ΠΑΡΑΡΤΗΜΑ 1

ΜΟΝΑΔΕΣ ΚΑΙ ΠΑΡΑΓΟΝΤΕΣ ΜΕΤΑΤΡΟΠΗΣ ΣΤΟ ΣΥΣΤΗΜΑ SI (FERGUSON, 1986)

Table 1.1 Names of International Units

PHYSICAL QUANTITY	NAME OF UNIT	SYMBOL	FORMULA
	BASIC UNITS		
Length	meter	m	
Mass	kilogram	kg	
Time	seconds	s	
Electric current	ampere	A	
Temperature	kelvin	K	
Luminous intensity	candela	cd	
	DERIVED UNITS		
Area	square meter	m^2	
Volume	cubic meter	m^3	
Frequency	hertz	Hz	(s^{-1})
Density	kilogram per cubic meter	kg/m^3	
Velocity	meter per second	m/s	
Angular velocity	radian per second	rad/s	
Acceleration	meter per second squared	m/s^2	
Angular acceleration	radian per second squared	rad/s^2	
Force	newton	N	$(kg \cdot m/s^2)$
Pressure and stress	pascal	Pa	(N/m^2)
Kinematic viscosity	square meter per second	m^2/s	
Dynamic viscosity	pascal-second	Pa · s	$(N \cdot s/m^2)$
Work, energy, quantity of heat	joule	J	$(N \cdot m)$
Power	watt	W	(J/s)
Electric charge	coulomb	C	$(A \cdot s)$
Voltage, potential difference, electromotive force	volt	V	(W/A)
Electric field strength	volt per meter	V/m	
Electric resistance	ohm	Ω	(V/A)
Electric capacitance	farad	F	$(A \cdot s/V)$
Magnetic flux	weber	Wb	$(V \cdot s)$
Inductance	henry	H	$(V \cdot s/A)$
Wave number	1 per meter	m^{-1}	
Entropy	joule per kelvin	J/K	
Specific heat	joule per kilogram kelvin	$J\,kg^{-1}\,K^{-1}$	
Thermal conductivity	watt per meter kelvin	$W/m^{-1}\,K^{-1}$	
Radiant intensity	watt per steradian	W/sr	
	SUPPLEMENTARY UNITS		
Plane angle	radian	rad	
Solid angle	steradian	sr	

Table 1.2 Names of Multiples and Submultiples Of SI Units May Be Formed by Application of Prefixes

FACTOR BY WHICH UNIT IS MULTIPLIED	PREFIX	SYMBOL
10^{12}	tera	T
10^{9}	giga	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	da
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a

Table 1.3 Physical constants

QUANTITY	SYMBOL	VALUE	ERROR (ppm)	UNIT
Speed of light in vacuum	c	2.997925×10^{8}	0.33	$m \cdot s^{-1}$
Gravitational constant	G	6.6732×10^{-11}	460	$N \cdot m^2 \cdot kg^{-2}$
Avogadro constant	N_A	6.022169×10^{26}	6.6	$kmole^{-1}$
Boltzmann constant	k	1.380622×10^{-23}	43	$J \cdot K^{-1}$
Gas constant	R	8.31434×10^{3}	42	$J \cdot kmole^{-1} \cdot K^{-1}$
Volume of ideal gas, standard conditions	V_G	2.24136×10^{1}	—	$m^3 \cdot kmole^{-1}$
Planck constant	h	6.626196×10^{-34}	7.6	$J \cdot s$
	$h/2\pi$	$1.0545919 \times 10^{-34}$	7.6	$J \cdot s$
Electron charge	e	$1.6021917 \times 10^{-19}$	4.4	C
Electron rest mass	m_e	9.109558×10^{-31}	6.0	kg
		5.485930×10^{-4}	6.2	u[a]
Stefan–Boltzmann constant	σ	5.66961×10^{-8}	170	$W \cdot m^{-2} \cdot K^{-4}$

[a]The unified atomic mass unit (u) is equal to the fraction $\frac{1}{12}$ of the mass of an atom of the nuclide ^{12}C.

