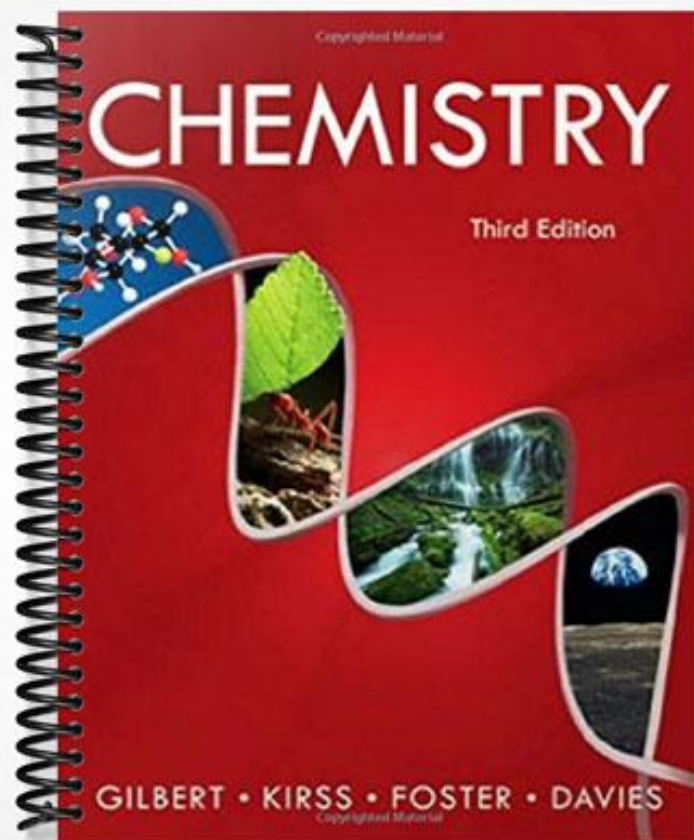


SOLUTIONS MANUAL



CHAPTER 2 | Atoms, Ions, and Compounds

2.1. 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 would imply that only one molecule, composed of two nitrogen and three oxygen atoms, was shown in the figure, not the seven molecules that are actually depicted. Finally, (d) a mixture of N_2 and O_3 cannot be correct because there are no pure blue–blue (N_2) or red–red–red (O_3) molecules depicted; all molecules show a mixture of nitrogen and oxygen.

2.2. Collect and Organize

This question asks us to consider the figure to identify the molecules depicted, consider a statement that the pressure of a gas is proportional to the number of molecules in a confined volume, then compare the masses of carbon atoms, and finally compare the ratio of atoms present. We have to consider not only the specific atoms present in each box, but also how the spheres are bonded together to form molecules and the number of each kind of molecule depicted in the boxes.

Analyze

Comparing the boxes 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 box on the right contains four molecules composed of one black sphere and one red sphere.

Solve

The boxes contain the same number of molecules but of different identity. The box on the left contains four molecules of CO_2 and the box on the right contains four molecules of CO ; so choice a is correct. To compare mass, we count 4 atoms of carbon on the left side and 4 atoms of carbon on the right side. Therefore, the masses of the carbon atoms are equal and choice b is also correct. There are 8 atoms of oxygen in the left box and 4 atoms of oxygen in the right box. This ratio is 2:1; so choice c is correct 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 box would be the same because they contain equal numbers of molecules; so choice d is also correct. All of these statements are 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.

2.3. Collect and Organize

This question asks us to recall which elements were formed after the Big Bang, to know which were present before galaxies formed, and to correlate the elements' identities with their position on the periodic table.

Analyze

After the Big Bang and initial cooling of the universe, we read in the chapter that the protons and neutrons fused together to form ${}^2\text{H}$ (an isotope of hydrogen), which then could fuse with another ${}^2\text{H}$ to form ${}^4\text{He}$.

Solve

Were other elements produced by fusion from ${}^4\text{He}$ and ${}^1\text{H}$? In the chapter, we read that, no, the next heavier elements (${}^5\text{Li}$ and ${}^8\text{Be}$) were not formed because these particular isotopes are unstable. It wasn't until galaxies were formed that elements other than hydrogen and helium were produced. The position of hydrogen on the periodic table is the first element under group 1. This element is not highlighted in the periodic table in Figure P2.3. Helium is the second element on the periodic table and is positioned as the first element in group 18. This is the element that is shaded dark blue in the periodic table.

Think about It

The heavy elements that make up the universe, and in particular Earth, have to be made in dense stars that support nucleosynthesis through processes such as neutron capture, α particle fusion, and β decay.

2.4. 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 thus produced in the fusion fires of giant stars. On the periodic table, therefore, all elements from 1 through 26 would be produced. In Figure P2.4 this correlates to the elements highlighted in groups 1 (K, dark blue), 4 (Ti, light blue), and 8 (Fe, yellow). The element shaded in group 12 (red) is Zn, which 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.

2.5. Collect and Organize

For this question we need to correlate properties of the elements with their positions in the periodic table. We need to use definitions of *inert* and *reactive* 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-hand side; nonmetallic elements are on the right-hand side. 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, and I.

- (a) Elements in group 1 form $1+$ ions; so K will form K^+ (dark blue).
- (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-hand side of the periodic table form cations and the ones on the right-hand side tend to form anions.

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. We have to first find the charge on the element that has combined with oxygen. We are then asked to find the element highlighted in the periodic table in Figure P2.7 that correlates to that charge.

Analyze

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

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 have to consider which elements combine with oxygen in a certain ratio to give polyatomic anions. We have to 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 correlates 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. To give a species with a $1-$ charge that has a 1:4 ratio of X to O, the X atom 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 elements for that 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 to (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

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."

2.10. 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.

2.11. 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. Pure energy "rays" would not be deflected by a magnetic field.

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.

2.12. Collect and Organize

We are asked to explain how helium might be associated with uranium ores.

