NATIONAL BUREAU OF STANDARDS REPORT

8992

FIFTH PRELIMINARY REPORT ON A SURVEY OF

THERMODYNAMIC PROPERTIES OF THE COMPOUNDS OF THE ELEMENTS CHNOPS

Progress Report for the Period 1 July to 30 September 1965

to

National Aeronautics and Space Administration

1 October 1965

NBS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards is a principal focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. Its responsibilities include development and maintenance of the national standards of measurement, and the provisions of means for making measurements consistent with those standards; determination of physical constants and properties of materials; development of methods for testing materials, mechanisms, and structures, and making such tests as may be necessary, particularly for government agencies; cooperation in the establishment of standard practices for incorporation in codes and specifications; advisory service to government agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; assistance to industry, business, and consumers in the development and acceptance of commercial standards and simplified trade practice recommendations; administration of programs in cooperation with United States business groups and standards organizations for the development of international standards of practice; and maintenance of a clearinghouse for the collection and dissemination of scientific, technical, and engineering information. The scope of the Bureau's activities is suggested in the following listing of its four Institutes and their organizational units.

Institute for Basic Standards. Applied Mathematics. Electricity. Metrology. Mechanics. Heat. Atomic Physics. Physical Chemistry. Laboratory Astrophysics.* Radiation Physics. Radio Standards Laboratory:* Radio Standards Physics; Radio Standards Engineering. Office of Standard Reference Data.

Institute for Materials Research. Analytical Chemistry. Polymers. Metallurgy. Inorganic Materials. Reactor Radiations. Cryogenics.* Materials Evaluation Laboratory. Office of Standard Reference Materials.

Institute for Applied Technology. Building Research. Information Technology. Performance Test Development. Electronic Instrumentation. Textile and Apparel Technology Center. Technical Analysis. Office of Weights and Measures. Office of Engineering Standards. Office of Invention and Innovation. Office of Technical Resources. Clearinghouse for Federal Scientific and Technical Information.**

Central Radio Propagation Laboratory.* Ionospheric Telecommunications. Tropospheric Telecommunications. Space Environment Forecasting. Aeronomy.

---

* Located at Boulder, Colorado 80301.

** Located at 5285 Port Royal Road, Springfield, Virginia 22171.

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT 1 October 1965 **NBS REPORT**

221-11-0429 8992

A SURVEY OF

THERMODYNAMIC PROPERTIES OF THE COMPOUNDS OF THE ELEMENTS CHNOPS

Mary K. Buresh, Martin L. Reilly, George T. Furukawa, and George T. Armstrong

Heat Division, Institute for Basic Standards

Progress Report for the Period 1 July to 30 September 1965

to

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Contract No. R-138, Amendment-1

U. S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

Table of Contents

FOREWORD

A study at the National Bureau of Standards (NBS), of which this is the fifth progress report, has been undertaken to meet the need of the National Aeronautics and Space Administration (NASA) for thermodynamic information on biologically related materials important to the space program for several reasons. Among these reasons are the necessity of inferring the maximum amount of useful chemistry of incompletely accessible environments, for which only limited information is available, the possibility of the occurrence of organic compounds naturally synthesized under primitive conditions, and the possibility of theoretically recovering part of the prebiological history of the earth.

This program is being carried out under the technical supervision of Dr. George Jacobs of NASA, and with the consultation of Dr. Harold Morowitz of the Yale University, Department of Molecular Biology and Biophysics, and Dr. C. W. Beckett of the Heat Division, Institute for Basic Standards (NBS). The contract (Contract No. R-138) was initiated 1 May 1964 and extended 29 April 1965. The program was extended by Amendment 1 for an additional year, beginning 1 July 1965. This report covers the first quarter of the extended contract.

George T. Armstrong

George T. Armstrong
Supervisory Chemist
Project Leader

Introduction

The survey of thermodynamic data on the compounds of the elements C-H-N-O-P-S which had been in progress for a year at the beginning of the quarter for which this report is written, had not yet provided a complete survey of the thermodynamic data available, and is being continued for an additional year. On September 1, a meeting for review and planning for work in this area was held at the NASA Headquarters. A brief, informal memorandum outlining the activity at the meeting is attached for information as Appendix I.

Most of the work which was carried on during the first year of the program was summarized and tabulated in NBS Reports 8521, 8591, 8641 and 8906. The current work underway in this quarter has not yet resulted in any completed new reviews. The partially completed literature reviews of the heat capacity data on several important compounds of the group of interest are outlined in the section beginning on page 2.

Literature Survey and Analysis of Low-Temperature Heat-Capacity Data on CHNOPS Compounds

Mary K. Buresh, Martin L. Reilly and George T. Furukawa

Analysis of heat-capacity data on the following substances has been in progress:

urea, cyanogen, glycylglycine, alanylglycine, leucylglycine, hippuric acid, hippurylglycine, creatine, creatine hydrate, creatinine, guanidine carbonate, hypoxanthine, xanthine, uric acid, adenine, guanine, allantoin, alloxan, and taurine.

It is expected that the analysis on most of the above substances will be completed during the next quarter.

A systematic compilation of a bibliography on heat-capacity data of ammonia, carbon dioxide, and water is being made. The literature data examined thus far are listed in the following section. The list is probably 30 percent complete.

Notations used to indicate the type of data found, experimental conditions, physical state of the substance, etc. are defined as follows:

c	=	crystalline phase
(C)	=	calculated from spectroscopic and molecular data
(cal)	=	calculated from calorimetric data obtained on the condensed phases, heat of vaporization, and compression, and adjusted for non-ideality of the gas
(emf)	=	calculated from emf measurements on chemical cells and other data
(eq)	=	calculated from chemical equilibrium data
g	=	gas phase
ℓ	=	liquid phase
(R)	=	review
(satd)	=	under saturation pressures corresponding to temperature T
tc	=	heat capacity
tc-	=	mean heat capacity over a broad range of temperature
tcj	=	heat capacity at constant volume
tck	=	ratio of the heat capacity, C_p/C_v
th	=	enthalpy (relative)

Literature Survey of Heat-Capacity, Enthalpy, and Entropy Data on Ammonia, Carbon Dioxide, and Water

