

Balancing Chemical Equations

A balanced equation has equal numbers of each type of atom on each side of the equation.

The Law of Conservation of Mass is the rationale for balancing a chemical equation. The law was discovered by Antoine Laurent Lavoisier (1743-94) and this is his formulation of it, translated into English in 1790 from the Traité élémentaire de Chimie (which was published in 1789):

“We may lay it down as an incontestable axiom, that, in all the operations of art and nature, nothing is created; an equal quantity of matter exists both before and after the experiment; the quality and quantity of the elements remain precisely the same; and nothing takes place beyond changes and modifications in the combination of these elements.”

A less wordy way to say it might be: “Matter is neither created nor destroyed.” Therefore, we must finish our chemical reaction with as many atoms of each element as when we started. Remember this: A balanced equation **MUST** have **EQUAL** numbers of **EACH** type of atom on **BOTH** sides of the arrow.

An equation is balanced by changing **coefficients** in a somewhat trial-and-error fashion. It is important to note that **ONLY** the **coefficients** can be changed, **NEVER** a **subscript**. Coefficients are whole numbers written in front of a molecule's formula.

Lets look at the following example: $\underline{\quad} \text{H}_2 + \underline{\quad} \text{O}_2 \rightarrow \underline{\quad} \text{H}_2\text{O}$ (The underlines are the only places you can write a coefficient.)

The correct way to balance the above equation is as follows: $2 \text{H}_2 + \text{O}_2 \rightarrow 2 \text{H}_2\text{O}$

Note that in order to balance this equation coefficients were placed in front of two formulas. The number one (1) is never used as a coefficient. If no coefficient is written, it is understood to be one.

After balancing an equation you should always check to see that there are the same number of each atom on either side of the arrow. If we check our equation above we see that there are 4 hydrogen on the left ($2 \times 2 = 4$) and 4 hydrogen on the right ($2 \times 2 = 4$); there are 2 oxygen on the left and 2 oxygen on the right ($2 \times 1 = 2$).

Two things you **CANNOT** do when balancing an equation.

1. You **cannot change a subscript**. For example, in the following equation you **cannot** change the oxygen's subscript in water from one to two, as in: $\text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O}_2$

True, this balances the equation, but you have changed the substances in it. H_2O_2 is a completely different substance from H_2O .

2. You **cannot place a coefficient in the middle of a formula**. The subscript goes at the beginning of a formula, not in the middle, as in: $\text{H}_2 + \text{O}_2 \rightarrow \text{H}_2\text{O}$

There are three rules to follow when balancing chemical equations. They do not work every time, but they do work most times and most people find them helpful.

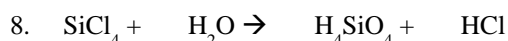
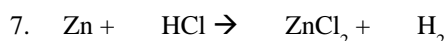
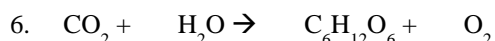
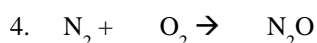
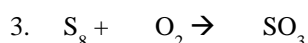
1. **If there is an element that is not bonded to any other atom or is diatomic, balance it last.**

For example in the equation: $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + \text{O}_2$, oxygen is diatomic. When balancing this equation, balance oxygen last.

