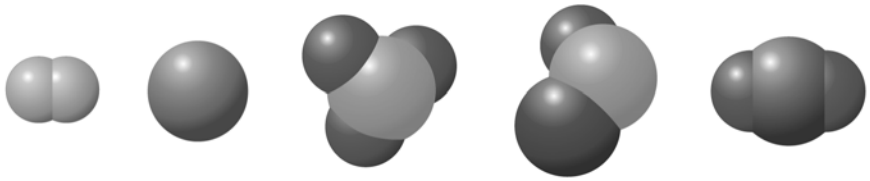
Chapter 2

Atoms, Molecules, and Ions

Concept Check 2.1

Like Dalton, chemists continue to model atoms using spheres. Modern models are usually drawn with a computer and use different colors to represent atoms of different elements. Which of the models below represents CO_2?



Solution

CO_2 is a compound that is a combination of one carbon atom combined with two oxygen atoms. Therefore, the chemical model must contain a chemical combination of three atoms stuck together, with two of the atoms being the same (oxygen). Since each “ball” represents an individual atom, the three models on the left can be eliminated since they don't contain the correct number of atoms. Keeping in mind that balls of the same color represent the same element, only the model on the far right contains two elements with the correct ratio of atoms, 1:2, therefore it must be CO_2.

Concept Check 2.2

What would be a feasible model for the atom if Geiger and Marsden had found that 7999 out of 8000 alpha particles were deflected back at the alpha-particle source?

Solution

If 7999 out of 8000 alpha particles deflected back at the alpha-particle source, this would imply that an atom is a solid, impenetrable mass. Keep in mind that this is in direct contrast to what was observed in the actual experiments, where the majority of the alpha particles passed through without being deflected.

Concept Check 2.3

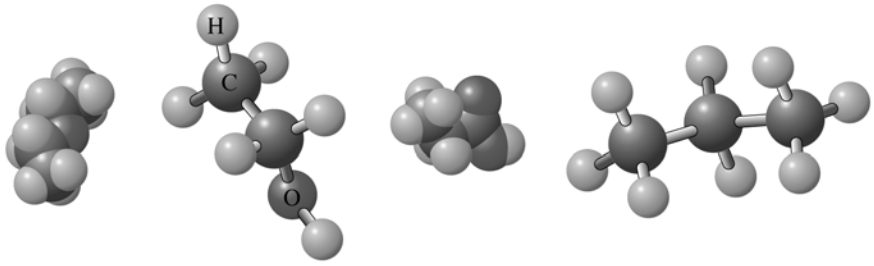
Consider the elements He, Ne, and Ar. Can you think of a reason why they are in the same group in the periodic table?

Solution

Elements are listed together in groups because they have similar chemical and/or physical properties.

Concept Check 2.4

Identify the following compounds as being a hydrocarbon, alcohol, ether, or carboxylic acid.



Solution

a. This compound is an ether because the compound has a functional group of an oxygen atom between two carbon atoms (-O-).
b. This compound is an alcohol because it has an –OH functional group.
c. This compound is a carboxylic acid because it has the –COOH functional group.
d. This compound is a hydrocarbon because it contains only carbon and hydrogen atoms.

Concept Check 2.5

You take a job with the U.S. Environmental Protection Agency (EPA) inspecting college chemistry laboratories. On the first day of the job while inspecting Generic University, you encounter a bottle with the formula Al_2Q_3 that was used as an unknown compound in an experiment. Before you send the compound off to the EPA lab for analysis, you want to narrow down the possibilities for element Q. What are the likely (real element) candidates for element Q?

Solution

A bottle containing a compound with the formula Al_2Q_3 would have an anion Q with a charge of 2-. The total positive charge in the compound due to the Al^{3+} is 6+ (2 x 3+), so the total negative charge must be 6-; therefore, each Q ion must have a charge of 2-. Thus, Q would probably be an element from Group VIA on the periodic table.

Conceptual Problem 2.21

One of the early models of the atom proposed that atoms were wispy balls of positive charge with the electrons evenly distributed throughout. What would you expect to observe if you conducted Rutherford's experiment and the atom had this structure?

Solution

If atoms were balls of positive charge with the electrons evenly distributed throughout, there would be no massive, positive nucleus to deflect the beam of alpha particles when it is shot at the gold foil.

Conceptual Problem 2.22

A friend is trying to balance the following equation.

$$N_2 + H_2 \rightarrow NH_3$$

He presents you with his version of the "balanced" equation.

$$N + H_2 \rightarrow NH_3$$

You immediately recognize that he has committed a serious error; however, he argues that there is nothing wrong since the equation is balanced. What reason can you give to convince him that his "method" of balancing the equation is flawed?

Solution

Once the subscripts of the compounds in the original chemical equation are changed (the molecule N_2 was changed to the atom N), the substances reacting are no longer the same.

