CRC HANDBOOK of THERMOPHYSICAL and THERMOCHEMICAL DATA

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INTRODUCTION

Thermodynamics is one of the few sciences that possesses a highly developed and elegant theoretical framework and also has widespread and immensely important industrial applications. While the theory was well established a century ago, the practical applications of thermodynamics have continued to grow. These applications touch on virtually every industry and have a strong influence on our efforts to understand and control environmental pollution. At the research level, thermodynamics plays a prominent role in fields ranging from astrophysics to biochemistry.

The practical applications of thermodynamics generally require data on properties of real physical systems. In most cases these data rest on laboratory measurements of various thermodynamic properties. While it sometimes is possible to calculate thermodynamic properties from microscopic parameters (e.g., ideal gas heat capacity may be calculated quite accurately for atoms and simple molecules from molecular structure parameters), the bulk of the data in use comes from laboratory measurements of calorimetric or volumetric parameters. Over the years, a very significant effort has been devoted to compiling such data from the original literature, reanalyzing and evaluating the data, and preparing tables and graphs for both scientific and industrial use. Hundreds of such compilations have been published, and electronic versions of thermodynamic databases have come into use in recent years.

The objective of this book is to give an overview of the most important thermodynamic properties (as well as the related transport properties) for a range of pure substances and mixtures. It is obviously impossible in a single volume to cover more than a small sample of the substances and mixtures for which thermodynamic and transport property data exist. We have attempted to select systems that have high industrial and laboratory importance and that are representative of different classes of chemical compounds. Thus a user may be able to find data on a chemically related substance even if the compound of direct interest is not listed. Furthermore, extensive references are given in each table to larger compilations and databases, in the hope that this book can serve as an entry point to the sizable literature on thermophysical and thermochemical properties.

One of the practical difficulties in presenting thermodynamic data is that the properties are generally dependent on temperature, pressure, and in the case of mixtures, composition. Thus comprehensive tables of thermodynamic properties require a very large number of pages. We have dealt with this problem by fitting the property values to equations representing the functional dependence on these parameters and tabulating the coefficients of the equations. Furthermore, a disk accompanies the book on which the equations have been programmed and the coefficients for each system stored. The user can calculate property values from this disk and can generate tables and graphs which cover any range of temperature, pressure, or composition at any desired interval (within the valid range of the data). A large selection of units is also offered. Therefore, the combination of book and disk provides data which would require many volumes to present in conventional printed form.

Other features of the book should be mentioned. While it is assumed that the user is familiar with the laws, concepts, and basic equations of thermodynamics, care has been taken to define each quantity for which data are given in an unambiguous way. Terminology and symbols recommended by the International Union of Pure and Applied Chemistry (IUPAC) have been used throughout. All data in the book (and the default values from programs on the disk) are given in SI units. The introduction to each table gives a brief discussion of the quantities tabulated and points out the variation in the data with environmental parameters and, when useful generalizations can be made, with chemical structure. The IUPAC name, symbol, and SI unit are listed for each quantity at the beginning of each table.

Most of the data in the book have been drawn from evaluated sources, i.e., from compilations in which the authors have correlated data extracted from the literature, resolved discrepancies, and selected recommended values. The major sources used are listed with each table. When it was necessary to go to the original literature, we have used our own judgement in the selection of values. While it has not been feasible to give an uncertainty for every value in the book, we have adjusted the significant figures in the printed tables to give a rough indication of the accuracy.

Finally, many of the tables in the book are related to each other, and the same thermodynamic quantity may appear in more than one table. In such cases we have attempted to maintain internal consistency to the extent possible. However, there are circumstances where slightly different values of a property may be found in different tables. For example, a normal boiling temperature may appear in one table as a selected "best value" while a non-identical number appears elsewhere as a value derived from a best fit of vapor pressure data over a range of temperatures. All discrepancies of this type are believed to be within the uncertainty of the data.

Since usage of chemical names and synonyms varies so widely, most of the tables are arranged by molecular formula following the Hill convention. In this convention the molecular formula is written with C first (if present), H second, and then all other elements in alphabetical order of their chemical symbols. The sequence of entries in the table follows alphabetical order of the symbols in the formula and the number of atoms of each element, in ascending order. We have deviated from the strict Hill convention as used, for example, by Chemical Abstracts Service, by first listing all substances that do not contain carbon and then continuing with the carbon-containing substances. In this way the list of inorganic substances, which is generally shorter, is not broken up by the long list of organic compounds.

As an aid in identifying chemical compounds, an extensive Substance List appears at the end of the book, which includes the systematic names and common synonyms for the compounds covered in the various tables. The Substance List also gives molecular weights and Chemical Abstracts Service Registry Numbers.

In a compilation of this scope it is impossible to avoid errors, even after careful checking. The authors will be grateful to users who call our attention to mistakes and make other suggestions for improvements.

The authors are grateful to a number of people who made important contributions to this work. Dr. Christine Kehiaian assisted in the data selection and correlation; Mr. John Miller was responsible for the layout of the Substance List; and Mr. Jean-Claude Fontaine developed the database management system. Ms. Lauren Bascom and Ms. Joanne Chen assisted in data entry and editing. Finally, Mr. Paul Gottehrer of CRC Press did a masterful job of typesetting from the computer files supplied by the authors.

INSTRUCTIONS ON USING THE DISKETTE

The CRCTHERM Program on the diskette can be used only in conjuction with the book. A property is selected from a table in the book, and the user refers to the corresponding *Property Code*, consisting of four capital letters, e.g., VLEG. He locates the particular chemical system of interest (a pure substance or mixture) in the table and notes the *System Number* (SN) given there. He then opens the *Property Code Menu* and selects the Property Code and then opens the *System Number Window* and enters the SN at the indicated prompt. The values displayed by the program are calculated from the smoothing equations given in the book. The results are viewed on the screen in tabular and/or graphical form and can be printed and/or saved to disk. The detailed procedure is described below.

Any property is characterized by following *Physical Quantities*:

- Y(i) — One or several interrelated quantities, functions of the variable X and the fitted *Coefficients* A(i) of the Smoothing Equation (i = 1 to 6).
- X — A single independent variable.

Certain properties are characterized additionally by:

- P(1) — A quantity having a constant value in the representation (*Parameter*).
- V(i) — *Auxiliary Values* in the Smoothing Equation (i = 1 or 2).

Each physical quantity has a specific *Symbol* and may be expressed - if not zero-dimensional - either in *SI Units* or in some user-selected *Current Units*. The calculations can be performed for one or several selected variables Y(i), within a given X-Range of variation of X (X-min, X-max), with a given step (X-step), or for any discrete value of X (X-value).

SYSTEM REQUIREMENTS

- Hardware: IBM 286 or higher or 100% compatible microcomputer; DOS 3.0 or higher.
- Memory: 640 K RAM.
- Hard disk space: 1 MB.
- Drive: One 5 1/4" double density floppy diskette drive.
- Graphics: VGA. Color adapter is recommended but not necessary.

INSTALLING THE PROGRAM

If there is a READ.ME file on the installation diskette, please read it for information not included in these Instructions.

The diskette contains an installation program. Put the diskette in the proper floppy diskette drive, change to that drive, type INSTALL, and then follow the procedure indicated on the screen. You may install the system on the hard disk partition of your choice, provided the required amount of free space is available (this is verified by the installation program).

OPENING THE PROGRAM

After installing the CRCTHERM Program, you can calculate properties for chemical systems that you specify.

- Type CT and press <Enter>. (See below for options which may be specified.)

After the title screen, the Program displays the *Property Window* with the Physical Quantities and Units, and - eventually - the *Chemical System Window*, with the X-value and the X-Range that were selected the last time the Program was run, and the X-step. You can directly perform calculations for this selection. Otherwise, you open the Property Code Menu and/or the Units Menu and/or the System Number Window and select a new property, unit, or system.

You can move the cursor in any of the fields of the Menus by means of the Arrow, PageUp, PageDn, Home, and End Keys. You can select your options, either by scrolling or by typing text, and pressing <Enter>.

DEFINING THE OBJECT

You need to define first the Property, the Physical Quantities and their Units, and the Chemical System. For this purpose, use the following commands:

- Press P to open the Property Code Menu and change the Property.
- Press S to open the System Number Window and enter or change the System Number.

These commands can be used from any place in the program, at any time, except when the cursor is in a field for typing text outside the Property Window. In that case, first:

- Press Esc to return to the Property Window.

Selecting Property

After pressing P, scroll with the cursor to the desired Property Code or, simpler, type the initial letters of the Property Code. Each typed letter moves the cursor to the corresponding Code. A few letters may suffice to find the desired Property. An audio bip signal indicates that the letter does not correspond to an existing Property Code. Press <Enter> to select the Property and open automatically the System Number Window. Press Esc if you wish to select specific physical quantities and/or change the units.

An alphabetical list of property codes with page references and brief descriptions is given at the end of these instructions.

Selecting Physical Quantity

If you wish to tabulate or graph only certain variables, Y(i), place the cursor on the line of the corresponding quantity in the Num column. Each time you press <Enter> you select or unselect that property. This is highlighted by, respectively, the appearance or disappearance of the askerisk (*) sign in the column.

Changing Units of Physical Quantities

If you wish to change the unit of a physical quantity, place the cursor on the line of the corresponding quantity in the Current Unit column and press <Enter>. You display the appropriate Unit Menu. Select the desired unit by scrolling and pressing <Enter>. You access the SI Unit directly by pressing the Home Key. For some complex physical quantities you may be prompted to select units for some more basic quantities; e.g., in the case of density, you have to specify the units of mass and volume. A quick way to restore the SI Unit of a physical quantity is to place the cursor on the line of the corresponding quantity in the Current Unit column and press <Delete>, instead of <Enter>.

Selecting System

After pressing S, type the System Number and press <Enter>. A bip signal indicates that the number does not correspond to an existing System Number for the property that you have specified (note that a given system has different SN's in different tables). The Insert Key permits you to toggle Insert/Overwrite mode.

The System Number may be obtained from the appropriate table in the book.

CALCULATING RESULTS

You next need to define the X-Range and carry out the calculation. You can then display the data both in a Numerical Output File and as a Graph.

Defining the X-Value or X-Range of Calculation

The Default line displays the lower (X-min) and upper (X-max) range of calculation, an X-value within this range, and a minimum step (X-step) in the selected unit of X. The Selected line displays round values for X-min and X-max, the corresponding X-value, and an X-step generating approximately 10 X-values within the X-range. You can change X-min, X-max, X-step, or X-value within the permitted range by placing the cursor in the appropriate column of the Selected line and typing the desired numbers. The numerical values need not be written in exponential form. Instead of typing the entire new number, you may wish to change the old one. Just press <Enter> to pass in the Overwrite edit mode. The Insert Key permits you to toggle Insert/Overwrite mode. A bip signal indicates that the typed number is outside the allowed range. Any typed number is rounded to the accuracy of the Default X-step. You can change quickly X-min, X-max, or X-value to the corresponding Default values by placing the cursor on that value and pressing <Delete>.

- Press C to calculate data in the X-Range and the X-step of the variable X given in the Selected line and display on the Numerical Output File.
- Press G to calculate data in the given X-Range and display as a Graph.
- Press Esc to stop the calculation before completion.
- To calculate results for a discrete Selected X-value place the cursor in the appropriate column and press <Enter>; you pass in the

Overwrite edit mode (see above), eventually change the value, and press <Enter> again. Another way is to place the cursor in the appropriate column, type the desired X-value, and press <Enter>. The calculated values are stored in the Numerical Output File. You can enter other discrete X-values and each time you press <Enter> the calculated results are appended to the Numerical Output File.

Numerical Output File

The Numerical Output File with the headings and all the calculated values is displayed on the screen after the first calculation. You may delimit a block from this file (or from the zoomed file described below), e.g., with all or part of the numerical values, by pressing the <Shift> key and moving the cursor by means of the Arrow, PageUp, PageDn, Home or End Keys. The delimited block is highlighted on the screen.

- Press Z to zoom the Numerical Output File. (To return, press Z again.)
- Press R to print the Numerical Output File or the delimited block. You are then prompted to specify the type of printer (see below).
- Press W to write the Numerical Output File or the delimited block in an external file. You are then prompted to accept or modify the default path, filename, and file format.
    - Press F to toggle the file format from an extended ASCII to a tab delimited format, for use by spreadsheet programs.
    - Press P to change the path.
    - Press N to change the filename.
    - Press W again to accept the default or the modified values.
- Press E to clear the Numerical Output File.

Changing the Property, the Units, or the System Number clears automatically the Numerical Output File. To keep a record of it, you should print or write it to a file in advance.

Graph

If you press G from any place of the Program, except when the cursor is in a field for typing text outside the Property Window, you calculate results within the selected X-Range and the results are presented graphically. Each independent variable Y(i) is graphed separately as a function of X. Press PageUp or PageDn to display all the selected Y(i)'s.

- Press G to display/remove the grid.
- Press L to change the lower limit of Y(i) by typing another value.
- Press U to change the upper limit of Y(i) by typing another value.
- Press D or <Delete> to restore the lower and upper limits of Y(i).
- Press R to print the Graph. You are then prompted to specify the type of printer (see below).
- Press Esc to return to the Property Window.

QUITTING THE PROGRAM

Press Q (followed by Y) to quit the Program.

PRINTER SPECIFICATION

Although CRCTHERM supports most of the commonly used printers, it may be necessary to experiment. When the command to print an output file or graph is given, you are prompted to specify the type of printer language required by your printer. The choices are:

- FX80 — The language recognized by Epson and many other dot matrix printers.
- HPGL — HP Graphics Language, used with many curve plotters.
- PCL — Printer Command Language, used with most laser printers.
- DJ500 — HP DeskJet 500 printer.

When you have specified one of these, it remains your default until you make a change. You may wish to try each of these options to determine the most safisfactory print result. In case of problems, consult your printer manual.

OPTIONS

When starting the program from the DOS prompt, several options may be invoked by attaching switches to the CT command. The options can be listed by entering CT /?. Note that a space must always be typed after CT. These options are:

- CT /M — instructs a color monitor to display in black-and-white mode.
- CT /S — turns off the sound.
- CT /Wnnn — where nnn is a number in the range 78 to 120, specifies the number of columns to be printed. The default is 100 columns.
- CT /Pnnn — where nnn is a number in the range 20 to 200, specifies the number of lines per printed page. The default value is 55.
- CT /C — cancels the condensed print mode.
- CT /Y — checks for possible corruption in the data files. If a problem is reported, the program should be reinstalled from the original diskette (or from a back-up diskette).
- CT /D — restores all the initial defaults.
- CT /? — displays this information.

Several switches may be used at the same time, such as CT /S /W80, as long as a space is included before each /. Once an option has been invoked, it remains in effect when the program is restarted. To change options, first return to the initial default by using CT /D, then restart with the new set of switches.

PROPERTY CODES

Code	Table	Page	Program calculates:
CPEX	3.3.2	393	Heat capacity of binary liquid mixtures as function of composition
CPGT	2.3.1	89	Gas heat capacity as function of temperature
CPLT	2.3.2	93	Liquid heat capacity as function of temperature
CPST	2.3.3	97	Solid heat capacity as function of temperature
HETX	3.3.1	375	Enthalpy of mixing of binary liquid mixtures as function of composition
LLEX	3.1.4	351	Liquid-liquid equilibrium temperature of binary mixtures as function of composition
PCXX	3.1.3	339	Critical pressure of binary liquid mixtures as function of composition
PVTL	2.2.2	81	Liquid density and molar volume as function of temperature
SLTP	2.1.5	63	Melting point as function of pressure
STLT	2.5.1	203	Surface tension as function of temperature
TCGT	4.2.1	415	Gas thermal conductivity as function of temperature
TCLT	4.2.2	417	Liquid thermal conductivity as function of temperature
TCST	4.2.3	419	Solid thermal conductivity as function of temperature
TCXX	3.1.3	339	Critical temperature of binary liquid mixtures as function of composition
VETX	3.2.1	363	Density and molar volume of binary liquid mixtures as function of composition
VIBT	2.2.1	69	Second virial coefficients as function of temperature
VIGT	4.1.1	407	Gas viscosity as function of temperature
VILT	4.1.2	409	Liquid viscosity as function of temperature
VLEG	3.1.1	211	Vapor pressure and related VLE properties of binary mixtures as function of composition
VLPT	2.1.3	49	Vapor pressure and enthalpy of vaporization as function of temperature
VLTP	2.1.3	49	Boiling point and enthalpy of vaporization as function of pressure
VSPT	2.1.4	61	Sublimation pressure as function of temperature

Section 1
Symbols, Units, and Terminology

1.1. NAMES AND SYMBOLS FOR THERMODYNAMIC AND TRANSPORT PROPERTIES

The recommended names and symbols for physical quantities encountered in the treatment of thermophysical and thermochemical data are listed in Table 1.1.1. These have been extracted from a more comprehensive list published by the International Union of Pure and Applied Chemistry; they are reprinted with permission of IUPAC. With a few minor exceptions, symbols recommended by the International Union of Pure and Applied Physics (IUPAP) and the International Organization for Standardization (ISO) agree with these.

General rules for expressing physical quantities are given first, followed by the table of names and symbols for general quantities, thermodynamic properties, and transport properties. The expression in the *Definition* column of this table is given as an aid in identifying the quantity but is not necessarily the complete or unique definition. The *SI unit* column gives one (not necessarily unique) expression for the coherent SI unit for the quantitiy. Other equivalent unit expressions, including those which involve SI prefixes, may be used.

REFERENCES

1. Mills, I., Ed., *Quantities, Units, and Symbols in Physical Chemistry*, IUPAC, Blackwell Scientific Publications, Oxford, 1988.
2. Cohen, E. R., and Giacomo, P., *Symbols, Units, Nomenclature, and Fundamental Constants in Physics*, Document IUPAP-25, 1987; also published in *Physica*, 146A, 1—68, 1987.
3. *ISO Standards Handbook 2: Units of Measurement*, International Organization for Standardization, Geneva, 1982.

GENERAL RULES

The value of a physical quantity is expressed as the product of a numerical value and a unit, e.g.:

$$T = 300\ \text{K}$$
$$V = 26.2\ \text{cm}^3$$
$$C_p = 45.3\ \text{J mol}^{-1}\ \text{K}^{-1}$$

The symbol for a physical quantity is always given in italic (sloping) type, while symbols for units are given in Roman type. Column headings in tables and axis labels on graphs may conveniently be written as the physical quantity symbol divided by the unit symbol, e.g.:

$$T/\text{K}$$
$$V/\text{cm}^3$$
$$C_p/\text{J mol}^{-1}\ \text{K}^{-1}$$

The values in the table column or graph axis are then pure numbers.

