Chapter 2: Atoms, Molecules, and Ions

2.2 Evolution of Atomic Theory

Question 10-1.

The existence of isotopes violates one of the original ideas of Dalton's atomic theory. Which one?

Solution

Dalton originally thought that all atoms of a particular element had identical properties, including mass. Thus, the concept of isotopes, in which an element has different masses, was a violation of the original idea. To account for the existence of isotopes, the second postulate of his atomic theory was modified to state that atoms of the same element must have identical chemical properties.

Question 10-2.

How are electrons and protons similar? How are they different?

Solution

Both are charged particles that are components of an atom. Although charges are the same size, the signs of the charges are opposite. Protons are much more massive than electrons. Protons are located within an atom's nucleus, whereas electrons are located outside the nucleus.

Question 10-3.

How are protons and neutrons similar? How are they different?

Solution

Both are subatomic particles that reside in an atom's nucleus. Both have approximately the same mass. Protons are positively charged, whereas neutrons are uncharged.

Question 10-4.

Predict and test the behavior of α particles fired at a "plum pudding" model atom.

(a) Predict the paths taken by α particles that are fired at atoms with a Thomson's plum pudding model structure. Explain why you expect the α particles to take these paths.

(b) If α particles of higher energy than those in (a) are fired at plum pudding atoms, predict how their paths will differ from the lower-energy α particle paths. Explain your reasoning.

(c) Now test your predictions from (a) and (b). Open the URL http://phet.colorado.edu/en/simulation/rutherford-scattering and select the "Plum Pudding Atom" tab. Set "Alpha Particles Energy" to "min," and select "show traces." Click on the gun to start firing α particles. Does this match your prediction from (a)? If not, explain why the actual path would be that shown in the simulation. Hit the pause button, or "Reset All." Set "Alpha Particles Energy" to "max," and start firing α particles. Does this match your prediction from (b)? If not, explain the effect of increased energy on the actual paths as shown in the simulation.

Solution

(a) The plum pudding model indicates that the positive charge is spread uniformly throughout the atom, so we expect the α particles to (perhaps) be slowed somewhat by the positive-positive repulsion, but to follow straight-line paths (i.e., not to be deflected) as they pass through the atoms. (b) Higher-energy α particles will be traveling faster (and perhaps slowed less) and will also follow straight-line paths through the atoms. (c) The α particles followed straight-line paths through the plum pudding atom. There was no apparent slowing of the α particles as they passed through the atoms.

Question 10-5.

Predict and test the behavior of α particles fired at a Rutherford atom model.

(a) Predict the paths taken by α particles that are fired at atoms with a Rutherford atom model structure. Explain why you expect the α particles to take these paths.

(b) If α particles of higher energy than those in (a) are fired at Rutherford atoms, predict how their paths will differ from the lower-energy α particle paths. Explain your reasoning.

(c) Predict how the paths taken by the α particles will differ if they are fired at Rutherford atoms of elements other than gold. What factor do you expect to cause this difference in paths, and why?

(d) Now test your predictions from (a), (b), and (c). Open the URL: http://phet.colorado.edu/en/simulation/rutherford-scattering and select the “Rutherford Atom” tab. Due to the scale of the simulation, it is best to start with a small nucleus, so select “20” for both protons and neutrons, “min” for energy, show traces, and then start firing α particles. Does this match your prediction from (a)? If not, explain why the actual path would be that shown in the simulation. Pause or reset, set energy to “max,” and start firing α particles. Does this match your prediction from (b)? If not, explain the effect of increased energy on the actual path as shown in the simulation. Pause or reset, select “40” for both protons and neutrons, “min” for energy, show traces, and fire away. Does this match your prediction from (c)? If not, explain why the actual path would be that shown in the simulation. Repeat this with larger numbers of protons and neutrons. What generalization can you make regarding the type of atom and effect on the path of α particles? Be clear and specific.

Solution

(a) The Rutherford atom has a small, positively charged nucleus, so most α particles will pass through empty space far from the nucleus and be undeflected. Those α particles that pass near the nucleus will be deflected from their paths due to positive-positive repulsion. The more directly toward the nucleus the α particles are headed, the larger the deflection angle will be. (b) Higher-energy α particles that pass near the nucleus will still undergo deflection, but the faster they travel, the less the expected angle of deflection. (c) If the nucleus is smaller, the positive charge is smaller and the expected deflections are smaller—both in terms of how closely the α particles pass by the nucleus undeflected and the angle of deflection. If the nucleus is larger, the positive charge is larger and the expected deflections are larger—more α particles will be deflected, and the deflection angles will be larger. (d) The paths followed by the α particles match the predictions from (a), (b), and (c).