Ammonia, NH_3, 17.03061

Physical State	Year Published	Type of Data and Temperature Range	Entropy at 298.15°K cal/deg-mol	References
g	1862	tc-, 293-468		[97]
c	1904	tc-, 85-170		[25]
c	1905	tc-, 85-170		[26]
c	1905	tc-, 85-170		[27]
ℓ,g	1913	th, 230-364 (7.43-761.4 lb/in^2)		[47]
g	1915	tc-, 492-878		[52]
ℓ	1916	th, 228-255 (R)		[64]
g	1916	th, 228-255 (R)		[64]
ℓ	1917	tc, 227-319		[87],[89]
ℓ	1918	tc, 227-319		[88]
ℓ,g	1920	tc, 303-398		[5]
c,ℓ	1924	tc, 25-221		[35]
ℓ (satd)	1925	tc, 240-323 (0-20 atm)		[23]
g	1925	tc, 193-288 (20-76 mm)		[40]
g	1925	tc, 240-423 (0-20 atm)		[23]
g	1925	tc, 258-423 (376-15,106 mm Hg)		[86]
g	1926	tc, 273-1273 (eq.)		[106]
g	1929	tc, 273-1200 (C)		[80]
c,ℓ,g	1932	tc, 10-298 (R)	47.2 ±1.0 (g) (R)	[62]
c,ℓ	1937	tc, 15-238	45.94(g)(cal)(C) S(g,239.68) = 44.13 (cal) S(g,239.68) = 44.10 (C)	[90]
g	1938	tc, 273-3273 (C)		[57]

NH_3 (Cont'd)

Physical State	Year Published	Type of Data and Temperature Range	Entropy at 298.15°K cal/deg-mol	References
g	1939	tc, 273-423 (C)		[53]
g	1939		46.034 (g)(C)	[118]
g	1952	tc, 298 (C)	46.01 (g)(C)	[98]
soln	1952		26.3 (aq)(eq.) (1 molal)	[98]
g	1954	tc, 273-1500 (R) th, 273-1500 (R)	46.03 (g) (R)	[66]
g	1954	tc, 300-600 (R)		[75]
g	1959	th, 300-6000 (C)	S(g,300) = 46.0629 (C)	[74]
g	1960	th, 400-2000 (C)		[63]

Carbon Dioxide, CO_2, 44.01015

Physical State	Year Published	Type of Data and Temperature Range	Entropy at 298.15°K cal/deg-mol	References
g	1862	tc-, 243-483		[97]
c	1904	tc-, 85-195		[25]
c	1905	tc-, 85-195		[26]
c	1905	tc-, 85-195		[27]
g	1909	tc, 293-373		[119]
ℓ	1913	tc-, 223-293		[56]
g	1913	tc-, 243-309 (138-824 lbs/sq.in)		[56]
g	1915	tc-, 492-878		[52]
c	1916	tc, 19-201		[32]
g	1919	tc, 195-293		[54]
g	1921	tck, 290		[91]
g	1922	tc-, 1273-2273 (C)		[125]
g	1925	tc, 291 (0.5-1 atm)		[40]
g	1925		52.19 (g)(C)(cal)	[4]
g	1925		49.55 (g)(eq)	[4]
c,ℓ	1926	th, 90-298		[72]
g	1926	tc, 300-3000 (eq)		[106]
g	1927	tc, 288-1273		[107]
c,ℓ	1928	tc, 80-320		[34]
g	1929	tc, 276-301		[13]
g	1929	tc-, 273-1273		[18]
g	1929	tc, 273-2800 (C)		[80]
g	1929	tc-, 3173 (50-150 atm)		[81]
g	1930	tc, 288-1473		[65]
g	1931	tc-, 273-1315		[19]
c,g	1932	tc, 10-298 (R)	50.0 ±2.0 (g)(R)	[62]

CO_2 (Cont'd)

Physical State	Year Published	Type of Data and Temperature Range	Entropy at 298.15°K cal/deg-mol	References
g	1932	tc, 300-1200 (C)	S(g,300)=51.19 (C)	[51]
g	1932	tc-, 690-871 (5.8-8.6 atm)		[36]
g	1932		51.07(g) (C)	[6]
g	1933		51.09(g) (C)	[48]
c	1934	th, 300-3500 (C) tc, 300-3500 (C)		[60]
g	1935	tc, 273-3273 (C)		[58]
g	1936	tck, 273-1273 (C) tcj, 273-1273 (C)		[105]
c	1937	tc, 16-190	51.11(g) (cal)(C) S(g,194.67) = 47.59 (cal) S(g,194.67) = 47.55 (C)	[43]
g	1937	tcj, 298-398 (amagat density 1-600)		[78]
g	1938	tc, 273-3273 (C)		[57]
g	1945	th, 298-3500 (C) tc, 298-3500 (C)	51.061(g) (C)	[124]
g	1950	th, 500-5000 (C) tc, 500-5000 (C)	S°(g,500)=56.113 (C)	[59]
g	1952	tc, 243-363 (0.5-1.5 atm)		[76]
g	1952	tc, 298 (C)	51.061(g) (C)	[98]
soln	1952		29.0(aq)(eq) (1 molal)	[98]
g	1954	tc, 50-5000 (C)	S°(g,300)=51.1066 (C)	[126]
g	1954	tc, 250-1500 (R)		[75]
g	1955	tc, 200-1500 (C) (0.01-100 atm) th, 200-1500 (C) (0.01-100 atm)	S(g,300)=51.102 (C)	[55]
g	1959	th, 300-6000 (C)	S(g,300)=51.1225 (C)	[74]

CO_2 (Cont'd)

Physical State	Year Published	Type of Data and Temperature Range	Entropy at 298.15°K cal/deg-mol	References
g	1959	th, 423-923 (R) (0-200 atm)		[71]
g	1960	th, 291-322 (1050-1200 p.s.i.a.)		[68]
g	1960	th, 298 (R)	51.10(g) (R)	[21]
g	1960	th, 400-5000 (C)		[63]
g	1962	th, 313-1273 (C) (1-1400 bars)	S(g,313)=51.488 (C) (1 bar)	[101]

