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Thermodynamic Data for Waste Incineration

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Chemical Thermodynamics Data Center
Chemical Thermodynamics Division
Center for Thermodynamics and Molecular Science
and the Office of Standard Reference Data
National Bureau of Standards
Washington, D.C. 20234

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Prepared for:

American Society for Mechanical Engineers
Research Committee on Industrial and Municipal Wastes
[U]nited Engineering Center
[N]ew York, N.Y.

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U.S. DEPARTMENT OF COMMERCE, Juanita M. Kreps, *Secretary*
Dr. Sidney Harman, *Under Secretary*
Jordan J. Baruch, *Assistant Secretary for Science and Technology*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

PREFACE

Incinerators have continued to play an important part in reducing the amount and modifying the type of waste discharged to the environment.

The ASME Research Committee on Industrial and Municipal Wastes was established in 1968. This committee recognized the need for greater understanding of combustion fundamentals if engineers are to design better incinerators to meet the challenge of improving the environment. It, therefore, created a subcommittee on fundamental combustion studies.

The first report of the subcommittee, published in 1974, was entitled: Combustion Fundamentals for Waste Incineration. The purpose of the report was to help engineers make better calculations and thereby design better incinerators. The report was divided into two parts. Part one covered theoretical engineering methods of calculation and tables of equilibrium products of combustion with practical examples. Part two included the scientific theory and tables of thermodynamic properties.

This is the second report of the subcommittee. The purpose of this report is to provide engineers with thermodynamic data on materials which are mixtures of various kinds and are often difficult to describe using a single stoichiometric formula. These materials (i.e., animals, foods, plants, polymers, wood species, etc.) are encountered perhaps more often by engineers engaged in the disposal of municipal wastes than pure substances. The bulk of the data consist of gross heating values and specific heats, and should be helpful in combustion calculations.

The report is dedicated to all engineers involved in designing, procuring, operating, and managing incinerators.

TABLE OF CONTENTS

Introduction

The general purpose of this table of thermodynamic data of selected materials is to make property information available to the engineering community on chemical mixtures, polymers, composite materials, solid wastes, and materials not easily identifiable by a single stoichiometric formula. Workers in many sectors need this type of information: construction engineers who require thermodynamic information on materials, safety engineers assessing the hazard potential of chemicals, cryogenic engineers involved in low temperature research, chemical engineers concerned with industrial unit processes, nutritionists interests in the heating values of foods, and scientists who want thermodynamic data for specific research projects.

The specific purpose of this table is to provide incinerator engineers with appropriate thermodynamic data so that they can dispose of waste materials in a more effective and environmentally acceptable manner. The effective disposal of waste materials is an important part of the maintenance of a high quality environment and incineration offers the most significant means of volume reduction for waste materials when compared to other methods of disposal.

This table of thermodynamic data was prepared in the Chemical Thermodynamics Data Center of the National Bureau of Standards and was administered through the NBS Office of Standard Reference Data over the period 1 January 1975 to 31 December 1976. A total of 331 materials have been compiled covering properties such as: specific heat, heat of combustion, heat of fusion, heat of vaporization, heat of explosion, vapor pressure, and explosion temperature. The information was obtained from the master files of the NBS Chemical Thermodynamics Data Center, the annual issues of the Bulletin of Thermodynamics and Thermochemistry, intermittent examinations of the Chemical Abstracts Subject Indexes, individual articles by various authors, and other general reference sources.

The basic format of the table is alphabetical according to the name of the material; similar materials, such as foods, polymers, woods, and explosives are grouped under the broader classification. For each material the following are given (1) the physical state, (2) information as to the composition of the material, (3) the kind of thermodynamic property reported, (4) the specific property values for the material, and (5) citations to the reference list. An index arranged by subject and property is provided which will assist a user in finding a specific material or property.

Units and Definitions

The notation in the tables for thermodynamic quantities follows, in general, that in "Combustion Fundamentals for Waste Incineration" [141]. In those tables values were reported on a molar basis. Here, because of the lack of definite stoichiometric compositions for most of the materials included, values of the thermodynamic quantities are given on a specific basis, for one gram of substance. Exceptions are noted. The symbols used are briefly defined below; more extensive discussions are given in [141].

T. The absolute temperature, on the International Practical Temperature Scale. Values are given in kelvins (symbol K). The Celsius ("Centigrade") scale (symbol °C) is used to indicate the temperature or temperature range for many reported measurements. It is defined as t(°C) = T(K) - 273.15. The Fahrenheit scale, involved in a few measurements, is defined as t(°F) = 1.8t°C + 32. Unless specifically indicated otherwise, all temperatures T involved in equations are absolute temperature (T, K).

q_v(gross). The specific isothermal gross heat of reaction at the specified temperature and at constant volume. q_v(gross) is equal to $-\Delta U/M$, where ΔU is the molar change in internal energy of the process and M is the molecular weight. Where possible, the values of q_v (or ΔU) have been converted to the standard state ($-\Delta U°/M$) [141]. Most of the data, though, are of such low precision, because of sample variability or measurement method, that this correction is impractical. For combustion reactions in oxygen the products are taken as $H_2O(1)$, $CO_2(g)$, $N_2(g)$, HCl (aq, dilute), H_2SO_4 (aq, dilute). Other products are identified. Metallic elements are assumed to form the oxide. For many of the substances considered, the metallic elements are included in the "ash" fraction; the values of q_v(gross) may have been reported on the "ash-free" basis, which assumes a neglibile heat effect from the non-combustible material.

The numerical values are given in J/g and cal/g. The calorie used is the thermochemical calorie, defined as 4.184 J. Values originally reported in other units, such as BTU/lb, have been systematically converted to J/g. Conversion factors are given in the Physical Constant Table.

q_v(net). The specific isothermal net heat of reaction at the specified temperature and at constant volume. Differs from q_v(gross) in that water formed is in the gaseous state.

q_p (net). The specific isothermal net heat of reaction at the specified temperature and at constant pressure. q_p(net) is equal to $-\Delta H/M$, where ΔH is the molar change in enthalpy of the process and M is the molecular weight. Where possible, the values of q_p(net) have been converted to the standard state, $(-\Delta H°/M)$ [141]. Most of the data, though, are of such low precision, because of sample variability or measurement method, that the correction is impractical. Unless indicated otherwise, the products of combustion in oxygen or of explosion are taken as $CO_2(g)$, $H_2O(g)$, $N_2(g)$; other products are indicated. For explosion heats, the products are not reported in many cases; in some cases, reactions have been assumed, based on data for similar substances.

L_f. The specific latent heat of fusion $(\Delta H_{fus}/M)$ at a pressure of 1 atm (101325 Pa). The value is the heat absorbed (in J and cal) when one gram of the substance goes from the solid state to the liquid state. For a pure compound, the melting occurs at a single temperature; for the complex materials considered here, the melting process may take place over a temperature range.

L_t. The specific latent heat of transition $(\Delta H_{trs}/M)$ at a pressure of 1 atm (101325 Pa). The value is the heat absorbed when one gram of the substance goes from one solid phase to another solid phase. For a pure compound, the transition occurs at a single temperature; for the complex materials considered here, the transition process may take place over a temperature range.

L_v. The specific latent heat of vaporization $(\Delta H_{vap}/M)$. The value is the heat absorbed when one gram of the substance goes from the liquid state to the gaseous state. If measured calorimetrically the value will be for a definite temperature and pressure. If derived from the vapor pressure equation through the relation $d(\ln P)/d(1/T) = -\Delta H/R$, the value may be referred to a definite temperature and pressure, depending upon the form of the equation. With the simple form $\ln P = A-B/T$, the value refers to the midpoint of the temperature range over which the equation is valid. The value thus obtained is for one mole of gaseous species; the average molecular weight must be obtained to calculate the specific heat of vaporization: $L_v = \Delta H_v/M$.

L_s. The specific latent heat of sublimation ($\Delta H_{sub}/M$). The value is the heat absorbed when one gram of the substance goes from the solid state to the gaseous state. The same considerations apply as for L_v.

Heat of combustion. The change in the internal energy ($-q_v$) or enthalpy ($-q_p$) when one gram of the substance is burned isothermally in oxygen. Usually measured by combustion in a calorimetric bomb at elevated oxygen pressure. Gross heat of combustion refers to a process in which the major products are $CO_2(g)$, $H_2O(l)$, $N_2(g)$. Net heat of combustion refers to $H_2O(g)$ as a product.

In accurate work the observed heat is corrected for side reactions and to a standard state in which all gases are at unit fugacity; for most of the data reported here, the precision of the measurements does not warrent such refinement.

Heat of explosion. The isothermal heat evolved during the explosive decomposition of the substance. All gaseous products, including water, are assumed to be at 1 atm pressure. The products are a complex mixture; in many cases, a quantitative description of the reaction is not possibly [see ref. 77].

Specific heat. The change in enthalpy with temperature at constant pressure (1 atm unless otherwise specified) for one gram of substance. $c_p = (\partial(H/M)/\partial T)p$. At constant volume $c_v = (\partial(U/M)/\partial T)$.

Vapor pressure. The saturated equilibrium pressure over the liquid substance at a given temperature. Values are expressed in pascals ($Pa = N \cdot m^{-2}$) and in Torr (Torr = 133.3224 Pa). The conventional atmosphere is taken as 101325 Pa.

Sublimation Pressure. The saturated equilibrium pressure over the solid substance at a given temperature. Values are expressed in pascals ($Pa = N \cdot m^{-2}$) and in Torr (Torr = 133.3224 Pa). The conventional atmosphere is taken as 101325 Pa.

Explosion temperature. A measure of the thermal stability of an explosive. The values listed in [77] were determined by the following procedure: "A 0.02-gm sample (0.01-g in the case of initiatiors) of explosive, loosely loaded in a No. 8 blasting cap, is immersed for a short period in a Wood's metal bath. The temperature determined is that which produces explosion, ignition or decomposition of the sample in 5 second." [77]

Heat content. The difference in enthalpy, for one gram of substance, between two temperatures, $(H_T-H_{T(ref)})/M = (q_T-q_{T(ref)})$. T(ref) is the reference temperature, usually 0 K, 273.15 K, or 298.15 K. It is specified as q_0, q_{273} or $q_{273.15}$, and q_{298} or $q_{298.15}$. If other then the kelvin scale is used, this is indicated as °C, °F, or °R (Rankine, T°R = 1.8 T K).

Uncertainties. No attempt has been made to assess the over-all uncertainty of the data included. For some substances, uncertainties are given for the values; these represent the original authors' estimates, and are usually a measure of the reproducibility of their measurements. A large assigned uncertainty usually indicates a variability of sample, not a low precision of measurement.

Multiple sources of data. Occasionally, several references are found in the literature which report the same thermodynamic property for a particular material. The measured values are most often not equivalent and a selection must be made as to which value is preferred. For some materials (such as coals), the values tabulated are typical values selected from a large number of results for samples of a similar nature. The selection process is based upon the personal and professional opinion of an evaluator after all of the property information for a material has been collected and examined. Factors which are taken into consideration are: (1) description of the method used to carry out the measurements, (2) characterization of the material, (3) number of measurements performed, (4) treatment of the experimental data, (5) dispersion of the results, and (6) background or experience of the laboratory personnel carrying out the measurements.

ALLOY, HASTELLOY X; solid; composition: carbon, 0.05-0.15%; chromium, 20.50-23.00%; cobalt, 0.05-2.50%; iron, 17.00-20.00%; manganese, 1.00% max.; molybdenum, 8.00-10.00%; silicon, 1.00% max.; tungsten, 0.2-1.0%; remainder nickel, 42.0-54.0%.

specific heat:

0 - 1100 °C

$$Cp(\text{cal g}^{-1}\text{ K}^{-1}) = 0.0924 + 4.438 \times 10^{-5}\,T - 2.812 \times 10^{-9}\,T^2 + 1.030 \times 10^{-11}\,T^3 - 1.885 \times 10^{-14}\,T^4 + 1.38 \times 10^{-17}\,T^5$$

$$Cp(\text{J g}^{-1}\text{ K}^{-1}) = 0.3866 + 1.8569 \times 10^{-4}\,T - 1.1765 \times 10^{-8}\,T^2 + 4.310 \times 10^{-11}\,T^3 - 7.887 \times 10^{-14}\,T^4 + 5.77 \times 10^{-17}\,T^5$$

heat content:

0 - 1100 °C

$$q_T - q_{273.2}\ (\text{cal g}^{-1}) = 0.0924T + 2.219 \times 10^{-5}\,T^2 - 9.373 \times 10^{-9}\,T^3 + 2.575 \times 10^{-12}\,T^4 - 3.770 \times 10^{-15}\,T^5 + 2.30 \times 10^{-18}\,T^6 - 27.1429$$

$$q_T - q_{273.2}\ (\text{J g}^{-1}) = 0.3866T + 9.284 \times 10^{-5}\,T^2 - 3.922 \times 10^{-8}\,T^3 + 1.0774 \times 10^{-11}\,T^4 - 1.5774 \times 10^{-14}\,T^5 + 9.62 \times 10^{-18}\,T^6 - 113.5659$$

[35]

ALLOY, 80 NICKEL-20 CHROMIUM; solid; composition: nickel, 77.4%; chromium, 19.52%; iron, 0.45%; maganese, 0.59%; silicon, 1.4%; carbon, 0.04%.

specific heat:

0 - 150 °C

$$Cp(\text{cal g}^{-1}\text{ K}^{-1}) = 0.0825 + 7.6 \times 10^{-5}\,T$$
$$Cp(\text{J g}^{-1}\text{ K}^{-1}) = 0.3452 + 3.18 \times 10^{-4}\,T$$

150 - 600 °C

$$Cp(\text{cal g}^{-1}\text{ K}^{-1}) = 0.0952 + 4.64 \times 10^{-5}\,T$$
$$Cp(\text{J g}^{-1}\text{ K}^{-1}) = 0.3983 + 1.941 \times 10^{-4}\,T$$

600 - 900 °C

$$Cp(\text{cal g}^{-1}\text{ K}^{-1}) = 0.1021 + 4.62 \times 10^{-5}\,T$$
$$Cp(\text{J g}^{-1}\text{ K}^{-1}) = 0.4271 + 1.933 \times 10^{-4}\,T$$

[97]

ALLOY, TITANIUM, Ti-75A; solid; composition: titanium, 99.75%; iron, 0.07%; oxygen, 0.131%; nitrogen, 0.048%; carbon, 0.06%; hydrogen, 0.0068%.

specific heat:

21 - 760 °C

$Cp(cal\ g^{-1}\ K^{-1}) = 0.1384 - 9.1526 \times 10^{-5}\ T + 1.555 \times 10^{-7}\ T^2$

$Cp(J\ g^{-1}\ K^{-1}) = 0.5791 - 3.8294 \times 10^{-4}\ T + 6.506 \times 10^{-7}\ T^2$

[66]

ALLOY, TITANIUM, Ti-150A; solid; composition: titanium, 95.65%; chromium, 2.71%; iron, 1.40%; oxygen, 0.105%; nitrogen, 0.076%; carbon, 0.05%; hydrogen, 0.0092%.

specific heat:

21 - 760 °C

$Cp(cal\ g^{-1}\ K^{-1}) = 0.1434 - 9.1526 \times 10^{-5}\ T + 1.555 \times 10^{-7}\ T^2$

$Cp(J\ g^{-1}\ K^{-1}) = 0.6000 - 3.8294 \times 10^{-4}\ T + 6.506 \times 10^{-7}\ T^2$

[66]

ALLOY, ZIRCALOY-2; solid, composition: tin, 1.46%; iron, 0.130%; chromium, 0.080%; nickel, 0.056%; carbon, 65 ppm; oxygen, 1489 ppm; nitrogen, 40 ppm; hydrogen, 11 ppm; copper, 20 ppm; tungsten, <20 ppm; aluminum, 40 ppm; silicon, 47 ppm; hafnium; <125 ppm; remainder is zirconium.

specific heat:

0 - 635 °C

$Cp(cal\ g^{-1}\ K^{-1}) = 0.06153 + 2.3872 \times 10^{-5}\ T$

$Cp(J\ g^{-1}\ K^{-1}) = 0.25744 + 9.9880 \times 10^{-5}\ T$

635 - 810 °C

$Cp(cal\ g^{-1}\ K^{-1}) = 0.08589$

$Cp(J\ g^{-1}\ K^{-1}) = 0.35936$

975 - 1050 °C

$Cp(cal\ g^{-1}\ K^{-1}) = 0.08548$

$Cp(J\ g^{-1}\ K^{-1}) = 0.35765$

[80]

heat of transition: temperature range: 810 - 975 °C, for the α - β transition

$L_t = 10.6\ cal\ g^{-1}$

$L_t = 44.4\ J\ g^{-1}$

[80]

ALLOY, ZIRCALOY-2 (LOW NICKEL); solid; composition: tin, 1.32%; iron, 0.152%; chromium, 0.99%; nickel, 10 ppm; carbon, 150 ppm; oxygen, 1380 ppm; nitrogen, 36 ppm; copper, 20 ppm; tungsten, <40 ppm; hafnium, 60 ppm; remainder is zirconium.

specific heat:

0 - 570 °C

$Cp(cal\ g^{-1}\ K^{-1}) = 0.06314 + 2.0726 \times 10^{-5}\ T$
$Cp(J\ g^{-1}\ K^{-1}) = 0.26418 + 8.6718 \times 10^{-5}\ T$

600 - 810 °C

$Cp(cal\ g^{-1}\ K^{-1}) = 0.08571$
$Cp(J\ g^{-1}\ K^{-1}) = 0.35861$

975 - 1050 °C

$Cp(cal\ g^{-1}\ K^{-1}) = 0.08548$
$Cp(J\ g^{-1}\ K^{-1}) = 0.35765$

[80]

ANIMALS

BARNACLE, Balanus cariosus; solid; invertebrate animal; crustacean of the order Cirripedia.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

$q_v(gross) = 4520\ cal\ g^{-1}$
$q_v(gross) = 18912\ J\ g^{-1}$

[73]

BEETLE, Tenebrio molitor; solid; an insect of the order Coleoptera, having four wings the outer pair being stiff cases which cover the others when they are folded.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

$q_v(gross) = 6314 \pm 516\ cal\ g^{-1}$
$q_v(gross) = 26418 \pm 2159\ J\ g^{-1}$

[75]

BIVALVE, Mytilus californianus; solid; invertebrate animal composed of two parts which open and shut, such as oysters and clams; mollusks.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

$q_v(gross) = 4600\ cal\ g^{-1}$
$q_v(gross) = 19246\ J\ g^{-1}$

[73]

ANIMALS

BLOOD, SHEEP; solid; Protein and fat composition determined on ash-free dry-basis for materials from bodies of 63 sheep; mean composition, protein, 98.80%; fat, 1.20%.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 5873 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 24573 \text{ J g}^{-1}$

For the % fat range 0.00 to 5.80:

$q_v(\text{gross}) = (5854 + 15.83 (\% \text{ fat})) \text{ cal g}^{-1}$
$q_v(\text{gross}) = (24493 + 66.23 (\% \text{ fat})) \text{ J g}^{-1}$

For the % protein range 94.20 to 100.00:

$q_v(\text{gross}) = (7435 - 15.83 (\% \text{ protein})) \text{ cal g}^{-1}$
$q_v(\text{gross}) = (31108 - 66.23 (\% \text{ protein})) \text{ J g}^{-1}$

[124]

BRACHIOPOD, Glottidia pyramidata; solid; a class of Molluscoida having bivalve shells.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

$q_v(\text{gross}) = 4397 \pm 2140 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 18397 \pm 8954 \text{ J g}^{-1}$

[75]

CARCASS, SHEEP; solid; Protein and fat composition determined on ash-free dry basis for carcasses of 63 sheep; mean composition, protein, 40.18%, fat, 59.82%.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 7778 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 32543 \text{ J g}^{-1}$

For the % fat range 33.32 to 81.69:

$q_v(\text{gross}) = (5327 + 40.97 (\% \text{ fat})) \text{ cal g}^{-1}$
$q_v(\text{gross}) = (22288 + 171.42 (\% \text{ fat})) \text{ J g}^{-1}$

For the % protein range 18.31 to 66.68:

$q_v(\text{gross}) = (9424 - 40.97 (\% \text{ protein})) \text{ cal g}^{-1}$
$q_v(\text{gross}) = (39430 - 171.42 (\% \text{ protein})) \text{ J g}^{-1}$

[124]

ANIMALS

CATTLE; solid; results apply to total body of cattle.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

For sample of 100% protein:

q_v(gross) = 5447 cal g^{-1}
q_v(gross) = 22790 J g^{-1}

For sample of 100% fat:

q_v(gross) = 9499 cal g^{-1}
q_v(gross) = 39744 J g^{-1}

[123]

CHITON, *Katherina tunicata*; solid; invertebrate animal; mollusk of the order Polyplacophora.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

q_v(gross) = 4700 cal g^{-1}
q_v(gross) = 19665 J g^{-1}

[73]

CILIATE, *Tetrahymena pyriformis*; solid; class of Protozoa characterized by presence of cilia and found in any exposed body of water.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

q_v(gross) = 5938 ± 207 cal g^{-1}
q_v(gross) = 24845 ± 866 J g^{-1}

[75]

CLADOCERA, *Leptodora kindtu*; solid; a group of minute, chiefly fresh-water, entomostracan crustaceans, often known as water fleas.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

q_v(gross) = 5605 ± 584 cal g^{-1}
q_v(gross) = 23451 ± 2443 J g^{-1}

[75]

ANIMALS

COPEPOD, Calanus helgolandicus; solid; a large subclass of crustaceans mostly minute in size found in both fresh and salt water.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

q_v(gross) = 5400 ± 197 cal g^{-1}
q_v(gross) = 22594 ± 824 J g^{-1}

[75]

COPEPOD, Trigriopus californicus; solid; a large subclass of crustaceans mostly minute in size and found in both fresh and salt water.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

q_v(gross) = 5515 ± 277 cal g^{-1}
q_v(gross) = 23075 ± 1159 J g^{-1}

[75]

FLATWORM, Dugesia tigrina; solid; a planarian worm of the phylum Platyhelminthes.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

q_v(gross) = 6286 ± 338 cal g^{-1}
q_v(gross) = 26301 ± 1414 J g^{-1}

[75]

FLATWORM, TERRESTRIAL, Bipalium keuense; solid; large worm found in the tropics, having the head end expanded into a semicircular plate.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

q_v(gross) = 5684 ± 124 cal g^{-1}
q_v(gross) = 23782 ± 519 J g^{-1}

[75]

FLY, CADDIS, Pycnopsyche guttifer; solid; insects having aquatic larvae, they are included in the Neuroptera, or constitute the order Trichoptera; they have four membranous wings densely hairy, vestigial mouth parts and many jointed antennas.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

q_v(gross) = 5706 cal g^{-1}
q_v(gross) = 23874 J g^{-1}

[75]

ANIMALS

FLY, CADDIS, Pycnopsyche lepido; solid; insects having aquatic larvae, they are included in the Neuroptera, or constitute the order Trichoptera, they are densely hairy, have four membranous wings, vestigial mouth parts and many jointed antennae.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

$q_v(\text{gross}) = 5687 \pm 530 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 23794 \pm 2218 \text{ J g}^{-1}$

[75]

GUPPIE, Lebistes reticulatus; solid; a small top minnow of the Barbados, Trinidad and Venezeula area; frequently kept as an aquarium fish.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

$q_v(\text{gross}) = 5823 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 24363 \text{ J g}^{-1}$

[75]

HIDE, SHEEP; solid; Protein and fat composition determined on ash-free dry basis for material from bodies of 63 sheep; mean composition, protein, 74.05%, fat, 25.95%.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 6473 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 27083 \text{ J g}^{-1}$

For the % fat range 18.37 to 38.72:

$q_v(\text{gross}) = (5458 + 38.47 \text{ (\% fat)}) \text{ cal g}^{-1}$
$q_v(\text{gross}) = (22836 + 160.96 \text{ (\% fat)}) \text{ J g}^{-1}$

For the % protein range 61.28 to 81.63:

$q_v(\text{gross}) = (9305 - 38.47 \text{ (\% protein)}) \text{ cal g}^{-1}$
$q_v(\text{gross}) = (38932 - 160.96 \text{ (\% protein)}) \text{ J g}^{-1}$

[124]

HYDRA, Hydra littoralis; solid; small fresh-water hydrozoan polyps usually found attached to submerged objects, the body is a simple tabe with a mouth at one extremity.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

$q_v(\text{gross}) = 6034 \pm 146 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 25246 \pm 611 \text{ J g}^{-1}$

[75]

ANIMALS

HYDRA, GREEN, Chlorohydra viridissima; solid; small fresh-water hydrozoan polyps which contains chlorophyll chromatophores, usually found attached to submerged objects, the body is a simple tube with a mouth at one extremity.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

$q_v(\text{gross}) = 5729 \pm 247 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 23970 \pm 1033 \text{ J g}^{-1}$

[75]

MITE, Tyroglyphus lintneri; solid; small arachnids which are parasitic in nature.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

$q_v(\text{gross}) = 5808 \pm 446 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 24301 \pm 1866 \text{ J g}^{-1}$

[75]

SHEEP, INGESTA-FREE BODY; solid; protein and fat composition determined on ash-free dry basis for bodies of 63 sheep; mean composition, protein, 43.33%, fat, 56.67%.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 7661 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 32054 \text{ J g}^{-1}$

For the % fat range 28.80 to 79.43:

$q_v(\text{gross}) = (5379 + 40.25\ (\%\ \text{fat})) \text{ cal g}^{-1}$
$q_v(\text{gross}) = (22506 + 168.41\ (\%\ \text{fat})) \text{ J g}^{-1}$

For the % protein range 20.57 to 71.20:

$q_v(\text{gross}) = (9405 - 40.25\ (\%\ \text{protein})) \text{ cal g}^{-1}$
$q_v(\text{gross}) = (39351 - 168.41\ (\%\ \text{protein})) \text{ J g}^{-1}$

[124]

SHRIMP, BRINE, Artenia sp. (nauplü); solid; a brachiopod crustacean.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

$q_v(\text{gross}) = 6737 \pm 863 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 28188 \pm 3611 \text{ J g}^{-1}$

[75]

ANIMALS

SNAIL, Tegula funebralis; solid; invertebrate animal; gastropod mollusk.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

$q_v(\text{gross}) = 5080 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 21255 \text{ J g}^{-1}$

[73]

SNAIL, AQUATIC, Succinea ovalis; solid; (without shell); a gastropod mollusk.

gross heat of combustion: assume values refer to room temperature and are corrected to an ash free basis.

$q_v(\text{gross}) = 5415 \pm 6 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 22656 \pm 25 \text{ J g}^{-1}$

[75]

SPITBUG, Philenus leucophthalmus; solid; a spittle insect.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

$q_v(\text{gross}) = 6962 \pm 510 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 29129 \pm 2134 \text{ J g}^{-1}$

[75]

STARFISH; solid; Pisaster ochraceus; invertebrate animal; echinoderm of the order Asteroidea.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

$q_v(\text{gross}) = 2110 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 8828 \text{ J g}^{-1}$

[73]

ANIMALS

VISCERA, SHEEP; solid; protein and fat composition determined on ash-free dry-basis for viscera from bodies of 63 sheep; mean composition, protein, 33.50%, fat, 66.50%.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 8011 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 33518 \text{ J g}^{-1}$

For the % fat range 26.62 to 87.12:

$q_v(\text{gross}) = (5428 + 38.81 (\% \text{ fat})) \text{ cal g}^{-1}$
$q_v(\text{gross}) = (22711 + 162.38 (\% \text{ fat})) \text{ J g}^{-1}$

For the % protein range 12.88 - 73.38:

$q_v(\text{gross}) = (9312 - 38.81 (\% \text{ protein})) \text{ cal g}^{-1}$
$q_v(\text{gross}) = (38961 - 162.38 (\% \text{ protein})) \text{ J g}^{-1}$

[124]

ASPHALT; solid; mixture of paraffinic, aromatic, and heterocyclic hydrocarbons (containing oxygen, nitrogen, and sulfur).

specific heat: Venezeulan distilled asphalt.

Softening Point, °C	$C_p(\text{cal g}^{-1} \text{K}^{-1})$ 0°C	100°C	200°C	300°C
39.5	0.425	0.472	0.520	0.567
62.5	0.409	0.463	0.518	0.572
96.5	0.382	0.455	0.527	0.600

Softening Point, °C	$C_p(\text{J g}^{-1} \text{K}^{-1})$ 0°C	100°C	200°C	300°C
39.5	1.778	1.975	2.176	2.372
62.5	1.711	1.937	2.167	2.393
96.5	1.598	1.904	2.205	2.510

[94,95]

BIPHENYL, POLYCHLORINATED, CLOPHEN A30; liquid; 30% chlorine; product of Bayer-Leverkusen Company; average molecular weight 190 ± 25.

heat of vaporization: 40° - 160 °C

$L_v = 96.45 \text{ cal g}^{-1}$
$L_v = 403.5 \text{ J g}^{-1}$

vapor pressure: 40° - 160 °C

$\log_{10} P(\text{Torr}) = 10.05 - 4005 T^{-1}$
$\log_{10} P(\text{Pa}) = 12.17 - 4005 T^{-1}$

[59]

<u>BIPHENYL, POLYCHLORINATED, CLOPHEN A40</u>; liquid; 40% chlorine; product of Bayer-Leverkusen Company; average molecular weight 205 ± 20.

<u>heat of vaporization</u>: 40° - 160 °C

$L_v = 92.29$ cal g^{-1}
$L_v = 386.1$ J g^{-1}

vapor pressure: 40° - 160 °C

$\log_{10} P(\text{Torr}) = 10.15 - 4135\ T^{-1}$
$\log_{10} P(\text{Pa}) = 12.27 - 4135\ T^{-1}$

[59]

<u>BIPHENYL, POLYCHLORINATED, CLOPHEN A50</u>; liquid; 50% chlorine; product of Bayer-Leverkusen Company; average molecular weight 225 ± 30.