Subscripts to symbols for physical quantities should be italic if the subscript refers to another physical quantity or to a number, e.g.:

C_p — heat capacity at constant pressure
B_n — nth virial coefficient

Subscripts that have other meanings should be in Roman type:

m_p — mass of the proton
E_k — kinetic energy

TABLE 1.1.1
RECOMMENDED NAMES AND SYMBOLS

Name	*Symbol*	*Definition*	*SI unit*
		GENERAL QUANTITIES	
number of entities (e.g. molecules, atoms, ions, formula units)	N		1
amount (of substance)	n	$n_B = N_B/L$	mol
Avogadro constant	L, N_A		mol^{-1}
mass of atom, atomic mass	m_a, m		kg
mass of entity (molecule, or formula unit)	m_f, m		kg
atomic mass constant	m_u	$m_u = m_a(^{12}C)/12$	kg
molar mass	M	$M_B = m/n_B$	$kg\ mol^{-1}$
relative molecular mass (relative molar mass, molecular weight)	M_r	$M_{r,B} = m_B/m_u$	1
molar volume	V_m	$V_{m,B} \equiv V/n_B$	$m^3\ mol^{-1}$
mass fraction	w	$w_B = m_B/\Sigma m_i$	1
volume fraction	ϕ	$\phi_B = V_B/\Sigma V_i$	1
mole fraction, amount fraction, number fraction	x, y	$x_B = n_B/\Sigma n_i$	1
(total) pressure	p, P		Pa
partial pressure	p_B	$p_B \equiv y_B p$	Pa
mass concentration (mass density)	γ, ρ	$\gamma_B = m_B/V$	$kg\ m^{-3}$
number concentration, number density of entities	C, n	$C_B = N_B/V$	m^{-3}
amount concentration, concentration	c	$c_B = n_B/V$	$mol\ m^{-3}$
solubility	s	$s_B = c_B$ (saturated solution)	$mol\ m^{-3}$
molality (of a solute)	m, (b)	$m_B = n_B/m_A$	$mol\ kg^{-1}$
surface concentration	Γ	$\Gamma_B \equiv n_B/A$	$mol\ m^{-2}$
stoichiometric number	ν		1
extent of reaction, advancement	ξ	$\Delta\xi = \Delta n_B/\nu_B$	mol
degree of dissociation	α		1
		THERMODYNAMIC PROPERTIES	
heat	q, Q		J
work	w, W		J
internal energy	U	$\Delta U = q + w$	J
enthalpy	H	$H = U + pV$	J
thermodynamic temperature	T		K
Celsius temperature	θ, t	$\theta/°C = T/K - 273.15$	°C
entropy	S	$dS \geqslant dq/T$	$J\ K^{-1}$
Helmholtz energy, (Helmholtz function)	A	$A = U - TS$	J

TABLE 1.1.1
RECOMMENDED NAMES AND SYMBOLS (continued)

Name	*Symbol*	*Definition*	*SI unit*
Gibbs energy, (Gibbs function)	G	$G=H-TS$	J
Massieu function	J	$J=-A/T$	JK^{-1}
Planck function	Y	$Y=-G/T$	JK^{-1}
surface tension	γ, σ	$\gamma=(\partial G/\partial A_s)_{T,p}$	Jm^{-2}, Nm^{-1}
molar quantity X	X_m	$X_m=X/n$	(varies)
specific quantity X	x	$x=X/m$	(varies)
pressure coefficient	β	$\beta=(\partial p/\partial T)_V$	PaK^{-1}
relative pressure coefficient	α_p	$\alpha_p=(1/p)(\partial p/\partial T)_V$	K^{-1}
compressibility,			
isothermal	κ_T	$\kappa_T=-(1/V)(\partial V/\partial p)_T$	Pa^{-1}
isentropic	κ_S	$\kappa_S=-(1/V)(\partial V/\partial p)_S$	Pa^{-1}
linear expansion coefficient	α_l	$\alpha_l=(1/l)(\partial l/\partial T)$	K^{-1}
cubic expansion coefficient	α, α_V, γ	$\alpha=(1/V)(\partial V/\partial T)_p$	K^{-1}
heat capacity,			
at constant pressure	C_p	$C_p=(\partial H/\partial T)_p$	JK^{-1}
at constant volume	C_V	$C_V=(\partial U/\partial T)_V$	JK^{-1}
ratio of heat capacities	γ, (κ)	$\gamma=C_p/C_V$	1
Joule–Thomson coefficient	μ, μ_{JT}	$\mu=(\partial T/\partial p)_H$	KPa^{-1}
second virial coefficient	B	$pV_m=RT(1+B/V_m+\cdots)$	m^3mol^{-1}
compression factor (compressibility factor)	Z	$Z=pV_m/RT$	1
partial molar quantity X	X_B, (X'_B)	$X_B=(\partial X/\partial n_B)_{T,p,n_{j\neq B}}$	(varies)
chemical potential (partial molar Gibbs energy)	μ	$\mu_B=(\partial G/\partial n_B)_{T,p,n_{j\neq B}}$	$Jmol^{-1}$
absolute activity	λ	$\lambda_B=\exp(\mu_B/RT)$	1
standard chemical potential	$\mu^\bullet$, μ°		$Jmol^{-1}$
standard partial molar enthalpy	$H_B^\bullet$	$H_B^\bullet=\mu_B^\bullet+TS_B^\bullet$	$Jmol^{-1}$
standard partial molar entropy	$S_B^\bullet$	$S_B^\bullet=-(\partial\mu_B^\bullet/\partial T)_p$	$Jmol^{-1}K^{-1}$
standard reaction Gibbs energy (function)	$\Delta_rG^\bullet$	$\Delta_rG^\bullet=\sum_B \nu_B\mu_B^\bullet$	$Jmol^{-1}$
affinity of reaction	A, ($\mathcal{A}$)	$A=-(\partial G/\partial\xi)_{p,T}=-\sum_B \nu_B\mu_B$	$Jmol^{-1}$
standard reaction enthalpy	$\Delta_rH^\bullet$	$\Delta_rH^\bullet=\sum_B \nu_BH_B^\bullet$	$Jmol^{-1}$
standard reaction entropy	$\Delta_rS^\bullet$	$\Delta_rS^\bullet=\sum_B \nu_BS_B^\bullet$	$Jmol^{-1}K^{-1}$
equilibrium constant	$K^\bullet$, K	$K^\bullet=\exp(-\Delta_rG^\bullet/RT)$	1
equilibrium constant, pressure basis	K_p	$K_p=\prod_B p_B^{\nu_B}$	$Pa^{\Sigma\nu}$

TABLE 1.1.1
RECOMMENDED NAMES AND SYMBOLS (continued)

Name	*Symbol*	*Definition*	*SI unit*
concentration basis	K_c	$K_c = \prod_B c_B^{\nu_B}$	$(\text{mol m}^{-3})^{\Sigma\nu}$
molality basis	K_m	$K_m = \prod_B m_B^{\nu_B}$	$(\text{mol kg}^{-1})^{\Sigma\nu}$
fugacity	f, $\tilde{p}$	$f_B = \lambda_B \lim_{p\to 0} (p_B/\lambda_B)_T$	Pa
fugacity coefficient	ϕ	$\phi_B = f_B/p_B$	1
activity and activity coefficient referenced to Raoult's law, (relative) activity	a	$a_B = \exp\left[\frac{\mu_B - \mu_B^*}{RT}\right]$	1
activity coefficient	f	$f_B = a_B/x_B$	1
activities and activity coefficients referenced to Henry's law, (relative) activity, molality basis	a_m	$a_{m,B} = \exp\left[\frac{\mu_B - \mu_B^*}{RT}\right]$	1
concentration basis	a_c	$a_{c,B} = \exp\left[\frac{\mu_B - \mu_B^*}{RT}\right]$	1
mole fraction basis	a_x	$a_{x,B} = \exp\left[\frac{\mu_B - \mu_B^*}{RT}\right]$	1
activity coefficient, molality basis	γ_m	$a_{m,B} = \gamma_{m,B} m_B/m^*$	1
concentration basis	γ_c	$a_{c,B} = \gamma_{c,B} c_B/c^*$	1
mole fraction basis	γ_x	$a_{x,B} = \gamma_{x,B} x_B$	1
ionic strength, molality basis	I_m, I	$I_m = \frac{1}{2}\Sigma m_B z_B^2$	mol kg^{-1}
concentration basis	I_c, I	$I_c = \frac{1}{2}\Sigma c_B z_B^2$	mol m^{-3}
osmotic coefficient, molality basis	ϕ_m	$\phi_m = (\mu_A^* - \mu_A)/(RTM_A\Sigma m_B)$	1
mole fraction basis	ϕ_x	$\phi_x = (\mu_A - \mu_A^*)/(RT\ln x_A)$	1
osmotic pressure	Π	$\Pi = c_B RT$ (ideal dilute solution)	Pa

(i) *Symbols used as subscripts to denote a chemical process or reaction*

These symbols should be printed in roman (upright) type, without a full stop (period).

vaporization, evaporation (liquid→gas)	vap
sublimation (solid→gas)	sub
melting, fusion (solid→liquid)	fus
transition (between two phases)	trs
mixing of fluids	mix
solution (of solute in solvent)	sol
dilution (of a solution)	dil
adsorption	ads
displacement	dpl
immersion	imm
reaction in general	r
atomization	at
combustion reaction	c
formation reaction	f

TABLE 1.1.1
RECOMMENDED NAMES AND SYMBOLS (continued)

Name	*Symbol*	*Definition*	*SI unit*
(ii) *Recommended superscripts*			
standard		$^{\ominus}$, ^{o}	
pure substance		*	
infinite dilution		$^{\infty}$	
ideal		^{id}	
activated complex, transition state		‡	
excess quantity		^{E}	
TRANSPORT PROPERTIES			
flux (of a quantity X)	J_X, J	$J_X = A^{-1}\,dX/dt$	(varies)
volume flow rate	q_V, $\dot{V}$	$q_v = dV/dt$	$m^3\,s^{-1}$
mass flow rate	q_m, $\dot{m}$	$q_m = dm/dt$	$kg\,s^{-1}$
mass transfer coefficient	k_d		$m\,s^{-1}$
heat flow rate	ϕ	$\phi = dq/dt$	W
heat flux	J_q	$J_q = \phi/A$	$W\,m^{-2}$
thermal conductance	G	$G = \phi/\Delta T$	$W\,K^{-1}$
thermal resistance	R	$R = 1/G$	$K\,W^{-1}$
thermal conductivity	λ, k	$\lambda = J_q/(dT/dl)$	$W\,m^{-1}\,K^{-1}$
coefficient of heat transfer	h, (k, K, α)	$h = J_q/\Delta T$	$W\,m^{-2}\,K^{-1}$
thermal diffusivity	a	$a = \lambda/\rho c_p$	$m^2\,s^{-1}$
diffusion coefficient	D	$D = J_n/(dc/dl)$	$m^2\,s^{-1}$

1.2. SI UNITS AND CONVERSION FACTORS

The International System of units (SI) was adopted by the 11th General Conference on Weights and Measures (CGPM) in 1960. It is a coherent system of units built from seven *SI base units*, one for each of the seven dimensionally independent base quantities: they are the meter, kilogram, second, ampere, kelvin, mole, and candela, for the dimensions length, mass, time, electric current, thermodynamic temperature, amount of substance, and luminous intensity, respectively, The definitions of the SI base units are given below. The *SI derived units* are expressed as products of powers of the base units, analogous to the corresponding relations between physical quantities but with numerical factors equal to unity.

In the International System there is only one SI unit for each physical quanitity. This is either the appropriate SI base unit itself or the appropriate SI derived unit. However, any of the approved decimal prefixes, called *SI prefixes*, may be used to construct decimal multiples or submultiples of SI units.

It is recommended that only SI units be used in science and technology (with SI prefixes where appropriate). Where there are special reasons for making an exception to this rule, it is recommended always to define the units used in terms of SI units. This section was reprinted with the permission of IUPAC.

Definitions of SI Base Units

Meter—The meter is the length of path travelled by light in vacuum during a time interval of 1/299 792 458 of a second (17th CGPM, 1983).

Kilogram — The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram (3rd CGPM, 1901).

Second— The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom (13th CGPM, 1967).

Ampere— The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 meter apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per meter of length (9th CGPM, 1948).

Kelvin — The kelvin, unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water (13th CGPM, 1967)

Mole—The mole is the amount of substance of a system which contains as many elementary entities as there are atoms in 0.012 kilogram of carbon-12. When the mole is used, the elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles (14th CGPM, 1971).

Examples of the use of the mole:

1 mol of H_2 contains about 6.022×10^{23} H_2 molecules, or 12.044×10^{23} H atoms
1 mol of HgCl has a mass of 236.04 g
1 mol of Hg_2Cl_2 has a mass of 472.08 g
1 mol of Hg_2^{2+} has a mass of 401.18 g and a charge of 192.97 kC
1 mol of $Fe_{0.91}S$ has a mass of 82.88 g
1 mol of e^- has a mass of 548.60 μg and a charge of –96.49 kC
1 mol of photons whose frequency is 10^{14} Hz has an energy of about 39.90 kJ

Candela — The candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} hertz and that has a radiant intensity in that direction of (1/683) watt per steradian (16th CGPM, 1979).

TABLE 1.2.1
NAMES AND SYMBOLS FOR THE SI BASE UNITS

Physical quantity	Name of SI unit	Symbol for SI unit
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

TABLE 1.2.2
SI DERIVED UNITS WITH SPECIAL NAMES AND SYMBOLS

Physical quantity	Name of SI unit	Symbol for SI unit	Expression in terms of SI base units
frequency[1]	hertz	Hz	s^{-1}
force	newton	N	$m\ kg\ s^{-2}$
pressure, stress	pascal	Pa	$N\ m^{-2} = m^{-1}\ kg\ s^{-2}$
energy, work, heat	joule	J	$N\ m = m^2\ kg\ s^{-2}$
power, radiant flux	watt	W	$J\ s^{-1} = m^2\ kg\ s^{-3}$
electric charge	coulomb	C	A s
electric potential, electromotive force	volt	V	$J\ C^{-1} = m^2\ kg\ s^{-3}\ A^{-1}$
electric resistance	ohm	Ω	$V\ A^{-1} = m^2\ kg\ s^{-3}\ A^{-2}$
electric conductance	siemens	S	$\Omega^{-1} = m^{-2}\ kg^{-1}\ s^3\ A^2$
electric capacitance	farad	F	$C\ V^{-1} = m^{-2}\ kg^{-1}\ s^4\ A^2$
magnetic flux density	tesla	T	$V\ s\ m^{-2} = kg\ s^{-2}\ A^{-1}$
magnetic flux	weber	Wb	$V\ s = m^2\ kg\ s^{-2}\ A^{-1}$
inductance	henry	H	$V\ A^{-1}\ s = m^2\ kg\ s^{-2}\ A^{-2}$
Celsius temperature[2]	degree Celsius	°C	K
luminous flux	lumen	lm	cd sr
illuminance	lux	lx	$cd\ sr\ m^{-2}$
activity[3] (radioactive)	becquerel	Bq	s^{-1}
absorbed dose[3] (of radiation)	gray	Gy	$J\ kg^{-1} = m^2\ s^{-2}$
dose equivalent[3] (dose equivalent index)	sievert	Sv	$J\ kg^{-1} = m^2\ s^{-2}$
plane angle[4]	radian	rad	$1 = m\ m^{-1}$
solid angle[4]	steradian	sr	$1 = m^2\ m^{-2}$

(1) For radial (circular) frequency and for angular velocity the unit rad s^{-1}, or simply s^{-1}, should be used, and this may not be simplified to Hz. The unit Hz should be used only for frequency in the sense of cycles per second.
(2) The Celsius temperature θ is defined by the equation:

$$\theta/°C = T/K - 273.15$$

The SI unit of Celsius temperature interval is the degree Celsius, °C, which is equal to the kelvin, K. °C should be treated as a single symbol, with no space between the ° sign and the letter C. (The symbol °K, and the symbol °, should no longer be used.)
(3) The units becquerel, gray, and sievert are admitted for reasons of safeguarding human health.
(4) The units radian and steradian are described as 'SI supplementary units'. However, in chemistry, as well as in physics,

TABLE 1.2.2
SI DERIVED UNITS WITH SPECIAL NAMES AND SYMBOLS (continued)

they are usually treated as dimensionless derived units, and this was recognized by CIPM in 1980. Since they are then of dimension 1, this leaves open the possibility of including them or omitting them in expressions of SI derived units, In practice this means that rad and sr may be used when appropriate and may be omitted if clarity is not lost thereby.

TABLE 1.2.3
SI PREFIXES

To signify decimal multiples and submultiples of SI units the following prefixes may be used.

Submultiple	Prefix	Symbol	Multiple	Prefix	Symbol
10^{-1}	deci	d	10	deca	da
10^{-2}	centi	c	10^{2}	hecto	h
10^{-3}	milli	m	10^{3}	kilo	k
10^{-6}	micro	μ	10^{6}	mega	M
10^{-9}	nano	n	10^{9}	giga	G
10^{-12}	pico	p	10^{12}	tera	T
10^{-15}	femto	f	10^{15}	peta	P
10^{-18}	atto	a	10^{18}	exa	E

Prefix symbols should be printed in roman (upright) type with no space between the prefix and the unit symbol.

Example kilometer, km

When a prefix is used with a unit symbol, the combination is taken as a new symbol that can be raised to any power without the use of parentheses.

Examples $1\ cm^3 = (0.01\ m)^3 = 10^{-6}\ m^3$
$1\ \mu s^{-1} = (10^{-6}\ s)^{-1} = 10^{6}\ s^{-1}$
$1\ V/cm = 100\ V/m$
$1\ mmol/dm^3 = 1\ mol\ m^{-3}$

A prefix should never be used on its own, and prefixes are not to be combined into compound prefixes.

Example pm, not μμm

The names and symbols of decimal multiples and sub-multiples of the SI base unit of mass, the kg, which already contains a prefix, are constructed by adding the appropriate prefix to the word gram and symbol g.

Examples mg, not μkg; Mg, not kkg

The SI prefixes are not to be used with °C.

