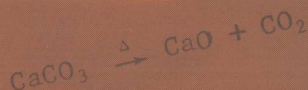
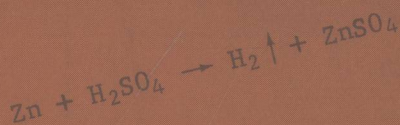
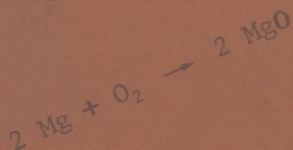
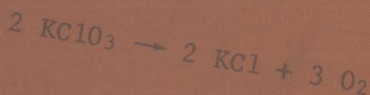


Balancing Chemical Equations

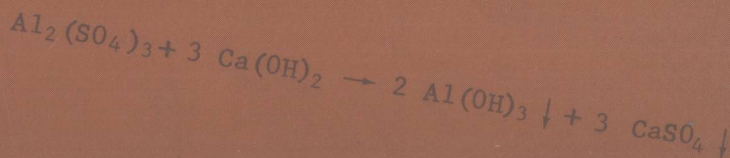
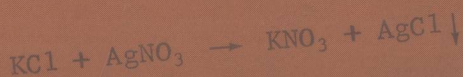


PROGRAMMED UNIT IN CHEMISTRY

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Programmed Unit in Chemistry

BALANCING CHEMICAL EQUATIONS

by



E8961707

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Objectives for this Unit

The purpose of this set is to help you learn how to balance chemical equations and how to use the conventional symbols which chemists employ in equation writing. You will also learn why balance must be achieved in chemical equations, but you will not be required in this unit to predict whether certain reactions occur or to indicate why reactions occur.

It is assumed that you can write the formulas of most substances if you are given the name of the substance. This also implies that you can give from memory the symbols of important elements. Your teacher will specify whether you should be prepared to write the formulas for substances from memory or whether you may have a Reference Table available.

Instructions to the Student

Programmed instruction is a method of helping you learn better and more easily. You proceed in small steps, check yourself at each step, make few errors, and work at your own speed. The form of programmed instruction may make it look like a test, but this is not a test. This is a method of teaching yourself. You will not be graded on the responses you make while learning. However, you will be held responsible at a later time for mastery of the content of this unit.

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05529-E

MOLECULAR EQUATIONS

Instructions to the Student

This set will teach you how to balance a molecular equation, if you know what the reaction is. In addition to a Periodic Table and this program, you need a sheet of paper and a pen. When you come to the blank spaces, write on your answer sheet the word or expression which best completes the thought. Your instructor will tell you whether to write your response in the book or on a separate sheet of paper.

1. The substances that are involved in a chemical reaction are called the reactants. The materials present at the beginning of a chemical reaction are called the _____.

reactants

2. The new substance or substances formed by the chemical reaction are known as products. The reactants undergo chemical change to form _____.

products

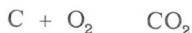
3. In the burning of charcoal, carbon and oxygen combine to form carbon dioxide. Carbon and oxygen are the _____. Carbon dioxide is the _____.

reactants product

4. Let us translate the word statement of the chemical reaction of the burning of charcoal into chemical and mathematical symbols.

On your answer sheet write a chemical or mathematical symbol to stand for as many words as you can in the following statement.

Carbon and oxygen produce carbon dioxide. _____



5. The symbol which means "forms," "yields," "produces" or a similar expression is \rightarrow . Insert this symbol in your equation.



6. Oxygen forms diatomic molecules by covalent bonding, and the element always has the formula O_2 . The other elements which commonly form diatomic molecules are

_____, _____, _____, _____, _____, _____, _____.

In any order H_2 , N_2 , Cl_2 , F_2 , Br_2 , I_2 , and probably At_2

7. If you did not know from memory that these elements form diatomic molecules, continue with this item. If you answered the item correctly, you may go on to item 8.

A memory device, in which the first letter or letters of each word stands for one of the diatomic gases, is as follows: I Bring Clay From Our New House. Write the formulas for the diatomic elements suggested by this memory device.