Analyze

As given in the question, the helium nucleus consists of two protons and two neutrons, which is the same as the α particle.

Solve

Helium in pitchblende, a radioactive mineral, is a result of the α decay of the heavier, radioactive elements in the mineral.

Think about It

After its discovery by spectroscopy of the sun, helium was first discovered on Earth in uraninite, the ore of uranium of which UO_2 is the major constituent.

2.13. Collect and Organize

We 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, 2, 2, 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 in the periodic table for the elements are calculated weighted averages.

2.14. 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

The high abundance of one isotope over another indicates its higher nuclear stability.

2.15. 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 give

$$\begin{aligned} n &> 2p - p \\ n &> p \end{aligned}$$

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 wouldn't 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.

2.16. 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 of the 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.

2.17. 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 average mass (10.81 amu) is greater than this; ^{11}B is more abundant.

(b) The simple average atomic mass for ^6Li and ^7Li would be 6.5 amu. The actual average mass (6.941 amu) is greater than this; ^7Li is more abundant.

(c) The simple average atomic mass for ^{14}N and ^{15}N would be 14.5 amu. The actual 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 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 the dominance of only two isotopes in terms of their abundance. It is a little harder to answer the same question for elements with more than two stable isotopes in relatively high abundances.

2.18. Collect and Organize

In this question we are provided with the masses and abundances of the naturally occurring isotopes of copper. From this information, we can calculate the average atomic mass of copper.

Analyze

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

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

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

For the average atomic mass of copper

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

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.

2.19. Collect and Organize

In this question we are provided with the abundances of the two naturally occurring isotopes of chlorine. From this information and the isotope masses from Appendix 3, we can calculate the average atomic mass of chlorine.

Analyze

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

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

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

For the average atomic mass of chlorine

$$m_{\text{Cl}} = (0.7578 \times 34.968852 \text{ amu}) + (0.2422 \times 36.965903 \text{ amu}) = 35.45 \text{ amu}$$

Think about It

Because chlorine-35 is more abundant than chlorine-37, we expect that the average atomic mass for chlorine would be below the simple average of 36.

2.20. Collect and Organize

In this question we are provided with the masses and abundances of the four naturally occurring isotopes of sulfur. From this information, we can calculate the average atomic mass of sulfur.

Analyze

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

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

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

For the average atomic mass of sulfur

$$\begin{aligned} m_{\text{S}} &= (0.9504 \times 31.97207 \text{ amu}) + (0.0075 \times 32.97146 \text{ amu}) + (0.0420 \times 33.96787 \text{ amu}) \\ &\quad + (0.0001 \times 35.96708 \text{ amu}) = 32.1 \text{ amu} \end{aligned}$$

Think about It

Because sulfur-32 is about 95% abundant and the other isotopes are present in low abundances, we would expect the average atomic mass to be close to the mass of sulfur-32.

2.21. Collect and Organize

Here we are asked to find out if the 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 average weighted 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	Mass of Mg in MgO Isotope (amu)	Abundance	Weighted Mass of Mg Isotope
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 = 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 shouldn't be close to the same value as on Earth; the magnesium on both planets arrived in the solar system via the same ancient stardust.

2.22. 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,

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

Solve

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

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

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.

2.23. 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,

$$m_{\text{Ti}} = a_{46\text{Ti}} m_{46\text{Ti}} + a_{47\text{Ti}} m_{47\text{Ti}} + a_{48\text{Ti}} m_{48\text{Ti}} + a_{49\text{Ti}} m_{49\text{Ti}} + a_{50\text{Ti}} m_{50\text{Ti}}$$

Solve

$$\begin{aligned} 47.87 \text{ amu} &= (0.0825 \times 45.95263) + (0.0744 \times 46.9518) + (0.7372 \times m_{48\text{Ti}}) \\ &\quad + (0.0541 \times 48.94787) + (0.0518 \times 49.9448) \\ m_{48\text{Ti}} &= 47.95 \text{ amu} \end{aligned}$$

Think about It

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

2.24. Collect and Organize

In this problem, we are comparing the isotopes of strontium. We must determine the number of neutrons in each isotope and then, from the given exact mass for each isotope and its abundance, calculate the average mass for strontium and compare that value to the mass found in the periodic table.

Analyze

The number of neutrons in each isotope can be found from subtracting the atomic number of strontium, which is 38, from the mass number for each isotope. The weighted atomic mass is computed according to the formula

$$m_x = a_1 m_1 + a_2 m_2 + a_3 m_3 + \dots$$

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

The following table summarizes the results of these calculations:

Isotope	Number of Protons	Number of Neutrons	Exact Mass (amu)	Abundance	Weighted Mass
^{84}Sr	38	46	83.9134	0.0056	0.4699
^{86}Sr	38	48	85.9094	0.0986	8.4707
^{87}Sr	38	49	86.9089	0.0700	6.0836
^{88}Sr	38	50	87.9056	0.8258	72.5924

Average atomic mass = 87.62 amu

The atomic mass of Sr in the periodic table is 87.62 amu.

Think about It

The average mass computed here exactly matches the value in the periodic table.

2.25. 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 at the time 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.

2.26. 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 was 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 missing as a column in his table.

Think about It

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

2.27. 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, to compute the number of neutrons to give that isotope.

Analyze

An isotope is given by the symbol ${}^A_ZX$, 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	Atomic Number = Number of Protons	Number of Neutrons = Mass Number – Atomic Number	Number of Electrons = Number of Protons
(a)	${}^{14}\text{C}$	14	6	8	6
(b)	${}^{59}\text{Fe}$	59	26	33	26
(c)	${}^{90}\text{Sr}$	90	38	52	38
(d)	${}^{210}\text{Pb}$	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.

2.28. 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, to compute the number of neutrons to give that isotope.