2.3 Atomic Structure and Symbolism

Question 11-1.

In what way are isotopes of a given element always different? In what way(s) are they always the same?

Solution

Isotopes of a given element by definition always exhibit different mass numbers (numbers of neutrons in their atoms' nuclei) and, consequently, different atomic masses. They always exhibit the same atomic number (number of protons in their atoms' nuclei), however, as this is the trait that defines their elemental identity.

Question 11-2.

Write the symbol for each of the following ions:

(a) the ion with a 1+ charge, atomic number 55, and mass number 133
(b) the ion with 54 electrons, 53 protons, and 74 neutrons
(c) the ion with atomic number 15, mass number 31, and a 3– charge
(d) the ion with 24 electrons, 30 neutrons, and a 3+ charge

Solution

(a) $^{133}Cs^{+}$; (b) $^{127}I^{-}$; (c) $^{31}P^{3-}$; (d) $^{57}Co^{3+}$

Question 11-3.

Write the symbol for each of the following ions:

(a) the ion with a 3+ charge, 28 electrons, and a mass number of 71
(b) the ion with 36 electrons, 35 protons, and 45 neutrons
(c) the ion with 86 electrons, 142 neutrons, and a 4+ charge
(d) the ion with a 2+ charge, atomic number 38, and mass number 87

Solution

In the following symbols, both atomic number and mass number are given if available from the problem. (a) Gallium has an atomic number of 31 and would form a 3+ ion with 28 electrons. The complete symbol is $^{71}Ga^{3+}$. (b) The element with 35 protons is bromine. Its 36 electrons are consistent with a single negative charge. The complete symbol is $^{80}Br^{-}$. (c) With 86 electrons and a 4+ charge, the neutral atom must have 90 electrons and 90 protons. The element with 90 protons is thorium (Th). The symbol is $^{232}Th^{4+}$. (d) Strontium has atomic number 38 and the symbol is $^{87}Sr^{2+}$.

Question 11-4.

Open the URL: http://phet.colorado.edu/en/simulation/build-an-atom and click on the Atom icon.

(a) Pick any one of the first 10 elements that you would like to build and state its symbol.
(b) Drag protons, neutrons, and electrons onto the atom template to make an atom of your element.

State the numbers of protons, neutrons, and electrons in your atom, as well as the net charge and mass number.

(c) Click on "Net Charge" and "Mass Number," check your answers to (b), and correct, if needed.
(d) Predict whether your atom will be stable or unstable. State your reasoning.
(e) Check the "Stable/Unstable" box. Was your answer to (d) correct? If not, first predict what you can do to make a stable atom of your element, and then do it and see if it works. Explain your reasoning.

Solution
(a) Carbon-12, ^{12}C; (b) This atom contains six protons and six neutrons. There are six electrons in a neutral ^{12}C atom. The net charge of such a neutral atom is zero, and the mass number is 12. (c) The above answers are correct. (d) The atom will be stable since C-12 is a stable isotope of carbon. (e) The above answer is correct. Other answers for this exercise are possible if a different element of isotope is chosen.

Question 11-5.

Open the URL: http://phet.colorado.edu/en/simulation/build-an-atom.
(a) Drag protons, neutrons, and electrons onto the atom template to make a neutral atom of Oxygen-16 and give the isotope symbol for this atom.
(b) Now add two more electrons to make and ion and give the symbol for the ion you have created.

Solution
(a) Oxygen-16 contains eight protons, eight neutrons, and eight electrons. The isotope symbol ^{16}O or $^{16}_{8}O$. (b) $^{16}O^{2-}$ or $^{16}_{8}O^{2-}$

Question 11-6.

Open the URL: http://phet.colorado.edu/en/simulation/build-an-atom.
(a) Drag protons, neutrons, and electrons onto the atom template to make a neutral atom of Lithium-6 and give the isotope symbol for this atom.
(b) Now remove one electron to make an ion and give the symbol for the ion you have created.

Solution
(a) Lithium-6 contains three protons, three neutrons, and three electrons. The isotope symbol is 6Li or $^{6}_{3}Li$. (b) $^{6}_{3}Li$ or $^{6}_{3}Li$

Question 11-7.

Determine the number of protons, neutrons, and electrons in the following isotopes that are used in medical diagnoses:
(a) atomic number 9, mass number 18, charge of 1–
(b) atomic number 43, mass number 99, charge of 7+
(c) atomic number 53, atomic mass number 131, charge of 1–
(d) atomic number 81, atomic mass number 201, charge of 1+
(e) Name the elements in parts (a), (b), (c), and (d).

