Name _____ CHEMISTRY ___/___/___

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: ___H_2 + ___O_2 → ___H_2O (The underlines are the only places you can write a coefficient.)

The correct way to balance the above equation is as follows: **2** H_2 + O_2 → **2** H_2O

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 (2x2=4) and 4 hydrogen on the right (2x2=4); there are 2 oxygen on the left and 2 oxygen on the right (2x1=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: $H_2 + O_2 \rightarrow H_2O$ ~~H_2O~~

   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: $H_2 + O_2 \rightarrow H$ ~~2~~ 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: $CO_2 + H_2O \rightarrow C_6H_{12}O_6 + O_2$, 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: $CO_2 + NH_3$ --> $OC(NH_2)_2 + H_2O$, 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.

1. H_2 + O_2 → H_2O
2. N_2 + H_2 → NH_3
3. S_8 + O_2 → SO_3
4. N_2 + O_2 → N_2O
5. HgO → Hg + O_2
6. CO_2 + H_2O → $C_6H_{12}O_6$ + O_2
7. Zn + HCl → $ZnCl_2$ + H_2
8. $SiCl_4$ + H_2O → H_4SiO_4 + HCl

9. $Na + H_2O \rightarrow NaOH + H_2$

10. $H_3PO_4 \rightarrow H_4P_2O_7 + H_2O$

11. $C_{10}H_{16} + Cl_2 \rightarrow C + HCl$

12. $CO_2 + NH_3 \rightarrow OC(NH_2)_2 + H_2O$

13. $Si_2H_3 + O_2 \rightarrow SiO_2 + H_2O$

14. $Al(OH)_3 + H_2SO_4 \rightarrow Al_2(SO_4)_3 + H_2O$

15. $Fe + O_2 \rightarrow Fe_2O_3$

16. $Fe_2(SO_4)_3 + KOH \rightarrow K_2SO_4 + Fe(OH)_3$

17. $C_7H_6O_2 + O_2 \rightarrow CO_2 + H_2O$

18. $H_2SO_4 + HI \rightarrow H_2S + I_2 + H_2O$

19. $FeS_2 + O_2 \rightarrow Fe_2O_3 + SO_2$

20. $Al + FeO \rightarrow Al_2O_3 + Fe$

21. $Fe_2O_3 + H_2 \rightarrow Fe + H_2O$

22. $Na_2CO_3 + HCl \rightarrow NaCl + H_2O + CO_2$

23. $K + Br_2 \rightarrow KBr$

24. $P_4 + O_2 \rightarrow P_2O_5$

25. $C_2H_2 + O_2 \rightarrow CO_2 + H_2O$

26. $K_2O + H_2O \rightarrow KOH$

27. $H_2O_2 \rightarrow H_2O + O_2$

28. $Al + O_2 \rightarrow Al_2O_3$

29. $C_7H_{16} + O_2 \rightarrow CO_2 + H_2O$

30. $Na_2O_2 + H_2O \rightarrow NaOH + O_2$

31. $SiO_2 + HF \rightarrow SiF_4 + H_2O$

32. $C + H_2O \rightarrow CO + H_2$

33. $KClO_3 \rightarrow KCl + O_2$

34. $H_3AsO_4 \rightarrow As_2O_5 + H_2O$

35. $KClO_3 \rightarrow KClO_4 + KCl$

36. $Al_2(SO_4)_3 + Ca(OH)_2 \rightarrow Al(OH)_3 + CaSO_4$

37. $P_4O_{10} + H_2O \rightarrow H_3PO_4$

38. $FeCl_3 + NH_4OH \rightarrow Fe(OH)_3 + NH_4Cl$

39. $Sb + O_2 \rightarrow Sb_4O_6$

40. $Ca_3(PO_4)_2 + SiO_2 \rightarrow P_4O_{10} + CaSiO_3$

41. $C_3H_8 + O_2 \rightarrow CO_2 + H_2O$

42. $N_2O_5 + H_2O \rightarrow HNO_3$

43. $Fe_2O_3 + CO \rightarrow Fe + CO_2$

44. $Al + HCl \rightarrow AlCl_3 + H_2$

45. $PCl_5 + H_2O \rightarrow HCl + H_3PO_4$

46. $H_3BO_3 \rightarrow H_4B_6O_{11} + H_2O$