Table 1.4 Conversion To SI Units[a]

MULTIPLY THIS UNIT	BY	TO OBTAIN THIS SI UNIT
	ACCELERATION	
ft/s^2	3.048 * E − 01	$meter/second^2$
free fall (standard gravity)	9.806 65 * E + 00	$meter/second^2$
$in./s^2$	2.54 * E − 02	$meter/second^2$
	AREA	
ft^2	9.290 304 * E − 02	$meter^2$
$in.^2$	6.4516 * E − 04	$meter^2$
	DENSITY	
$gram/cm^3$	1.00 * E + 03	$kilogram/meter^3$
$lbm/in.^3$	2.767 990E + 04	$kilogram/meter^3$
lbm/ft^3	1.601 846E + 01	$kilogram/meter^3$
$slug/ft^3$	5.153 788E + 02	$kilogram/meter^3$
	ENERGY	
British thermal unit (mean)	1.055 87E + 03	joule
British thermal unit (International Steam Tables)	1.055 06E + 03	joule
British thermal unit (Thermochemical)	1.054 35E + 03	joule
calorie (mean)	4.190 * E + 00	joule
calorie (International Steam Tables)	4.1868E + 00	joule
calorie (Thermochemical)	4.184E + 00	joule
electron volt	1.602 19E − 19	joule
erg	1.00 * E − 07	joule
ft lbf	1.355 82E + 00	joule
joule (International of 1948)	1.000 165E + 00	joule
watt h	3.60 * E + 03	joule
kW h	3.60 * E + 06	joule
	ENERGY/AREA · TIME	
Btu (thermochemical)/ft^2 s	1.134E + 04	$watt/meter^2$
Btu (thermochemical)/ft^2 min	1.891E + 02	$watt/meter^2$
Btu (thermochemical)/ft^2 h	3.152E + 00	$watt/meter^2$
Btu (thermochemical)/$in.^2$ s	1.634E + 06	$watt/meter^2$
calorie (thermochemical)/cm^2 min	6.973E + 02	$watt/meter^2$
erg/cm^2 · s	1.00 * E − 03	$watt/meter^2$
$watt/cm^2$	1.00 * E + 04	$watt/meter^2$
	FORCE	
dyne	1.00 * E − 05	newton
kilogram force (kgf)	9.806 65 * E + 00	newton
kilopond force	9.806E + 00	newton
kip	4.448E + 03	newton
lbf (pound force, avoirdupois)	4.448E + 00	newton
poundal	1.382E − 01	newton

Table 1.4 Conversion To SI Units

MULTIPLY THIS UNIT	BY	TO OBTAIN THIS SI UNIT
	LENGTH	
angstrom	1.00 * E − 10	meter
ft	3.048 * E − 01	meter
in.	2.54 * E − 02	meter
micron	1.00 * E − 06	meter
mil	2.54 * E − 05	meter
	MASS	
kgf s^2/meter (mass)	9.806 65 * E + 00	kilogram
kilogram - mass	1.00 * E + 00	kilogram
lbm (pound mass, avoirdupois)	4.535 924E − 01	kilogram
slug	1.459 390E + 01	kilogram
	POWER	
Btu (thermochemical)/s	1.054E + 03	watt
Btu (thermochemical)/min	1.757E + 01	watt
calorie (thermochemical)/s	4.184 * E + 00	watt
calorie (thermochemical)/min	6.973E − 02	watt
ft lbf/h	3.766E − 04	watt
ft lbf/min	2.259E − 02	watt
ft lbf/s	1.355E + 00	watt
hp (550 ft lbf/s)	7.456E + 02	watt
kilocalorie (thermochemical)/min	6.973E + 01	watt
kilocalorie (thermochemical)/s	4.184 * E + 03	watt
	PRESSURE	
atmosphere	1.013 25 * E + 05	pascal
bar	1.00 * E + 05	pascal
dyne/cm^2	1.00 * E − 01	pascal
in. of mercury (60°F)	3.376 85E + 03	pascal
in. of water (60°F)	2.4884E + 02	pascal
kgf/cm^2	9.806 65 * E + 04	pascal
lbf/ft^2	4.788 026E + 01	pascal
$lbf/in.^2$ (psi)	6.894 757 2E + 03	pascal
mm of mercury (0°C)	1.333 224E + 02	pascal
torr (0°C)	1.333 224E + 02	pascal
N/m^2	1.00 * E + 00	pascal
	SPEED	
miles/h	4.4704E − 01	meter/s
ft/min	5.08E − 03	meter/s
in./s	2.54 * E − 02	meter/s
	TEMPERATURE	
Celsius	$T_K = T_C + 273.15$	kelvin
Fahrenheit	$T_K = (5/9)(T_F + 459.67)$	kelvin
Fahrenheit	$T_C = (5/9)(T_F - 32)$	celsius

Table 1.4 Conversion To SI Units[a] (*Continued*)

