Chemistry 20

Lesson 4 – Chemical equations

I. Identifying chemical reactions

In a chemical change, the compounds and/or elements we start off with are called the **reactants**, and the compounds and/or elements we end up with or produce are called **products**.

reactant(s) → product(s)

A chemical reaction occurs when the **atoms or ions rearrange themselves** into a new combination. The chemical reaction is expressed as a chemical equation. There are five basic reaction types which may be used to predict the products or reactants for a chemical equation. Of course, other types of reactions exist in nature, but the following cover a large array of chemical reactions.

1. **formation**
   element + element → compound
   compound + compound → compound
   A + B → AB

2. **decomposition**
   compound → element + element
   AB → A + B

3. **single replacement**
   element + compound → element + compound
   A + BC → B + AC
   D + BC → C + AD

4. **double replacement**
   compound + compound → compound + compound
   AB + CD → AD + CB

5. **complete combustion**
   element + oxygen → common oxide(s)
   compound + oxygen → common oxides

II. Balancing chemical equations

A chemical equation is a simple, precise, and logical method of communicating a chemical reaction. When balancing a chemical equation the theory of **conservation of atoms** (atoms can be rearranged, but they cannot be destroyed in a chemical reaction) is used to predict the coefficients necessary to balance the reaction equation. In most cases, trial and error, as well as intuition and experience, play an important role in successfully balancing chemical equations. The following steps outline a systematic approach to balancing equations.

Step 1: Write the chemical formula for each reactant and product, including the state of matter for each one. (At the beginning of this course you may not know what the state of matter is for a particular reactant. We will learn more about this as we move along.)

Step 2: Try balancing the atom or ion present in the greatest number. Find the lowest common multiple to obtain coefficients to balance this particular atom or ion.

Step 3: Repeat step 2 to balance each of the remaining atoms and ions.

Step 4: Check the final reaction equation to ensure that all atoms and ions are balanced.

In addition, there are several techniques that can make the balancing of chemical reactions easier:

- Persevere and realize that, like solving puzzles, several attempts may be necessary for more complicated chemical equations.
- The most *common student error* is to use *incorrect chemical formulas* to balance the chemical equation. *Always write correct chemical formulas first and then balance the equation as a separate step*.
- If polyatomic ions remain intact, balance them as a *single unit*.
- Delay balancing any atom that is present in more than two substances in the chemical equation until all other atoms or ions are balanced. (Oxygen is a common example.)
- If a fractional coefficient is required to balance an atom, multiply all coefficients by the denominator of the fraction to obtain integer values. For example, in balancing the following equation, hydrogen atoms are balanced first, then nitrogen, and oxygen is balanced last. This requires 7 oxygen atoms.

$$2\ NH_{3\,(g)} + \mathbf{?}\ O_{2\,(g)} \rightarrow 3\ H_2O_{\,(g)} + 2\ NO_{2\,(g)}$$

The only number that can balance the oxygen atoms is 7/2. By doubling all coefficients, the reaction equation can then be balanced using only integers.

$$4\ NH_{3\,(g)} + 7\ O_{2\,(g)} \rightarrow 6\ H_2O_{\,(g)} + 4\ NO_{2\,(g)}$$

Important note:

Many students merely learn the techniques of identifying a reaction type, completeing the reaction, and then balancing the chemical equation. Students often become mechanical and treat chemistry as just a bunch of steps to learn and follow. This leads to a very weak understanding of chemistry. It is much wiser to remind oneself that the chemical equation *represents* the reorganization of atoms that actually takes place in the real, physical world. Therefore, always attempt to *imagine* the atoms breaking their original bonds and creating bonds with different atoms as *represented* by the chemical equation.

III. Practice problems

Balance the following equations and identify the reaction type.

Reaction Type

1. ____ $Al_{(s)}$ + ____ $O_{2\,(g)}$ → ____ $Al_2O_{3\,(s)}$ __________
2. ____ $HCl_{\,(aq)}$ + ____ $Ca(OH)_{2\,(aq)}$ → ____ $HOH_{\,(l)}$ + ____ $CaC1_{2\,(aq)}$ __________
3. ____ $CH_{4\,(g)}$ + ____ $O_{2\,(g)}$ → ____ $CO_{2\,(g)}$ + ____ $H_2O_{\,(g)}$ __________
4. ____ $Zn_{(s)}$ + ____ $Pb(CH_3COO)_{2\,(aq)}$ → ____ $Pb_{(s)}$ + ____ $Zn(CH_3COO)_{2\,(aq)}$ __________
5. ____ $SO_{3\,(g)}$ + ____ $H_2O_{\,(l)}$ → ____ $H_2SO_{4\,(aq)}$ __________
6. ____ $HgO_{\,(s)}$ → ____ $Hg_{\,(l)}$ + ____ $O_{2\,(g)}$ __________
7. ____ $CaCO_{3\,(s)}$ → ____ $CaO_{\,(s)}$ + ____ $CO_{2\,(g)}$ __________
8. ____ $NaI_{\,(aq)}$ + ____ $Pb(NO_3)_{2\,(aq)}$ → ____ $PbI_{2\,(s)}$ + ____ $NaNO_{3\,(aq)}$ __________
9. ____ $C1_{2\,(aq)}$ + ____ $NaI_{\,(aq)}$ → ____ $I_{2\,(aq)}$ + ____ $NaCl_{\,(aq)}$ __________
10. ____ $Al_2(SO_4)_{3\,(aq)}$ + ____ $Ca(OH)_{2\,(aq)}$ → ____ $Al(OH)_{3\,(s)}$ + ____ $CaSO_{4\,(s)}$ __________

IV. Assignment

For each of the following:

A. Identify the reaction type.

B. If necessary complete the chemical equation. Be sure to properly write the chemical formulas.

C. Balance the equation using the smallest whole numbers possible.

D. Provide states of matter for each compound in the reaction. If you are unsure of any, ask your kind and benevolent teacher.