_____, _____, _____, _____, _____, _____, _____.

I_2 , Br_2 , Cl_2 , F_2 , O_2 , N_2 , H_2

8. Since matter is neither created nor destroyed in ordinary chemical reactions, you should check that an equation shows the same kinds and numbers of atoms among the reactants and products. Begin checking systematically with the first formula in the equation.



1 C atom = 1 C atom

___ O atom(s) = ___ O atom(s)

2 O atoms = 2 O atoms (Since the kinds and numbers of atoms are in balance on both sides of the equation, or on each side of the \rightarrow sign, the equation is already balanced. Most equations do not balance so easily; you must make further adjustments.)

9. There are two steps in writing a balanced equation. The first is converting the word statement to a symbolic statement. Write a statement in symbols for the reaction in which sodium combines with chlorine to form sodium chloride, _____.



10. These are the correct formulas for each substance but the equation is not balanced. (Once you have determined the correct formulas for each of the reactants and products, do not change their formulas.) Equations are balanced by adjusting the coefficients preceding each formula.

Step 2: Are there the same number of atoms of each element on both sides of the equation? Begin to check with the first term.

Left side of equation \rightarrow Right side of equation

_____ Na \rightarrow _____ Na

1 Na = 1 Na

11. Proceed to check the next term in $\text{Na} + \text{Cl}_2 \rightarrow \text{NaCl}$

Cl_2 does not equal (\neq) 1 Cl

To obtain the required 2 atoms of Cl in the product, one needs 2 formulas of NaCl on the right side of the equation. The number of formulas is indicated by a coefficient preceding the formula.

$\text{Na} + \text{Cl}_2 \rightarrow$ _____ NaCl



12. The 2 NaCl contain 2 atoms of Cl and also 2 atoms of Na since a coefficient governs all symbols that occur until the next mathematical sign. Since 2 atoms of Na are required in the product, 2 atoms of Na must have been present among the reactants. Supply the missing coefficient: _____ $\text{Na} + \text{Cl}_2 \rightarrow 2 \text{NaCl}$



13. Finally, beginning with the first term, check for a balance of the number and kinds of atoms on both sides of the equation.

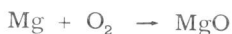
_____ Na = _____ Na

_____ Cl = _____ Cl

2 Na = 2 Na (The equation $2 \text{Na} + \text{Cl}_2 \rightarrow 2 \text{NaCl}$ is now balanced.)

2 Cl = 2 Cl

14. Magnesium burns in oxygen to form magnesium oxide. The formulas are _____ + _____ \rightarrow _____.



15. Do not change these formulas; they are correct. To bring the equation into balance, adjust only coefficients. Checking the first term

$$\underline{\hspace{1cm}} \text{Mg} = \underline{\hspace{1cm}} \text{Mg}$$

$$1 \text{ Mg} = 1 \text{ Mg}$$

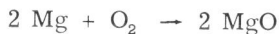
16. The magnesium balances so far. Is the oxygen in balance?

No, $\text{O}_2 \neq \text{O}$ therefore for

17. $\text{Mg} + \text{O}_2 \rightarrow \underline{\hspace{1cm}} \text{MgO}$ are required.



18. The coefficient 2 in 2 MgO affects the Mg as well as the O so the left side of the equation needs to be adjusted. $\underline{\hspace{1cm}} \text{Mg} + \text{O}_2 \rightarrow 2 \text{MgO}$



19. Checking all atoms for final balance

$$\underline{\hspace{1cm}} \text{Mg} = \underline{\hspace{1cm}} \text{Mg}$$

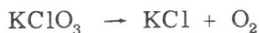
$$\underline{\hspace{1cm}} \text{O} = \underline{\hspace{1cm}} \text{O}$$

2 Mg = 2 Mg (The equation is balanced.)

2 O = 2 O

20. Potassium chlorate decomposes in the presence of heat and a catalyst, manganese dioxide, to produce potassium chloride and oxygen. Write a symbolic statement for the reaction. (A catalyst affects a chemical reaction but is not changed itself.)