TABLE 1.2.4
CONVERSION FACTORS

To convert a quantity expressed in a non-SI unit to a value in SI units, multiply the value in the non-SI unit by the factor k in the middle column. For the inverse process, multiply the value in the SI unit by the factor k^{-1} in the last column to obtain the value in the non-SI unit.

TABLE 1.2.4
CONVERSION FACTORS (continued)

Non-SI unit	k 1 (non-SI unit) = k (SI unit)	k^{-1} 1 (SI unit) = k^{-1} (non-SI unit)
Length	**SI unit, m**	
Å (angstrom)	0.1×10^{-9}*	0.1×10^{11}*
cm (centimeter)	0.1×10^{-1}*	0.1×10^{3}*
in (inch)	0.254×10^{-1}*	0.3937008×10^{2}
ft (foot)	0.3048*	0.3280840×10
Area	**SI unit, m^2**	
cm^2 (square centimeter)	0.1×10^{-3}*	0.1×10^{5}*
in^2 (square inch)	0.64516×10^{-3}*	0.1550003×10^{4}
ft^2 (square foot)	0.9290304×10^{-1}*	0.1076391×10^{2}
Volume	**SI unit, m^3**	
cm^3 (cubic centimeter)	0.1×10^{-5}*	0.1×10^{7}*
dm^3 (cubic decimeter)	0.1×10^{-2}*	0.1×10^{4}*
in^3 (cubic inch)	$0.16387064 \times 10^{-4}$*	0.6102374×10^{5}
ft^3 (cubic foot)	0.2831685×10^{-1}	0.3531467×10^{2}
L (liter)	0.1×10^{-2}*	0.1×10^{4}*
mL (milliliter)	0.1×10^{-5}*	0.1×10^{7}*
UKgal (UK gallon)	0.45461×10^{-2}	0.21997×10^{3}
USgal (US gallon)	0.37854×10^{-2}	0.26417×10^{3}
Mass	**SI unit, kg**	
g (gram)	0.1×10^{-2}*	0.1×10^{4}*
mg (milligram)	0.1×10^{-5}*	0.1×10^{7}*
t (tonne)	0.1×10^{4}*	0.1×10^{-2}
lb (pound)	0.45359237*	0.2204623×10
Density	**SI unit, kg m^{-3}**	
g cm^{-3} (gram per cubic centimeter)	0.1×10^{4}*	0.1×10^{-2}*
g L^{-1} (gram per liter)	0.1×10*	0.1×10*
lb in^{-3} (pound per cubic inch)	0.2767991×10^{5}	0.3612728×10^{-4}
lb ft^{-3} (pound per cubic foot)	0.1601847×10^{2}	0.6242795×10^{-1}
lb $UKgal^{-1}$ (pound per UK gallon)	0.99776×10^{2}	0.100224×10^{-1}
lb $USgal^{-1}$ (pound per US gallon)	0.1198264×10^{3}	0.8345406×10^{-2}
Time	**SI unit, s**	
min (minute)	0.6×10^{2}*	0.1666667×10^{-1}
h (hour)	0.36×10^{4}*	0.2777778×10^{-3}
d (day)	0.864×10^{5}*	0.1157407×10^{-4}

TABLE 1.2.4
CONVERSION FACTORS (continued)

Non-SI unit	k 1 (non-SI unit) = k (SI unit)	k^{-1} 1 (SI unit) = k^{-1} (non-SI unit)
Force	**SI unit, N (newton, kg m s^{-2})**	
dyn (dyne)	0.1×10^{-4}*	0.1×10^{6}*
kgf (kilogram-force)	0.980665×10*	0.1019716
lbf (pound-force)	0.44482×10	0.22481
Pressure	**SI unit, Pa (pascal, kg m^{-1} s^{-2})**	
bar	0.1×10^{6}*	0.1×10^{-4}*
atm (atmosphere)	0.101325×10^{6}*	0.9869233×10^{-5}
dyn cm^{-2} (dyne per square centimeter)	0.1*	0.1×10^{2}*
kgf cm^{-2} (kilogram-force per square centimeter)	0.980665×10^{5}*	0.1019716×10^{-4}
lbf in^{-2} (p.s.i., pound-force per square inch)	0.6894757×10^{4}	0.1450377×10^{-3}
lbf ft^{-2} (pound-force per square foot)	0.4788026×10^{2}	0.2088543×10^{-1}
inHg (inch of mercury)	0.3386388×10^{4}	0.2952999×10^{-3}
mmHg (millimeter of mercury, torr)	0.1333224×10^{3}	0.7500617×10^{-2}
Energy	**SI unit, J (joule, kg m^{2} s^{-2})**	
erg	0.1×10^{-6}*	0.1×10^{8}*
cal_{IT} (I.T. calorie)	0.41868×10*	0.2388459
cal_{th} (thermochemical calorie)	0.4184×10*	0.2390057
kW h (kilowatt hour)	0.36×10^{7}*	0.2777778×10^{-6}
L atm (liter atmosphere)	0.101325×10^{3}*	0.9869233×10^{-2}
ft lbf (foot pound-force)	0.1355818×10	0.7375622
hp h (horse power hour)	0.2684519×10^{7}	0.3725062×10^{-6}
Btu_{IT} (British thermal unit)	0.1055056×10^{4}	0.9478172×10^{-3}
Viscosity (absolute)	**SI unit, Pa s (pascal second, kg m^{-1} s^{-1})**	
P (poise)	0.1*	0.1×10^{2}*
cP (centipoise)	0.1×10^{-2}*	0.1×10^{4}*
lbf s in^{-2} (pound-force second per square inch)	0.6894757×10^{4}	0.1450377×10^{-3}
lb ft^{-1} s^{-1} (pound per foot second)	0.1488164×10	0.6719689
Viscosity (kinematic)	**SI unit, m^{2} s^{-1}**	
St (stokes)	0.1×10^{-3}*	0.1×10^{5}*
cSt (centistokes)	0.1×10^{-5}*	0.1×10^{7}*
ft^{2} s^{-1} (square foot per second)	0.9290304×10^{-1}*	0.1076391×10^{2}

TABLE 1.2.4
CONVERSION FACTORS (continued)

Non-SI unit	k 1 (non-SI unit) = k (SI unit)	k^{-1} 1 (SI unit) = k^{-1} (non-SI unit)
Thermal conductivity	**SI unit, W m^{-1} K^{-1} (watt per meter kelvin, kg m K^{-1} s^{-3})**	
W cm^{-1} K^{-1} (watt per centimeter kelvin)	0.1×10^{3}*	0.1×10^{-1}*
cal_{th} s^{-1} cm^{-1} °C^{-1} (calorie per second centimeter degree Celsius)	0.4184×10^{3}*	0.2390057×10^{-2}
$kcal_{th}$ h^{-1} m^{-1} °C^{-1} (kilocalorie per hour meter degree Celsius)	0.116222×10*	0.8604223
Btu_{IT} h^{-1} ft^{-1} °F^{-1} (British thermal unit per hour foot degree Fahrenheit)	0.173073×10	0.5777909
Diffussion coefficient	**SI unit, m^2 s^{-1}**	
cm^2 s^{-1} (square centimeter per second)	0.1×10^{-3}*	0.1×10^{5}*
in^2 s^{-1} (square inch per second)	0.64516×10^{-3}*	0.1550003×10^{4}
ft^2 h^{-1} (square foot per hour)	0.258064×10^{-4}*	0.3875008×10^{5}
Surface tension	**SI unit, N m^{-1} (newton per meter, kg s^{-2})**	
mN m^{-1} (millinewton per meter)	0.1×10^{-2}*	0.1×10^{4}*
dyn cm^{-1} (dyne per centimeter)	0.1×10^{-2}*	0.1×10^{4}*

* These factors are exact.

1.3. INTERNATIONAL TEMPERATURE SCALE OF 1990

A new temperature scale, the International Temperature Scale of 1990 (ITS-90), was officially adopted by the Comité International des Poids et Mesures (CIPM), meeting 26—28 September 1989 at the Bureau International des Poids et Mesures (BIPM). The ITS-90 was recommended to the CIPM for its adoption following the completion of the final details of the new scale by the Comité Consultatif de Thermométrie (CCT), meeting 12—14 September 1989 at the BIPM in its 17th Session. The ITS-90 became the official international temperature scale on 1 January 1990. The ITS-90 supersedes the present scales, the International Practical Temperature Scale of 1968 (IPTS-68) and the 1976 Provisional 0.5 to 30 K Temperature Scale (EPT-76).

The ITS-90 extends upward from 0.65 K, and temperatures on this scale are in much better agreement with thermodynamic values that are those on the IPTS-68 and the EPT-76. The new scale has subranges and alternative definitions in certain ranges that greatly facilitate its use. Furthermore, its continuity, precision, and reproducibility throughout its ranges are much improved over that of the present scales. The replacement of the thermocouple with the platinum resistance thermometer at temperatures below 961.78°C resulted in the biggest improvement in reproducibility.

The ITS-90 is divided into four primary ranges:

1. Between 0.65 and 3.2 K, the ITS-90 is defined by the vapor pressure-temperature relation of ^{3}He, and between 1.25 and 2.1768 K (the λ point) and between 2.1768 and 5.0 K by the vapor pressure-temperature relations of ^{4}He. T_{90} is defined by the vapor pressure equations of the form:

$$T_{90}/\mathrm{K} = A_0 + \sum_{i=1}^{9} A_i \left[\left(\ln(p/\mathrm{Pa}) - B \right) / C \right]^i$$

   The values of the coefficients A_i, and of the constants A_o, B, and C of the equations, are given below.
2. Between 3.0 and 24.5561 K, the ITS-90 is defined in terms of a ^{3}He or ^{4}He constant volume gas thermometer (CVGT). The thermometer is calibrated at three temperatures: at the triple point of neon (24.5561 K), at the triple point of equilibrium hydrogen (13.8033 K), and at a temperature between 3.0 and 5.0 K, the value of which is determined by using either ^{3}He or ^{4}He vapor pressure thermometry.
3. Between 13.8033 K (–259.3467°C) and 1234.93 K (961.78°C), the ITS-90 is defined in terms of the specified fixed points given below, by resistance ratios of platinum resistance thermometers obtained by calibration at specified sets of the fixed points, and by reference functions and deviation functions of resistance ratios which relate to T_{90} between the fixed points.
4. Above 1234.93 K, the ITS-90 is defined in terms of Planck's radiation law, using the freezing-point temperature of either silver, gold, or copper as the reference temperature.

Full details of the calibration procedures and reference functions for various subranges are given in Reference 1.

REFERENCES

1. Preston-Thomas, H., *Metrologia*, 27, 3—10, 1990 (Official release on ITS-90); errata in *Metrologia*, 27, 107, 1990.
2. McGlashan, M. L., *J. Chem. Thermodynamics*, 22, 653—663, 1990 (General description of ITS-90 and its relation to previous scales).
3. Rusby, R. L., *J. Chem. Thermodynamics*, 23, 1153—1161, 1991 (Conversion from previous scales to ITS-90).
4. Lide, D. R., Editor, *CRC Handbook of Chemistry and Physics, 74th Edition*, CRC Press, Boca Raton, FL, 1993 (Conversion from previous scales; ITS-90 thermocouple tables).

TABLE 1.3.1
DEFINING FIXED POINTS OF THE ITS-90

Material[a]	Equilibrium state[b]	Temperature	
		T_{90}/K	t_{90}/°C
He	VP	3 to 5	−270.15 to −268.15
e-H_2	TP	13.8033	−259.3467
e-H_2 (or He)	VP (or CVGT)	≈17	≈ −256.15
e-H_2 (or He)	VP (or CVGT)	≈20.3	≈ −252.85
Ne[c]	TP	24.5561	−248.5939
O_2	TP	54.3584	−218.7916
Ar	TP	83.8058	−189.3442
Hg[c]	TP	234.3156	−38.8344
H_2O	TP	273.16	0.01
Ga[c]	MP	302.9146	29.7646
In[c]	FP	429.7485	156.5985
Sn	FP	505.078	231.928
Zn	FP	692.677	419.527
Al[c]	FP	933.473	660.323
Ag	FP	1234.93	961.78
Au	FP	1337.33	1064.18
Cu[c]	FP	1357.77	1084.62

[a] e-H_2 indicates equilibrium hydrogen, that is, hydrogen with the equilibrium distribution of its ortho and para states. Normal hydrogen at room temperature contains 25% para hydrogen and 75% ortho hydrogen.

[b] VP indicates vapor pressure point; CVGT indicates constant volume gas thermometer point; TP indicates triple point (equilibrium temperature at which the solid, liquid, and vapor phases coexist); FP indicates freezing point, and MP indicates melting point (the equilibrium temperatures at which the solid and liquid phases coexist under a pressure of 101 325 Pa, one standard atmosphere). The isotopic composition is that naturally occurring.

[c] Previously, these were secondary fixed points.

TABLE 1.3.2
VALUES OF COEFFICIENTS IN THE VAPOR PRESSURE EQUATIONS FOR HELIUM

Coef.or constant	^{3}He 0.65—3.2 K	^{4}He 1.25—2.1768 K	^{4}He 2.1768—5.0 K
A_0	1.053 447	1.392 408	3.146 631
A_1	0.980 106	0.527 153	1.357 655
A_2	0.676 380	0.166 756	0.413 923
A_3	0.372 692	0.050 988	0.091 159
A_4	0.151 656	0.026 514	0.016 349
A_5	−0.002 263	0.001 975	0.001 826
A_6	0.006 596	−0.017 976	−0.004 325
A_7	0.088 966	0.005 409	−0.004 973
A_8	−0.004 770	0.013 259	0
A_9	−0.054 943	0	0
B	7.3	5.6	10.3
C	4.3	2.9	1.9

Section 2
Thermodynamic Properties of Pure Substances

2.1. PHYSICAL CONSTANTS AND PHASE BEHAVIOR

Most pure substances at moderate pressures exhibit a phase diagram of the type shown schematically in Figure 1a. The horizontal dashed line in this figure represents normal atmospheric pressure. The solid, liquid, and gas phases are in equilibrium at the triple point (TP), and the liquid-gas phase boundary ends at the critical point (CP). The overall phase behavior is conveniently described by the physical constants indicated in the figure: the normal melting point temperature T_m (where "normal" signifies a pressure of 101 325 Pa), normal boiling point temperature T_b, critical temperature T_c, and critical pressure P_c. Other solid phases usually exist at higher pressures; for some substances, especially metals, other solid phases are significant even at ambient pressure.

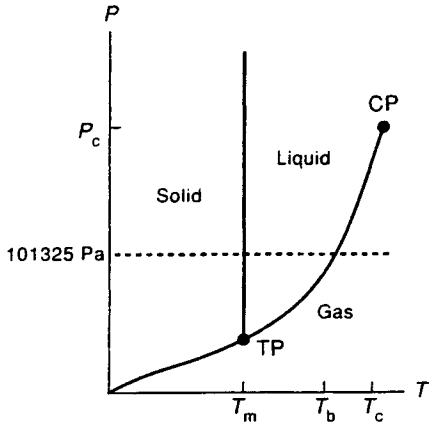

FIGURE 1a

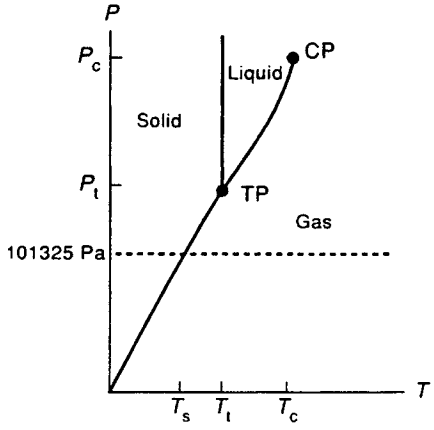

FIGURE 1b

Some substances, including such common compounds as carbon dioxide, show a somewhat different phase behavior as illustrated in Figure 1b. In such cases the normal melting and boiling points are undefined because of the steepness of the solid-gas phase boundary. Here the most useful physical constants are the triple point temperature and pressure, T_t and P_t, and the normal sublimation temperature T_s, which is the temperature at which the sublimation pressure of the solid reaches atmospheric pressure.

The tables in this section summarize the physical constants of some common substances and give details of the liquid-gas phase boundary (vapor pressure), the solid-gas boundary (sublimation pressure), and the solid-liquid boundary (variation of melting temperature with pressure).

TABLE 2.1.1
SUMMARY OF PHYSICAL CONSTANTS OF IMPORTANT SUBSTANCES

This table gives the normal melting and boiling temperatures, the liquid-gas critical constants, and the density at 298.15 K (25°C) for a selected list of about 1000 important substances. The properties are defined as follows:

Normal Melting Point Temperature: Temperature at which the solid and liquid phases are in equilibrium at a pressure of 101325 Pa. For most substances, this differs by less than 0.1 K from the triple point temperature, T_t, at which the solid, liquid, and gas phases are in equilibrium. However, for a few highly volatile solids such as carbon dioxide the sublimation pressure of the solid reaches 101325 Pa at a temperature below T_t, so that the normal melting point is undefined. In such cases the value in this table is followed by "t" and represents the triple point temperature (see Table 2.1.2. for triple point temperatures and pressures of other substances).
Normal Boiling Point Temperature: Temperature at which the liquid and gas phases are in equilibrium at a pressure of 101325 Pa. A value followed by "s" is a sublimation temperature, where the solid and gas are in equilibrium at 101325 Pa. See Table 2.1.3 for boiling point temperatures as a function of pressure.
Critical Temperature: Temperature above which the liquid phase does not exist.
Critical Pressure: Pressure corresponding to the critical temperature on the liquid-gas phase boundary.
Critical Molar Volume: Volume of one mole of the substance at the critical temperature and pressure.
Density: Ratio of mass to volume. The density value in the table refers to the solid phase if the normal melting point T_m>298.15 K and to the liquid phase if T_m<298.15 K. The pressure is taken to be nominal atmospheric pressure (about 100 kPa) except for those density values preceded by an * , where the applicable pressure is the saturation pressure of the liquid (greater than atmospheric) at 298.15 K. See Table 2.2.2 for liquid densities as a function of temperature.
Note on temperature scales: The values in this table come from many sources and were published over a period of many years. Thus it has not been possible to correct all values to the ITS-90 temperature scale (see Section 1.3). Only in the case of the elements are the values given consistently on the ITS-90 scale. For temperatures up to 1300 K, the difference between the previous scale, IPTS-68, and ITS-90 is less than 0.25 K.

Substances are arranged in the Hill order, with substances that do not contain carbon preceding those that do contain carbon.