<u>heat of vaporization</u>: 40° - 160 °C

$L_v = 88.46$ cal g^{-1}
$L_v = 370.1$ J g^{-1}

<u>vapor pressure</u>: 40° - 160 °C

$\log_{10} P(\text{Torr}) = 10.15 - 4350\ T^{-1}$
$\log_{10} P(\text{Pa}) = 12.27 - 4350\ T^{-1}$

[59]

α-BRASS; solid; chemical composition in wt.%; (sample 1): copper, 79.75%; lead, 0.003%; iron, 0.015%; nickel, 0.01%; zinc, 20.22%; (sample 2): copper, 70.42%; tin, 0.045%; lead, 0.05%; iron, 0.02%; nickel, 0.02%; zinc, 29.445%; (sample 3): copper, 65.18%; lead, 0.001%; iron, 0.002%; nickel, 0.002%; zinc, 34.815%.

specific heat:

Temperature, K	Cp(cal g^{-1} K^{-1})	Cp(J g^{-1} K^{-1})
sample 1		
298.15	0.0908	0.3798
400	0.0940	0.3935
500	0.1014	0.4243
600	0.1005	0.4205
700	0.1039	0.4347
800	0.1056	0.4418
sample 2		
298.15	0.0905	0.3787
400	0.0943	0.3946
500	0.1114	0.4661
600	0.1011	0.4230
700	0.1045	0.4372
800	0.1064	0.4452
sample 3		
298.15	0.0905	0.3787
400	0.0941	0.3937
500	0.1050	0.4393
600	0.1016	0.4251
700	0.1060	0.4435
800	0.1091	0.4565

[126]

CELLULOID; solid; (trade mark, © Celanese Corp. of America); a solid solution of cellulose nitrate and camphor or other related plasticizers.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 4224\ \text{cal g}^{-1}$
$q_v(\text{gross}) = 17673\ \text{J g}^{-1}$

[115]

CEMENT HYDRATES; solid; general formula; $x\text{CaO}\cdot y\text{Al}_2\text{O}_3\cdot z\text{CaSO}_4\cdot m\text{CaCO}_3\cdot n\text{H}_2\text{O}\cdot$(C=CaO, A=$Al_2O_3$, H=$H_2O$, Cs=$CaSO_4$, and Cc=$CaCO_3$).

heat of dehydration: gaseous water formed.

	temp range, °C	moles H_2O lost	ΔH (kcal gmol^{-1})	ΔH (kJ gmol^{-1})
$C_{3.97}AH_{11.0}$	120-200	4	48.9±0.2	204.5±0.8
	210-290	3.5	10.2±0.2	42.7±0.8
$C_{2.97}AH_{5.96}$	260-350	4.5	76.9±1.8	321.7±7.5
$C_{3.51}ACs_{2.54}H_{30.4}$	65-145	23	213.9±3.1	895.0±13.0
$C_{3.14}ACs_{0.94}H_{12.1}$	95-125	1.6	2.75±0.2	11.51±0.8
	140-200	6	34.4±0.7	143.9±2.9
	240-310	1.5	14.6±0.6	61.1±2.5
$C_{3.53}ACcH_{8.1}$	70-170	2	19.7±2	82.4±8
	250-320	5	31.0±0.5	129.7±2.1
$C_{1.97}AH_{12.9}$	120-160	5.9	2.4±0.7	10.0±2.9
	230-325	4.8	76.0±5.8	318.0±24.1
$C_{2.19}AH_{9.3}$	45-100	3	12.9±2.7	54.0±11.3
	125-190	1.5	14.6±2.3	61.1±9.6
	250-300	3.5	6.0±0.7	25.1±2.9
$C_{1.07}AH_{6.3}$	120-190	2	11.2±1.9	46.9±7.9
	230-300	3	22.3±1.0	93.3±4.2
$C_{1.03}AH_{3.98}$	240-340	2.8	43.7±2.7	182.8±11.3

[125]

CHARCOAL, WOOD; solid; Ultimate analysis: carbon, 93.0%; hydrogen, 2.5%; nitrogen and sulfur, 1.5%; moisture, 2%; proximate analysis: fixed carbon, 89%; ash, 1%; volatile matter, 10%.

gross heat of combustion: assume values refer to room temperature.

ash free and moisture free

$q_v(\text{gross}) = 8300 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 34727 \text{ J g}^{-1}$

as received; "good commercial fuel"

$q_v(\text{gross}) = 8050 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 33681 \text{ J g}^{-1}$

[52]

COAL, ANTHRACITE; solid; Ultimate analysis of combustible, ash free and moisture free: carbon, 94.39%; hydrogen, 1.77%; oxygen, 2.13%; nitorgen, 0.71%; sulfur, 1.00%; proximate analysis: ash, 7.83%; moisture, 2.80%; volatile matter, 1.3%; loss on air drying, 1.5%.

gross heat of combustion: assume values refer to room temperature.

ash free and moisture free

$q_v(\text{gross}) = 8273 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 34616 \text{ J g}^{-1}$

as received

$q_v(\text{gross}) = 7393 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 30931 \text{ J g}^{-1}$

[47,48]

COAL, SEMI-ANTHRACITE; solid; Ultimate analysis of combustible, ash free and moisture free: carbon, 92.15%; hydrogen, 3.76%; oxygen, 2.17%; nitrogen, 1.18%; sulfur, 0.74%; proximate analysis: ash, 11.50%; moisture, 3.38%; volatile matter, 10.0%; loss on air drying, 2.6%.

gross heat of combustion: assume values refer to room temperature.

ash free and moisture free

$q_v(\text{gross}) = 8593 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 35953 \text{ J g}^{-1}$

as received

$q_v(\text{gross}) = 7314 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 30601 \text{ J g}^{-1}$

[47,48]

COAL, BITUMINOUS (HIGH GRADE); solid; Ultimate analysis of combustible, ash free and moisture free: carbon, 85.09%; hydrogen, 4.99%; oxygen, 6.99%; nitrogen, 1.80%; sulfur, 1.13%; proximate analysis: ash, 2.79%; moisture, 2.18%; volatile matter, 33.4%; loss on air drying, 1.0%.

gross heat of combustion: assume values refer to room temperature.

ash free and moisture free

$q_v(\text{gross}) = 8667 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 36262 \text{ J g}^{-1}$

as received

$q_v(\text{gross}) = 8237 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 34462 \text{ J g}^{-1}$

[47,48]

COAL, BITUMINOUS (MEDIUM GRADE); solid; (sample 1) Ultimate analysis of combustible, ash free and moisture free: carbon, 82.08%; hydrogen, 5.40%; oxygen, 5.98%; nitrogen, 1.32%; sulfur, 5.22%; proximate analysis: ash, 12.97%; moisture, 4.99%; volatile matter, 39.8%; loss on air drying, 1.3%; (sample 2) ultimate analysis of combustible, ash free and moisture free: carbon, 76.55%; hydrogen, 5.26%; oxygen, 11.83%; nitrogen, 1.40%; sulfur, 4.96%; proximate analysis: ash, 23.38%; moisture, 17.30%; volatile matter, 44.6%; loss on air drying, 15.2%.

gross heat of combustion: assume values refer to room temperature.

sample 1, ash free and moisture free

$q_v(\text{gross}) = 8296 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 34709 \text{ J g}^{-1}$

sample 1, as received

$q_v(\text{gross}) = 6806 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 28475 \text{ J g}^{-1}$

sample 2, ash free and moisture free

$q_v(\text{gross}) = 7723 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 32313 \text{ J g}^{-1}$

sample 2, as received

$q_v(\text{gross}) = 4581 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 19166 \text{ J g}^{-1}$

[47,48]

COAL, BITUMINOUS (LOW GRADE); solid; Ultimate analysis of combustible, ash free and moisture free: carbon, 76.11%; hydrogen, 4.03%; oxygen, 16.14%; nitrogen, 0.84%; sulfur, 2.88%; proximate analysis: ash, 26.88%; moisture, 10.88%; volatile matter, 32.6%; loss on air drying, 5.4%.

gross heat of combustion: assume values refer to room temperature.

ash free and moisture free

$q_v(\text{gross}) = 6915 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 28931 \text{ J g}^{-1}$

as received

$q_v(\text{gross}) = 4304 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 18008 \text{ J g}^{-1}$

[47,48]

COAL, SEMI-BITUMINOUS; solid; Ultimate analysis of combustible, ash free and moisture free: carbon, 89.79%; hydrogen, 4.76%; oxygen, 2.47%; nitrogen, 2.00%; sulfur, 0.98%; proximate analysis: ash, 6.80%; moisture, 2.60%; volatile matter, 17.5%; loss on air drying, 2.0%.

gross heat of combustion: assume values refer to room temperature.

ash free and moisture free

$q_v(\text{gross}) = 8811 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 36867 \text{ J g}^{-1}$

as received

$q_v(\text{gross}) = 7983 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 33401 \text{ J g}^{-1}$

[47,48]

COAL, SUB-BITUMINOUS; solid; Ultimate analysis of combustible, ash free and moisture free; carbon, 69.17%; hydrogen, 4.46%; oxygen, 24.35%; nitrogen, 1.66%; sulfur, 0.36%; proximate analysis: ash, 3.71%; moisture, 18.41%; volatile matter, 44.3%; loss on air drying, 10.0%.

gross heat of combustion: assume values refer to room temperature.

ash free and moisture free

$q_v(\text{gross}) = 6516 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 27265 \text{ J g}^{-1}$

as received

$q_v(\text{gross}) = 5076 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 21236 \text{ J g}^{-1}$

[47,48]

COAL, CANNEL; solid; Ultimate analysis of combustible, ash free and moisture free: carbon, 82.59%; hydrogen, 7.13%; oxygen, 7.57%; nitrogen, 1.33%; sulfur, 1.38%; proximate analysis: ash, 10.49%; moisture, 2.36%; volatile matter, 55.5%; loss on air drying, 1.5%.

gross heat of combustion: assume values refer to room temperature.

ash free and moisture free

q_v(gross) = 8784 cal g^{-1}
q_v(gross) = 36751 J g^{-1}

as received

q_v(gross) = 7655 cal g^{-1}
q_v(gross) = 32029 J g^{-1}

[47,48]

COKE; solid; Produced from the destructive distillation of gas-coal in gas retorts; (sample 1, as received): fixed carbon, 59.56%; sulfur, 0.31%; moisture, 22.30%; ash, 17.56%; volatile matter, 0.58%; (sample 1, dry): fixed carbon, 76.65%; sulfur, 0.40%; ash, 22.60%; volatile matter, 0.75%; (sample 2, as received): fixed carbon, 67.89%; sulfur, 0.51%; ash, 4.45%; moisture, 26.80%; volatile matter, 0.86%; (sample 2, dry): fixed carbon, 92.75%; sulfur, 0.70%; ash, 6.08%; volatile matter, 1.17%; (dry represents sample as drawn from retort before quenching).

gross heat of combustion: assume values refer to room temperature.

sample 1, as received

q_v(gross) = 4826 cal g^{-1}
q_v(gross) = 20192 J g^{-1}

sample 1, dry

q_v(gross) = 6211 cal g^{-1}
q_v(gross) = 25988 J g^{-1}

sample 2, as received

q_v(gross) = 5612 cal g^{-1}
q_v(gross) = 23479 J g^{-1}

sample 2, dry

q_v(gross) = 7666 cal g^{-1}
q_v(gross) = 32076 J g^{-1}

[47,50]

COKE; solid; Produced from the destructive distillation of bituminous coal in beehive ovens; (sample 1): fixed carbon, 91.43%; volatile carbon, 1.27%; sulfur, 0.51%; ash, 6.09%; (sample 2): fixed carbon, 79.83%; volatile carbon, 1.05%; sulfur, 2.13%; ash, 15.75%; water, 1.22%.

gross heat of combustion: assume values refer to room temperatures; corrected for moisture and ash content.

sample 1

$q_v(\text{gross}) = 8011 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 33520 \text{ J g}^{-1}$

sample 2

$q_v(\text{gross}) = 7718 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 32292 \text{ J g}^{-1}$

[47]

COKE; solid; Produced from the destructive distillation to red heat of petroleum; fixed carbon, 98.05%; volatile carbon, 0.50%.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 8063 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 33734 \text{ J g}^{-1}$

[47]

COKE BREEZE; solid; Ultimate analysis: carbon, 94.79%; hydrogen, 1.51%; oxygen, 1.48%; nitrogen, 1.19%; sulfur, 1.03%; proximate analysis: ash, 12.05%; moisture, 10.77%; volatile matter, 4.92%; loss on air drying, 10.1%.

gross heat of combustion: assume values refer to room temperature.

ash free and moisture free

$q_v(\text{gross}) = 8038 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 33632 \text{ J g}^{-1}$

as received

$q_v(\text{gross}) = 6204 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 25958 \text{ J g}^{-1}$

[47,51]

DOWTHERM A; liquid; (trademark © Dow Chemical Co.); a mixture of diphenyl and diphenyl oxide.

specific heat:

50 - 240 °C

$Cp(\text{cal g}^{-1} \text{ K}^{-1}) = 0.167 + 7.40 \times 10^{-4} \text{ T}$
$Cp(\text{J g}^{-1} \text{ K}^{-1}) = 0.699 + 3.096 \times 10^{-3} \text{ T}$

[100]

AMATOL; solid; an explosive mixture of ammonium nitrate (AN) and trinitrotoluene (TNT). Density of cast material, g cm^{-3}: 80/20 AN/TNT, 1.46; 60/40 AN/TNT, 1.60; 50/50 AN/TNT, 1.59.

gross heat of combustion: 25 °C; calculated from the composition of the mixture.

80/20 AN/TNT

q_v(gross) = 1219 cal g^{-1}
q_v(gross) = 5100 J g^{-1}

60/40 AN/TNT

q_v(gross) = 1811 cal g^{-1}
q_v(gross) = 7577 J g^{-1}

50/50 AN/TNT

q_v(gross) = 2107 cal g^{-1}
q_v(gross) = 8816 J g^{-1}

[77,132,134]

specific heat: for the temperature range 20° to 80 °C for 50/50 AN/TNT mixture.

c_p = 0.383 cal $g^{-1}K^{-1}$
c_p = 1.602 J $g^{-1}K^{-1}$

[77]

net heat of explosion: 25 °C; calculated from composition of the mixture; assumed decomposition reactions of AN and TNT are given below; all products are gaseous unless otherwise indicated.

80/20 AN/TNT

q_v(net) = 499 cal g^{-1}
q_v(net) = 2088 J g^{-1}

60/40 AN/TNT

q_v(net) = 646 cal g^{-1}
q_v(net) = 2703 J g^{-1}

50/50 AN/TNT

q_v(net) = 719 cal g^{-1}
q_v(net) = 3008 J g^{-1}

[77,132,133,134]

decomposition reactions:

(AN)(solid) = 2 H_2O + N_2 + 0.5 O_2
(TNT)(solid) = 1.25 CO_2 + 2.0 CO + 1.5 H_2O + 1.25 N_2 + 0.5 NH_3 + 0.5 H_2 + 3.75 C(solid)

explosion temperature after 5 seconds:

80/20 AN/TNT, 280 °C
60/40 AN/TNT, 270 °C
50/50 AN/TNT, 265 °C

[77]

EXPLOSIVES

BARATOL; solid; barium nitrate, 75%; trinitrotoluene (TNT), 25%.

heat of fusion:

$L_f = 2.8$ cal g^{-1}
$L_f = 11.7$ J g^{-1}

[77]

specific heat:

temperature (°C)	Cp(cal g^{-1} K^{-1})	Cp(J g^{-1} K^{-1})
-75	0.152	0.636
0	0.147	0.615
25	0.180	0.753
50	0.229	0.958
75	0.280	1.172
85	0.213	0.891
90	0.201	0.841
100	0.171	0.715

[77]

BARONAL; solid; barium nitrate, 50%; trinitrotoluene (TNT), 35%; aluminum, 15%; density 2.32 g cm^{-3}.

gross heat of combustion: 25 °C; calculated from the composition of the mixture.

q_v(gross) = 2367 cal g^{-1}
q_v(gross) = 9904 J g^{-1}

[77,132,133,134]

net heat of explosion: reaction products unspecified.

q_v(net) = 1135 cal g^{-1}
q_v(net) = 4749 J g^{-1}

explosion temperature after 5 seconds: Ignites at 345 °C.

[77]

BLACK POWDER; solid; potassium nitrate, 74%; sulfur, 10.4%; charcoal, 15.6%.

net heat of explosion: 25 °C; calculated from composition of mixture; assumed decomposition reaction below.

q_v(net) = 649 cal g^{-1}
q_v(net) = 2715 J g^{-1}

[77,132,133,134]

explosion temperature after 5 seconds: Ignites at 427 °C.

decomposition reaction:

KNO_3(solid) + 0.25 S(solid) + C(solid) = 0.25 K_2SO_3(solid) + 0.25 K_2CO_3(solid) + 0.75 CO_2(gas)

EXPLOSIVES

BLASTING GELATINE; solid; gelatine with about 5% of an oxidizer, such as ammonium nitrate, potassium nitrate, or potassium chlorate, added.

net heat of combustion: unclear whether a gaseous oxidizer, such as air or oxygen, took part in combustion in addition to oxidizer in gelatine; assume values refer to room temperature, and one atm. pressure, and gaseous products.

$q_p(\text{net}) = 570 \text{ cal g}^{-1}$
$q_p(\text{net}) = 2385 \text{ J g}^{-1}$

[109]

CELLULOSE NITRATE; solid; cellulose does not nitrate in a stoichiometric manner; the degree of nitration is measured by the percent of nitrogen in the ester.

mononitrocellulose: $[C_6H_9NO_7]_x$; 6.76% nitrogen

dinitrocellulose: $[C_6H_8N_2O_9]_x$; 11.11% nitrogen

trinitrocellulose: $[C_6H_7N_3O_{11}]_x$; 14.14% nitrogen

Cellulose Nitrate, Grade B (Guncotton) $C_6H_{7\ 26}\ N_{2\ 74}O_{10\ 48}$

Cellulose Nitrate, Grade C (Type I) $C_6H_{7.36}\ N_{2.67}O_{10.27}$

Cellulose Nitrate, Grade C (Type II) $C_6H_{7.33}\ N_{2.67}O_{10.34}$

Cellulose Nitrate, Grade D (Pyroxylin) $C_6H_{7.68}\ N_{2.32}O_{0.64}$

[4]

gross heat of combustion: at 30 °C for $[0.115 \le N \le 0.135]$; N = wt. fraction nitrogen.

$q_v(\text{gross}) = 4176.0 - 14126N \text{ cal g}^{-1}$
$q_v(\text{gross}) = 17472.4 - 59103N \text{ J g}^{-1}$

specific heat:

298 - 390 K

Grade B (Guncotton) 13.4% nitrogen

$Cp(\text{cal g}^{-1}\text{ K}^{-1}) = 0.0184 - 7.64 \times 10^{-4}\ T$
$Cp(\text{J g}^{-1}\text{ K}^{-1}) = 0.0770 - 3.197 \times 10^{-3}\ T$

Grade C (Type I) 13.1% nitrogen

$Cp(\text{cal g}^{-1}\text{ K}^{-1}) = 0.0201 - 7.86 \times 10^{-4}\ T$
$Cp(\text{J g}^{-1}\text{ K}^{-1}) = 0.0841 - 3.289 \times 10^{-3}\ T$

Grade C (Type II) 13.2% nitrogen

$Cp(\text{cal g}^{-1}\text{ K}^{-1}) = 0.0241 - 7.91 \times 10^{-4}\ T$
$Cp(\text{J g}^{-1}\text{ K}^{-1}) = 0.1008 - 3.310 \times 10^{-3}\ T$

Grade D (pyroxylin) 12.2% nitrogen

$Cp(\text{cal g}^{-1}\text{ K}^{-1}) = 0.0256 - 8.17 \times 10^{-4}\ T^{-1}$
$Cp(\text{J g}^{-1}\text{ K}^{-1}) = 0.1071 - 3.418 \times 10^{-3}\ T^{-1}$

[5]

COMPOSITION B; solid; cyclotrimethylenetrinitramine (RDX), 60%; trinitrotoluene (TNT), 40%; wax alcohol ~1%; density, cast, 1.65 g cm^{-3}.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 2790 cal g^{-1}
q_v(gross) = 11673 J g^{-1}

[77]

net heat of explosion: assume values refer to room temperature; reaction products unspecified.

q_v(net) = 1240 cal g^{-1}
q_v(net) = 5188 J g^{-1}

heat of fusion: at 78 - 80 °C.

L_f = 8.0 cal g^{-1}
L_f = 33.5 J g^{-1}

[77]

explosion temperature after 5 seconds: Decomposes at 278 °C.

[77]

specific heat:

temperature, °C	Cp(cal g^{-1} K^{-1})	Cp(J g^{-1} K^{-1})
-75	0.235	0.983
0	0.220	0.920
25	0.254	1.063
50	0.305	1.276
75	0.376	1.573
85	0.354	1.481
90	0.341	1.427
100	0.312	1.305

[77]

CYCLOTOL; solid; an explosive mixture of cyclotrimethylenetrinitramine (RDX) and trinitrotoluene (TNT); density of cast material (g cm^{-3}): 75/25 RDX/TNT, 1.71; 70/30 RDX/TNT, 1.71; 65/35 RDX/TNT, 1.75; 60/40 RDX/TNT, 1.68.

gross heat of combustion: 25 °C; calculated from the composition of the mixture.

75/25 RDX/TNT

q_v(gross) = 2609 cal g^{-1}
q_v(gross) = 10916 J g^{-1}

70/30 RDX/TNT

q_v(gross) = 2674 cal g^{-1}
q_v(gross) = 11188 J g^{-1}

65/35 RDX/TNT

q_v(gross) = 2739 cal g^{-1}
q_v(gross) = 11460 J g^{-1}

60/40 RDX/TNT

q_v(gross) = 2804 cal g^{-1}
q_v(gross) = 11732 J g^{-1}

[77,132,138]

net heat of explosion: assume values refer to room temperature; calculated from the composition of the mixture; reaction products unspecified.

75/25 RDX/TNT

q_v(net) = 1231 cal g^{-1}
q_v(net) = 5150 J g^{-1}

70/30 RDX/TNT

q_v(net) = 1222 cal g^{-1}
q_v(net) = 5113 J g^{-1}

65/35 RDX/TNT

q_v(net) = 1212 cal g^{-1}
q_v(net) = 5071 J g^{-1}

60/40 RDX/TNT

q_v(net) = 1202 cal g^{-1}
q_v(net) = 5029 J g^{-1}

[77]

specific heat: 75/25 RDX/TNT.

temperature, °C	Cp(cal g^{-1} K^{-1})	Cp(J g^{-1} K^{-1})
-75	0.220	0.920
0	0.225	0.941
25	0.254	1.063
50	0.296	1.238
75	0.352	1.473
85	0.325	1.360
90	0.332	1.389
100	0.351	1.469

[77]

heat of fusion: 75/25 RDX/TNT.

L_f = 5.0 cal g^{-1} (T=?)
L_f = 20.9 J g^{-1}

[77]

explosion temperature after 5 seconds:

70/30 RDX/TNT, decomposes 265 °C.
65/35 RDX/TNT, decomposes 270 °C.
60/40 RDX/TNT, decomposes 280 °C.

[77]

DBX; solid; ammonium nitrate (AN), 21% cyclotrimethylenetrinitramine (RDX), 21%; trinitrotoluene (TNT), 40%; aluminum, 18%; density 1.68 g cm^{-3}.

gross heat of combustion: assume values refer to room temperature; calculated from the composition of the mixture.

q_v(gross) = 3379 cal g^{-1}
q_v(gross) = 14138 J g^{-1}

[77,132,134,136,138]

net heat of explosion: assume values refer to room temperature; reaction products unspecified.

q_v(net) = 1700 cal g^{-1}
q_v(net) = 7113 J g^{-1}

[77]

specific heat: -5 °C

Cp(cal g^{-1} K^{-1}) = 0.25
Cp(J g^{-1} K^{-1}) = 1.05

[77]

explosion temperature after 5 seconds: Ignites at 400 °C.

[77]

EXPLOSIVES

H-6; solid, cyclotrimethylenetrinitramine (RDX), 45%; trinitrotoluene (TNT), 30%; aluminum, 20%; D-2 wax, 5%; calcium chloride added, 0.5%; density; cast, 1.74 g cm^{-3}.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 3972 cal g^{-1}
q_v(gross) = 16619 J g^{-1}

[77]

net heat of explosion: assume values refer to room temperature; reaction products unspecified.

q_v(net) = 923 cal g^{-1}
q_v(net) = 3862 J g^{-1}

heat of fusion: at 78 °C.

L_f = 10.25 cal g^{-1}
L_f = 42.89 J g^{-1}

[77]

specific heat:

Cp(cal g^{-1} K^{-1}) = 0.269 (30 °C)
Cp(J g^{-1} K^{-1}) = 1.125 (30 °C)
Cp(cal g^{-1} K^{-1}) = 0.268 (50 °C)
Cp(J g^{-1} K^{-1}) = 1.121 (50 °C)

[77]

explosion temperature after 5 seconds: 610 °C (minimum)

[77]

HBX-1; solid; cyclotrimethylenetrinitramine (RDX), 40%; trinitrotoluene (TNT), 38%; aluminum, 17%; D-2 wax, 5%; calcium chloride added, 0.5%; density, cast, 1.72 g cm^{-3}.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 3882 cal g^{-1}
q_v(gross) = 16242 J g^{-1}

[77]

net heat of explosion: assume values refer to room temperature; reaction products unspecified.

q_v(net) = 919 cal g^{-1}
q_v(net) = 3845 J g^{-1}

heat of fusion: at 78 °C.

L_f = 9.25 cal g^{-1}
L_f = 38.70 J g^{-1}

[77]

specific heat:

Cp(cal g^{-1} K^{-1}) = 0.249 (30 °C)
Cp(J g^{-1} K^{-1}) = 1.042 (30 °C)
Cp(cal g^{-1} K^{-1}) = 0.264 (50 °C)
Cp(J g^{-1} K^{-1}) = 1.105 (50 °C)

explosion temperature after 5 seconds: 480 °C

[77]

EXPLOSIVES

HBX-3; solid; cyclotrimethylenetrinitramine (RDX), 31%; trinitrotoluene (TNT), 29%; aluminum, 35%; D-2 wax, 5%; calcium chloride added, 0.5%; density, cast, 1.84 g cm^{-3}.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 4495 cal g^{-1}
q_v(gross) = 18807 J g^{-1}

[77]

net heat of explosion: assume values refer to room temperature; reaction products unspecified.

q_v(net) = 877 cal g^{-1}
q_v(net) = 3669 J g^{-1}

[77]

heat of fusion:

L_f = 9.30 cal g^{-1} (T=?)
L_f = 38.9 J g^{-1}

[77]

specific heat:

30 - 50 °C.

Cp(cal g^{-1} K^{-1}) = 0.254
Cp(J g^{-1} K^{-1}) = 1.063

[77]

explosion temperatures after 5 seconds: 500 °C.

[77]

HEX-24; solid; potassium perchlorate (17 microns), 32%; aluminum, atomized, (20 microns), 48%; cyclotrimethylenetrinitramine (RDX) (through 325 mesh), 16%; asphaltum (through 100 mesh), 4%; density, 1.39 g cm^{-3}.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 4197 cal g^{-1}
q_v(gross) = 17560 J g^{-1}

[77]

net heat of explosion: assume values refer to room temperature; reaction products unspecified.

q_v(net) = 1858 cal g^{-1}
q_v(net) = 7774 J g^{-1}

[77]

explosion temperature after 5 seconds: 520 °C.

[77]

HEX-48; solid; potassium perchlorate, (17 microns), 32%; aluminum, flaked (1 micron), 48%; cyclotrimethylenetrinitramine (RDX) (through 325 mesh), 16%; asphaltum (through 100 mesh), 4%; density, 0.69 g cm^{-3}.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 4119 cal g^{-1}
q_v(gross) = 17234 J g^{-1}

[77]

net heat of explosion: assume values refer to room temperature; reaction products unspecified.

q_v(net) = 1735 cal g^{-1}
q_v(net) = 7259 J g^{-1}

[77]

explosion temperature after 5 seconds: 545 °C.

[77]

HTA-3; solid; cyclotetramethylenetetranitramine (HMX), 49%; trinitrotoluene (TNT), 29%; aluminum, 22%; density, cast, 1.90 g cm^{-3}.

gross heat of combustion: 25 °C; calculated from the composition of the mixture.

q_v(gross) = 3785 cal g^{-1}
q_v(gross) = 15836 J g^{-1}

[74,132,134,138]

net heat of explosion: assume values refer to room temperature; reaction products unspecified.

q_v(net) = 1190 cal g^{-1}
q_v(net) = 4979 J g^{-1}

[77]

specific heat:

32 - 74 °C.

Cp(cal g^{-1} K^{-1}) = 0.245
Cp(J g^{-1} K^{-1}) = 1.025

[77]

explosion temperature after 5 seconds: Flames erratically at 370 °C.

[77]

EXPLOSIVES

MOX-1; solid; ammonium perchlorate, 35%; atomized aluminum, 26.2%; atomized magnesium, 26.2%; tetryl, 9.7%; calcium stearate, 1.9%; artificial graphite, 1.0%; density, pressed, 2.0 g cm^{-3}.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 4087 cal g^{-1}
q_v(gross) = 17100 J g^{-1}

[77]

net heat of explosion: assume values refer to room temperature; reaction products unspecified.

q_v(net) = 2087 cal g^{-1}
q_v(net) = 8732 J g^{-1}

[77]

explosion temperature after 5 seconds: 285 °C

[77]

MOX-2B; solid; ammonium perchlorate, 35%; atomized aluminum, 52.4%; cyclotrimethylenetrinitramine (RDX), 5.8%; trinitrotoluene (TNT), 3.9%; calcium stereate, 1.9%; artificial graphite, 1.0%; density, pressed, 2.0 g cm^{-3}.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 4484 cal g^{-1}
q_v(gross) = 18761 J g^{-1}

[77]

net heat of explosion: assume values refer to room temperature; reaction products unspecified.

q_v(net) = 1472 cal g^{-1}
q_v(net) = 6159 J g^{-1}

[77]

explosion temperature after 5 seconds: 375 °C

[77]

MOX-3B; solid; potassium nitrate, 18%; atomized aluminum, 50%; cyclotrimethylenetrinitramine (RDX), 29.1%; wax, 0.9%; trinitrotoluene (TNT), 2.0%; artificial graphite, 1.0%; calcium stearate 2.0% added; density, pressed, 2.0 g cm^{-3}.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 4331 cal g^{-1}
q_v(gross) = 18121 J g^{-1}

[77]

net heat of explosion: assume values refer to room temperature; reaction products unspecified.

q_v(net) = 980 cal g^{-1}
q_v(net) = 4100 J g^{-1}

[77]

explosion temperature after 5 seconds: 540 °C.