21. Check the balance of atoms.

$$\begin{array}{rcl} \underline{\hspace{1cm}} & \text{K} & = \underline{\hspace{1cm}} \text{K} \\ \underline{\hspace{1cm}} & \text{Cl} & = \underline{\hspace{1cm}} \text{Cl} \\ \underline{\hspace{1cm}} & \text{O} & = \underline{\hspace{1cm}} \text{O} \end{array}$$

$$1 \text{ K} = 1 \text{ K}$$

$$1 \text{ Cl} = 1 \text{ Cl}$$

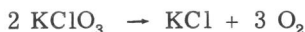
$$\text{but } 3 \text{ O} \neq 2 \text{ O}$$

22. To balance the O atoms

$$\underline{\hspace{1cm}} \times 3 \text{ O} = \underline{\hspace{1cm}} \times 2 \text{ O}$$

$$2 \times 3 \text{ O} = 3 \times 2 \text{ O}$$

23. Substituting these coefficients in the equation, you obtain



24. This disturbs the previous balance of K and Cl, therefore a coefficient is required before KCl.



25. Recheck the balance

$$\begin{array}{rcl} \underline{\hspace{1cm}} & \text{K} & = \underline{\hspace{1cm}} \text{K} \\ \underline{\hspace{1cm}} & \text{Cl} & = \underline{\hspace{1cm}} \text{Cl} \\ \underline{\hspace{1cm}} & \text{O} & = \underline{\hspace{1cm}} \text{O} \end{array}$$

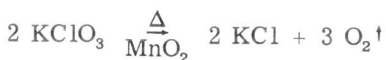
$$2 \text{ K} = 2 \text{ K}$$

$$2 \text{ Cl} = 2 \text{ Cl}$$

$$6 \text{ O} = 6 \text{ O}$$

26. The equation is balanced. Reread the original statement of the reaction: Potassium chlorate decomposes in the presence of heat and a catalyst, manganese dioxide, MnO_2 , to form potassium chloride and oxygen. In equation writing the conditions under which the reaction occurs are indicated above or below the arrow (\rightarrow), and sometimes both above and below. Chemists use the symbol \uparrow to indicate that a product (not a reactant) in a reaction is a gas.

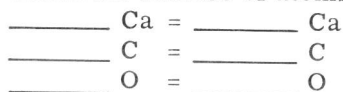
Since one of the products, oxygen, is a gas, an \uparrow is needed. Rewrite the equation showing the conditions under which the reaction takes place and show the vertical arrow for the gaseous products.



27. Calcium carbonate decomposes under heating to yield calcium oxide and carbon dioxide. Write the formulas for the reactants and products.



28. Check the balance of atoms



$$1 \text{ Ca} = 1 \text{ Ca}$$

$$1 \text{ C} = 1 \text{ C}$$

$$3 \text{ O} = 3 \text{ O} \text{ (1 from CaO and 2 from CO}_2\text{)}$$

29. The equation is balanced but does not describe the conditions of the reaction.

The complete reaction is

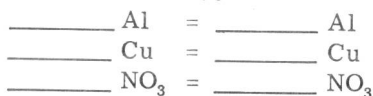


30. Aluminum and copper (II) nitrate in solution yield aluminum nitrate and copper.

Step 1: Write correct formulas _____ + _____ \rightarrow _____ + _____.