Analyze

An isotope is given by the symbol ${}_Z^AX$, 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	Atomic Number = Number of Protons	Number of Neutrons = Mass Number – Atomic Number	Number of Electrons = Number of Protons
(a)	${}^{11}\text{B}$	11	5	6	5
(b)	${}^{19}\text{F}$	19	9	10	9
(c)	${}^{131}\text{I}$	131	53	78	53
(d)	${}^{222}\text{Rn}$	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.

2.29. 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 we have to work backward in some cases from the number of electrons or protons and mass number for the element symbol.

Analyze

An isotope is given by the symbol ${}_Z^AX$, 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	${}^{23}\text{Na}$	${}^{89}\text{Y}$	${}^{118}\text{Sn}$	${}^{197}\text{Au}$
Number of protons	11	39	50	79
Number of neutrons	12	50	68	118
Number of electrons	11	39	50	79
Mass number	23	89	118	197

Think about It

Because the nuclear particles are all related to each other, we can work from either 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.

2.30. 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 we have to work backward in some cases from the number of electrons or protons and the mass number for the element symbol.

Analyze

An isotope is given by the symbol ${}^A_ZX$, 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	${}^{27}\text{Al}$	${}^{98}\text{Mo}$	${}^{143}\text{Nd}$	${}^{238}\text{U}$
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 either 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.

2.31. Collect and Organize

An isotope is given by the symbol ${}^A_ZX^n$, 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

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

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) compared to the number of protons in the nucleus. For a doubly charged ion, we add or take away two electrons.

2.32. Collect and Organize

An isotope is given by the symbol ${}_Z^AX^n$, 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

Symbol	${}^{137}\text{Ba}^{2+}$	${}^{64}\text{Zn}^{2+}$	${}^{32}\text{S}^{2-}$	${}^{90}\text{Zr}^{4+}$
Number of protons	56	30	16	40
Number of neutrons	81	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.

2.33. 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 to 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.

2.34. 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 to 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.

2.35. Collect and Organize

We need to refer to the periodic table to determine the atomic number of the element or anion and then count up the electrons for each species.

Analyze

According to the periodic table, neutral fluorine would have 9 electrons, oxygen with 2 extra electrons (the oxide anion) would have 10 electrons, sulfur with 2 extra electrons (the sulfide anion) would have 18 electrons, and a neutral chlorine atom would have 17 electrons.

Solve

The species with the most electrons is (c) S^{2-} .

Think about It

What determines the greatest number of electrons for this series of neutral and anionic elements is not only position in the periodic table (larger elements have more electrons), but also the charge on the species (chlorine has fewer electrons than sulfide).

2.36. Collect and Organize

We need to refer to the periodic table to determine the atomic number of the element or anion and then count up the electrons for each species.

Analyze

According to the periodic table, neutral fluorine would have 9 electrons, oxygen with 2 extra electrons (the oxide anion) would have 10 electrons, sulfur with 2 extra electrons (the sulfide anion) would have 18 electrons, and a neutral chlorine atom would have 17 electrons.

Solve

The species with the lowest number of electrons is (a) F.

Think about It

Sometimes two species are *isoelectronic*, meaning that they have the same number of electrons. Can you write the formula for a species of fluorine that is isoelectronic with O^{2-} ? (Answer: F^-) Neutral Ne is also isoelectronic with F^- and O^{2-} .

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 species in this series that are also *isoelectronic* with each other are (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 which element is classified as a nonmetal.

Analyze

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

Solve

Only (b) Br is clearly a nonmetal. (c) Ca and (d) Ru are clearly metals, and (a) Si is classified as a metalloid.

Think about It

There are more metallic elements in the periodic table than nonmetals.

2.40. Collect and Organize

We need to refer to the periodic table to determine which element is classified as a metalloid.

Analyze

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

Solve

Only (a) Si is a metalloid. (c) Ca and (d) Ru are clearly metals, and (b) Br is classified as a nonmetal.

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

For the chloride and sulfate salts of the sodium, potassium, calcium, and magnesium cations we are to write the chemical formulas.

Analyze

The chemical symbols and charges of the cations are: Na^+ , K^+ , Ca^{2+} , and Mg^{2+} . The chemical symbols and charges of the anions are: Cl^- and SO_4^{2-} . In writing the formula for the neutral salts, we must balance the cation charge with the anion charge,

Solve

NaCl and NaSO_4

KCl and K_2SO_4

CaCl_2 and CaSO_4

MgCl_2 and MgSO_4

Think about It

One formula unit of the salts Na_2SO_4 and K_2SO_4 contains three ions (2 cations + 1 anion). Likewise, one formula unit of the salts MgSO_4 and CaSO_4 contains two ions (1 cation + 1 anion).

2.42. Collect and Organize

In this question we are asked to explain why the law of constant composition is a *law*, while Dalton's atomic theory is a *theory*.

Analyze

A scientific law is a statement of fact based on recurrent observations. A scientific theory is a system of ideas to explain something.

Solve

The *law* of constant composition is a law because many, many empirical observations have proved that any sample of a particular compound always has the same elements in the same proportions. It is a fact that nature combines elements in that way. Dalton's *theory*, however, attempts to explain why elements combine in definite proportions.

Think about It

The difference in these two terms is subtle. Keep in mind, however, that *theory* in science is not used in the way the term is used in everyday speech. It is the best current explanation science has for many, many observations, not an opinion on the matter.

2.43. 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 kinds (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 would occur as whole-number ratios. Thus, with water the ratio of hydrogen to oxygen 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.

2.44. Collect and Organize

In this question we use NO and NO₂ 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 NO₂, we would find that the mass of oxygen present in NO₂ would be twice that found in NO for a given amount of nitrogen.

Think about It

Because NO and NO₂ have different ratios of nitrogen and oxygen in their molecules, we expect that they will have different chemical and physical properties.