[77]

MOX-4B; solid; barium nitrate, 18%; atomized aluminum, 50%; cyclotrimethylenetrinitramine (RDX), 29.1%; wax, 0.9%; trinitrotoluene (TNT), 2.0%; calcium stearate, 2.0% added; artificial graphite, 1.0% added; density, pressed, 2.0 g cm^{-3}.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 4392 cal g^{-1}
q_v(gross) = 18376 J g^{-1}

[77]

net heat of explosion: assume values refer to room temperature; reaction products unspecified.

q_v(net) = 709 cal g^{-1}
q_v(net) = 2966 J g^{-1}

[77]

explosion temperature after 5 seconds: 610 °C

[77]

EXPLOSIVES

MOX-6B; solid; atomized aluminum, 49.2%; cupric oxide, 19.7%; cyclotrimethylenetrinitramine (RDX), 28.7%; wax, 0.9%; artificial graphite, 1.5%.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 4293 cal g^{-1}
q_v(gross) = 17962 J g^{-1}

[77]

net heat of explosion: assume values refer to room temperature; reaction products unspecified.

q_v(net) = 750 cal g^{-1}
q_v(net) = 3138 J g^{-1}

[77]

explosion temperature after 5 seconds: 510 °C

[77]

PB-RDX; solid; cyclotrimethylenetrinitramine (RDX), 90%; unmodified polystyrene, 8.5%; dioctyl phthalate, 1.5%.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 3027 cal g^{-1}
q_v(gross) = 12665 J g^{-1}

[77]

net heat of explosion: assume values refer to room temperature; reaction products unspecified.

q_v(net) = 983 cal g^{-1}
q_v(net) = 4113 J g^{-1}

[77]

explosion temperature after 5 seconds: Smokes, 275 °C.

[77]

MINOL-2; solid; ammonium nitrate (AN); 40%; trinitrotoluene (TNT); 40%; aluminum, 20%; density, 1.65 g cm^{-3}.

gross heat of combustion: 25 °C; calculated from the composition of the mixture.

q_v(gross) = 3166 cal g^{-1}
q_v(gross) = 13247 J g^{-1}

[77,132,134]

net heat of explosion: assume values refer to room temperature; reaction products unspecified.

q_v(net) = 1620 cal g^{-1}
q_v(net) = 6778 J g^{-1}

[77]

specific heat: at -5 °C

Cp = 0.30 cal $g^{-1}K^{-1}$
Cp = 1.26 J $g^{-1}K^{-1}$

[77]

explosion temperature after 5 seconds: Ignites 435 °C.

[77]

OCTOL; solid; an explosive mixture of cyclotetramethylenetetranitramine (HMX) and trinitrotoluene (TNT); density, cast, 70/30 HMX/TNT, 1.80 g cm^{-3}; 75/25 HMX/TNT, 1.81 g cm^{-3}.

gross heat of combustion: 25 °C; calculated from the composition of the mixture.

70/30 HMX/TNT

q_v(gross) = 2670 cal g^{-1}
q_v(gross) = 11171 J g^{-1}

75/25 HMX/TNT

q_v(gross) = 2604 cal g^{-1}
q_v(gross) = 10895 J g^{-1}

[77,132,138]

EXPLOSIVES

net heat of explosion: assume values refer to room temperature; reaction products unspecified.

70/30 HMX/TNT

$q_v(\text{net}) = 1074 \text{ cal g}^{-1}$
$q_v(\text{net}) = 4494 \text{ J g}^{-1}$

75/25 HMX/TNT

$q_v(\text{net}) = 1131 \text{ cal g}^{-1}$
$q_v(\text{net}) = 4732 \text{ J g}^{-1}$

[77]

explosion temperature after 5 seconds:

70/30 HMX/TNT; Flames erratically, 335 °C

75/25 HMX/TNT; Flames erratically, 350 °C

[77]

heat of fusion:

76.9/23.1 HMX/TNT

$L_f = 29.4 \text{ cal g}^{-1}$ (T=?)
$L_f = 123.0 \text{ J g}^{-1}$

[77]

specific heat:

76.9/23.1 HMX/TNT

temperature range, °C	Cp(cal g^{-1} K^{-1})	Cp(J g^{-1} K^{-1})
-79	0.200	0.837
-80 to 80	0.240	1.004
30 to 74	0.245	1.025
90 to 150	0.323	1.351

[77]

EXPLOSIVES

PENTOLITE; solid; an explosive mixture of trinitrotoluene (TNT) and pentaerythritol tetranitrate (PETN); 50/50 PETN/TNT; density 1.65 g cm^{-3}.

gross heat of combustion: 25 °C; calculated from the composition of the mixture.

q_v(gross) = 2774 cal g^{-1}
q_v(gross) = 11606 J g^{-1}

[77,132]

net heat of explosion: assume values refer to room temperature; reaction products unspecified.

q_v(net) = 1220 cal g^{-1}
q_v(net) = 5104 J g^{-1}

[77]

explosion temperature after 5 seconds: decomposes, 220 °C.

[77]

POLYVINYL NITRATE; solid; repeating unit: $C_2H_3NO_3$.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 2960 cal g^{-1}
q_v(gross) = 12385 J g^{-1}

[77]

net heat of explosion: assume values refer to room temperature; reaction products unspecified.

q_v(net) = 900 cal g^{-1}
q_v(net) = 3766 J g^{-1}

[77]

explosion temperature after 5 seconds: 265 °C

[77]

EXPLOSIVES

TORPEX; solid; cyclotrimethylenetrinitramine (RDX), 42%; trinitrotoluene (TNT), 40%; aluminum, 18%; density, cast 1.76-1.81 g cm^{-3}.

gross heat of combustion: 25 °C; calculated from composition of mixture.

q_v(gross) = 3727 cal g^{-1}
q_v(gross) = 15594 J g^{-1}

[77,132,134,138]

net heat of explosion: assume values refer to room temperature; reaction products unspecified.

q_v(net) = 1800 cal g^{-1}
q_v(net) = 7531 J g^{-1}

[77]

specific heat: density, 1.82 g cm^{-3}.

Cp(cal g^{-1} K^{-1}) = 0.22 (-5 °C)
Cp(J g^{-1} K^{-1}) = 0.92 (-5 °C)
Cp(cal g^{-1} K^{-1}) = 0.24 (15 °C)
Cp(J g^{-1} K^{-1}) = 1.00 (15 °C)

[77]

explosion temperature after 5 seconds: decomposes, 260 °C.

[77]

TRITONAL; solid; an explosive mixture of 80% trinitrotoluene (TNT) and 20% aluminum (Al); 80/20 TNT/Al; density, cast, 1.72 g cm^{-3}.

gross heat of combustion: 25 °C; calculated from composition of mixture.

q_v(gross) = 4352 cal g^{-1}
q_v(gross) = 18209 J g^{-1}

[77,132,134]

net heat of explosion: assume values refer to room temperature; reaction products unspecified.

q_v(net) = 1770 cal g^{-1}
q_v(net) = 7406 J g^{-1}

[77]

specific heat: density, 1.74 g cm^{-3}.

Cp(cal g^{-1} K^{-1}) = 0.23 (-5 °C)
Cp(J g^{-1} K^{-1}) = 0.96 (-5 °C)
Cp(cal g^{-1} K^{-1}) = 0.31 (20 °C)
Cp(J g^{-1} K^{-1}) = 1.30 (20 °C)

[77]

explosion temperature after 5 seconds: decomposes 470 °C.

[77]

EXPLOSIVES

VELTEX NO. 448; solid; cyclotetramethylenetetranitramine (HMX), 70%; nitrocellulose (13.15% N), 15%; nitroglycerine, 10.7%; 2-nitrodiphenylamine, 1.3%; triacetin, 3.0%; density, pressed, 1.72 g cm^{-3}.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 2359 cal g^{-1}
q_v(gross) = 9870 J g^{-1}

[77]

net heat of explosion: assume values refer to room temperature; reaction products unspecified.

q_v(net) = 1226 cal g^{-1}
q_v(net) = 5130 J g^{-1}

[77]

FAT, WOOL; solid; (Lanolin), main constituents are cholesterol esters of higher molecular weight fatty acids.

gross heat of combustion: assume values refer to room temperature, and are corrected for moisture and ash content.

q_v(gross) = 9741±3.5 cal g^{-1}
q_v(gross) = 40756±14.6 J g^{-1}

[124]

FOODS

ALMONDS, Prunus amygdalus; solid; 4.4% moisture.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 3129 cal g^{-1}
q_v(gross) = 13092 J g^{-1}

[9]

BEANS, NAVY, WHITE, DRY, Phaseolus vulgaris; solid; 11.2% moisture.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 3900 cal g^{-1}
q_v(gross) = 16320 J g^{-1}

[9]

BEETS, Beta vulgaris; solid; 82.6% moisture.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 673 cal g^{-1}
q_v(gross) = 2816 J g^{-1}

[9]

FOODS

CABBAGE, Brassica oleracea var. capitata; solid; 94.6% moisture.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 210 cal g^{-1}
q_v(gross) = 880 J g^{-1}

[9]

CITRUS FRUIT, RINDS AND SEEDS; solid; Ultimate analysis: carbon, 44.11%; hydrogen, 5.22%; oxygen, 38.34%; nitrogen, 1.02%; sulfur, 0.11%; ash, 3.18% moisture, 8.02%; proximate analysis as received: moisture, 8.02%; volatile matter, 71.46%; fixed carbon, 17.34%; ash, 3.18%.

gross heat of combustion: assume values refer to room temperature.

as received:

q_v(gross) = 949 cal g^{-1}
q_v(gross) = 3970 J g^{-1}

air dried:

q_v(gross) = 4098 cal g^{-1}
q_v(gross) = 17146 J g^{-1}

[62,84]

COCONUT, Cocos nucifera; solid; meat; 19.2% moisture.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 2712 cal g^{-1}
q_v(gross) = 11347 J g^{-1}

[9]

CORN (MAIZE), GREEN, Zea mays; solid; 76.0% moisture.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 1112 cal g^{-1}
q_v(gross) = 4653 J g^{-1}

[9]

COWPEAS, Vigna sinesis; solid; 10.0% moisture.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 4000 cal g^{-1}
q_v(gross) = 16736 J g^{-1}

[9]

EGG ALBUMIN; solid; a crystallizable protein; molecular weight about 33,800; from egg white.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 5710 cal g^{-1}
q_v(gross) = 23891 J g^{-1}

[9]

specific heat: temperature range: 0-25 °C; anhydrous.

Cp(cal g^{-1} K^{-1}) = 0.267
Cp(J g^{-1} K^{-1}) = 1.117

[116]

EGG YOLK; solid; yellow, semi-solid material of an egg; specific gravity, 0.95: high chloresterol content.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 5840 cal g^{-1}
q_v(gross) = 24435 J g^{-1}

[9]

FAT, ANIMAL; solid; mixture of glycerides of fatty acids.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 9500 cal g^{-1}
q_v(gross) = 39750 J g^{-1}

[9]

whole animal:

q_v(gross) = 9499 cal g^{-1}
q_v(gross) = 39744 J g^{-1}

[123]

FAT, BARLEY; solid; ether extracted.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 9070 cal g^{-1}
q_v(gross) = 37950 J g^{-1}

[9]

FOODS

FAT, BEEF; solid.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 9500 cal g^{-1}
q_v(gross) = 39750 J g^{-1}

[9]

fat obtained by ether extraction.

q_v(gross) = 9240 cal g^{-1}
q_v(gross) = 38660 J g^{-1}

[9]

FAT, BUTTER; solid; processed from cream of cow's milk; composed mainly of glycerides (90%) of oleic, palmitic and stearic acids; remainder (10%) is made up of glycerides of butyric, capric, caprylic and caproic acids. Saponification Number 210-230.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 9270 cal g^{-1}
q_v(gross) = 38785 J g^{-1}

[9]

FAT, FRIED; solid; Ultimate analysis; carbon, 73.14%; hydrogen, 11.54%; oxygen, 14.28%; nitrogen, 0.43%; sulfur, 0.07%; ash, 0.00%; proximate analysis as received: moisture, 0.00%; volatile matter, 97.64%; fixed carbon, 2.36%; ash, 0.00%.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 9154 cal g^{-1}
q_v(gross) = 38300 J g^{-1}

[62]

FAT, LARD; solid; purified internal fat of the hog; fatty acid composition (typical): myristic 1.1%; palmitic 30.4%; stearic 17.9%; oleic 41.2%; linoleic 5.7%. Iodine no. 46-66.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 9590 cal g^{-1}
q_v(gross) = 40120 J g^{-1}

[9]

FAT, MUTTON; solid.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 9510 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 39790 \text{ J g}^{-1}$

[9]

fat obtained by ether extraction

$q_v(\text{gross}) = 9320 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 39000 \text{ J g}^{-1}$

[9]

FAT, PORK; solid.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 9500 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 39750 \text{ J g}^{-1}$

[9]

fat obtained by ether extraction

$q_v(\text{gross}) = 9130 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 38200 \text{ J g}^{-1}$

[9]

FAT, OAT, Avena sativa; solid; ether extract.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 9070 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 37950 \text{ J g}^{-1}$

[9]

FAT, RYE, Secale cereale; solid; ether extract.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 9020 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 37740 \text{ J g}^{-1}$

[9]

FOODS

FAT, WHEAT, *Triticum aestivum*; solid; ether extract.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 9070 cal g^{-1}
q_v(gross) = 37950 J g^{-1}

[9]

FLOUR, SOY BEAN, *Soia hispida*.

gross heat of combustion: assume values refer to room temperature.

4.17% moisture, 6.5% fat

q_v(gross) = 3716 cal g^{-1}
q_v(gross) = 15548 J g^{-1}

[9]

6.5% moisture, 3.3% fat

q_v(gross) = 3480 cal g^{-1}
q_v(gross) = 14560 J g^{-1}

[9]

FLOUR, WHEAT; solid; the finely ground and bolted meal of wheat, *triticum aestivum* density 0.73 g cm^{-3}.

net heat of explosion: nonisothermal in air; temperature ∿250 °C.

q_p(net) = 185 cal g^{-1}
q_p(net) = 774 J g^{-1}

[76]

specific heat:

100 - 250 °C

Cp(cal g^{-1} K^{-1}) = 0.5
Cp(J g^{-1} K^{-1}) = 2.1

[76]

gross heat of combustion: assume values refer to room temperature.

graham, whole grain; 10.5% moisture

q_v(gross) = 4004 cal g^{-1}
q_v(gross) = 16750 J g^{-1}

[9]

standard patent; 10.3% moisture

q_v(gross) = 4010 cal g^{-1}
q_v(gross) = 16780 J g^{-1}

[9]

semolina; 7.57% moisture

q_v(gross) = 4160 cal g^{-1}
q_v(gross) = 17405 J g^{-1}

[9]

FOOD WASTES, VEGETABLE; solid; Ultimate analysis: carbon, 49.06%; hydrogen, 6.62%; oxygen, 37.55%; nitrogen, 1.68%; sulfur, 0.20%; ash, 4.8%; proximate analysis as received: moisture, 78.29%; volatile matter, 17.10%; fixed carbon, 3.55%; ash, 1.06%.

gross heat of combustion: assume values refer to room temperature.

(as received)

q_v(gross) = 998 cal g^{-1}
q_v(gross) = 4175 J g^{-1}

(dry basis)

q_v(gross) = 4598 cal g^{-1}
q_v(gross) = 19236 J g^{-1}

[62]

FOODS

HOMINY; from corn (maize), *Zea mays*; 10.96% moisture.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 3986 cal g^{-1}
q_v(gross) = 16677 J g^{-1}

[9]

MEAL, CORN (MAIZE) *Zea mays*; 11.79% moisture.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 3823 cal g^{-1}
q_v(gross) = 15995 J g^{-1}

[9]

MEAT, COOKED SCRAPS; solid; Ultimate analysis: carbon, 59.59%; hydrogen, 9.47%; oxygen, 24.65%; nitrogen, 1.02%; sulfur, 0.19%; ash, 5.08%; proximate analysis as received: moisture, 38.74%; volatile matter, 56.34%; fixed carbon, 1.81%; ash, 3.11%.

gross heat of combustion: assume values refer to room temperature.

as received:

q_v(gross) = 4238 cal g^{-1}
q_v(gross) = 17731 J g^{-1}

dry basis:

q_v(gross) = 6917 cal g^{-1}
q_v(gross) = 28942 J g^{-1}

[62]

OATS, *Avena sativa*; solid; rolled; 8.66% moisture.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 4560 cal g^{-1}
q_v(gross) = 19080 J g^{-1}

[9]

OIL, BARLEY; liquid; oil from barley, *Hordeum vulgare*; obtained by ether extraction.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 9070 cal g^{-1}
q_v(gross) = 37950 J g^{-1}

[9]

OIL, COCONUT; liquid; extracted from coconut meat, *Cocos nucifera*; mixture of glycerides of lauric (∿48%) and myristic (∿17.5%) acids; remainder made up of glycerides of capyrlic, capric, palmitic, stearic, oleic and linoleic acids. Saponification Number 253-262.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 9070 cal g^{-1}
q_v(gross) = 37950 J g^{-1}

[9]

OIL, CORN (MAIZE); liquid; extracted from corn (maize), *Zea mays*; typical analysis: triglycerides 98.6%; unsaponifiable 1.4%; sitosteral 1%; fatty acid composition: palmitic 2%; stearic 3.5%; oleic 46.3%; linoleic 42.0%. Iodine value 117-130.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 9280 cal g^{-1}
q_v(gross) = 38830 J g^{-1}

[9]

OIL, COTTONSEED, HYDROGENATED; liquid; yellow oil from various *Gossipyium* species; chief constituents are glycerides of palmitic (∿21%); oleic (∿33%); stearic (∿2%); and linoleic (∿44%) acids; density 0.91-0.92 g cm^{-3}; before measurement oil was heated at 100 °C for 3 to 6 hours at 2-3 mm of Hg to remove moisture; iodine no. was 6.5.

specific heat:

80° - 270 °C

$Cp(cal\ g^{-1}\ K^{-1}) = 0.5363 - 4.7376 \times 10^{-4}\ T + 1.2398 \times 10^{-6}\ T^2$
$Cp(J\ g^{-1}\ K^{-1}) = 2.2439 - 1.9822 \times 10^{-3}\ T + 5.1875 \times 10^{-6}\ T^2$

[46]

OIL, OAT; liquid; obtained from oats; *Avena saliva*; obtained by ether extraction.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 8930 cal g^{-1}
q_v(gross) = 37365 J g^{-1}

[9]

OIL, OLIVE; liquid; mixture of glycerides of several fatty acids; chiefly glycerides of oleic acid, with lesser amounts of palmitic, stearic, and linoleic acids. Saponification Number 185-196.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 9470 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 39620 \text{ J g}^{-1}$

[9]

vapor pressure: 245° - 310 °C

$\log_{10} P(\text{Torr}) = 17.92 - 9430 \, T^{-1}$
$\log_{10} P(\text{Pa}) = 20.05 - 9430 \, T^{-1}$

[45]

OIL, RYE; liquid; oil extracted from rye grain, Secale cereale.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 9320 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 38990 \text{ J g}^{-1}$

[9]

obtained by ether extraction:

$q_v(\text{gross}) = 9200 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 38495 \text{ J g}^{-1}$

[9]

OIL, SOYBEAN; liquid; the bean of Soia hispida (Leguminosae); average composition: proteins 40%; oils 18%; phosphatides 2%; remainder urease, raffinose, stachyose, saponins, phytosterins, and isoflavone; density is 0.925 at 15 °C; saponification no. 189-193.5; iodine no. 122-134.

vapor pressure: 250° - 285 °C

$\log_{10} P(\text{Torr}) = 18.30 - 9650 \, T^{-1}$
$\log_{10} P(\text{Pa}) = 20.42 - 9650 \, T^{-1}$

[45]

specific heat: sample was heated at 100 °C for 3 to 6 hours under a pressure of 2-3 mm of Hg to remove moisture.

$Cp(\text{cal g}^{-1} \text{K}^{-1}) = 0.03911 + 2.858 \times 10^{-3} T - 5.912 \times 10^{-6} T^2 + 5.667 \times 10^{-9} T^3$
$Cp(\text{J g}^{-1} \text{K}^{-1}) = 0.16362 + 1.1957 \, 10^{-2} T - 2.474 \times 10^{-5} T^2 + 2.371 \times 10^{-8} T^3$

[46]

FOODS

OIL, WHEAT; liquid; from wheat grain, *Triticum acestivum*.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 9360 cal g^{-1}
q_v(gross) = 39162 J g^{-1}

[9]

oil obtained by ether extraction:

q_v(gross) = 9070 cal g^{-1}
q_v(gross) = 37950 J g^{-1}

[9]

PECANS, *Carya illinoensis*; solid, 4.30% moisture.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 3551 cal g^{-1}
q_v(gross) = 14857 J g^{-1}

[9]

PEANUTS, *Arachis hypogaea*; solid; 4.88% moisture.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 3040 cal g^{-1}
q_v(gross) = 12720 J g^{-1}

[9]

POTATO, WHITE; solid; approximate analysis: moisture, 79.5%; carbohydrates 16.7%; protein, 2%; fiber, 0.4%; ash, 0.8%; and fat, 0.1%.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 848 cal g^{-1}
q_v(gross) = 3548 J g^{-1}

[9]

specific heat: at 30 °C, with a moisture content (W) range of 0.23 to 0.83 wt. fraction.

(W > 0.50)

$Cp(cal\ g^{-1}\ K^{-1}) = 0.216 + 0.780\ W$
$Cp(J\ g^{-1}\ K^{-1}) = 0.904 + 3.264\ W$

(0.50 > W > 0.20)

$Cp(cal\ g^{-1}\ K^{-1}) = 0.393 + 0.437\ W$
$Cp(J\ g^{-1}\ K^{-1}) = 1.644 + 1.828\ W$

[55]

FOODS

RICE, *Oryza sativa*; solid; white; polished; 12.9% moisture.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 3854 cal g^{-1}
q_v(gross) = 16125 J g^{-1}

[9]

WALNUTS, ENGLISH, *Juglans regia*; solid; 3.97% moisture.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 3318 cal g^{-1}
q_v(gross) = 13882 J g^{-1}

[9]

WHEAT, *Triticum aestivum*; 8.5% moisture.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 4090 cal g^{-1}
q_v(gross) = 17115 J g^{-1}

[9]

FUEL, AVIATION; liquid; petroleum fraction with B.P. range 175° - 350 °C (kerosine). Military jet fuels labeled JP-3, JP-4, JP-5, etc. Commercial jet fuels labeled as ASTM types A, A-1, or B.

net heat of combustion: A is the aniline point, in degrees Fahrenheit, identifying the minimum equilibrium solution temperature for equal volumes of aniline and sample. G is the API gravity defined as: API gravity (deg) = 141.5/(sp. gr. 60/60 °F)-131.5. Tables are provided in ASTM Specification D 1405 to calculate q_p (net) if sulfur impurities are known.

Aviation gasoline, Grades 100-130 and 115-145:

$q_p(\text{net}) = (10027 + 0.0463\ (A \times G))\ \text{cal g}^{-1}$
$q_p(\text{net}) = (41954 + 0.1938\ (A \times G))\ \text{J g}^{-1}$

Jet fuels:

JP-3

$q_p(\text{net}) = (9973 + 0.0587\ (A \times G))\ \text{cal g}^{-1}$
$q_p(\text{net}) = (41728 + 0.2456\ (A \times G))\ \text{J g}^{-1}$

JP-4

$q_p(\text{net}) = (9994 + 0.0587\ (A \times G))\ \text{cal g}^{-1}$
$q_p(\text{net}) = (41815 \times 0.2456\ (A \times G))\ \text{J g}^{-1}$

JP-5

$q_p(\text{net}) = (9959 + 0.0587\ (A \times G))\ \text{cal g}^{-1}$
$q_p(\text{net}) = (41668 + 0.2456\ (A \times G))\ \text{J g}^{-1}$

Kerosine, Jet A or A-1 (see ASTM Speciation D 1655):

$q_p(\text{net}) = (9962 + 0.06072\ (A \times G))\ \text{cal g}^{-1}$
$q_p(\text{net}) = (41680 + 0.25407\ (A \times G))\ \text{J g}^{-1}$

[2]

FUEL, GASOLINE; liquid; a mixture of volatile hydrocarbons with boiling points ranging from 140° to 390 °F (branched-chain paraffins, cycloparaffins, and aromatics).

auto-ignition temperature:

octane rating	temperature	
	°C	°F
65	248	478
73	258	496
87	412	774

[72]

FUEL, KEROSINE; liquid; mixture of hydrocarbons with boiling points ranging from 180° to 300 °C; ultimate composition: carbon, 85.8%; hydrogen, 14.2%; sulfur, 58 ppm; total paraffins, 30.9%; total naphthenes, 64.3%; total aromatics, 4.8%; density, 0.8019; g cm^{-3} at 24 °C; API gravity, 43.5.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 11087 cal g^{-1}
q_v(gross) = 46390 J g^{-1}

[98]

GAS, NATURAL; gas; composition in mole percent; (sample A), N_2 = 15.6%, He = 0.84%, CO_2 = 0.03%, CH_4 = 72.2%, C_2H_6 = 6.5%, propane = 3.8%, n-butane = 0.66%, isobutane = 0.28%, pentanes = 0.02%, hexanes = 0.01%, and heptanes = 0.01%. (sample B), N_2 = 2.8%, He = 0.23%, CO_2 = 0.19%, CH_4 = 86.2%, C_2H_6 = 6.2%, propane = 2.7%, n-butane = 0.63%, isobutane = 0.52%, pentanes = 0.32%, hexanes = 0.22%, and heptanes = 0.07%. (sample C), N_2 = 0.24%, He = 0.00%, CO_2 = 0.87%, CH_4 = 94.7%, C_2H_6 = 3.2%, propane = 0.67%, n-butane = 0.12%, isobutane = 0.06%, pentanes = 0.06%, hexanes = 0.06%, and heptanes = 0.04%. (sample D), N_2 = 7.1% He = 0.32%, CO_2 = 0.49%, CH_4 = 84.3%, C_2H_6 = 5.2%, propane = 1.9%, n-butane = 0.31%, isobutane = 0.28%, pentanes = 0.04%, hexanes = 0.04%, and heptanes = 0.03%.

gross heat of combustion: at 60 °F (15.56 °C) and 1 atm (101325 Pa); where SCF is standard cubic foot.

(sample A)

q_v(gross) = 958 Btu$(SCF)^{-1}$
q_v(gross) = 35.7 x 10^6 J m^{-3}

(sample B)

q_v(gross) = 1101 Btu$(SCF)^{-1}$
q_v(gross) = 41.0 x 10^6 J m^{-3}

(sample C)

q_v(gross) = 1028 Btu$(SCF)^{-1}$
q_v(gross) = 38.3 x 10^6 J m^{-3}

(sample D)

q_v(gross) = 999 Btu$(SCF)^{-1}$
q_v(gross) = 37.2 x 10^6 J m^{-3}

compressibility factor, Z = PV/RT: at 60 °C (15.56 °C) and 1 atm (101325 Pa).

