 2.8 for a discussion of the different classes of organic compounds. Comparing the depiction of glycine to the functional groups depicted in Table 2.5, we can identify those present in this molecule.



Solve
Glycine contains both an R–NH_2 unit and an R–C(O)OH unit. These correspond to an amine and a carboxylic acid.

Think About It
All of the amino acids contain both an amine and a carboxylic acid functional group. This class of molecules is named to describe this substitution pattern.

2.101. **Collect and Organize**

We must define *chemistry* and *cosmology* and give examples of how these two sciences are related.

Analyze
Chemistry looks at the properties of matter at the atomic or molecular level. Cosmology looks at the properties of the universe.

Solve
Chemistry is the study of the composition, structure, properties, and reactivity of matter. Cosmology is the study of the history, structure, and dynamics of the universe. A few of the ways that these two sciences are related might be as follows: (1) Because the universe is composed of matter and the study of matter is

chemistry, the study of the universe is really chemistry. (2) The changing universe is driven by chemical and atomic or nuclear reactions, which are also studied in chemistry. (3) Cosmology often asks what the universe (including stars and black holes) is made of at the atomic level.

Think About It

Cosmologists, even though they study the vast universe, must understand chemistry to understand the dynamic processes that formed and continue to shape our universe.

2.102. **Collect and Organize**

Of the particles listed, we are asked which formed first and which formed last in the universe's history.

Analyze

We expect the smaller, least complex particles to have formed first and the larger, more complicated particles to form later. In rough order of size: quarks < neutron = proton < deuteron (^{2}H nucleus).

Solve

The first particles formed in the universe were quarks (d), the smallest elementary particles; the last particle from the list formed would be the deuteron (a), which would have had to result from the fusing of a proton with a neutron.

Think About It

The early universe was too hot to allow for anything but the smallest fundamental particles to exist.

2.103. **Collect and Organize**

We are asked why chemists do not include quarks in their study of subatomic particles.

Analyze

Chemists are interested in the reactivity and properties of atoms and molecules.

Solve

Chemists do not include quarks in the category of subatomic particles because the very small quarks combine to make up the three larger subatomic particles that are important to the properties and reactivity of atoms: protons, neutrons, and electrons.

Think About It

The quarks make up the neutron and protons, each containing three quarks. There are six "flavors" of quarks: up, down, charm, strange, top, and bottom. The word *quark* was first used by physicist Murray Gell-Mann, but later he found the word was also used previously by James Joyce in *Finnegan's Wake*.

2.104. **Collect and Organize**

We are asked to explain why early synthesis of the elements lasted only a (relatively) short time.

Analyze

Nucleosynthesis through fusion reactions must occur at very high temperatures and with high densities of particles.

Solve

Early nucleosynthesis lasted such a short time because the universe was quickly expanding and cooling, conditions that would not support further nuclear fusion.

Think About It
The high abundance of helium in the universe today supports the model of nucleosynthesis proposed in the Big Bang theory.

2.105. **Collect and Organize**
We consider how the density of the universe is changing as it expands.

Analyze
Density is simply defined as mass per volume.

Solve
If the universe's volume is expanding with time and the amount of matter in the universe is constant, then its density is decreasing.

Think About It
The density of the universe has been calculated to be about 2.11×10^{-29} g/cm^3.

2.106. **Collect and Organize**
We are given that the ions most prevalent in the solar wind are hydrogen ions, and we are asked to predict the element with the next most abundant ions.

Analyze
Hydrogen is the most abundant element in the Sun, so it is reasonable that the solar wind is composed mostly of hydrogen ions. The second most abundant element in the Sun is helium.

Solve
The Sun (and indeed the universe!) is composed mostly of hydrogen and helium, so it is likely that helium ions would be the second most abundant ions in the solar wind.

Think About It
The northern (and southern) lights are caused by the charged particles in the solar wind colliding with atmospheric atoms.

2.107. **Collect and Organize**
We are asked to identify and name the missing element from the series of oxoacids HClO, $HClO_2$, and $HClO_4$.

Analyze
Oxoacids are named according to the names of their oxoanions. The chlorine oxoanions are
ClO^- hypochlorite
ClO_2^- chlorite
ClO_3^- chlorate
ClO_4^- perchlorate

The missing compound is the acid of the chlorate anion, ClO_3^-. Oxoacids are named such that the anion suffix -*ite* becomes -*ous acid* and the suffix -*ate* becomes -*ic acid.*

Solve
The missing acid is chloric acid, $HClO_3$.