31. Step 2: Check and balance



$$1 \text{ Al} = 1 \text{ Al}$$

$$1 \text{ Cu} = 1 \text{ Cu}$$

If a radical does not decompose in chemical reaction the whole radical can be treated as a single unit.

$$2 \text{ NO}_3 \neq 3 \text{ NO}_3$$

32. Balance

$$\underline{\hspace{1cm}} \times 2 \text{ NO}_3 = \underline{\hspace{1cm}} \times 3 \text{ NO}_3$$

$$3 \times 2 \text{ NO}_3 = 2 \times 3 \text{ NO}_3$$

33. Substituting coefficients



34. But now $\underline{\hspace{1cm}} \text{ Al} = \underline{\hspace{1cm}} \text{ Al}$
 $\underline{\hspace{1cm}} \text{ Cu} = \underline{\hspace{1cm}} \text{ Cu}$

$$1 \text{ Al} \neq 2 \text{ Al}$$

$$3 \text{ Cu} \neq 1 \text{ Cu}$$

35. The adjusted coefficients are



36. Metals are insoluble in water and therefore are precipitated. A precipitate is indicated by \downarrow .

Chlorine reacts with a solution of potassium iodide to form iodine and potassium chloride.



37. $\underline{\hspace{1cm}} \text{ Cl} = \text{or } \neq \underline{\hspace{1cm}} \text{ Cl} ?$

$$2 \text{ Cl} \neq 1 \text{ Cl}$$

38. Therefore, the reaction is written





39. _____ K = or \neq 2 K ?

1 K \neq 2 K



41. Now recheck each element

_____ Cl	=	_____ Cl
_____ K	=	_____ K
_____ I	=	_____ I

2 Cl = 2 Cl

2 K = 2 K

2 I = 2 I

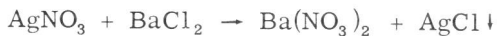
42. The equation is balanced. Iodine is only slightly soluble in water. Indicate this in the equation.

_____ + _____ \rightarrow _____ + _____



43. Silver nitrate and barium chloride yield barium nitrate and a precipitate of silver chloride.

_____ + _____ \rightarrow _____ + _____



44. _____ Ag = or \neq _____ Ag?
 _____ NO₃ = or \neq _____ NO₃ ?

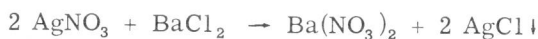
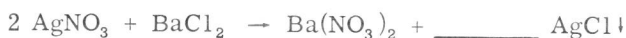
1 Ag = 1 Ag

1 NO₃ \neq 2 NO₃

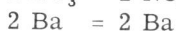
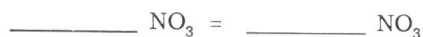
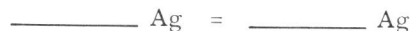




46. Now $2 \text{Ag} \neq 1 \text{Ag}$ so



47. Rechecking



48. The rules for equation writing require that you know the correct _____ for each of the reactants and products.

formulas

49. You then make the equation conform to the Law of Conservation of Matter so that the number of atoms of every element in the reactants is the same as

the _____ among the products. You do this by adjusting the coefficients preceding the formulas.

number of atoms of every element

50. Gaseous products are indicated (symbol). Precipitates are indicated (symbol) and the conditions of the reaction are written (where).

↑ ↓ above or below the arrow (→).

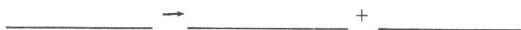
51. Write balanced equations for the following reactions, first checking your answer for the correct formulas, then going on to adjust coefficients. Any errors should be self evident.

Zinc and sulfuric acid (H_2SO_4) form hydrogen and zinc sulfate.



$\text{Zn} + \text{H}_2\text{SO}_4 \rightarrow \text{H}_2\uparrow + \text{ZnSO}_4$ (The equation is balanced as written.)

52. Mercuric oxide decomposes on heating to form mercury and oxygen.



(a) $\text{HgO} \rightarrow \text{Hg} + \text{O}_2\uparrow$

(b) $2 \text{HgO} \rightarrow 2 \text{Hg} + \text{O}_2\uparrow$

53. Zinc chloride and ammonium sulfide form ammonium chloride and zinc sulfide (a precipitate).



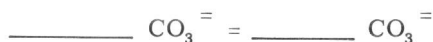
(a) $\text{ZnCl}_2 + (\text{NH}_4)_2\text{S} \rightarrow \text{NH}_4\text{Cl} + \text{ZnS}\downarrow$

(b) $\text{ZnCl}_2 + (\text{NH}_4)_2\text{S} \rightarrow 2 \text{NH}_4\text{Cl} + \text{ZnS}\downarrow$

54. Calcium carbonate and hydrochloric acid (HCl) form calcium chloride + water + carbon dioxide.



Check each element systematically beginning at the left.