Water, H_2O, 18.01534

Physical State	Year Published	Type of Data and Temperature Range	Entropy at 298.15°K cal/deg-mol	References
c	1845	single value no temp. range		[24]
g	1862	tc-, 283-489		[97]
c	1864	tc-, 195-273 (R)		[67]
ℓ	1871	tc, 373		[16]
ℓ	1900	tc, 278-368		[7]
ℓ	1902	tc-, 268-293		[9]
ℓ	1902	tc, 278-368		[8]
c	1904	tc-, 21-291		[25]
c	1905	tc-, 21-255		[26]
c	1905	tc-, 21-255		[27]
c	1911	tc, 83-266		[79]
ℓ	1911	tc, 273-353		[15]
c	1913	tc, 22-87		[92]
c	1915	tc-, 227-273		[30]
ℓ	1915	tc, 272-311		[28]
ℓ	1917	tc-, 286-328		[14]
ℓ (tap water)	1917	tc-, 286-327		[14]
g	1922	tc-, 1273-2273 (C)		[125]
c	1925	th, 90-290		[73]
g	1927	tc, 373-1273 (C)		[107]
ℓ	1928		15.92 ±0.02(ℓ) (R)	[69]
g	1929	tc, 273-2800 (C)		[80]
g	1929	tc-, 289-3000 (C) (50-150 atm)		[81]
c	1930	tc, 195-270		[10]
c,ℓ	1930	tc, 195-298		[11]
ℓ (satd)	1930	th, 273-543		[82]
g (satd)	1930	th, 273-543		[82]

H_2O (Cont'd)

Physical State	Year Published	Type of Data and Temperature Range	Entropy at 298.15°K cal/deg-mol	References
c,ℓ	1932	tc, 10-298 (R)	15.9 ±0.1(ℓ) (R)	[62]
ℓ	1932		19.21(ℓ) (C)	[51]
g	1932	tc, 400-1200 (C)	S(g,1 atm,400) = 50.03 (C)	[51]
g(satd)	1932		S(g,satd,300) = 54.39 (C)	[51]
g	1933		45.26(g)(cal)	[42]
g	1933		45.17(g) (C)	[42]
g	1933		45.19(g) (emf)	[42]
g	1933		45.1(g) (eq)	[42]
g	1933		47.93(g) (C) (with nuclear spin)	[48]
g	1934	tc, 298-1500 (C)	45.101(g) (C)	[49]
g	1934	tc, 1500-3000 (C)	S(g,1500)=59.78 (C)	[50]
g	1935	tc, 273-3273 (C)		[58]
c	1936	tc, 16-268	44.28 ±0.05(g)(cal) (without residual entropy)	[44]
ℓ(satd)	1937	th, 373-747 (56-225 kg/cm^2)		[83]
g(satd)	1937	th, 373-747 (56-225 kg/cm^2)		[83]
g	1937		45.10(g) (C)	[41]
ℓ	1938	tc, 273-373 (R)		[99]
g	1938	tc, 273-3273 (C)		[57]
ℓ(satd)	1939	tc, 273-373		[84]
ℓ(satd)	1939	th, 273-373 (C)		[84]
ℓ(satd)	1939	th, 273-647 (R)		[85]
g(satd)	1939	th, 273-647 (R)		[85]
ℓ	1940	tc, 290-321		[20]
c	1941	tc, 6-10		[29]
c	1945	tc, 5.65-9.97		[31]

H_2O (Cont'd)

Physical State	Year Published	Type of Data and Temperature Range	Entropy at 298.15°K cal/deg-mol	References
g	1945	tc, 298-3000 (C) th, 298-3000 (C)	45.106(g) (C)	[124]
ℓ	1949	tc, 273-373 (R)		[33]
ℓ	1949	tc, 313-343		[70]
g	1950	tc, 500-5000 (C) th, 500-5000 (C)	S°(g,500) = 49.344 (C)	[59]
ℓ	1952	tc, 298 (R)	16.716(ℓ) (R)	[98]
g	1952	tc, 298 (C)	45.106(g) (C)	[98]
g	1952	tc, 362-487 (92-760 mm)		[77]
ℓ	1953	tc, 273-373 (R) th, 273-373 (R)		[46]
g	1953	tc, 373 (C)		[12]
g	1954	tc, 50-5000 (C)	S(g,300)=45.137 (C)	[38]
g	1954	tc, 400-3000 (R)		[75]
g	1955	tc, 50-1150 (C) (1-100 atm) th, 50-1150 (C) (1-100 atm)	S(g,300)=45.154 (C)	[55]
ℓ,g	1957	tc, 507-655		[2]
ℓ,g	1957	tc, 556-959 (300-500 kg/cm^2)		[94]
ℓ,g	1958	tc, 507-655		[1]
ℓ,g	1958	tc, 556-959 (300-500 kg/cm^2)		[93]
ℓ,g	1958	tc, 556-959 (300-500 kg/cm^2)		[95]
ℓ,g	1958	tc, 556-959 (300-500 kg/cm^2)		[96]
ℓ,g	1958	tc, 557-972 (550-700 kg/cm^2)		[122]
g	1958	tc, 50-5000 (C)		[108]
g(satd)	1958	tc, 443-643 (R) (8.076-214.68 kg/cm^2)		[102]

H_2O (Cont'd)

Physical State	Year Published	Type of Data and Temperature Range	Entropy at 298.15°K cal/deg-mol	References
g	1958	th, 473-1273 (R) (100-1000 atm)		[100]
g	1958	tc, 573-873 (20-500 kg/cm^2)		[61]
g	1958	tc, 587-827		[109]
g	1958	th, 720-823 (199.5-404.5 kg/cm^2)		[123]
c	1959	tc, 10-270 (R)	S(c,270)=8.99 (R)	[45]
ℓ	1959	tc, 273-519 (R)		[39]
ℓ	1959	tc, 293-573 (50-500 kg/cm^2)		[111]
ℓ,g	1959	tc, 285-774 (26-500 kg/cm^2)		[112]
g	1959	th, 300-6000 (C)	S(g,300)=45.1159 (C)	[74]
g	1959	tc, 373-923 (R) (1-700 kg/cm^2)		[103]
soln (sea water)	1959	tc, 275-304 (0-39.786 g/kg salinity)		[22]
c	1960	tc, 2-27		[37]
ℓ	1960	th, 350-373 (R)		[63]
ℓ,g (satd)	1960	tc, 273-613 (R) (0.006228-148.96 kg/cm^2)		[104]
ℓ,g	1960	tc, 273-613 (C)		[120]
ℓ,g	1960	tc, 285-774 (26-500 kg/cm^2)		[117]
g	1960	th, 298 (R)	45.11(g) (R)	[21]
g	1960	th, 400-5000 (C)		[63]
g	1960	th, 473-873 (5-225 kg/cm^2)		[17]
g	1960	tc, 613-773 (R) (293-500 kg/cm^2)		[116]
g	1960	tc, 736-872 (300-500 kg/cm^2)		[113]