Solution
(a) 9 protons, 10 electrons, 9 neutrons; (b) 43 protons, 36 electrons, 56 neutrons; (c) 53 protons, 54 electrons, 78 neutrons; (d) 81 protons, 80 electrons, 120 neutrons; (e) fluorine, technetium, iodine, thallium

Question 11-8.

The following are properties of isotopes of two elements that are essential in our diet. Determine the number of protons, neutrons and electrons in each and name them.

(a) atomic number 26, mass number 58, charge of 2+

(b) atomic number 53, mass number 127, charge of 1–

Solution

(a) Iron, 26 protons, 24 electrons, and 32 neutrons; (b) iodine, 53 protons, 54 electrons, and 74 neutrons

Question 11-9.

Give the number of protons, electrons, and neutrons in neutral atoms of each of the following isotopes:

(a) ${}^{10}_{5}B$

(b) ${}^{199}_{80}Hg$

(c) ${}^{63}_{29}Cu$

(d) ${}^{13}_{6}C$

(e) ${}^{77}_{34}Se$

Solution

(a) 5 protons, 5 electrons, 5 neutrons; (b) 80 protons, 80 electrons, 119 neutrons; (c) 29 protons, 29 electrons, 34 neutrons; (d) 6 protons, 6 electrons, 7 neutrons; (e) 34 protons, 34 electrons, 43 neutrons

Question 11-10.

Give the number of protons, electrons, and neutrons in neutral atoms of each of the following isotopes:

(a) ${}^{7}_{3}Li$

(b) ${}^{125}_{52}Te$

(c) ${}^{109}_{47}Ag$

(d) ${}^{15}_{7}N$

(e) ${}^{31}_{15}P$

Solution

(a) 3 protons, 3 electrons, 4 neutrons; (b) 52 protons, 52 electrons, 73 neutrons; (c) 47 protons, 47 electrons, 62 neutrons; (d) 7 protons, 7 electrons, 8 neutrons; (e) 15 protons, 15 electrons, 16 neutrons

Question 11-11.

Click on the URL: http://phet.colorado.edu/en/simulation/isotopes-and-atomic-mass and select the “Mix Isotopes” tab, hide the “Percent Composition” and “Average Atomic Mass” boxes, and then select the element boron.

(a) Write the symbols of the isotopes of boron that are shown as naturally occurring in significant amounts.
(b) Predict the relative amounts (percentages) of these boron isotopes found in nature. Explain the reasoning behind your choice.
(c) Add isotopes to the black box to make a mixture that matches your prediction in (b). You may drag isotopes from their bins or click on "More" and then move the sliders to the appropriate amounts.
(d) Reveal the "Percent Composition" and "Average Atomic Mass" boxes. How well does your mixture match with your prediction? If necessary, adjust the isotope amounts to match your prediction.
(e) Select "Nature's" mix of isotopes and compare it to your prediction. How well does your prediction compare with the naturally occurring mixture? Explain. If necessary, adjust your amounts to make them match "Nature's" amounts as closely as possible.

Solution

(a) ^{10}B and ^{11}B; (b) The atomic mass for boron is 10.8. Thus, it makes sense to predict that naturally occurring boron contains about 80% of Boron-11 and about 20% of Boron-10. (c) and (d) After using four atoms of Boron-11 and one atom of Boron-10, the atomic mass is 10.81003 amu, which is not too far from the experimental number of 10.811 amu. (e) The natural composition is 80.1% of Boron-11 and 19.9% of Boron-10, which is close to our prediction.

Question 11-12.

Repeat Exercise 20 using an element that has three naturally occurring isotopes.

Solution

Let us use neon as an example. Since there are three isotopes, there is no way to be sure to accurately predict the abundances to make the total of 20.18 amu average atomic mass. Let us guess that the abundances are 9% Ne-22, 91% Ne-20, and only a trace of Ne-21. The average mass would be 20.18 amu. Checking the nature's mix of isotopes shows that the abundances are 90.48% Ne-20, 9.25% Ne-22, and 0.27% Ne-21, so our guessed amounts have to be slightly adjusted.

Question 11-13.

An element has the following natural abundances and isotopic masses: 90.92% abundance with 19.99 amu, 0.26% abundance with 20.99 amu, and 8.82% abundance with 21.99 amu. Calculate the average atomic mass of this element.