Think About It

The three acids provided in this question are hypochlorous acid (HClO), chlorous acid ($HClO_2$), and perchloric acid ($HClO_4$).

2.108. **Collect and Organize**

We are told that two carbon-12 nuclei fuse to produce an alpha particle and a new element. We are asked to write an equation to describe the process. Recall that an alpha particle contains two protons and two neutrons and may be depicted as ${}^{4}_{2}\alpha$. You should also recall that the 12 in carbon-12 represents the mass number and that the identity of an element is determined by the number of protons (the atomic number).

Analyze

When balancing nuclear equations, both atomic mass and atomic number are conserved (i.e., the sum of the atomic masses on the reactant side must equal the sum of the atomic masses on the product side, and similarly for atomic number). It may be easier to rephrase the question as a nuclear equation that we must balance by determining the identity of the particle formed. Write each reactant or product showing both the mass number and the atomic number:

$${}^{12}_{6}\mathrm{C} + {}^{12}_{6}\mathrm{C} \rightarrow {}^{4}_{2}\alpha + \text{¾¾¾¾}$$

Here the blank space represents the new element whose identity we are to determine. The new element is likely to have a mass slightly higher than that of carbon, but it should not be significantly higher in mass.

Solve

There are 12 protons on the reactant side, so our new element must contain 12 – 2 = 10 protons. This identifies the new element as neon. Using the same process, we may determine which isotope of neon is formed. The atomic mass of the neon nuclide is 12 + 12 – 4 = 20. The equation describing this process is

$${}^{12}_{6}\mathrm{C} + {}^{12}_{6}\mathrm{C} \rightarrow {}^{4}_{2}\alpha + {}^{20}_{10}\mathrm{Ne}$$

Think About It

It is important to keep track of both the atomic mass and the atomic number throughout a nuclear equation. The carbon fusion reaction described above is one of the possible steps in the formation of heavier elements in the core of a star.

2.109. **Collect and Organize**

We are told that an alpha particle and a neon-21 nucleus combine to produce the nucleus of another element and a neutron. We are asked to write an equation describing this nuclear reaction. Recall that an alpha particle contains two protons and two neutrons and may be depicted as ${}^{4}_{2}\alpha$ and a neutron may be depicted as ${}^{1}_{0}\mathrm{n}$. You should also recall that the 21 in neon-21 represents the mass number and that the identity of an element is determined by the number of protons (the atomic number).

Analyze

When balancing nuclear equations, both atomic mass and atomic number are conserved (i.e., the sum of the atomic masses on the reactant side must equal the sum of the atomic masses on the product side, and similarly for atomic number). It may be easier to rephrase the question as a nuclear equation that we must balance by determining the identity of the particle formed. Write each reactant or product showing both the mass number and the atomic number:

$${}^{21}_{10}\mathrm{Ne} + {}^{4}_{2}\alpha \rightarrow {}^{1}_{0}\mathrm{n} + \text{¾¾¾¾}$$

Here the blank space represents the new element whose identity we are to determine. The new element is likely to have a mass slightly higher than that of neon, but it should not be significantly higher in mass.

Solve

There are 12 protons on the reactant side, so our new element must contain 12 − 0 = 12 protons. This identifies the new element as magnesium. Using the same process, we may determine which isotope of magnesium is formed. The atomic mass of the magnesium nuclide is 21 + 4 − 1 = 24. The equation describing this process is

$$^{21}_{10}\mathrm{Ne} + {}^{4}_{2}\alpha \rightarrow {}^{1}_{0}\mathrm{n} + {}^{24}_{12}\mathrm{Mg}$$

Think About It

Our estimate was reasonable—the mass number and atomic number for the new element are very close to those of neon-21. It is easier to see that the number of subatomic particles are conserved when the nuclear equation is written out.

2.110. **Collect and Organize**

J. J. Thomson's experiment revealed the electron and its behavior in magnetic and electric fields. In this question, we look closely at his experiment.

Analyze

Thomson showed that a cathode ray was deflected by a magnetic field in one direction and by an electric field in the other direction. He was able to visualize the deflection of the cathode ray when the ray hit a fluorescent plate at the end of his experimental apparatus, as shown in Figure P2.106. The cathode ray was deflected by the electrically charged plates as shown. We can imagine the experiment proceeding from no voltage across the charged plates to low voltages and then to higher voltages. From this thought experiment, we imagine the ray must be deflected more by an increased voltage across the charged plates. Thomson reasoned that the cathode ray was composed of tiny charged particles, which were later called electrons.