Z (sample A) = 0.9978
Z (sample B) = 0.9974
Z (sample C) = 0.9978
Z (sample D) = 0.9979

[56]

GLASS, PYREX; solid (Corning 7740); SiO_2 80.66%, B_2O_3 12.93%, Na_2O 3.80%, Al_2O_3 2.14%, and K_2O 0.46%.

heat content:

.373 - 850 K

$$q_T - q_{273.8}\ (\text{cal g}^{-1}) = -94.88 + 0.2325T + 4.39 \times 10^{-5}\ T^2 + 8.083 \times 10^3\ T^{-1}$$

$$q_T - q_{273.8}\ (\text{J g}^{-1}) = -396.98 + 0.9728T + 1.837 \times 10^{-4}\ T^2 + 3.382 \times 10^4\ T^{-1}$$

[18]

specific heat:

173 - 293 K

$$Cp(\text{cal g}^{-1}\ \text{K}^{-1}) = -0.245 + 2.63 \times 10^{-3}\ T - 3.80 \times 10^{-6}\ T^2$$
$$Cp(\text{J g}^{-1}\ \text{K}^{-1}) = -1.025 + 1.100 \times 10^{-2}\ T - 1.59 \times 10^{-5}\ T^2$$

[10]

373 - 850 K

$$Cp(\text{cal g}^{-1}\ \text{K}^{-1}) = 0.2325 + 8.78 \times 10^{-5}\ T - 8.083 \times 10^3\ T^{-2}$$
$$Cp(\text{J g}^{-1}\ \text{K}^{-1}) = 0.9728 + 3.674 \times 10^{-4}\ T - 3.382 \times 10^4\ T^{-2}$$

[18]

GLASS, PYREX: liquid; (Corning 7740); SiO_2 80.66%, B_2O_3 12.93%, Na_2O 3.80%, Al_2O_3 2.14%, K_2O, 0.46%.

specific heat: over temperature range 850 to 1200 K the specific heat appears to be independent of temperature.

$$Cp(\text{cal g}^{-1}\ \text{K}^{-1}) = 0.3471$$
$$Cp(\text{J g}^{-1}\ \text{K}^{-1}) = 1.4523$$

heat content:

850 - 1200 K

$$q_T - q_{273.8}\ (\text{cal g}^{-1}) = -152.28 = 0.3471\ T$$
$$q_T - q_{273.8}\ (\text{J g}^{-1}) = -637.14 + 1.4523\ T$$

[18]

GLASS, SODA-LIME; solid; (Lillie 1); SiO_2 73.59%, Na_2O 16.65%, CaO 9.76%.

specific heat:

273 - 850 K

$$Cp(cal\ g^{-1}\ K^{-1}) = 0.1347 + 1.932 \times 10^{-4}\ T + 2.423 \times 10^{3}\ T^{-2}$$
$$Cp(J\ g^{-1}\ K^{-1}) = 0.5636 + 8.083 \times 10^{-4}\ T + 1.0138 \times 10^{4}\ T^{-2}$$

heat content:

273 - 850 K

$$q_T - q_{273.8}\ (cal\ g^{-1}) = -36.37 + 0.1347\ T + 9.66 \times 10^{-5}\ T^2 - 2.423 \times 10^{3}\ T^{-1}$$
$$q_T - q_{273.8}\ (J\ g^{-1}) = -152.17 + 0.5636T + 4.042 \times 10^{-4}\ T^2 - 1.0138 \times 10^{4}\ T^{-1}$$

[18]

GLASS, SODA-LIME; liquid; (Lillie 1); SiO_2 73.59%, Na_2O 16.65%, CaO 9.76%.

specific heat: over the temperature range 850 to 1200 K, the specific heat appears to be independent of temperature.

$$Cp(cal\ g^{-1}\ K^{-1}) = 0.3570$$
$$Cp(J\ g^{-1}\ K^{-1}) = 1.4937$$

heat content:

850 to 1200 K

$$q_T - q_{273.8}\ (cal\ g^{-1}) = -158.81 + 0.3570\ T$$
$$q_T - q_{273.8}\ (J\ g^{-1}) = -664.46 + 1.4937\ T$$

[18]

GLASS, VYCOR; solid; SiO_2 96.3%, B_2O_3 2.9%, Al_2O_3 0.4%, and other metal oxides 0.4%.

specific heat: 0 - 306 °C, mean values

$$Cp(cal\ g^{-1}\ K^{-1}) = 0.12393 + 1.4333 \times 10^{-4}\ T$$
$$Cp(J\ g^{-1}\ K^{-1}) = 0.51852 + 5.9969 \times 10^{-4}\ T$$

[14]

GRAPHITE, ARTIFICIAL; solid; National Carbon Co. spectroscopic grade.

gross heat of combustion: at 25 °C, average of 2 samples.

q_v(gross) = 7035.8 ± 2.4 cal g^{-1}
q_v(gross) = 32785 ± 10 J g^{-1}

[142]

GRAPHITE, BUCKINGHAM; solid; 0.25% ash.

gross heat of combustion: at 25 °C, corrected for ash content.

q_v(gross) = 7836.8 ± 2.0 J g^{-1}
q_v(gross) = 32789 ± 8 J g^{-1}

[142]

GRAPHITE, CEYLON; solid; 2.2% ash.

gross heat of combustion: at 25 °C, corrected for ash content.

q_v(gross) = 7825.0 ± 0.5 cal g^{-1}
q_v(gross) = 32740 ± 2 J g^{-1}

[142]

GRAPHITE, PYROLYTIC; solid; The total gas content is less than 1 ppm; (sample 1) annealed at 2200 °C, having a density of 2.204 g ml^{-1}; (sample 2) annealed at 3000 °C, having a density of 2.265 g ml^{-1}.

gross heat of combustion: at 298 °K

(sample 1)

q_v(gross) = 7844.9 ± 1.7 cal g^{-1}
q_v(gross) = 32823.1 ± 7.1 J g^{-1}

(sample 2)

q_v(gross) = 7823.9 ± 3.0 cal g^{-1}
q_v(gross) = 32735.2 ± 12.6 J g^{-1}

[64]

GRAPHITE, TICONDEROGA; solid; 0.33% ash.

gross heat of combustion: at 25 °C, corrected for ash content.

q_v(gross) = 7836.0 ± 1.0 cal g^{-1}
q_v(gross) = 32786 ± 4 J g^{-1}

[142]

GREASE, APIEZON N; solid; low vapor-pressure residues of paraffin oil distillation products.

specific heat: 1 to 20 K.

$Cp = \Sigma A_n T^n$, where Cp is in mJ g^{-1} K^{-1} and T is in K; values are valid to ± 1%.

n	A_n
3	2.80019×10^{-2}
4	-4.87887×10^{-3}
5	3.81486×10^{-3}
6	-9.072917×10^{-4}
7	9.76703×10^{-5}
8	-5.23844×10^{-6}
9	1.21072×10^{-7}
11	-3.12038×10^{-11}

[69]

80 - 200 K

$$Cp(\text{cal } g^{-1} K^{-1}) = -1.4486 \times 10^{-2} + 2.3281 \times 10^{-3} T - 8.0195 \times 10^{-6} T^2 + 1.8998 \times 10^{-8} T^3$$

$$Cp(\text{J } g^{-1} K^{-1}) = -6.0609 \times 10^{-2} + 9.7408 \times 10^{-3} T - 3.3554 \times 10^{-5} T^2 + 7.9488 \times 10^{-8} T^3$$

[1]

In the temperature range 200-324 K, Cp is anomalous; values are given below:

T(K)	Cp(cal g^{-1} deg^{-1})	Cp(J g^{-1} deg^{-1})
200	0.2813	1.177
210	0.301	1.26
220	0.344	1.44
230	0.392	1.64
240	0.421	1.76
250	0.445	1.86
260	0.468	1.96
270	0.543	2.27
280	0.679	2.84
290	0.853	3.57
296	0.899	3.76
300	0.858	3.59
310	0.626	2.62
320	0.554	2.32
324	0.538	2.25

[1]

glass temperature: 236.5 ± 0.5 K or -36.7 ± 0.5 °C

[70]

GREASE, APIEZON P; solid; low vapor-pressure residues of paraffin oil distillation products; average molecular weight 410 ± 70.

heat of vaporization: temperature range 40° to 160 °C.

L_v = 84.70 cal g^{-1}
L_v = 354.4 J g^{-1}

vapor pressure: temperature range 40° to 160 °C.

$\log_{10}$ P(Torr) = 13.91 - 7590 T^{-1}
$\log_{10}$ P(Pa) = 16.03 - 7590 T^{-1}

[59]

GREASE, APIEZON R; solid; low vapor-pressure residues of paraffin oil distillation products; average molecular weight 660 ± 100.

heat of vaporization: temperature range 40° to 160 °C.

L_v = 48.88 cal g^{-1}
L_v = 204.5 J g^{-1}

vapor pressure: temperature range 40° to 160 °C.

$\log_{10}$ P(Torr) = 12.54 - 7050 T^{-1}
$\log_{10}$ P(Pa) = 14.66 - 7050 T^{-1}

[59]

GREASE, APIEZON S; solid; low vapor-pressure residues of paraffin oil distillation products; average molecular weight 460 ± 60.

heat of vaporization: temperature range 40° to 160 °C.

L_v = 70.08 cal g^{-1}
L_v = 293.2 J g^{-1}

vapor pressure: temperature range 40° to 160 °C.

$\log_{10}$ P(Torr) = 12.52 - 7045 T^{-1}
$\log_{10}$ P(Pa) = 14.64 - 7045 T^{-1}

[59]

GREASE, APIEZON T; solid; low vapor-pressure residues of paraffin oil distillation products; also contains an aluminum soap [1].

specific heat: specific heat is anomalous between 205 and 320 K.

temperature (K)	Cp(cal g^{-1} K^{-1})	Cp(J g^{-1} K^{-1})
5	0.001035	0.0004330
50	0.07746	0.3241
100	0.1518	0.6351
150	0.2149	0.8991
200	0.2811	1.1761
220	0.362	1.515
240	0.447	1.870
260	0.498	2.084
280	0.526	2.201
300	0.517	2.163
320	0.5022	2.101
340	0.5180	2.167
350	0.5259	2.200

[110]

glass temperature: 209.5 ± 1.0 K

[70]

INSULIN, BOVINE ZINC; solid; the anhydrous material from beef pancreas made up of 16 amino acids arranged in two chains connected by sulfur bridges, ($C_{508}H_{752}O_{150}N_{130}S_{12}Zn$). The ash content = 0.95%; zinc present (as ZnO) = 0.67%.

specific heat:

temperature (K)	Cp(cal g^{-1} K^{-1})	Cp(J g^{-1} K^{-1})
10	0.00475	0.01987
100	0.1192	0.4987
200	0.2089	0.8740
250	0.2541	1.0632
298.15	0.2996	1.2535
300	0.3014	1.2611

[128]

IRON, CAST; liquid; composition of cast iron: base iron (Fe), the compound cementite (Fe_3C), and alloying elements of graphite (C), and silicon (Si), and lesser elements such as Mn, P, and S. A typical composition for ductile iron is C = 3.2-4.2%, Si = 1.1-3.5%, Mn = 0.3-0.8%, P = 0.08%, S = 0.02%, and remainder Fe.

heat content: The temperature range is 2600° to 2900 °F (~1400-1600 °C); T is in K; the equation applies to all cast iron and is the sum of individual heat content equations where the lesser elements are ignored. X is weight fraction of substance.

$$q_T - q_{273}\ (\text{cal g}^{-1}) = (0.1758T - 1.08)\,X_{Fe} + (0.1758T - 2.98)\,X_{Fe_3C} + (0.5002T + 830.2)\,X_C + (0.2168T + 549.7)\,X_{Si}$$

$$q_T - q_{273}\ (\text{J g}^{-1}) = (0.7357T - 4.53)\,X_{Fe} + (0.7357T - 12.47)\,X_{Fe_3C} + (2.0929T + 3473.5)\,X_C + (0.9072T + 2300.1)\,X_{Si}$$

[63]

LEATHER; solid; an animal skin or hide which has been permanently combined with a tanning agent; the tanning agent produces a transformation in the protein composition of the skin rendering it resistant to putrefactive bacteria, increasing its strength and abrasion resistance.

specific heat: 25 °C

moisture content, %	Cp(cal g^{-1} K^{-1})	Cp(J g^{-1} K^{-1})
vegetable-tanned		
0	0.3334	1.3949
1.15	0.3202	1.3397
1.32	0.3274	1.3698
2.59	0.3280	1.3724
3.85	0.3844	1.6083
6.20	0.3730	1.5606
7.83	0.3835	1.6046
9.31	0.3844	1.6083
10.81	0.4129	1.7276
chrome-tanned		
0	0.3045	1.2740
1.98	0.2918	1.2209
3.69	0.3631	1.5192
7.59	0.3576	1.4962
9.39	0.3737	1.5636
11.07	0.3893	1.6288
13.46	0.3841	1.6071
14.96	0.4098	1.7146
chrome-retanned		
0	0.3404	1.4242
1.52	0.3287	1.3753
2.12	0.3266	1.3665
4.23	0.3448	1.4426
7.23	0.3458	1.4468
9.23	0.3474	1.4535
11.29	0.3606	1.5088

[78]

LIGNIN, LOBLOLLY PINE (Pinus Taeda L) WOOD; solid; major (29.4% lignin [81]) non-carbohydrate constituent of wood; functions as a natural plastic binder for cellulose fibers.

specific heat: 333 to 413 K; samples were oven-dried at 100 °C for 12 hours before measurements were made.

$$Cp(cal\ g^{-1}\ K^{-1}) = 0.06133 + 7.7 \times 10^{-4}\ T$$
$$Cp(J\ g^{-1}\ K^{-1}) = 0.25660 + 3.22 \times 10^{-3}\ T$$

[83]

LIGNIN, HARDWOOD: solid; composition: carbon, 60%; hydrogen, 6%; oxygen, 34%; empirical formula: $C_{10}H_{12}O_{4.2}$. No general agreement prevails about the structure of lignin. Studies show that a dioxyphenylpropyl grouping is an important part of the polymer.

gross heat of combustion: assume values refer to room temperature.

$$q_v(gross) = 5900\ cal\ g^{-1}$$
$$q_v(gross) = 24685\ J\ g^{-1}$$

[101,102]

LIGNIN, SOFTWOOD: solid; composition: carbon, 64%; hydrogen, 6%; oxygen, 30%; empirical formula: $C_{10}H_{11.2}O_{3.3}$; no general agreement prevails about the structure of lignin. Studies show that a dioxyphenylpropyl grouping is an important part of the polymer.

gross heat of combustion: assume values refer to room temperature.

$$q_v(gross) = 6300\ cal\ g^{-1}$$
$$q_v(gross) = 26360\ J\ g^{-1}$$

[101,102]

LIGNITE; solid; lignite is also called Brown Coal; (sample 1) ultimate analysis: carbon, 68.32%; hydrogen, 4.00%; oxygen, 25.54%; nitrogen, 1.42%; sulfur, 0.72%; proximate analysis: ash, 13.27%; moisture, 23.30%; volatile matter, 43.5%; loss on air drying, 17.3%; (sample 2) ultimate analysis: carbon, 63.30%; hydrogen, 3.32%; oxygen, 29.86%; nitrogen, 1.35%; sulfur, 2.17%; proximate analysis: ash, 10.12%; moisture, 31.37%; volatile matter, 50.6%; loss on air drying, 14.2%.

gross of heat of combustion: assume values refer to room temperature.

(sample 1, ash free and moisture free)

$q_v(\text{gross}) = 6132 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 25656 \text{ J g}^{-1}$

(sample 1, as received)

$q_v(\text{gross}) = 4503 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 18841 \text{ J g}^{-1}$

(sample 2, ash free and moisture free)

$q_v(\text{gross}) = 5353 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 22399 \text{ J g}^{-1}$

(sample 2, as received)

$q_v(\text{gross}) = 3132 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 13104 \text{ J g}^{-1}$

[47,48]

LUNAR MATERIAL; solid; (Sample 10057) SiO_2, 36%; Al_2O_3, 11%; TiO_2, 12.5%; FeO, 20%; MgO, 9.5%; CaO, 10%; Na_2O, 0.59%; K_2O, 0.064%; MnO_2, 0.32%; Cr_2O_3, 0.95%; vesicular basalt.

specific heat: 90 to 200 K

$$Cp(\text{cal g}^{-1}\text{ K}^{-1}) = 0.04880 - 5.476 \times 10^{-4}\, T + 9.030 \times 10^{-6}\, T^2 - 2.074 \times 10^{-8}\, T^3$$

$$Cp(\text{J g}^{-1}\text{ K}^{-1}) = 0.20418 - 2.291 \times 10^{-3}\, T + 3.778 \times 10^{-5}\, T^2 - 8.678 \times 10^{-8}\, T^3$$

200 to 350 K

$$Cp(\text{cal g}^{-1}\text{ K}^{-1}) = -0.03797 + 1.248 \times 10^{-3}\, T - 2.277 \times 10^{-6}\, T^2 + 1.743 \times 10^{-9}\, T^3$$

$$Cp(\text{J g}^{-1}\text{ K}^{-1}) = -0.15887 + 5.222 \times 10^{-3}\, T - 9.527 \times 10^{-6}\, T^2 + 7.293 \times 10^{-9}\, T^3$$

[8,16]

LUNAR MATERIAL; solid; (Sample 10084) SiO_2, 41.86%; TiO_2, 7.56%; Al_2O_3, 13.55%; FeO, 15.94%; MnO, 0.21%; MgO, 7.82%; CaO, 12.08%; Na_2O, 0.40%; K_2O, 0.13%; P_2O_5, 0.11%; S, 0.15%; Cr_2O_3, 0.32%; regolith soil.

specific heat: 90 to 200 K

$$Cp(\text{cal g}^{-1}\text{ K}^{-1}) = 0.08584 - 1.343 \times 10^{-3}\, T + 1.514 \times 10^{-5}\, T^2 - 3.620 \times 10^{-8}\, T^3$$

$$Cp(\text{J g}^{-1}\text{ K}^{-1}) = 0.35915 - 5.619 \times 10^{-3}\, T + 6.335 \times 10^{-5}\, T^2 - 1.515 \times 10^{-7}\, T^3$$

200 to 350 K

$$Cp(\text{cal g}^{-1}\text{ K}^{-1}) = 0.03706 + 5.331 \times 10^{-4}\, T - 1.273 \times 10^{-7}\, T^2 - 3.131 \times 10^{-10}\, T^3$$

$$Cp(\text{J g}^{-1}\text{ K}^{-1}) = 0.15506 + 2.230 \times 10^{-3}\, T - 5.326 \times 10^{-7}\, T^2 - 1.310 \times 10^{-9}\, T^3$$

[17]

MANURE, PIG; solid; faeces from hogs; oven dried; 0% moisture.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 4280 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 17900 \text{ J g}^{-1}$

[140]

NAPHTHA, ALASKA; liquid; Ultimate analysis: carbon, 86.3%; hydrogen, 13.7%; nitrogen, 0.3 ppm; sulfur, 99 ppm, total paraffins, 39.7%; total naphthenes, 39.6%; total aromatics, 20.5%; density, 0.7703 g cm^{-3} at 24 °C; API gravity, 50.5.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 10841 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 45360 \text{ J g}^{-1}$

[98]

NAPHTHA, AROMATIC; liquid; Ultimate analysis: carbon, 90.1%; hydrogen, 9.8%; sulfur, 760 ppm; total paraffins, 0.0%; total naphthenes, 0.0%; total aromatics, 83.1%; total olefins, 16.9%; density, 0.8449; g cm^{-3} at 24 °C; API gravity, 34.5.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 10287 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 43040 \text{ J g}^{-1}$

[98]

NAPHTHA, HIGH BOILING; liquid; Ultimate analysis: carbon, 85.4%; hydrogen, 14.6%; sulfur, 357 ppm; total paraffins, 59.3%; total naphthenes, 30.8%; total aromatics, 9.9%; density, 0.7559; g cm^{-3} at 24 °C; API gravity, 54.2.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 11217 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 46934 \text{ J g}^{-1}$

[98]

NAPHTHA, JET; liquid; Ultimate analysis: carbon, 86.05%; hydrogen, 13.95%; sulfur, 132 ppm; total paraffins, 18.6%; total naphthenes, 69.8%; total aromatics, 10.6%; sulfur compounds, 1.0%; density, 0.7981; g cm^{-3} at 24 °C; API gravity, 44.4.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 11025 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 46129 \text{ J g}^{-1}$

[98]

NAPHTHA, LOW BOILING; liquid; Ultimate analysis: carbon, 85.1%; hydrogen, 14.9%; sulfur, 376 ppm; total paraffins, 61.9%; total naphthenes, 30.6%; total aromatics, 7.6%; density, 0.7559; g cm^{-3} at 24 °C; API gravity, 59.9.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 11265 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 47132 \text{ J g}^{-1}$

[98]

OIL, APIEZON C; liquid; low vapor-pressure residues of paraffin oil distillation products; average molecular weight 450 ± 70.

heat of vaporization: 40° to 160 °C

$L_v = 60.25 \text{ cal g}^{-1}$
$l_v = 252.1 \text{ J g}^{-1}$

vapor pressure: 40° to 160 °C

$\log_{10} P(\text{Torr}) = 11.67 - 5925\ T^{-1}$
$\log_{10} P(\text{Pa}) = 13.79 - 5925\ T^{-1}$

[59]

OIL, APIEZON E; liquid; low vapor-pressure residues of paraffin oil distillation products; average molecular weight 290 ± 30.

heat of vaporization: 40° to 160 °C

L_v = 80.47 cal g^{-1}
L_v = 336.7 J g^{-1}

vapor pressure: 40° to 160 °C

$\log_{10}$ P(Torr) = 9.30 - 5100 T^{-1}
$\log_{10}$ P(Pa) = 11.42 - 5100 T^{-1}

[59]

OIL, CASTOR; liquid, oil from seeds of the castor bean, Ricinus communis; chief constituent: glyceride of ricinoleic acid (12-hydroxyoleic acid); saponification no. is 175-183; iodine no. is 83 after heating at 100 °C for 3 to 6 hours at 2-3 mm pressure; density is 0.945-0.965 g cm^{-3} at 25 °C.

specific heat: 25° to 275 °C

$Cp(cal\ g^{-1}\ K^{-1}) = -1.265 + 0.01241\ T - 2.8650 \times 10^{-5}\ T^2 + 2.264 \times 10^{-8}\ T^3$
$Cp(J\ g^{-1}\ K^{-1}) = -5.292 + 0.05192\ T - 1.1987 \times 10^{-4}\ T^2 + 9.474 \times 10^{-8}\ T^3$

[46]

OIL, CRUDE; liquid; ADMEG, Zakum (export), specific gravity 60/60 °F = 0.8256, upper pour point = -15 °C, wax content = 7.0 wt. %: Barrow Island, specific gravity 60/60 °F = 0.8399, upper pour point less than -50 °C, wax content less than 1 wt. %: Libyan (Tobruk export), specific gravity 60/60 °F = 0.8429, upper pour point = 24 °C, wax content = 20.0 wt. %: Iranian Light (export), specific gravity 60/60 °F = 0.8568, upper pour point = -21 °C, wax content = 7.0 wt. %: Kuwait (export), specific gravity 60/60 °F = 0.8709, upper pour point = -32 °C, wax content = 5.5 wt. %: Iranian Heavy (export), specific gravity 60/60 °F = 0.8732, upper pour point = - 12 °C, wax content = 6.7 wt. %: Alaskan (North Slope), specific gravity 60/60 °F = 0.8914, upper pour point = -1 °C, wax content = 6.5 wt. %.

gross heat of combustion: assume values refer to room temperature.

$$q_v(\text{gross}) = 12400 - 2100d^2 \text{ cal g}^{-1}$$
$$q_v(\text{gross}) = 51881.6 - 8786.4d^2 \text{ J g}^{-1}$$

where d is the specific gravity at 60/60 °F, equation assumes crude oil to be water, ash, and sulfur free; combustion products are gaseous CO_2 and liquid H_2O.

$$q_v'(\text{gross}) = q_v(\text{gross}) - 0.01\, q_v(\text{gross})X + 22.5\ (\%S) \text{ cal g}^{-1}$$
$$q_v'(\text{gross}) = q_v(\text{gross}) - 0.04\, q_v\ (\text{gross})X + 94.1\ (\%S) \text{ J g}^{-1}$$

[130]

where q_v'(gross) is heat of combustion at constant volume of crude oil yielding ash, gaseous CO_2, SO_2, and liquid H_2O as combustion products; $X = (\%H_2O + \%ash + \%S)$

isothermal compressibility: 10^5 bar = 1 Pa

ADMEG/Zakum/(export)

T(°C)	=	4.44	15.56	37.78	60.00	76.67
$\bar{\beta}(Pa^{-1})$	=	7.45	7.89	9.19	10.40	11.58

Barrow Island

T(°C)	=	4.44	15.56	37.78	60.00	76.67
$\bar{\beta}(Pa^{-1})$	=	7.28	7.83	9.06	10.10	11.18

Libyan (Tobruk export)

T(°C)	=	37.78	50.00	60.00	76.67
$\bar{\beta}(Pa^{-1})$	=	8.59	8.92	9.41	10.31

Iranian Light (export)

T(°C)	=	4.44	15.56	37.78	60.00	76.67
$\bar{\beta}(Pa^{-1})$	=	6.71	7.14	8.26	9.62	10.66

Iranian Heavy (export)

T(°C)	=	4.44	15.56	37.78	60.00	76.67
$\bar{\beta}(Pa^{-1})$	=	6.37	6.90	8.04	9.11	10.10

Kuwait (export)

T(°C)	=	4.44	15.56	37.78	60.00	76.67
$\bar{\beta}(Pa^{-1})$	=	6.46	6.83	8.03	9.06	10.20

Alaskan (North Slope)

T(°C)	=	4.44	15.56	37.78	60.00	76.67
$\bar{\beta}(Pa^{-1})$	=	6.18	6.22	7.25	8.26	9.11

[130]

specific heat: The equation provided is based on over 100 measurements made at the National Bureau of Standards over the temperature range 0 to 204 °C. The experimental results differ from the values calculated from this equation by less than 2%, with a maximum deviation of 4%; oils from mixed base crudes are in good agreement; oils from paraffin base crudes are systematically high by about 2%; oils from naphthene base crudes are systematically low by about 2%.

d is the specific gravity at 60°/60 °F,

$$Cp(cal\ g^{-1}\ K^{-1}) = (0.1811 + 8.1 \times 10^{-4}\ T)/d^{1/2}$$
$$Cp(J\ g^{-1}\ K^{-1}) = (0.7577 + 3.39 \times 10^{-3}\ T)/d^{1/2}$$

[130]

OIL, FUEL; liquid; Ultimate analysis: carbon, 86.9%; hydrogen, 13.1%; sulfur, 172 ppm; total paraffins, 29.8%; total naphthenes, 45.6%; total aromatics, 22.4%; sulfur compounds, 1.3%; density, 0.8553; g cm^{-3} at 24 °C; API gravity 33.0.

gross heat of combustion: assume values refer to room temperature.

$$q_v(gross) = 9763\ cal\ g^{-1}$$
$$q_v(gross) = 40847\ J\ g^{-1}$$

[98]

OIL, GAS; liquid; Ultimate analysis: carbon, 86.5%; hydrogen, 13.4%; sulfur, 261 ppm; nitrogen, 3 ppm; total paraffins, 38.8%; total naphthenes, 41.5%; total aromatics, 17.2%; sulfur compounds, 2.4%; density, 0.8415; g cm^{-3} at 24 °C; API gravity, 35.3.

gross heat of combustion: assume values refer to room temperature.

$$q_v(gross) = 10977\ cal\ g^{-1}$$
$$q_v(gross) = 45927\ J\ g^{-1}$$

[98]

OIL, LEYBOLD F; liquid; a mixture of hydrocarbons prepared by Leybold Köln; average molecular weight 360 ± 50.

heat of vaporization: temperature range 40° to 160 °C.

L_v = 69.02 cal g^{-1}
L_v = 288.8 J g^{-1}

vapor pressure: temperature range 40° to 160 °C.

$\log_{10} P(\text{Torr}) = 10.43 - 5430\ T^{-1}$
$\log_{10} P(\text{Pa}) = 12.55 - 5430\ T^{-1}$

[59]

OIL, LEYBOLD H; liquid; a mixture of hydrocarbons prepared by Leybold Köln; average molecular weight 385 ± 40.

heat of vaporization: temperature range 40° to 160 °C.

L_v = 70.12 cal g^{-1}
L_v = 293.4 J g^{-1}

vapor pressure: temperature range 40° to 160 °C.

$\log_{10} P(\text{Torr}) = 11.82 - 5900\ T^{-1}$
$\log_{10} P(\text{Pa}) = 13.95 - 5900\ T^{-1}$

[59]

OIL, LINSEED; liquid; (flaxseed oil); obtained from dried seeds of flax, Linum usitatissiumum (Linaceae); chief constituents are glycerides of linoleic (∿61.5%), linolenic (∿25.0%), palmitic (∿5%), oleic (∿5%), and stearic (∿3.5%) acids; iodine no. 172.1, density 0.930 - 0.938 g cm^{-3}.

specific heat: sample was heated at 100 °C for 3 to 6 hours under a pressure of 2-3 mm of Hg to remove moisture; equations valid 30 to 270 °C.

$$Cp(\text{cal } g^{-1} K^{-1}) = -0.4606 + 6.4288 \times 10^{-3}\ T - 1.4922 \times 10^{-5}\ T^2 + 1.2492 \times 10^{-8}\ T^3$$

$$Cp(\text{J } g^{-1} K^{-1}) = -1.9272 + 2.6898 \times 10^{-2}\ T - 6.2434 \times 10^{-5}\ T^2 + 5.2267 \times 10^{-8}\ T^3$$

[46]

OIL, LUBRICATING, P-10; liquid; chief ingredient is di-(2-ethylhexyl) sebacate [$C_{22}H_{50}O_4$], other ingredients are Plexol 201, rust inhibitor, and antioxidant.

vapor pressure: 20 - 108 °C

$\log_{10} P(\text{Torr}) = 7.23 - 4109\ T^{-1}$
$\log_{10} P(\text{Pa}) = 9.36 - 4109\ T^{-1}$

[7]

OIL, NEATSFOOT; liquid; pale yellow oil obtained by boiling the shin bones and feet (hoofs removed) of cattle in water; oil is separated from fat obtained.

specific heat: 25 °C

$Cp(cal\ g^{-1}\ K^{-1}) = 0.5191$
$Cp(J\ g^{-1}\ K^{-1}) = 2.1719$

[78]

OIL, PARAFFIN; liquid; repeating unit: $CH_{1.891}$.

gross heat of combustion: 25 °C

$q_v(gross) = 10984\ cal\ g^{-1}$
$q_v(gross) = 45957\ J\ g^{-1}$

[24]

OIL, PERILLA; liquid; obtained from seeds of *Perilla ocimoides*; chief constituents are glycerides of linoleic (~39%) linolenic (~46%) acids, with small amounts of palmitic (~8%) and oleic (8%) acids; density 0.93 - 0.94 g cm^{-3}; before measurement oil was heated at 100 °C for 3 to 6 hours at 2-3 mm of Hg to remove moisture; iodine no. 186.2.

specific heat: 6° to 270 °C

$Cp(cal\ g^{-1}\ K^{-1}) = 0.4082 - 2.410 \times 10^{-4}\ T + 1.000 \times 10^{-6}\ T^2$
$Cp(J\ g^{-1}\ K^{-1}) = 1.7081 - 1.008 \times 10^{-3}\ T + 4.184 \times 10^{-6}\ T^2$

[46]

OIL, TUNG; liquid; a yellow drying oil from the nuts of the trees *Aleurites cordata* and *Aleurites fordii*; glycerides of eleostearic (~80%); palmitic (~4%); stearic (~1%); and oleic (~15%) acids; density 0.936 - 0.942 g cm^{-3}; before measurement oil was heated at 100 °C for 3 to 6 hours at 2-3 mm of Hg pressure to remove moisture; iodine no. 154.4.

specific heat: 20° to 200 °C

$$Cp(cal\ g^{-1}\ K^{-1}) = -0.6053 + 7.0447 \times 10^{-3}\ T - 1.5461 \times 10^{-5}\ T^2 + 1.2178 \times 10^{-8}\ T^3$$

$$Cp(J\ g^{-1}\ K^{-1}) = -2.5324 + 2.9475 \times 10^{-2}\ T - 6.4687 \times 10^{-5}\ T^2 + 5.0954 \times 10^{-8}\ T^3$$

[46]

PAPER, BROWN; solid; Ultimate analysis in percent by weight; carbon, 44.90%; hydrogen, 6.08%; oxygen, 47.84%; nitrogen, 0.00%; sulfur, 0.11%; ash, 1.07%; proximate analysis as received in percent by weight; moisture, 5.83%; volatile matter, 83.92%; fixed carbon, 9.24%; ash, 1.01%.

gross heat of combustion: assume values refer to room temperature.