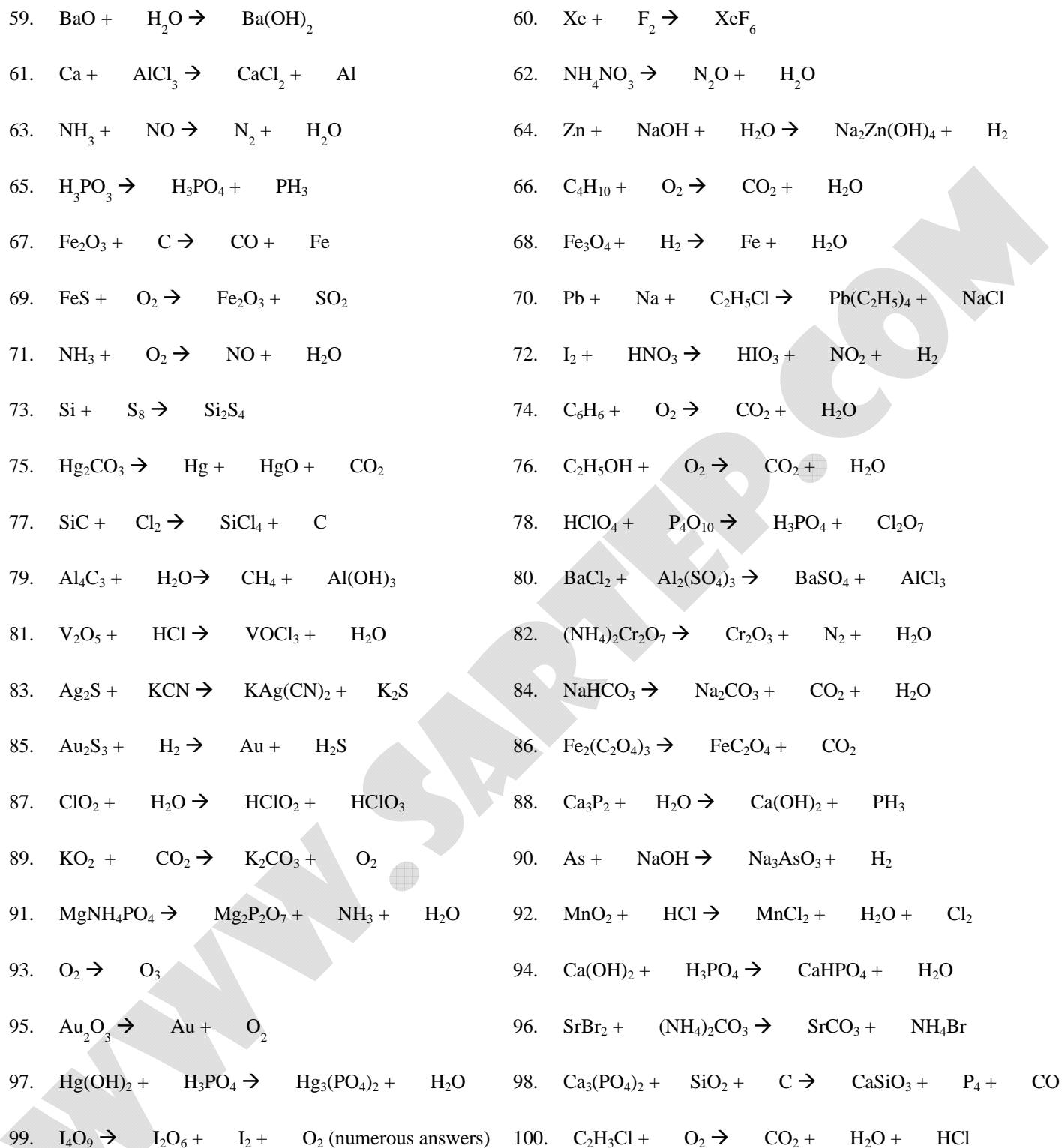
2. **If you are balancing an equation with both hydrogen and oxygen and neither is a diatomic molecule, balance hydrogen last and balance oxygen second to last.** For example in the equation: $\text{CO}_2 + \text{NH}_3 \rightarrow \text{OC}(\text{NH}_2)_2 + \text{H}_2\text{O}$, both hydrogen and oxygen are used and neither exist as a diatomic molecule. When balancing this equation, balance hydrogen last and oxygen second to last.

3. **If you come to the point where you have an odd number of a certain element on one side of the equation and an even number of the same element on the opposite side on the equation, double the coefficient of the formula with the odd number of the element.** If the coefficient is 1, change it to 2.

One final note: Make sure that your final set of coefficients is **reduced to the lowest whole number ratio**. Also, you may want to **use pencil instead of pen**. You will be doing a good deal of erasing at first.

Homework: Balance the following equations.