2.45. Collect and Organize

This question asks how the masses of two elements in compounds of cobalt and sulfur 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 Co₂S₃. 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 Co₂S₃, applying Dalton's law of multiple proportions means that, if we compare the mass of sulfur needed to react with a gram of cobalt to form Co₂S₃ in one experiment to the amount of sulfur needed to form CoS in a second experiment, we would find the mass of sulfur in the first experiment to be 1.5 times that needed for the second experiment. Adjusting that to a whole-number ratio would give us a 2:3 ratio for Co to S for the first compound if the second compound is taken as CoS (in a 1:1 ratio).

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, however, 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.

2.46. 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 PbO₂. We need only to 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 PbO₂, applying Dalton's law of multiple proportions means that, if we compare the mass of oxygen needed to react with a gram of lead to form PbO in one experiment to the amount of oxygen needed to form PbO₂ in a second experiment, we would find the mass of oxygen in the second experiment is twice that needed for the first experiment. The ratio of oxygen masses then to form PbO, compared to PbO₂, is 1:2.

Think about It

The writing of chemical formulas reflects these ratios of masses developed after Dalton's atomic theory, but you can see that the formula for compounds also reflects Dalton's theory because the elements appear in whole-number ratios.

2.47. Collect and Organize

Given the mass ratio of sulfur to oxygen needed to make SO₂, we are asked in this problem to use Dalton's law of multiple proportions to determine the amount of oxygen to prepare SO₃ 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 combine with 5 g of oxygen to give SO₂ (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 SO₃ (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 SO₃ compared to SO₂. Therefore, we will need $5.0 \times 1.5 = 7.5$ g of oxygen to react with 5.0 g of sulfur to make SO₃.

Think about It

We know that this amount of oxygen must be less than twice the amount of oxygen (10 g) because that amount would result in a 1:4 ratio of S:O giving a formula of SO_4 .

2.48. 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_2 , we can simply multiply the mass of oxygen in NO by 2 to find the mass of oxygen. 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 are present. From this, we also know that $100 - 46.7 = 53.3$ g of O are present by mass in NO. Because NO_2 contains twice the mass of O compared to NO, NO_2 contains $53.3 \times 2 = 106.6$ 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 $(46.7 \text{ g}/153.3 \text{ g}) \times 100 = 30.5\%$.

Think about It

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

2.49. Collect and Organize

We are asked to write formulas for chloride and sulfate salts in this question. We have to keep in mind the charges on the cations and anions and be sure to balance the charge to obtain neutral salts.

Analyze

The chloride ion has a charge of $1-$ and is written as Cl^- . The sulfate polyatomic anion has a charge of $2-$ and is written as SO_4^{2-} . Group 1 elements typically form cations with a $1+$ charge (Na^+ and K^+) and those of group 2 form cations with a $2+$ charge (Ca^{2+} , Mg^{2+} , and Sr^{2+}) in salts. In writing the formulas for the salts, we balance the charges between the anion and cation so as to obtain a neutral salt.

Solve

Combining the chloride anion with both sodium and potassium will give a 1:1 cation-to-anion ratio to form the neutral salts NaCl and KCl. For magnesium, calcium, and strontium two chloride ions are needed in the formula to obtain neutral salts: MgCl_2 , CaCl_2 , and SrCl_2 . In combination with the sulfate anion, the group 2 cations have formulas with a 1:1 cation-to-anion ratio: MgSO_4 , CaSO_4 , and SrSO_4 . Sulfate salts of the group 1 cations will require a 2:1 ratio of cations to anion to form neutral salts: Na_2SO_4 and K_2SO_4 .

Think about It

The dissolved salts in seawater come mainly from the dissolution of rocks and minerals through erosion.

2.50. 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^- , $\text{B}(\text{OH})_4^-$.

Solve

The formulas for the neutral salts of these anions with sodium are NaCl, Na₂SO₄, Na₂CO₃, NaHCO₃, NaBr, NaF, and NaB(OH)₄.

Think about It

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

2.51. Collect and Organize

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

Analyze

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

Solve

- (a) All elements in CH₃COOH are nonmetallic. This compound consists of molecules.
- (b) Strontium is a metal and chlorine is a nonmetal. SrCl₂ consists of ions.
- (c) Magnesium is a metal, and both carbon and oxygen are nonmetals (they are in combination to form the polyatomic anion carbonate, CO₃²⁻). MgCO₃ consists of ions.
- (d) All the elements in H₂SO₄ are nonmetals. Sulfuric acid 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).

2.52. Collect and Organize

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

Analyze

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

Solve

- (a) Lithium is a metal and hydroxide (OH⁻) is composed of two nonmetallic elements. LiOH consists of ions.
- (b) Barium is a metal and nitrate (NO₃⁻) is composed of two nonmetallic elements, oxygen and nitrogen. Ba(NO₃)₂ consists of ions.
- (c) All the elements in HNO₃ are nonmetals. Nitric acid consists of molecules.
- (d) Butanol, CH₃(CH₂)₃OH, is composed entirely of nonmetallic elements. This compound consists of molecules.

Think about It

Salts are often composed of polyatomic anions such as NO₃⁻ (nitrate) and OH⁻ (hydroxide), as shown in this question. It is wise to be familiar with the formulas and with the charges of the more common polyatomic ions (Table 2.3).

2.53. Collect and Organize

For the oxoanions of element X, XO₂²⁻ and XO₃²⁻, 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 XO₂²⁻ and XO₃²⁻, the oxoanion XO₂²⁻ 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*.

2.54. Collect and Organize

For the oxoanions in Problem 2.53, 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 2.53, 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, we require use of the two prefixes: ClO^- is hypochlorite, ClO_2^- is chlorite, ClO_3^- is chlorate, and ClO_4^- is perchlorate (Table 2.4).

2.55. 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.

2.56. 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 1+ cations, and alkaline earth metals form 2+ cations. 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.

2.57. 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 | (e) N ₂ O ₃ , dinitrogen trioxide |
| (b) N ₂ O ₅ , dinitrogen pentoxide | (f) NO, nitrogen monoxide |
| (c) N ₂ O ₄ , dinitrogen tetroxide | (g) N ₂ O, dinitrogen monoxide |
| (d) NO ₂ , nitrogen dioxide | (h) N ₄ O, tetranitrogen monoxide |

Think about It

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

2.58. Collect and Organize

All the compounds here are oxides of sulfur. These are all molecular compounds composed of two nonmetallic elements. We will write the formula for these compounds using the naming rule for binary compounds.