(as received)

q_v(gross) = 4034 cal g^{-1}
q_v(gross) = 16877 J g^{-1}

(dry basis)

q_v(gross) = 4284 cal g^{-1}
q_v(gross) = 17924 J g^{-1}

[62]

PAPER, CORRUGATED BOX; solid; Ultimate analysis in percent by weight; carbon, 43.73%; hydrogen, 5.70; oxygen, 44.93%; nitrogen, 0.09%; sulfur, 0.21%; ash, 5.34%; proximate analysis as received in percent by weight; moisture, 5.20%; volatile matter, 77.47%; fixed carbon, 12.27%; ash, 5.06%.

gross heat of combustion: assume values refer to room temperature.

(as received)

q_v(gross) = 3915 cal g^{-1}
q_v(gross) = 16382 J g^{-1}

(dry basis)

q_v(gross) = 4130 cal g^{-1}
q_v(gross) = 17280 J g^{-1}

[62]

PAPER, FOOD CARTONS; solid; Ultimate analysis in percent by weight; carbon, 44.74%; hydrogen, 6.10%; oxygen, 41.92%; nitrogen, 0.15%; sulfur, 0.16%; ash, 6.93%; proximate analysis as received in percent by weight; moisture, 6.11%; volatile matter, 75.59%; fixed carbon, 11.80%; ash, 6.50%.

gross heat of combustion: assume values refer to room temperature.

(as received)

q_v(gross) = 4035 cal g^{-1}
q_v(gross) = 16882 J g^{-1}

(dry basis)

q_v(gross) = 4297 cal g^{-1}
q_v(gross) = 17980 J g^{-1}

[62]

PAPER, JUNK MAIL; solid; Ultimate analysis in percent by weight; carbon, 37.87%; hydrogen, 5.41%; oxygen, 42.74%; nitrogen, 0.17%; sulfur, 0.09%; ash, 13.72%; proximate analysis as received in percent by weight; moisture, 4.56%; volatile matter, 73.32%; fixed carbon, 9.03%; ash, 13.09%.

gross heat of combustion: assume values refer to room temperature.

(as received)

q_v(gross) = 3385 cal g^{-1}
q_v(gross) = 14161 J g^{-1}

(dry basis)

q_v(gross) = 3546 cal g^{-1}
q_v(gross) = 14835 J g^{-1}

[62]

PAPER, MAGAZINE; solid; Ultimate analysis in percent by weight; carbon, 32.91%; hydrogen, 4.95%; oxygen, 38.55%; nitrogen, 0.07%; sulfur, 0.09%; ash, 23.43%; proximate analysis as received in percent by weight; moisture, 4.11%; volatile matter, 66.39%; fixed carbon, 7.03%; ash, 22.47%.

gross heat of combustion: assume values refer to room temperature.

(as received)

q_v(gross) = 2921 cal g^{-1}
q_v(gross) = 12221 J g^{-1}

(dry basis)

q_v(gross) = 3046 cal g^{-1}
q_v(gross) = 12746 J g^{-1}

[62]

PAPER, NEWSPRINT; solid; Ultimate analysis in percent by weight; carbon, 49.14%; hydrogen, 6.10%; oxygen, 43.03%; nitrogen, 0.05%; sulfur, 0.16%; ash, 1.52%; proximate analysis as received in percent by weight; moisture, 5.97%; volatile matter, 81.12%; fixed carbon, 11.48%; ash, 1.43%.

gross heat of combustion: assume values refer to room temperature.

(as received)

q_v(gross) = 4433 cal g^{-1}
q_v(gross) = 18548 J g^{-1}

(dry basis)

q_v(gross) = 4714 cal g^{-1}
q_v(gross) = 19724 J g^{-1}

[62]

PAPER, PLASTIC COATED; solid; Ultimate analysis in percent by weight; carbon, 45.30%; hydrogen, 6.17%; oxygen, 45.50%; nitrogen, 0.18%; sulfur, 0.08%; ash, 2.77%; proximate analysis as received in percent by weight; moisture, 4.71%; volatile matter, 84.20%; fixed carbon, 8.45%; ash, 2.64%.

gross heat of combustion: assume values refer to room temperature.

(as received)

q_v(gross) = 4081 cal g^{-1}
q_v(gross) = 17075 J g^{-1}

(dry basis)

q_v(gross) = 4282 cal g^{-1}
q_v(gross) = 17917 J g^{-1}

[62]

PAPER, WAXED MILK CARTONS; solid; Ultimate analysis in percent by weight; carbon, 59.18%; hydrogen, 9.25%; oxygen, 30.13%; nitrogen, 0.12%; sulfur, 0.10%; ash, 1.22%; proximate analysis as received in percent by weight; moisture, 3.45%; volatile matter, 90.92%; fixed carbon, 4.46%; ash, 1.17%.

gross heat of combustion: assume values refer to room temperature.

(as received)

q_v(gross) = 6297 cal g^{-1}
q_v(gross) = 26347 J g^{-1}

(dry basis)

q_v(gross) = 6522 cal g^{-1}
q_v(gross) = 27289 J g^{-1}

[62]

PEAT; solid; highly organic soil containing partially decomposed vegetable matter and having more than 50% combustible content.

gross heat of combustion: assume values refer to room temperature.

sample 1; air dried; moisture, 8.68%; volatile material; 50.92%; fixed carbon, 23.79%; ash, 16.61%; sulfur, 0.99%.

$q_v(\text{gross}) = 4182 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 17496 \text{ J g}^{-1}$

[47]

sample 2; brown fibrous; air dried; moisture, 6.34%; ash, 7.93%; sulfur, 0.69%.

$q_v(\text{gross}) = 5161 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 21594 \text{ J g}^{-1}$

[53]

sample 3; black; air dried; moisture, 6.62%; ash, 24.44%; sulfur, 0.65%.

$q_v(\text{gross}) = 3992 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 16703 \text{ J g}^{-1}$

[53]

sample 4; brown; air dried; moisture, 12.10%; ash, 7.22%; sulfur, 0.83%.

$q_v(\text{gross}) = 4269 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 17861 \text{ J g}^{-1}$

[53]

PLANTS

ALGAE; solid; chlorophyl-bearing organisms occurring in both salt and fresh water; contain minerals, proteins, lipids, amino acids; a source of iodine.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

Ulva rigida (green alga)

$q_v(\text{gross}) = 3750 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 15690 \text{ J g}^{-1}$

Alaria nana (brown)

$q_v(\text{gross}) = 3250 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 13598 \text{ J g}^{-1}$

Fucus distichus (brown)

$q_v(\text{gross}) = 3430 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 14351 \text{ J g}^{-1}$

[73]

PLANTS

GRASS, LAWN CLIPPINGS; solid; Ultimate analysis: carbon, 43.65%; hydrogen, 6.74%; oxygen, 33.33%; nitrogen, 4.22%; sulfur, 0.40%; ash, 6.19%; moisture, 5.47%; proximate analysis as received: moisture, 5.47%; volatile matter, 71.16%; fixed carbon, 17.18%; ash, 6.19%.

gross heat of combustion: assume values refer to room temperature.

(air dried at 80 °C)

$q_v(\text{gross}) = 4369 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 18277 \text{ J g}^{-1}$

(as received)

$q_v(\text{gross}) = 1144 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 4787 \text{ J g}^{-1}$

[62,84]

HERBS, ALPINE TUNDRA; solid; samples of 20 species of herbs were collected in the alpine tundra of Mt. Washington, New Hampshire. Mean lipid content was 1.43 ± 0.1% of volatile-free dry weight. Samples ground and oven-dried at 80 °C.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

$q_v(\text{gross}) = 4601 \pm 29 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 19251 \pm 121 \text{ J g}^{-1}$

[61]

LEAVES, TREE, RIPE HARDWOOD MIXTURE; solid; Ultimate analysis: carbon, 52.15%; hydrogen, 6.11%; oxygen, 30.34%; nitrogen, 6.99%; sulfur, 0.16%; ash, 4.25%; proximate analysis as received: moisture, 9.97%; volatile matter, 66.92%; fixed carbon, 19.29%; ash, 3.82%.

gross heat of combustion: assume values refer to room temperature.

(as received)

$q_v(\text{gross}) = 4439 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 18571 \text{ J g}^{-1}$

(dry basis)

$q_v(\text{gross}) = 4930 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 20629 \text{ J g}^{-1}$

[62]

PLANTS

MOSSES, ALPINE TUNDRA; solid; samples of 7 species of mosses were collected in the alpine tundra of Mt. Washington, New Hampshire. Mean lipid content was 1.0% of the volatile-free dry weight. Samples were ground and air-dried at 80 °C.

gross heat of combustion: assume values refer to room temperature, and are corrected for moisture and ash content.

$q_v(\text{gross}) = 4410 \pm 70 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 18450 \pm 293 \text{ J g}^{-1}$

[61]

PLANTS, FLOWER GARDEN; solid; Ultimate analysis: carbon, 46.65%; hydrogen, 6.61%; oxygen, 40.18%; nitrogen, 1.21%; sulfur, 0.26%; ash, 5.09%; proximate analysis as received: moisture, 53.94%; volatile matter, 35.64%; fixed carbon, 8.08%; ash, 2.34%.

gross heat of combustion: assume values refer to room temperature.

(as received)

$q_v(\text{gross}) = 2055 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 8599 \text{ J g}^{-1}$

(dry basis)

$q_v(\text{gross}) = 4462 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 18671 \text{ J g}^{-1}$

[62]

PLANTS, VASCULAR AQUATIC; solid; plants taken from Par Pond, U.S. AEC Savannah River Plant, near Aiken, South Carolina; samples dried at 60 °C and pulverized to pass 40 mesh screen.

gross heat of combustion: assume values refer to room temperature.

Species	Protein Content g (100 g dry wt.)	q_v(gross)	
Typha latifolia	4.0	4262 cal g^{-1}	17832 J g^{-1}
Hydrotrida carolinensis	10.5	4058	16979
Brasenia schreberi	10.9	4026	16845
Utricularia inflata	11.4	4023	16832
Nelumbo lutea	12.1	4227	17686
Myriophyllum heterophyllum	13.5	3961	16573
Eleocharis acicularis	14.1	4256	17807
Najas guadalupensis	14.4	3918	16393
Nymphaea odorata	14.6	4180	17489
Ceratophyllum demensum	17.1	3906	16343
Nuphar advena	21.6	4315	18054

[113]

SHRUBS, DECIDUOUS, ALPINE TUNDRA; solid; samples of 9 species of shrubs were collected in the alpine tundra of Mt. Washington, New Hampshire. Mean lipid content was 1.97 ± 0.3% of the volatile-free dry weight. Samples were ground and oven-dried at 80 °C.

gross heat of combustion: assume values refer to room temperature, and are corrected for moisture and ash content.

q_v(gross) = 4932 ± 33 cal g^{-1}
q_v(gross) = 20635 ± 138 J g^{-1}

[61]

SHRUBS, EVERGREEN, ALPINE TUNDRA; solid; samples of 11 species of shrubs were collected in the alpine tundra of Mt. Washington, New Hampshire. Mean lipid content is 3.72 ± 0.5% of the volatile-free dry weight. Samples were ground and oven-dried at 80 °C.

gross heat of combustion: assume values refer to room temperature, and are corrected for moisture and ash content.

q_v(gross) = 5098 ± 48 cal g^{-1}
q_v(gross) = 21330 ± 201 J g^{-1}

[61]

SHRUBS, EVERGREEN, CUTTINGS; solid; Ultimate analysis: carbon, 48.51%; hydrogen, 6.54%; oxygen, 40.44%; nitrogen, 1.71%; sulfur, 0.19%; ash, 2.61%; proximate analysis as received: moisture, 69.00%; volatile matter, 25.18%; fixed carbon, 5.01%; ash, 0.81%.

gross heat of combustion: assume values refer to room temperature.

(as received)

q_v(gross) = 1505 cal g^{-1}
q_v(gross) = 6299 J g^{-1}

(dry basis)

q_v(gross) = 4856 cal g^{-1}
q_v(gross) = 20318 J g^{-1}

[62]

POLYMERS

BUTADIENE-STYRENE COPOLYMER, GL-622; solid; composition: carbon 90.100%; hydrogen, 9.710%; sulfur, 0.081%; oxygen, 0.14%; ash, 0.111%; styrene, 42.98%; phenyl-β-naphthylamine 0.1%; polymerized at 50 °C.

specific heat:

Temperature (K)	Cp(cal g^{-1} K^{-1})	Cp(J g^{-1} K^{-1})
5	0.00081	0.0034
50	0.076	0.318
100	0.136	0.569
150	0.190	0.794
200	0.244	1.022
220	0.268	1.122
255	0.405	1.694

for temperature range: 255° - 330 °K

$$Cp(cal\ g^{-1}\ K^{-1}) = 0.316 + 4.37 \times 10^{-5}\ T + 1.195 \times 10^{-6}\ T^2$$
$$Cp(J\ g^{-1}\ K^{-1}) = 1.322 + 1.83 \times 10^{-4}\ T + 5.000 \times 10^{-6}\ T^2$$

[121]

BUTADIENE-STYRENE COPOLYMER, X-454; solid; composition: carbon 88.869%; hydrogen, 10.872%; sulfur, 0.056%; oxygen, 0.235%; ash, 0.18%; styrene, 8.58%; phenyl-β-naphthylamine, 0.1%; polymerized at 5 °C.

specific heat:

Temperature (K)	Cp(cal g^{-1} K^{-1})	Cp(J g^{-1} K^{-1})
50	0.084	0.351
100	0.153	0.464
150	0.220	0.92
200	0.373	1.56
250	0.423	1.77
300	0.464	1.94
330	0.485	2.03

[122]

BUTADIENE-STYRENE COPOLYMER, X-478; solid; composition: carbon, 89.443%; hydrogen, 10.4008%; sulfur, 0.048%; oxygen, 0.15%; ash, 0.098%; styrene, 22.61%; phenyl-β-naphthylamine, 0.1%; polymerized at 5 °C.

specific heat:

Temperature (K)	$Cp(cal\ g^{-1}\ K^{-1})$	$Cp(J\ g^{-1}\ K^{-1})$
15	0.016	0.067
50	0.081	0.338
100	0.147	0.617
150	0.209	0.874
195	0.262	1.096
225	0.405	1.693

225 to 330 °K

$$Cp(cal\ g^{-1}\ K^{-1}) = 0.3337 + 6.29 \times 10^{-5}\ T + 1.1205 \times 10^{-6}\ T^2$$
$$Cp(J\ g^{-1}\ K^{-1}) = 1.396 + 2.632 \times 10^{-4}\ T + 4.6882 \times 10^{-6}\ T^2$$

[121]

BUTENE-1-POLYSULFONE; solid; repeating unit: $C_4H_8O_2S$.

gross heat of combustion: at 25 °C

$$q_v(gross) = 5748.3 \pm 3.8\ cal\ g^{-1}$$
$$q_v(gross) = 24050.9 \pm 15.9\ J\ g^{-1}$$

[28]

cis-BUTENE-2-POLYSULFONE; solid; repeating unit: $C_4H_8O_2S$.

gross heat of combustion: at 25 °C.

$$q_v(gross) = 5744.6 \pm 2.6\ cal\ g^{-1}$$
$$q_v(gross) = 24035.4 \pm 10.9\ J\ g^{-1}$$

[28]

trans-BUTENE-2-POLYSULFONE; solid; repeating unit: $C_4H_8O_2S$.

gross heat of combustion: at 25 °C.

$$q_v(gross) = 5745.7 \pm 2.5\ cal\ g^{-1}$$
$$q_v(gross) = 24040.0 \pm 10.5\ J\ g^{-1}$$

[28]

POLYMERS

iso-BUTENE POLYSULFONE (2-methylpropene polysulfone); solid; repeating unit: $C_4H_8O_2S$.

gross heat of combustion: at 25 °C.

q_v(gross) = 5753.2 ± 2.9 cal g^{-1}
q_v(gross) = 24071.4 ± 12.1 J g^{-1}

[28]

DELRIN; solid; (polyoxymethylene); E.I. duPont de Nemours and Co. trade name; crystallized resin granules, 99.3%; unspecified organic additives 0.7%; repeating unit: CH_2O.

gross heat of combustion: at 25 °C.

q_v(gross) = 4047.1 ± 0.8 cal g^{-1}
q_v(gross) = 16933.3 ± 3.3 J g^{-1}

[30]

DICYANDIAMIDE (TECHNICAL); solid; elementary analysis; carbon, 28.97%; hydrogen, 4.44%; nitrogen, 66.60%; formula $C_2H_4N_4$.

gross heat of combustion: at 25 °C.

unhardened

q_v(gross) = 3735.4 ± 1.7 cal g^{-1}
q_v(gross) = 15628.9 ± 7.1 J g^{-1}

hardened

q_v(gross) = 3762.4 ± 2.1 cal g^{-1}
q_v(gross) = 15741.9 ± 8.8 J g^{-1}

[60]

DURETHAN U20; solid; a polyurethane from 1,4-butanediol and hexamethyldiisocyanate; formula $C_{12}H_{22}O_4N_2$.

gross heat of combustion: at 25 °C.

q_v(gross) = 6221.4 ± 1.9 cal g^{-1}
q_v(gross) = 26030.3 ± 7.9 J g^{-1}

[60]

EPILOX EG1, HARDENED; solid; empirical formula $C_{39}H_{40}O_{8.5}$; the unhardened resin plus phthalic anhydride.

gross heat of combustion: at 25 °C.

q_v(gross) = 7233.9 ± 1.9 cal g^{-1}
q_v(gross) = 30266.6 ± 7.9 J g^{-1}

[60]

POLYMERS

EPILOX EG1, UNHARDENED; solid; elementary analysis; carbon, 74.74%; hydrogen, 7.27%; oxygen, 17.99%; a diepoxide from epichlorhydrin plus 4,4'-dihydroxydiphenyl-2,2'-propane; empirical formula $C_{31}H_{36}O_{5.5}$.

gross heat of combustion: at 25 °C.

q_v(gross) = 7867.0 ± 2.5 cal g^{-1}
q_v(gross) - 32915.5 ± 10.5 J g^{-1}

[60]

LUCITE; solid; (polymethylmethacrylate); (E.I. duPont de Nemours and Company trade name); repeating unit $C_5H_8O_2$.

gross heat of combustion: at 25 °C.

q_v(gross) = 6367.8 ± 2.3 cal g^{-1}
q_v(gross) = 26642.9 ± 9.6 J g^{-1}

[60]

specific heat: assume values refer to room temperature.

Cp(cal g^{-1} K^{-1}) = 0.343
Cp(J g^{-1} K^{-1}) = 1.435

[43]

2,5-METHYLOLMELAMINE, HARDENED; solid; elementary analysis; carbon, 34.19%; hydrogen, 5.27%; oxygen, 17.07%; nitrogen, 43.47%; empirical formula $C_{11}H_{20}O_4N_{12}$; a melamine-formaldehyde polymer.

gross heat of combustion: at 25 °C.

q_v(gross) = 3861.6 ± 1.3 cal g^{-1}
q_v(gross) = 16156.9 ± 5.4 J g^{-1}

[60]

2,5-METHYLOLMELAMINE, UNHARDENED; solid; elementary analysis; carbon, 32.70%; hydrogen, 5.53%; oxygen, 20.51%; nitrogen, 41.26%; empirical formula $C_{5.5}H_{11}O_{2.5}N_6$; a melamine-formaldehyde polymer.

gross heat of combustion: at 25 °C.

q_v(gross) = 3721.8 ± 1.2 cal g^{-1}
q_v(gross) = 15572.0 ± 5.0 J g^{-1}

[60]

NORYL RESIN III; solid; composition: polystyrene = 47%; polyphenylene oxide = 47%; polybutadiene = 5%; and polyethylene = 1%.

heat of fusion: between 83 and 103 °C.

L_f = 0.2 cal g^{-1}
L_f = 0.8 J g^{-1}

specific heat:

temperature, °C	Cp(cal g^{-1} K^{-1})	Cp(J g^{-1} K^{-1})
-79	0.178	0.745
+4	0.242	1.013
+25	0.228	1.205
+50	0.316	1.322
+100	0.393	1.644
+151	0.439	1.837
+209	0.483	2.021
+246	0.503	2.105

specific heat change at glass transition temperature:

temperature, °C	ΔCp(cal g^{-1} K^{-1})	ΔCp(J g^{-1} K^{-1})
-61	0.005	0.021
+141	0.044	0.184

[127]

NYLON-6; solid; (poly-ε-caprolactam); repeating unit: $C_6H_{11}NO$.

gross heat of combustion: at 20 °C.

slow condensation

q_v(gross) = 7575 cal g^{-1}
q_v(net) = 31694 J g^{-1}

[23]

rapid condensation

q_v(gross) = 7587 cal g^{-1}
q_v(gross) = 31744 J g^{-1}

[23]

Miramid H: 25 °C

q_v(gross) = 7454.1 ± 2.8 cal g^{-1}
q_v(gross) = 31188.0 ± 11.7 J g^{-1}

[60]

specific heat: 0 - 160 °C; amorphous Nylon-6.

Cp(cal g^{-1} deg^{-1}) = $-0.085 + 1.5 \times 10^{-3}$ T
Cp(J g^{-1} deg^{-1}) = $-0.356 + 6.3 \times 10^{-3}$ T

[33]

melting point: maximum melting temperature is 225 °C (498 K).

heat of fusion: at 225 °C.

L_f = 45 cal g^{-1}
L_f = 188 J g^{-1}

glass transition temperatures: depends upon prior treatment of polymer and amount of monomer present.

Physical Form	Transition Temp. (°C)	Percent Monomer Present
Flake	45-48	1.7
Undrawn filaments	37	4
Pre-melt annealed	38	4
Melt annealed	20	11

[33]

POLYMERS

NYLON-6; liquid; (poly-ε-caprolactam); repeating unit: $C_6H_{11}NO$.

specific heat:

160° to 280 °C.

$$Cp(cal\ g^{-1}\ K^{-1}) = 0.485 + 3.36 \times 10^{-4}\ T$$
$$Cp(J\ g^{-1}\ K^{-1}) = 2.029 + 1.406 \times 10^{-3}\ T$$

[33]

NYLON-6,6; solid; (polyhexamethyleneadipamide); repeating unit: $C_{12}H_{22}N_2O_2$; average mol. wt. is 11000.

gross heat of combustion: at 20 °C.

$q_v(\text{gross}) = 7581 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 31719 \text{ J g}^{-1}$

[23]

Ultramid A

$q_v(\text{gross}) = 7543.8 \pm 2.4 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 31563.3 \pm 10.0 \text{ J g}^{-1}$

[60]

specific heat: 0 °C to 280 °C.

Temperature, °C	$Cp(\text{cal g}^{-1}\text{ K}^{-1})$	$Cp(\text{J g}^{-1}\text{ K}^{-1})$
Annealed		
0	0.311	1.301
20	0.333	1.393
40	0.367	1.536
60	0.424	1.774
80	0.468	1.958
100	0.505	2.113
120	0.548	2.293
140	0.583	2.439
160	0.642	2.686
180	0.620	2.594
200	0.646	2.703
220	0.664	2.778
240	0.80	3.347
250	1.13	4.728
260	2.75	11.51
270	1.3	5.439
280	0.75	3.138
Drawn		
0	0.302	1.264
20	0.345	1.443
40	0.376	1.573
60	0.420	1.757
80	0.458	1.916
100	0.479	2.004
120	0.503	2.105
140	0.528	2.209
160	0.542	2.268
180	0.560	2.343
200	0.582	2.435
220	0.567	2.372
240	0.676	2.828
250	1.55	6.485
260	6.5	27.20
270	1.35	5.648
280	0.75	3.138

[34]

melting point:

	Ribbon	Undrawn Filaments	Drawn Filaments	Annealed
M.P., °C	263	264	259	262
Melting Range, °C	25	40	18	30

Heat of fusion:

	Ribbon	Drawn Filaments	Annealed
L_f(cal g^{-1})	29.0	29.5	33.3
L_f(J g^{-1})	121.3	165.3	139.3

[34]

NYLON-6,10; solid; ribbon; (polyhexamethylenesebacamide); repeating unit: $C_{16}H_{30}N_2O_2$; average mol. wt. 9250.

specific heat: ribbon

Temperature, °C	Cp(cal g^{-1} K^{-1})	Cp(J g^{-1} K^{-1})
0	0.327	1.368
20	0.373	1.561
40	0.420	1.757
60	0.486	2.033
80	0.512	2.142
100	0.518	2.167
120	0.531	2.222
140	0.561	2.347
160	0.592	2.477
180	0.588	2.460
200	0.686	2.870
220	1.95	8.159
240	0.737	3.084
250	0.639	2.674
260	0.627	2.623
270	0.632	2.644
280	0.639	2.674

melting point:

M.P. = 225 °C; melting range 30°-40 °C

heat of fusion: ribbon

L_f(cal g^{-1}) = 26.3
L_f(J g^{-1}) = 110.0

[34]

POLYMERS

PHENOL-FORMALDEHYDE RESIN, HARDENED (EDELKUNSTHARZ B); solid; empirical formula: $C_{13}H_{12}O_2$.

gross heat of combustion: at 25 °C.

q_v(gross) = 7554.3 ± 2.1 cal g^{-1}
q_v(gross) = 31607.2 ± 8.8 J g^{-1}

[60]

PHENOL-FORMALDEHYDE RESIN, UNHARDENED; solid; empirical formula $C_{14}H_{14}O_3$.

gross heat of combustion: at 25 °C.

q_v(gross) = 7204.2 ± 2.0 cal g^{-1}
q_v(gross) = 30142.4 ± 8.4 J g^{-1}

[60]

POLYACENAPHTHYLENE; solid; amorphous; repeating unit: $C_{12}H_8$; degree of polymerization ∿ 600 units.

gross heat of combustion: at 25 °C.

q_v(gross) = 9388.0 ± 2.0 cal g^{-1}
q_v(gross) = 39279.4 ± 8.4 J g^{-1}

[25]

POLYALLYLPHTHALATE; solid; empirical formula $C_{14}H_{14}O$.

gross heat of combustion: at 25 °C.

q_v(gross) = 6629.8 ± 2.1 cal g^{-1}
q_v(gross) = 27739.1 ± 8.8 J g^{-1}

[60]

POLYBUTADIENE 41 °F; solid; Analysis: carbon, 88.47%; hydrogen, 11.160%; sulfur, 0.083%; oxygen, 0.12%; ash, 0.34%; phenyl-β-naphthaylamine, 0.10%; Repeating unit: C_4H_6.

specific heat:

Temperature, K	Cp(cal g^{-1} K^{-1})	Cp(J g^{-1} K^{-1})
50	0.08532	0.3570
100	0.15832	0.6624
150	0.22416	0.9379
200	0.359	1.50
250	0.433	1.81
300	0.471	1.97
330	0.4940	2.067

[108]

POLYMERS

POLYBUTADIENE 122 °F; solid; Analysis: carbon, 88.66%; hydrogen, 11.180%; sulfur, 0.150%; oxygen, 0.145%; ash, .097%; phenyl-β-naphthylamine, 0.12%; repeating unit: C_4H_6.

specific heat:

Temperature, K	Cp(cal g^{-1} K^{-1})	Cp(J g^{-1} K^{-1})
50	0.08640	0.3615
100	0.15777	0.6601
150	0.22299	0.9330
200	0.3967	1.66
250	0.4326	1.81
300	0.4680	1.958
330	0.4919	2.058

[108]

POLY-1-BUTENE; solid; isotactic; 34% crystallinity; repeating unit: C_4H_8; degree of polymerization ∿ 800 units.

gross heat of combustion: at 25 °C.

q_v(gross) = 11109.4 ± 0.5 cal g^{-1}
q_v(gross) = 46481.7 ± 2.1 J g^{-1}

[25]

POLY-iso-BUTENE; (Sample 1) viscous liquid; molecular weight ∿ 4900; (Sample 2) amorphous solid, rubberlike; molecular weight ∿ 200000; 0.033% ash; (Sample 3) solid; Opanol B 100; repeating unit: C_4H_8.

gross heat of combustion: at 25 °C

Sample 1

q_v(gross) = 11179.8 ± 1.3 cal g^{-1}
q_v(gross) = 46776.3 ± 5.4 J g^{-1}

[29]

Sample 2

q_v(gross) = 11175.8 ± 2.0 cal g^{-1}
q_v(gross) = 46759.5 ± 8.3 J g^{-1}

[29]

Sample 3

q_v(gross) = 11179.1 ± 4.3 cal g^{-1}
q_v(gross) = 46773.4 ± 18.0 J g^{-1}

[60]

POLYMERS

POLY-1,1-DICHLOROETHYLENE (polyvinylidene chloride); solid; repeating unit: $C_2H_2Cl_2$; purity 99.9 mol %.

gross heat of combustion: at 25 °C.

q_v(gross) = 2515.1 ± 2.1 cal g^{-1}
q_v(gross) = 10523.2 ± 8.8 J g^{-1}

[31]

POLY-1,1-DIFLUOROETHYLENE (polyvinylidene fluoride); solid; repeating unit: $C_2H_2F_2$; particle size 100 mesh.

gross heat of combustion: at 25 °C.

q_v(gross) = 3529.1 ± 0.4 cal g^{-1}
q_v(gross) = 14765.8 ± 1.7 J g^{-1}

[32]

POLY-2,6-DIMETHYLPHENYLENE ETHER; solid; repeating unit: C_8H_8O; 20% crystallinity; degree of polymerization ∿ 300 units.

gross heat of combustion: at 25 °C.

q_v(gross) = 8273.2 ± 1.4 cal g^{-1}
q_v(gross) = 34615.1 ± 5.9 J g^{-1}

[25]

POLY-4,4'-DIOXYDIPHENYL-2,2-PROPANE CARBONATE; solid; empirical formula $C_{16}H_{14}O_3$.

gross heat of combustion: at 25 °C.