1. ____ $N_{2\,(g)}$ + ____ $H_{2(g)}$ → ____ $NH_{3(g)}$
2. ____ $HIO_{4(s)}$ + ____ $H_2O_{(l)}$ → $H_5IO_{6(s)}$
3. ____ $H_2S_{(g)}$ + ____ $O_{2(g)}$ → ____ $SO_{2(g)}$ + ____ $H_2O_{(g)}$
4. ____ $CH_{4(g)}$ + ____ $O_{2(g)}$ → ____ $CO_{2(g)}$ + ____ $H_2O_{(g)}$
5. ____ $C_3H_{8(g)}$ + ____ $O_{2(g)}$ → ____ $CO_{2(g)}$ + ____ $H_2O_{(g)}$
6. ____ $Al(OH)_{3(s)}$ + ____ $H_2SO_{4(aq)}$ → ____ $Al_2(SO_4)_{3aq)}$ + ____ $HOH_{(l)}$
7. iron + sulfur → iron (II) sulfide

8. aluminum + fluorine → aluminum fluoride

9. copper + silver nitrate → silver + copper (II) nitrate

10. iron (III) chloride + sodium hydroxide →

11. iron (III) oxide → iron + oxygen

12. potassium chlorate → potassium chloride + oxygen

13. barium chloride + sodium phosphate →

14. → diphosphorous pentaoxide

15. hydroiodic acid + magnesium →

16. Iron pipes are strongly attacked and corroded by hydrosulfuric acid. (iron (II) sulfide is one product)

Balanced reaction:

Reaction type:

17. Coal (C_9H_6) undergoes complete combustion.

Balanced reaction:

Reaction type:

18. The first recorded observation of hydrogen gas was made by Paracelsus (1493-1541) when he added iron to sulfuric acid.

Balanced reaction:

Reaction type:

19. When hydrogen gas and oxygen gas are mixed they form an explosive combination.

Balanced reaction:

Reaction type:

20. A precipitate forms when potassium iodide is mixed with lead (II) nitrate.

Balanced reaction:

Reaction type:

21. Joseph Priestly (1733-1804) decomposed cinnabar (mercury (II) sulfide).

Balanced reaction:

Reaction type:

22. A sulfurous acid solution used in the lab neutralises an ammonium hydroxide solution.

Balanced reaction:

Reaction type:

23. Potassium metal may be obtained by decomposing molten potassium chloride.

Balanced reaction:

Reaction type:

V. Remedial assignment – for extra practice

For each of the following reactions:

A. Classify each reaction:
  - **F** formation
  - **D** decomposition
  - **SR** single replacement
  - **DR** double replacement
  - **CC** complete combustion
  - **O** other

B. Complete the reaction if necessary.

C. Balance the reaction.

____ 1. $Cu_{(s)} + O_{2(g)} \rightarrow CuO_{(s)}$

____ 2. $H_2O_{(l)} \rightarrow H_{2(g)} + O_{2(g)}$

____ 3. $Fe_{(s)} + H_2O_{(g)} \rightarrow H_{2(g)} + Fe_3O_{4(s)}$

____ 4. arsenic chloride + $H_2S_{(aq)} \rightarrow As_2S_{3(s)} + HCl_{(aq)}$

____ 5. $CuSO_4 \cdot 5H_2O_{(s)} \rightarrow CuSO_{4(s)} + H_2O_{(g)}$

____ 6. $Fe_2O_{3(s)}$ + hydrogen $\rightarrow Fe_{(s)} + H_2O_{(l)}$

____ 7. $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$

____ 8. iron + sulfur →

____ 9. hydrogen sulfide + potassium hydroxide → water + potassium sulfide

____ 10. $NaCl_{(l)} \rightarrow Na_{(l)} + Cl_{2(g)}$

____ 11. aluminum + $H_2SO_{4(aq)} \rightarrow$

____ 12. $H_3PO_{4(aq)}$ + $NH_4OH_{(aq)}$ → $HOH_{(l)}$ + $(NH_4)_3PO_{4(aq)}$

____ 13. $C_3H_{8(g)}$ + $O_{2(g)}$ → $CO_{2(g)}$ + $H_2O_{(g)}$

____ 14. aluminum + oxygen →

____ 15. $CH_{4(g)}$ + $O_{2(g)}$ → $CO_{2(g)}$ + $H_2O_{(g)}$

____ 16. potassium + chlorine →

____ 17. → copper (I) sulphide + potassium bromide

____ 18. aluminum chloride + sodium hydroxide →

____ 19. $HNO_{3(aq)}$ + potassium hydroxide →

____ 20. iron + copper (II) sulfate →

____ 21. $H_2SO_{4(aq)}$ + barium hydroxide →

____ 22. → zinc oxide

____ 23. $C_{25}H_{52(g)}$ + $O_{2(g)}$ →

____ 24. iron (III) hydroxide + $H_2SO_{4(aq)}$ →

____ 25. → calcium carbonate + sodium sulfate

____ 26. sodium + chlorine →

____ 27. → lead + zinc acetate