Analyze

The prefixes before the elements in the names indicate the number of atoms present in the formula (Table 2.2). If there is no prefix before *sulfur* in the name, then there is only one sulfur atom in the formula. Because sulfur is always named first, we write it first in the formula.

Solve

- | | |
|--------------------------------------|--|
| (a) sulfur monoxide, SO | (d) disulfur monoxide, S ₂ O |
| (b) sulfur dioxide, SO ₂ | (e) hexasulfur monoxide, S ₆ O |
| (c) sulfur trioxide, SO ₃ | (f) heptasulfur dioxide, S ₇ O ₂ |

Think about It

From the unique names, it is quite easy to write the chemical formulas for these binary compounds of sulfur and oxygen.

2.59. 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−}): Na₂S, sodium sulfide
 (b) strontium (Sr²⁺) and chlorine (Cl[−]): SrCl₂, strontium chloride
 (c) aluminum (Al³⁺) and oxygen (O^{2−}): Al₂O₃, 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.

2.60. 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.

2.61. 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 oxidation state, we use the naming rules that incorporate Roman numerals into the name to indicate the charge on the cobalt in the compound.

Analyze

In these compounds oxygen has a charge of 2−. The charge on the cobalt atoms must balance out the charge on the oxygen atoms 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 has a 2+ charge, cobalt(II) oxide
- (b) Co_2O_3 : cobalt has a 3+ charge, cobalt(III) oxide
- (c) CoO_2 : cobalt 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 oxides that must be present in the formula.

2.62. 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 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/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 either the 1+ or the 2+ cation.

2.63. Collect and Organize

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

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) hypobromite, BrO^- in analogy with hypochlorite
- (b) sulfate, SO_4^{2-}
- (c) iodate, IO_3^-
- (d) nitrite, NO_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 chlorine can help because we can name the other halogen oxoanions by analogy with chlorine oxoanions.

2.64. Collect and Organize

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

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) tellurite, TeO_3^{2-}
- (b) arsenate, AsO_3^-
- (c) selenite, SeO_3^{2-}
- (d) chlorate, ClO_3^{2-}

Think about It

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

2.65. Collect and Organize

Each of these compounds contains a metal in combination with a polyatomic anion. These compounds are ionic and follow the naming rules for ionic compounds.

Analyze

For these compounds, we name the metal cation first as the element name, then the anion.

Solve

- (a) NiCO_3 , nickel(II) carbonate
- (b) NaCN , sodium cyanide
- (c) LiHCO_3 , lithium bicarbonate or lithium hydrogen carbonate
- (d) $\text{Ca}(\text{ClO})_2$, calcium hypochlorite

Think about It

These are named much like the binary ionic compounds. The anion name often ends in *-ide*, but can end in *-ate* or *-ite*, depending on the name of the polyatomic anion.

2.66. Collect and Organize

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

Analyze

For these compounds, we name the metal cation as the element name or polyatomic cation first, then the anion.

Solve

- (a) $\text{Mg}(\text{ClO}_4)_2$, magnesium perchlorate
- (b) NH_4NO_3 , ammonium nitrate
- (c) $\text{Cu}(\text{CH}_3\text{COO})_2$, copper(II) acetate
- (d) K_2SO_3 , potassium sulfite

Think about It

These are named much like the binary ionic compounds. The anion name often ends in *-ide*, but can end in *-ate* or *-ite*, depending on the name of the polyatomic anion.

2.67. Collect and Organize

We need to name or 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) HF , a binary acid, hydrofluoric acid
- (b) HBrO_3 , an acid of the bromate anion, bromic acid
- (c) phosphoric acid, acid of the phosphate anion, H_3PO_4
- (d) nitrous acid, acid of the nitrite anion, HNO_2

Think about It

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

2.68. Collect and Organize

We need to name or 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, in addition to replacing the last syllable with *-ic*. 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) HBr, a binary acid, hydrobromic acid
- (b) HIO_4 , an acid of the iodate anion, periodic acid
- (c) selenous acid, an acid of the selenite anion, H_2SeO_3
- (d) hydrocyanic acid, HCN

Think about It

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

2.69. 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.

2.70. 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.

2.71. 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 1+ cations, we have to balance the charge by having two cations for every anion in the formula.

2.72. 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 1+ cations, 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.

2.73. Collect and Organize

The formulas for the compounds to be named all contain transition metals with variable charges. In the name, therefore, we must be sure to indicate the charge of the cation.

Analyze

The naming of these compounds is the same as naming other ionic compounds. All that is needed is to add Roman numerals to indicate the charge on the transition metal cation.

Solve

- (a) MnS , manganese(II) sulfide
- (b) V_3N_2 , vanadium(II) nitride
- (c) $Cr_2(SO_4)_3$, chromium(III) sulfate
- (d) $Co(NO_3)_2$, cobalt(II) nitrate
- (e) Fe_2O_3 , iron(III) oxide

Think about It

The addition of the Roman numerals to these names clearly indicates the charge of the cation. If the charges were not indicated, it would be unclear from the names of these compounds how to write their formulas.

2.74. Collect and Organize

The formulas for the compounds to be named all contain transition metals with variable charges. In the name, therefore, we must be sure to indicate the charge of the cation.

Analyze

The naming of these compounds is the same as naming other ionic compounds. All that is needed is to add Roman numerals to indicate the charge on the transition metal cation.

Solve

- (a) RuS, ruthenium(II) sulfide
- (b) PdCl₂, palladium(II) chloride
- (c) Ag₂O, silver(I) oxide
- (d) WO₃, tungsten(VI) oxide
- (e) PtO₂, platinum(IV) oxide

Think about It

The addition of the Roman numerals to these names clearly indicates the charge of the cation. If the charges were not indicated, it would be unclear from the names of these compounds how to write their formulas.