PKU T 22

q_v(gross) = 7408.7 ± 2.1 cal g^{-1}
q_v(gross) = 30998.0 ± 8.8 J g^{-1}

[60]

Lexan; 20% crystallinity; degree of polymerization ∿ 150 units.

q_v(gross) = 7392.9 ± 1.4 cal g^{-1}
q_v(gross) = 30931.9 ± 5.9 J g^{-1}

[25]

Makrolon; solid.

q_v(gross) = 7408.7 ± 2.0 cal g^{-1}
q_v(gross) = 30998.0 ± 8.4 J g^{-1}

[60]

POLYMERS

POLY-ε-ENANTHOLACTAM; solid; repeating unit: $C_7H_{13}NO$.

gross heat of combustion: at 20 °C.

$q_v(\text{gross}) = 7977.2 \pm 5.5 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 33376.6 \pm 23.0 \text{ J g}^{-1}$

[23]

POLYETHYLENE; solid; NBS Standard Reference Material (SRM) 1475; linear polymer; wt.-ave. molecular weight is 52000; methyl group content is 0.15 methyl groups per 100 carbon atoms; ash content 0.002 percent; 111 ppm of anti-oxidant [tetrakis-(methylene-3-(3', 5'-di-tert-butyl-4'-hydroxphenyl) propionate) methane] added to polymer by manufacturer (E.I. Du Pont de Nemours and Co.); density at 23 °C is 0.9784 g cm^{-3}; degree of crystallinity detd. to be 72 percent; repeating unit: C_2H_4.

gross heat of combustion: at 25 °C.

SRM 1475, crystallinity 72%;

$q_v(\text{gross}) = 11073.7 \pm 2.1 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 46332.4 \pm 8.8 \text{ J g}^{-1}$

SRM 1475 modified by recrystallization under high pressure; crystallinity 96%.

$q_v(\text{gross}) = 11058.6 \pm 2.0 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 46269.1 \pm 8.1 \text{ J g}^{-1}$

[40]

specific heat: SRM 1475

Temperature, K	Cp(cal g^{-1} K^{-1})	Cp(J g^{-1} K^{-1})
10	0.0029	0.0123
100	0.1632	0.6829
200	0.2839	1.1877
250	0.3537	1.4800
273.15	0.3936	1.6468
298.15	0.4376	1.8308
320	0.4790	2.0040
360	0.5904	2.4702

[120]

POLYMERS

POLYETHYLENE; solid; (sample 1) high pressure; molecular weight 18000-20000; crystallinity 50%; (sample 2) linear; Marlex; crystallinity 98%; (sample 3) low density; (sample 4) high density, Mirathen H; repeating unit: C_2H_4.

gross heat of combustion: at 25 °C.

sample 1

$q_v(\text{gross}) = 11093.6 \pm 0.8$ cal g^{-1}
$q_v(\text{gross}) = 46415.6 \pm 3.3$ J g^{-1}

[29]

sample 2

$q_v(\text{gross}) = 11080.9 \pm 2.0$ cal g^{-1}
$q_v(\text{gross}) = 46362.5 \pm 8.4$ J g^{-1}

[30]

sample 3

$q_v(\text{gross}) = 11042.7 \pm 3.5$ cal g^{-1}
$q_v(\text{gross}) = 46202.7 \pm 14.6$ J g^{-1}

[60]

sample 4

$q_v(\text{gross}) = 11102.9 \pm 4.6$ cal g^{-1}
$q_v(\text{gross}) = 46485.5 \pm 19.2$ J g^{-1}

[60]

POLY-α-METHYL STYRENE; solid; anionic; amorphous; samples with different degrees of polymerization, ∿34000 units and ∿13000 units gave the same heat of combustion; repeating unit: C_9H_{10}.

gross heat of combustion: at 25 °C.

$q_v(\text{gross}) = 10111.8 \pm 2.8$ cal g^{-1}
$q_v(\text{gross}) = 42307.8 \pm 11.7$ J g^{-1}

[25]

POLYMERS

POLYPROPYLENE; solid; repeating unit: C_3H_6.

gross heat of combustion: at 25 °C.

isotactic; 58% crystallinity

q_v(gross) = 11082.4 ± 2.2 cal g^{-1}
q_v(gross) = 46368.8 ± 9.2 J g^{-1}

[30]

degree of polymerization ∿ 4000 units

q_v(gross) = 11080.5 ± 2.2 cal g^{-1}
q_v(gross) = 46360.8 ± 9.2 J g^{-1}

[30]

Polypropylene VK166, untangled

q_v(gross) = 11021.2 ± 5.1 cal g^{-1}
q_v(gross) = 46112.7 ± 21.3 J g^{-1}

[60]

POLYSTYRENE: solid; repeating unit: C_8H_8.

gross heat of combustion: at 25 °C.

isotactic, 40% crystallinity

q_v(gross) = 9909.9 ± 3.1 cal g^{-1}
q_v(gross) = 41463.0 ± 13.0 J g^{-1}

isotactic, amorphous

q_v(gross) = 9918.5 ± 2.4 cal g^{-1}
q_v(gross) = 41499.0 ± 10.0 J g^{-1}

atactic, amorphous

q_v(gross) = 9921.2 ± 1.4 cal g^{-1}
q_v(gross) = 41510.3 ± 5.9 J g^{-1}

[25]

polystyrol BW

q_v(gross) = 9922.4 ± 4.0 cal g^{-1}
q_v(gross) = 41515.3 ± 16.7 J g^{-1}

[60]

polystyrol P70

q_v(gross) = 9900.5 ± 3.0 cal g^{-1}
q_v(gross) = 41423.7 ± 12.6 J g^{-1}

[60]

POLYUREA (POLYHARNSTOFF); solid; empirical formula is $C_{15}H_{18}O_4N_4$; a polymer of adipic acid diamide plus (2,4-2,6)-toluene diisocyanate.

gross heat of combustion: at 25 °C.

$q_v(\text{gross}) = 5954.0 \pm 1.7 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 24911.5 \pm 7.1 \text{ J g}^{-1}$

[60]

RESIN, ABS I; solid; copolymer of styrene-acrylonitrile = 76%; and polybutadiene = 15%.

specific heat:

temperature (°C)	cp(cal g^{-1} K^{-1})	cp(J g^{-1} K^{-1})
-110	0.184	0.770
-56	0.240	1.004
+4	0.311	1.301
+25	0.338	1.414
+55	0.373	1.561
+107	0.492	2.059
+157	0.518	2.167
+204	0.541	2.264

specific heat change at glass transition temperature:

temperature (°C)	ΔCp(cal g^{-1} K^{-1})	ΔCp(J g^{-1} K^{-1})
-85	0.014	0.059
+103	0.069	0.289

[127]

RILSAN; solid; (poly-11-aminodecanoic acid); empirical formula is $C_{11}H_{21}ON$.

gross heat of combustion: at 25 °C.

$q_v(\text{gross}) = 8840.3 \pm 2.2 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 36987.8 \pm 8.4 \text{ J g}^{-1}$

[60]

POLYMERS

TEFLON; solid; (polytetrafluoroethylene); repeating unit: C_4F_4; density, 2.2 g cm^{-3}.

gross heat of combustion in oxygen: at 25 °C; combustion products are gaseous carbon dioxide and carbon tetrafluoride.

q_v(gross) = 1196.7 ± 10.0 cal g^{-1}
q_v(gross) = 5007.0 ± 42 J g^{-1}

gross heat of combustion in fluorine: 25 °C; combustion product is carbon tetrafluoride.

q_v(gross) = 2478.8 ± 0.7 cal g^{-1}
q_v(gross) = 10371.3 ± 3.1 J g^{-1}

[105]

specific heat:

Temperature, K	Cp(cal g^{-1} K^{-1})	Cp(J g^{-1} K^{-1})
50	.04821	.2017
100	.09218	.3857
150	.13380	.5598
200	.17706	.7408
250	.21076	.8818
270	.22768	.9526
280	.24187	1.012
310	.24402	1.021
330	.24809	1.038
360	.25669	1.074

[106]

transition temperatures:

293 K (20 °C)
303 K (30 °C)

[106]

heat of transition: for the temperature range 280 to 310 K.

L_f = 8.72 cal g^{-1}
L_f = 36.5 J g^{-1}

[106]

TROCKENLEIM; solid; elementary analysis; carbon, 35.49%; hydrogen, 6.19%; oxygen, 30.91%; nitrogen, 27.41%; a urea-formaldehyde resin; empirical formula $C_3H_6O_2N_2$.

gross heat of combustion: at 25 °C.

q_v(gross) = 3800.4 ± 2.0 cal g^{-1}
q_v(gross) = 15900.9 ± 8.4 J g^{-1}

[60]

POLYPEPTIDE, PHENYLALANINE; solid; repeating unit: C_9H_9NO.

gross heat of combustion: at 25 °C.

benzene soluble

$q_v(\text{gross}) = 7503.2 \pm 6.0$ cal g^{-1}
$q_v(\text{gross}) = 31393.4 \pm 25.1$ J g^{-1}

benzene insoluble

$q_v(\text{gross}) = 7479.1 \pm 6.9$ cal g^{-1}
$q_v(\text{gross}) = 31292.6 \pm 28.9$ J g^{-1}

[36]

POLYPEPTIDE, POLY-N-ETHYL-N-METHYL PROPIONAMIDE; solid; density 1.4400 g cm^{-3}; repeating unit: $C_6H_{13}NO$.

gross heat of combustion: at 25 °C.

$q_v(\text{gross}) = 8069.3 \pm 1.0$ cal g^{-1}
$q_v(\text{gross}) = 33762.0 \pm 4.2$ J g^{-1}

[22]

POLYPETIDE, SARCOSINE; solid; repeating unit: C_3H_5NO.

gross heat of combustion: at 25 °C.

$q_v(\text{gross}) = 5626.4 \pm 4.2$ cal g^{-1}
$q_v(\text{gross}) = 23540.9 \pm 17.6$ J g^{-1}

[36]

POLYSACCHARIDES

CELLULOSE; solid; repeating unit: $C_6H_{10}O_5$, constitutes about 60 percent of the composition of wood; hydrolysis can reduce cellulose to a cellobiose repeating unit, $C_{12}H_{22}O_{11}$, and ultimately to glucose, $C_6H_{12}O_6$.

gross heat of combustion: at 30 °C.

from cotton linters:

$q_v(\text{gross}) = 4165.0$ cal g^{-1}
$q_v(\text{gross}) = 17426.4$ J g^{-1}

from wood pulp:

$q_v(\text{gross}) = 4172.0$ cal g^{-1}
$q_v(\text{gross}) = 17455.6$ J g^{-1}

[4]

POLYSACCHARIDES

α-CELLULOSE, FROM LOBLOLLY PINE WOOD (Pinus taeda L.); solid; modification of cellulose which has the highest degree of polymerization; chief constituent of paper pulp: 46.70% α-cellulose [81]; repeating unit: $C_6H_{10}O_5$.

specific heat: 60-140 °C; samples were oven-dried at 100 °C for 12 hours before measurements were made.

$$Cp(cal\ g^{-1}\ K^{-1}) = -0.01708 + 9.9 \times 10^{-4}\ T$$
$$Cp(J\ g^{-1}\ K^{-1}) = -0.07146 + 4.14 \times 10^{-3}\ T$$

[83]

CELLULOSE, HOLOCELLULOSE, FROM LOBLOLLY PINE WOOD; (Pinus taeda L.); solid; total water-insoluble carbohydrate constituents of loblolly pine wood; 71.18% holocellulose [81]; repeating unit: $C_6H_{10}O_5$.

specific heat: 60-140 °C; samples were oven-dried at 100 °C for 12 hours before measurements were made.

$$Cp(cal\ g^{-1}\ K^{-1}) = -0.01724 + 9.9 \times 10^{-4}\ T$$
$$Cp(J\ g^{-1}\ K^{-1}) = -0.07213 + 4.14 \times 10^{-3}\ T$$

[83]

CELLULOSE DIACETATE; solid; repeating unit: $C_{10}H_{10}O_7$; density = 1.36 g cm^{-3} at 20 °C; 0.04% ash.

gross heat of combustion: assume values refer to room temperature.

$$q_v(gross) = 4446.2\ cal\ g^{-1}$$
$$q_v(gross) = 18602.9\ J\ g^{-1}$$

[90]

CELLULOSE TRIACETATE; solid; repeating unit: $C_{12}H_{16}O_8$.

gross heat of combustion: assume values refer to room temperature.

$$q_v(gross) = 4511.5\ cal\ g^{-1}$$
$$q_v(gross) = 18876.1\ J\ g^{-1}$$

[90]

COTTON (THREAD); solid; staple fibers surrounding the seeds of various species of Gossypium; absorbent cotton is almost pure α-cellulose; $CH_{1.774}O_{0.887}$ is elemental analysis of thread used in combustion measurements.

gross heat of combustion: at 25 °C.

$$q_v(gross) = 4050\ cal\ g^{-1}$$
$$q_v(gross) = 16945\ J\ g^{-1}$$

[6]

$$q_v(gross) = 4108\ cal\ g^{-1}$$
$$q_v(gross) = 17188\ J\ g^{-1}$$

[74]

POLYSACCHARIDES

DEXTRIN; solid; general formula; $C_6H_{10}O_5$; partial hydrolysis product of starch containing a variable number of glucose units; dextrin is obtained in several different grades by heating starch for varying lengths of time over the temperature range from 170° to 240°C.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 4110 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 17196 \text{ J g}^{-1}$

[9]

GLYCOGEN; solid; general formula; $C_6H_{10}O_5$; polysaccharide found in the liver and muscles of man and animals; can be hydrolyzed to glucose.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 4188 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 17523 \text{ J g}^{-1}$

[137]

INULIN; solid; repeating unit: $C_6H_{10}O_5$; similar in physical appearance to starch except upon complete hydrolysis yields fructose instead of glucose; inulin is the chief source of fructose.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 4190 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 17531 \text{ J g}^{-1}$

[20]

INULIN TRIACETATE; solid; repeating unit: $C_{12}H_{16}O_8$; dried at 120 °C in vacuum over P_2O_5.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 4522 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 18920 \text{ J g}^{-1}$

[111]

STARCH; solid; general formula; $C_6H_{10}O_5$; polysaccharide is widely distributed in the vegetable kingdom and is stored in all grains and tubers.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 4200 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 17570 \text{ J g}^{-1}$

[9]

POLYSACCHARIDES

STARCH TRIACETATE; solid; repeating unit: $C_{12}H_{16}O_8$.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 4499 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 18824 \text{ J g}^{-1}$

[111]

XYLAN; solid; repeating unit; $C_5H_8O_4$; polysaccharide which often occurs in association with cellulose; xylose is the repeating unit; occurs in large amounts (20-40%) in cereal straws and brans.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 4242.8 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 17751.9 \text{ J g}^{-1}$

[21]

PORCELAIN; solid; a mixture of clays, quartz, and feldspar, usually containing at least 25% aluminum. Sample 1: SiO_2, 65.14%; Al_2O_3, 28.76%; Fe_2O_3, 1.08%; K_2O, 3.61%; MgO, 1.21%; sample 2: SiO_2, 41.1%; Al_2O_3, 57.1%; Fe_2O_3, 0.3%; MgO, 0.5%; CaO, traces.

specific heat: temperature range 0 - 1600 °C.

sample 1

$Cp(\text{cal g}^{-1} \text{ K}^{-1}) = 0.10848 + 2.6497 \times 10^{-4} T - 7.7124 \times 10^{-8} T^2$
$Cp(\text{J g}^{-1} \text{ K}^{-1}) = 0.45388 + 1.10863 \times 10^{-3} T - 3.2269 \times 10^{-7} T^2$

sample 2

$Cp(\text{cal g}^{-1} \text{ K}^{-1}) = 0.20698 + 1.1542 \times 10^{-4} T - 5.685 \times 10^{-9} T^2$
$Cp(\text{J g}^{-1} \text{ K}^{-1}) = 0.86600 + 4.8292 \times 10^{-4} T - 3.2319 \times 10^{-8} T^2$

[118]

PROPELLANT, OS/AP; solid; oxygen-styrene copolymer was prepared by passing oxygen at 1 atm through styrene for 24 hours in the presence of azobisisobutyronitrile; the reaction was completed by adding benzoyl peroxide and maintaining the solution at 50 °C for another 24 hours until it became sufficiently viscous; (OS/AP) = (oxygen-styrene copolymer) - ammonium perchlorate composite propellant.

gross heat of combustion: assume values refer to room temperature.

	q_v(gross)	
copolymer (wt. %)	cal g^{-1}	J g^{-1}
30	1109 ± 10	4640 ± 42
25	1168 ± 23	4887 ± 96
20	1301 ± 8	5443 ± 33

[57]

PROPELLANT, PS/AP; solid; inhibitor-free styrene was polymerized by benzoyl peroxide and mixed with ammonium perchlorate; PS/AP = polystyrene-ammonium perchlorate composite propellant.

gross heat of combustion: assume values refer to room temperature.

polystyrene (Wt. %)	q_v(gross) cal g^{-1}	J g^{-1}
30	1017 ± 15	4255 ± 63
25	1101 ± 10	4607 ± 42
20	1291 ± 5	5402 ± 21

[57]

PROPELLANT X14; solid; double base propellant processed by water mixing nitrocellulose with nitroglycerine and a stabilizer (such as: N, N'-diethyl-N, N'-diphenyl urea, or 2-nitrodiphenylamine).

specific heat: 283 to 343 K.

$Cp(cal\ g^{-1}\ K^{-1}) = 0.118 + 6.60 \times 10^{-4}\ T$
$Cp(J\ g^{-1}\ K^{-1}) = 0.494 + 2.761 \times 10^{-3}\ T$

[15]

PROTEIN

BOVINE CHYMOTRYPSINOGEN A; solid; the anhydrous material is a protein from beef pancreas made up of 245 amino acids with molecular weight of 25646.

specific heat:

temperature (K)	Cp(cal g^{-1} K^{-1})	Cp(J g^{-1} K^{-1})
10	0.00448	0.01874
100	0.1120	0.4686
150	0.1696	0.7096
200	0.2153	0.9008
250	0.2617	1.9050
298.15	0.3090	1.2929
300	0.3109	1.3008

[128]

CASEIN, MILK; solid; carbon 53%; hydrogen 7%; oxygen 22.65%; nitrogen 15.7%; sulfur 0.8%; phosphorus 0.85%.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 5670 ± 200 cal g^{-1}
q_v(gross) = 23700 ± 800 J g^{-1}

[9]

PROTEIN

COLLAGEN; solid; fibrous protein which comprises the major portion of the white fiber in connective tissues of the animal body; chief amino acids present are: proline, hydroxyproline, and glycine; converted to gelatine by boiling with water.

specific heat: 25 °C.

moisture content (wt. %)	Cp(cal g^{-1} K^{-1})	Cp(J g^{-1} K^{-1})
0	0.3723	1.5577
1.02	0.3490	1.4602
1.96	0.3659	1.5309
4.56	0.4014	1.6795
6.49	0.4061	1.6991
17.03	0.4280	1.7908

[78]

GELATINE; solid; a protein obtained from collagen by boiling skin, ligaments, tendons, bones etc. with water; can absorb 5 to 10 times its weight of water.

gross heat of combustion: assume values refer to room temperature.

As received: ash content, 0.6%-0.8%; water content not determined.

q_v(gross) = 4400 cal g^{-1}
q_v(gross) = 18410 J g^{-1}

Ash free and moisture free

q_v(gross) = 5150 ± 100 cal g^{-1}
q_v(gross) = 21550 ± 400 J g^{-1}

[115]

PROTEIN

GLIADIN; solid; also called prolomin; simple vegetable protein found in gluten; typical composition: carbon, 52.7%; hydrogen, 6.9%; oxygen, 21.7%; nitrogen, 17.7%; sulfur, 1.0%.

gross heat of combustion:

variation with thermal denaturation temperature.

denaturation temp., °C	q_v(gross) cal g^{-1}	q_v(gross) J g^{-1}
30	5986.3	25046.7
35	5911.3	24732.9
50	5777.2	24171.8
70	5809.3	24306.1
110	5852.8	24488.1

[91]

variation with concentration of aqueous alcohol used in extraction.

alcohol %	q_v(gross) cal g^{-1}	q_v(gross) J g^{-1}
40	5891	24648
50	5869	24556
60	5942	24861
70	6028	25221

[91]

GLUTEN; solid; mixture of proteins found in the seeds of cereal grains (wheat, corn (maize), etc.) which remains after washing the starch out of flour with water; amino acids of glutens are: glutamic acid, leucine, proline, and arginine.

gross heat of combustion: variation with thermal denaturation temperature.

denaturation temp., °C	q_v(gross) cal g^{-1}	q_v(gross) J g^{-1}
30	5797.9	24258.4
35	5873.2	24573.5
50	5648.8	23634.6
70	5721.1	23937.1
110	5779.6	24181.8

[91]

PROTEIN

GLUTENIN; solid; wheat protein soluble in dilute alkalies.

gross heat of combustion: variation with thermal denaturation temperature.

denaturation temp., °C	q_v(gross) cal g^{-1}	q_v(gross) J g^{-1}
30	5710.1	23891.1
35	5730.3	23975.6
50	5583.1	23359.7
70	5654.0	23656.3
110	5699.9	23848.4

[91]

VITELLIN; solid; globulin protein from egg yolk; typical composition; water 49.4%; protein 16.3%; fat 31.9%; carbohydrate 0.7%; remainder includes small amounts of elements such as: phosphorus, sulfur, iron, and calcium.

gross heat of combustion: assume values refer to room temperature.

$q_v(\text{gross}) = 5760 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 24100 \text{ J g}^{-1}$

[9]

WOOL PROTEIN; solid; material is a keratin containing 14.3% of cystine, 3.9% of sulfur, and 16.85% nitrogen.

gross heat of combustion: assume values refer to room temperature and are corrected for moisture and ash content.

$q_v(\text{gross}) = 5609 \pm 2.3 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 23468 \pm 9.6 \text{ J g}^{-1}$

[124]

REFUSE, MUNICIPAL; solid; waste from the city of St. Louis; particle size of 1.5 inches and less, magnetic metal removed; (batch 1); from 210 samples collected April 1972 through February 1973, unclassified material; with only magnetic metal removed; moisture, 9.3-50.0%; sulfur, 0.01-0.40%; chlorine, 0.13-0.95%; ash, 12.1-52.2%. (batch 2); from 99 samples collected November 1973 through January 1974, classified material; heavy fraction of waste removed by air-density separation; light fraction only; moisture, 11.1-66.3%; sulfur, 0.05-0.28%; chlorine, 0.14-0.94%; ash, 7.6-21.4%.

gross heat of combustion: assume values refer to room temperature.

(batch 1)

minimum q_v(gross) = 1683 cal g^{-1}
minimum q_v(gross) = 7041 J g^{-1}
maximum q_v(gross) = 4128 cal g^{-1}
maximum q_v(gross) = 17270 J g^{-1}
average q_v(gross) = 2597 cal g^{-1}
average q_v(gross) = 10867 J g^{-1}

(batch 2)

minimum q_v(gross) = 1275 cal g^{-1}
minimum q_v(gross) = 5333 J g^{-1}
maximum q_v(gross) = 4221 cal g^{-1}
maximum q_v(gross) = 17661 J g^{-1}
average q_v(gross) = 2789 cal g^{-1}
average q_v(gross) = 11669 J g^{-1}

[54]

REFUSE, MUNICIPAL; solid; waste from an English town; (sample 1) (on dry basis); paper, 29.6%; rags, 5.3%; vegetable matter, 5.1%; animal matter 1.3%; wood, etc., 3.5%; coal, coke, cinders, 16.5%; metal, 4.9%; glass, pottery, and other non-combustible matter, 23.7%; fines, passing 1/4 x 1/4" square mesh, 10.1%; moisture, 34.0%; (sample 2) (on dry basis) paper, 4.8%, rags, 0.3%; vegetable matter 1.0%; animal matter, 0.7%; wood, etc., 0.8%; coal, coke, cinders, 36.1%; metal 0.9%; glass pottery, and other non-combustible material, 10.0%; fines, passing 1/4 x 1/4" square mesh, 45.4%; moisture, 17.2%.

gross heat of combustion: assume values refer to room temperature; dry basis.

sample 1

q_v(gross) = 3110 cal g^{-1}
q_v(gross) = 13012 J g^{-1}

sample 2

q_v(gross) = 4060 cal g^{-1}
q_v(gross) = 16987 J g^{-1}

[52]

RUBBER; solid; (sample 1) latex, digested with water at 190 °C, extracted with water and ethanol; soluble in ether; 0.02% ash; (sample 2) latex, trypsin treated; 75% ether soluble, 25% ether insoluble.

gross heat of combustion: 30 °C.

sample 1, 0.02% ash

q_v(gross) = 10814 cal g^{-1}
q_v(gross) = 45247 J g^{-1}

sample 2, 0.4% ash

q_v(gross) = 10753 cal g^{-1}
q_v(gross) = 44991 J g^{-1}

sample 2, 0.15% ash

q_v(gross) = 10784 cal g^{-1}
q_v(gross) = 45120 J g^{-1}

sample 2, ether soluble fraction, 0.1% ash

q_v(gross) = 10802 cal g^{-1}
q_v(gross) = 45196 J g^{-1}

sample 2, ether insoluble fraction, 0.7% ash

q_v(gross) = 10746 cal g^{-1}
q_v(gross) = 44961 J g^{-1}

sample 2, ether insoluble fraction, 1.8% ash

q_v(gross) = 10627 cal g^{-1}
q_v(gross) = 44464 J g^{-1}

[26]

RUBBER-SULFUR COMPOUNDS; solid; repeating unit: $[(C_5H_8)_xS_y]$; x varies between 1 and 4; y varies between 0 and 3; maximum sulfur content ∿ 32%.

gross heat of combustion: at 30 °C, sulfur as gaseous SO_2.

q_v(gross) = 10791 - 9041 m cal g^{-1}
q_v(gross) = 45150 - 37828 m J g^{-1}

m is grams of sulfur per gram of compound.

[26]

SANTOWAX R; liquid; (trade mark, © Monsanto Co.); mixture of terphenyl hydrocarbons.

specific heat:

180 - 320 °C.

Cp(cal g^{-1} K^{-1}) = 0.222 + 5.86 x 10^{-4} T
Cp(J g^{-1} K^{-1}) = 0.929 + 2.452 x 10^{-3} T

[100]

SEA WATER; aqueous; a uniform solution of essentially constant composition containing 96.5% water and 3.5% ionized salts, related compounds, elements, and ionic complexes; sodium chloride is the chief salt constituent; other common ions are: K^+, Mg^{2+}, Ca^{2+}, SO_4^{2-}, HCO_3^-; salinity (S) is defined as the number of grams of salt in one kilogram of sea water when bromides and iodides are converted to chlorides, the carbonates to oxides, organic matter destroyed, and the mass heated to 450 °C for 72 hours; S = 0.03 + 1.805 (chloride content).

specific heat:

Temperature, °C	Cp(cal g^{-1} K^{-1})	Cp(J g^{-1} K^{-1})
salinity, 0.0%		
0	1.0080	4.2175
20	0.9995	4.1819
50	0.9992	4.1807
100	1.0076	4.2158
200	1.0747	4.4965
salinity, 3%		
0	0.9601	4.0171
20	0.9606	4.0192
50	0.9638	4.0325
100	0.9715	4.0648
200	1.0254	4.2903
salinity, 6%		
0	0.9198	3.8484
20	0.9257	3.8731
50	0.9313	3.8966
100	0.9387	3.9275
200	0.9833	4.1141
salinity, 9%		
0	0.8874	3.7129
20	0.8944	3.7422
50	0.9009	3.7694
100	0.9079	3.7987
200	0.9450	3.9539
salinity, 12%		
0	0.8637	3.6137
20	0.8670	3.6275
50	0.8729	2.6522
100	0.8791	3.6782
200	0.9096	3.8058

[104]

SHOE, LEATHER; solid; ultimate analysis in percent by weight; carbon, 42.01%; hydrogen, 5.32%; oxygen, 22.83%; nitrogen, 5.98%; sulfur, 1.00%; ash, 22.86%; proximate analysis as received in percent by weight; moisture, 7.46%; volatile matter, 57.12%; fixed carbon, 14.26%; ash, 21.16%.

gross heat of combustion: assume values refer to room temperature.