Solve

(a) Today we call cathode rays electrons.

(b) The beam of electrons was deflected between the charged plates because they are attracted to the oppositely charged plate as the beam passes through the electric field. Indeed, in Figure P2.106 we see the beam is deflected up toward the (+) plate.

(c) If the polarities of the plates were switched, the electron would still be deflected toward the positively charged plate, which would now be at the bottom of the tube.

(d) If we reduced the voltage by half, the light spot would be deflected half as much, so the position of the light spot on the fluorescent screen would be halfway between the position where it was before the voltage was reduced and the 0-spot position when there is no voltage between the plates.

Think About It

This experiment was key to the discovery of subatomic particles, which, until then in the atomic theory, were not known to exist. Before that time, it was believed that the atom was the smallest, indivisible component of matter.

2.111. **Collect and Organize**

This question considers Thomson's cathode-ray tube experiment when using a radioactive source in place of electricity to generate a beam.

Analyze

The particles that are coming from the radioactive source include the β particle (an electron with 1− charge), an α particle (a helium nucleus with 2+ charge), and rays of energy with no charge (perhaps these are γ rays). Each of these is deflected differently when the beam passes through two charged metal plates.

Solve

(a) Because each of the beams of particles or energy is deflected differently due to their different charges, there will be three spots on the phosphorescent screen.

(b) The rays of energy with no charge are unaffected by the electric field, so these would appear in the center of the screen. The β particles are deflected toward the positively charged plate. The α particles, with a higher positive charge (2+), would be deflected toward the negatively charged plate.

Think About It

This simple experiment could discriminate not only differently charged particles (negative, positive, and neutral), but could also discriminate between two positively or negatively charged particles of different masses (e.g., protons versus α particles) or two species with the same mass but with different charges.

2.112. **Collect and Organize**

This question considers Thomson's cathode-ray tube experiment when a radioactive source is used in place of electricity to generate a beam. The beam produces, in this case, protons and α particles at the same velocities in the tube.

Analyze

The difference between protons and α particles is the charge (1+ for the proton and 2+ for the α particle). If both particles are passing through the electric field of the apparatus at the same speed, we need to think only about how they might differently be attracted to the negatively charged plate. Because the 2+ particle will feel more of an attraction, it will be deflected more.

Solve

(a) We would expect two light spots on the phosphorescent screen because these two particles differ in their charges and therefore in their attraction to the negatively charged plate.

(b) Both spots would be seen below the center of the screen. The spot lowest on the screen (farthest from the middle) would be the α particle, and the one closest to the middle would be the proton.

Think About It

If we were able to strip the electrons off other atoms, such as Li and Be, and produce "nucleus beams," we would see an even greater deflection.

2.113. **Collect and Organize**

We consider that the early universe was composed of 75% ^{1}H and 25% ^{4}He by mass.

Analyze

We must first convert the percentage by mass into percentage of atoms by considering that the helium nucleus weighs four times that of hydrogen. We can then compare that value to the 10:1 hydrogen-to-helium composition in our solar system and propose a way that any difference might have occurred.

Solve

(a) Because helium's mass is four times that of hydrogen, the atom ratio of these two elements would be given by

$$\frac{(25 \text{ g He}/4 \text{ g})}{(75 \text{ g H}/1 \text{ g})} = \frac{6.25}{75} = \frac{1}{12}$$

This means that in the early universe there were 12 H atoms for every 1 He atom.

(b) Comparing the ratio of hydrogen to helium in the solar system (10:1) to the ratio in the early universe (12:1), we see that there is proportionately more helium present in our solar system than at the beginning of the universe.

(c) Stars burn hydrogen fuel, which gives off energy. One product of this fusion process is helium. As a star burns away its hydrogen, more helium is produced.
(d) We could propose to look at the composition of galaxies that have older stars. Are more helium and heavier elements present as the stars burn up their hydrogen?

Think About It
If the fusion process continues, with lighter elements fusing to form heavier elements, it could be imagined that stars might run out of hydrogen fuel and then have to rely on helium fusion to produce energy.

