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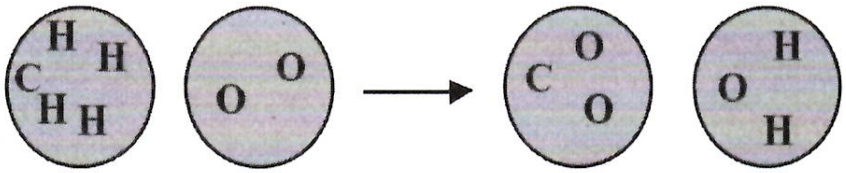
Module 5: Balancing Chemical Equations

Introduction

A chemical reaction is an example of a chemical change and it involves rearrangement of atoms or group of atoms to make new atoms. In this process atoms are neither created nor destroyed, thus satisfying the Law of Conservation of Mass. Only when this law is satisfied can the reaction be used to make quantitative relationships. A **balanced chemical reaction** is a chemical equation that has the same number of atoms of each element involved in the reaction on each side of the equation. Thus, the essence of balancing a chemical reaction is to make sure the Law of Conservation of Mass is satisfied.

Take for example, the reaction between methane and oxygen to form carbon dioxide and water. The equation is given by

$$CH_4 + O_2 \rightarrow CO_2 + H_2O$$



LHS

C = 1

H = 4

O = 2

RHS

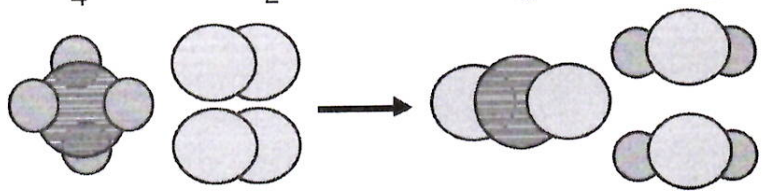
C = 1

H = 2

O = 3

Clearly, for this reaction the number of atoms on the left hand side (LHS) is not equal to the number of atoms on the right hand side (RHS). To achieve this, we need to use coefficients in front of the reactants or products. An **equation coefficient** is a number placed to the left of a chemical formula in a chemical equation that changes the amount but not the identity of a substance. By putting 2 in front of O_2 and 2 in front of H_2O, we can make the atoms on the LHS equals that on the RHS as shown below.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$



LHS	RHS
C=1	C=1
H=4	H=4
O=4	O=4

The following must be noted when balancing any chemical reaction.

(a) Do not ever change the chemical formula subscript of the reactants or products when balancing a chemical reaction. For example, in the reaction above it would have been incorrect to change O_2 to O_4 in order to balance the equation. You must leave the chemical formulas just as they are given. The only thing you can do is to place coefficients in front of the chemical formulas.

(b) It is also important to note that an atom may be present as an element, a compound, or an ion.

(c) Coefficients used must give the give the smallest integer to give a balanced chemical equation.

For example, the balance chemical equation between potassium and water to form hydrogen and potassium hydroxide is

$$2K_{(s)} + 2H_2O_{(l)} \rightarrow H_{2(g)} + 2KOH_{(aq)}$$

Not

$$4K_{(s)} + 4H_2O_{(l)} \rightarrow 2H_{2(g)} + 4KOH_{(aq)}$$

The chemical equation below has been balanced using the guided steps below:

$$\_\_Fe_3O_4 + \_\_\_\_H_2 \rightarrow \_\_\_\_\_Fe + \_\_\_\_\_H_2O$$

Guided Steps to Balancing a Chemical Reaction

1. Examine the chemical equation and pick one element to balance first.
   Let's balance O first. There are four O atoms on the LHS and only one O atom on the RHS. To balance for O atoms, we put a four in front of H_2O. By placing one and four in front of Fe_3O_4 and H_2O, we have balance for the oxygen on either side. Now there are four O atoms on either side of the equation.

   $$\underline{1}\_Fe_3O_4 + \_\_\_\_H_2 \rightarrow \_\_\_\_\_Fe + \underline{4}\_H_2O$$

2. Next pick a second element to balance. Let's balance for Fe, next. This can be achieved by putting a three in front of Fe in the product. Now there are three Fe atoms on either side of the equation.