H_2O (Cont'd)

Physical State	Year Published	Type of Data and Temperature Range	Entropy at 298.15°K cal/deg-mol	References
ℓ,g	1961	tc, 333-1273 (R) (0-1000 kg/cm^2)		[121]
ℓ,g	1962	tc, 323-725		[3]
ℓ,g	1962	tc, 578-775 (125-275 kg/cm^2)		[114]
g	1962	tc, 620-869 (60-225 kg/cm^2)		[115]
ℓ(satd)	1963	tc, 273-645 (0.006-215.63 x 10^5 n/m^2)		[110]
g(satd)	1963	tc, 273-645 (0.006-215.63 x 10^5 n/m^2)		[110]

REFERENCES

[1] Amirchanoff, Ch. J. and Kerimoff, A. M.,
Spezifische Wärme C_V von Wasser und Wasserdampf im kritischen Gebiet und in seiner Nähe,
Brennstoff-Wärme-Kraft 10, No. 7, 346 (1958).

[2] Amirkhanov, Kh. I. and Kerimov, A. M.,
Heat Capacity of Water and Water-Steam Near the Boundary Curve, Including the Critical Region,
Teploenergetika 4, No. 9, 68-72 (1957).

[3] Amirkhanov, Kh. I. and Kerimov, A. M.,
Experimental Investigation of the Heat Capacity of Water and Water Vapor from 50 to 450°C and Pressures of 1 to 1000 kg/cm^2,
Teploenergetika 9, No. 6, 72-78 (1962).

[4] Andrews, J. W.,
The Heat of Sublimation of Carbon Dioxide,
J. Am. Chem. Soc. 47, 1597-1602 (1925).

[5] Babcock, H. A.,
The Specific Heat of Ammonia,
Proc. Am. Acad. Arts Sci. 55, No. 8, 327-409 (1920).

[6] Badger, R. M. and Woo, S. C.,
The Entropies of Some Simple Polyatomic Gases Calculated from Spectral Data,
J. Am. Chem. Soc. 54, 3523-3529 (1932).

[7] Barnes, H. T.,
On the Capacity for Heat of Water between the Freezing and Boiling Points, together with a Determination of the Mechanical Equivalent of Heat in Terms of the International Electrical Units. Experiments by the Continuous-Flow Method of Calorimetry performed in the Macdonald Physical Laboratory of McGill University, Montreal,
Proc. Roy. Soc. 67, 238-245 (1900).

[8] Barnes, H. T.,
On the Capacity for Heat of Water between the Freezing and Boiling-Points, together with a Determination of the Mechanical Equivalent of Heat in Terms of the International Electrical Units. Experiments by the Continuous-Flow method of Calorimetry, performed in the Macdonald Physical Laboratory of McGill University, Montreal,
Phil. Trans. Roy. Soc. (London) 199A, 149-263 (1902).

[9] Barnes, H. T. and Cooke, H. L.,
On the Specific Heat of Supercooled Water,
Phys. Rev. [1] 15, No. 2, 65-72 (1902).

[10] Barnes, W. H. and Maass, O.,
A New Adiabatic Calorimeter,
Can. J. Res. 3, 70-79 (1930).

[11] Barnes, W. H. and Maass, O.,
Specific Heats and Latent Heat of Fusion of Ice,
Can. J. Res. 3, 205-213 (1930).

[12] Barrow, G. M.,
Vapor Heat Capacities Determined by the Use of Vapor Pressure Equations,
J. Chem. Phys. 21, No. 11, 1912-1913 (1953).

[13] Blackett, P. M. S., Henry, P. S. H., and Rideal, E. K.,
A Flow Method for Comparing the Specific Heats of Gases. Part I. The Experimental Method,
Proc. Roy. Soc. (London) 126A, 319-332 (1929-1930).

[14] Bousfield, W. R.,
Note on the Specific Heat of Water,
Proc. Roy. Soc. (London) 93A, 587-591 (1916-1917).

[15] Bousfield, W. R. and Bousfield, W. E.,
The Specific Heat of Water and the Mechanical Equivalent of the Calorie at Temperatures from 0°C. to 80°C.,
Phil. Trans. Roy. Soc. (London) 211A, 199-251 (1911).

[16] Bunsen, R.,
Calorimetric Researches,
Phil. Mag. [4] 41, 161-182 (1871).

[17] Callendar, G. S. and Egerton, A.,
An Experimental Study of the Enthalpy of Steam,
Phil. Trans. Roy. Soc. (London) 252A, 133-164 (1960).

[18] Chopin, M.,
Déterminations à température élevée de la chaleur spécifique de l'azote et de l'acide carbonique,
Compt. rend. 188, 1660-1662 (1929).

[19] Chopin, M.,
Nouvelle méthode de mesure de la température des gaz; Application a la détermination de leur chaleur spécifique aux températures élevées,
Ann. phys. 16, 101-149 (1931).

[20] Cockett, A. H. and Ferguson, A.,
The Specific Heat of Water and of Heavy Water,
Phil. Mag. [7] 29, 185-199 (1940).

[21] Corrêa da Silva, L. C.,
Fundamentos Termodinâmicos da Reducão dos Óxidos de Ferro,
ABM (Bol. Assoc. Brasil. Metais) (São Paulo) 16, No. 60,
617-640 (1960).

[22] Cox, R. A. and Smith, N. D.,
The Specific Heat of Sea Water,
Proc. Roy. Soc. (London) 252A, 51-62 (1959).

[23] Cragoe, C. S.,
Ratio of Specific Heats and Joule-Thomson Coefficient for Ammonia,
Refrig. Eng. 12, No. 5, 131-142 (1925).

[24] Desains, E.,
Ueber die specifische Wärme des Eises,
Ann. Physik. 65, 435-440 (1845).

[25] Dewar, J.,
Liquid Hydrogen Calorimetry,
Proc. Roy. Inst. (London) 17, 581-596 (1904).

[26] Dewar, J.,
Studies with the Liquid Hydrogen and Air Calorimeters,
Proc. Roy. Soc. (London) 76A, 325-340 (1905).

[27] Dewar, J.,
Studies with the Liquid Hydrogen and Air Calorimeters. I.
Specific Heats,
Chem. News 92, 181-184 (1905).

