10 Math Skills

Balancing Chemical Equations

Aluminum reacts with copper(II) chloride, $CuCl_2$, to form copper metal and aluminum chloride, $AlCl_3$. Write the balanced equation for this reaction.

1. **Identify the reactants and products.**
   Aluminum and copper(II) chloride are the reactants, and aluminum chloride and copper are the products.
2. **Write a word equation for the reaction.**

   aluminum + copper(II) chloride → aluminum chloride + copper

3. **Write the equation using formulas for the reactants and products.**

   $$Al + CuCl_2 \rightarrow AlCl_3 + Cu$$

4. **Balance the equation one element at a time.** The same number of each type of atom must appear on both sides. So far, there are three chlorine atoms on the right and only two on the left. To balance the number of chlorine atoms, you must multiply the amount of copper(II) chloride by 3 and multiply the amount of aluminum chloride by 2.

   $$Al + 3CuCl_2 \rightarrow 2AlCl_3 + Cu$$

Atom	Reactants	Products	Balance
Al	1	2	✖
Cu	3	1	✖
Cl	6	6	✓

This equation gives you two aluminum atoms on the right and only one on the left. So you need to multiply the amount of aluminum by 2.

$$2Al + 3CuCl_2 \rightarrow 2AlCl_3 + Cu$$

Atom	Reactants	Products	Balance
Al	2	2	✓
Cu	3	1	✖
Cl	6	6	✓

To balance the equation, multiply the amount of copper produced by 3.

$$2Al + 3CuCl_2 \rightarrow 2AlCl_3 + 3Cu$$

Atom	Reactants	Products	Balance
Al	2	2	✓
Cu	3	3	✓
Cl	6	6	✓

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Practice

1. Combustion in automobile engines takes place when fuel and oxygen are combined and ignited in the cylinders of the engine. However, the air that provides the oxygen for combustion also introduces nitrogen into the engine. The nitrogen reacts with oxygen at the high temperatures present in the engine, producing nitrogen oxide compounds, which are a major component of smog. In one of these reactions, nitric oxide, NO, reacts with oxygen, O_2, to form nitrogen dioxide, NO_2. Write the balanced equation for this reaction.

2. During the centuries following the collapse of the western Roman Empire, marble (calcium carbonate, $CaCO_3$) was taken from the monuments of Rome and heated to form quicklime (calcium oxide, CaO), which was used to make plaster. Carbon dioxide, CO_2, was also produced in this decomposition reaction. Write the balanced equation for this reaction.

3. When a match is lit, sulfur (S_8) reacts with oxygen to release energy and form sulfur dioxide, SO_2. Write the balanced equation for this reaction.

4. Zinc reacts with water to produce zinc hydroxide, $Zn(OH)_2$, and molecular hydrogen gas, H_2. Write the balanced equation for this reaction.

5. Barium, Ba, reacts with sulfur, S_8, to form barium sulfide, BaS. Write the balanced equation for this synthesis reaction.

6. Automobile airbags rely on the decomposition of the compound sodium azide (NaN_3) to produce the nitrogen gas, N_2, needed to rapidly inflate the bag. Sodium is also produced in the reaction. Write the balanced equation for this decomposition reaction.

7. A useful single-displacement reaction involves thermite, which is a mixture of aluminum and iron oxide, Fe_2O_3. When the thermite reaches a high temperature, the components react to produce molten iron, aluminum oxide (Al_2O_3), and a great deal of energy. Write the balanced equation for the thermite reaction.

8. Acid indigestion can occur when the stomach produces too much hydrochloric acid, HCl. An old and effective remedy for this involves drinking a solution of baking soda (sodium hydrogen carbonate, $NaHCO_3$), which reacts with the hydrochloric acid to produce sodium chloride (NaCl), water, and carbon dioxide. Write the balanced equation for this reaction.

9. A problem with the remedy given in problem 8 for acid indigestion is that the carbon dioxide produced can cause discomfort. In many modern antacids, the active ingredient is magnesium hydroxide, $Mg(OH)_2$. When this compound reacts with the hydrochloric acid, a double-displacement reaction occurs that produces only water and magnesium chloride, $MgCl_2$. Write the balanced equation for this reaction.

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Sample Problem

Write the equation that describes the formation of glucose and oxygen, by means of photosynthesis, from carbon dioxide and water.

1. **Identify the reactants and products.** Carbon dioxide and water, the reactants, form glucose and oxygen, the products.
2. **Write a word equation for the reaction.**

   carbon dioxide + water → glucose + oxygen

3. **Write the equation using formulas for the reactants and products.** Some gaseous elements are molecules, not atoms. Oxygen in air is O_2, not O.

   $$CO_2 + H_2O \rightarrow C_6H_{12}O_6 + O_2$$

4. **Balance the equation one element at a time.** The same number of each type of atom must appear on both sides. So far, there are six carbon atoms on the right and only one on the left. To balance the number of carbon atoms, multiply the amount of carbon dioxide by 6.

   $$6CO_2 + H_2O \rightarrow C_6H_{12}O_6 + O_2$$

Atom	Reactants	Products	Balance
C	6	6	✓
H	2	12	✖
O	13	8	✖

This equation gives you twelve hydrogen atoms on the right and only two on the left. So you need to multiply the amount of water by 6.

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + O_2$$

Atom	Reactants	Products	Balance
C	6	6	✓
H	12	12	✓
O	18	8	✖

To balance the equation, multiply the amount of oxygen produced by 6.

