Table A.5 Equilibrium constants, K_p, of some combustion reactions

Temperature, K	Dissociation of water vapour, $Kp = \frac{P_{H_2O}}{P_{H_2} \times P_{O_2}^{0.5}}$	Dissociation of carbon dioxide, $Kp = \frac{P_{CO_2}}{P_{CO} \times P_{O_2}^{0.5}}$	Producer gas equilibrium, $Kp = \frac{P_{CO}^2}{P_{CO_2}}$	Formation of carbon monoxide, $Kp = \frac{P_{CO}}{P_{O_2}^{0.5}}$	Water gas equilibrium, $Kp = \frac{P_{CO} \times P_{H_2O}}{P_{CO_2} \times P_{H_2}}$	Dissociation of hydrogen, $Kp = \frac{P_{H_2}}{P_H^2}$	Dissociation of oxygen, $Kp = \frac{P_{O_2}}{P_O^2}$	Dissociation of water vapour into H_2 and OH, $Kp = \frac{P_{H_2O}}{P_{OH} \times P_{H_2}^{0.5}}$	Formation of nitric oxide, $Kp = \frac{P_{NO}}{P_{O_2}^{0.5} \times P_{N_2}^{0.5}}$
298.16	1.11×10^{40}	1.11×10^{45}	1.01×10^{-21}	1.12×10^{24}	1.01×10^{-5}	—	—	—	—
300	6.12×10^{39}	5.49×10^{44}	1.55×10^{-21}	8.48×10^{23}	1.11×10^{-5}	5.50×10^{70}	1.23×10^{80}	1.95×10^{46}	8.14×10^{-16}
400	1.74×10^{29}	2.57×10^{32}	5.21×10^{-14}	1.34×10^{19}	6.76×10^{-4}	5.50×10^{51}	3.24×10^{58}	8.13×10^{33}	6.99×10^{-12}
500	7.68×10^{22}	1.01×10^{25}	1.77×10^{-9}	1.79×10^{16}	7.60×10^{-3}	—	—	—	—
600	4.29×10^{18}	1.16×10^{20}	1.87×10^{-6}	2.17×10^{14}	3.69×10^{-2}	4.27×10^{32}	7.24×10^{36}	2.95×10^{21}	6.04×10^{-8}
700	3.83×10^{15}	3.45×10^{16}	$2..67 \times 10^{-4}$	9.22×10^{12}	1.11×10^{-1}	—	—	—	—
800	1.94×10^{13}	7.85×10^{13}	1.09×10^{-2}	8.55×10^{11}	2.48×10^{-1}	1.18×10^{23}	9.77×10^{25}	1.66×10^{15}	5.62×10^{-6}
900	3.14×10^{11}	6.93×10^{11}	1.92×10^{-1}	1.33×10^{11}	4.53×10^{-1}	—	—	—	—
1,000	1.15×10^{10}	1.58×10^{10}	1.90	3.00×10^{10}	7.29×10^{-1}	1.94×10^{17}	2.75×10^{19}	2.75×10^{11}	8.55×10^{-5}
1,100	7.63×10^{8}	7.21×10^{8}	1.22×10^{1}	8.80×10^{9}	1.06	—	—	—	—
1,200	7.92×10^{7}	5.52×10^{7}	5.71×10^{1}	3.15×10^{9}	1.44	2.57×10^{13}	1.15×10^{15}	8.36×10^{8}	5.25×10^{-4}
1,300	1.16×10^{7}	6.29×10^{6}	2.08×10^{2}	1.31×10^{9}	1.84	—	—	—	—
1,400	2.23×10^{5}	9.81×10^{5}	6.29×10^{2}	6.17×10^{8}	2.27	4.24×10^{10}	8.55×10^{11}	1.31×10^{7}	1.92×10^{-3}
1,500	5.32×10^{5}	1.97×10^{5}	1.62×10^{3}	3.19×10^{8}	2.70	—	—	—	—
1,600	1.50×10^{5}	4.83×10^{4}		1.80×10^{8}	3.09	3.39×10^{8}	3.76×10^{9}	5.73×10^{5}	5.08×10^{-3}
1,800	1.83×10^{4}	4.70×10^{3}		6.75×10^{7}	3.90	7.82×10^{6}	5.50×10^{7}	5.01×10^{4}	1.08×10^{-2}
2,000	3.40×10^{3}	7.30×10^{2}		3.06×10^{7}	4.66	3.79×10^{5}	1.86×10^{6}	7.11×10^{3}	1.98×10^{-2}
2,200	8.53×10^{2}	1.61×10^{2}		1.59×10^{7}	5.31	3.16×10^{4}	1.16×10^{5}	1.44×10^{3}	3.25×10^{-2}
2,400	2.69×10^{2}	4.59×10^{1}		9.14×10^{6}	5.85	3.96×10^{3}	1.14×10^{4}	3.78×10^{2}	4.91×10^{-2}
2,600	1.01×10^{1}	1.60×10^{1}		5.74×10^{6}	6.31	6.81×10^{2}	1.61×10^{3}	1.22×10^{2}	6.97×10^{-2}
2,800	4.35×10^{1}	6.41		3.78×10^{6}	6.78	1.50×10^{2}	2.99×10^{2}	4.68×10^{1}	9.38×10^{-2}
3,000	2.10×10^{1}	2.94		2.62×10^{6}	7.13	4.02×10^{1}	6.92×10^{1}	2.00×10^{1}	1.22×10^{-1}
3,200	1.11×10^{1}	1.50		1.88×10^{6}	7.43	1.27×10^{1}	1.93×10^{1}	9.62	1.52×10^{-1}
3,500	4.93	6.30×10^{-1}		1.24×10^{6}	7.83	2.87	3.72	3.78	2.03×10^{-1}
4,000	1.66	2.00×10^{-1}		6.93×10^{5}	8.32	3.93×10^{-1}	4.15×10^{-1}	1.08	2.98×10^{-1}

