

## Thermochemical Data of Selected Elements and Compounds (at 25°C and 100.000 kPa)

Substance	$\Delta H_f^\circ$ (kJ/mol)	$S^\circ$ (J/K·mol)	$\Delta G_f^\circ$ (kJ/mol)	Substance	$\Delta H_f^\circ$ (kJ/mol)	$S^\circ$ (J/K·mol)	$\Delta G_f^\circ$ (kJ/mol)
Al <sub>(s)</sub>	0	28.3	0	NH <sub>3(g)</sub>	-46.1	192.5	-16.5
Al <sub>2</sub> O <sub>3(s)</sub>	-1675.7	50.9	-1582.3	N <sub>2</sub> H <sub>4(1)</sub>	50.6	121.2	149.3
Br <sub>2(1)</sub>	0	151.6	0	NH <sub>4</sub> Cl <sub>(s)</sub>	-314.4	94.6	-202.9
HBr <sub>(g)</sub>	-36.4	198.7	-53.5	NH <sub>4</sub> NO <sub>3(s)</sub>	-365.6	151.1	-183.9
Ca <sub>(s)</sub>	0	41.4	0	NO <sub>(g)</sub>	90.3	210.8	86.6
CaCO <sub>3(s)</sub> (calcite)	-1206.9	92.9	-1128.8	NO <sub>2(g)</sub>	33.2	240.1	51.3
CaCl <sub>2(s)</sub>	-795.8	104.6	-748.1	N <sub>2</sub> O <sub>(g)</sub>	82.1	219.9	104.2
C <sub>(s)</sub> (graphite)	0	5.7	0	N <sub>2</sub> O <sub>4(g)</sub>	9.2	304.3	97.9
C <sub>(s)</sub> (diamond)	1.9	2.38	2.90	HNO <sub>3(1)</sub>	-174.1	155.6	-80.7
CCl <sub>4(1)</sub>	-135.4	216.4	-65.2	O <sub>(g)</sub>	249.2	161.1	231.7
CCl <sub>4(g)</sub>	-96.0	309.9	-60.6	O <sub>2(g)</sub>	0	205.1	0
CHCl <sub>3(1)</sub>	-134.5	201.7	-73.7	O <sub>3(g)</sub>	142.7	238.9	163.2
CH <sub>4(g)</sub>	-74.8	186.3	-50.7	P <sub>4(s)</sub> (white)	0	164.4	0
C <sub>2</sub> H <sub>2(g)</sub>	226.7	200.9	209.2	P <sub>4(s)</sub> (red)	-70.4	91.2	-48.4
C <sub>2</sub> H <sub>4(g)</sub>	52.3	219.6	68.2	PH <sub>3(g)</sub>	5.4	310.2	13.4
C <sub>2</sub> H <sub>6(g)</sub>	-84.7	229.6	-32.8	PCl <sub>3(g)</sub>	-287.0	311.8	-267.8
C <sub>3</sub> H <sub>8(g)</sub>	-103.8	269.9	-23.5	P <sub>4</sub> O <sub>6(s)</sub>	-2144.3	345.6	-2247.4
C <sub>6</sub> H <sub>6(1)</sub>	49.0	172.8	124.5	P <sub>4</sub> O <sub>10(s)</sub>	-2984.0	228.9	-2697.7
CH <sub>3</sub> OH <sub>(1)</sub>	-238.7	126.8	-166.3	H <sub>3</sub> PO <sub>4(s)</sub>	-1279.0	110.5	-1119.1
C <sub>2</sub> H <sub>5</sub> OH <sub>(1)</sub>	-277.7	160.7	-178.8	K <sub>(s)</sub>	0	64.2	0
CH <sub>3</sub> CO <sub>2</sub> H <sub>(1)</sub>	-484.5	159.8	-389.9	KCl <sub>(s)</sub>	-436.7	82.6	-409.1
CO <sub>(g)</sub>	-110.5	197.7	-137.2	KClO <sub>3(s)</sub>	-397.7	143.1	-296.3
CO <sub>2(g)</sub>	-393.5	213.7	-394.4	KOH <sub>(s)</sub>	-428.8	78.9	-379.1
COCl <sub>2(g)</sub>	-218.8	283.5	-204.6	Ag <sub>(s)</sub>	0	42.6	0
CS <sub>2(g)</sub>	+117.4	237.8	67.1	AgCl <sub>(s)</sub>	-127.1	96.2	-109.8
Cl <sub>2(g)</sub>	0	223.1	0	AgNO <sub>3(s)</sub>	-124.4	140.9	-33.4
HCl <sub>(g)</sub>	-92.3	186.9	-95.3	Na <sub>(s)</sub>	0	51.2	0
Cr <sub>(s)</sub>	0	23.8	0	NaCl <sub>(s)</sub>	-411.2	72.1	-384.1
CrCl <sub>3(s)</sub>	-556.5	123.0	-486.1	NaOH <sub>(s)</sub>	-425.6	64.5	-379.5
Cu <sub>(s)</sub>	0	33.2	0	Na <sub>2</sub> CO <sub>3(s)</sub>	-1130.7	135.0	-1044.0
CuO <sub>(s)</sub>	-157.3	42.6	-129.7	S <sub>(s)</sub> (rhombic)	0	31.8	0
CuCl <sub>(s)</sub>	-137.2	86.2	-119.9	S <sub>(g)</sub>	278.8	167.8	238.3
CuCl <sub>2(s)</sub>	-220.1	108.1	-175.7	SF <sub>6(g)</sub>	-1209.0	291.8	-1105.3
F <sub>2(g)</sub>	0	202.8	0	H <sub>2</sub> S <sub>(g)</sub>	-20.6	205.8	-33.6
HF <sub>(g)</sub>	-271.1	173.8	-273.2	SO <sub>2(g)</sub>	-296.8	248.2	-300.2
He <sub>(g)</sub>	0	126.0	0	SO <sub>3(g)</sub>	-395.7	256.8	-371.1
H <sub>2(g)</sub>	0	130.7	0	H <sub>2</sub> SO <sub>4(1)</sub>	-814.0	156.9	-690.0
H <sub>2</sub> O <sub>(1)</sub>	-285.8	69.9	-237.1	Sn <sub>(s)</sub> (white)	0	51.6	0
H <sub>2</sub> O <sub>(g)</sub>	-241.8	188.8	-228.6	Sn <sub>(s)</sub> (gray)	-2.1	44.1	0.1
H <sub>2</sub> O <sub>2(1)</sub>	-187.8	109.6	-120.4	SnCl <sub>2(s)</sub>	-325.1	122.6	-302.1
Fe <sub>(s)</sub>	0	27.8	0	SnCl <sub>4(1)</sub>	-155.3	258.6	-440.1
FeO <sub>(s)</sub>	-272.0	57.6	245.1				
Fe <sub>2</sub> O <sub>3(s)</sub>	-824.2	87.4	-742.2				
Fe <sub>3</sub> O <sub>4(s)</sub>	-1118.4	146.4	-1015.4				
FeCl <sub>2(s)</sub>	-341.8	118.0	-302.3				
FeCl <sub>3(s)</sub>	-399.5	142.3	-344.0				
FeS <sub>2(s)</sub>	-178.2	52.9	-166.9				
Pb <sub>(s)</sub>	0	64.8	0				
PbCl <sub>2(s)</sub>	-359.4	136.0	-314.1				
Mg <sub>(s)</sub>	0	32.7	0				
MgCl <sub>2(s)</sub>	-641.3	89.6	-591.8				
MgO <sub>(s)</sub>	-601.7	26.9	-569.4				
Hg <sub>(1)</sub>	0	76.0	0				
HgS <sub>(s)</sub>	-58.2	82.4	-50.6				
Ne <sub>(g)</sub>	0	146.2	0				
N <sub>2(g)</sub>	0	191.6	0				