Physical quantity	Symbol	SI unit
Normal melting point temperature	T_m	K
Normal boiling point temperature	T_b	K
Critical temperature	T_c	K
Critical pressure	P_c	Pa
Critical molar volume	V_c	$m^3 mol^{-1}$
Density at 298.15 K	ρ_o	$kg\ m^{-3}$

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TABLE 2.1.1
SUMMARY OF PHYSICAL CONSTANTS OF IMPORTANT SUBSTANCES (continued)

Molecular formula	Name	T_m/ K	T_b/ K	T_c/ K	P_c/ MPa	V_c/ $cm^3\ mol^{-1}$	ρ_o/ $g.cm^{-3}$
Ac	Actinium	1324	3471				10
Ag	Silver	1234.93	2435				10.5
AgBr	Silver bromide	705	1775				6.47
AgCl	Silver chloride	728	1820				5.56
AgI	Silver iodide	831	1779				5.68
Al	Aluminum	933.47	2792				2.70
AlB_3H_{12}	Aluminum trihydride-tris(borane)	208.6	317.6				
$AlBr_3$	Aluminum tribromide	370.6	528	763	2.89	310	3.21
$AlCl_3$	Aluminum trichloride	463		620	2.63	257	2.48
AlI_3	Aluminum triiodide	464	655	983		408	3.98
Al_2O_3	Dialuminum trioxide	2327					3.97
Ar	Argon	83.80	87.30	150.87	4.898	75	
As	Arsenic	1090 t	887 s	1673		35	5.78
$AsBr_3$	Arsenic tribromide	304.2	494				3.40
$AsCl_3$	Arsenic trichloride	257	403	654		252	2.150
AsF_3	Arsenic trifluoride	267.2	330.9				2.7
AsF_5	Arsenic pentafluoride	193.3	219.9				
AsH_3	Arsane	157	210.6	373.1			
AsI_3	Arsenic triiodide	414.0	697				4.73
Au	Gold	1337.33	3129				19.3
B	Boron	2348	4273				2.34
BBr_3	Boron tribromide	228	364	581		272	2.6
BCl_3	Boron trichloride	166	285.80	455	3.87	239	
BF_3	Boron trifluoride	146.3	172	260.8	4.98	115	
BI_3	Boron triiodide	316	483	773		356	3.96
B_2Cl_4	Tetrachlorodiborane(4)	180.5	338				
B_2F_4	Tetrafluorodiborane(4)		239.3				
B_2H_6	Diborane(6)	107.6	180.77	289.8	4.05		
B_2O_3	Diboron trioxide	723					2.46
$B_3H_6N_3$	Cyclotriborazane	215	326				0.80
B_4H_{10}	Tetraborane(10)	153	291				
B_5H_9	Pentaborane(9)	226.5	333				0.60
B_5H_{11}	Pentaborane(11)	150	336				
B_6H_{10}	Hexaborane(10)	210.8	381				0.67
Ba	Barium	1000	2170				3.62
$BaCl_2$	Barium dichloride	1235					3.9
BaF_2	Barium difluoride	1641					4.893
BaO_4S	Barium sulfate	1623					4.49
Be	Beryllium	1560	2744				1.85
$BeCl_2$	Beryllium dichloride	688	820				1.90
BeF_2	Beryllium difluoride	825	1432				2.1
BeI_2	Beryllium diiodide	753	760				4.32
BeO	Beryllium oxide	2780					3.01
Bi	Bismuth	544.55	1837				9.79
$BiBr_3$	Bismuth tribromide	491	726	1220		301	5.72
$BiCl_3$	Bismuth trichloride	503	712.5	1179	12.0	261	4.75
BrCs	Cesium bromide	909					4.43
BrF_3	Bromine trifluoride	281.92	398.9				2.803
BrF_5	Bromine pentafluoride	212.6	313.91				2.460
BrH	Hydrogen bromide	186.34	206.77	363.2	8.55		
BrI	Iodine bromide	313	389	719		139	4.3
BrIn	Indium bromide	563	929				4.96
BrK	Potassium bromide	1007					2.74
BrLi	Lithium bromide	825					3.464
BrNa	Sodium bromide	1014					3.200
BrRb	Rubidium bromide	955	1613				3.35
BrTl	Thallium bromide	733	1092				7.5
Br_2	Bromine	265.9	331.9	588	10.34	127	3.1028
Br_2Ca	Calcium dibromide	1015					3.38
Br_2Cd	Cadmium dibromide	841	1117				5.19
Br_2Hg	Mercury dibromide	509	595	1012			6.05
Br_2Pb	Lead dibromide	644	1165				6.69
Br_2Sn	Tin dibromide	488	912				5.12

TABLE 2.1.1
SUMMARY OF PHYSICAL CONSTANTS OF IMPORTANT SUBSTANCES (continued)

Molecular formula	Name	T_m/ K	T_b/ K	T_c/ K	P_c/ MPa	V_c/ $cm^3\ mol^{-1}$	ρ_o/ $g\ cm^{-3}$
Br_2Zn	Zinc dibromide	667	970				4.5
Br_3Ga	Gallium tribromide	394.6	552	806.7		303	
Br_3HSi	Tribromosilane	200	382	610.0		305	2.7
Br_3P	Phosphorus tribromide	233	446.10	711		300	2.8
Br_3Sb	Antimony tribromide	369.7	560.26	904		300	4.35
Br_4Ge	Germanium tetrabromide	299.2	459.50	718		392	
Br_4Si	Silicon tetrabromide	278.3	427	663		382	2.8
Br_4Sn	Tin tetrabromide	304	478	744		417	3.7
Br_4Ti	Titanium tetrabromide	312	503	795.7		391	3.37
Br_4Zr	Zirconium tetrabromide	723		805		424	3.98
Br_5Ta	Tantalum pentabromide	538	622	974		461	4.99
Ca	Calcium	1115	1757				1.54
$CaCl_2$	Calcium dichloride	1045	2208.6				2.22
CaF_2	Calcium difluoride	1691	2806.5				3.18
CaI_2	Calcium diiodide	1052					3.96
CaO	Calcium oxide	3200					3.34
CaO_4S	Calcium sulfate	1723					2.96
Cd	Cadmium	594.22	1040				8.69
$CdCl_2$	Cadmium dichloride	837	1233				4.08
CdF_2	Cadmium difluoride	1383	2021				6.33
CdI_2	Cadmium diiodide	660	1015				5.64
Ce	Cerium	1072	3697				8.16
Ce_2O_3	Dicerium trioxide	2503					6.2
ClCs	Cesium chloride	918	1570				3.988
ClF	Chlorine fluoride	117.5	172.0				
$ClFO_3$	Perchloryl fluoride	126	226.40	368.4	5.37	161	
ClF_3	Chlorine trifluoride	196.81	284.90				
ClF_3Si	Chlorotrifluorosilane		203.10	307.7	3.46		
ClF_5	Chlorine pentafluoride		260	416	5.27	233	
ClH	Hydrogen chloride	158.97	188.15	324.7	8.31	81	*0.804
ClH_3Si	Chlorosilane		242.7				
ClH_4N	Ammonium chloride	793		1155	163.5		1.519
ClK	Potassium chloride	1043					1.988
ClLi	Lithium chloride	878	1656				2.07
ClNO	Nitrosyl chloride	211.6	267.60	440			
ClNa	Sodium chloride	1073.5	1738				2.17
$ClNaO_3$	Sodium chlorate	521					2.5
ClO_2	Chlorine dioxide	214	284				
ClRb	Rubidium chloride	990	1663				2.76
ClTl	Thallium chloride	703	1080				7.0
Cl_2	Chlorine	171.6	239.18	416.9	7.991	124	*1.394
Cl_2Cr	Chromium dichloride	1087	1573				2.88
Cl_2CrO_2	Chromyl dichloride	176.6	390				1.91
Cl_2Cu	Copper dichloride	703					3.4
Cl_2H_2Si	Dichlorosilane	151	281.4				
Cl_2Hg	Mercury dichloride	549	577	973		174	5.6
Cl_2Hg_2	Dimercury dichloride	816					6.97
Cl_2O	Dichlorine oxide	152.5	275.3				
Cl_2OS	Sulfinyl dichloride	172	348.7				1.631
Cl_2OSe	Selenosyl dichloride	281.6	453	730	7.09	235	2.430
Cl_2O_2S	Sulfonyl dichloride	222	342.5				1.680
Cl_2Pb	Lead dichloride	774	1224				5.98
Cl_2Sn	Tin dichloride	520	896				3.90
Cl_2Zn	Zinc dichloride	563	1005				2.907
Cl_3FSi	Trichlorofluorosilane		285.40	438.6	3.58		
Cl_3Ga	Gallium trichloride	351.0	474	694		263	2.47
Cl_3HSi	Trichlorosilane	144.9	306	479		268	1.3313
Cl_3OP	Phosphoryl trichloride	274	378.6				1.645
Cl_3OV	Vanadyl trichloride	194	400				
Cl_3P	Phosphorus trichloride	161	349.10	563		264	1.574
Cl_3PS	Thiophosphoryl chloride	236.9	398				
Cl_3Sb	Antimony trichloride	346.5	493.4	794		272	3.14
Cl_4Ge	Tetrachlorogerman	223.6	359.70	553.2	3.861	330	1.88

TABLE 2.1.1
SUMMARY OF PHYSICAL CONSTANTS OF IMPORTANT SUBSTANCES (continued)

Molecular formula	Name	T_m/ K	T_b/ K	T_c/ K	P_c/ MPa	V_c/ cm^3 mol^{-1}	ρ_o/ g cm^{-3}
Cl_4Hf	Hafnium tetrachloride			725.7	5.42	314	
Cl_4ORe	Rhenosyl tetrachloride	302.4	496	781		362	
Cl_4OW	Tungstenosyl tetrachloride	484	500.70	782		338	
Cl_4Si	Silicon tetrachloride	205	330.80	508.1	3.593	326	1.5
Cl_4Sn	Tin tetrachloride	240	387.30	591.9	3.75	351	2.3
Cl_4Te	Tellurium tetrachloride	497	660	1002	8.56	310	3.0
Cl_4Th	Thorium tetrachloride	1043	1194				4.59
Cl_4Ti	Titanium tetrachloride	248	409.60	638	4.66	339	1.73
Cl_4V	Vanadium tetrachloride	247.4	425				
Cl_4Zr	Zirconium tetrachloride	710		778	5.77	319	2.80
Cl_5Mo	Molybdenum pentachloride	467	541	850		369	2.93
Cl_5Nb	Niobium pentachloride	477.8	527.20	803.5	4.88	397	2.73
Cl_5P	Phosphorus pentachloride		433	646			
Cl_5Ta	Tantalum pentachloride	489	512.50	767		402	3.68
Cl_6W	Tungsten hexachloride	548	619.90	923		422	3.52
Co	Cobalt	1768	3200				8.86
CoO	Cobalt oxide	2103					6.5
Cr	Chromium	2180	2944				7.15
Cr_2O_3	Dichromium trioxide	2603					5.22
Cs	Cesium	302.9	944				1.93
Cu	Copper	1357.77	2835				8.96
CuO	Copper oxide	1719					6.5
CuO_4S	Copper sulfate						3.6
Dy	Dysprosium	1684	2834				8.55
Dy_2O_3	Didysprosium trioxide	2681					8.0
Er	Erbium	1802	3135				9.07
Er_2O_3	Dierbium trioxide	2691					8.6
Eu	Europium	1095	1869				5.24
FH	Hydrogen fluoride	189.79	292.65	461	6.48	69	*0.9580
FH_3Si	Fluorosilane		174.5				
FK	Potassium fluoride	1131	1775				2.48
FLi	Lithium fluoride	1121.3	1946				2.640
FNO	Nitrosyl fluoride	140.6	213.2				
FNO_2	Nitryl fluoride	107	200.7	349.5			
FNa	Sodium fluoride	1265	1977				2.78
FRb	Rubidium fluoride	1106					3.2
FTl	Thallium fluoride	595	928				8.36
F_2	Fluorine	53.49	84.95	144.13	5.172	66	
F_2HN	Difluoroazane		250	403			
F_2N_2	*cis*-Difluorodiazene		167.40	272	7.09		
F_2N_2	*trans*-Difluorodiazene		161.70	260	5.57		
F_2O	Oxygen difluoride	49.3	128.40	215			
F_2OS	Sulfinyl difluoride	143.6	229.3				
F_2Pb	Lead difluoride	1103	1566				8.44
F_2Zn	Zinc difluoride	1145	1773				4.9
F_2Xe	Xenon difluoride		387.50	631	9.32	148	
F_3HSi	Trifluorosilane		178				
F_3N	Nitrogen trifluoride	66.36	144.40	234.0	4.46	126	
F_3NO	Trifluoroazane oxide	112	185.60	303	6.43	147	
F_3P	Phosphorus trifluoride	121.6	171.6	271.2		4.33	
F_3PS	Thiophosphoryl trifluoride	124.3	220.90	346.0	3.82		
F_3Sb	Antimony trifluoride	565	649				4.38
F_4N_2	Tetrafluorohydrazine	108.6	199	309	3.75		
F_4S	Sulfur tetrafluoride	148	232.70	364			
F_4Si	Silicon tetrafluoride	182.9	187	259.0	3.72		
F_4Th	Thorium tetrafluoride	1383	1953				6.1
F_4U	Uranium tetrafluoride	1309	1690				6.7
F_4Xe	Xenon tetrafluoride	387	388.90	612	7.04	188	
F_5I	Iodine pentafluoride	282.58	373.6				3.19
F_5Nb	Niobium pentafluoride	353	502	737	6.28	155	2.7
F_5P	Phosphorus pentafluoride		188.5				
F_5Ta	Tantalum pentafluoride	368.2	502.3				5.0
F_5V	Vanadium pentafluoride	292.6	321.4				2.50

TABLE 2.1.1
SUMMARY OF PHYSICAL CONSTANTS OF IMPORTANT SUBSTANCES (continued)

Molecular formula	Name	T_m/ K	T_b/ K	T_c/ K	P_c/ MPa	V_c/ $cm^3\ mol^{-1}$	ρ_o/ $g\ cm^{-3}$
F_6Ir	Iridium hexafluoride	317	326				4.8
F_6Mo	Molybdenum hexafluoride	290.6	307	473	4.75	226	2.54
F_6S	Sulfur hexafluoride	222.4 t	209.3 s	318.69	3.77	199	
F_6Se	Selenium hexafluoride		227	345.5			
F_6Te	Tellurium hexafluoride		234	356			
F_6U	Uranium hexafluoride	337.20 t	329.6 s	505.8	4.66	250	5.09
F_6W	Tungsten hexafluoride	275.4	290	444	4.34	233	
Fe	Iron	1811	3134				7.87
FeO	Iron oxide	1650					6.0
FeS	Iron sulfide	1463					4.3
Fe_3O_4	Triiron tetraoxide	1870					5.2
Ga	Gallium	303.0	2477				5.91
GaI_3	Gallium triiodide	485	613	951		395	4.5
Gd	Gadolinium	1587	3537				7.90
Ge	Germanium	1211.40	3106				5.3234
GeH_4	Germane	108	183	312.2	4.95	147	
GeI_4	Germanium tetraiodide	417	650	973		500	4.4
Ge_2H_6	Digermane		303.9				
HI	Hydrogen iodide	222.38	237.60	424.0	8.31		
HKO	Potassium hydroxide	679	1600				
HLiO	Lithium hydroxide	744.3	1899				1.5
HNO_3	Nitric acid	231.5	356				1.55
HN_3	Hydrogen azide	193	308.8				
HNaO	Sodium hydroxide	596	1661				2.13
H_2	Hydrogen	13.81	20.38	32.97	1.293	65	
H_2O	Water	273.15	373.15	647.14	22.06	56	0.9970
H_2O_2	Dihydrogen peroxide	272.72	423.3				1.4
H_2O_4S	Sulfuric acid	283.46	610				1.8
H_2S	Dihydrogen sulfide	187.6	212.84	373.2	8.94	99	*0.769
H_2Se	Dihydrogen selenide	207.42	231.90	411	8.92		
H_2Te	Dihydrogen telluride	224	271				
H_3N	Ammonia	195.41	239.72	405.5	11.35	72	*0.602
H_3NO	Hydroxylamine	306.2	331				1.21
H_3O_2P	Phosphonous acid	299.6	403				1.49
H_3O_3P	Phosphorous acid	347.5	473				1.65
H_3O_4P	Phosphoric acid	315.5	680				
H_3P	Phosphine	140	185.40	324.5	6.54		
H_3Sb	Stibine	185	256				
H_4N_2	Hydrazine	274.5	386.70	653	14.7		1.0036
$H_4N_2O_3$	Ammonium nitrate	442.7					1.72
H_4Si	Silane	88	161				
H_4Sn	Stannane		221.3				
H_6Si_2	Disilane	140.8	258.8				
H_8Si_3	Trisilane	155.7	326				0.7
He	Helium		4.22	5.19	0.227	57	
Hf	Hafnium	2506	4876				13.3
HfI_4	Hafnium tetraiodide	722		916		528	5.6
Hg	Mercury	234.32	629.88	1750	172.00	43	13.5336
HgI_2	Mercury diiodide	532	627	1072			6.3
Ho	Holmium	1745	2967				8.80
IIn	Indium iodide	624	985				5.3
IK	Potassium iodide	954	1596				3.12
ILi	Lithium iodide	742	1444				4.06
INa	Sodium iodide	928	1577				3.67
IRb	Rubidium iodide	915	1573				3.55
ITl	Thallium iodide	713	1097				7.1
I_2	Iodine	386.8	457.5	819		155	4.933
I_2Pb	Lead diiodide	683	1145				6.16
I_2Sr	Strontium diiodide	811	2046				4.4
I_2Zn	Zinc diiodide	719	898				4.74
I_3Sb	Antimony triiodide	441	674	1102			4.92
I_4Si	Silicon tetraiodide	393.6	560.50	944		558	4.1
I_4Sn	Tin tetraiodide	416	637.50	968		531	4.46

TABLE 2.1.1
SUMMARY OF PHYSICAL CONSTANTS OF IMPORTANT SUBSTANCES (continued)