MULTIPLY THIS UNIT	BY	TO OBTAIN THIS SI UNIT
	THERMAL CONDUCTIVITY	
Btu/h ft °F	1.731E + 00	watt/meter kelvin
Btu/s in. °F	7.478E + 04	watt/meter kelvin
	VISCOSITY	
centistoke	1.00 * E − 06	meter^2/second
ft^2/s	9.290 304 * E − 02	meter^2/second
in.^{2}/s	6.4516 * E − 04	meter^2/second
centipoise	1.00 * E − 03	pascal-second
lbf s/ft^2	4.788 026E + 01	pascal-second
poise	1.00 * E − 01	pascal-second
lbf s/in.^{2} (reyn)	6.894 757E + 03	pascal-second
rhe (1/pascal s)	1.00 * E + 01	meter^2/newton second
Saybolt Sec Universal[b]		
	VOLUME	
fluid ounce (U.S. fluid)	2.957 353E − 05	meter^3
ft^3	2.831 685E − 02	meter^3
gallon (U.K. liquid)	4.546 092E − 03	meter
gallon (U.S. dry)	4.404 884E − 03	meter^3
gallon (U.S. liquid)	3.785 412E − 03	meter^3
in.^{3}	1.638 706E − 05	meter^3
litre	1.00 * E − 03	meter^3
	TORQUE	
ft lbf	1.355 82E + 00	N-m
	SPECIFIC FUEL CONSUMPTION	
lbm/hp h	6.083 6E − 01	kg/kw - h

[a] Factors with asterisk are exact.
[b] Saybolt Sec Universal and other units see Table B.5.

ΠΑΡΑΡΤΗΜΑ 2

ΒΑΣΙΚΕΣ ΣΧΕΣΕΙΣ ΜΗ ΑΝΤΙΔΡΩΝΤΩΝ ΜΙΓΜΑΤΩΝ ΚΑΙ ΠΑΡΑΓΩΓΟΙ ΘΕΡΜΟΔΥΝΑΜΙΚΗΣ

Για μίγμα J συστατικών ισχύουν οι παρακάτω τύποι:

Συνολική μάζα: $m = \sum_{i=1}^{J} m_i$

Κλάσμα μάζας: $x_i = m_i/m$

Συνολικά moles: $N = \sum_{i=1}^{J} N_i$

Κλάσμα moles: $x_i = N_i/N$

Συνολική εσωτερική ενέργεια: $u = \sum_{i=1}^{J} x_i u_i$ $\qquad$ $U = \sum_{i=1}^{J} N_i u_i$

Ανάλογες σχέσεις για την ενθαλπία: $h = \sum_{i=1}^{J} y_i h_i$ $\qquad$ $H = \sum_{i=1}^{J} N_i h_i$

Μοριακό βάρος μίγματος: $M = \sum_{i=1}^{J} x_i M_i$

Ειδική σταθερά αερίων: $R = Ru / M$

σχέσεις P, V, T: $PV = NRT$, $PV = mRT$, $Pu = RT$

Μερική πίεση συστατικού: $P_i = y_i P$

Εντροπία μίγματος: $S = \sum m_i s_i = \sum N_i s_i$ $\qquad$ $s = -R \ln(P/P_o) + \sum_{i=1}^{J} x_i (s_i^o - R_i \ln x_i)$

Εντροπία συστατικού: $s_i = s_i^o - R_i \ln(P_i/P_o)$ $\qquad$ $s = -R \ln(P/P_o) + \sum_{i=1}^{J} x_i (s_i^o - R \ln x_i)$

ΠΑΡΑΡΤΗΜΑ 3

ΣΤΟΙΧΕΙΑ ΥΠΟΛΟΓΙΣΜΟΥ ΣΤΑΘΕΡΩΝ ΘΕΡΜΟΧΗΜΕΙΑΣ

1. ΘΕΡΜΟΔΥΝΑΜΙΚΑ ΔΕΔΟΜΕΝΑ ΣΥΝΗΘΕΣΤΕΡΩΝ ΠΡΟΪΟΝΤΩΝ ΤΗΣ ΚΑΥΣΗΣ ΥΔΡΟΓΟΝΑΝΘΡΑΚΩΝ

α) Μικρό εύρος θερμοκρασιών (υψηλότερη ακρίβεια, μικρό δείγμα από πίνακες JANNAF))

$$\frac{c_p}{R} = a_1 + a_2 T + a_3 T^2 + a_4 T^3 + a_5 T^4$$

$$\frac{h}{RT} = a_1 + \frac{a_2}{2} T + \frac{a_3}{3} T^2 + \frac{a_4}{4} T^3 + \frac{a_5}{5} T^4 + \frac{a_6}{T}$$

$$\frac{s^o}{R} = a_1 \ln T + a_2 T + \frac{a_3}{2} T^2 + \frac{a_4}{3} T^3 + \frac{a_5}{4} T^4 + a_7$$