2.114. **Collect and Organize**
Potassium forms several compounds in combination with oxygen. We are asked to determine the ratio of masses of oxygen that would form K_2O, K_2O_2, and KO_2 from a given amount of potassium.

Analyze
The law of multiple proportions states that, if more than one compound is formed from two elements, the masses of the two elements in the compounds will be in whole-number ratios. In this problem we consider the mass of oxygen that would combine with a certain mass of potassium to form K_2O, K_2O_2, and KO_2. We need only look at the ratio of the two elements in the compounds to answer this.

Solve
The ratio of potassium to oxygen in K_2O is 2:1, in K_2O_2 the ratio is 2:2, and in KO_2 it is 1:2. To compare the three compounds, this last ratio (for KO_2) could also be expressed as 2:4. When all the compounds have 2 as the amount of potassium, the ratio of oxygen among the compounds can be compared directly. From the oxygen ratio between compounds of 1:2:4, we see that it would take twice the mass of oxygen to form K_2O_2 for a given amount of potassium as it would to prepare K_2O. By the same reasoning, it would take four times the mass of oxygen to form KO_2 for a given amount of potassium as it would to prepare K_2O.

Think About It
The charge on the oxygen atom varies among these compounds. Only in K_2O does the oxygen atom have a charge of 2–, which we would predict from its position in group 16 of the periodic table. Considering that the potassium atom in each of these compounds has a 1+ charge, in K_2O_2, the oxygen atoms each carry a 1– charge and in KO_2 each oxygen atom carries a $\frac{1}{2}-$ charge.

2.115. **Collect and Organize**
Bronze contains copper and tin at 88% and 12% by mass, respectively. We are asked what is the ratio of copper to tin atoms in bronze. We need to first assume that in 100 amu of bronze there are 90 amu of Cu and 10 amu of Sn.

Analyze
We need the mass of Cu (63.546 amu) and Sn (118.710 amu) to calculate the number of atoms of Cu and Sn in 100 amu of bronze.

Solve
The number of atoms of Cu in 100 amu of bronze is

$$\frac{88 \text{ amu}}{63.546 \text{ amu/Cu atom}} = 1.4 \text{ Cu atoms}$$

The number of atoms of Sn in 100 amu of bronze is

$$\frac{12 \text{ amu}}{118.710 \text{ amu/Sn atom}} = 0.10 \text{ Sn atom}$$

The ratio of Cu to Sn atoms is

$$\frac{1.4\ \text{Cu}}{0.10\ \text{Sn}} = 14$$

or 14 Cu : 1 Sn.

Think About It

Bronze, because it contains a homogeneous mixture of metals, is an alloy.

2.116. **Collect and Organize**

We are to discern from the formulas for the composition of the element with hydrogen (MH_3) and oxygen (M_2O_5) the Roman numeral Mendeleev assigned to the group containing these elements.

Analyze

The Roman numerals that Mendeleev used are closely related to the charge on the ion for the element. In compounds, hydrogen can be 1+ or 1– and oxygen is usually 2–.

Solve

Looking first at M_2O_5, we would assign an oxidation number of 5+ to M so that the 10+ from two M ions in the compound balances the 10– charge from the five O atoms. The compound MH_3 fits if we consider compounds such as NH_3 and PH_3 that also have oxides of N_2O_5 and P_2O_5. Mendeleev would have designated this group as V.

Think About It

With close inspection of Mendeleev's table in Figure 2.9, you can see that indeed his Roman numerals often correspond to oxidation numbers typical for those elements.

2.117. **Collect and Organize**

Mendeleev left "holes" in his periodic table for undiscovered elements, including those with masses of 44, 68, and 72. We are asked to identify these elements from a modern periodic table and to consult a reference to determine when these elements were discovered.

Analyze

The elements that Mendeleev predicted have average masses of about 44, 68, and 72. We can find these on the modern periodic table and compare their locations to those in his original table shown in Figure 2.9. We can use www.webelements.com to look up when the elements were discovered.

Solve

(a) The element between Ca and Ti in Mendeleev's table is scandium (Sc) with an average mass of 44.956 amu. The element after Zn in Mendeleev's table is gallium (Ga) with an average mass of 69.723 amu. The element before As in Mendeleev's table is germanium (Ge) with an average mass of 72.61 amu.
(b) Ekaaluminum is gallium, ekaboron is scandium, and ekasilicon is germanium.
(c) Scandium was discovered in 1879 by Lars Fredrik Nilson in Sweden; gallium was discovered in 1875 by Paul-Emile Lecoq de Boisbaudran in France; and germanium was discovered in 1886 by Clemens Winkler in Germany.