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

Atom	Reactants	Products	Balance
C	6	6	✓
H	12	12	✓
O	18	18	✓

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Practice

10. Uranium reacts with fluorine gas, F_2, to form uranium(VI) fluoride, UF_6. Write the balanced equation for this synthesis reaction.

11. Iron reacts with chlorine gas, Cl_2, to form iron(III) chloride, $FeCl_3$. Write the balanced equation for this synthesis reaction.

12. Aluminum sulfate, $Al_2(SO_4)_3$, decomposes to form aluminum oxide, Al_2O_3, and sulfur trioxide, SO_3. Write the balanced equation for this reaction.

13. Water is decomposed by electrolysis to form the gaseous products hydrogen, H_2, and oxygen, O_2. Write the balanced equation for this reaction.

14. Potassium chlorate, $KClO_3$, decomposes to form potassium chloride, KCl, and oxygen gas. Write the balanced equation for this decomposition reaction.

15. Chlorine gas, Cl_2, reacts with potassium bromide, KBr, to form potassium chloride and bromine, Br_2. Write the balanced equation for this single-displacement reaction.

16. Aluminum reacts with lead nitrate, $Pb(NO_3)_2$, to form lead and aluminum nitrate, $Al(NO_3)_3$. Write the balanced equation for this single-displacement reaction.

17. Ammonium chloride, NH_4Cl, reacts with calcium hydroxide, $Ca(OH)_2$, to form calcium chloride ($CaCl_2$), ammonia (NH_3), and water. Write the balanced equation for this reaction.

18. Zinc reacts with hydrochloric acid, HCl, to form zinc chloride, $ZnCl_2$, and hydrogen gas. Write the balanced equation for this reaction.

19. Fluorine reacts with sodium chloride, NaCl, to form sodium fluoride, NaF, and chlorine. Write the balanced equation for this single-displacement reaction. (**Hint:** Remember that both fluorine and chlorine have two atoms per molecule when they are in elemental form.)

20. Calcium oxide, CaO, reacts with sulfur dioxide to form calcium sulfite, $CaSO_3$. Write the balanced equation for this synthesis reaction.

21. In air, calcium sulfite, $CaSO_3$, reacts slowly with oxygen to form calcium sulfate, $CaSO_4$. Write the balanced equation for this reaction.

22. When heated, mercury(II) oxide, HgO, decomposes to form mercury and oxygen. Through this reaction, Joseph Priestley demonstrated the existence of oxygen in 1774. Write the balanced equation for the decomposition of mercury(II) oxide.

23. Methanol, CH_3OH, decomposes to form carbon monoxide, CO, and hydrogen gas, H_2. Write the balanced equation for this decomposition reaction.

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Mixed Review

24. Potassium nitrate, KNO_3, decomposes to form potassium nitrite, KNO_2, and oxygen gas, O_2. Write the balanced equation for this decomposition reaction.

25. Antimony(V) chloride, $SbCl_5$, reacts with potassium iodide, KI, to form the products potassium chloride, KCl, iodine, I_2, and antimony(III) chloride, $SbCl_3$. Write the balanced equation for this reaction.

26. Nitric acid, HNO_3, reacts with hydrogen sulfide, H_2S, to form nitrogen dioxide (NO_2), water, and sulfur (S). Write the balanced equation for this reaction.

27. Chromium(III) oxide, Cr_2O_3, reacts with silicon to form chromium metal and silicon dioxide, SiO_2. Write the balanced equation for this reaction.

28. Ammonium dichromate, $(NH_4)_2Cr_2O_7$, decomposes to form chromium(III) oxide, Cr_2O_3, nitrogen gas, N_2, and water. Write the balanced equation for this decomposition reaction.

29. Iron(II) chloride, $FeCl_2$, reacts with water at high temperatures to form triiron tetraoxide (Fe_3O_4), hydrochloric acid, and hydrogen gas. Write the balanced equation for this reaction.

30. Aluminum sulfate, $Al_2(SO_4)_3$, reacts with calcium hydroxide, $Ca(OH)_2$, to form aluminum hydroxide, $Al(OH)_3$, and calcium sulfate, $CaSO_4$. Write the balanced equation for this double-displacement reaction.

31. Lead chloride, $PbCl_2$, reacts with sodium chromate, Na_2CrO_4, to form lead chromate, $PbCrO_4$, and sodium chloride, NaCl. Write the balanced equation for this double-displacement reaction.

32. Vanadium pentoxide, V_2O_5, reacts with calcium to form vanadium metal and calcium oxide, CaO. Write the balanced equation for this reaction.

33. When heated, tantalum metal reacts with chlorine gas to form tantalum pentachloride, $TaCl_5$. Write the balanced equation for this reaction.

34. Potassium manganate(VI), K_2MnO_4, can be made to react with water, forming potassium permanganate, $KMnO_4$, potassium hydroxide, KOH, and hydrogen gas. This reaction is used in industry to produce potassium permanganate, which is widely used in analytical chemistry. Write the balanced equation for this reaction.

35. Phosphorus pentoxide, P_4O_{10}, can be made to react with water (as steam) to form phosphoric acid, H_3PO_4. This reaction is an important industrial source of phosphoric acid. Write the balanced equation for this reaction.

36. Iron sulfide, FeS, reacts with hydrochloric acid, HCl, to form hydrogen sulfide, H_2S, and iron(II) chloride, $FeCl_2$. Write the balanced equation for this reaction.

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