(as received)

$q_v(\text{gross}) = 4027 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 16847 \text{ J g}^{-1}$

(dry basis)

$q_v(\text{gross}) = 4351 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 18203 \text{ J g}^{-1}$

[62]

STEEL, ALLOY, NPL NO. 19; solid; composition: carbon, 0.315%; silicon, 0.20%; manganese, 0.69%; sulfur, 0.036%; phosphorous, 0.039%; chromium, 1.09%; nickel, 0.073%; molybdenum, 0.012%; copper, 0.066%; aluminum, 0.005%; arsenic, 0.028%; remainder is iron; annealed at 860 °C; density, 7.842 g cm^{-3} at 15 °C.

specific heat:

Temperature (°C)	Cp(cal g^{-1} K^{-1})	Cp(J g^{-1} K^{-1})
50	0.1153	.4824
127	0.1232	.5155
217	0.1277	.5343
316	0.1354	.5665
409	0.1471	.6155

[103]

STEEL, STAINLESS 347; solid; nickel, 11.1%; chromium, 18.3%; manganese, 1.30%; silicon, 0.52%; carbon, 0.08%; remainder is iron.

specific heat:

0 to 900 °C

$\text{Cp(cal g}^{-1}\text{ K}^{-1}) = 0.1158 + 3.41 \times 10^{-5}\,T - 4.04\,T^{-1}$
$\text{Cp(J g}^{-1}\text{ K}^{-1}) = 0.4845 + 1.427 \times 10^{-4}\,T - 16.90\,T^{-1}$

[97]

STEEL, STAINLESS, 446; solid; nickel, 0.32%; chromium, 25.58%; manganese, 0.42%; silicon, 0.68%; carbon, 0.23%; remainder is iron.

specific heat:

0 to 500 °C

$$Cp(cal\ g^{-1}\ K^{-1}) = 0.0785 + 1.074 \times 10^{-4}\ T$$
$$Cp(J\ g^{-1}\ K^{-1}) = 0.3284 + 4.494 \times 10^{-4}\ T$$

600 to 900 °C

$$Cp(cal\ g^{-1}\ K^{-1}) = 0.1618 + 2209 \times 10^{-0.0078(T-273.2)}$$
$$Cp(J\ g^{-1}\ K^{-1}) = 0.6770 + 9242 \times 10^{-0.0078(T-273.2)}$$

[97]

STEEL, STAINLESS; solid; En-58C (sample 1): Cr 17.7%; Ni 10.9%; Mn 1.73%; En-58B (sample 2): Cr 17.8%; Ni 8.05%; Mn 1.21%.

specific heat:

Sample 1 (En-58C)

60 - 190 K

$$Cp(cal\ g^{-1}\ K^{-1}) = -0.04976 + 1.7309 \times 10^{-3}\ T - 6.980 \times 10^{-6}\ T^2 + 1.043 \times 10^{-8}\ T^3$$
$$Cp(J\ g^{-1}\ K^{-1}) = -0.20819 + 7.2421 \times 10^{-3}\ T - 2.9206 \times 10^{-5}\ T^2 + 4.364 \times 10^{-8}\ T^3$$

190 - 320 K

$$Cp(cal\ g^{-1}\ K^{-1}) = 0.00635 + 8.4104 \times 10^{-4}\ T - 2.323 \times 10^{-6}\ T^2 + 2.377 \times 10^{-9}\ T^3$$
$$Cp(J\ g^{-1}\ K^{-1}) = 0.02658 + 3.5189 \times 10^{-3}\ T - 9.721 \times 10^{-6}\ T^2 + 9.946 \times 10^{-9}\ T^3$$

Sample 2 (En-58B)

60 - 190 K

$$Cp(cal\ g^{-1}\ K^{-1}) = -0.04950 + 1.6893 \times 10^{-3}\ T - 6.596 \times 10^{-6}\ T^2 + 9.449 \times 10^{-9}\ T^3$$
$$Cp(J\ g^{-1}\ K^{-1}) = -0.20711 + 7.0680 \times 10^{-3}\ T - 2.7598 \times 10^{-5}\ T^2 + 3.9535 \times 10^{-8}\ T^3$$

190 - 320 K

$$Cp(cal\ g^{-1}\ K^{-1}) = -0.00345 + 9.5756 \times 10^{-4}\ T - 2.802 \times 10^{-6}\ T^2 + 3.032 \times 10^{-9}\ T^3$$
$$Cp(J\ g^{-1}\ K^{-1}) = -0.01443 + 4.0064 \times 10^{-3}\ T - 1.1725 \times 10^{-5}\ T^2 + 1.2686 \times 10^{-8}\ T^3$$

[13]

SULFITE LIQUOR, SPENT; aqueous; calcium and magnesium base waste liquor from pulping of wood by sulfite process; gaseous sulfur dioxide, 2-4%; aqueous sulfite, 2-7%; aqueous sulfate, 2-5%; solids, 80-90%; also lignin sulfonate, Ca and Mg compounds, and carbohydrates.

gross heat of combustion: assume value refers to room temperature.

55% solids non-neutralized spent liquor

$q_v(\text{gross}) = 4500 - 4650 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 18800 - 19500 \text{ J g}^{-1}$

fermented and stripped liquor

$q_v(\text{gross}) = 4700 - 4875 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 19700 - 20400 \text{ J g}^{-1}$

[37]

TANNIN EXTRACT, CHESTNUT; solid; dry powder obtained from concentrated solution produced from treatment of chestnut chips with water.

specific heat:

25 °C

$Cp(\text{cal g}^{-1} \text{ K}^{-1}) = 0.2889$
$Cp(\text{J g}^{-1} \text{ K}^{-1}) = 1.2088$

[78]

TANNIN EXTRACT, QUEBRACHO; solid; dry extract from a wood-derived tannin; tannin obtained from Aspidosperma Quebracho and Quebracho Lorentzi imported as logs from Argentina.

specific heat:

25 °C

$Cp(\text{cal g}^{-1} \text{ K}^{-1}) = 0.3152$
$Cp(\text{J g}^{-1} \text{ K}^{-1}) = 1.3188$

[78]

TIRE; solid; typical compounding formulae for passenger tire treads.

	Natural rubber	SBR cis-polybutadiene*
Smoked sheet	57.6%	-
SBR 1712	-	46.8%
cis-Polybutadiene	-	11.3
Reogen	1.2	-
K-Stay G	-	2.3
Stearic acid	1.4	0.9
Zinc oxide	2	1.4
Agerite resin D	0.9	0.7
Agerite HP	0.3	0.2
Antozite 67S	2.3	1.8
Microcrystalline wax	0.6	0.5
Philrich 5	2.9	3.2
HAF	28.8	-
ISAF	-	29.5
Sulfur	1.4	0.8
Amax No. 1	0.3	-
Amax	-	0.7
Redax	0.3	-

*SBR is styrene-butadiene rubber

gross heat of decomposition: at 375 °C the mean value is for random samples of black-sidewall tire tread; products are a liquid distillate with a heat of combustion $q_v = 4 \times 10^4$ J g^{-1} (1×10^4 cal g^{-1}) and a combustible gas.

q_v(gross) = 0.7×10^2 cal g^{-1}
q_v(gross) = 3×10^2 J g^{-1}

gross heat of combustion: value for the tire residue remaining after heating to 1000 °C.

q_v(gross) = 0.780×10^4 cal g^{-1}
q_v(gross) = 3.264×10^4 J g^{-1}

[71]

TOPAZ; solid, an aluminum fluorosilicate occuring in igneous rocks and pegmatites, often found in association with tin ores; $Al_2SiO_4(F,OH)_2$; natural colorless orthorhombic crystals.

specific heat:

Temperature, K	Cp(cal g^{-1} K^{-1})	Cp(J g^{-1} K^{-1})
80	0.022	0.092
100	0.043	0.180
200	0.126	0.527
300	0.185	0.774
400	0.217	0.908

[119]

VACUUM CLEANER CATCH; solid; Ultimate analysis on dry basis in percent by weight; carbon, 35.69%; hydrogen, 4.73%; oxygen, 20.08%; nitrogen, 6.26%; sulfur, 1.15%; ash, 32.09%; proximate analysis as received in percent by weight; moisture, 5.47%; volatile matter, 55.68%; fixed carbon, 8.51%; ash, 30.34%.

gross heat of combustion: assume values refer to room temperature.

(as received)

q_v(gross) = 3550 cal g^{-1}
q_v(gross) = 14854 J g^{-1}

(dry basis)

q_v(gross) = 3756 cal g^{-1}
q_v(gross) = 15714 cal g^{-1}

[62]

VASELINE; solid; semi-solid mixture of hydrocarbons having a melting point range from 38 to 60 °C; colorless or pale yellow petroleum jelly.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 11050 cal g^{-1}
q_v(gross) = 46233 J g^{-1}

[112]

WAX, PARAFFIN; solid; hard wax, freezing point 53-55 °C; density 0.902 g cm^{-3}; repeating unit: CH_2.

gross heat of combustion: 25 °C

q_v(gross) = 11049 cal g^{-1}
q_v(gross) = 46229 J g^{-1}

[27]

WOOD

ASH; *Fraxinus excelsior*; solid; Ultimate analysis: carbon, 49.18%; hydrogen, 6.27%; nitrogen, 0.07%; ash, 0.57%.

gross heat of combustion: 20 °C; air dried at 110 - 115 °C, ash free.

q_v(gross) = 4726 cal g^{-1}
q_v(gross) = 19774 J g^{-1}

[89]

ASH, WHITE; Fraxinus americana; solid; air dried at 105 - 110 °C; density 0.63 g cm^{-3}.

specific heat:

0 - 106 °C

Cp(cal g^{-1} K^{-1}) = 0.327
Cp(J g^{-1} K^{-1}) = 1.368

[139]

ASPEN, QUAKING; Populus tremuloides Michx; solid; air dried at 105 - 110 °C, density 0.42 g cm^{-3}.

specific heat:

0 - 106 °C

Cp(cal g^{-1} K^{-1}) = 0.329
Cp(J g^{-1} K^{-1}) = 1.377

[139]

BEECH; Fagus silvatiea; solid; Ultimate analysis: carbon, 49.06%; hydrogen, 6.11%; nitrogen, 0.09%; ash, 0.57%.

gross heat of combustion: 20 °C, air dried at 110 - 115 °C, ash free.

q_v(gross) = 4791 cal g^{-1}
q_v(gross) = 20046 J g^{-1}

[89]

BEECH; Fagus atropunicea (Marsh) Sudworth; solid; air dried at 105 - 110 °C; density 0.75 g cm^{-3}.

specific heat:

0 - 106 °C

Cp(cal g^{-1} K^{-1}) = 0.326
Cp(J g^{-1} K^{-1}) = 1.364

[139]

WOOD

BIRCH; Betula alba; solid; Ultimate analysis: carbon, 48.88%; hydrogen, 6.06%; nitrogen, 0.10%; ash, 0.29%.

gross heat of combustion: 20 °C, air dried at 110 - 115 °C, ash free.

$q_v(\text{gross}) = 4775 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 19979 \text{ J g}^{-1}$

[89]

species not identified: 10.18% moisture.

$q_v(\text{gross}) = 4224 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 17672 \text{ J g}^{-1}$

air dried one hour at 105 °C

$q_v(\text{gross}) = 4703 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 19677 \text{ J g}^{-1}$

[88]

CEDAR, RED; Juniperus virginiana L.; solid; air dried at 105 - 110 °C; density 0.46 g cm^{-3}.

specific heat:

0 - 106 °C

$Cp(\text{cal g}^{-1} \text{ K}^{-1}) = 0.324$
$Cp(\text{J g}^{-1} \text{ K}^{-1}) = 1.356$

[139]

CHERRY; solid; genus Prunus.

gross heat of combustion: assume values refer to room temperature.

as received: 8.85% moisture.

$q_v(\text{gross}) = 4370 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 18282 \text{ J g}^{-1}$

air dried one hour at 105 °C

$q_v(\text{gross}) = 4794 \text{ cal g}^{-1}$
$q_v(\text{gross}) = 20058 \text{ J g}^{-1}$

[88]

CHESTNUT; Castanea dentata (Marsh) Borkh; solid; air dried at 105 - 110 °C; density 0.32 g cm^{-3}.

specific heat:

0 - 106 °C

$Cp(cal\ g^{-1}\ K^{-1}) = 0.317$
$Cp(J\ g^{-1}\ K^{-1}) = 1.326$

[139]

COCOBOLA NEGRA; Lecythis costariconsis Pittier; solid; from Costa Rica; air dried at 105 - 110 °C; density 0.92 g cm^{-3}.

Specific heat:

0 - 106 °C

$Cp(cal\ g^{-1}\ K^{-1}) = 0.327$
$Cp(J\ g^{-1}\ K^{-1}) = 1.368$

[139]

ELM, WHITE; Ulmus americana L.; solid; air dried at 105 - 110 °C; density 0.64 g cm^{-1}.

specific heat:

0 - 106 °C

$Cp(cal\ g^{-1}\ K^{-1}) = 0.325$
$Cp(J\ g^{-1}\ K^{-1}) = 1.360$

[139]

FIR; Pinus silvestri S.; solid; Ultimate analysis: carbon, 50.36%; hydrogen, 5.92%; nitrogen, 0.05%; ash, 0.28%.

gross heat of combustion: 20 °C; air dried at 110 - 115 °C, ash free.

$q_v(gross) = 5038\ cal\ g^{-1}$
$q_v(gross) = 21079\ J\ g^{-1}$

[89]

FIR, DOUGLAS; Pseudotsuga taxifolia (Lam.) Britt; solid; air dried at 105 - 110 °C, density 0.48 gm cm^{-3}.

$Cp(cal\ g^{-1}\ K^{-1}) = 0.327$
$Cp(J\ g^{-1}\ K^{-1}) = 1.368$

[139]

WOOD

GUM, BLACK; *Nyssa sylvatica Marsh*; solid; air dried at 105 - 110 °C; density 0.52 g cm^{-3}.

specific heat:

0 - 106 °C

$Cp(cal\ g^{-1}\ K^{-1}) = 0.325$
$Cp(J\ g^{-1}\ K^{-1}) = 1.360$

[139]

HEMLOCK, WESTERN; *Tsuga heterophylla (Raf.) Sargent*; solid; air dried at 105 - 110 °C; density 0.45 g cm^{-3}.

specific heat:

0 - 106 °C

$Cp(cal\ g^{-1}\ K^{-1}) = 0.322$
$Cp(J\ g^{-1}\ K^{-1}) = 1.347$

[139]

gross heat of combustion: assume values refer to room temperature; air dried.

$q_v(gross) = 4792\ cal\ g^{-1}$
$q_v(gross) = 20050\ J\ g^{-1}$

[84,85]

HICKORY; solid; genus *Carya*.

gross heat of combustion: assume values refer to room temperature.

as received: 10.30% moisture.

$q_v(gross) = 4213\ cal\ g^{-1}$
$q_v(gross) = 17626\ J\ g^{-1}$

air dried one hour at 105 °C.

$q_v(gross) = 4697\ cal\ g^{-1}$
$q_v(gross) = 19652\ J\ g^{-1}$

[88]

HORNBEAM; *Carpinus betulus*; solid; Ultimate analysis: carbon, 48.99%; hydrogen, 6.20%; nitrogen, 0.06%; ash, 0.50%.

gross heat of combustion: 20 °C, air dried 110 - 115 °C, ash free.

$q_v(gross) = 4742\ cal\ g^{-1}$
$q_v(gross) = 19841\ J\ g^{-1}$

[89]

MAI CHAMPAH; Michelia; solid; from Thailand; air dried at 105 - 110 °C; density 0.32 g cm^{-3}.

specific heat:

0 - 106 °C

$Cp(cal\ g^{-1}\ K^{-1}) = 0.323$
$Cp(J\ g^{-1}\ K^{-1}) = 1.351$

[139]

MAPLE; solid; Ultimate analysis: carbon, 50.40%; hydrogen, 5.90%; oxygen, 39.10%; nitrogen, 0.50%; sulfur, 0.0%; ash, 4.10%; proximate analysis as received in percent by weight; moisture, 0.0%; volatile matter, 76.1%; fixed carbon, 19.6%; ash, 4.3%; genus, Acer.

gross heat of combustion: assume values refer to room temperature.

$q_v(gross) = 4553\ cal\ g^{-1}$
$q_v(gross) = 19050\ J\ g^{-1}$

[84, 85]

MAPLE, SUGAR; Acer saccharum Marsh; solid; air dried at 105 - 110 °C; density 0.66 g cm^{-3}.

specific heat:

0 - 106 °C

$Cp(cal\ g^{-1}\ K^{-1}) = 0.327$
$Cp(J\ g^{-1}\ K^{-1}) = 1.368$

[139]

OAK; Quereus pedunculata; Ultimate analysis: solid; carbon, 50.16%; hydrogen, 6.02%; nitrogen, 0.09%; ash, 0.37%.

gross heat of combustion: 20 °C; air dried at 110 - 115 °C; ash free.

$q_v(gross) = 4609\ cal\ g^{-1}$
$q_v(gross) = 19284\ J\ g^{-1}$

species not identified; room temperature; air dried one hour at 105 °C.

$q_v(gross) = 4756\ cal\ g^{-1}$
$q_v(gross) = 19899\ J\ g^{-1}$

[88]

WOOD

OAK, RED; Quercus rubra (L); solid; air dried at 105 - 110 °C, density 0.62 g cm^{-3}

specific heat:

0 - 106 °C

$Cp(cal\ g^{-1}\ K^{-1}) = 0.331$
$Cp(J\ g^{-1}\ K^{-1}) = 1.385$

[139]

OAK, WHITE; Quercus alba (L); solid; air dried at 105 - 110 °C, density 0.78 g cm^{-3}.

specific heat:

0 - 106 °C

$Cp(cal\ g^{-1}\ K^{-1}) = 0.325$
$Cp(J\ g^{-1}\ K^{-1}) = 1.360$

[139]

PINE, LOBLOLLY; Pinus taeda L.; solid; unextracted specific gravity, 0.49 (oven dry weight and green volume).

specific heat: 60 - 140 °C; samples were oven-dried at 100 °C for 12 hours before measurements were made.

$Cp(cal\ g^{-1}\ K^{-1}) = 0.01153 + 9.497 \times 10^{-4}\ T$
$Cp(J\ g^{-1}\ K^{-1}) = 0.04824 + 3.9735 \times 10^{-3}\ T$

[82]

PINE, LOBLOLLY (Pinus taeda L.), EXTRACTIVES; solid; residue obtained from alcohol-benzene extraction of loblolly pine wood; mean extractive content, 6.08% [81].

specific heat: 60 - 140 °C; samples were oven-dried at 100 °C for 12 hours before measurements were made.

$Cp(cal\ g^{-1}\ K^{-1}) = 0.06945 + 1.09 \times 10^{-3}\ T$
$Cp(J\ g^{-1}\ K^{-1}) = 0.29058 + 4.56 \times 10^{-3}\ T$

[83]

PINE, LONGLEAF; Pinus palustris Mill; solid; air dried at 105 - 110 °C, density 0.68 g cm^{-3}.

specific heat:

0 - 106 °C

$Cp(cal\ g^{-1}\ K^{-1}) = 0.337$
$Cp(J\ g^{-1}\ K^{-1}) = 1.410$

[139]

PINE, PONDEROSA; *Pinus ponderosa*; solid; samples were conditioned to moisture equilibrium at 80 °F and 30% relative humidity; moisture content of wood ∿6%.

gross heat of combustion: assume values refer to room temperature.

q_v(gross) = 4626 ± 38 cal g^{-1}
q_v(gross) = 19355 ± 159 J g^{-1}

[86,87]

PINE, WHITE; *Pinus strobus L.*; solid; air-dried at 105 - 110 °C; density 0.25 g cm^{-3}.

specific heat:

0 - 106 °C

Cp(cal g^{-1} K^{-1}) = 0.331
Cp(J g^{-1} K^{-1}) = 1.385

[139]

sawdust; proximate analysis, as delivered: moisture, 7.0%; volatile matter, 78.76%; fixed carbon, 14.10%; ash, 0.14%.

gross heat of combustion: air dried; assume values refer to room temperature.

q_v(gross) = 4592 cal g^{-1}
q_v(gross) = 19213 J g^{-1}

[84,85]

POPLAR; solid; genus *Populus*.

gross heat of combustion: assume values refer to room temperature.

as received:

10.69% H_2O

q_v(gross) = 4290 cal g^{-1}
q_v(gross) = 17948 J g^{-1}

air-dried one hour at 105 °C.

q_v(gross) = 4803 cal g^{-1}
q_v(gross) = 20096 J g^{-1}

[88]

SPRUCE, BALSAM; Abies Lasiocarpa; solid; Ultimate analysis: carbon, 51.41%; hydrogen, 6.41%; nitrogen, 1.44%; sulfur, 0.19%; ash, 3.07%; moisture, 3.67%; proximate analysis as received: moisture, 74.35%; volatile matter, 20.20%; fixed carbon, 4.13%; ash, 0.82%.

gross heat of combustion: assume values refer to room temperature.

air-dried at 80 °C:

q_v(gross) = 5304 cal g^{-1}
q_v(gross) = 22191 J g^{-1}

as received:

q_v(gross) = 1360 cal g^{-1}
q_v(gross) = 5692 J g^{-1}

[84]

SPRUCE, NORWAY; Pinus abies; solid; carbon, 50.31%; hydrogen, 6.20%; nitrogen, 0.04%; ash, 0.37%.

gross heat of combustion: at 20 °C; air-dried at 110 - 115 °C; ash free.

q_v(gross) = 5093 cal g^{-1}
q_v(gross) = 21309 J g^{-1}

[89]

SPRUCE, RED; Picea rubens Sargent; solid; air-dried at 105 - 110 °C; density 0.39 g cm^{-3}.

specific heat:

0 - 106 °C

Cp(cal g^{-1} K^{-1}) = 0.332
Cp(J g^{-1} K^{-1}) = 1.389

[139]

SPRUCE PINE; Pinus glabra Walt.; solid; samples were dried for 8 hours in a vacuum oven at 103 °C.

specific heat:

60 to 140 °C

Cp(cal g^{-1} K^{-1}) = $-0.0091 + 1.004 \times 10^{-3}$ T
Cp(J g^{-1} K^{-1}) = $-0.0389 + 4.201 \times 10^{-3}$ T

[94]

WOOD

SPRUCE PINE, BARK; Pinus glabra Walt.; solid; bark specimens oven-dried at 152 °C.

specific heat:

60 to 140 °C

$$Cp(cal\ g^{-1}\ K^{-1}) = 0.7859 - 3.0645 \times 10^{-3}\ T + 5.137 \times 10^{-6}\ T^2$$
$$Cp(J\ g^{-1}\ K^{-1}) = 3.2882 - 1.2822 \times 10^{-2}\ T + 2.1493 \times 10^{-5}\ T^2$$

[94]

WOOL; solid; staple fibers obtained from the fleece of sheep (and also alpaca, vicuna, and certain goats); protein chains (Keratin) bound together by disulfide cross linkages; chief amino acids: cysteine and cystine, 15%; glutamic acid, 16%; arginine, 10%; proline, 8%; leucine, 8%; sulfur content of wool sample, 3.5%.

gross heat of combustion: assume values refer to room temperature; dry basis, sulfur product aqueous H_2SO_4.

$$q_v(gross) = 5499\ cal\ g^{-1}$$
$$q_v(gross) = 23008\ J\ g^{-1}$$

[117]

WOOL ACETATE; solid; salt formed from reaction of wool with acetic acid; 0.30% acetate.

gross heat of combustion: assume values refer to room temperature; sulfur product aqueous H_2SO_4.

$$q_v(gross) = 5490\ cal\ g^{-1}$$
$$q_v(gross) = 22970\ J\ g^{-1}$$

[117]

WOOL β-NAPHTHALENE SULFONATE; solid; salt formed from reaction of wool with β-naphthalenesulfonic acid; 19.9% β-naphthalenesulfonate.

gross heat of combustion: assume values refer to room temperature; sulfur product aqueous H_2SO_4.

$$q_v(gross) = 5482\ cal\ g^{-1}$$
$$q_v(gross) = 22937\ J\ g^{-1}$$

WOOL OXALATE; solid; salt formed from reaction of wool with oxalic acid; 2.22% oxalate.

gross heat of combustion: assume values refer to room temperature; sulfur product aqueous H_2SO_4.

$$q_v(gross) = 5360\ cal\ g^{-1}$$
$$q_v(gross) = 22426\ J\ g^{-1}$$

[117]

__WOOL PICRATE__; solid; salt formed from reaction of wool with picric acid; 18.4% picrate.

__gross heat of combustion__: assume values refer to room temperature; sulfur product aqueous H_2SO_4.

q_v(gross) = 5043 cal g^{-1}
q_v(gross) = 21100 J g^{-1}

[117]

__WOOL SULFATE__; solid; salt formed from reaction of wool with sulfuric acid, 2.21% sulfate.

__gross heat of combustion__: assume values refer to room temperature, sulfur product aqueous H_2SO_4.

q_v(gross) = 5347 cal g^{-1}
q_v(gross) = 22372 J g^{-1}

[117]

__WOOL p-TOLUENESULFONATE__; solid; salt formed from reaction of wool with p-toluenesulfonic acid; 6.6% p-toluenesulfonate.

__gross heat of combustion__: assume values refer to room temperature; sulfur product aqueous H_2SO_4.

q_v(gross) = 5458 cal g^{-1}
q_v(gross) = 22836 J g^{-1}

__ZEOLITE, SILVER A__; solid; synthetic ion-exchange resin; hydrated aluminum silicates containing alkali or alkaline earth metals; 90% Ag^+ relative to Na^+.

__specific heat__: at 310 K; nearly all water eliminated by heating in N_2 at 500 °C.

Cp(cal g^{-1} K^{-1}) = 0.205
Cp(J g^{-1} K^{-1}) = 0.858

[96]

__ZEOLITE, SODIUM A__; solid; synthetic ion-exchange resin; hydrated aluminum silicates containing alkali or alkaline earth metals.

__specific heat__: at 310 K; nearly all water eliminated by heating in N_2 at 500 °C.

Cp(cal g^{-1} K^{-1}) = 0.227
Cp(J g^{-1} K^{-1}) = 0.950

[96]

REFERENCES

(1) Bunting, J. G., Ashworth, T., and Steeple, H., Cryogenics 9, 385-386 (1969).

(2) 1968 Book of ASTM Standards with Related Material, Part 17, Petroleum Products, Standard Method for Estimation of Net Heat of Combustion of Aviation Fuels ASTM Designation D1405-64. (published by ASTM, 1916 Race Street, Philadelphia, PA. 19103).

(3) Mazur, J., and Zacharko, W., Acta Phys. Polon. 32, 501-514 (1967).

(4) Jessup, R. S., and Prosen, E. J., J. Research NBS 44, 387-393 (1950).

(5) Decker, L. J., Ward, J. R., and Freedman, E., Thermochim. Acta 8, 177-183 (1974).

(6) Good, W. D., and Scott, D. W., Chapter 2, "Combustion in a Bomb of Organic Fluorine Compounds", in Experimental Thermochemistry, Vol. 2, H. A. Skinner, Ed., (Interscience Publishers, New York, London 1962).

(7) Gardos, M., Rev. Sci. Instrum. 43, 1679-1687 (1972).

(8) Robie, R. A., Hemingway, B. S., and Wilson, W. H., Science 167, 749-750 (1970); see also Proceedings of the Apollo 11 Lunar Science Conference, Geochim. Cosmoschim. Acta, Suppl. 1, 3, 2361-2367.

(9) Merill, A. L., and Watts, B. K., Agriculture Handbook No. 74 (U. S. Government Printing Office, Washington, D. C., 1955) 105 pp; taken from: Atwater, W. O., and Bryant, A. P., The Availability and Fuel Value of Food Materials, Conn. (Storrs) Agr. Expt. Station, 12th Ann. Rept. (1899), pp. 73-110.

(10) Gattow, G., and Krebs, B., Z. Anorg. Allgem. Chem. 322, 113-128 (1963).

(11) "Water and Aqueous Solutions Structure, Thermodynamics, and Transport Processes.", R. A. Horne, Ed, (John Wiley and Sons, New York, 1972).

(12) Bromley, L. A., J. Chem. Eng. Data 13, 399-402 (1968).

(13) Martin, J. F., J. Iron Steel Inst. 204, 56 (1966).

(14) Campbell, A. N., and van der Kouwe, E. T., Can. J. Chem. 46, 1287-1291 (1968).

(15) Ward, J. R., AIAA J. 12, 107-108 (1974).

(16) Apollo 11, Prelim. Science Rept., NASA SP-214, 132 (1969).

(17) Apollo 15, Prelim. Science Rept., NASA SP-289, 6-17 (1972).

(18) Haggerty, J. S., Cooper, A. R., and Heasley, J. H., Phys. Chem. Glasses 9, 47-51 (1968).

(19) Emery, A. G., and Benedict, F. G., Am. J. Physiol. 28, 301-307 (1911).

(20) Berthelot, M. P. E., and Vieille, P., Ann. chim. et phys. [6] 10, 455-463 (1887).

(21) Karrer, P., and Fioroni, W., Helv. Chim. Acta 6, 396-401 (1923).

(22) Kozina, M. P., and Skuratov, S. M., Doklady Akad. Nauk SSSR 127, 561-563 (1959).

(23) Kachinskaya, O. N., Vestn. Mosk. Univ., Ser. Mat. Mekh. Astron. Fiz. Khim. 12, 227-234 (1957).

(24) Good, W. D., Lacina, J. L., and McCullough, J. P., J. Am. Chem. Soc. 82, 5589-5591 (1960).

(25) Joshi, R. M., and Zwolinski, B. J., Macromolecule 1, 25-30 (1968).

(26) Jessup, R. S., and Cummings, A. D., J. Research NBS 13, 357-369 (1934).

(27) Magnus, A., Z. physik. Chem. [N.F.] 9, 141-161 (1956).

(28) Ivin, K. J., Keith, W. A., and Mackle, H., Trans. Faraday Soc. 55, 262-267 (1959).

(29) Parks, G. S., and Mosley, J. R., J. Chem. Phys. 17, 691-694 (1949).

(30) Parks, G. S., and Mosher, H. P., J. Polymer Sci. (A) 1, (6), 1979-1984 (1963).

(31) Sinke, G. C., and Stull, D. R., J. Phys. Chem. 62, 397-401 (1958).

(32) Good, W. D., Lacina, J. L., DePrater, B. L., and McCullough, J. P., J. Phys. Chem. 68, 579-586 (1964).

(33) Marx, P., Smith, C. W., Worthington, A. E., and Dole, M., J. Phys. Chem. 59, 1015-1019 (1955).

(34) Wilhoit, R. C., and Dole, M., J. Phys. Chem. 57, 14-21 (1953).

(35) Thais, R. R., and Kohn, J. P., J. Chem. Eng. Data 9, 546-547 (1964).

(36) Breitenbach, J. W., Terkosch, J., and Wessely, F., Monatsh. Chem. 83, 591-598 (1952).