[28] Dickinson, H. C. and Osborne, N. S.,
An Aneroid Calorimeter,
Bull. Bur. Std. (U.S.) 12, 23-48 (1915).

[29] Duyckaerts, G.,
Chaleur spécifique de la glace de 5° à 10°K,
Bull. Soc. Roy. Sci. Liége 10, 111-118 (1941).

[30] Dickinson, H. C. and Osborne, N. S.,
Specific Heat and Heat of Fusion of Ice,
Bull. Bur. Std. (U.S.) 12, 49-81 (1915).

[31] Duyckaerts, G.,
Les mesures de chaleur spécifique de métaux et de sels aux très
basses températures en relation avec l'étude électronique des
corps cristallins,
Mem. Soc. Roy. Sci., Liége, 6, 193-329 (1945).

[32] Eucken, A.,
Über das thermische Verhalten einiger komprimierter und kondensierter Gase bei tiefen Temperaturen,
Ber. deut. physik. Ges. 18, 4-17 (1916).

[33] Eucken, A.,
Unterschiede zwischen den thermisch-kalorischen Eigenschaften des schweren und leichten Wassers,
Nachr. Akad. Wiss. Göttingen,
Math.-physik. Klasse, Biol.-physiol.-chem. Abt. 1949, No. 1, 11 pp. (1949).

[34] Eucken, A. and Hauck, F.,
Die spezifischen Wärmen Cp und C_V einiger Stoffe im festen, flüssigen und hyperkritischen Gebiet zwischen 80° und 320° abs.,
Z. physik. Chem. 134, 161-177 (1928).

[35] Eucken, A. and Karwat, E.,
Die Bestimmung des Wärmeinhaltes einiger kondensierter Gase,
Z. physik. Chem. 112, 467-485 (1924).

[36] Eucken, A. and Mücke, O.,
Die Bestimmung der wahren spezifischen Wärme einiger Gase bei hohen Temperaturen nach der Lummer-Pringsheimischen Methode,
Z. physik. Chem. 18B, No. 2/3, 167-188 (1932).

[37] Flubacher, P., Leadbetter, A. J., and Morrison, J. A.,
Heat Capacity of Ice at Low Temperatures,
J. Chem. Phys. 33, No. 6, 1751-1755 (1960).

[38] Friedman, A. S. and Haar, L.,
High-Speed Machine Computation of Ideal Gas Thermodynamic Functions. I. The Isotopic Water Molecules,
J. Chem. Phys. 22, No. 12, 2051-2058 (1954).

[39] Gambill, W. R.,
Physical Properties of Water,
Chem. Eng. 66, No. 7, 139-140, No. 10, 241 (1959).

[40] Giacomini, F. A.,
The Temperature Dependency of the Molecular Heats of Gases, especially of Ammonia, Methane, and Hydrogen, at Low Temperatures,
Phil. Mag. [6] 50, 146-156 (1925).

[41] Giauque, W. F. and Archibald, R. C.,
The Entropy of Water from the Third Law of Thermodynamics. The Dissociation Pressure and Calorimetric Heat of the Reaction $Mg(OH)_2 = MgO + H_2O$. The Heat Capacities of $Mg(OH)_2$ and MgO from 20 to 300°K.,
J. Am. Chem. Soc. 59, 561-569 (1937).

[42] Giauque, W. F. and Ashley, M. F.,
Molecular Rotation in Ice at 10°K. Free Energy of Formation and Entropy of Water,
Phys. Rev. 43, 81-82 (1933).

[43] Giauque, W. F. and Egan, C. J.,
Carbon Dioxide. The Heat Capacity and Vapor Pressure of the Solid. The Heat of Sublimation. Thermodynamic and Spectroscopic Values of the Entropy,
J. Chem. Phys. 5, 45-54 (1937).

[44] Giauque, W. F. and Stout, J. W.,
The Entropy of Water and the Third Law of Thermodynamics. The Heat Capacity of Ice from 15 to 273°K.,
J. Am. Chem. Soc. 58, 1144-1150 (1936).

[45] Giguère, P. A.,
On the Anomalous Thermodynamic Properties of Ice,
J. Phys. Chem. Solids 11, Nos. 3/4, 249-256 (1959).

[46] Ginnings, D. C. and Furukawa, G. T.,
Heat Capacity Standards for the Range 14 to 1200°K.,
J. Am. Chem. Soc. 75, 522-527 (1953).

[47] Goodenough, G. A. and Mosher, W. E.,
The Properties of Saturated and Superheated Ammonia Vapor,
Univ. Illinois Bull. 10, No. 18, 1-94 (1913), Bull. No. 66.

[48] Gordon, A. R.,
The Free Energy of Steam and of Carbon Dioxide,
J. Chem. Phys. 1, 308-312 (1933).

[49] Gordon, A. R.,
The Calculation of Thermodynamic Quantities from Spectroscopic Data for Polyatomic Molecules; the Free Energy, Entropy, and Heat Capacity of Steam,
J. Chem. Phys. 2, 65-72 (1934).

[50] Gordon, A. R.,
Thermodynamic Properties of Steam at High Temperatures,
J. Chem. Phys. 2, 549 (1934).

[51] Gordon, A. R. and Barnes, C.,
The Entropy of Steam, and the Water-Gas Reaction,
J. Phys. Chem. 36, 1143-1151 (1932).

[52] Haber, F. and Tamaru, S.,
Untersuchungen über Ammoniak. Sieben Metteilungen. VI. Über die spezifische Wärme des Ammoniaks,
Z. Elektrochem. 21, 228-241 (1915).

[53] Haupt, R. F. and Teller, E.,
Specific Heat and Double Minimum Problem of NH_3,
J. Chem. Phys. 7, 925-927 (1939).

[54] Heuse, W.,
Die spezifische Wärme von Argon und einigen mehratomigen Gasen,
Ann. Physik. [4] 59, 86-94 (1919).

[55] Hilsenrath, J., Beckett, C. W., Bennedict, W. S., Fano, L., Hoge, H. J., Masi, J. F., Nuttall, R. L., Touloukian, Y. S., and Woolley, H. W.,
Tables of Thermal Properties of Gases Comprising Tables of Thermodynamic and Transport Properties of Air, Argon, Carbon Dioxide, Carbon Monoxide, Hydrogen, Nitrogen, Oxygen, and Steam,
Natl. Bur. Std. (U.S.), Circ. 564, 488 pp. (1955).