   $$\underline{1}\_Fe_3O_4 + \_\_\_\_H_2 \rightarrow \underline{3}\_Fe + \underline{4}\_H_2O$$

3. Now pick a third element to balance. The only element left to balance is the H. Currently there are eight H atoms on the RHS but only two H atoms on the LHS. To balance for H, we therefore put a four in front of H_2 on the LHS.

$$\underline{1}\ Fe_3O_4 + \underline{4}\ H_2 \rightarrow \underline{3}\ Fe + \underline{4}\ H_2O$$

4. As a final check on the correctness of the balancing procedure, count atoms on each side of the chemical equation

$Fe_3O_4 + \mathbf{4}\ H_2 \rightarrow \mathbf{3}\ Fe + \mathbf{4}\ H_2O$

Atom	LHS	RHS
Fe	$1 \times 3 = 3$	$3 \times 1 = 3$
O	$1 \times 4 = 4$	$4 \times 1 = 4$
H	$4 \times 2 = 8$	$4 \times 2 = 8$

Balancing Chemical Equations – Practice Exercises

Complete these practice exercises on this text document. Submit your work.

Watch lecture video and supplement video on Reactions before doing this lab.

Indicate in the spaced provided next to the equations below whether each of the chemical equations is balanced or unbalanced.

1. $FeO + CO \rightarrow Fe + CO_2$ — *balanced*
2. $CH_4 + O_2 \rightarrow H_2O + CO_2$ — unbalanced
3. $NH_3 + HNO_3 \rightarrow NH_4NO_3$ — balanced
4. $KCl + O_2 \rightarrow KClO_3$ — unbalanced
5. $Mg + O_2 \rightarrow MgO$ — unbalanced
6. $NaBr + AgNO_3 \rightarrow AgBr + NaNO_3$ — balanced
7. $SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$ — balanced
8. $PCl_3 + H_2 \rightarrow PH_3 + HCl$ — unbalanced

2 +1 4 H

For each of the following balanced chemical equations below, indicate how many atoms of each element are present on the reactant (LHS) and product (RHS) sides of the chemical reaction.

9. $2Cu + O_2 \rightarrow 2CuO$ LHS 2 Cu, 2 O RHS 2 Cu, 2 O

10. $2H_2O \rightarrow 2H_2 + O_2$ LHS 4 H, 2 O RHS 4 H, 2 O

11. $BaCl_2 + Na_2S \rightarrow BaS + 2NaCl$ LHS 1 Ba, 2 Cl, 2 Na, 1 S RHS 1 Ba, 1 S, 2 Na, 2 Cl

12. $2C_3H_8O + 9O_2 \rightarrow 8H_2O + 6CO_2$ LHS 6 C, 16 H, 20 O RHS 16 H, 6 C, 20 O

13. $N_2 + 3H_2 \rightarrow 2NH_3$ LHS 2 N, 6 H RHS 2 N, 6 H

14. $4Fe + 3O_2 \rightarrow 2Fe_2O_3$ LHS 4 Fe, 6 O RHS 4 Fe, 6 O

15. $Au_2S_3 + 3H_2 \rightarrow 3H_2S + 2Au$ LHS 2 Au, 3 S, 6 H RHS 6 H, 3 S, 2 Au

16. $C_4H_{10}O + 6O_2 \rightarrow 5H_2O + 4CO_2$ LHS 4 C, 10 H, 13 O RHS 10 H, 4 C, 13 O

Using coefficients only, balance each of the following chemical equations.

17. $2 N_2 + 3 O_2 \rightarrow 2 N_2O_3$

18. $4 NH_3 + 6 NO \rightarrow 5 N_2 + 6 H_2O$ → R: N 4, H 12, O 6 / P: N 10, H 12, O 6

19. $1 CS_2 + 3 O_2 \rightarrow 1 CO_2 + 2 SO_2$ → R: C 1, S 2, O 6 / P: C 1, S 2, O 6

20. $1 Mg + 2 HBr \rightarrow 1 MgBr_2 + 1 H_2$ ← R: Mg 1, H 2, Br 2 / P: Mg 1, H 2, Br 2

21. $4 Al + 3 O_2 \rightarrow 2 Al_2O_3$ → R: Al 4, O 6 / P: Al 4, O 6

22. $2 Na + 2 H_2O \rightarrow 2 NaOH + 1 H_2$ ← R: Na 2, H 4, O 2 / P: Na 2, H 4, O 2