Your friend may be able to balance the second equation, but it is no longer the same chemical reaction.

Conceptual Problem 2.23

Given that the periodic table is an organizational scheme for the elements, what might be some other logical ways of grouping the elements that would provide meaningful chemical information?

Solution

You could group elements by similar physical properties, such as density, mass, color, conductivity, etc., or by chemical properties, such as reaction with air, reaction with water, etc.

Conceptual Problem 2.24

You discover a new set of polyatomic anions that have the newly discovered element "X" combined with oxygen. Since you made the discovery, you get to name these new polyatomic ions. In developing the names, you want to follow convention. How would you name the following, given that a colleague in the lab came up with a name that she really likes for one of the ions?

Formula	Name
XO_4^{2-}	
XO_3^{2-}	
XO_2^{2-}	excite
XO^{2-}	

Solution

You would name the ions with the formula XO_4^{2-}, XO_3^{2-}, and XO^{2-} using the name for XO_2^{2-} (excite) as the example to determine the root name of the element X (exc). Thus, XO_4^{2-}, with the greatest number of oxygen atoms in the group, would be perexcate; XO_3^{2-} would be excate; and XO^{2-}, with the fewest oxygen atoms in the group, would be hypoexcite.

Conceptual Problem 2.25

You have the mythical metal element "X" that can exist as X^+, X^{2+}, and X^{5+} ions.

a. What would be the chemical formulas for compounds that form from the combination of each of the X ions and SO_4^{2-}?

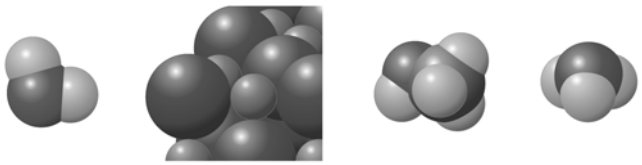
b. If the name of the element X is exy, what would be the names of each of the compounds from part a. of this problem?

Solution

a. In each case, the total positive charge and the total negative charge in the compounds must cancel. Therefore, the compounds with the cations X^{+}, X^{2+}, and X^{5+}, combined with the SO_4^{2-} anion, are X_2SO_4, XSO_4, and $X_2(SO_4)_5$, respectively.
b. You recognize the fact that whenever a cation can have multiple oxidation states, 1+, 2+, and 5+ in this case, the name of the compound must indicate this charge. Therefore, the names of the compounds in part a. would be exy(I) sulfate, exy(II) sulfate, and exy(V) sulfate, respectively.

Conceptual Problem 2.26

Match the molecular model with the correct chemical formula: CH_3OH, NH_3, KCl, H_2O. (In order to arrive at the correct answer(s), viewing the color text version of the figure associated with this problem is advisable.)



Solution

The first step in solving this problem is to classify the above compounds as either ionic or molecular (covalent). The only ionic compound is KCl with the others being molecular. Ionic compounds are made up of a crystal composed of a regular three-dimensional arrangement of atoms. Keeping this in mind, moving from models a-d:

a. This model contains three atoms of two different elements (H and O). Therefore, the model is of H_2O.
b. This model represents a crystal that contains two different elements in a 1:1 ratio (K^{+} and Cl^{-}). Therefore, the model represents the ionic compound, KCl.
c. This model contains six atoms, four of which are the same (H), and two others (C and O). Therefore, the model is of CH_3OH.

d. This model contains four atoms of two different elements (N and H). Therefore, the model is of NH_3.

Conceptual Problem 2.27

Consider a hypothetical case in which the charge on a proton is twice that of an electron. Using this hypothetical case and the fact that atoms maintain a charge of 0, how many protons, neutrons, and electrons would a potassium-39 atom contain?

Solution

A potassium-39 atom in this case would contain 19 protons and 20 neutrons. If the charge of the proton were twice that of an electron, it would take twice as many electrons as protons, or 38 electrons, to maintain a charge of zero.

Conceptual Problem 2.28

Currently, the atomic mass unit (amu) is exactly 1/12th the mass of a carbon-12 atom and is equal to 1.66×10^{-27} kg.

a. If the amu were based on sodium-23 with a mass equal to exactly 1/23rd of the mass of a sodium-23 atom, would the mass of the amu be different?
b. If the new mass of the amu based on sodium-23 is 1.67×10^{-27} kg, how would the mass of a hydrogen atom, in amu, compare with the current mass of a hydrogen atom in amu?

Solution

a. Since the mass of an atom is not only due to the sum of the masses of the protons, neutrons, and electrons, when you change the element on which you are basing the amu, the mass of the amu must change as well.
b. Since the amount of material that makes up a hydrogen atom doesn't change, when the amu gets larger, as in this problem, the hydrogen atom must have a smaller mass in amu.