[56] Jenkin, C. F. and Pye, D. R.,
The Thermal Properties of Carbonic Acid at Low Temperatures,
Phil. Trans. Roy. Soc. (London) 213A, 67-117 (1913).

[57] Justi, E.,
Spezifische Wärme, Enthalpie, Entropie und Dissoziation technischer Gase,
Julius Springer, Berlin, 157 pp. (1938).

[58] Justi, E. and Lüder, H.,
Spezifische Wärme, Entropie, und Dissoziation technischer gase und Dämpfe,
Forschungsarb. Gebiete Ingenieurw. 6, No. 5, 209-216 (1935).

[59] Kallmann, H. K.,
Thermodynamic Properties of Real Gases for Use in High Pressure Problems,
AD-103216, 44 pp. (1950).

[60] Kassel, L. S.,
Thermodynamic Functions of Nitrous Oxide and Carbon Dioxide,
J. Am. Chem. Soc. 56, 1838-1842 (1934).

[61] Kazavchinskii, Ya. Z. and Katkhe, O. I.,
Equation of State for Water Vapor,
Teploenergetika 5, No. 7, 26-30 (1958).

[62] Kelley, K. K.,
Contributions to the Data on Theoretical Metallurgy. I. The Entropies of Inorganic Substances,
U. S. Bur. Mines Bull. 350, 63 pp. (1932).

[63] Kelley, K. K.,
Contributions to the Data on Theoretical Metallurgy. XIII. High-Temperature Heat-Content, Heat-Capacity, and Entropy Data for the Elements and Inorganic Compounds,
U. S. Bur. Mines Bull. 584, 48, 79, 134 (1960).

[64] Keyes, F. G. and Brownlee, R. B.,
The Thermodynamic Properties of Ammonia,
John Wiley and Sons, Inc., New York, 29-37 (1916).

[65] King, F. E. and Partington, J. R.,
Measurements of Sound-Velocities to Air, Oxygen, and Carbon Dioxide at Temperatures from 900°C to 1200°C, with special reference to the Temperature-Coefficients of Molecular Heats,
Phil. Mag. [7] 9, 1020-1026 (1930).

[66] Kobe, K. A. and Harrison, R. H.,
Thermo Data for Petrochemicals. Part XXI. Ammonia, Hydrazine and the Methylamines,
Petrol. Refiner 33, No. 11, 161-164 (1954).

[67] Kopp, H.,
Untersuchungen über die specifische Wärme der starren und tropfbar-flüssigen Körper,
Ann. Chem. Pharm. [3] 3, Suppl. No. 1, 1-126, 289-342 (1864).

[68] Koppel, L. B. and Smith, J. M.,
Thermal Properties of Carbon Dioxide in the Critical Region,
J. Chem. Eng. Data 5, 437-440 (1960).

[69] Latimer, W. M. and Greensfelder, B. S.,
The Heat Capacity and Entropy of Cesium Alum from 18 to 300° Absolute. The Entropy of Aluminum Ion. The Potential of the Aluminum Electrode from Thermal Data,
J. Am. Chem. Soc. 50, 2202-2213 (1928).

[70] Leech, J. W.,
The Measurement of the Specific Heats of some Organic Liquids using the Cooling Method,
Proc. Phys. Soc. (London) 62B, 390-398 (1949).

[71] Liley, P. E.,
Thermodynamic Data for Carbon Dioxide at High Pressure and Temperature,
J. Chem. Eng. Data 4, No. 3, 238-241 (1959).

[72] Maass, O. and Barnes, W. H.,
Some Thermal Constants of Solid and Liquid Carbon Dioxide,
Proc. Roy. Soc. 111A, 224-244 (1926).

[73] Maass, O. and Waldbauer, L. J.,
The Specific Heats and Latent Heats of Fusion of Ice and of Several Organic Compounds,
J. Am. Chem. Soc. 47, No. 1, 1-9 (1925).

[74] Mader, C. L.,
Ideal Gas Thermodynamic Properties of Detonation Products (U),
U. S. At. Energy Comm., AECU-4508, 206 pp. (1959).

[75] Masi, J. F.,
Survey of Experimental Determinations of Heat Capacity of Ten Technically Important Gases,
Trans. Am. Soc. Mech. Engrs. 76, 1067-1074 (1954), Paper No. 53-A-206.

[76] Masi, J. F. and Petkof, B.,
Heat Capacity of Gaseous Carbon Dioxide,
J. Res. Natl. Bur. Std. 48, No. 3, 179-187 (1952), Res. Paper No. 2303.

[77] McCullough, J. P., Pennington, R. E., and Waddington, G.,
A Calorimetric Determination of the Vapor Heat Capacity and Gas Imperfection of Water,
J. Am. Chem. Soc. 74, 4439-4442 (1952).

[78] Michels, A., Bijl, A., and Michels, C.,
Thermodynamic Properties of CO_2 up to 3000 Atmospheres between 25° and 150°C.,
Proc. Roy. Soc. (London) 160A, 376-384 (1937).

[79] Nernst, W.,
Der Energieinhalt fester Stoffe,
Ann. Physik. [4] 36, 395-439 (1911).

[80] Nernst, W. and Wohl, K.,
Spezifische Wärme bei hohen Temperaturen,
Z. tech. Physik. 10, No. 12, 608-614 (1929).

[81] Newitt, D. M.,
Gaseous Combustion at High Pressures. Part XIII. The Molecular Heats of Nitrogen, Steam and Carbon Dioxide at High Temperatures,
Proc. Roy. Soc. (London) 125A, 119-134 (1929).

[82] Osborne, N. S., Stimson, H. F., and Fiock, E. F.,
A Calorimetric Determination of Thermal Properties of Saturated Water and Steam from 0° to 270°C.,
J. Res. Natl. Bur. Std. 5, 411-480 (1930), Res. Paper No. 209.

[83] Osborne, N. S., Stimson, H. F., and Ginnings, D. C.,
Calorimetric Determination of the Thermodynamic Properties of Saturated Water in Both the Liquid and Gaseous States from 100° to 374°C.,
J. Res. Natl. Bur. Std. 18, 389-447 (1937).

[84] Osborne, N. S., Stimson, H. F., and Ginnings, D. C.,
Measurements of Heat Capacity and Heat of Vaporization of Water in the Range 0° to 100°C.,
J. Res. Natl. Bur. Std. 23, No. 2, 197-260 (1939)

[85] Osborne, N. S., Stimson, H. F., and Ginnings, D. C.,
Thermal Properties of Saturated Water and Steam,
J. Res. Natl. Bur. Std. 23, No. 2, 261-270 (1939).