2.75. Collect and Organize

We are asked to identify a compound by name from a list of formulas.

Analyze

Sodium sulfite would have the sodium cation (Na⁺) and the sulfite anion (SO₃²⁻) in its formula. To balance out the charge, there would be two Na⁺ cations for every one SO₃²⁻ anion.

Solve

The answer is (b) Na₂SO₃.

Think about It

To write a formula, we have to be very familiar with the names of the cations and anions. It would be easy here to confuse sulfite with sulfate (SO₄²⁻) or sulfide (S²⁻).

2.76. Collect and Organize

We are asked to identify a compound by name from a list of formulas.

Analyze

Calcium nitrate would have the calcium cation (Ca²⁺) and the nitrate anion (NO₃⁻) in its formula. To balance out the charge, there would be two NO₃⁻ anions for every one Ca²⁺ cation.

Solve

The answer is (d) Ca(NO₃)₂.

Think about It

To write a formula, we have to be very familiar with the names of the cations and anions and with their charges. Answers (b) Ca₂NO₃ and (c) Ca₂(NO₃)₂ have the correct cation and polyatomic anion, but in the wrong ratio. In b it appears that the calcium cation has a charge of 1+ and the nitrate anion has a charge of 2-. In c it appears as if the cation and anion have charges of 2+ and 2-, respectively.

2.77. Collect and Organize

We are asked to identify an element from the list that is a halogen.

Analyze

The halogens are the elements in group 17 of the periodic table. These include fluorine, chlorine, bromine, iodine, and astatine.

Solve

The answer is (b) Cl₂.

Think about It

Notice that the elemental form of chlorine is diatomic, meaning that there are two atoms in the formula. This is also true for hydrogen, nitrogen, oxygen, fluorine, bromine, and iodine.

2.78. Collect and Organize

We are asked to identify an element from the list that is a noble gas.

Analyze

The noble gases are the elements in group 18 of the periodic table. These include helium, neon, argon, krypton, xenon, and radon.

Solve

The answer is (c) Xe.

Think about It

Notice that the noble gases are not diatomic in their elemental state, unlike nitrogen, chlorine, and iodine.

2.79. Collect and Organize

We are asked to identify an element from the list that is an alkali metal.

Analyze

The alkali metals are the elements in group 1 of the periodic table. These include lithium, sodium, potassium, rubidium, cesium, and francium.

Solve

The answer is (a) Na.

Think about It

All the other elements on the list are nonmetals.

2.80. Collect and Organize

We are asked to identify an element from the list that is an alkaline earth metal.

Analyze

The alkaline earth metals are the elements belonging to group 2 of the periodic table. These include beryllium, magnesium, calcium, strontium, barium, and radium.

Solve

The answer is (b) Ca.

Think about It

The alkaline earth metals were so named by the alchemists because they have a bitter taste (alkalis) and did not melt (earths).

2.81. Collect and Organize

We 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 (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; and (3) cosmology often asks what the universe (including stars, black holes, etc.) are 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.

2.82. 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 from them. In rough order of size: quarks < neutron = proton < deuteron (^2H 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.

2.83. 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 don't 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, named 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*.

2.84. 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.

2.85. 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 $2.11 \times 10^{-29} \text{ g/cm}^3$.

2.86. 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.

2.87. Collect and Organize

We consider why helium requires higher temperatures to undergo fusion compared to hydrogen.

Analyze

To fuse nuclei, the strong repulsive forces between the nuclei must be overcome.

Solve

Helium fusion would require higher temperatures compared to hydrogen fusion because we must force nuclei with 2+ charges (two protons) together rather than nuclei with 1+ charges. The higher the charge (the number of protons) is, the more repulsion the nuclei feel for each other.

Think about It

"Burning" higher elements, such as carbon, in fusion reactions would require even higher temperatures.

2.88. Collect and Organize

We consider why the triple- α process would be rare in a rapidly cooling universe.

Analyze

The triple- α process involves the fusion of 3 He nuclei to form a carbon nucleus. For this process to occur, there must be a high concentration of He nuclei and very high temperatures.

Solve

As the universe was expanding after the Big Bang, particles were getting farther away from each other and therefore were colliding less often with each other (and so had a lower chance to undergo fusion). Also, the high temperatures required for the triple- α process were not available as the universe cooled.

Think about It

No carbon was synthesized in the Big Bang. The temperature cooled too quickly (within minutes) for this process to occur.

2.89. 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 compared to a hydrogen atom because it is being held by a nucleus of 2+ charge rather than one of 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 is being “shielded” by the other electrons.

2.90. Collect and Organize

We are asked why there is carbon in our sun when it is not hot enough to have produced it through fusion reactions.

Analyze

Stars are formed from the “space dust” of other exploded stars.

Solve

The carbon in the sun was produced by other stars that were hot enough to produce it and that exploded in supernovae in the distant past.

Think about It

The higher elements can be made only on very hot stars and in supernovae.

2.91. Collect and Organize

We are asked to explain why elements other than H, He, and Li were not formed early in the history of the universe.

Analyze

The early universe (within minutes) cooled significantly after the Big Bang.

Solve

Elements other than H, He, and Li were not formed in the primordial nucleosynthesis because the expanding universe was cooling and therefore could not support the high temperatures needed for fusion. Also, the expanding universe was not dense enough for nuclei to fuse.

Think about It

The heavier elements all were produced later in stars.

2.92. Collect and Organize

We consider here what happens to the neutron-to-proton ratio when a nucleus undergoes β decay.

Analyze

Beta decay converts a neutron into a proton.

Solve

In a nucleus that undergoes β decay, a neutron is “lost” and a proton is “gained.” The neutron-to-proton ratio will decrease.