Table 3.1 Thermo Data ($300 \le T \le 1000$ K)

	SPECIES	a_{i1}	a_{i2}	a_{i3}	a_{i4}	a_{i5}	a_{i6}	a_{i7}
1	Gasoline[a] C_7H_{17}	0.406E+01	0.601E−01	−0.188E−05	−0	0	−0.4053E+05	−0.28325E
1	CO_2	0.24007797E+01	0.87350957E−05	−0.66070878E−05	0.20021861E−08	0.63274039E−15	−0.48377527E+05	0.969514
2	H_2O	0.40701275E+01	−0.11084499E−02	0.41521180E−05	−0.29637404E−08	0.80702103E−12	−0.30279722E+05	−0.322700
3	N_2	0.36748261E+01	−0.12081500E−02	0.23240102E−05	−0.63217559E−09	−0.22577253E−12	−0.10611588E+04	0.235804
4	O_2	0.36255985E+01	−0.18782184E−02	0.70554544E−05	−0.67635137E−08	0.21555993E−11	−0.10475226E+04	0.430527
5	CO	0.37100928E+01	−0.16190964E−02	0.36923594E−05	−0.20319674E−08	0.23953344E−12	−0.14356310E+05	0.295553
6	H_2	0.30574451E+01	0.26765200E−02	−0.58099162E−05	0.55210391E−08	−0.18122739E−11	−0.98890474E+03	−0.22997
7	H	0.25000000E+01	0	0	0	0	0.25471627E+05	−0.46011
8	O	0.29464287E+01	−0.16381665E−02	0.24210316E−05	−0.16028432E−08	0.38906964E−12	0.29147644E+05	0.29639
9	OH	0.38375943E+01	−0.10778858E−02	0.96830378E−06	0.18713972E−09	−0.22571094E−12	0.36412823E+04	0.49370
10	NO	0.40459521E+01	−0.34181783E−02	0.79819190E−05	−0.61139316E−08	0.15919076E−11	0.97453934E+04	0.29974

Source: From Gordon and McBride (1971).

β) Μεγάλο εύρος θερμοκρασιών

$$h(T) = A + BT + C\ln(T) \qquad \left(\frac{KT}{kmole}\right)$$

$$c_p(T) = B + \frac{C}{T} \qquad \text{(kJ/kmol K)}$$

$$c_v(T) = B - 8.314 + \frac{C}{T} \qquad \text{(kJ/kmol K)}$$

$$u(T) = A + (B - 8.314)T + C\ln(T) \qquad \text{(kJ/kmol)} \qquad \text{C-3}$$

$$\phi(T) = B\ln(T) - \frac{C}{T} + D \qquad \text{(kJ/kmol K)}$$

$$K_p(T) = \exp\left[\frac{a}{T} + \left(b + \frac{c}{T}\right)\ln(T) + d\right] \qquad (P \text{ in atm})$$

TABLE C.1
A, B, C, AND *D* COEFFICIENTS FOR EQS. C-3

Gas	*A*	*B*	*C*	*D*
		$400 \leqslant T \leqslant 1600$ K		
CO	299180.	37.85	−4571.9	−31.10
CO_2	56835.	66.27	−11634.0	−200.0
H	357070.	20.79	−7.9	−3.9
H_2	326490.	40.35	−8085.2	−121.0
H_2O	88923.	49.36	−7940.8	−117.0
N_2	31317.	37.46	−4559.3	−34.82
O	265120.	24.60	−2729.2	13.86
O_2	43388.	42.27	−6635.4	−55.15
OH	217810.	37.36	−5561.4	−44.06
NO	111050.	37.81	−2874.8	−15.70
N	326040.	17.19	5371.4	64.67
		$1600 \leqslant T \leqslant 6000$ K		
CO	309070.	39.29	−6201.9	−42.77
CO_2	93048.	68.58	−16979.0	−220.4
H	357010.	20.79	0	−3.82
H_2	461750.	46.23	−27649.0	−176.6
H_2O	154670.	60.43	−19212.0	−204.6
N_2	44639.	39.32	−6753.4	−50.24
O	298360.	23.17	−6910.3	21.81
O_2	127010.	46.25	−18798.0	−92.15
OH	298750.	42.86	−17695.0	−92.24
NO	138670.	39.92	−7061.8	−33.90
N	486400.	26.91	−18159.0	−20.31