[86] Osborne, N. S., Stimson, H. F., Sligh, Jr., T. S., and Cragoe, C.S.,
Specific Heat of Superheated Ammonia Vapor,
Natl. Bur. Std. (U.S.), Sci. Papers 20, No. 501, 65-110 (1925).

[87] Osborne, N. S. and Van Dusen, M. S.,
Specific Heat of Liquid Ammonia,
Bull. Bur. Std. (U.S.) 14, 397-432 (1917), Sci. Paper No. 313.

[88] Osborne, N. S. and Van Dusen, M. S.,
Specific Heat of Liquid Ammonia,
J. Am. Chem. Soc. 40, No. 1, 1-13 (1918).

[89] Osborne, N. S. and Van Dusen, M. S.,
Specific Heat of Liquid Ammonia,
J. Am. Soc. Refrig. Eng. 4, No. 2, 134-166 (1917).

[90] Overstreet, R. and Giauque, W. F.,
Ammonia. The Heat Capacity and Vapor Pressure of Solid and Liquid. Heat of Vaporization. The Entropy Values from Thermal and Spectroscopic Data,
J. Am. Chem. Soc. 59, 254-259 (1937).

[91] Partington, J. R.,
The Ratio of the Specific Heats of Air and of Carbon Dioxide,
Proc. Roy. Soc. (London) 100A, 27-49 (1921-1922).

[92] Pollitzer, F.,
Bestimmung spezifischer Wärmen bei tiefen Temperaturen und ihre Verwertung zur Berechnung elektromotorischer Kräfte. II,
Z. Elektrochem. 19, 513-518 (1913).

[93] Rasskasoff, D. S. and Scheindlin, A. E.,
Spezifische Wärme C_p von Wasser und Wasserdampf im überkritischen Gebiet,
Brennstoff-Wärme-Kraft 10, No. 7, 345 (1958).

[94] Rasskazov, D. S. and Sheindlin, A. E.,
An Experimental Investigation into the Heat Capacity (C_p) of Water and Water Vapor of High Parameters,
Teploenergetika 4, No. 11, 81-83 (1957).

[95] Rasskazov, D. S. and Sheindlin, A. E.,
An Experimental Investigation of the Specific Heat C_p of Water and Water Vapor at High Parameters,
Dokl. Akad. Nauk SSSR 120, 771-773 (1958).

[96] Rasskazov, D. S. and Sheindlin, A. E.,
Experimental Investigation of Water and Water Vapor Heat Capacity C_p at High Pressures and Temperatures,
Soviet Phys. "Doklady" 3, 652-654 (1958).

[97] Regnault, V.,
Mémoire sur la chaleur spécifique des fluides elastiques,
Mémoires acad. sci. Inst. Impérial France, Paris [2] 26, 1-928 (1862).

[98] Rossini, F. D., Wagman, D. D., Evans, W. H., Levine, S., and Jaffe, I.,
Selected Values of Chemical Thermodynamic Properties,
Natl. Bur. Std. (U.S.), Circ. 500, (1952).

[99] Roth, W. A.,
Die spezifischen Wärmen des Wassers (H_2O) zwischen 0° und 100°C.,
Z. physik. Chem. 183A, 38-42 (1938).

[100] Sarukhanian, G.,
Neue Zustandsgleichung und Tafeln für Wasserdampf bis 1000 ata und 1000°C,
Brennstoff-Wärme-Kraft 10, No. 7, 320-321 (1958).

[101] Sharp, W. E.,
The Thermodynamic Functions for Carbon Dioxide in the Range 40 to 1000°C and 1 to 1400 Bars,
U. S. At. Energy Comm., UCRL-7168, 52 pp. (1962).

[102] Sheindlin, A. E., Shpil'rain, E. E., and Sychev, V. V.,
The Specific Heat C_p of Water Vapor on the Saturation Curve,
Teploenergetika 5, No. 7, 13-17 (1958).

[103] Sheindlin, A. E., Shpil'rain, E. E., and Sychev, V. V.,
Reference Values of Specific Heat C_p for Water Vapor,
Teploenergetika 6, No. 12, 80-83 (1959).

[104] Sheindlin, A. E., Shpil'rain, E. E., and Sychev, V. V.,
Specific Heat of Water and Water Vapor on the Line of Saturation,
Teploenergetika 7, No. 7, 23-27 (1960).

[105] Sherratt, G. G. and Griffiths, E.,
The Determination of the Specific Heat of Gases at High Temperatures by the Sound Velocity Method. II. Carbon Dioxide,
Proc. Roy. Soc. (London) 156A, 504-517 (1936).

[106] Shilling, W. G.,
Calculation of the Molecular Heats of Gases from Equilibrium Constants,
Trans. Faraday Soc. 22, Part 6, 377-400 (1926).

[107] Shilling, W. G.,
Measurements of the Velocity of Sound in Steam, Nitrous Oxide, and Carbon Dioxide, with special reference to the Temperature Coefficient of the Molecular Heats,
Phil. Mag. [7] 3, 273-301 (1927).

[108] Siletskii, V. S.,
On the Calorific Values of Water Vapor in the Perfect Gaseous State,
Teploenergetika 5, No. 7, 18-21 (1958).

[109] Sirota, A. M.
Specific Heat and Enthalpy of Water Vapor under Subcritical Pressures,
Teploenergetika 5, No. 7, 10-13 (1958).

[110] Sirota, A. M.,
Heat Capacity of Water and Steam at Constant Pressure on the Saturation Curve,
Inzh.-Fiz. Zh., Akad. Nauk Belorussk. SSR 6, No. 12, 52-55 (1963).

[111] Sirota, A. M. and Belyakova, P. E.,
About Calorific Properties of Water under Pressures up to 500 kg/cm^2 and Temperatures up to 300°C,
Teploenergetika 6, No. 10, 67-70 (1959).

[112] Sirota, A. M. and Mal'tsev, B. K.,
An Experimental Investigation into the Heat Capacity of Water at Temperatures from 10 to 500°C and Pressures up to 500 kg/cm^2,
Teploenergetika 6, No. 9, 7-15 (1959).

[113] Sirota, A. M. and Mal'tsev, B. K.,
The Experimental Data on Thermal Capacity of Water Vapor Under Pressures from 300 to 500 Atm and at Temperatures from 500 to 600°C,
Teploenergetika 7, No. 10, 67-68 (1960).