23. $2 Co + 3 HgCl_2 \rightarrow 2 CoCl_3 + 3 Hg$ → R: Co 2, Hg 3, Cl 6 / P: Co 2, Hg 3, Cl 6

24. $2 NH_3 + 2 O_2 \rightarrow 1 N_2O + 3 H_2O$ ← R: N 2, H 6, O 4 / P: N 2, H 6, O 4

25. $3 PbO + 2 NH_3 \rightarrow 3 Pb + 1 N_2 + 3 H_2O$ → R: Na 2, H 4, C 2, O 10, I 1 / P: Na 2, H 4, C 2, O 10, I 1

26. $2 NaHCO_3 + 1 H_2SO_4 \rightarrow 1 Na_2SO_4 + 2 H_2O + 2 CO_2$

27. $1 TiO_2 + 2 Cl_2 + 1 C \rightarrow 1 TiCl_4 + 1 CO_2$ → R: Ti 1, O 2, Cl 4, C 1 / P: Ti 1, O 2, Cl 4, C 1

28. $2 NBr_3 + 3 NaOH \rightarrow 1 N_2 + 3 NaBr + 3 HBrO$ ← R: N 2, Br 6, Na 3, O 3, H 3 / P: N 2, Br 6, Na 3, O 3, H 3

29. $2 NH_3 + 3 O_2 + 2 CH_4 \rightarrow 2 HCN + 6 H_2O$ ↓ R: N 2, H 14, O 6, C 2 / P: N 2, H 14, O 6, C 2

30. 1 $KClO_3$ + 6 HCl → 1 KCl + 3 Cl_2 + 3 H_2O

31. 1 SO_2Cl_2 + 8 HI → 1 H_2S + 2 H_2O + 2 HCl + 4 I_2

32. 2 NO + 2 CH_4 → 2 HCN + 2 H_2O + 1 H_2

33. 1 C_5H_{12} + 8 O_2 → 5 CO_2 + 6 H_2O

34. 2 C_5H_{10} + 15 O_2 → 10 CO_2 + 10 H_2O

35. 1 C_5H_8 + 7 O_2 → 5 CO_2 + 4 H_2O

36. 1 $C_5H_{10}O$ + 7 O_2 → 5 CO_2 + 5 H_2O

37. 2 C_6H_{14} + 19 O_2 → 12 CO_2 + 14 H_2O

38. 1 C_6H_{12} + 9 O_2 → 6 CO_2 + 6 H_2O

39. 2 C_6H_{10} + 17 O_2 → 12 CO_2 + 10 H_2O

40. 2 $C_6H_{10}O_2$ + 15 O_2 → 12 CO_2 + 10 H_2O

41. 1 $Ca(OH)_2$ + 2 HNO_3 → 1 $Ca(NO_3)_2$ + 2 H_2O

42. 1 $BaCl_2$ + 1 $(NH_4)_2SO_4$ → 1 $BaSO_4$ + 2 NH_4Cl

43. 2 $Fe(OH)_3$ + 3 H_2SO_4 → 1 $Fe_2(SO_4)_3$ + 6 H_2O

44. 1 Na_3PO_4 + 3 $AgNO_3$ → 3 $NaNO_3$ + 1 Ag_3PO_4

45. 2 Al + 3 $Sn(NO_3)_2$ → 2 $Al(NO_3)_3$ + 3 Sn

46. 2 $Al(NO_3)_3$ + 3 H_2SO_4 → 1 $Al_2(SO_4)_3$ + 6 HNO_3

47. 1 Na_2CO_3 + 1 $Mg(NO_3)_2$ → 1 $MgCO_3$ + 2 $NaNO_3$

48. 3 $Ba(C_2H_3O_2)_2$ + 2 $(NH_4)_3PO_4$ → 1 $Ba_3(PO_4)_2$ + 6 $NH_4C_2H_3O_2$

49. 3 Fe_2O_3 + 1 CO → 2 Fe_3O_4 + 1 CO_2

50. 1 WO_3 + 3 H_2 → 1 W + 3 H_2O

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Module 5; Classifying Chemical Reactions

Introduction

You will be studying five kinds of reactions:

1. Decomposition: $AB \rightarrow A + B$
2. Synthesis: $A + B \rightarrow AB$
3. Single Replacement: $AB + C \rightarrow AC + B$
4. Double Replacement: $AB + CD \rightarrow AD + CB$
5. Combustion: Compound with carbon + $O_2 \rightarrow CO_2 + H_2O$

In your unit on COMPOUNDS, you did a lab called "Making Ionic Compounds from Elements" in which you reacted iron and copper with S, Cl_2 and O_2. You observed the ionic compounds and named them and wrote their formula. In this experiment, you will be asked to analyze those reactions – to classify them and to write out balanced chemical equations. In addition, you will observe other reactions and classify them.

Data and Data Analysis

PART A: Reaction of Magnesium and Oxygen

Watch the following video and answer the following questions: https://www.youtube.com/watch?v=w2ydd9rJHws

1) Write out the balanced equation for the reaction of magnesium with oxygen gas:

$2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

2) Describe what the magnesium looks like in this experiment:

Before the reaction, the magnesium metal looks like a long silvery-gray strip of shiny, solid metal.

3) Describe what happens when magnesium is heated up in the presence of O_2 (in the air):

The magnesium gives off a large amount of light, heat, and gas, the color of all of which being an incredibly bright white.

4) Describe the product of this reaction. In particular, what TWO ways is the product different than magnesium:

The magnesium oxide formed after the fact is still solid, but unlike the magnesium, it is now (1) very brittle and (2) bright white in color

5) Was this change physical or chemical?

Chemical.

6) At the end of the video a practice slide is shown with four reactions (call them 1, 2, 3 and 4). Classify these four reactions. (synthesis, decomposition, single replacement, double replacement or combustion).

(1) Decomposition

(2) Synthesis

(3) Double Replacement

(4) Synthesis

Part B: Reactions of metals with nonmetals (review)

Rewatch the video showing the reaction of copper with chlorine:
https://www.youtube.com/watch?v=edLpxdERQZc

Recall that a colored Copper product has a Copper with a 2^+ charge.

Write the name of the product: Copper (II) Chloride

Write the formula of the product: $CuCl_2$

Write the balanced equation for this reaction;

$1\ Cu + 1\ Cl_2 \rightarrow Cu\ Cl_2$

Classify this reaction.

Synthesis

Rewatch the video showing the reaction of copper with sulfur. Remember to focus on the copper wire.
https://www.youtube.com/watch?v=Jhu-0ACrMsQ

Recall that a colored Copper product has a Copper with a 2^+ charge.

Write the name of the product: Copper (II) sulfide

Write the formula of the product: CuS

Write the balanced equation for this reaction;

$1\ Cu + 1\ S \rightarrow Cu\ S$

Classify this reaction. Synthesis

Rewatch the video showing the reaction of Iron (the steel wool) with Oxygen to make Iron (III) oxide.
https://www.youtube.com/watch?v=TkE1uVjrY0w

Write the formula of the product: Fe_2O_3

Write the balanced equation for this reaction;

$4\ Fe + 3\ O_2 \rightarrow 2\ Fe_2O_3$

Classify this reaction.

Synthesis

Rewatch the video showing the reaction of Copper with Oxygen:
https://www.youtube.com/watch?v=1qZxJG8xMmQ

Recall that a colored copper product has a copper with a 2^+ charge. But red copper-oxygen products have a 1^+ charge.

Write the name of the "inside" product: Copper (I) oxide

Write the formula of the product: Cu_2O

Write the balanced equation for this reaction;

$4Cu + O_2 \rightarrow 2Cu_2O$

Write the name of the "outside" product: Copper (II) oxide

Write the formula of the product: CuO

Write the balanced equation for this reaction;

$2Cu + O_2 \rightarrow 2CuO$

Classify these reactions.

Synthesis

Part C: Classifying Reactions

Watch the video showing six different reactions and answer the questions below.
https://www.youtube.com/watch?v=nsEkKIiOz7Q

Reaction #1: DECOMPOSITION reaction.