Think About It

Mendeleev's predictions about not only the missing elements' masses but also their densities and physical properties were quite accurate and actually helped in the discovery of the missing elements.

2.118. **Collect and Organize**

Given that *thio*- in a chemical name means that a sulfur atom has replaced one of the oxygen atoms, we are asked to write the formulas for the thiosulfate ion and for its salt with sodium.

Analyze

The sulfate ion is SO_4^{2-}.

Solve

(a) If we replace an oxygen atom with a sulfur in SO_4^{2-}, we get the thiosulfate ion, $S_2O_3^{2-}$.
(b) To balance the charges to form a neutral salt, we need two sodium ions in the formula for sodium thiosulfate, $Na_2S_2O_3$.

Think About It

Other *thio*- compounds are also similarly named. Thiocyanate is SCN^- from cyanate (OCN^-), and thiourea is $(NH_2)_2CS$ from urea, $(NH_2)_2CO$.

2.119. **Collect and Organize**

One isotope of gallium weighs 68.92558 amu (^{69}Ga), and the other weighs 70.9247050 amu (^{71}Ga). From the average atomic mass of 69.7231 amu, we are to calculate the abundance of ^{69}Ga.

Analyze

The weighted-average atomic mass is derived from a weighted-average of the isotopes' atomic masses. If x = abundance of ^{69}Ga and y = abundance of ^{71}Ga, then the weighted average can be expressed as

$$68.92558 \text{ amu } (x) + 70.9247050 \text{ amu } (y) = 69.7231 \text{ amu}$$

Because there are only two isotopes, the sum of their abundances (in decimal form) must equal 1.00.

$$x + y = 1.00$$

Thus

$$x = 1.00 - y$$

Substituting this expression for x into the preceding weighted-average equation gives

$$68.92558 \text{ amu } (1 - y) + 70.9247050 \text{ amu } (y) = 69.7231 \text{ amu}$$

Solve

$$68.92558 \text{ amu} - 68.92558 \text{ amu } (y) + 70.9247050 \text{ amu } (y) = 69.7231 \text{ amu}$$

$$1.99913 \text{ amu } (y) = 0.7975 \text{ amu}$$

$$y = 0.3989$$

The abundance of $^{69}Ga = 1 - y = 1 - 0.3989 = 0.6011$, or 60.11%.

Think About It

Because there are only two isotopes for gallium, it follows that the abundance of ^{71}Ga is $100 - 60.11 = 39.89\%$.

2.120. **Collect and Organize**

One isotope of bromine weighs 78.9183 amu (^{79}Br), and the other weighs 80.9163 amu (^{81}Br). From the average atomic mass of 79.9091 amu, we are to calculate the abundance of ^{81}Br.

Analyze

The average atomic mass is derived from a weighted average of the isotopes' atomic masses. If x = abundance of ^{79}Br and y = abundance of ^{81}Br, then the weighted average can be expressed as

$$78.9183 \text{ amu } (x) + 80.9163 \text{ amu } (y) = 79.9091 \text{ amu}$$

Because there are only two isotopes, the sum of their abundances (in decimal form) must equal 1.00.

$$x + y = 1.00$$

Thus

$$x = 1.00 - y$$

Substituting this expression for x into the preceding weighted-average equation gives

$$78.9183 \text{ amu } (1 - y) + 80.9163 \text{ amu } (y) = 79.9091 \text{ amu}$$

Solve

$$78.9183 \text{ amu} - 78.9183 \text{ amu } (y) + 80.9163 \text{ amu } (y) = 79.9091 \text{ amu}$$

$$1.9980 \text{ amu } (y) = 0.9908 \text{ amu}$$

$$y = 0.4959$$

The abundance of ^{81}Br is $y \times 100 = 49.59\%$.

Think About It

Because there are only two isotopes for bromine, it follows that the abundance of ^{79}Br is 100 − 49.59 = 50.41%.

2.121. **Collect and Organize**

From the previous problem, we use the values of 78.9183 amu (^{79}Br) and 80.9163 amu (^{81}Br) along with their relative abundances (50.41% and 49.59%, respectively) to determine the mass of the possible isotopic combinations for individual Br_2 molecules and the natural abundance of these different Br_2 molecules.