9. $\text{Na} + \text{H}_2\text{O} \rightarrow \text{NaOH} + \text{H}_2$
10. $\text{H}_3\text{PO}_4 \rightarrow \text{H}_4\text{P}_2\text{O}_7 + \text{H}_2\text{O}$
11. $\text{C}_{10}\text{H}_{16} + \text{Cl}_2 \rightarrow \text{C} + \text{HCl}$
12. $\text{CO}_2 + \text{NH}_3 \rightarrow \text{OC}(\text{NH}_2)_2 + \text{H}_2\text{O}$
13. $\text{Si}_2\text{H}_3 + \text{O}_2 \rightarrow \text{SiO}_2 + \text{H}_2\text{O}$
14. $\text{Al}(\text{OH})_3 + \text{H}_2\text{SO}_4 \rightarrow \text{Al}_2(\text{SO}_4)_3 + \text{H}_2\text{O}$
15. $\text{Fe} + \text{O}_2 \rightarrow \text{Fe}_2\text{O}_3$
16. $\text{Fe}_2(\text{SO}_4)_3 + \text{KOH} \rightarrow \text{K}_2\text{SO}_4 + \text{Fe}(\text{OH})_3$
17. $\text{C}_7\text{H}_6\text{O}_2 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$
18. $\text{H}_2\text{SO}_4 + \text{HI} \rightarrow \text{H}_2\text{S} + \text{I}_2 + \text{H}_2\text{O}$
19. $\text{FeS}_2 + \text{O}_2 \rightarrow \text{Fe}_2\text{O}_3 + \text{SO}_2$
20. $\text{Al} + \text{FeO} \rightarrow \text{Al}_2\text{O}_3 + \text{Fe}$
21. $\text{Fe}_2\text{O}_3 + \text{H}_2 \rightarrow \text{Fe} + \text{H}_2\text{O}$
22. $\text{Na}_2\text{CO}_3 + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O} + \text{CO}_2$
23. $\text{K} + \text{Br}_2 \rightarrow \text{KBr}$
24. $\text{P}_4 + \text{O}_2 \rightarrow \text{P}_2\text{O}_5$
25. $\text{C}_2\text{H}_2 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$
26. $\text{K}_2\text{O} + \text{H}_2\text{O} \rightarrow \text{KOH}$
27. $\text{H}_2\text{O}_2 \rightarrow \text{H}_2\text{O} + \text{O}_2$
28. $\text{Al} + \text{O}_2 \rightarrow \text{Al}_2\text{O}_3$
29. $\text{C}_7\text{H}_{16} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$
30. $\text{Na}_2\text{O}_2 + \text{H}_2\text{O} \rightarrow \text{NaOH} + \text{O}_2$
31. $\text{SiO}_2 + \text{HF} \rightarrow \text{SiF}_4 + \text{H}_2\text{O}$
32. $\text{C} + \text{H}_2\text{O} \rightarrow \text{CO} + \text{H}_2$
33. $\text{KClO}_3 \rightarrow \text{KCl} + \text{O}_2$
34. $\text{H}_3\text{AsO}_4 \rightarrow \text{As}_2\text{O}_5 + \text{H}_2\text{O}$
35. $\text{KClO}_3 \rightarrow \text{KClO}_4 + \text{KCl}$
36. $\text{Al}_2(\text{SO}_4)_3 + \text{Ca}(\text{OH})_2 \rightarrow \text{Al}(\text{OH})_3 + \text{CaSO}_4$
37. $\text{P}_4\text{O}_{10} + \text{H}_2\text{O} \rightarrow \text{H}_3\text{PO}_4$
38. $\text{FeCl}_3 + \text{NH}_4\text{OH} \rightarrow \text{Fe}(\text{OH})_3 + \text{NH}_4\text{Cl}$
39. $\text{Sb} + \text{O}_2 \rightarrow \text{Sb}_4\text{O}_6$
40. $\text{Ca}_3(\text{PO}_4)_2 + \text{SiO}_2 \rightarrow \text{P}_4\text{O}_{10} + \text{CaSiO}_3$
41. $\text{C}_3\text{H}_8 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$
42. $\text{N}_2\text{O}_5 + \text{H}_2\text{O} \rightarrow \text{HNO}_3$
43. $\text{Fe}_2\text{O}_3 + \text{CO} \rightarrow \text{Fe} + \text{CO}_2$
44. $\text{Al} + \text{HCl} \rightarrow \text{AlCl}_3 + \text{H}_2$
45. $\text{PCl}_5 + \text{H}_2\text{O} \rightarrow \text{HCl} + \text{H}_3\text{PO}_4$
46. $\text{H}_3\text{BO}_3 \rightarrow \text{H}_4\text{B}_6\text{O}_{11} + \text{H}_2\text{O}$
47. $\text{H}_2\text{S} + \text{Cl}_2 \rightarrow \text{S}_8 + \text{HCl}$
48. $\text{Mg} + \text{N}_2 \rightarrow \text{Mg}_3\text{N}_2$
49. $\text{Fe} + \text{H}_2\text{O} \rightarrow \text{Fe}_3\text{O}_4 + \text{H}_2$
50. $\text{NaOH} + \text{Cl}_2 \rightarrow \text{NaCl} + \text{NaClO} + \text{H}_2\text{O}$
51. $\text{Li}_2\text{O} + \text{H}_2\text{O} \rightarrow \text{LiOH}$
52. $\text{H}_3\text{PO}_4 + \text{HCl} \rightarrow \text{PCl}_5 + \text{H}_2\text{O}$
53. $\text{CaC}_2 + \text{H}_2\text{O} \rightarrow \text{C}_2\text{H}_2 + \text{Ca}(\text{OH})_2$
54. $\text{HCl} + \text{K}_2\text{CO}_3 \rightarrow \text{KCl} + \text{H}_2\text{O} + \text{CO}_2$
55. $\text{Fe}(\text{OH})_3 \rightarrow \text{Fe}_2\text{O}_3 + \text{H}_2\text{O}$
56. $\text{Ca}(\text{ClO}_3)_2 \rightarrow \text{CaCl}_2 + \text{O}_2$
57. $\text{Pb}(\text{NO}_3)_2 \rightarrow \text{PbO} + \text{NO}_2 + \text{O}_2$
58. $\text{C}_2\text{H}_5\text{OH} + \text{O}_2 \rightarrow \text{CO} + \text{H}_2\text{O}$



Extra Credit (10 points!!!): Balance the following. You MUST show all of your work!!!