TABLE C.2
COEFFICIENTS FOR CALCULATION OF REACTION CONSTANTS K_p WITH THE EQUATION

$$K_p = \exp\left[\frac{a}{T} + \left(b + \frac{c}{T}\right)\ln(T) + d\right]$$

VALID FOR $1600 < T < 6000$ K. *Pressures must be in units of atmospheres.*

Reaction	*a*	*b*	*c*	*d*
$H_2 + \frac{1}{2}O_2 \rightleftharpoons H_2O$	42450.	−1.0740	−2147.0	3.2515
$CO + \frac{1}{2}O_2 \rightleftharpoons CO_2$	33805.	0.7422	165.8	−16.5739
$2H \rightleftharpoons H_2$	33587.	0.5604	3327.0	−20.8683
$2O \rightleftharpoons O_2$	57126.	−0.0100	599.0	−16.3201
$2H + O \rightleftharpoons H_2O$	104702.	−0.5181	1480.0	−25.8073
$O + H \rightleftharpoons OH$	44216.	−0.1319	1298.0	−13.1303
$CO + H_2O \rightleftharpoons CO_2 + H_2$	−8645.	1.8162	2312.0	−19.8254
$O_2 + N_2 \rightleftharpoons 2NO$	−14096.	−0.6893	−1375.3	9.668
$2N \rightleftharpoons N_2$	108142.	−1.744	−3558.2	0.595

2. ΥΠΟΛΟΓΙΣΜΟΙ ΓΙΑ ΣΥΝΗΘΗ ΚΑΥΣΙΜΑ Μ.Ε.Κ

$$\frac{c_p}{R} = a_o + b_o T + c_o T^2$$

$$\frac{h}{RT} = a_o + \frac{b_o}{2} T + \frac{c_o}{3} T^2 + \frac{d_o}{T}$$

$$\frac{s^o}{R} = a_o \ln T + b_o T + \frac{c_o}{2} T^2 + e_o$$

FUEL	a_o	b_o	c_o	d_o	e_o
CH_3NO_2	1.412633	2.087101E − 02	−8.142134E − 06	−1.026351E + 04	1.917125E + 01
CH_4	1.971324	7.871586E − 03	−1.048592E − 06	−9.030422E + 03	8.873723
CH_3OH	1.779819	1.262503E − 02	−3.624890E − 06	−2.525420E + 04	1.50884E + 01
C_6H_5	−2.545087	4.79554E − 02	−2.030765E − 05	8.782234E + 03	3.348825E + 01
C_7H_{17}[a]	4.0652	6.0977E − 02	−1.8801E − 05	−3.5880E + 04	1.545E + 01
$C_{14.4}H_{34.9}$[b]	7.9710	1.1954E − 01	−3.6858E − 05	−1.9385E + 04	−1.7879