(37) Hulden, B., Proc. Symp. Recovery Pulping Chem., 1st, 387-405 (1968); (published 1969).

(38) Fisher, R. A., Brodale, G. E., Hornung, E. W., and Giauque, W. F., Rev. Sci. Instr. 39, 108-114 (1968).

(39) Giauque, W. F., Fisher, R. A., Hornung, E. W., and Brodale, G. E., J. Chem. Phys. 58, 2621-2637 (1973).

(40) Splitstone, P. L., and Johnson, W. H., J. Research NBS 78A, 611-616 (1974).

(41) Chang, S. S., and Bestul, A. B., J. Research NBS 77A, 395-405 (1973).

(42) Chang, S. S., J. Research NBS 78A, 387-400 (1974).

(43) Gucker, F. T., Jr., and Ford, W. L., J. Am. Chem. Soc. 60, 2563 (1938).

(44) Perry, E. S., and Weber, W. H., J. Am. Chem. Soc. 71, 3726-3730 (1949).

(45) Perry, E. S., Weber, W. H., and Daubert, B. F., J. Am. Chem. Soc. 71, 3720-3726 (1949).

(46) Clark, P. E., Waldeland, C. R., and Cross, R. P., Ind. Eng. Chem. 38, 350-356 (1946).

(47) Poole, H., "The Calorific Power of Fuels", rewritten by R. T. Kent, 3rd Edition (John Wiley and Sons, Inc., New York, 1918).

(48) Lord, N. W., et al., "Analysis of Coals in the United States, Part 1 - Analysis", U. S. Bureau of Mines Bulletin 22 (U. S. Government Printing Office, Washington, D. C., 1915).

(49) Halsam, R. T., and Russell, R. P., "Fuels and their Combustion", Chapter III. (McGraw-Hill Book Co., Inc., New York, 1926).

(50) White, A. H., and Barker, P., "Coals available for the Manufacture of Illuminating Gas", U. S. Bureau of Mines Bulletin 6, (U. S. Government Printing Office, Washington, D. C., 1911).

(51) Fernald, R. H., "Notes on the Uses of Low-Grade Fuel in Europe", U. S. Bureau of Mines Technical Paper 123 (U. S. Government Printing Office, Washington, D. C., 1915).

(52) "Technical Data on Fuel", H. M. Spiers, Ed., Fifth Edition (The Brit. Nat. Committee, World Power Conf., London, 1955).

(53) Davis, C. A., "The Uses of Peat", U. S. Bureau of Mines Bulletin 16 (U. S. Government Printing Office, Washington, D. C., 1911).

(54) Wisely, F. E., Sutterfield, G. W., and Klumb, D. L., Proceedings of the Fourth Mineral Waste Utilization Symposium, E. Aleshin (co-sponsored by the U. S. Bureau of Mines and the IIT Research Institute) May 7, 8 (1974), Chicago, Ill., pp. 191-195.

(55) Yamada, T., Nippon Nogei Kagaku Kaishi, 44, 587-590 (1970).

(56) Mason, D. M., and Eakin, B. E., Inst. Gas Technol., Research Bull. No. 32 18 pp. (1961).

(57) Rastogi, R. P., Kishore, K., and Singh, G., AIAA J. 12, 9-10 (1974).

(58) Rastogi, R. P., Kishore, K., and Singh, G., Thermochim. Acta 12, 89-96 (1975).

(59) Herlet, A., and Reich, G., Z. Angew. Phys. 9, 14-23 (1957).

(60) Franz, J., Mische, W., and Kuzay, P., Plaste Kautsch. 14, 472-476 (1967).

(61) Bliss, L. C., Ecology 43, 753-757 (1962).

(62) Kaiser, E. R., Proceedings of the 1966 National Incinerator Conference, ASME, 84-88 (1966).

(63) Duca, W. J., Trans Am. Foundrymen's Soc. 81, 108-109 (1973).

(64) Lewis, D. C., Frisch, M. A., and Margrave, J. L., Carbon 2, 431-432 (1965).

(65) Zoller, P., Decker, P. R., and Dillinger, J. R., J. Appl. Phys. 40, 1964-1966 (1969).

(66) Loewen, E. G., Trans. ASME 78, 667-670 (1956).

(67) Deighton, M., J. Iron Steel Inst. 208, 1012-1014 (1970).

(68) Matwejew, G. M., Agarkow, A. S., and Kerbe, F., Silikattechnik 18, 324-326 (1967).

(69) Wun, M., and Phillips, N. E., Cryogenics 36-37 (1975).

(70) Kreitman, M. M., Advan. Cryog. Eng. 16, 51-53 (1970).

(71) Collins, L. W., Downs, W. R., Gibson, E. K., and Moore, G. W., Thermochim. Acta 10, 153-159 (1974).

(72) Setchkin, N. P., J. Research NBS 53, 49-66 (1954).

(73) Paine, R. T., Ann. Rev. Ecological Systems 2, 145-164 (1971).

(74) Mansson, M., Rapport, N., and Westrum, E. F., Jr., J. Am. Chem. Soc. 92, 7296-7299 (1970).

(75) Slobodkin, L. B., and Richman, S., Nature 191, 299 (1961).

(76) Abramova, L. T., Abramov, V. G., and Merzhanov, A. G., Russ. J. Phys. Chem. 43, 647-650 (1969).

(77) Engineering Design Handbook, Explosive Series, Properties of Explosives of Military Interest, U. S. Army Material Command Pamphlet (AMCP) 706-177, January, 1971.

(78) Kanagy, J. R., J. Research NBS 55, 191-195 (1955).

(79) Marklund, K., Bystrom, S., Larsson, M., and Lindqvist, T., Cryogenics 13, 671-672 (1973).

(80) Eldridge, E. A., and Deem, H. W., U. S. AEC BMI 1803, 17 pp. (1967).

(81) McMillin, C. W., Wood Sci. and Technol. 2, 233,-240 (1968).

(82) McMillin, C. W., Wood Sci. 2, 107-111 (1969).

(83) McMillin, C. W., Wood Sci. 3, 52-53 (1970).

(84) Kaiser, E. R., and Friedman, S. B., Combustion, 31-36, May, 1968.

(85) "Combustion Engineering", Fryling, G. R., Ed., rev. ed., Chapter 27, p. 3, (Combustion Eng. Inc., New York, 1966).

(86) Roberts, A. F., Combust. Flame 11, 437-441 (1967).

(87) Browne, F. L., U. S. Dept. Agri, Forest Service Res. Paper FPL-19, 16 pp. Dec. 1964.

(88) Parr, S. W., and Davidson, C. N., J. Ind. Eng. Chem. 14, 935-936 (1922).

(89) Gottlieb, E., J. prakt. Chem. 28, 385-421 (1883).

(90) Tavernier, P., and Lamouroux, M., Mem. poudres 39, 335-356 (1957).

(91) Ponomarev, V. V., Russ. J. Phys. Chem. 40, 600-601 (1966).

(92) Suzuki, H., and Koyama, M., Cryogenics 15, 38-39 (1975).

(93) Koch, P., Wood Sci. 1, 203-214 (1969).

(94) "Asphalt Science and Technology", E. J. Barth (Gordon and Breash, Science Publishers, New York and London, 1962).

(95) Saal, R., Heukelom, W., and Blokker, P., J. Inst. Petroleum 26, (No. 195), 29-39 (1940).

(96) Vucelic, D., Vucelic, V., and Juranic, N., J. Thermal Anal. 5, 459-463 (1972).

(97) Douglas, T. B., and Dever, J. L., J. Research NBS 54, 15-19 (1955).

(98) Lenoir, J. M., and Hipkin, H. G., J. Chem. Eng. Data 18, 195-202 (1973).

(99) Scanes, F. S., and Martin, R. A. M., Combust. Flame 23, 357-362 (1974).

(100) Bowring, R. W., Garton, D. A., and Norris, H. F., Atomic Energy Establishment, Winfrith, Dorchester (Great Britain) AEEW-R-38, 23 pp. (1960).

(101) Rydholm, S. A., Pulp and Paper Mag. Canada, T2-T15. Jan. 1967.

(102) Gullichsen, J., Proc. Sym. Recovery of Pulping Chemicals, Helsinki 221-225 (1968).

(103) Martin, W. H., and Rixon, J., J. Sci. Instruments 36, 179-182 (1959).

(104) Bromley, L. A., Diamond, A. E., Salami, E., and Wilkins, D. G., J. Chem. Eng. Data 15, 246-253 (1970).

(105) Domalski, E. S., and Armstrong, G. T., J. Research NBS 71A, 105-117 (1967).

(106) Furukawa, G. T., McCoskey, R. E., and King., G. J., J. Research NBS 49, 273-278 (1952).

(107) Suurkuusk, J., and Wadso, I., J. Chem. Thermodynamics 6, 667-679 (1974).

(108) Furukawa, G. T., and McCoskey, R. E., J. Research NBS 51, 321-326 (1953).

(109) Persson, A., Ark. Fys. 23, 229-234 (1963).

(110) Westrum, E. F., Jr., Chien Chow, Osborne, D. W., and Flotow, H. E., Cryogenics 7, 43-44 (1967).

(111) Karrer, P., and Fioroni, W., Ber. deut. chem. Ges. 55B, 2854-2863 (1922).

(112) Roth, W. A., and Becker, F., "Kalorimetrisohe Methoden zur Bestimmung Chemischer Reaktionswarmen" p. 75 (F. Vieweg & Sohn, Braunschweig, 1956).

(113) Boyd, C. E., Ecology 51, 902-906 (1970).

(114) Aleksandrov, V. V., Buletov, N. S., Pastukhova, T. V., and Tukhaev, R. K., Fiz. Goreniya Vzryva 9, 75-83 (1973).

(115) Roth, W. A., and Wallasch, H., Ann. 407, 134-145 (1915).

(116) Berlin, E., Kliman, P. G., and Pallansch, M. J., Thermochim. Acta 4, 11-16 (1972).

(117) Päsler, W., and König, W., Z. angew. Chem. 44, 288-291, 304-309 (1931).

(118) Jaeger, F. M., and Rosenbohm, E., Rec. trav. chim. 47, 513-557 (1928).

(119) Romanova, M. V., Smirnov, I. A., and Tikhonov, V. V., Fiz. Tverd. Tela. 13, 1812-1814 (1971).

(120) Chang, S. S., and Bestul, A. B., J. Research NBS 77A, 395-405 (1973).

(121) Furukawa, G. T., McCoskey, R. E., and Reilly, M. L., J. Research NBS, 55, 127-132 (1955).

(122) Furukawa, G. T., McCoskey, R. E., and King, G. J., J. Research NBS 50, 357-365 (1953).

(123) Stroud, J. W., Ph.D. Thesis, Cornell University, (1961).

(124) Paladines, O. L., Reid, J. T., Bensadoun, A., and Van Niekerk, B. D. H., J. Nutrition 82, 145-149 (1964).

(125) Henning, O., and Strobel, U., Wiss. Z. Hochsch. Architekt. Bauw. Weimar. 17, 354-355 (1970).

(126) Chang, Y. A., and Hultgren, R., J. Chem. Eng. Data 12, 98-99 (1967).

(127) Bair, H. E., Soc. Plast. Eng. Annu. Tech. Conf. Tech. Pap. 28th 16, 115-117 (1970).

(128) Hutchens, J. O., Cole, A. G., and Stout, J. W., J. Biol. Chem. 244, 26-32 (1969).

(129) Downer, L., and Gardiner, K. E. S., J. Inst. Petroleum 58, 6-13 (1972).

(130) Cragoe, C. S., Bur. Standards Misc. Publ. No. 97, (1929).

(131) Stull, D. R., Westrum, E. F., Jr., and Sinke, G., "Thermodynamics of Organic Compounds" (J. Wiley and Sons, Inc., New York, 1969).

(132) Cox, J. D., and Pilcher, G., "Thermochemistry of Organic and Organometallic Compounds" (Academic Press, Inc., Publishers, New York and London, 1970).

(133) Ornellas, D. L., J. Phys. Chem. 72, 2390-2394 (1968).

(134) Wagman, D. D., Evans, W. H., Parker, V. B., Halow, I., Bailey, S. M., and Schumm, R. H., NBS Technical Note 270-3, (1968).

(135) Henkin, H., and McGill, R., Ind. Eng. Chem. 44, 1391-1395 (1952).

(136) Wagman, D. D., Evans, W. H., Parker, V. B., and Schumm, R. H., NBSIR 76-1034 (1976).

(137) Meier, A., and Meyerhof, O., Biochem. Z. 150, 233-252 (1924).

(138) Krien, G., Licht, H. H., and Zierath, J., Thermochim. Acta 6, 465-472 (1973).

(139) Dunlap, F., Forest Service, U. S. Department of Agriculture, Bull. 110, 28p. (1912).

(140) Backhurst, J. R., and Harker, J. H., Fuel 52, 302-303 (1973).

(141) ASME Research Committee on Industrial and Municipal Wastes, "Combustion Fundamentals for Waste Incineration," 212p. (American Society of Mechanical Engineers, New York, 1974).

(142) Dewey, P.H., Harper, D. R., J. Research NBS 21, 457-474 (1938).

APPENDIX

SYMBOLS FOR THERMODYNAMIC QUANTITIES

The symbols indicated in this Appendix are those adopted by the International Union of Pure and Applied Chemistry (IUPAC), 1969.

Symbols in parentheses are alternates, accepted but not recommended by IUPAC. Also indicated are other commonly used symbols and names of quantities not accepted by IUPAC.

Primary Symbols

- T — thermodynamic temperature (absolute temperature)
- t, θ — Celsius temperature
- R — molar gas constant
- k — Boltzmann constant
- q, Q — heat
- w, W — work
- U, (E) — internal energy
- H — enthalpy: $H = U + pV$
- S — entropy
- A — Helmholtz energy: $A = U - TS$
- J — Massieu function: $J = -A/T$
- G — Gibbs energy: $G = H - TS$

NOTE: The Gibbs energy is frequently called free energy, Gibbs free energy, or Gibbs function. The commonly encountered term free energy in American work on thermodynamics almost invariably refers to Gibbs energy. This usage of the term free energy and the symbol F are being discouraged by the IUPAC because of confusion with the Helmholtz energy and the common European usage of F for the latter.

- Y — Planck function: $Y = -G/T$
- Z — compressibility factor: $Z = pV/nRT$
- C — heat capacity
- c — specific heat capacity (heat capacity divided by mass)
- γ, (k) — heat capacity ratio: Cp/Cv
- μ — Joule-Thomson coefficient
- λ, k — thermal conductivity
- a — thermal diffusivity: $a = \lambda/\rho C_p$
- h — coefficient of heat transfer
- α — cubic expansion coefficient: $\alpha = (\partial V/\partial T)_p/V$
- k — isothermal compressibility: $k = -(\partial V/\partial p)_T/V$
- β — pressure coefficient: $\beta = (\partial p/\partial T)_V$
- μ_B — chemical potential of substance B
- λ_B — absolute activity of substance B: $\lambda_B = \exp(\mu_B/RT)$
- f, (p*) — fugacity
- Π — osmotic pressure
- I — ionic strength: $I = \frac{1}{2}\Sigma_i m_i z_i^2$ or $I = \frac{1}{2}\Sigma_i c_i z_i^2$
- a_B — activity, relative activity of substance B
- f_B — activity coefficient, mole fraction basis
- γ_B — activity coefficient, molality basis
- y_B — activity coefficient, concentration basis
- φ — osmotic coefficient

Selected Symbols for Other Quantities in Thermodynamics

- A, S — area
- V — volume
- t — time
- m — mass
- ρ — density (mass divided by volume)
- P — pressure
- A_r — relative atomic mass (also called "atomic weight")
- M_r — relative molecular mass (also called "molecular weight")

L, N_A	Avogadro constant
N	number of molecules
$n, (\nu)$	amount of substance
x_B, y_B	mole fraction of substance B: $x_B = n_B/\Sigma_i n_i$
w_B	mass fraction of substance B
ϕ_B	volume fraction of substance B
m_B	molality of solute substance B (amount of B divided by the mass of solvent)
c_B, [B]	concentration of substance B (amount of B divided by the volume of the solution)
ρ_B	mass concentration of substance B (mass of B divided by the volume of the solution)
ν_B	stoichiometric coefficient of substance B (negative for reactants, positive for products). (The general equation for a chemical reaction is - $\Sigma_B \nu_B B = 0$,· [Example: for the reaction $H_2O \rightarrow H_2 + \frac{1}{2}O_2$, $H_2 + \frac{1}{2}O_2 - H_2O = 0$]
ζ	extent of reaction: $(d\zeta = dn_b/\nu_B)$
K	equilibrium constant
α	degree of dissociation
z_B	charge number of an ion B (positive for cations, negative for anions)

UNITS OF MEASUREMENT - INTERNATIONAL SYSTEM (SI)

SI - BASE UNITS AND SUPPLEMENTARY UNITS

quantity	name of unit	symbol
length	metre	m
mass	kilogram	kg
time	second	s
temperature	kelvin	K
electric current	ampere	A
luminous intensity	candela	cd
amount of substance	mole	mol
plane angle	radian	rad
solid angle	steradian	sr

DEFINITIONS OF THE SI BASE UNITS

metre: The metre is the length equal to 1 650 763.73 wavelengths in vacuum of the radiation corresponding to the transition between the levels $2p_{10}$ and $5d_5$ of the krypton-86 atom.

kilogram: The kilogram is equal to the mass of the international prototype of the kilogram.

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.

kelvin: The kelvin is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water. The kelvin is used both for thermodynamic temperature and for thermodynamic temperature interval.

ampere: The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible cross section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length.

candela: The candela is the luminous intensity, in the perpendicular direction, of a surface of 1/600 000 square metre of a black body at the temperature of freezing platinum under a pressure of 101 325 newtons per square metre.

mole: The mole is the amount of substance of a system which contains as many elementary entities as there are carbon atoms in 0.012 kilogram of carbon-12.

NOTE: The elementary entities must be specified and may be atoms, molecules, ions, electrons, other particles, or specified groups of such particles.

PREFIXES

SI Symbol	Prefix name	Multiplication factor
T	tera	10^{12}
G	giga	10^{9}
M	mega	10^{6}
k	kilo	10^{3}
h	hecto	10^{+2}
da	deka	10^{+1}
d	deci	10^{-1}
c	centi	10^{-2}
m	milli	10^{-3}
μ	micro	10^{-6}
n	nano	10^{-9}
p	pico	10^{-12}
f	femto	10^{-15}
a	atto	10^{-18}

OTHER UNITS EXACTLY DEFINED IN TERMS OF SI UNITS (PARTIAL LISTING)

Quantity	Name	Symbol	Definition
length	inch	in.	2.54×10^{-2} m
mass	pound (av.)	lb	0.453 592 37 kg
force	kilogram force	kgf	9.806 65 N
pressure	atmosphere	atm	$101\ 325\ N \cdot m^{-2}$
pressure	torr	Torr	$(101\ 325/760)\ N \cdot m^{-2}$
pressure	millimetre of mercury	mmHg	$13.5951 \times 980.665 \times 10^{-2} N \cdot m^{-2}$
energy	kilowatt-hour	kWh	3.6×10^6 J
energy	thermochemical calorie***	cal_{th}	4.184 J
energy	IT calorie**	cal_{IT}	4.1868 J
energy	IT British thermal unit**	Btu_{IT}	1055.06 J*
temperature (thermodynamic)	degree Rankine	°R	5/9 K****
temperature	degree Celsius	°C	K*****
temperature	degree Fahrenheit	°F	5/9 K******
volume	litre	l	10^{-3} m^3

* The exact relationship is: 1 Btu_{IT} = (4.1868/1.8) x 453.59237

** IT refers to International Tables (International Steam Tables).

*** The thermochemical calorie is used in tables in this monograph.

**** [T(°R) = 1.8T(K)]; [T(°R) = t(°F) + 459.67]; [T(°R) = 1.8t(°C) + 491.67].

***** [t(°C) = T(K) - 273.15].

****** [t(°F) = 1.8t(°C) + 32].

Auxiliary Conversion Factors

$1\ J\ g^{-1} = 0.429923\ Btu_{IT}\ (lb)^{-1}$

$1\ cal_{IT}\ g^{-1} = 1.8\ Btu_{IT}\ (lb)^{-1}$

PHYSICAL CONSTANTS

The physical constants indicated below are excerpted from a list recommended by the National Bureau of Standards. The complete list is found in National Bureau of Standards Technical News Bulletin, October, 1963.

±Error limits are approximately 3 standard deviations and apply to last digits of the value.

A more recent list of constants differing by small amounts from the above values, is under consideration by the Task Group on Fundamental Constants of the Committee on Data for Science and Technology (International Council on Scientific Unions). The new values are not significantly different from those with which this handbook was prepared. (See NBS Special Publications 344, March, 1971.)

PHYSICAL CONSTANTS

Constant	Symbol	Value	Error Limit		Units (SI)
Speed of light in vacuum	c	2.997 925	3	x 10^8	$m \cdot s^{-1}$
Elementary charge	e	1.602 10	7	10^{19}	C
Avogadro constant	N_A	6.022 52	28	10^{23}	mol^{-1}
Electron rest mass	m_e	9.109 1	4	10^{-31}	kg
Proton rest mass	m_p	1.672 52	8	10^{-27}	kg
Neutron rest mass	m_n	1.674 82	8	10^{-27}	kg
Faraday constant	F	9.648 70	16	10^4	mol^{-1}
Planck constant	h	6.625 6	5	10^{-34}	$J \cdot s$
Rydberg constant	R_∞	1.097 373 1	3	10^{-11}	m^{-1}
Bohr radius	a_o	5.291 67	7	10^{-11}	m
Electron radius	r_e	2.817 77	11	10^{-15}	m
Gas constant	R	8.314 3	12	10^0	$J \cdot K^{-1} \cdot mol^{-1}$
Normal volume perfect gas	V_o	2.241 36	30	10^{-2}	$m^3 \cdot mol^{-1}$
Boltzmann constant	k	1.380 54	18	10^{-23}	$J \cdot K^{-1}$
First radiation constant	c_1	3.741 5	3	10^{-16}	$W \cdot m^2$
Second radiation constant	c_2	1.438 79	19	10^{-2}	$m \cdot K$
Wien displacement constant	b	2.897 8	4	10^{-3}	$m \cdot K$
Stefan-Boltzmann constant	σ	5.669 7	29	10^{-8}	$W \cdot m^{-2} \quad K^{-4}$
Energy associated with -					
Electron volt	eV	1.602 10	7	10^{-19}	$J \cdot (eV)^{-1}$
Frequency (electromagnetic)	e/h	2.418 04	7	10^{14}	$Hz \cdot (eV)^{-1}$
Wavelength (electromagnetic)	ch/e	1.239 81	4	10^{-6}	$eV \cdot m$
Wave number	e/ch	8.065 73	23	10^5	$m^{-1} \cdot (eV)^{-1}$
Kelvin	e/k	1.160 49	16	10^4	$K \cdot (eV)^{-1}$

SI DERIVED UNITS (PARTIAL LISTING)

		Symbol for SI unit	Definition of SI unit	Other Definitions
force	newton	N	$m \cdot kg \cdot s^{-2}$	
pressure	pascal	Pa	$m^{-1} \cdot kg \cdot s^{-2}$	$N \cdot m^{-2}$
energy	joule	J	$m^2 \cdot kg \cdot s^{-2}$	$N \cdot m$
power	watt	W	$m^2 \cdot kg \cdot s^{-3}$	$J \cdot s^{-1}$
electric charge	coulomb	C	$A \cdot s$	
electric potential difference	volt	V	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$	$W \cdot A^{-1}$
electric resistance	ohm	Ω	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$	$V \cdot A^{-1}$
electric conductance	siemens	S	$m^{-2} \cdot kg^{-1} \cdot s^3 \cdot A^2$	$A \cdot V^{-1}$
electric capacitance	farad	F	$m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$	$C \cdot V^{-1}$
magnetic flux	weber	Wb	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$	$V \cdot s$
inductance	henry	H	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-2}$	$Wb \cdot A^{-1}$
magnetic flux density	tesla	T	$kg \cdot s^{-2} \cdot A^{-1}$	$Wb \cdot m^{-2}$
luminous flux	lumen	lm	$cd \cdot sr$	
illumination	lux	lx	$m^{-2} \cdot cd \cdot sr$	
frequency	hertz	Hz	s^{-1}	

ATOMIC WEIGHTS

The atomic weights indicated below are those used in calculation of formula weights of the substances listed in the table. Since the data were calculated more recent tables of atomic weights (Pure and Applied Chemistry 21, 91-108 (1970); 30, 639-649 (1972); 37, 591-603 (1974); 47, 75-95 (1976) have been recommended by the Commission on Atomic Weights of the International Union of Pure and Applied Chemistry (IUPAC). The changes which occur as a result of the new atomic weights are not significant for the purposes for which this handbook was prepared, and so no changes have been made in the tables. This keeps the values consistent with those in "Combustion Fundamentals for Waste Incineration" [141].

Elements and their new atomic weights, which occur most prominently in the tables of thermodynamic data contained in this report, are: carbon, 12.011; and hydrogen, 1.0080. Of lesser importance are: sulfur, 32.06; bromine, 79.904; iodine, 126.9045, and boron, 10.81. Minor changes have also been made in the atomic weights of certain metals.

ATOMIC WEIGHTS (RELATIVE ATOMIC MASSES) OF THE ELEMENTS (1961)

Name	Symbol	Atomic number	Atomic Weight
Actinium	Ac	89	....
Aluminum	Al	13	26.9815
Americium	Am	95	....
Antimony	Sb	51	121.75
Argon	Ar	18	39.948
Arsenic	As	33	74.9216
Astatine	At	85	....
Barium	Ba	56	137.34
Berkelium	Bk	97	....
Beryllium	Be	4	9.0122
Bismuth	Bi	83	208.980
Boron	B	5	10.811
Bromine	Br	35	79.909
Cadmium	Cd	48	112.40
Calcium	Ca	20	40.08
Californium	Cf	98	....
Carbon	C	6	12.01115
Cerium	Ce	.58	140.12
Cesium	Cs	55	132.905
Chlorine	Cl	17	35.453
Chromium	Cr	24	51.996
Cobalt	Co	27	58.9332
Copper	Cu	29	63.54
Curium	Cm	96	....
Dysprosium	Dy	66	162.50
Einsteinium	Es	99	....
Erbium	Er	68	167.26
Europium	Eu	63	151.96
Fermium	Fm	100	....
Fluorine	F	9	18.9984
Francium	Fr	87	....
Gadolinium	Gd	64	157.25
Gallium	Ga	31	69.72
Germanium	Ge	32	72.59
Gold	Au	79	196.967
Hafnium	Hf	72	178.49
Helium	He	2	4.0026
Holmium	Ho	67	164.930
Hydrogen	H	1	1.00797
Indium	In	49	114.82
Iodine	I	53	126.9044
Iridium	Ir	77	192.2
Iron	Fe	26	55.847
Krypton	Kr	36	83.80
Lanthanum	La	57	138.91
Lead	Pb	82	207.19
Lithium	Li	3	6.939
Lutetium	Lu	71	174.97
Magnesium	Mg	12	24.312
Manganese	Mn	25	54.9380
Mendelevium	Md	101	....
Mercury	Hg	80	200.59
Molybdenum	Mo	42	95.94
Neodymium	Nd	60	144.24
Neon	Ne	10	20.183
Neptunium	Np	93	....
Nickel	Ni	28	58.71
Niobium	Nb	41	92.906
Nitrogen	N	7	14.0067
Nobelium	No	102	....
Osmium	Os	76	190.2
Oxygen	O	8	15.9994
Palladium	Pd	46	106.4
Phosphorus	P	15	30.9738
Platinum	Pt	78	195.09
Plutonium	Pu	94	....
Polonium	Po	84	....
Potassium	K	19	39.102
Praseodymium	Pr	59	140.907
Promethium	Pm	61	....
Protactinium	Pa	91	....
Radium	Ra	88	....
Radon	Rn	86	....
Rhenium	Re	75	186.2
Rhodium	Rh	45	102.905
Rubidium	Rb	37	85.47
Ruthenium	Ru	44	101.07
Samarium	Sm	62	150.35
Scandium	Sc	21	44.956
Selenium	Se	34	78.96
Silicon	Si	14	28.086
Silver	Ag	47	107.870
Sodium	Na	11	22.9898
Strontium	Sr	38	87.62
Sulfur	S	16	32.064
Tantalum	Ta	73	180.948
Technetium	Tc	43	....

Name	Symbol	Atomic number	Atomic Weight
Tellurium	Te	52	127.60
Terbium	Tb	65	158.924
Thallium	Tl	81	204.37
Thorium	Th	90	232.038
Thulium	Tm	69	168.934
Tin	Sn	50	118.69
Titanium	Ti	22	47.90
Tungsten	W	74	183.85
Uranium	U	92	238.03
Vanadium	V	23	50.942
Xenon	Xe	54	131.30
Ytterbium	Yb	70	173.04
Yttrium	Y	39	88.905
Zinc	Zn	30	65.37
Zirconium	Zr	40	91.22

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15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

A table of thermodynamic data of 331 selected materials has been compiled for the purpose of providing engineers with information on materials which are not easily identifiable by a stoichiometric formula. Examples of such materials are: foods, wood species, oils, animals, plants, polymers, etc. The table is arranged alphabetically according to the names of the various materials, and whenever possible, the chief components or all readily identifiable components are supplied. In addition, the physical state, the kind of thermodynamic property, specific-property values, and citations to a list of 142 references are furnished. In order to assist the reader with finding a specific material or property, a material name and property index has been put together. A section on Units and Definitions explains the various thermodynamic properties being reported and the condition under which they apply. An appendix supplies auxiliary information on symbols for thermodynamic quantities, units, physical constants and atomic weights.

The table is oriented more toward engineers involved in the disposal of municipal wastes than any other group; however, applications in other engineering and scientific sectors can easily be made.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Heat of combustion; heat of explosion; miscellaneous materials; specific heat; vapor pressure.

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