Solution

In problems in which the percentage composition is given, multiply each percentage (expressed as a decimal) by its isotopic mass. Then add to find the sum of all components. The resulting number is the average atomic mass.

$$\begin{aligned}\text{average atomic mass} &= (0.9092 \times 19.99\ \text{amu}) + (0.0026 \times 20.99\ \text{amu}) + (0.0882 \times 21.99\ \text{amu}) \\ &= 18.1749\ \text{amu} + 0.0546\ \text{amu} + 1.9395\ \text{amu} \\ &= 20.169\ \text{amu}\end{aligned}$$

The element is likely Ne.

Question 11-14.

Average atomic masses listed by IUPAC are based on a study of experimental results. Bromine has two isotopes, ^{79}Br and ^{81}Br, whose masses (78.9183 and 80.9163 amu, respectively) and abundances (50.69% and 49.31%, respectively) were determined in earlier experiments. Calculate the average atomic mass of bromine based on these experiments.

Solution

$$\begin{aligned}\text{average atomic mass } &= (0.5069 \times 78.9183 \text{ amu}) + (0.4931 \times 80.9163 \text{ amu}) \\ &= 79.90 \text{ amu}\end{aligned}$$

Question 11-15.

Variations in average atomic mass may be observed for elements obtained from different sources. Lithium provides an example of this. The isotopic composition of lithium from naturally occurring minerals is 7.5% ^{6}Li and 92.5% ^{7}Li, which have masses of 6.01512 amu and 7.01600 amu, respectively. A commercial source of lithium, recycled from a military source, was 3.75% ^{6}Li (and the rest 7Li). Calculate the average atomic mass values for each of these two sources.

Solution

Mineral sources:

$$\begin{aligned}\text{average atomic mass } &= (0.075 \times 6.01512 \text{ amu}) + (0.925 \times 7.01600 \text{ amu}) \\ &= 6.9 \text{ amu}\end{aligned}$$

Recycled military source:

$$\begin{aligned}\text{average atomic mass } &= (0.0375 \times 6.01512 \text{ amu}) + (0.9625 \times 7.01600 \text{ amu}) \\ &= 6.98 \text{ amu}\end{aligned}$$

Question 11-16.

The average atomic masses of some elements may vary, depending upon the sources of their ores. Naturally occurring boron consists of two isotopes with accurately known masses (^{10}B, 10.0129 amu and ^{11}B, 11.00931 amu). The actual atomic mass of boron can vary from 10.807 to 10.819, depending on whether the mineral source is from Turkey or the United States. Calculate the percent abundances leading to the two values of the average atomic masses of boron from these two countries.

Solution

Two items, the percentage of each isotope, are unknown. As both unknowns are related through an equation that says that the sum of the two fractions is equal to 1, we can write:

Turkey source:

$$\begin{aligned}10.807 \text{ amu} &= 10.0129\,(1 - x) + 11.00931x \\ 10.807 - 10.0129 &= -10.0129x + 11.00931x \\ x &= 0.797 \text{ (of 11.00931 amu isotope)} \\ 1 - x &= 0.203 \text{ (of 10.0129 amu isotope)}\end{aligned}$$

US source:

$$\begin{aligned}10.819 \text{ amu} &= 10.0129\,(1 - x) + 11.00931x \\ 10.819 - 10.0129 &= -10.0129x + 11.00931x \\ x &= 0.809 \text{ (of 11.00931 amu isotope)} \\ 1 - x &= 0.191 \text{ (of 10.0129 amu isotope)}\end{aligned}$$

Question 11-17.

The ^{18}O:^{16}O abundance ratio in some meteorites is greater than that used to calculate the average atomic mass of oxygen on earth. Is the average mass of an oxygen atom in these meteorites greater than, less than, or equal to that of a terrestrial oxygen atom?

Solution

The greater relative abundance of the heavier oxygen isotope found in meteorites will result in a greater contribution of its larger isotopic mass to the (*weighted*) average atomic mass for oxygen. And so, the average atomic mass computed for oxygen in the meteorite will be greater than that for terrestrial oxygen.

2.4 Chemical Formulas

Question 12-1.

Explain why the symbol for an atom of the element oxygen and the formula for a molecule of oxygen differ.

Solution

The symbol for the element oxygen, O, represents both the element and one atom of oxygen. A molecule of oxygen, O_2, contains two oxygen atoms; the subscript 2 in the formula must be used to distinguish the diatomic molecule from two single oxygen atoms.

Question 12-2.

Explain why the symbol for the element sulfur and the formula for a molecule of sulfur differ.

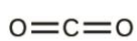
Solution

The symbol for the sulfur atom, S, represents the element and one atom of the element. The sulfur molecule (S_8) consists of eight sulfur atoms linked in a ring. Thus, S without a subscript would be an inadequate representation of the molecule.