Note : Carbon, where involved, is in the form of solid ß- graphite.

Table A.3 Enthalpy of gases above 0°C
(Mass basis, kcal/kg)

t°C	O_2	N_2	Air	CO	H_2	CO_2	H_2O vapour	Methane	Ethylene	Ethane	Benzene vapour	Propane
100	22.0	24.8	24.0	24.9	344	20.8	44.5	54.5	38.8	45.0	27.3	40.7
200	44.7	49.8	48.4	50.0	689	43.8	90.2	118.0	86.1	100.1	63.1	91.2
300	68.0	75.0	73.1	75.6	1037	68.6	136.8	190.4	141.2	164.5	106.5	151.3
400	92.2	100.7	98.4	101.7	1386	94.5	185.1	270.7	202.9	237.5	156.1	221.2
500	117.0	127.0	124.1	128.3	1734	122.1	235.1	359.3	270.9	318.2	210.6	300.7
600	142.2	153.6	150.4	155.7	2087	150.3	286.4	454.6	344.2	405.5	269.2	390.0
700	167.9	180.8	177.2	183.4	2442	179.3	339.0	555.9	421.7	499.2	331.2	488.9
800	194.2	208.9	204.8	212.2	2802	209.9	394.7	664.3	502.4	598.6	396.1	597.6
900	220.6	237.2	232.5	241.0	3166	239.1	451.5	777.6	585.7	702.3	463.5	715.9
1,000	247.4	266.1	260.7	270.0	3533	269.8	509.5	896.1	671.2	809.4	533.0	844.0
1,100	274.2	295.4	289.1	300.0	3902	301.0	569.0					
1,200	301.3	324.8	317.8	329.8	4287	332.2	629.5					
1,300	329.3	354.1	346.6	360.1	4670	363.7	691.3					
1,400	356.8	384.4	375.7	390.3	5057	395.8	755.4					
1,500	384.2	414.5	405.6	420.3	5448	427.9	819 3					
1,600	411.8	444.3	434.9	451.2	5842	460.0	884.5					
1,700	439.6	474.6	464.4	481.8	6242	492.2	952.2					
1,800	468.3	505.7	494.2	512.7	6653	524.9	1019.1					
1,900	497.3	535.8	523.6	543.9	7061	557.5	1086.3					
2,000	526.0	566.8	554.0	574.7	7473	590.0	1155.7					
2,100	554.3	597.4	583.8	606.4	7887	622.9	1226.2					
2,200	582.7	629.0	613.1	637.7	8318	656.0	1295.6					
2,300	612.0	660.0	644.2	669.1	8741	689.0	1367.3					
2,400	641.7	690.5	673.9	700.8	9170	721.7	1437.4					
2,500	670.7	722.8	705.3	732.6	9601	755.1	1508.4					
2,600	700.7	754.5	735.4	764.7	10037	787.7	1581.7					
2,700	729.5	785.4	766.4	796.1	10463	821.1	1653.0					
2,800	759.1	817.4	796.7	827.5	10905	854.0	1726.7					
2,900	789.8	848.7	827.2	859.2	11352	887.8	1799.6					
3,000	820.8	880.1	857.8	891.0	11788	921.2	1870.0					

Note : Values for the undissociated gas. At temperatures above 1,500°C dissociation must be taken into account.

Table A.4 Enthalpy of gases above 0°C
(Volume basis, kcal/Nm³)

Appendix

Table A.1 Mean specific heat of gases at constant pressure between O°C and T°C (Mass basis, kcal/kg . deg C)