Think about It

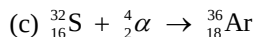
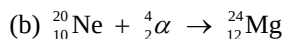
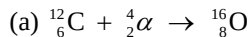
Remember that, although the β particle is an electron, it is emitted from the nucleus of an atom. It is not simply lost by the atom in the ionization process to become a cation.

2.93. Collect and Organize

We are asked to predict the products of fusion reactions in a giant star.

Analyze

To answer this, we fuse the two isotopes, determining the identity of the element and its mass number by balancing the nuclear reaction.

Solve**Think about It**

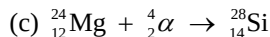
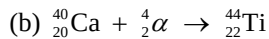
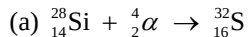
When helium nuclei (α particles) are added to the nucleus, the mass number increases by 4 and the atomic number increases by 2.

2.94. Collect and Organize

We are asked to predict the products of fusion reactions in a giant star.

Analyze

To answer this, we fuse the two isotopes, determining the identity of the element and its mass number by balancing the nuclear reaction.

Solve**Think about It**

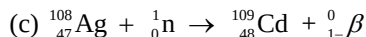
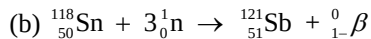
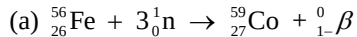
When helium nuclei (α particles) are added to the nucleus, the mass number increases by 4 and the atomic number increases by 2.

2.95. Collect and Organize

We are asked to predict the products of neutron capture reactions in the core of a collapsing giant star.

Analyze

To solve this problem, we balance the reactions for mass number and atomic number between the reactants and products. We have to take into account that multiple neutrons can be added under these conditions.

Solve**Think about It**

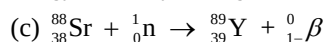
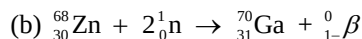
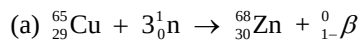
Adding neutrons to the nucleus does not itself change the atomic number. Subsequent β emission, however, does and the result is the building up of heavier elements in the periodic table.

2.96. **Collect and Organize**

We are asked to predict the products of neutron capture reactions in the core of a collapsing giant star.

Analyze

To solve this problem, we balance the reactions for mass number and atomic number between the reactants and products. We have to take into account that multiple neutrons can be added under these conditions.

Solve**Think about It**

Adding neutrons to the nucleus does not itself change the atomic number. Subsequent β emission, however, does and the result is the building up of heavier elements in the periodic table.

2.97. **Collect and Organize**

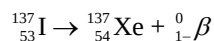
We are asked to consider whether the transmutations of ${}^{137}\text{I}$ to ${}^{137}\text{Xe}$ to ${}^{137}\text{Cs}$ involve β decay. We have to write balanced nuclear equations to determine the type of decay for each of these nuclear reactions.

Analyze

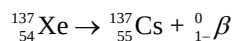
Two nuclear processes are under consideration here: the transformation of ${}^{137}\text{I}$ to ${}^{137}\text{Xe}$ and the transformation of ${}^{137}\text{Xe}$ to ${}^{137}\text{Cs}$. Therefore, we write two nuclear reactions. To balance the reactions, we must balance the superscripts (mass numbers) and subscripts (atomic numbers or numbers of protons) for the reactants and the products. If a beta particle, ${}_{-1}^0\beta$, is used to balance the equations on the products side, then the process involves β emission.

Solve

The transformation of ${}^{137}\text{I}$ to ${}^{137}\text{Xe}$ can be balanced as



The transformation of ${}^{137}\text{Xe}$ to ${}^{137}\text{Cs}$ can be balanced as



Both of these nuclear reactions involve β emission.

Think about It

When a nucleus undergoes β emission, a neutron becomes a proton. This means that the atomic number increases by one, but the mass number (the total number of protons and neutrons) remains the same.

2.98. **Collect and Organize**

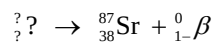
We are asked to identify the isotope that undergoes β decay to produce ${}^{87}\text{Sr}$.

Analyze

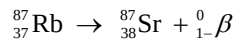
We can use the balancing of a nuclear equation to determine the identity of this particular element. Beta decay transforms a neutron into a proton with the emission of a β particle (electron) from the nucleus.

Solve

The nuclear process can be written as



Balancing this equation, we obtain a mass number of the reactant of 87 and an atomic number of 37. The isotope that decays to increase the amount of ^{87}Sr in the soil samples is ^{87}Rb .



Think about It

An isotope that undergoes β decay will always produce the element one atomic number higher in the periodic table.

2.99. 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 P2.99. 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, the ray must be deflected more by an increase in the 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 P2.99 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. It was believed before that time that the atom was the smallest indivisible component of matter.

2.100. 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.

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 be 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.

2.101. 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 not their charge (they are both positive), but the magnitude of that 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.

2.102. Collect and Organize

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

Analyze

We have to 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 that is made in 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 the lighter elements fusing to form the heavier elements, it could be imagined that we might run out of hydrogen fuel and then have to rely on helium fusion to produce energy in stars.

2.103. 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 to 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. 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 of 1:2:4, 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 . Likewise, 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 is the oxygen atom $2-$, 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.

2.104. Collect and Organize

Stainless steel contains chromium and nickel at 19% and 9% by mass, respectively. We are asked to name the two compounds that form on the surface of stainless steel to protect it from corrosion, Cr_2O_3 and NiO , and determine the charges on the transition metal cations in those ionic compounds.

Analyze

In naming the compounds, we must indicate the charge on the metal. To determine the charge on the Cr and Ni cations in these compounds, we use the normal charge for oxygen ($2-$).

Solve

- (a) Cr_2O_3 , chromium(III) oxide
 NiO , nickel(II) oxide

- (b) Each Cr atom is $3+$, for a total charge of $6+$ on the two Cr atoms so as to balance the $3 \times -2 = 6-$ charge of the three oxygen atoms. The charge on the Ni atom is $2+$ to balance the $2-$ charge on the oxygen atom in NiO .