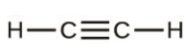
Question 12-3.

Write the molecular and empirical formulas of the following compounds:

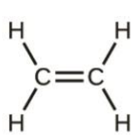
(a)



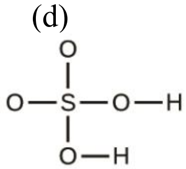
(b)



(c)



(d)



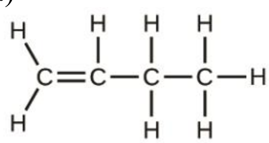
Solution

(a) molecular CO_2, empirical CO_2; (b) molecular C_2H_2, empirical CH; (c) molecular C_2H_4, empirical CH_2; (d) molecular H_2SO_4, empirical H_2SO_4

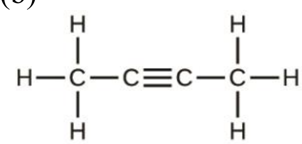
Question 12-4.

Write the molecular and empirical formulas of the following compounds:

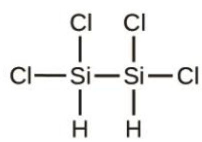
(a)



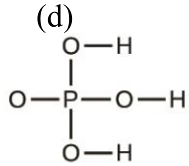
(b)



(c)



(d)



Solution

(a) molecular C_4H_8, empirical CH_2; (b) molecular C_4H_6, empirical C_2H_3; (c) molecular $Si_2H_2Cl_4$, empirical $SiHCl_2$; (d) molecular H_3PO_4, empirical H_3PO_4

Question 12-5.

Determine the empirical formulas for the following compounds:

(a) caffeine, $C_8H_{10}N_4O_2$
(b) sucrose, $C_{12}H_{22}O_{11}$
(c) hydrogen peroxide, H_2O_2
(d) glucose, $C_6H_{12}O_6$
(e) ascorbic acid (vitamin C), $C_6H_8O_6$

Solution

(a) $C_4H_5N_2O$; (b) $C_{12}H_{22}O_{11}$; (c) HO; (d) CH_2O; (e) $C_3H_4O_3$

Question 12-6.

Determine the empirical formulas for the following compounds:

(a) acetic acid, $C_2H_4O_2$
(b) citric acid, $C_6H_8O_7$
(c) hydrazine, N_2H_4
(d) nicotine, $C_{10}H_{14}N_2$
(e) butane, C_4H_{10}

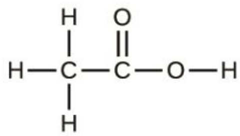
Solution

(a) CH_2O; (b) $C_6H_8O_7$; (c) NH_2; (d) C_5H_7N; (e) C_2H_5

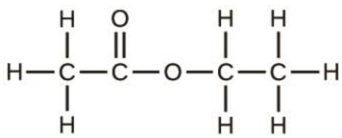
Question 12-7.

Write the empirical formulas for the following compounds:

(a)



(b)



Solution

(a) CH_2O; (b) C_2H_4O

Question 12-8.

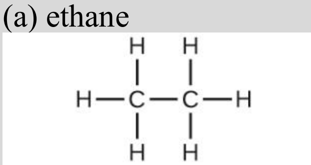
Open the URL: http://phet.colorado.edu/en/simulation/build-a-molecule and select the "Larger Molecules" tab. Select an appropriate atom's "Kit" to build a molecule with two carbon and six hydrogen atoms. Drag atoms into the space above the "Kit" to make a molecule. A name will appear when you have made an actual molecule that exists (even if it is not the one you want). You can use the scissors tool to separate atoms if you would like to change the connections. Click on "3D" to see the molecule, and look at both the space-filling and ball-and-stick possibilities.

(a) Draw the structural formula of this molecule and state its name.

(b) Can you arrange these atoms in any way to make a different compound?

Solution

(a) ethane



(b) No, unless more than one molecule can be made, such as, $C_2H_4 + H_2$. The carbon atoms have to be connected to each other, and then there is only one way to place the hydrogens.

Question 12-9.

Use the URL: http://phet.colorado.edu/en/simulation/build-a-molecule to repeat Exercise 34, but build a molecule with two carbons, six hydrogens, and one oxygen.

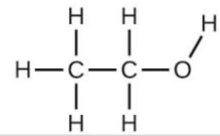
(a) Draw the structural formula of this molecule and state its name.

(b) Can you arrange these atoms to make a different molecule? If so, draw its structural formula and state its name.