t°C	O_2	N_2	Air	CO	H_2	CO_2	H_2O vapour	Methane	Ethylene	Ethane	Benzene vapour	Propane	Butane
0	0.218	0.248	0.240	0.249	3.40	0.195	0.443	0.496	0.342	0.397	0.224	0.359	0.342
100	0.220	0.248	0.240	0.249	3.44	0.208	0.445	0.545	0.387	0.450	0.273	0.407	0.390
200	0.223	0.249	0.242	0.250	3.45	0.219	0.450	0.590	0.431	0.501	0.316	0.456	0.438
300	0.227	0.250	0.243	0.252	3.46	0.228	0.456	0.634	0.470	0.548	0.356	0.504	0.486
400	0.230	0.252	0.246	0.254	3.46	0.236	0.462	0.677	0.508	0.594	0.390	0.553	0.534
500	0.234	0.254	0.248	0.257	3.47	0.244	0.470	0.719	0.542	0.636	0.422	0.601	0.582
600	0.237	0.256	0.250	0.259	3.48	0.250	0.477	0.758	0.574	0.676	0.448	0.650	0.630
700	0.240	0.258	0.253	0.262	3.49	0.256	0.485	0.794	0.602	0.713	0.474	0.698	0.678
800	0.243	0.261	0.256	0.265	3.50	0.261	0.494	0.830	0.628	0.748	0.494	0.747	0.726
900	0.245	0.264	0.258	0.268	3.51	0.266	0.501	0.864	0.651	0.780	0.514	0.795	0.774
1,000	0.247	0.266	0.260	0.270	3.53	0.270	0.510	0.896	0.671	0.810	0.534	0.844	0.822
1,100	0.249	0.268	0.263	0.273	3.55	0.274	0.517						
1,200	0.251	0.271	0.265	0.275	3.57	0.277	0.525						
1,300	0.253	0.272	0.267	0.277	3.59	0.280	0.531						
1,400	0.255	0.275	0.269	0.278	3.61	0.283	0.540						
1,500	0.256	0.276	0.271	0.280	3.63	0.285	0.546						
1,600	0.258	0.278	0.272	0.282	3.65	0.288	0.552						
1,700	0.258	0.280	0.273	0.283	3.67	0.290	0.560						
1,800	0.260	0.281	0.274	0.285	3.69	0.292	0.566						
1,900	0.262	0.282	0.276	0.286	3.71	0.293	0.572						
2,000	0.263	0.284	0.277	0.287	3.74	0.295	0.577						
2,100	0.264	0.285	0.278	0.289	3.76	0.297	0.583						
2,200	0.265	0.286	0.279	0.290	3.78	0.298	0.588						
2,300	0.266	0.288	0.280	0.291	3.80	0.300	0.595						
2,400	0.267	0.288	0.281	0.292	3.82	0.301	0.598						
2,500	0.268	0.289	0.282	0.293	3.84	0.302	0.603						
2,600	0.269	0.291	0.283	0.294	3.86	0.303	0.608						
2,700	0.270	0.291	0.284	0.295	3.87	0.304	0.612						
2,800	0.271	0.292	0.284	0.295	3.89	0.305	0.617						
2,900	0.272	0.293	0.285	0.296	3.91	0.306	0.621						
3,000	0.274	0.294	0.286	0.297	3.93	0.307	0.623						

Note : Values for the undissociated gas. At temperatures above 1,500°C dissociation must be taken into account.

Table A.2 Mean specific heat of gases at constant pressure between O°C and T°C (Volume basis, kcal/Nm³ deg C)

Table 2.1 Heat of formation of some important species at 25°C, 0.1 MPa [1]

Chemical formula	*Species name*	*State*	*Standard heat of formation (kJ/mol)*
O_2	Oxygen	Gas	0.0
O	Element oxygen	Gas	247.4
H_2	Hydrogen	Gas	0.0
H	Element hydrogen	Gas	218.1
OH	Hydroxyl	Gas	42.3
H_2O	Water	Gas	−242.0
H_2O	Water	Liquid	−286.0
H_2O_2	Hydrogen peroxide	Liquid	−187.5
H_2O_2	Hydrogen peroxide	Gas	−133.2
C	Graphite	Solid	0.0
CO	Carbon monoxide	Gas	−110.5
CO_2	Carbon dioxide	Gas	−394.0
CH_4	Methane	Gas	−74.5
C_2H_6	Ethane	Gas	−86.2
C_3H_8	Propane	Gas	−103.8
C_4H_{10}	Butane (n)	Gas	−124.7
C_4H_{10}	Butane (iso)	Gas	−131.8
C_2H_2	Acetylene	Gas	226.9
$CH_{1.842}$	Kerosene	Liquid	−51.6
CH_3OH	Methyl alcohol	Gas	−201.0
CH_3OH	Methyl alcohol	Liquid	−238.6
N_2	Nitrogen	Gas	0
N	Element nitrogen	Gas	471.8
N_2H_4	Hydrazine	Liquid	50.4
HNO_3	Nitric acid	Liquid	−171.8
Cl_2	Chlorine	Gas	0
Cl	Chlorine atom	Gas	121.4
HCl	Hydrogen chloride	Gas	−92.1
NH_4NO_3	Ammonium nitrate	Solid	−365.3
NH_4ClO_4	Ammonium per chlorate	Solid	−290.5
NH_4Cl	Ammonium chloride	Liquid	−315.6
$(CH_3)_2N_2H_2$	UDMH	Liquid	88.4
N_2O_4	Nitrogen tetroxide	Gas	9.63
NO_2	Nitrogen dioxide	Gas	33.9
NO	Nitric acid	Gas	90.4