Think about It

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

2.105. Collect and Organize

Bronze contains copper and tin at 90% and 10% 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

$$\frac{90 \text{ amu}}{63.546 \text{ amu/Cu atom}} = 1.4 \text{ Cu atoms}$$

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

$$\frac{10 \text{ amu}}{118.710 \text{ amu/Sn atom}} = 0.084 \text{ Sn atom}$$

The ratio of Cu to Sn atoms is

$$\frac{1.4 \text{ Cu}}{0.084 \text{ Sn}} = 17$$

or 17 Cu : 1 Sn.

Think about It

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

2.106. 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 cation 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 $10+$ charge from two M atoms 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.

2.107. 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.

2.108. Collect and Organize

We are asked to give the systematic names and chemical formulas for some commonly named chemicals.

Analyze

Any Internet source or search engine could help us find the names and chemical formulas for these. One such source is Wikipedia (http://en.wikipedia.org/wiki/Main_Page).

Solve

- (a) magnesia = magnesium oxide, MgO
- (b) Epsom salt = magnesium sulfate, MgSO₄
- (c) K-Dur = potassium chloride, KCl
- (d) lime = calcium oxide, CaO
- (e) baking soda = sodium bicarbonate, NaHCO₃
- (f) caustic soda = sodium hydroxide, NaOH
- (g) muriatic acid = hydrogen chloride solution, HCl(aq)
- (h) zirconia = zirconium dioxide, ZrO₂

Think about It

Epsom salt and lime are often in hydrated form, [MgSO₄ · 7H₂O] and Ca(OH)₂.

2.109. Collect and Organize

Given the mass of a ruby in carats, we are to determine the percent mass of Al in the ruby and the volume of the ruby.

Analyze

First, we have to convert the mass of the ruby in carats to the mass in grams using the conversions 1 carat = 200.0 mg and 1000 mg = 1 g).

$$12.04 \text{ carats} \times \frac{200.0 \text{ mg}}{1 \text{ carat}} \times \frac{1 \text{ g}}{1000 \text{ mg}} = 2.408 \text{ g}$$

- (a) The percent mass of Al in the ruby can then be determined by assuming we have one formula unit of the ruby (Al₂O₃, weighing 101.96 amu). In each formula unit of Al₂O₃, there are two atoms of Al that weigh 53.964 amu (2 mol × 26.982 amu). The percent mass will be the mass of Al in one formula unit of ruby divided by the total mass of one formula unit multiplied by 100.
- (b) To calculate the volume of the ruby, we divide the mass of the ruby in grams by the given density, 4.02 g/cm³.

Solve

(a) Percent mass of Al in ruby: $\frac{53.964 \text{ amu Al}}{101.96 \text{ amu Al}_2\text{O}_3} \times 100 = 52.93\%$

(b) Volume of ruby: $\frac{2.408 \text{ g}}{4.02 \text{ g/cm}^3} = 0.599 \text{ cm}^3$

Think about It

Rubies are red due to the presence of chromium impurity ions in the Al₂O₃ crystal. If iron and titanium are present as impurities, we have sapphires.

2.110. 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 SO₄²⁻.

Solve

- (a) If we replace an oxygen atom in SO₄²⁻, we get the thiosulfate ion, S₂O₃²⁻.
- (b) To balance the charges to form a neutral salt, we need two sodium ions in the formula for sodium thiosulfate, Na₂S₂O₃.

Think about It

Other *thio*- compounds are also similarly named. Thiocyanate is SCN^- from cyanate (OCN^-), and thiourea is $(\text{NH}_2)_2\text{CS}$ from urea, $(\text{NH}_2)_2\text{CO}$.

2.111. 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 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

$$68.92558x + 70.9247050y = 69.7231$$

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

$$68.92558(1 - y) + 70.9247050y = 69.7231$$

Solve

$$68.92558 - 68.92558y + 70.9247050y = 69.7231$$

$$1.99913y = 0.7975$$

$$y = 0.3989$$

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

Think about It

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

2.112. 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

$$78.9183x + 80.9163y = 79.9091$$

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

$$78.9183(1 - y) + 80.9163y = 79.9091$$

Solve

$$78.9183 - 78.9183y + 80.9163y = 79.9091$$

$$1.9980y = 0.9908$$

$$y = 0.4959$$

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 $100 - 49.59 = 50.41\%$.

2.113. 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 $^{79}\text{Br}-^{79}\text{Br}$, $^{79}\text{Br}-^{81}\text{Br}$, and $^{81}\text{Br}-^{81}\text{Br}$. 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

$$(a) \quad ^{79}\text{Br}-^{79}\text{Br} = 157.8366 \text{ amu}$$

$$^{79}\text{Br}-^{81}\text{Br} = 159.8346 \text{ amu}$$

$$^{81}\text{Br}-^{81}\text{Br} = 161.8326 \text{ amu}$$

(b) For $^{79}\text{Br}-^{79}\text{Br}$, 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 $^{79}\text{Br}-^{81}\text{Br}$, we have to consider the second combination, $^{81}\text{Br}-^{79}\text{Br}$, as well as that of $^{79}\text{Br}-^{81}\text{Br}$. The probability for this combination is $2 \times (0.5041 \times 0.4959) = 0.49997$ for an abundance of 50.00%. For $^{81}\text{Br}-^{81}\text{Br}$, 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.

2.114. Collect and Organize

In this problem we are provided with the masses of the three isotopes of magnesium ($^{24}\text{Mg} = 23.9850$ amu, $^{25}\text{Mg} = 24.9858$ amu, and $^{26}\text{Mg} = 25.9826$ 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

$$(0.7899 \times 23.9850) + 24.9858x + 25.9826y = 24.3050$$

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

$$(0.7899 \times 23.9850) + 24.9858(0.2101 - y) + 25.9826y = 24.3050$$

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 in setting up the equation. We have to solve this problem algebraically by setting up two equations with two unknowns.