Analyze

The possible combinations of isotopes for the Br_2 molecule are ^{79}Br–^{79}Br, ^{79}Br–^{81}Br, and ^{81}Br–^{81}Br. We can simply add the masses for the two isotopes present in each to get the mass of each isotope combination. To calculate the relative abundance of each isotopic combination, we need only multiply the probabilities of choosing that isotope from a large collection of natural bromine to form the Br_2 combination.

Solve

(a) ^{79}Br–^{79}Br = 157.8366 amu
^{79}Br–^{81}Br = 159.8346 amu
^{81}Br–^{81}Br = 161.8326 amu

(b) For ^{79}Br–^{79}Br, we have a 0.5041 chance of choosing the ^{79}Br isotope from the natural collection of bromine atoms. The probability of both isotopes being ^{79}Br is $0.5041 \times 0.5041 = 0.2541$ for an abundance of 25.41%. For ^{79}Br–^{81}Br, we have to consider the second combination, ^{81}Br–^{79}Br, as well as that of ^{79}Br–^{81}Br. The probability for this combination is $2 \times (0.5041 \times 0.4959) = 0.49997$ for an abundance of 50.00%. For ^{81}Br–^{81}Br, we have a 0.4959 chance of choosing from the natural collection of bromine atoms the ^{81}Br isotope. The probability of both isotopes being ^{81}Br is $0.4959 \times 0.4959 = 0.2459$ for an abundance of 24.59%.

Think About It

All these abundances for the combination of isotopes add up to (25.41 + 50.00 + 24.59)% = 100%, as we would expect.

2.122. **Collect and Organize**

In this problem we are provided with the masses of the three isotopes of magnesium (^{24}Mg = 23.9850 amu, ^{25}Mg = 24.9858 amu, and ^{26}Mg = 25.9826 amu) and given that the abundance for ^{24}Mg is 78.99%. From this information and the average (weighted) atomic mass units of magnesium (24.3050 amu), we must calculate the abundances of the other two isotopes, ^{25}Mg and ^{26}Mg.

Analyze

The average atomic mass is derived from a weighted average of the isotopes' atomic masses. If x = abundance of ^{25}Mg and y = abundance of ^{26}Mg, the weighted average of magnesium is

$$(0.7899 \times 23.9850 \text{ amu}) + 24.9858 \text{ amu } (x) + 25.9826 \text{ amu } (y) = 24.3050 \text{ amu}$$

Because the sum of the abundances of the isotopes must add up to 1.00

$$0.7899 + x + y = 1.00$$

So

$$x = 1.00 - 0.7899 - y = 0.2101 - y$$

Substituting this expression for x in the weighted-average mass equation gives

$$(0.7899 \times 23.9850 \text{ amu}) + 24.9858 \text{ amu } (0.2101 - y) + 25.9826 \text{ amu } (y) = 24.3050 \text{ amu}$$

Solve

$$18.94575 + 5.249517 - 24.9858y + 25.9826y = 24.3050$$

$$0.9968y = 0.1097$$

$$y = 0.1101$$

So

$$x = 0.2101 - 0.1101 = 0.1000$$

The abundance of ^{25}Mg is $x \times 100$ = 10.00%, and the abundance of ^{26}Mg is $y \times 100$ = 11.01%.

Think About It

Although the abundances of ^{25}Mg and ^{26}Mg are nearly equal to each other at the end of this calculation, we cannot assume that when setting up the equation. We have to solve this problem algebraically by setting up two equations with two unknowns.

2.123. **Collect and Organize**

We are asked to identify the elements in each molecule based on their group. After identifying the elements, we are asked to name the compound and provide the chemical formula.

Analyze
Each of the listed elements is from a different group
Li – group 1
Fe – group 8
Al – group 13
O – group 16
N – group 15
C – group 14

Solve
(a) "A" is C (a group 14 element) and "B" is O (a group 16 element). The compound is CO_2, carbon dioxide.
(b) "C" is Li (a group 1 element) and "D" is N (a group 15 element). The compound is Li_3N, lithium nitride.

Think About It
Remember to name the compounds according to the rules for ionic or molecular compounds, depending on the component atoms. Because Li_3N is an ionic compound, there must be three Li^+ ions, so the prefix *tri-* is not required, as it would be for a molecular compound.

2.124. **Collect and Organize**

We are asked to write a chemical symbol based on the information given about each nuclide.