In this reaction, hydrogen peroxide decomposes. It is the only reactant. Soap captures the gas produced in bubbles and food coloring colors the bubbles. So, these just make the reaction fun. Potassium Iodide is a catalyst: it is needed to make the reaction go, but it is not changed during the reaction, so it will not show up in the reaction equation. The reaction is given in words in the video. Write the reaction equation using standard symbols. Balance it. Hint: Hydrogen peroxide is H_2O_2 and don't forget that oxygen gas is diatomic (O_2).

Reaction Equation: $2H_2O_{2(L)} \rightarrow 2H_2O_{(L)} + O_{2(g)}$

	H	O
R	4	4
P	4	4

In your own words, why is this considered a decomposition reaction?
There is one reactant and multiple products.

Reaction #2: DOUBLE REPLACEMENT reaction

In this reaction, potassium chromate (K_2CrO_4) and silver nitrate ($AgNO_3$) react to form silver chromate (Ag_2CrO_4) and potassium nitrate (KNO_3). Write the reaction equation and balance it.

Reaction Equation: $K_2CrO_{4(L)} + 2AgNO_{3(L)} \rightarrow Ag_2CrO_{4(S)} + 2KNO_{3(L)}$

What color is the reactant, potassium chromate? Bright yellow.
What color is the reactant, silver nitrate? Colourless
What color is the product, silver chromate? Orange-ish Red.

	K	Cr	O	Ag	N
R	2	1	10	2	2
P	2	1	10	2	2

In your own words, why is this considered a double replacement reaction?
Across two of the reactants, two components of the reactants (NO_3 and CrO_4) are swapped.

Reaction #3: COMBUSTION reaction

In this reaction, ethanol (C_2H_6O) reacts with oxygen gas from the air in the bottle when heat is applied. The reaction produces carbon dioxide and water. Write and balance the reaction equation.

Reaction Equation: $C_2H_6O_{(S)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(L)}$

	C	H	O
	2	6	7
	2	6	7

Two products were made in this reaction. Describe the product you saw. There was a very small amount of visible, colorless, liquid water produced, but the CO_2 was not easily visible.

Combustion reactions ALWAYS have O_2 and ALWAYS make CO_2 and H_2O. So, the above reaction was the combustion of ethanol. Write the reaction equation (and balance it) for the combustion of methanol (CH_5O).

$4CH_5O_{(L)} + 7O_{2(g)} \rightarrow 4CO_{2(g)} + 10H_2O_{(L)}$

	C	H	O
R	4	20	18
P	4	20	18

Note: I tried the reaction myself and the CO_2 is visible as a gray gas.

	H	Cl	Zn
R	2	2	1
P	2	2	1

Reaction #4: SINGLE REPLACEMENT reaction

×2 $ZnCl_2$

In this reaction, hydrochloric acid (HCl) reacts with zinc (Zn) to make Zinc chloride (you can figure out its formula with the help of your periodic table) and hydrogen gas (H_2). Write and balance the reaction equation.

Reaction Equation: $2HCl_{(L)} + Zn_{(S)} \rightarrow ZnCl_{2(S)} + H_{2(g)}$

Why did the balloons fill up? (Look at the products in the reaction equation you just wrote).
The reaction produced Hydrogen gas, which filled the balloons.

Both Erlenmeyer flasks had the same chemicals in them. Why do you think the pink balloon got twice as big?
The pink balloon either had more of the chemicals to react with (higher volume) or was agitated more to induce the reaction.

In your own words, why is this considered a single replacement reaction?
There is one element (H) of a compound (HCl) being replaced for one other element (Zn), to form another binary compound ($ZnCl_2$).

Reaction #5: SYNTHESIS reaction

In this reaction, iron and sulfur react to make Iron (II) sulfide (Presenter has updated it under the video description).

What is the formula for Iron (II) sulfide? FeS

Write and balance the reaction equation. $Fe + S \rightarrow FeS$

What color is the iron? The sulfur? The iron/sulfur mix? The iron is dark gray, the sulfur is yellow, and the mix is both colors.

When the iron and sulfur are mixed, is this a physical or chemical change? Chemical

What color is the Iron (II) sulfide at the end of the reaction? Blue-ish gray.

Why do you think the experiment required the heated glass rod?
To cause the reaction. Perhaps the metals require a higher temp to react, as higher temp.s cause faster moving and more "chaotic" molecules.

In your own words, why is this considered a synthesis reaction?
There are only two reactants and one product.