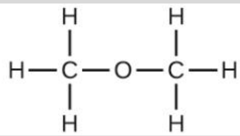
(c) How are the molecules drawn in (a) and (b) the same? How do they differ? What are they called (the type of relationship between these molecules, not their names)?

Solution

(a) ethanol



(b) methoxymethane, more commonly known as dimethyl ether



(c) These molecules have the same chemical composition (types and number of atoms) but different chemical structures. They are structural isomers.

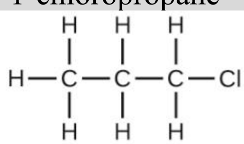
Question 12-10.

Use the URL http://phet.colorado.edu/en/simulation/build-a-molecule to repeat Exercise 34, but build a molecule with three carbons, seven hydrogens, and one chlorine.

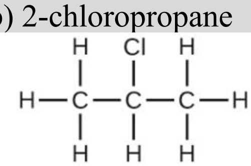
(a) Draw the structural formula of this molecule and state its name.
(b) Can you arrange these atoms to make a different molecule? If so, draw its structural formula and state its name.
(c) How are the molecules drawn in (a) and (b) the same? How do they differ? What are they called (the type of relationship between these molecules, not their names)?

Solution

(a) 1-chloropropane



(b) 2-chloropropane



(c) These molecules have the same chemical composition (types and number of atoms) but different chemical structures. They are structural isomers.

2.5 The Periodic Table

Question 13-1.

Using the periodic table, classify each of the following elements as a metal or a nonmetal, and then further classify each as a main-group (representative) element, transition metal, or inner transition metal:

(a) uranium
(b) bromine
(c) strontium

(d) neon
(e) gold
(f) americium
(g) rhodium
(h) sulfur
(i) carbon
(j) potassium

Solution
(a) metal, inner transition metal; (b) nonmetal, representative element; (c) metal, representative element; (d) nonmetal, representative element; (e) metal, transition metal; (f) metal, inner transition metal; (g) metal, transition metal; (h) nonmetal, representative element; (i) nonmetal, representative element; (j) metal, representative element

Question 13-2.

Using the periodic table, classify each of the following elements as a metal or a nonmetal, and then further classify each as a main-group (representative) element, transition metal, or inner transition metal:

(a) cobalt
(b) europium
(c) iodine
(d) indium
(e) lithium
(f) oxygen
(g) cadmium
(h) terbium
(i) rhenium

Solution
(a) metal, transition metal; (b) metal, inner transition metal; (c) nonmetal, representative element; (d) metal, representative element; (e) metal, representative element; (f) nonmetal, representative element; (g) metal, representative element; (h) metal, representative element; (i) metal, inner transition metal; (j) metal, transition metal

Question 13-3.

Using the periodic table, identify the lightest member of each of the following groups:

(a) noble gases
(b) alkaline earth metals
(c) alkali metals
(d) chalcogens

Solution
(a) He; (b) Be; (c) Li; (d) O

Question 13-4.

Using the periodic table, identify the heaviest member of each of the following groups:

(a) alkali metals
(b) chalcogens

(c) noble gases
(d) alkaline earth metals

Solution
(a) Fr; (b) Po; (c) Rn; (d) Ra

Question 13-5.

Use the periodic table to give the name and symbol for each of the following elements:
(a) the noble gas in the same period as germanium
(b) the alkaline earth metal in the same period as selenium
(c) the halogen in the same period as lithium
(d) the chalcogen in the same period as cadmium

Solution
(a) krypton, Kr; (b) calcium, Ca; (c) fluorine, F; (d) tellurium, Te

Question 13-6.

Use the periodic table to give the name and symbol for each of the following elements:
(a) the halogen in the same period as the alkali metal with 11 protons
(b) the alkaline earth metal in the same period with the neutral noble gas with 18 electrons
(c) the noble gas in the same row as an isotope with 30 neutrons and 25 protons
(d) the noble gas in the same period as gold

Solution
(a) chlorine, Cl; (b) magnesium, Mg; (c) krypton, Kr; (d) radon, Rn

Question 13-7.

Write a symbol for each of the following neutral isotopes. Include the atomic number and mass number for each.
(a) the alkali metal with 11 protons and a mass number of 23
(b) the noble gas element with and 75 neutrons in its nucleus and 54 electrons in the neutral atom
(c) the isotope with 33 protons and 40 neutrons in its nucleus
(d) the alkaline earth metal with 88 electrons and 138 neutrons

Solution
(a) ${}^{23}_{11}\text{Na}$; (b) ${}^{129}_{54}\text{Xe}$; (c) ${}^{73}_{33}\text{As}$; (d) ${}^{226}_{88}\text{Ra}$

Question 13-8.