[114] Sirota, A. M. and Mal'tsev, B. K.,
Heat Capacity of Water in the Critical Region,
Teploenergetika 9, No. 1, 52-57 (1962).

[115] Sirota, A. M. and Mal'tsev, B. K.
Experimental Investigation of the Heat Capacity of Steam,
Teploenergetika 9, No. 7, 70-73 (1962).

[116] Sirota, A. M., Mal'tsev, B. K., and Belyakova, P. E.,
About Maximum Values of the Specific Heat of Water,
Teploenergetika 7, No. 7, 16-23 (1960).

[117] Sirota, A. M. and Malzev, B. K.,
Experimentelle Untersuchung der spezifischen Wärme von Wasser bei 10 bis 500°C and bei Drücken bis 500 kg/cm^2,
Brennstoff-Wärme-Kraft 12, No. 2, 73-74 (1960).

[118] Stephenson, C. C. and McMahon, H. O.,
The Free Energy of Ammonia,
J. Am. Chem. Soc. 61, 437-441 (1939).

[119] Swann, W. F. G.,
The Specific Heat of Air and Carbon Dioxide at Atmospheric Pressure, by the Continuous Electrical Method, at 20°C and 100°C,
Proc. Roy. Soc. (London) 82A, 147-149 (1909).

[120] Sychev, V. V.,
Specific Heat C_V in the Coexistence Region of Water,
Inzh.-Fiz. Zh., Akad. Nauk Belorussk. SSR 3, No. 7, 10-16 (1960).

[121] Vukalovich, M. P., Dzampov, B. V., Rasskazov, D. S., and Remizov, S.A.,
Tables of Heat Capacities, C_p, of Water and Water Vapor,
Teploenergetika 8, No. 12, 70-71 (1961).

[122] Vukalovich, M. P., Sheindlin, A. E., and Rasskazov, D. C.,
An Investigation into the Specific Heat C_p of Water Vapor under Pressures up to 700 atm. and Temperatures up to 700°C,
Teploenergetika 5, No. 7, 7-9 (1958).

[123] Vukalovich, M. P., Zubarev, V. N., and Prusakov, P. G.,
Experimental Investigation of the Enthalpy of Water Vapor,
Teploenergetika 5, No. 7, 22-26 (1958).

[124] Wagman, D. D., Kilpatrick, J. E., Taylor, W. J., Pitzer, K. S., and Rossini, F. D.,
Heats, Free Energies, and Equilibrium Constants of Some Reactions Involving O_2, H_2, H_2O, C, CO, CO_2, and CH_4,
J. Res. Natl. Bur. Std. 34, 143-161 (1945).

[125] Womersley, W. D.,
The Specific Heats of Air, Steam and Carbon Dioxide,
Proc. Roy. Soc. (London) 100A, 483-498 (1921-1922).

[126] Woolley, H. W.,
Thermodynamic Functions for Carbon Dioxide in the Ideal Gas State,
J. Res. Natl. Bur. Std. 52, No. 6, 289-292 (1954),
Res. Paper No. 2502.

FORM CD-121 (9-22-59)
(PRES. BY A.O. 206-10)

APPENDIX I

UNITED STATES GOVERNMENT

Memorandum

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

TO : Project 221-0429 Files

DATE: September 2, 1965

FROM : G. T. Armstrong

SUBJECT: Meeting on CHNOPS program progress at NASA Headquarters, September 1, 1965

Present at the meeting were

Prof. H. A. Morowitz - Yale University, presiding
Dr. Goel - Yale University and University of Maryland
Drs. C. W. Beckett, G. T. Armstrong and G. T. Furukawa, NBS
Drs. M. O. Dayhoff, R. V. Eck, and one other from National Biomedical Research Foundation
Prof. E. R. Lippincott - University of Maryland
Dr. Freeman Quimby - NASA

The meeting consisted of presentations by each of the groups present in which they discussed to a greater or less extent tasks performed, present status, difficult problems, and modes of action in the future.

Armstrong and Furukawa started with a description of the work at the NBS on the literature search and evaluation of thermodynamic data.

Margaret Dayhoff for NBRF described calculations of equilibrium compositions which were plotted on a CHO triangle.

Richard Eck described calculations of planetary atmospheres, in which the atmosphere of the Earth and Jupiter are shown to be not at equilibrium. The data for the compositions of the atmospheres of Venus and Mars are inadequate for definitive statements, but no information available is inconsistent with equilibrium atmospheres.

Ellis Lippincott described an experimental study of electrode discharge processes in atmospheres selected from the NBRF charts in which the formation of aromatic hydrocarbons (asphalt line) was confirmed.

Harold Morowitz proposed phospholipids (phosphate-fatty acid mixed esters of glycerol) as an important group of ubiquitous compounds. They are ubiquitous ingredients of the cell membrane, forming a layer ~40A° thick bounded by a layer of protein on each side. The primitive character of these lipids is inferred by Morowitz from the fact that they are non-specific with respect to fatty acids. (Various fatty acids can be substituted at random.)

Harold Morowitz presented a picture of non-equilibrium and the formation of excessive amounts of higher-than-equilibrium quantities of complex compounds as a natural consequence of the fact that the earth lies as an intermediate between an energy source (the sun) and an energy sink (outer space).

The meeting was brought to a close (4:00 P.M.) by a discussion of the selection of type compounds of several categories for attempts to get as much thermodynamic information as possible, with a view that other compounds of the same categories would not offer essentially new information.

Compounds suggested were

- Glycine (heat of sol'n, vap'n)
- Thioacetic acid
- H_2S
- Phosphites and phosphates (vs. pH)
- D ribose
- Glucose
- Glycerol
- Phosphoserine
- Fatty acids

This list is apparently not complete. The list of ubiquitous compounds should be examined for other types.

At various points in the meeting the following thoughts were brought up:

(1) NBRF suggested that thermodynamic information be made available on tab cards or tape.

(2) Ways of estimating free energies of formation, their variation with temperature and heats of vaporization and solution would be a help to NBRF for compounds lacking data.

(3) Because the flow of energy produces some highly unstable or reactive compounds, a treatment involving an atmosphere containing small amounts of such compounds might be fruitful.

DEPARTMENT OF COMMERCE ★ NATIONAL BUREAU OF STANDARDS ★