1 Ca = 1 Ca

$1 \text{CO}_3^- \neq 0 \text{CO}_3^-$ (CO_3^- radicals do not occur among the products)

55. When a radical decomposes, you must check each element in the radical separately.



$$1 \text{ C} = 1 \text{ C}$$

$$3 \text{ O} = 3 \text{ O} \text{ (2 from CO}_2 + 1 \text{ from H}_2\text{O)}$$

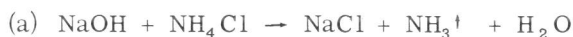
56. The total number of atoms of an element is the same on both sides of an equation, no matter how it is distributed among products or reactants. Continue checking: _____ H = _____ H

$$1 \text{ H} \neq 2 \text{ H}$$



2 Cl = 2 Cl (The equation is apparently balanced as now written, but check again. When you adjust several coefficients, you may make careless errors.)

59. Balance the equation for the following reaction: sodium hydroxide and ammonium chloride form sodium chloride, ammonia (NH₃), and water.



(b) The equation is balanced in (a). There are 5 H on the left, 1 from NaOH and 4 from NH₄Cl. There are 5 H on the right, 3 from NH₃ and 2 from H₂O.

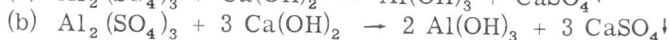
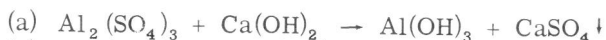
60. Balance the equation for the following reaction: potassium and water form hydrogen and potassium hydroxide.



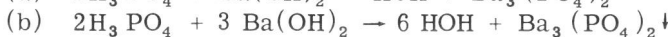
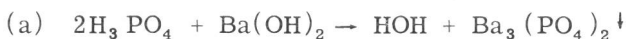
(a) $\text{K} + \text{HOH} \rightarrow \text{H} + \text{KOH}$ (In reactions showing the replacement of some of the hydrogen in water by active metals, it is wise to write the formula for water as HOH. This reminds you that not all of the hydrogen reacts. The product is a hydroxide not an oxide, KOH not K₂O.)



61. Balance the equation for the following reactions: aluminum sulfate and calcium hydroxide \rightarrow aluminum hydroxide and calcium sulfate.



62. Phosphoric acid (H_3PO_4) neutralizes barium hydroxide to form water and barium phosphate.



63. Hydrocarbons, compounds containing hydrogen and carbon, are among our most important fuels. The complete combustion or oxidation of hydrocarbons produces carbon dioxide and water. Methane, CH_4 , the simplest hydrocarbon, is a major component of natural gas.

Write a balanced equation for the reaction in which methane combines with oxygen to form carbon dioxide and water.



64. Propane, C_3H_8 , is a gaseous hydrocarbon which liquefies easily. It is sold as "bottled gas" for cooking and heating.

Write an equation to describe the reaction which occurs when propane burns. $\underline{\hspace{2cm}} + \underline{\hspace{2cm}} \rightarrow \underline{\hspace{2cm}} + \underline{\hspace{2cm}}$



65. Another useful hydrocarbon is octane, C_8H_{18} . You may recognize octane as an ingredient of gasoline.

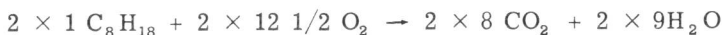
Write a balanced equation for the complete combustion of octane.