Write a symbol for each of the following neutral isotopes. Include the atomic number and mass number for each.
(a) the chalcogen with a mass number of 125
(b) the halogen whose longest-lived isotope is radioactive
(c) the noble gas, used in lighting, with 10 electrons and 10 neutrons
(d) the lightest alkali metal with three neutrons

Solution
(a) ${}^{125}_{52}\text{Te}$; (b) ${}^{210}_{85}\text{At}$; (c) ${}^{20}_{10}\text{Ne}$; (d) ${}^{6}_{3}\text{Li}$

2.6 Ionic and Molecular Compounds

Question 14-1.

Using the periodic table, predict whether the following chlorides are ionic or covalent: KCl, NCl_3, ICl, $MgCl_2$, PCl_5, and CCl_4.

Solution

In general, those elements that are widely separated in the periodic table—that is, at the extreme left and extreme right—will form compounds that are ionic. Those elements that are near one another in the periodic table generally will form covalent compounds. More specifically, when a metal is combined with one or more nonmetals, the compound is usually ionic. Covalent compounds are usually formed by a combination of nonmetals. Ionic: KCl, $MgCl_2$; Covalent: NCl_3, ICl, PCl_5, CCl_4

Question 14-2.

Using the periodic table, predict whether the following chlorides are ionic or covalent: $SiCl_4$, PCl_3, $CaCl_2$, CsCl, $CuCl_2$, and $CrCl_3$.

Solution

Covalent compounds are usually formed by a combination of nonmetals. Ionic compounds are usually formed when a metal is combined with one or more nonmetals. Ionic: $CaCl_2$, CsCl, $CuCl_2$; Covalent: $SiCl_4$, PCI_3

Question 14-3.

For each of the following compounds, state whether it is ionic or covalent. If it is ionic, write the symbols for the ions involved:

(a) NF_3
(b) BaO
(c) $(NH_4)_2CO_3$
(d) $Sr(H_2PO_4)_2$
(e) IBr
(f) Na_2O

Solution

(a) covalent; (b) ionic, Ba^{2+}, O^{2-}; (c) ionic, NH_4^+, CO_3^{2-}; (d) ionic, Sr^{2+}, $H_2PO_4^-$; (e) covalent; (f) ionic, Na^+, O^{2-}

Question 14-4.

For each of the following compounds, state whether it is ionic or covalent, and if it is ionic, write the symbols for the ions involved:

(a) $KClO_4$
(b) $Mg(C_2H_3O_2)_2$
(c) H_2S
(d) Ag_2S

(e) N_2Cl_4
(f) $Co(NO_3)_2$

Solution
(a) ionic, K^+, ClO_4^-; (b) ionic, Mg^{2+}, $C_2H_3O_2$, charge 2–; (c) covalent; (d) ionic, Ag^+, S^{2-}; (e) covalent; (f) ionic, Co^{2+}, NO_3^-

Question 14-5.

For each of the following pairs of ions, write the symbol for the formula of the compound they will form:

(a) Ca^{2+}, S^{2-}
(b) NH_4^+, SO_4^{2-}
(c) Al^{3+}, Br^-
(d) Na^+, HPO_4^{2-}
(e) Mg^{2+}, PO_4^{3-}

Solution
a) CaS; (b) $(NH_4)_2SO_4$; (c) $AlBr_3$; (d) Na_2HPO_4; (e) $Mg_3 (PO_4)_2$

Question 14-6.

For each of the following pairs of ions, write the symbol for the formula of the compound they will form:

(a) K^+, O^{2-}
(b) NH_4^+, PO_4^{3-}
(c) Al^{3+}, O^{2-}
(d) Na^+, CO_3^{2-}
(e) Ba^{2+}, PO_4^{3-}

Solution
(a) K_2O; (b) $(NH_4)_3PO_4$; (c) Al_2O_3; (d) Na_2CO_3; (e) $Ba_3 (PO_4)_2$

2.7 Chemical Nomenclature

Question 15-1.

Name the following compounds:

(a) CsCl
(b) BaO
(c) K_2S
(d) $BeCl_2$
(e) HBr
(f) AlF_3

Solution
(a) cesium chloride; (b) barium oxide; (c) potassium sulfide; (d) beryllium chloride; (e) hydrogen bromide; (f) aluminum fluoride

Question 15-2.