Molecular formula	Name	T_m/ K	T_b/ K	T_c/ K	P_c/ MPa	V_c/ $cm^3\ mol^{-1}$	ρ_o/ $g\ cm^{-3}$
I_4Ti	Titanium tetraiodide	423	650	1040		505	
In	Indium	429.75	2345				7.31
Ir	Iridium	2719	4701				22.5
K	Potassium	336.53	1032				0.89
KNO_3	Potassium nitrate	610					2.11
Kr	Krypton	115.79	119.93	209.41	5.50	91	
La	Lanthanum	1193	3728				6.15
Li	Lithium	453.6	1615				0.534
$LiNO_3$	Lithium nitrate	526					2.38
Lu	Lutetium	1936	3666				9.84
Mg	Magnesium	923	1363				1.74
MgO	Magnesium oxide	3099					3.6
Mn	Manganese	1519	2334				7.3
Mo	Molybdenum	2896	4912				10.2
MoO_3	Molybdenum trioxide	1074	1428				4.70
$NNaO_3$	Sodium nitrate	580					2.26
NO	Nitrogen oxide	109.5	121.41	180	6.48	58	*0.505
NO_2	Nitrogen dioxide (see N_2O_4)						
N_2	Nitrogen	63.15	77.35	126.21	3.39	90	
N_2O	Dinitrogen oxide	182.3	184.67	309.57	7.255	97	
N_2O_4	Dinitrogen tetraoxide	263.8	294.30	431	10.1	167	
N_2O_5	Dinitrogen pentaoxide	303	320				2.0
Na	Sodium	370.87	1156				0.97
Na_2O_4S	Disodium sulfate	1157					2.7
Nb	Niobium	2750	5017				8.57
Nd	Neodymium	1289	3339				7.01
Nd_2O_3	Dineodymium trioxide	2593					7.2
Ne	Neon	24.56	27.07	44.4	2.76	42	
Ni	Nickel	1728.3	3186				8.90
OTl_2	Dithallium oxide	573	773				
OZn	Zinc oxide	2248					5.6
O_2	Oxygen	54.36	90.17	154.59	5.043	73	
O_2S	Sulfur dioxide	197.6	263.13	430.8	7.884	122	
O_2Se	Selenium dioxide	613					3.9
O_2Si	Silicon dioxide	1883	2503				2.6481
O_3	Ozone	80	161.80	261.1	5.57	89	
O_3S	Sulfur trioxide	289.9	318	491.0	8.2	127	1.92
O_3Y_2	Diyttrium trioxide	2712					5.03
O_3Yb_2	Diytterbium trioxide	2708					9.2
O_4Os	Osmium tetraoxide	314	408	678			5.0
O_5P_2	Diphosphorus pentaoxide	693					2.30
O_5V_2	Divanadium pentaoxide	943	2073				3.35
O_7Re_2	Dirhenium heptaoxide	570	723	942		334	6.103
Os	Osmium	3306	5285				22.5
P	Phosphorus	317.30	550	994			2.69
Pb	Lead	600.61	2022				11.3
PbS	Lead sulfide	1386.5					7.60
Pd	Palladium	1828	3236				12.0
Pm	Promethium	1315	3273				7.26
Pr	Praseodymium	1204	3783				6.77
Pt	Platinum	2041.5	4098				21.5
Pu	Plutonium	913	3501				19.7
Rb	Rubidium	312.46	961				1.53
Rh	Rhodium	2237	3968				12.4
Rn	Radon	202	211.4	377	6.28		
Ru	Ruthenium	2607	4423				12.1
S	Sulfur	388.36	717.75	1314	20.7		2.07
STl_2	Dithallium sulfide	721	1640				8.39
Sb	Antimony	903.78	1860				6.68
Sc	Scandium	1814	3103				2.99
Se	Selenium	495	958	1766	27.2		4.79
Si	Silicon	1687	3538				2.3290
Sm	Samarium	1345	2063				7.52

TABLE 2.1.1
SUMMARY OF PHYSICAL CONSTANTS OF IMPORTANT SUBSTANCES (continued)

Molecular formula	Name	T_m/ K	T_b/ K	T_c/ K	P_c/ MPa	V_c/ $cm^3\ mol^{-1}$	ρ_o/ $g\ cm^{-3}$
Sn	Tin	505.08	2875				7.28
Sr	Strontium	1050	1655				2.64
Ta	Tantalum	3290	5731				16.4
Tb	Terbium	1632	3494				8.23
Tc	Technetium	2430	4538				11
Te	Tellurium	722.66	1261				6.24
Th	Thorium	2023	5061				11.7
Ti	Titanium	1941	3560				4.5
Tl	Thallium	577	1746				11.8
Tm	Thulium	1818	2219				9.32
U	Uranium	1408	4404				19.1
V	Vanadium	2183	3680				6.0
W	Tungsten	3695	5828				19.3
Xe	Xenon	161.40	165.11	289.73	5.84	118	
Y	Yttrium	1799	3609				4.47
Yb	Ytterbium	1097	1467				6.90
Zn	Zinc	692.68	1180				7.14
Zr	Zirconium	2127.85	4682				6.52
C	Carbon	4247 t	4098 s				3.51
$CBrClF_2$	Bromochlorodifluoromethane	113.6	269.14	426.88	4.254	246	
$CBrCl_3$	Bromotrichloromethane	267.4	378				2.012
$CBrF_3$	Bromotrifluoromethane	101	215.26	340.2	3.97	196	
CBrN	Cyanogen bromide	325	334.6				2.005
CBr_2F_2	Dibromodifluoromethane	163.0	295.9	471.3			
CBr_3Cl	Tribromochloromethane	328	431.6				
CBr_4	Tetrabromomethane	363.2	462.6				3.42
$CCaO_3$	Calcium carbonate	1612.2					2.711
$CClF_3$	Chlorotrifluoromethane	92	191.7	302	3.870	180	*0.830
CClN	Cyanogen chloride	266.60	286				
CCl_2F_2	Dichlorodifluoromethane	117	243.3	384.95	4.136	217	*1.311
CCl_2O	Carbonyl dichloride	145.2	281	455	5.67	190	*1.3719
CCl_3F	Trichlorofluoromethane	162.04	296.78	471.2	4.41	248	*1.4760
CCl_4	Tetrachloromethane	250	349.8	556.6	4.516	276	1.5844
CF_2O	Carbonyl difluoride	161.89	188.58				
CF_4	Tetrafluoromethane	89.56	145.07	227.6	3.74	140	
$CHBrCl_2$	Bromodichloromethane	216	363				1.970
$CHBr_3$	Tribromomethane	281.20	422.36				2.8761
$CHClF_2$	Chlorodifluoromethane	115.73	232.40	369.3	4.99	169	1.3113
$CHCl_2F$	Dichlorofluoromethane	138	282.05	451.58	5.18	196	
$CHCl_3$	Trichloromethane	209.5	334.33	536.4	5.47	239	1.480
CHF_3	Trifluoromethane	117.97	191.0	299.3	4.858	133	*0.673
CHI_3	Triiodomethane	392	491				4.008
CHN	Hydrogen cyanide	259.7	298.81	456.7	5.39	139	0.684
CH_2BrCl	Bromochloromethane	185.20	341.20				1.925
CH_2Br_2	Dibromomethane	220.60	370				2.48
CH_2Cl_2	Dichloromethane	176.5	312.79	510	6.10		1.3168
CH_2F_2	Difluoromethane	137	221.45	351.6	5.830	121	*0.960
CH_2I_2	Diiodomethane	279.2	455				3.3079
CH_2N_2	Diazomethane	128	250				
CH_2O	Methanal	181	254.05				
CH_2O_2	Methanoic acid	281.4	373.71	588			1.214
CH_3Br	Bromomethane	179.4	276.7				
CH_3Cl	Chloromethane	175.4	248.95	416.25	6.679	139	*0.911
CH_3Cl_3Si	Trichloromethylsilane	183	339.27	517	3.28	348	1.267
CH_3F	Fluoromethane	131.3	194.7	317.8	5.88	113	*0.566
CH_3I	Iodomethane	206.70	315.57	528			2.2650
CH_3NO	Methanamide	275.70	493				1.1291
CH_3NO_2	Nitromethane	244.60	374.35	588	5.87	173	1.1313
CH_4	Methane	90.69	111.65	190.53	4.604	99	
CH_4N_2O	Urea	405.8					1.32
CH_4O	Methanol	175.47	337.7	512.64	8.092	118	0.7866
CH_4S	Methanethiol	150	279.10	470.0	7.23	145	
CH_5N	Methylamine	179.71	266.82	430.7	7.614		*0.656

TABLE 2.1.1
SUMMARY OF PHYSICAL CONSTANTS OF IMPORTANT SUBSTANCES (continued)

Molecular formula	Name	T_m/ K	T_b/ K	T_c/ K	P_c/ MPa	V_c/ cm^3 mol^{-1}	ρ_o/ g cm^{-3}
CH_6N_2	Methylhydrazine	220.7	364.1	567	8.24	271	
CH_6Si	Methylsilane	116.6	215.60	352.5			
CI_4	Tetraiodomethane	444					4.3
CN_4O_8	Tetranitromethane	286.9	399.2				1.6229
CNa_2O_3	Disodium carbonate	1131.2					2.54
CO	Carbon oxide	68	81.6	132.91	3.499	93	
COS	Carbonyl sulfide	134.3	223	375	5.88	137	
CO_2	Carbon dioxide	216.58 t	194.7 s	304.14	7.375	94	*0.720
CS_2	Carbon disulfide	161.6	319.37	552	7.90	173	1.2555
$C_2Br_2ClF_3$	1,2-Dibromo-1-chloro-1,2,2-trifluoroethane		366	560.7	3.61	368	
$C_2Br_2F_4$	1,2-Dibromotetrafluoroethane	162.7	320.50	487.8	3.393	341	2.163
C_2ClF_3	Chlorotrifluoroethene	115	245.0	379	4.05	212	
C_2ClF_5	Chloropentafluoroethane	173.71	234.0	353.2	3.229	252	*1.288
$C_2Cl_2F_4$	1,1-Dichlorotetrafluoroethane	216.5	277	418.6	3.30	294	*1.455
$C_2Cl_2F_4$	1,2-Dichlorotetrafluoroethane	179	276.9	418.78	3.252	297	*1.455
$C_2Cl_3F_3$	1,1,1-Trichlorotrifluoroethane	287.3	318.95				1.571
$C_2Cl_3F_3$	1,1,2-Trichlorotrifluoroethane	238	320.8	487.3	3.42	325	1.5642
C_2Cl_4	Tetrachloroethene	250.80	394.2	620.2			1.6130
$C_2Cl_4F_2$	Tetrachloro-1,2-difluoroethane	299	366	551			1.6447
C_2Cl_6	Hexachloroethane	460	460				2.080
C_2F_4	Tetrafluoroethene	130.6	197.50	306.5	3.94	172	
C_2F_6	Hexafluoroethane	172.4	194.9	293		222	
C_2HCl	Chloroethyne	147	243				
C_2HClF_2	1-Chloro-2,2-difluoroethene	134.6	254.60	400.6	4.46	197	
C_2HClF_4	1-Chloro-1,1,2,2-tetrafluoroethane	156	263	399.9	3.72	244	
C_2HCl_3	Trichloroethene	188.40	360.34	544.2	5.02		1.4578
C_2HCl_3O	Trichloroethanal	215.6	370.9				1.505
$C_2HCl_3O_2$	Trichloroethanoic acid	330.6	470.7				
C_2HCl_5	Pentachloroethane	244	433.03				1.6749
$C_2HF_3O_2$	Trifluoroethanoic acid	257.90	344.9	491.3	3.258	204	1.485
C_2H_2	Ethyne	192.40 t	188.43 s	308.33	6.139	113	*0.377
$C_2H_2Br_4$	1,1,2,2-Tetrabromoethane	273	516.70				2.9529
$C_2H_2Cl_2$	1,1-Dichloroethene	150.6	304.7				1.18
$C_2H_2Cl_2$	*cis*-1,2-Dichloroethene	193	333.78	544.2			1.2649
$C_2H_2Cl_2$	*trans*-1,2-Dichloroethene	223.3	320.82	516.5	5.51		1.2444
$C_2H_2Cl_2O$	Chloroacetyl chloride	251	379				1.413
$C_2H_2Cl_4$	1,1,1,2-Tetrachloroethane	202.94	403.3				1.5346
$C_2H_2Cl_4$	1,1,2,2-Tetrachloroethane	229.3	418.3	661.15			1.5872
$C_2H_2F_2$	1,1-Difluoroethene	129	187.4	302.9	4.46	154	
C_2H_2O	Ketene	122	223.34				
$C_2H_2O_2$	Ethanedial	288	323.5				1.134
C_2H_3Br	Bromoethene	135.3	288.9				
C_2H_3BrO	Acetyl bromide	177	349				1.65
C_2H_3Cl	Chloroethene	119.36	259.34				
$C_2H_3ClF_2$	1-Chloro-1,1-difluoroethane	142.3	263.40	409.6	4.332	231	*1.107
C_2H_3ClO	Acetyl chloride	160.30	323.90				1.100
C_2H_3ClO	Chloroethanal	256.8	358.6				
$C_2H_3ClO_2$	Chloroethanoic acid	334.4	462.50				
$C_2H_3Cl_3$	1,1,1-Trichloroethane	242.7	347.24	545	4.30		1.3303
$C_2H_3Cl_3$	1,1,2-Trichloroethane	236.5	387.0				1.4346
C_2H_3F	Fluoroethene	112.6	201	327.9	5.24	144	
C_2H_3FO	Acetyl fluoride	189	293.9				
$C_2H_3F_3$	1,1,1-Trifluoroethane	161.8	225.60	346.3	3.76	194	*0.963
C_2H_3N	Ethanenitrile	229.32	354.80	545.5	4.85	173	0.7765
C_2H_3NO	Methyl isocyanate	228	312.2				
$C_2H_3NaO_2$	Sodium ethanoate	597					1.528
C_2H_4	Ethene	103	169.38	282.34	5.041	131	
$C_2H_4Br_2$	1,1-Dibromoethane	210	382				2.045
$C_2H_4Br_2$	1,2-Dibromoethane	283.08	404.5	583.0	7.2		2.1687
$C_2H_4Cl_2$	1,1-Dichloroethane	176.19	330.5	523	5.07	236	1.1680
$C_2H_4Cl_2$	1,2-Dichloroethane	237.6	356.6	561	5.4	225	1.2457
$C_2H_4Cl_2O$	Bis(chloromethyl) ether	231.6	379				1.31

TABLE 2.1.1
SUMMARY OF PHYSICAL CONSTANTS OF IMPORTANT SUBSTANCES (continued)

Molecular formula	Name	T_m/ K	T_b/ K	T_c/ K	P_c/ MPa	V_c/ cm^3 mol^{-1}	ρ_o/ g cm^{-3}
$C_2H_4F_2$	1,1-Difluoroethane	156	248.20	386.7	4.50	181	*0.896
C_2H_4O	Ethanal	150	293.6	466		154	
C_2H_4O	Oxirane	161.4	283.6	469	7.19	140	*0.8717
$C_2H_4O_2$	Ethanoic acid	289.7	391.0	592.71	5.786	171	1.0439
$C_2H_4O_2$	Methyl methanoate	174	304.9	487.2	5.998	172	0.9664
$C_2H_4O_3$	Peroxyethanoic acid	272.9	383				
$C_2H_4O_3$	Hydroxyethanoic acid	352.6	373				
C_2H_5Br	Bromoethane	154.5	311.6	503.9	6.23	215	1.4505
C_2H_5Cl	Chloroethane	134.4	285.4	460.4	5.3		*0.8889
C_2H_5ClO	2-Chloroethanol	205.6	401.7				1.1965
C_2H_5F	Fluoroethane	129.9	235.50	375.31	5.028		
C_2H_5I	Iodoethane	162.0	345.6				1.9244
C_2H_5N	Aziridine	195.20	329				0.832
C_2H_5NO	Ethanamide	354	495.16				
C_2H_5NO	*N*-Methylmethanamide	269.3	472.66				1.00
$C_2H_5NO_2$	Nitroethane	183.63	387.22				1.0427
C_2H_6	Ethane	90.3	184.5	305.4	4.884	148	*0.315
$C_2H_6Cl_2Si$	Dichlorodimethylsilane	257	343.4	520.4	3.49	350	1.064
C_2H_6O	Dimethyl ether	131.6	248.3	400.0	5.37	190	*0.661
C_2H_6O	Ethanol	159.0	351.44	513.92	6.132	167	0.7849
C_2H_6OS	Dimethyl sulfoxide	291.67	462.2				1.0955
$C_2H_6O_2$	1,2-Ethanediol	260	470.49	718			1.1101
$C_2H_6O_2S$	Dimethyl sulfone	382	511				
C_2H_6S	2-Thiapropane	174.8	310.48	503.0	5.53	201	0.8423
C_2H_6S	Ethanethiol	125.26	308.2	499	5.49	207	0.8315
$C_2H_6S_2$	2,3-Dithiabutane	188	382.9				1.057
C_2H_7N	Dimethylamine	180.9	280.03	437.22	5.340		*0.6501
C_2H_7N	Ethylamine	192.62	289.80	456	5.62	182	*0.677
C_2H_7NO	2-Aminoethanol	283.6	444.1				1.0136
$C_2H_8N_2$	1,1-Dimethylhydrazine	215	337.0				0.785
$C_2H_8N_2$	1,2-Ethanediamine	284.2	390				0.8931
C_2N_2	Ethanedinitrile	245.2	252.0	400	5.98		
C_3F_6	Hexafluoropropene	116.6	243.5				
C_3F_6O	Hexafluoro-2-propanone	148	245.70	357.14	2.84	329	*1.313
C_3F_8	Octafluoropropane	125.46	236.40	345.1	2.680	299	
C_3HN	Propynenitrile	278	315.6				
C_3H_3N	Propenenitrile	189.6	350.57				0.8002
C_3H_3NO	Oxazole		342.6				
C_3H_3NO	Isoxazole		368	552.0			1.073
C_3H_4	Propyne	170.4	250.16	402.38	5.628	164	*0.607
C_3H_4	Propadiene	136.87	238.70	393			*0.584
$C_3H_4Cl_2$	2,3-Dichloropropene	283	367				1.205
$C_3H_4N_2$	Imidazole	363.6	530				
$C_3H_4N_2$	Pyrazole	341	460				
C_3H_4O	Propenal	185.4	325.26				0.837
C_3H_4O	2-Propyn-1-ol	221.3	386.7				0.9450
$C_3H_4O_2$	Propenoic acid	285.4	414.2				1.046
$C_3H_4O_2$	2-Oxetanone	239.7	435				1.1420
C_3H_5Br	3-Bromopropene	154	343.2				1.391
C_3H_5Cl	*cis*-1-Chloropropene	138.3	305.9				0.930
C_3H_5Cl	*trans*-1-Chloropropene	174	310.5				0.930
C_3H_5Cl	2-Chloropropene	135.7	295.80				
C_3H_5Cl	3-Chloropropene	138.6	318.30	514			0.933
C_3H_5ClO	(Chloromethyl)oxirane	215.9	389.26				1.1746
$C_3H_5ClO_2$	Methyl chloroethanoate	241.03	402.6				1.228
$C_3H_5Cl_3$	1,2,3-Trichloropropane	258.4	430				1.382
C_3H_5N	Propanenitrile	180.26	370.6	561.3	4.26	229	0.7768
C_3H_5NO	3-Hydroxypropanenitrile	227	494				1.0404
C_3H_5NO	Propenamide	357.6	465.7				1.12
C_3H_6	Propene	87.90	225.46	364.85	4.601	181	*0.505
C_3H_6	Cyclopropane	145.7	240.34	398.3	5.579	162	*0.617
$C_3H_6Br_2$	1,2-Dibromopropane	217.9	415.0				1.9234