Analyze
Chemical symbols may include information about the atomic number (number of protons), mass number (sum of the number of protons and the number of neutrons), elemental symbol, and charge. Knowing something about the number of electrons, atomic number, or mass number, we may deduce the other values.

Solve
(a) Atomic number 12 identifies the element as magnesium (Mg). Incorporating the information about the charge and mass number, the chemical symbol is ${}^{24}_{12}Mg^{2+}$.
(b) An ion with a charge of 3+ and 48 electrons must have 48 + 3 = 51 protons. This identifies the element as antimony (Sb). With 70 neutrons, the mass number for this nuclide is 51 + 70 = 121, and the chemical symbol for the nuclide is ${}^{121}_{51}Sb^{3+}$.
(c) A noble gas with 48 neutrons is likely to have a similar number of protons. The likely candidates are xenon (Xe, Z = 54) and krypton (Kr, Z = 36). If the element were xenon, the mass number for this nuclide would be 102, which is significantly smaller than the average atomic mass for xenon (131.293 amu). Krypton gives us a much more realistic mass number of 36 + 48 = 84 (close to the average atomic mass for krypton of 83.798 amu). Since no charge is mentioned, we can assume it is a neutral atom, as is often the case for the noble gases. The chemical symbol for the nuclide is ${}^{84}_{36}Kr$.

Think About It
Remember that electrons have a negative charge. A cation is formed by losing one or more electrons, and an anion is formed by gaining one or more electrons. Forgetting this small detail could lead you to the wrong element!

2.125. **Collect and Organize**

We are asked to predict some physical and chemical properties of the element radium, Ra. We are also asked to predict the melting points for $RaCl_2$ and RaO by comparing the melting points for other alkaline earth metal chlorides and oxides.

Analyze
Radium is the heaviest known member of group 2, the alkaline earth metals. Elements in the same group may be assumed to have similar physical and chemical properties.

Solve
Like other alkaline earth metals, it is reasonable to expect that radium would adopt a 2+ charge to form Ra^{2+} compounds. As a metallic element, it would likely be malleable, be relatively dense, conduct heat and electric current, and melt at a fairly high temperature. The melting points of various alkaline earth metal chlorides and oxides are listed below, along with estimates for $RaCl_2$ and RaO.

	Melting Point (ºC)		Melting Point (ºC)
$CaCl_2$	772	CaO	2572
$SrCl_2$	874	SrO	2531
$BaCl_2$	962	BaO	1923
$RaCl_2$	(950 to 1050)	RaO	(1700 to 2000)

Think About It
Mendeleev used the periodicity of the chemical and physical properties of the elements to predict the location of several undiscovered elements. The similarity of elements in a group is one of the defining characteristics of the modern periodic table.

2.126. **Collect and Organize**
We are asked to predict which of the listed elements might be good electrical conductors.

Analyze
Metals are good electrical conductors. Elements that are identified as metals may be expected to serve as conductors.

Solve
Of the elements listed, Ti, Ag, Tb, and Mo are metals and thus are expected to be good electrical conductors.

Think About It
As we will see later in the textbook, electrical conductivity relates to the movement of electrons between adjacent atoms. Metals are particularly well suited to transfer electrons between atoms, due to the nature of metallic bonding in the solid state.

2.127. **Collect and Organize**
We are asked to explain why argon is placed before potassium in the modern periodic table, despite having a larger average atomic mass.

Analyze
The modern periodic table is sorted by atomic number rather than by average atomic mass, as Mendeleev's periodic table was.

Solve
Despite being heavier (on average), argon contains 18 protons, whereas potassium contains 19 protons. Since the modern periodic table is organized by increasing atomic number, argon is placed before potassium.

Think About It

The argon nuclide $^{40}_{18}Ar$ is 99.6% abundant in nature; the potassium nuclide $^{39}_{19}K$ is 93.3% abundant.

2.128. **Collect and Organize**

We are asked to explain why it takes twice the energy to remove an electron from He as it does from H.

Analyze

The electrons in He must be held more tightly to the nucleus so that they are harder to remove.

Solve

The electron is twice as hard to remove from a helium atom than from a hydrogen atom because it is being held by a nucleus with a 2+ charge rather than one with a 1+ charge.

Think About It

As we will see later in the textbook, it does not take three times the energy to remove an electron from Li because the electron that we remove is higher in energy in the atom and the positive charge of the nucleus is being “shielded” by the other electrons.