Name the following compounds:

(a) NaF
(b) Rb_2O
(c) BCl_3
(d) H_2Se
(e) P_4O_6
(f) ICl_3

Solution

(a) sodium fluoride; (b) rubidium oxide; (c) boron trichloride; (d) hydrogen selenide; (e) tetraphosphorus hexaoxide; (f) iodine trichloride

Question 15-3.

Write the formulas of the following compounds:

(a) rubidium bromide
(b) magnesium selenide
(c) sodium oxide
(d) calcium chloride
(e) hydrogen fluoride
(f) gallium phosphide
(g) aluminum bromide
(h) ammonium sulfate

Solution

(a) RbBr; (b) MgSe; (c) Na_2O; (d) $CaCl_2$; (e) HF; (f) GaP; (g) $AlBr_3$; (h) $(NH_4)_2SO_4$

Question 15-4.

Write the formulas of the following compounds:

(a) lithium carbonate
(b) sodium perchlorate
(c) barium hydroxide
(d) ammonium carbonate
(e) sulfuric acid
(f) calcium acetate
(g) magnesium phosphate
(h) sodium sulfite

Solution

(a) Li_2CO_3; (b) $NaClO_4$; (c) $Ba(OH)_2$; (d) $(NH_4)_2CO_3$; (e) H_2SO_4; (f) $Ca(C_2H_3O_2)_2$; (g) $Mg_3(PO_4)_2$; (h) Na_2SO_3

Question 15-5.

Write the formulas of the following compounds:

(a) chlorine dioxide
(b) dinitrogentetraoxide
(c) potassium phosphide

(d) silver sulfide
(e) aluminum fluoride trihydrate
(f) silicon dioxide

Solution
(a) ClO_2; (b) N_2O_4; (c) K_3P; (d) Ag_2S; (e) $AlF_3{\cdot}3H_2O$; (f) SiO_2

Question 15-6.

Write the formulas of the following compounds:
(a) barium chloride
(b) magnesium nitride
(c) sulfur dioxide
(d) nitrogentrichloride
(e) dinitrogen trioxide
(f) tin(IV) chloride

Solution
(a) $BaCl_2$; (b) Mg_3N_2; (c) SO_2; (d) NCl_3; (e) N_2O_3; (f) $SnCl_4$

Question 15-7.

Each of the following compounds contains a metal that can exhibit more than one ionic charge. Name these compounds:
(a) Cr_2O_3
(b) $FeCl_2$
(c) CrO_3
(d) $TiCl_4$
(e) $CoCl_2{\bullet}6H_2O$
(f) MoS_2

Solution
(a) chromium(III) oxide; (b) iron(II) chloride; (c) chromium(VI) oxide; (d) titanium(IV) chloride; (e) cobalt(II) chloride hexahydrate; (f) molybdenum(IV) sulfide

Question 15-8.

Each of the following compounds contains a metal that can exhibit more than one ionic charge. Name these compounds:
(a) $NiCO_3$
(b) MoO_3
(c) $Co(NO_3)_2$
(d) V_2O_5
(e) MnO_2
(f) Fe_2O_3

Solution
(a) nickel(II) carbonate; (b) molybdenum(VI) oxide; (c) cobalt(II) nitrate; (d) vanadium(V) oxide; (e) manganese(IV) oxide; (f) iron(III) oxide

Question 15-9.

The following ionic compounds are found in common household products. Write the formulas for each compound:

(a) potassium phosphate
(b) copper(II) sulfate
(c) calcium chloride
(d) titanium dioxide
(e) ammonium nitrate
(f) sodium bisulfate (the common name for sodium hydrogen sulfate)

Solution

(a) K_3PO_4; (b) $CuSO_4$; (c) $CaCl_2$; (d) TiO_2; (e) NH_4NO_3; (f) $NaHSO_4$

Question 15-10.

The following ionic compounds are found in common household products. Name each of the compounds:

(a) $Ca(H_2PO_4)_2$
(b) $FeSO_4$
(c) $CaCO_3$
(d) MgO
(e) $NaNO_2$
(f) KI

Solution

(a) calcium dihydrogen phosphate; (b) iron(II) sulfate; (c) calcium carbonate; (d) magnesium oxide; (e) sodium nitrite; (f) potassium iodide

Question 15-11.

What are the IUPAC names of the following compounds?

(a) manganese dioxide
(b) mercurous chloride (Hg_2Cl_2)
(c) ferric nitrate [$Fe(NO_3)_3$]
(d) titanium tetrachloride
(e) cupric bromide ($CuBr_2$)

Solution

(a) manganese(IV) oxide; (b) mercury(I) chloride; (c) iron(III) nitrate; (d) titanium(IV) chloride; (e) copper(II) bromide