TABLE 2.1.1
SUMMARY OF PHYSICAL CONSTANTS OF IMPORTANT SUBSTANCES (continued)

Molecular formula	Name	T_m/ K	T_b/ K	T_c/ K	P_c/ MPa	V_c/ $cm^3\ mol^{-1}$	ρ_o/ $g\ cm^{-3}$
$C_3H_6Cl_2$	1,2-Dichloropropane	172.6	369.52				1.1496
$C_3H_6Cl_2$	1,3-Dichloropropane	173.6	394.0				1.182
C_3H_6O	2-Propanone	178.3	329.20	508.1	4.700	209	0.7844
C_3H_6O	2-Propen-1-ol	144	370.23				0.850
C_3H_6O	Propanal	193	321.2	504.4	5.27	204	0.797
C_3H_6O	Methyloxirane	161.22	308	482.2	4.92	186	0.8209
C_3H_6O	Oxetane		320.7				0.8930
C_3H_6O	Methyl vinyl ether	151	278.2				
$C_3H_6O_2$	Ethyl methanoate	193.5	327.5	508.5	4.74	229	0.9153
$C_3H_6O_2$	Methyl ethanoate	175	330.02	506.55	4.75	228	0.9279
$C_3H_6O_2$	Propanoic acid	252.4	414.30	604	4.53	222	0.9881
$C_3H_6O_2$	1,3-Dioxolane	178	348.8				1.055
$C_3H_6O_3$	1,3,5-Trioxane	333.3	387.18				
C_3H_6S	Thiacyclobutane	199.9	368				1.015
C_3H_7Br	1-Bromopropane	163	344.1				1.3452
C_3H_7Br	2-Bromopropane	184	332.6				1.3060
C_3H_7Cl	1-Chloropropane	150.3	319.67	503	4.58		0.8830
C_3H_7Cl	2-Chloropropane	155.9	308.89				0.8563
C_3H_7F	1-Fluoropropane	114	275.6				
C_3H_7I	1-Iodopropane	171.8	375.7				1.740
C_3H_7I	2-Iodopropane	183	362.6				1.6946
C_3H_7N	Allylamine	184.9	326.4				0.755
C_3H_7N	Cyclopropylamine	237.7	323.6				0.820
C_3H_7NO	*N,N*-Dimethylmethanamide	212.72	426	649.6		262	0.9447
$C_3H_7NO_2$	1-Nitropropane	165	404.33				0.9961
$C_3H_7NO_2$	2-Nitropropane	181.83	393.40				0.9835
C_3H_8	Propane	85.46	231.08	369.82	4.250	203	*0.493
C_3H_8O	1-Propanol	147.0	370.3	536.78	5.168	219	0.7996
C_3H_8O	2-Propanol	183.6	355.4	508.3	4.762	220	0.7813
C_3H_8O	Ethyl methyl ether	160	280.35	437.8	4.40	221	*0.6922
$C_3H_8O_2$	1,2-Propanediol	213	460.7				1.0327
$C_3H_8O_2$	1,3-Propanediol	246.4	487.5				1.050
$C_3H_8O_2$	2-Methoxyethanol	188.0	397.8				0.9598
$C_3H_8O_2$	2,4-Dioxapentane	168.3	315				0.8538
$C_3H_8O_3$	1,2,3-Propanetriol	291.3	563.2				1.2567
C_3H_8S	2-Thiabutane	167.2	339.8	533	4.26		0.838
C_3H_8S	1-Propanethiol	159.8	340.9	536.6		286	0.836
C_3H_8S	2-Propanethiol	142.6	325.7				0.810
$C_3H_8S_2$	1,3-Propanedithiol	194	446.0				1.072
C_3H_9ClSi	Chlorotrimethylsilane	233	333	497.8	3.20	366	0.856
C_3H_9N	Propylamine	190	320.37	497.0	4.72		0.7121
C_3H_9N	Isopropylamine	178.01	304.91	471.8	4.54	221	0.6821
C_3H_9N	Trimethylamine	156.0	276.02	432.79	4.087	254	*0.627
C_3H_9NO	3-Amino-1-propanol	284	460.6				
C_3H_9NO	*DL*-1-Amino-2-propanol	274.89	432.61				
C_4F_8	Octafluorocyclobutane	232.96	267.16	388.46	2.784	324	*1.500
C_4F_{10}	Decafluorobutane	144.9	270.96	386.4	2.323	378	
C_4F_{10}	Perfluoroisobutane		273	395.4			
$C_4H_2O_3$	1-Oxa-3-cyclopenten-2,5-dione	325.9	475				1.5
$C_4H_4N_2$	Pyrazine	328	388				1.27
$C_4H_4N_2$	Pyridazine	265	481				1.102
$C_4H_4N_2$	Pyrimidine	295	396.9				
$C_4H_4N_2$	Butanedinitrile	327.6	539				1.023
C_4H_4O	Furan	187.5	304.5	490.2	5.50	218	0.9348
C_4H_4S	Thiophene	233.7	357.1	579.4	5.69	219	1.0588
C_4H_5N	Pyrrole	249.73	402.94	639.7	6.34	200	0.9656
C_4H_6	1,2-Butadiene	136.9	284.0				
C_4H_6	1,3-Butadiene	164.2	268.74	425	4.33	221	*0.6149
C_4H_6	1-Butyne	147.43	281.23	463.7			
C_4H_6	2-Butyne	240.79	300.12	488.7			0.688
C_4H_6O	Cyclobutanone	222.2	372				0.93
$C_4H_6O_2$	Oxolan-2-one	229.78	477				1.40

TABLE 2.1.1
SUMMARY OF PHYSICAL CONSTANTS OF IMPORTANT SUBSTANCES (continued)

Molecular formula	Name	T_m/ K	T_b/ K	T_c/ K	P_c/ MPa	V_c/ cm^3 mol^{-1}	ρ_o/ g cm^{-3}
$C_4H_6O_2$	*cis*-2-Butenoic acid	288	442				1.022
$C_4H_6O_2$	*trans*-2-Butenoic acid	345	457.8				
$C_4H_6O_2$	Vinyl ethanoate	179.9	345.7				0.927
$C_4H_6O_3$	Ethanoic anhydride	200	412.20	606	4.0		1.077
$C_4H_7ClO_2$	Ethyl chloroethanoate	252	417.4				1.151
C_4H_7N	Butanenitrile	161.2	390.77	585.4	3.88		0.7865
C_4H_8	1-Butene	87.80	267.0	419.57	4.023	240	*0.588
C_4H_8	*cis*-2-Butene	134.2	276.86	435.58	4.197	234	*0.616
C_4H_8	*trans*-2-Butene	167.62	274.03	428.63	3.985	238	*0.599
C_4H_8	2-Methylpropene	132.7	266.05	417.9	4.000	239	*0.589
C_4H_8	Cyclobutane	182.48	285.7	460.0	4.98	210	0.689
$C_4H_8Cl_2O$	Bis(2-chloroethyl) ether	221.2	451.6				1.2130
C_4H_8O	Butanal	174	348.0	537.2	4.32	258	0.798
C_4H_8O	2-Butanone	186.48	352.74	536.78	4.207	267	0.7994
C_4H_8O	Oxolane	164.76	339.1	540.1	5.19	224	0.8800
C_4H_8O	Ethyl vinyl ether	157.3	308.70	475	4.07		0.755
$C_4H_8O_2$	1,3-Dioxane	228	379.2				1.029
$C_4H_8O_2$	1,4-Dioxane	284.9	374.47	587	5.21	238	1.0286
$C_4H_8O_2$	Ethyl ethanoate	189.5	350.26	523.3	3.882	286	0.8945
$C_4H_8O_2$	Methyl propanoate	185.6	352.5	530.6	4.004	282	0.9090
$C_4H_8O_2$	Propyl methanoate	180.2	354.0	538.0	4.06	285	0.8996
$C_4H_8O_2$	Butanoic acid	267.4	436.90	624	4.03	290	0.9529
$C_4H_8O_2$	2-Methylpropanoic acid	227	427.85	605	3.7	292	0.9431
$C_4H_8O_2S$	Thiolane 1,1-dioxide	300.7	558				1.2660
C_4H_8S	Thiacyclopentane	176.99	394.1	632.0			0.9938
C_4H_9Br	1-Bromobutane	160.7	374.7				1.2686
C_4H_9Br	2-Bromobutane	160.4	364.5				1.2530
C_4H_9Cl	1-Chlorobutane	150.0	351.58				0.8810
C_4H_9Cl	2-Chlorobutane	141.8	341.4				0.866
C_4H_9I	1-Iodobutane	170	403.7				1.6072
C_4H_9N	Pyrrolidine	215.31	359.71	568.2	5.59	238	0.8538
C_4H_9NO	*N,N*-Dimethylethanamide	253	439.3				0.9365
C_4H_9NO	Morpholine	268.2	402.1				0.9959
C_4H_{10}	Butane	134.86	272.6	425.14	3.784	255	*0.573
C_4H_{10}	2-Methylpropane	134.8	261.42	407.85	3.630	257	*0.551
$C_4H_{10}O$	1-Butanol	183.3	390.88	563.05	4.423	275	0.8058
$C_4H_{10}O$	2-Butanol	158.4	372.66	536.05	4.179	269	0.8026
$C_4H_{10}O$	2-Methyl-2-propanol	298.5	355.5	506.21	3.973	275	0.7812
$C_4H_{10}O$	2-Methyl-1-propanol	165	381.04	547.78	4.300	273	0.7978
$C_4H_{10}O$	Diethyl ether	156.8	307.6	466.74	3.638	280	0.7078
$C_4H_{10}O$	Methyl propyl ether		312.2	476.25	3.801		0.727
$C_4H_{10}O$	Isopropyl methyl ether		303.92	464.48	3.762		
$C_4H_{10}O_2$	1,4-Butanediol	293.2	508				1.015
$C_4H_{10}O_2$	2-Ethoxyethanol	203	408.8				0.9247
$C_4H_{10}O_2$	2,5-Dioxahexane	215	358	536	3.87	271	0.859
$C_4H_{10}O_3$	3-Oxa-1,5-pentanediol	262.70	518.84				1.1150
$C_4H_{10}S$	1-Butanethiol	157.4	371.6	570.1		324	0.8367
$C_4H_{10}S$	3-Thiapentane	169.20	365.2	557	3.96	318	0.8312
$C_4H_{11}N$	Butylamine	224.05	350.15	531.9	4.25	277	0.7369
$C_4H_{11}N$	(2-Methylpropyl)amine	186.4	340.90	519	4.07	278	0.7297
$C_4H_{11}N$	2-Aminobutane	168.6	335.88	514.3	4.20	278	0.7200
$C_4H_{11}N$	(1,1-Dimethylethyl)amine	206.20	317.19	483.9	3.84	292	0.6901
$C_4H_{11}N$	Diethylamine	223.3	328.7	499.99	3.758		0.7016
$C_4H_{11}NO_2$	Bis(2-hydroxyethyl)amine	301	541.9				1.0899
$C_4H_{12}Si$	Tetramethylsilane	174.11	299.80	448.64	2.821	362	0.643
$C_4H_{12}Sn$	Tetramethylstannane	218.3	351	521.8	2.981		1.314
$C_4H_{13}N_3$	Bis(2-aminoethyl)amine	234	480				0.952
C_5F_{12}	Dodecafluoropentane	263	302.40	420.59	2.045	473	
$C_5H_2F_6O_2$	1,1,1,5,5,5-Hexafluoroacetylacetone		327.30	485.1	2.767		1.478
$C_5H_4O_2$	2-Furaldehyde	236.6	435.00	670	5.89		1.1554
C_5H_5N	Pyridine	231.49	388.38	620.0	5.67	243	0.9786
C_5H_6	1,3-Cyclopentadiene	188	314				0.7966

TABLE 2.1.1
SUMMARY OF PHYSICAL CONSTANTS OF IMPORTANT SUBSTANCES (continued)

Molecular formula	Name	T_m/ K	T_b/ K	T_c/ K	P_c/ MPa	V_c/ cm^3 mol^{-1}	ρ_o/ g cm^{-3}
$C_5H_6N_2$	2-Methylpyrazine	244	410	634.3	5.01	283	1.025
C_5H_6O	2-Methylfuran		338	527	4.72	247	0.909
$C_5H_6O_2$	2-Furylmethanol	242	444				1.1308
C_5H_8	*cis*-1,3-Pentadiene	132.3	317.2				0.688
C_5H_8	*trans*-1,3-Pentadiene	186	315.1				0.671
C_5H_8	1,4-Pentadiene	124.3	299				0.658
C_5H_8	Cyclopentene	138.0	317.39	507.0	4.802	245	0.768
C_5H_8	Spiropentane	138.5	312				0.723
C_5H_8	1-Pentyne	183	313.33	493.5			0.687
C_5H_8O	Cyclopentanone	221.8	403.9	624.5	4.60		0.944
C_5H_8O	Cyclopropyl methyl ketone	204.8	384.4				0.894
C_5H_8O	3,4-Dihydro-2-H-pyran		359	561.7	4.56	268	
$C_5H_8O_2$	Ethyl propenoate	201.9	372.5				0.917
$C_5H_8O_2$	Methyl 2-methylpropenoate	225	373.5				0.939
C_5H_9N	Pentanenitrile	176.9	414.5	610.3	3.58		0.797
C_5H_9NO	1-Methyl-2-pyrrolidinone	249	475	721.8		311	1.0251
C_5H_{10}	1-Pentene	107.9	303.11	464.78	3.527	293	0.6353
C_5H_{10}	*cis*-2-Pentene	121.7	310.08	475	3.69		0.6508
C_5H_{10}	2-Methyl-1-butene	135.58	304.3	470	3.8		0.6451
C_5H_{10}	2-Methyl-2-butene	139.39	311.72	481	3.91		0.6570
C_5H_{10}	Cyclopentane	179.3	322.4	511.7	4.508	260	0.7405
$C_5H_{10}O$	Cyclopentanol	254	413.57	619.5	4.90		0.943
$C_5H_{10}O$	2-Pentanone	196.2	375.41	561.08	3.694	301	0.8020
$C_5H_{10}O$	3-Pentanone	234	375.11	561.46	3.729	336	0.811
$C_5H_{10}O$	3-Methyl-2-butanone	181	367.48	553.4	3.85	310	0.801
$C_5H_{10}O$	Oxane	228	361	572.2	4.77	263	0.8772
$C_5H_{10}O$	2-Methyloxolane		351	537	3.76	267	0.851
$C_5H_{10}O$	Pentanal	181.6	376	566.1	3.97	313	0.805
$C_5H_{10}O$	Allyl ethyl ether		340.80	518			0.761
$C_5H_{10}O_2$	Butyl methanoate	181.6	379.3				0.884
$C_5H_{10}O_2$	Isobutyl methanoate	177.3	371.40	551	3.88	352	0.8732
$C_5H_{10}O_2$	Propyl ethanoate	180	374.69	549.7	3.36	345	0.8830
$C_5H_{10}O_2$	Isopropyl ethanoate	199.7	361.7	531			0.8711
$C_5H_{10}O_2$	Ethyl propanoate	199.2	372.2	546.0	3.362	345	0.8840
$C_5H_{10}O_2$	Methyl butanoate	187.3	375.9	554.4	3.47	340	0.8926
$C_5H_{10}O_2$	Methyl 2-methylpropanoate	188.4	365.6	540.8	3.43	339	0.8854
$C_5H_{10}O_2$	Pentanoic acid	239	458.70	643	3.58	340	0.9345
$C_5H_{10}O_2$	3-Methylbutanoic acid	243.8	449.70	629	3.40		0.926
$C_5H_{10}O_3$	2-Methoxyethyl ethanoate	203	416				1.0049
$C_5H_{11}Br$	1-Bromopentane	178	402.9				1.212
$C_5H_{11}Cl$	1-Chloropentane	174	380.9				0.877
$C_5H_{11}I$	1-Iodopentane	187.5	428				1.509
$C_5H_{11}N$	Piperidine	262.12	379.37	594.1	4.94	288	0.8578
C_5H_{12}	Pentane	143.4	309.21	469.69	3.364	311	0.6214
C_5H_{12}	2-Methylbutane	113.2	301.03	460.43	3.381	306	0.6142
C_5H_{12}	2,2-Dimethylpropane	256.5	282.63	433.8	3.197	307	*0.5852
$C_5H_{12}O$	Butyl methyl ether	157.6	343.31	512.78	3.371	329	0.741
$C_5H_{12}O$	Isobutyl methyl ether		331.7				0.727
$C_5H_{12}O$	*tert*-Butyl methyl ether	164.5	328.3	497.1	3.430		0.737
$C_5H_{12}O$	Ethyl propyl ether	145.6	336.36	500.23	3.370	339	0.735
$C_5H_{12}O$	1-Pentanol	194.2	411.13	588.15	3.909	326	0.8108
$C_5H_{12}O$	2-Pentanol	200	392.2	560.4			0.8054
$C_5H_{12}O$	3-Pentanol	204	389.40	559.6			0.8160
$C_5H_{12}O$	2-Methyl-2-butanol	264.3	375.3	545			0.8050
$C_5H_{12}O$	3-Methyl-1-butanol	155.9	404.2	579.4			0.8071
$C_5H_{12}O$	2,2-Dimethyl-1-propanol	325.6	386.6				0.808
$C_5H_{12}O_2$	3,5-Dioxaheptane	206.6	361				0.828
$C_5H_{12}O_4$	Pentaerythritol	533					0.886
$C_5H_{12}S$	1-Pentanethiol	197.4	399.8				0.846
$C_5H_{12}S$	3-Methyl-1-butanethiol		393	604			0.831
$C_5H_{13}N$	Pentylamine	218	377.4				0.750
C_6BrF_5	Bromopentafluorobenzene	242	410	601	3.0		1.948
C_6ClF_5	Chloropentafluorobenzene		391.11	570.81	3.238	376	1.567