**TABLE 8.3 Thermochemical Properties of Some Fuels**

Fuel	Combustion Enthalpy		
	kJ/mol	kJ/g	kJ/mL
Hydrogen, H <sub>2</sub>	-285.8	-141.8	-9.9*
Ethanol, C <sub>2</sub> H <sub>5</sub> OH	-1367	-29.7	-23.4
Graphite, C	-393.5	-32.8	-73.8
Methane, CH <sub>4</sub>	-890.3	-55.5	-30.8*
Methanol, CH <sub>3</sub> OH	-726.4	-22.7	-17.9
Octane, C <sub>8</sub> H <sub>18</sub>	-5470	-47.9	-33.6
Toluene, C <sub>7</sub> H <sub>8</sub>	-3910	-42.3	-36.7

\*Calculated for the compressed liquid at 0°C

### MORE HEATS OF COMBUSTION $\Delta H_c$ (with H<sub>2</sub>O liquid forming)

<b>FUEL</b>	<b>kJ/mol</b>
C <sub>2</sub> H <sub>6</sub> (ethane)	- 1,437
C <sub>3</sub> H <sub>8</sub> (propane)	- 2,202
C <sub>4</sub> H <sub>10</sub> (butane)	- 2,659
C <sub>5</sub> H <sub>12</sub> (pentane)	- 3,507
C <sub>6</sub> H <sub>14</sub> (hexane)	- 3,857

Fuel	kJ/g	kcal/g	BTU/lb
Hydrogen	141.9	33.9	61,000
Gasoline	47.0	11.3	20,000
Diesel	45.0	10.7	19,300
Ethanol	29.8	7.1	12,000
Propane	49.9	11.9	21,000
Butane	49.2	11.8	21,200
Wood	15.0	3.6	6,000
Coal (Lignite)	15.0	4.4	8,000
Coal (Anthracite)	27.0	7.8	14,000
Natural Gas	54.0	13.0	23,000