47. $H_2S + Cl_2 \rightarrow S_8 + HCl$

48. $Mg + N_2 \rightarrow Mg_3N_2$

49. $Fe + H_2O \rightarrow Fe_3O_4 + H_2$

50. $NaOH + Cl_2 \rightarrow NaCl + NaClO + H_2O$

51. $Li_2O + H_2O \rightarrow LiOH$

52. $H_3PO_4 + HCl \rightarrow PCl_5 + H_2O$

53. $CaC_2 + H_2O \rightarrow C_2H_2 + Ca(OH)_2$

54. $HCl + K_2CO_3 \rightarrow KCl + H_2O + CO_2$

55. $Fe(OH)_3 \rightarrow Fe_2O_3 + H_2O$

56. $Ca(ClO_3)_2 \rightarrow CaCl_2 + O_2$

57. $Pb(NO_3)_2 \rightarrow PbO + NO_2 + O_2$

58. $C_2H_5OH + O_2 \rightarrow CO + H_2O$

59. $BaO + H_2O \rightarrow Ba(OH)_2$

60. $Xe + F_2 \rightarrow XeF_6$

61. $Ca + AlCl_3 \rightarrow CaCl_2 + Al$

62. $NH_4NO_3 \rightarrow N_2O + H_2O$

63. $NH_3 + NO \rightarrow N_2 + H_2O$

64. $Zn + NaOH + H_2O \rightarrow Na_2Zn(OH)_4 + H_2$

65. $H_3PO_3 \rightarrow H_3PO_4 + PH_3$

66. $C_4H_{10} + O_2 \rightarrow CO_2 + H_2O$

67. $Fe_2O_3 + C \rightarrow CO + Fe$

68. $Fe_3O_4 + H_2 \rightarrow Fe + H_2O$

69. $FeS + O_2 \rightarrow Fe_2O_3 + SO_2$

70. $Pb + Na + C_2H_5Cl \rightarrow Pb(C_2H_5)_4 + NaCl$

71. $NH_3 + O_2 \rightarrow NO + H_2O$

72. $I_2 + HNO_3 \rightarrow HIO_3 + NO_2 + H_2$

73. $Si + S_8 \rightarrow Si_2S_4$

74. $C_6H_6 + O_2 \rightarrow CO_2 + H_2O$

75. $Hg_2CO_3 \rightarrow Hg + HgO + CO_2$

76. $C_2H_5OH + O_2 \rightarrow CO_2 + H_2O$

77. $SiC + Cl_2 \rightarrow SiCl_4 + C$

78. $HClO_4 + P_4O_{10} \rightarrow H_3PO_4 + Cl_2O_7$

79. $Al_4C_3 + H_2O \rightarrow CH_4 + Al(OH)_3$

80. $BaCl_2 + Al_2(SO_4)_3 \rightarrow BaSO_4 + AlCl_3$

81. $V_2O_5 + HCl \rightarrow VOCl_3 + H_2O$

82. $(NH_4)_2Cr_2O_7 \rightarrow Cr_2O_3 + N_2 + H_2O$

83. $Ag_2S + KCN \rightarrow KAg(CN)_2 + K_2S$

84. $NaHCO_3 \rightarrow Na_2CO_3 + CO_2 + H_2O$

85. $Au_2S_3 + H_2 \rightarrow Au + H_2S$

86. $Fe_2(C_2O_4)_3 \rightarrow FeC_2O_4 + CO_2$

87. $ClO_2 + H_2O \rightarrow HClO_2 + HClO_3$

88. $Ca_3P_2 + H_2O \rightarrow Ca(OH)_2 + PH_3$

89. $KO_2 + CO_2 \rightarrow K_2CO_3 + O_2$

90. $As + NaOH \rightarrow Na_3AsO_3 + H_2$

91. $MgNH_4PO_4 \rightarrow Mg_2P_2O_7 + NH_3 + H_2O$

92. $MnO_2 + HCl \rightarrow MnCl_2 + H_2O + Cl_2$

93. $O_2 \rightarrow O_3$

94. $Ca(OH)_2 + H_3PO_4 \rightarrow CaHPO_4 + H_2O$

95. $Au_2O_3 \rightarrow Au + O_2$

96. $SrBr_2 + (NH_4)_2CO_3 \rightarrow SrCO_3 + NH_4Br$

97. $Hg(OH)_2 + H_3PO_4 \rightarrow Hg_3(PO_4)_2 + H_2O$

98. $Ca_3(PO_4)_2 + SiO_2 + C \rightarrow CaSiO_3 + P_4 + CO$

99. $I_4O_9 \rightarrow I_2O_6 + I_2 + O_2$ (numerous answers)

100. $C_2H_3Cl + O_2 \rightarrow CO_2 + H_2O + HCl$

Extra Credit (15 points!!!): Balance the following. You MUST show all of your work!!!

$[Cr(N_2H_4CO)_6]_4[Cr(CN)_6]_3 + KMnO_4 + H_2SO_4 \rightarrow K_2Cr_2O_7 + MnSO_4 + CO_2 + KNO_3 + K_2SO_4 + H_2O$