TABLE 2.1.1
SUMMARY OF PHYSICAL CONSTANTS OF IMPORTANT SUBSTANCES (continued)

Molecular formula	Name	T_m / K	T_b / K	T_c / K	P_c / MPa	V_c / cm^3 mol^{-1}	ρ_o / g cm^{-3}
$C_6Cl_3F_3$	1,3,5-Trichloro-2,4,6-trifluorobenzene		471.52	684.8	3.27	448	
C_6Cl_6	Hexachlorobenzene	504.9	598				2.040
C_6F_6	Hexafluorobenzene	278.50	353.41	516.73	3.273	335	1.6144
C_6F_{10}	Decafluorocyclohexene		325.20	461.8			
C_6F_{12}	Dodecafluorocyclohexane	321.6	323.76	457.2	2.43		
C_6F_{14}	Tetradecafluorohexane	186.0	329.80	448.77	1.868	606	1.680
C_6HF_5	Pentafluorobenzene	225.8	358.89	530.97	3.531	324	1.514
C_6HF_5O	Pentafluorophenol	305.9	418.79	609	4.0	348	
C_6HF_{11}	Undecafluorocyclohexane		335.20	477.7			
$C_6H_2F_4$	1,2,3,4-Tetrafluorobenzene		367.51	550.83	3.791	313	1.423
$C_6H_2F_4$	1,2,3,5-Tetrafluorobenzene	225	357.61	535.25	3.747		1.319
$C_6H_2F_4$	1,2,4,5-Tetrafluorobenzene	277.6	363.41	543.35	3.801		1.424
$C_6H_3Cl_3$	1,2,4-Trichlorobenzene	290	486.6				1.459
$C_6H_3Cl_3$	1,3,5-Trichlorobenzene	336.6	481				1.66
$C_6H_3Cl_3O$	2,4,6-Trichlorophenol	342	519				1.490
$C_6H_4ClNO_2$	1-Chloro-2-nitrobenzene	305.6	518.6				
$C_6H_4ClNO_2$	1-Chloro-3-nitrobenzene	317.5	508.6				1.53
$C_6H_4ClNO_2$	1-Chloro-4-nitrobenzene	356.6	515				1.520
$C_6H_4Cl_2$	1,2-Dichlorobenzene	256.4	453.6				1.3003
$C_6H_4Cl_2$	1,3-Dichlorobenzene	248.3	446.14				1.2828
$C_6H_4Cl_2$	1,4-Dichlorobenzene	325.8	447.27				1.211
$C_6H_4FNO_2$	1-Fluoro-4-nitrobenzene	294	478				1.323
$C_6H_4F_2$	1,2-Difluorobenzene	239	367				1.150
$C_6H_4F_2$	1,3-Difluorobenzene	204.06	355.7				1.151
$C_6H_4F_2$	1,4-Difluorobenzene	260	362	556	4.40		1.163
C_6H_5Br	Bromobenzene	242.5	429.06	670	4.52	324	1.4882
C_6H_5Cl	Chlorobenzene	227.9	404.87	632.4	4.52	308	1.1009
C_6H_5ClO	2-Chlorophenol	282.9	448.0				1.257
C_6H_5ClO	3-Chlorophenol	305.7	487				1.218
C_6H_5ClO	4-Chlorophenol	315.8	493				1.40
C_6H_5F	Fluorobenzene	230.94	357.88	560.09	4.551	269	1.019
C_6H_5I	Iodobenzene	241.8	461.48	721	4.52	351	1.8229
$C_6H_5NO_2$	Nitrobenzene	278.8	483.9				1.1985
$C_6H_5NO_3$	2-Nitrophenol	317.9	489				
C_6H_6	Benzene	278.68	353.24	562.16	4.898	259	0.8736
C_6H_6ClN	2-Chloroaniline	259	481.99				1.206
C_6H_6ClN	3-Chloroaniline	262.7	503.6				1.210
C_6H_6ClN	4-Chloroaniline	345.6	505				1.41
$C_6H_6N_2O_2$	2-Nitroaniline	344.3	557				0.9015
$C_6H_6N_2O_2$	3-Nitroaniline	387					0.9011
$C_6H_6N_2O_2$	4-Nitroaniline	420	605				1.42
C_6H_6O	Phenol	314.0	455.02	694.2	6.13		1.132
$C_6H_6O_2$	1,4-Benzenediol	445.4	559				1.33
C_6H_6S	Benzenethiol	258.2	442.2				1.0727
C_6H_7N	Aniline	267.13	457.14	699	4.89	287	1.0175
C_6H_7N	2-Methylpyridine	206.47	402.53	621.0	4.60	292	0.9398
C_6H_7N	3-Methylpyridine	255.01	417.29	645.0	4.48	288	0.952
C_6H_7N	4-Methylpyridine	276.81	418.51	645.7	4.70	292	0.9502
$C_6H_8N_2$	Hexanedinitrile	274	568				0.9599
$C_6H_8N_2$	Phenylhydrazine	292.7	516.70				1.095
$C_6H_8N_2$	1,2-Phenylenediamine	375.6	530				
$C_6H_8N_2$	1,3-Phenylenediamine	336.6	558				1.23
$C_6H_8N_2$	1,4-Phenylenediamine	419	540				1.2
C_6H_{10}	Cyclohexene	169.6	356.13	560.48			0.806
C_6H_{10}	1,5-Hexadiene	132.4	332.60	507			0.688
C_6H_{10}	1-Hexyne	141.2	344.4				0.712
$C_6H_{10}O$	Cyclohexanone	242	428.80	653.0	4.0		0.9425
$C_6H_{10}O_2$	2-Oxepanone	255	488				1.064
$C_6H_{10}O_3$	Ethyl acetylethanoate	228	453.9				1.022
$C_6H_{10}O_4$	Hexanedioic acid	426.3	610.6				1.360
$C_6H_{10}S$	4-Thia-1,6-heptadiene	188	411.7	653			0.89
$C_6H_{11}Cl$	Chlorocyclohexane	229	415				0.995

TABLE 2.1.1
SUMMARY OF PHYSICAL CONSTANTS OF IMPORTANT SUBSTANCES (continued)

Molecular formula	Name	T_m/ K	T_b/ K	T_c/ K	P_c/ MPa	V_c/ cm^3 mol^{-1}	ρ_o/ g cm^{-3}
$C_6H_{11}F$	Fluorocyclohexane	286	374				0.923
$C_6H_{11}N$	Hexanenitrile	192.8	436.61	633.8	3.30		0.801
$C_6H_{11}NO$	Hexahydro-2-azepinone	342.4	543				
C_6H_{12}	Cyclohexane	279.7	353.88	553.5	4.07	308	0.7739
C_6H_{12}	Methylcyclopentane	130.6	344.96	532.73	3.784	319	0.745
C_6H_{12}	1-Hexene	133.39	336.63	504.1	3.206	348	0.6686
C_6H_{12}	*cis*-2-Hexene	132.0	341.9				0.6824
C_6H_{12}	2,3-Dimethyl-2-butene	198.5	346.4				0.7037
$C_6H_{12}O$	Cyclohexanol	298.61	434.25	650.0	4.26		0.9604
$C_6H_{12}O$	2-Hexanone	217.6	400.7	587.0	3.32		0.8070
$C_6H_{12}O$	3-Hexanone	217.6	396.6	582.82	3.320		0.808
$C_6H_{12}O$	4-Methyl-2-pentanone	189	389.6	571	3.27		0.7962
$C_6H_{12}O$	Butyl vinyl ether	181	367				0.785
$C_6H_{12}O$	Hexanal	217	404	591	3.46		0.829
$C_6H_{12}O_2$	Pentyl methanoate	199.6	403.60	576	3.46		0.881
$C_6H_{12}O_2$	3-Methylbutyl methanoate	179.6	396.70	578			0.873
$C_6H_{12}O_2$	Butyl ethanoate	195	399.2	579			0.8761
$C_6H_{12}O_2$	Isobutyl ethanoate	174.30	389.70	561	3.16		0.8695
$C_6H_{12}O_2$	Propyl propanoate	197.2	395.6	578			0.878
$C_6H_{12}O_2$	Ethyl butanoate	175	394.6	566	3.06	421	0.874
$C_6H_{12}O_2$	Ethyl 2-methylpropanoate	184.9	383.2	553	3.07	421	0.864
$C_6H_{12}O_2$	Methyl pentanoate		400.5	567	3.19		0.890
$C_6H_{12}O_2$	Hexanoic acid	270	478.17	662	3.20		0.923
$C_6H_{12}O_2$	4-Hydroxy-4-methyl-2-pentanone	229	441.0				0.9342
$C_6H_{12}O_3$	2,4,6-Trimethyl-1,3,5-trioxane	285.7	397.50	563			0.991
$C_6H_{12}O_3$	3-Oxapentyl ethanoate	211.4	429.5	607.3	3.166	443	0.9730
$C_6H_{13}Br$	1-Bromohexane	188.4	428.4				1.169
$C_6H_{13}Cl$	1-Chlorohexane	179	408				0.874
$C_6H_{13}I$	1-Iodohexane	198.9	454				1.433
$C_6H_{13}N$	Cyclohexylamine	255.4	407.11				0.8627
C_6H_{14}	Hexane	177.8	341.88	507.7	3.010	370	0.6548
C_6H_{14}	2-Methylpentane	119.4	333.41	497.7	3.031	367	0.650
C_6H_{14}	3-Methylpentane	110.2	336.42	504.5	3.126	367	0.6598
C_6H_{14}	2,2-Dimethylbutane	174	322.88	488.8	3.090	359	0.645
C_6H_{14}	2,3-Dimethylbutane	144.3	331.13	500.0	3.131	358	0.6570
$C_6H_{14}O$	Methyl pentyl ether		372	546.53	3.042	391	0.757
$C_6H_{14}O$	Dipropyl ether	147.0	363.23	530.6	3.028		0.7419
$C_6H_{14}O$	Diisopropyl ether	186.3	341.66	500.32	2.832	386	0.7207
$C_6H_{14}O$	1-Hexanol	228.5	430.7	610.7	3.47	381	0.8153
$C_6H_{14}O$	2-Hexanol		413.0	586.2			0.8105
$C_6H_{14}O$	4-Methyl-1-pentanol		425.0	603.5			0.8095
$C_6H_{14}O$	2-Methyl-2-pentanol	170	394.2	559.5			0.8095
$C_6H_{14}O$	4-Methyl-2-pentanol	183	404.80	574.4			0.8033
$C_6H_{14}O_2$	1,1-Diethoxyethane	173	375.40	527			0.822
$C_6H_{14}O_2$	3,6-Dioxaoctane		392.5				0.844
$C_6H_{14}O_2$	2-Butoxyethanol	198.3	441.5	633.9		424	0.8964
$C_6H_{14}O_2$	2-Methyl-2,4-pentanediol	223	470.2				0.9182
$C_6H_{14}O_3$	2,5,8-Trioxanonane	209	435				0.939
$C_6H_{14}O_4$	3,6-Dioxa-1,8-octanediol	266	558				1.12
$C_6H_{15}N$	Hexylamine	250.2	405.9				0.762
$C_6H_{15}N$	Triethylamine	158.4	362	535.6	3.032	389	0.7230
$C_6H_{15}N$	Dipropylamine	210	382.4	555.8	3.63		0.7329
$C_6H_{15}N$	Diisopropylamine	212	357.0	523.1	3.02		0.7100
$C_6H_{15}NO_3$	Tris(2-hydroxyethyl)amine	293.6	608.5				1.1205
$C_6H_{18}OSi_2$	Hexamethyldisiloxane	207	372				0.760
C_7F_8	Octafluorotoluene	207.5	377.73	534.47	2.705	428	
C_7F_{14}	Tetradecafluoromethylcyclohexane	228.4	349.50	485.91	2.019	570	1.788
C_7F_{16}	Hexadecafluoroheptane	195	355.66	474.8	1.62	664	1.725
C_7HF_{15}	1-Hydropentadecafluoroheptane		369.20	495.8			1.725
$C_7H_3F_5$	2,3,4,5,6-Pentafluorotoluene	243.3	390.6	566.52	3.126	384	1.439
C_7H_5ClO	Benzoyl chloride	272.1	470.3				1.2070
$C_7H_5Cl_3$	(Trichloromethyl)benzene	268	494				1.365

TABLE 2.1.1
SUMMARY OF PHYSICAL CONSTANTS OF IMPORTANT SUBSTANCES (continued)

Molecular formula	Name	T_m/ K	T_b/ K	T_c/ K	P_c/ MPa	V_c/ $cm^3\ mol^{-1}$	ρ_o/ $g\ cm^{-3}$
C_7H_5N	Benzonitrile	260.40	464.30	699.4	4.21		1.00
$C_7H_6Cl_2$	2,4-Dichlorotoluene	259.6	474				1.241
C_7H_6O	Benzaldehyde	247	451.9	695	4.65		1.044
$C_7H_6O_2$	Benzoic acid	395.5	522.3				1.322
$C_7H_6O_2$	2-Hydroxybenzaldehyde	266	470				1.162
C_7H_7Br	4-Bromotoluene	301.6	457.4				
C_7H_7Cl	2-Chlorotoluene	237.5	432.3				1.077
C_7H_7Cl	3-Chlorotoluene	225.3	434.9				1.070
C_7H_7Cl	4-Chlorotoluene	280.6	435.14				1.064
C_7H_7Cl	Benzyl chloride	228	452				1.095
C_7H_7F	4-Fluorotoluene	217	389.7				0.992
C_7H_7NO	Benzamide	402.2	563				1.28
$C_7H_7NO_2$	2-Nitrotoluene	263	495				1.154
$C_7H_7NO_2$	3-Nitrotoluene	288.6	505				1.152
$C_7H_7NO_2$	4-Nitrotoluene	324.7	511.4				1.286
C_7H_8	Toluene	178.16	383.78	591.79	4.104	316	0.8622
C_7H_8O	2-Methylphenol	302.9	464.19	697.6	5.01		1.135
C_7H_8O	3-Methylphenol	284.9	475.42	705.8	4.56	309	1.0302
C_7H_8O	4-Methylphenol	307.8	475.13	704.6	5.15		1.154
C_7H_8O	Phenylmethanol	257.9	478.46	715	4.3		1.044
C_7H_8O	Anisole	235.6	426.8	645.6	4.25		0.9893
C_7H_9N	*N*-Methylaniline	216	469.40	701	5.20		0.9822
C_7H_9N	2-Methylaniline	256.80	473.49	707	4.37		0.9947
C_7H_9N	3-Methylaniline	241.90	476.52	707	4.28		0.9850
C_7H_9N	4-Methylaniline	316.90	473.7	706	4.58		0.957
C_7H_9N	2,3-Dimethylpyridine		434.41	655.4			0.932
C_7H_9N	2,4-Dimethylpyridine		431.6	647			0.926
C_7H_9N	2,5-Dimethylpyridine	257	430.16	644.2			0.925
C_7H_9N	2,6-Dimethylpyridine	267.0	417.2	623.8			0.9181
C_7H_9N	3,4-Dimethylpyridine		452.28	683.8			0.923
C_7H_9N	3,5-Dimethylpyridine	266.5	445.06	667.2			0.938
C_7H_9N	Benzylamine		458				0.977
$C_7H_{10}N_2$	2,4-Diaminotoluene	372	565				
$C_7H_{12}O$	4-Methylcyclohexanone	232.5	443				0.909
C_7H_{14}	Cycloheptane	265.12	391.95	604.2	3.81	353	0.8066
C_7H_{14}	Methylcyclohexane	146.5	374.08	572.2	3.471	368	0.7651
C_7H_{14}	Ethylcyclopentane	134.71	376.6	569.5	3.397	375	0.763
$C_7H_{14}O$	2-Heptanone	238	424.20	611.5	3.436		0.8111
$C_7H_{14}O$	Heptanal	229.8	425.9				0.8132
$C_7H_{14}O_2$	Pentyl ethanoate	202.3	422.40				0.8721
$C_7H_{14}O_2$	3-Methylbutyl ethanoate	194.6	415.70	599			0.8666
$C_7H_{14}O_2$	Methyl hexanoate	202	422.6				0.880
$C_7H_{14}O_2$	Ethyl pentanoate	181.9	419.2	570			0.873
$C_7H_{14}O_2$	Propyl butanoate	177.9	416.20	600			0.869
$C_7H_{14}O_2$	Propyl 2-methylpropanoate		408.60	589			
$C_7H_{14}O_2$	Isobutyl propanoate	201.7	410	592			0.87
$C_7H_{14}O_2$	Ethyl 3-methylbutanoate	173.8	408.20	588			0.861
$C_7H_{14}O_2$	Heptanoic acid	265.6	495.40	679	2.90		0.9140
$C_7H_{15}Br$	1-Bromoheptane	215	452				1.134
$C_7H_{15}Cl$	1-Chloroheptane	203.6	432				0.871
C_7H_{16}	Heptane	182.5	371.6	540.3	2.756	428	0.6795
C_7H_{16}	2-Methylhexane	154.9	363.19	530.4	2.734	421	0.6744
C_7H_{16}	3-Methylhexane	153.7	364.99	535.3	2.814	404	0.6829
C_7H_{16}	2,2-Dimethylpentane	149.3	352.3	520.5	2.773	416	0.6695
C_7H_{16}	2,3-Dimethylpentane		362.93	537.4	2.908	393	0.6909
C_7H_{16}	2,4-Dimethylpentane	153.2	353.64	519.8	2.737	418	0.6683
C_7H_{16}	3,3-Dimethylpentane	138.2	359.21	536.4	2.946	414	0.6891
C_7H_{16}	3-Ethylpentane	154.5	366.6	540.7	2.891	416	0.6940
C_7H_{16}	2,2,3-Trimethylbutane	248	354.01	531.2	2.954	398	0.6859
$C_7H_{16}O$	1-Heptanol	239	449.85	632.5	3.135	435	0.8187
$C_7H_{16}O$	(±)-2-Heptanol	243	432	611.4			0.8139
$C_7H_{16}O$	(±)-3-Heptanol	203	430	605.4			0.8170