The first trial balance produces $\text{C}_8\text{H}_{18} + ? \text{O}_2 \rightarrow 8 \text{CO}_2 + 9 \text{H}_2\text{O}$

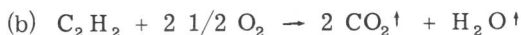
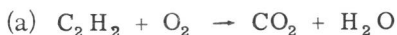
The products indicate that 25 atoms of oxygen are required, 16 from 8 CO_2 and 9 from 9 H_2O . For 25 atoms of oxygen we need 12 1/2 molecules of diatomic oxygen, O_2 . Since we usually show whole molecules, not fractions of a molecule, we clear the equation of fractions by multiplying every term by 2.



This method is used whenever fractional numbers of molecules occur.

66. Acetylene, C_2H_2 , another kind of hydrocarbon, is used in welding torches because of the great energy released in its burning.

Write a balanced equation to show this reaction.



You have learned the principles of balancing molecular equations. Now return to the beginning of the program and work through it again, writing out your answers. Also, as you work through the set, outline in your notebook the important principles for balancing molecular equations. After you have balanced each equation a second time, copy the correctly balanced equation in your notebook. This will provide you with a handy reference of correctly balanced equations. The set includes important and typical examples of the major kinds of chemical reactions.

If you find an equation difficult or "impossible" to balance, you have probably made an error in writing one of the formulas. Use your checklist for formula writing.

IONIC EQUATIONS

Instructions to the Student

Ionic equations are used to show the change of ions into molecules or the reverse. They are also used in double replacement reactions to show the formation of gases, precipitates, or weakly ionized substances. They are not used to show oxidation-reduction reactions; electronic equations are used for that purpose.

It is assumed that you can balance molecular equations and can distinguish between ionically and covalently bonded substances. You should be able to define acid, base, salt, and ion.

You need a Periodic Table and reference material, including the solubilities of common salts and the relative degree of ionization of common acids and bases.

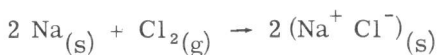
1. The reaction between metallic sodium and gaseous chlorine produces ionically bonded sodium chloride. It is often easier to write and balance the equation in molecular form first. Write a molecular equation for this reaction.

_____ + _____ → _____



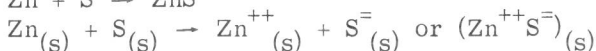
2. In ionic equations the state and molecular or ionic form are indicated. The state (solid, liquid, or gas) is indicated by (s) for solid, and (g) for gas. The symbol (l), for liquid is often omitted. The symbol (aq) indicates the particle is in water solution and is an abbreviation for aqueous.

The reaction under consideration is written



Using these conventions write first a molecular and then an ionic equation for the reaction between zinc and sulfur.



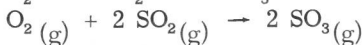
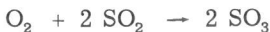


3. The reaction between carbon and oxygen is written



Note that none of these substances are ionic. Also note that when (g) is used, the † is omitted.

Write an equation for the formation of sulfur trioxide from oxygen and sulfur dioxide.



4. Ionic equations are very useful in describing the ionization of acids.

Polar covalent hydrogen chloride reacts with covalent water to form the hydronium ion and the chloride ion. This is written

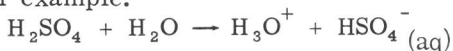


The mixture of hydronium and chloride ions is known as hydrochloric acid. Since hydrochloric acid is highly ionized, the \rightarrow is longer than \rightleftharpoons .

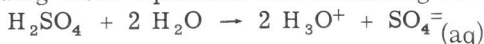
Water reacts with hydrogen bromide to form hydrobromic acid. Write an ionic equation for this reaction.



5. Substances which form two hydronium ions are also written this way. For example:



Adding these equations and collecting terms, gives



Write an ionic equation for the reaction in which hydrogen sulfide reacts with water to form the hydronium ion and the hydrosulfide ion.



6. The $\text{HS}^{-}_{(\text{aq})}$ further reacts with water to form an additional hydronium ion and the sulfide ion. Write an ionic equation for this reaction.

