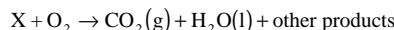
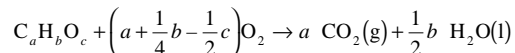


## HEAT OF COMBUSTION

The heat of combustion of a substance at 25°C can be calculated from the enthalpy of formation ( $\Delta_f H^\circ$ ) data in the table "Standard Thermodynamic Properties of Chemical Substances" in this Section. We can write the general combustion reaction as



For a compound containing only carbon, hydrogen, and oxygen, the reaction is simply



and the standard heat of combustion  $\Delta_c H^\circ$ , which is defined as the negative of the enthalpy change for the reaction (i.e., the heat released in the combustion process), is given by

$$\begin{aligned} \Delta_c H^\circ &= -a\Delta_f H^\circ(CO_2, g) - \frac{1}{2}b \Delta_f H^\circ(H_2O, l) + \Delta_f H^\circ(C_a H_b O_c) \\ &= 393.51 a + 142.915 b + \Delta_f H^\circ(C_a H_b O_c) \end{aligned}$$

This equation applies if the reactants start in their standard states (25°C and one atmosphere pressure) and the products return to the same conditions. The same equation applies to a compound containing another element if that element ends in its standard reference state (e.g., nitrogen, if the product is  $N_2$ ); in general, however, the exact products containing the other elements must be known in order to calculate the heat of combustion.

The following table gives the standard heat of combustion calculated in this manner for a few representative substances.

| Molecular formula           | Name                | $\Delta_c H^\circ / \text{kJ mol}^{-1}$ | Molecular formula         | Name                 | $\Delta_c H^\circ / \text{kJ mol}^{-1}$ |
|-----------------------------|---------------------|---|---------------------------|----------------------|---|
| <b>Inorganic substances</b> |                     |   |                           |                      |   |
| C                           | Carbon (graphite)   | 393.5                                   | $C_3H_8O$                 | 1-Propanol (l)       | 2021.3                                  |
| CO                          | Carbon monoxide (g) | 283.0                                   | $C_3H_8O_3$               | Glycerol (l)         | 1655.4                                  |
| $H_2$                       | Hydrogen (g)        | 285.8                                   | $C_4H_{10}O$              | Diethyl ether (l)    | 2723.9                                  |
| $H_3N$                      | Ammonia (g)         | 382.8                                   | $C_5H_{12}O$              | 1-Pentanol (l)       | 3330.9                                  |
| $H_4N_2$                    | Hydrazine (g)       | 667.1                                   | $C_6H_6O$                 | Phenol (s)           | 3053.5                                  |
| $N_2O$                      | Nitrous oxide (g)   | 82.1                                    | <b>Carbonyl compounds</b> |                      |   |
| <b>Hydrocarbons</b>         |                     |   | $CH_2O$                   | Formaldehyde (g)     | 570.7                                   |
| $CH_4$                      | Methane (g)         | 890.8                                   | $C_2H_2O$                 | Ketene (g)           | 1025.4                                  |
| $C_2H_2$                    | Acetylene (g)       | 1301.1                                  | $C_2H_4O$                 | Acetaldehyde (l)     | 1166.9                                  |
| $C_2H_4$                    | Ethylene (g)        | 1411.2                                  | $C_3H_6O$                 | Acetone (l)          | 1789.9                                  |
| $C_2H_6$                    | Ethane (g)          | 1560.7                                  | $C_3H_6O$                 | Propanal (l)         | 1822.7                                  |
| $C_3H_6$                    | Propylene (g)       | 2058.0                                  | $C_4H_8O$                 | 2-Butanone (l)       | 2444.1                                  |
| $C_3H_6$                    | Cyclopropane (g)    | 2091.3                                  | <b>Acids and esters</b>   |                      |   |
| $C_3H_8$                    | Propane (g)         | 2219.2                                  | $CH_2O_2$                 | Formic acid (l)      | 254.6                                   |
| $C_4H_6$                    | 1,3-Butadiene (g)   | 2541.5                                  | $C_2H_4O_2$               | Acetic acid (l)      | 874.2                                   |
| $C_4H_{10}$                 | Butane (g)          | 2877.6                                  | $C_2H_4O_2$               | Methyl formate (l)   | 972.6                                   |
| $C_5H_{12}$                 | Pentane (l)         | 3509.0                                  | $C_3H_6O_2$               | Methyl acetate (l)   | 1592.2                                  |
| $C_6H_6$                    | Benzene (l)         | 3267.6                                  | $C_4H_8O_2$               | Ethyl acetate (l)    | 2238.1                                  |
| $C_6H_{12}$                 | Cyclohexane (l)     | 3919.6                                  | $C_7H_6O_2$               | Benzoic acid (s)     | 3226.9                                  |
| $C_6H_{14}$                 | Hexane (l)          | 4163.2                                  | <b>Nitrogen compounds</b> |                      |   |
| $C_7H_8$                    | Toluene (l)         | 3910.3                                  | CHN                       | Hydrogen cyanide (g) | 671.5                                   |
| $C_7H_{16}$                 | Heptane (l)         | 4817.0                                  | $CH_3NO_2$                | Nitromethane (l)     | 709.2                                   |
| $C_{10}H_8$                 | Naphthalene (s)     | 5156.3                                  | $CH_5N$                   | Methylamine (g)      | 1085.6                                  |
| <b>Alcohols and ethers</b>  |                     |   | $C_2H_3N$                 | Acetonitrile (l)     | 1247.2                                  |
| $CH_4O$                     | Methanol (l)        | 726.1                                   | $C_2H_5NO$                | Acetamide (s)        | 1184.6                                  |
| $C_2H_6O$                   | Ethanol (l)         | 1366.8                                  | $C_3H_9N$                 | Trimethylamine (g)   | 2443.1                                  |
| $C_2H_6O$                   | Dimethyl ether (g)  | 1460.4                                  | $C_5H_5N$                 | Pyridine (l)         | 2782.3                                  |
| $C_2H_6O_2$                 | Ethylene glycol (l) | 1189.2                                  | $C_6H_7N$                 | Aniline (l)          | 3392.8                                  |