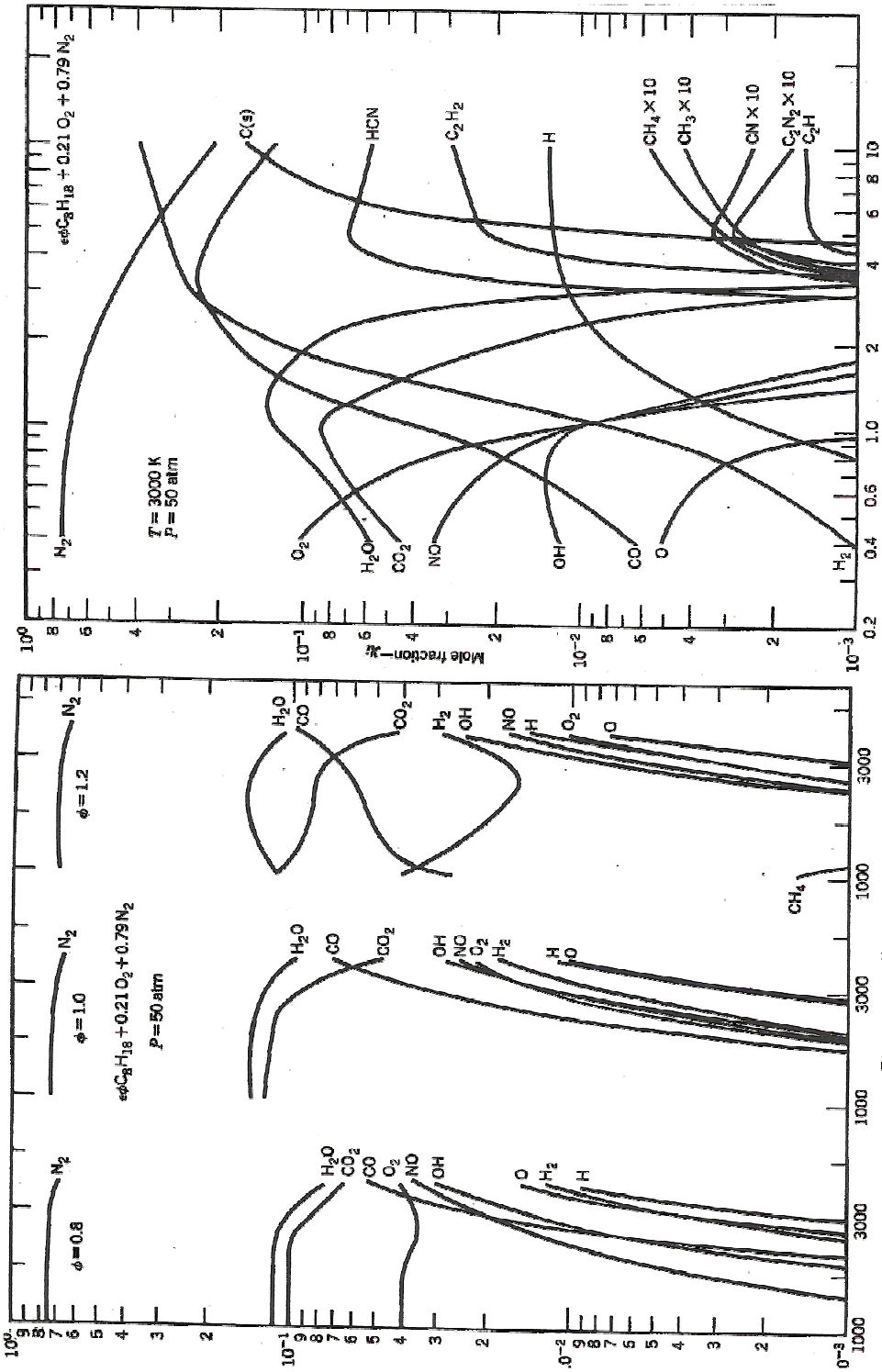
[a] Gasoline.
[b] Diesel fuel.

3. ΘΕΡΜΟΤΗΤΑ ΚΑΥΣΗΣ ΚΑΙ ΑΔΙΑΒΑΤΙΚΗ ΘΕΡΜΟΚΡΑΣΙΑ ΤΗΣ ΦΛΟΓΑΣ ΓΙΑ ΜΕΡΙΚΑ ΚΑΥΣΙΜΑ

FUEL		$q_{c,298}$ (kJ/g)	$T_{f,\phi=1.0}$ (K)
C_2N_2 (g)	Cyanogen	21.0	2596
H_2 (g)	Hydrogen	141.6	2383
NH_3 (g)	Ammonia	22.5	2076
CH_4 (g)	Methane	55.5	2227
C_3H_8 (g)	Propane	50.3	2268
C_8H_{18} (l)	Octane	47.9	2266
$C_{15}H_{32}$ (l)	Pentadecane	47.3	2269
$C_{20}H_{40}$ (g)	Eicosane	47.3	2291
C_2H_2 (g)	Acetylene	49.9	2540
$C_{10}H_8$ (s)	Naphthalene	40.3	2328
CH_4O (l)	Methanol	22.7	2151
C_2H_6O (l)	Ethanol	29.7	2197
CH_3NO_2 (l)	Nitromethare	11.6	2545

ΠΑΡΑΡΤΗΜΑ 4

ΣΥΝΘΕΣΗ ΚΑΥΣΑΕΡΙΩΝ ΣΕ ΧΗΜΙΚΗ ΙΣΟΡΡΟΠΙΑ (Ferguson, 1986)



Συνθεση καυσαεριου μιγματος οκτανιου αερα σε T=3000 K και P=50 atm

Συνθεση καυσαεριου μιγματος οκτανιου αεριου για φ=0.8, 1.0, 1.2 σε διαφορες θερμοκρασιες