TABLE 2.1.1
SUMMARY OF PHYSICAL CONSTANTS OF IMPORTANT SUBSTANCES (continued)

Molecular formula	Name	T_m/ K	T_b/ K	T_c/ K	P_c/ MPa	V_c/ cm^3 mol^{-1}	ρ_o/ g cm^{-3}
$C_7H_{16}O$	4-Heptanol	231.9	429	602.6			0.8149
$C_7H_{17}N$	Heptylamine	255	429				0.772
C_8F_{18}	Octadecafluorooctane		379.0	502	1.66		1.770
$C_8H_4O_3$	1,2-Benzenedicarboxylic anhydride	403.9	568				1.494
C_8H_7N	2-Tolunitrile	259.6	478				0.991
C_8H_7N	3-Tolunitrile	250	486				1.026
C_8H_7N	4-Tolunitrile	302.6	490.20	723			
C_8H_8	Vinylbenzene	242	418.29				0.9001
C_8H_8O	Methyl phenyl ketone	293	475	709.5		386	1.023
$C_8H_8O_2$	Methyl benzoate	258	472				1.0838
$C_8H_8O_3$	Methyl 2-hydroxybenzoate	265	496.10	709			1.179
C_8H_{10}	Ethylbenzene	178.20	409.34	617.2	3.600	374	0.8625
C_8H_{10}	1,2-Dimethylbenzene	247.9	417.6	630.3	3.730	369	0.8759
C_8H_{10}	1,3-Dimethylbenzene	225.3	412.27	617.05	3.535	376	0.8601
C_8H_{10}	1,4-Dimethylbenzene	286.3	411.52	616.2	3.511	379	0.8566
$C_8H_{10}O$	2-Ethylphenol	291	477.67	703.0			1.0146
$C_8H_{10}O$	3-Ethylphenol	269	491.57	718.8			1.023
$C_8H_{10}O$	4-Ethylphenol	318.23	491.13	716.4			0.991
$C_8H_{10}O$	2,3-Dimethylphenol	345.9	490.07	722.8			0.942
$C_8H_{10}O$	2,4-Dimethylphenol	297.68	484.13	707.6			0.980
$C_8H_{10}O$	2,5-Dimethylphenol	347.9	484.33	706.9			0.975
$C_8H_{10}O$	2,6-Dimethylphenol	318.8	474.22	701.0			0.891
$C_8H_{10}O$	3,4-Dimethylphenol	333.9	500	729.8			1.012
$C_8H_{10}O$	3,5-Dimethylphenol	336.7	494.89	715.6			0.984
$C_8H_{10}O$	Ethyl phenyl ether	243.63	442.96	647	3.42		0.9605
$C_8H_{11}N$	*N,N*-Dimethylaniline	275.60	467.20	687	3.63		0.9523
$C_8H_{11}N$	*N*-Ethylaniline	209.6	476.20	698			0.961
C_8H_{14}	1-Octyne	193.8	399.4				0.742
$C_8H_{14}O_4$	Ethyl succinate	252	490.90	663			1.035
$C_8H_{15}N$	Octanenitrile	227.5	478.40	674.4	2.85		0.810
C_8H_{16}	Cyclooctane	287.98	424.3	647.2	3.56	410	0.8320
C_8H_{16}	Ethylcyclohexane	161.8	405.0				0.784
C_8H_{16}	1,1-Dimethylcyclohexane	239.8	392.7				0.777
C_8H_{16}	*cis*-1,2-Dimethylcyclohexane	223.2	402.9				0.792
C_8H_{16}	*trans*-1,2-Dimethylcyclohexane	183	396.6				0.772
C_8H_{16}	*cis*-1,3-Dimethylcyclohexane	197.5	393.2				0.762
C_8H_{16}	*trans*-1,3-Dimethylcyclohexane	183.0	397.6				
C_8H_{16}	*cis*-1,4-Dimethylcyclohexane	185.7	397.5				0.779
C_8H_{16}	*trans*-1,4-Dimethylcyclohexane	236.2	392.5	587.7			
C_8H_{16}	1-Octene	171.4	394.44	566.7	2.675	464	0.711
$C_8H_{16}O_2$	Octanoic acid	289.4	513.1	695	2.64		0.9066
$C_8H_{16}O_2$	Propyl 3-methylbutanoate		429.10	609			0.857
$C_8H_{16}O_2$	Isobutyl butanoate		430.10	611			0.866
$C_8H_{16}O_2$	Isobutyl 2-methylpropanoate	192.4	421.80	602			0.850
$C_8H_{16}O_2$	3-Methylbutyl propanoate		433.40	611			0.865
$C_8H_{17}Br$	1-Bromooctane	218	473				1.108
$C_8H_{17}Cl$	1-Chlorooctane	215.3	454.6				0.869
C_8H_{18}	Octane	216.3	398.82	568.9	2.493	492	0.6986
C_8H_{18}	2-Methylheptane	164.16	390.81	559.7	2.484	488	0.6939
C_8H_{18}	3-Methylheptane	152.6	392.09	563.7	2.546	464	0.7018
C_8H_{18}	4-Methylheptane	152	390.87	561.8	2.542	476	0.7006
C_8H_{18}	2,2-Dimethylhexane	151.97	380.01	549.9	2.529	478	0.6911
C_8H_{18}	2,3-Dimethylhexane		388.77	563.5	2.628	468	0.7081
C_8H_{18}	2,4-Dimethylhexane		382.6	553.6	2.556	472	0.6962
C_8H_{18}	2,5-Dimethylhexane	182	382.27	550.1	2.487	482	0.6893
C_8H_{18}	3,3-Dimethylhexane	147.0	385.12	562.1	2.654	443	0.7060
C_8H_{18}	3,4-Dimethylhexane		390.88	568.9	2.692	466	0.715
C_8H_{18}	3-Ethylhexane		391.7	565.5	2.608	455	0.7095
C_8H_{18}	3-Ethyl-2-methylpentane	158.20	388.81	567.1	2.700	443	0.7152
C_8H_{18}	3-Ethyl-3-methylpentane	182.2	391.42	576.6	2.808	455	0.7235
C_8H_{18}	2,2,3-Trimethylpentane	160.89	383	563.5	2.730	436	0.7121
C_8H_{18}	2,2,4-Trimethylpentane	165.8	372.37	544.0	2.568	468	0.6878

TABLE 2.1.1
SUMMARY OF PHYSICAL CONSTANTS OF IMPORTANT SUBSTANCES (continued)

Molecular formula	Name	T_m/ K	T_b/ K	T_c/ K	P_c/ MPa	V_c/ cm^3 mol^{-1}	ρ_o/ g cm^{-3}
C_8H_{18}	2,3,3-Trimethylpentane	172.22	387.9	573.6	2.820	455	0.7223
C_8H_{18}	2,3,4-Trimethylpentane	163.9	386.6	566.5	2.730	461	0.7150
C_8H_{18}	2,2,3,3-Tetramethylbutane	373.8	379.60	567.8	2.87	461	0.820
$C_8H_{18}O$	1-Octanol	257.6	468.31	652.5	2.86	490	0.8223
$C_8H_{18}O$	(±)-2-Octanol	241	453.03	638	2.9		0.8171
$C_8H_{18}O$	4-Methyl-3-heptanol	150	443	623.5			0.7940
$C_8H_{18}O$	5-Methyl-3-heptanol	181.9	445	621.2			0.8143
$C_8H_{18}O$	2-Ethyl-1-hexanol	203	457.77	641	2.8		0.8290
$C_8H_{18}O$	Dibutyl ether	177.9	413.43	584.1	3.01		0.7641
$C_8H_{18}O$	Di-*tert*-butyl ether		380.38	550			0.762
$C_8H_{18}S$	5-Thianonane	198.1	462				0.834
$C_8H_{19}N$	Dibutylamine	211	432.7	607.5	3.11		0.7571
$C_8H_{19}N$	Bis(2-methylpropyl)amine	199.6	412.84	584.4	3.20		
$C_8H_{20}Si$	Tetraethylsilane		427.90	603.7	2.602		0.762
$C_9H_6N_2O_2$	2,4-Diisocyanatotoluene	293.6	524				1.221
C_9H_7N	Quinoline	258.37	510.25	782	4.86	437	1.090
C_9H_7N	Isoquinoline	299.62	516.37	803	5.10	374	
C_9H_8	Indene	271.3	455				0.996
C_9H_{10}	Indan	221.7	451.12	684.9	3.95		0.959
C_9H_{12}	Isopropylbenzene	177.14	425.56	631.1	3.209		0.8574
C_9H_{12}	2-Ethyltoluene	192.3	438.3				0.876
C_9H_{12}	3-Ethyltoluene	177.6	434.4				0.860
C_9H_{12}	4-Ethyltoluene	210.8	435				0.857
C_9H_{12}	Propylbenzene	173.59	432.39	638.32	3.200	440	0.8579
C_9H_{12}	1,2,3-Trimethylbenzene	247.7	449.27	664.47	3.454		0.890
C_9H_{12}	1,2,4-Trimethylbenzene	229.3	442.53	649.17	3.232		0.8723
C_9H_{12}	1,3,5-Trimethylbenzene	228.4	437.89	637.25	3.127		0.8614
$C_9H_{13}N$	*N,N*-Dimethyl-2-toluidine	213	467.30	668	3.12		0.924
$C_9H_{14}O$	3,5,5-Trimethyl-2-cyclohexen-1-one	265.0	488.3				0.9196
$C_9H_{14}O_6$	1,2,3-Propanetriol tris(ethanoate)	195	532				1.154
C_9H_{18}	*trans*-1,3,5-Trimethylcyclohexane	165.7	413.70	602.2			0.776
$C_9H_{18}O$	5-Nonanone	267.2	461.60	640			0.818
$C_9H_{18}O$	Nonanal		464				0.824
$C_9H_{18}O$	2,6-Dimethyl-4-heptanone	231.6	442.5				0.802
$C_9H_{18}O_2$	Nonanoic acid	285.50	527.70	711	2.40		0.9013
$C_9H_{18}O_2$	3-Methylbutyl butanoate		452	619			0.860
$C_9H_{18}O_2$	Isobutyl 3-methylbutanoate		441.70	621			0.849
C_9H_{20}	Nonane	219.6	423.97	594.9	2.288		0.7138
C_9H_{20}	2-Methyloctane	192.78	416.43	587.0	2.310		0.705
C_9H_{20}	2,2-Dimethylheptane	160	405.8	576.8	2.350		0.707
C_9H_{20}	2,2,5-Trimethylhexane	167.39	397.24	568			0.7032
C_9H_{20}	2,2,3,3-Tetramethylpentane	263.3	413.44	607.7	2.741		0.753
C_9H_{20}	2,2,3,4-Tetramethylpentane	152.06	406.18	592.7	2.602		0.735
C_9H_{20}	3,3-Diethylpentane	240.0	419.3				0.750
C_9H_{20}	2,2,4,4-Tetramethylpentane	206.61	395.44	574.7	2.485		0.716
C_9H_{20}	2,3,3,4-Tetramethylpentane	171.0	414.72	607.7	2.716		0.751
$C_9H_{20}O$	1-Nonanol	268	486.65	671.5	2.63		0.8247
$C_{10}F_8$	Perfluoronaphthalene	360.6	482	673.1			
$C_{10}F_{18}$	Perfluorodecalin	263	415	566	1.52		
$C_{10}F_{22}$	Perfluorodecane		417.40	542	1.45		
$C_{10}H_7Cl$	1-Chloronaphthalene	270.6	532.4				1.189
$C_{10}H_8$	Azulene	372					1.175
$C_{10}H_8$	Naphthalene	353.3	491.14	748.4	4.051	413	1.1536
$C_{10}H_8O$	1-Naphthol	369	561				1.292
$C_{10}H_8O$	2-Naphthol	396	558				1.252
$C_{10}H_{10}O_4$	Dimethyl 1,2-benzenedicarboxylate	278.6	556.8				1.193
$C_{10}H_{12}$	1,2,3,4-Tetrahydronaphthalene	237.40	480.77	719.9		408	0.9671
$C_{10}H_{14}$	Butylbenzene	185.2	456.46	660.5	2.887	497	0.856
$C_{10}H_{14}$	Isobutylbenzene	221.70	445.94	650	3.05		0.8491
$C_{10}H_{14}$	2-Isopropyltoluene	201.6	451.2				0.8726
$C_{10}H_{14}$	3-Isopropyltoluene	209.4	448.2				0.857
$C_{10}H_{14}$	4-Isopropyltoluene	204.2	450.28	651	2.73		0.8525

TABLE 2.1.1
SUMMARY OF PHYSICAL CONSTANTS OF IMPORTANT SUBSTANCES (continued)

Molecular formula	Name	T_m/ K	T_b/ K	T_c/ K	P_c/ MPa	V_c/ $cm^3\ mol^{-1}$	ρ_o/ $g\ cm^{-3}$
$C_{10}H_{14}$	1,2-Diethylbenzene	241.9	457				0.876
$C_{10}H_{14}$	1,3-Diethylbenzene	189.2	454.2				0.856
$C_{10}H_{14}$	1,4-Diethylbenzene	230.32	456.94	657.88	2.803		0.858
$C_{10}H_{14}$	1,2,4,5-Tetramethylbenzene	352.4	469.99	675	2.9		1.03
$C_{10}H_{14}O$	2-Isopropyl-5-methylphenol	324.6	505.70	698			0.970
$C_{10}H_{16}$	2,7,7-Trimethylbicyclo[3.1.1]hept-2-ene	209	429				0.855
$C_{10}H_{16}O$	1,7,7-Trimethylbicyclo[2.2.1]hepten-2-one	453	480				0.992
$C_{10}H_{18}$	*cis*-Bicyclo[4.4.0]decane	230.20	468.96	702.3	3.20		0.893
$C_{10}H_{18}$	*trans*-Bicyclo[4.4.0]decane	242.79	460.46	687.1			0.866
$C_{10}H_{18}$	1,3-Decadiene		442	615			
$C_{10}H_{20}$	1-Decene	206.8	443.7	616.4	2.218	584	0.737
$C_{10}H_{20}O$	(±)-2-Isopropyl-5-methylcyclohexanol	315	489.50	694			0.89
$C_{10}H_{20}O$	Decanal	268	481.6	674.2			
$C_{10}H_{20}O_2$	Decanoic acid	305.14	541.90	726	2.23		
$C_{10}H_{20}O_2$	Ethyl octanoate	230.0	481.70	659			0.860
$C_{10}H_{22}$	Decane	243.4	447.30	617.65	2.104		0.7264
$C_{10}H_{22}$	3,3,5-Trimethylheptane		428.8	609.7	2.317		0.721
$C_{10}H_{22}$	2,2,3,3-Tetramethylhexane	219	433.48	623.2	2.510		0.7609
$C_{10}H_{22}$	2,2,5,5-Tetramethylhexane	260.5	410.63	581.6	2.186		0.7148
$C_{10}H_{22}O$	1-Decanol	280.0	504.27	689	2.41		0.8263
$C_{10}H_{22}S$	Bis(3-methylbutyl) sulfide		484	664			0.828
$C_{11}H_{10}$	1-Methylnaphthalene	242.67	517.83	772			1.015
$C_{11}H_{10}$	2-Methylnaphthalene	307.5	514.2	761			1.001
$C_{11}H_{16}$	4-*tert*-Butyltoluene	221	463				0.857
$C_{11}H_{22}O_2$	Ethyl nonanoate	236.4	500.20	674			0.861
$C_{11}H_{24}$	Undecane	247.5	469.08	638.85	1.955		0.7365
$C_{12}H_8$	Acenaphthylene	365.6	553				0.899
$C_{12}H_9N$	Carbazole	519.3	627.85	901.8	3.93	502	1.1
$C_{12}H_{10}$	Acenaphthene	366.5	552				1.19
$C_{12}H_{10}$	Biphenyl	342	528.4	789	3.85	502	1.04
$C_{12}H_{10}N_2$	Azobenzene	340.2	566				1.2
$C_{12}H_{10}N_2O$	Azoxybenzene	309					1.159
$C_{12}H_{10}O$	Diphenyl ether	300.02	531.20	766.8			
$C_{12}H_{11}N$	Diphenylamine	326.13	575				1.16
$C_{12}H_{12}N_2$	4,4′-Biphenyldiamine	393					
$C_{12}H_{14}O_4$	Diethyl 1,2-benzenedicarboxylate	232.6	568				1.22
$C_{12}H_{18}$	Hexamethylbenzene	439.6	536.60	758			1.0630
$C_{12}H_{24}$	1-Dodecene	237.9	486.9	657.6	1.930		0.755
$C_{12}H_{24}O_2$	Dodecanoic acid	316.37	364.5				1.032
$C_{12}H_{26}$	Dodecane	263.5	489.47	658.65	1.830		0.7452
$C_{12}H_{26}O$	1-Dodecanol	297	537.7	720	2.08		0.8308
$C_{12}H_{27}N$	Tributylamine	203	489.6				0.7748
$C_{13}H_{10}$	Fluorene	387.9	568				1.202
$C_{13}H_{10}O$	Diphenyl ketone	321.03	578.5				1.103
$C_{13}H_{12}$	Diphenylmethane	298.39	537	770	2.86		1.001
$C_{13}H_{26}O_2$	Methyl dodecanoate	278.3	540	712			0.866
$C_{13}H_{28}$	Tridecane	267.76	508.62	676	1.71		0.7527
$C_{14}H_{10}$	Anthracene	488.1	614	869.3		554	1.28
$C_{14}H_{10}$	Phenanthrene	372.39	612.5	873		554	1.179
$C_{14}H_{10}O_2$	Benzil	368.01	620				1.22
$C_{14}H_{12}$	*cis*-1,2-Diphenylethene	268					
$C_{14}H_{12}$	*trans*-1,2-Diphenylethene	396	580				1.046
$C_{14}H_{14}$	1,1-Diphenylethane	255.2	545.7				0.995
$C_{14}H_{30}$	Tetradecane	279.01	526.66	693	1.61		0.7592
$C_{15}H_{32}$	Pentadecane	283.0	543.76	708	1.515		0.765
$C_{16}H_{10}$	Pyrene	424.3	677				1.268
$C_{16}H_{22}O_4$	Dibutyl 1,2-benzenedicarboxylate	238	613				1.0426
$C_{16}H_{34}$	Hexadecane	291.34	560.01	722	1.435		0.769
$C_{17}H_{36}$	Heptadecane	295	575.1	735	1.37		0.7746