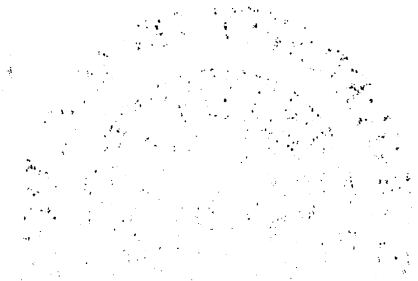

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ENGINEERING RESEARCH INSTITUTE
UNIVERSITY OF MICHIGAN
ANN ARBOR

Study of the Feasibility of Aqueous Recovery of Spent Fuels

PART 2. PROPERTIES OF MATERIALS UNDERGOING CHEMICAL PROCESSING

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Project 2240

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FOR THE DOW CHEMICAL—DETROIT EDISON AND ASSOCIATES
ATOMIC-POWER DEVELOPMENT PROJECT

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STUDY ON THE FEASIBILITY OF AQUEOUS RECOVERY OF SPENT FUELS

PART 2
PROPERTIES OF MATERIALS UNDERGOING CHEMICAL PROCESSING

INTRODUCTION

This report is a portion of a study being conducted on the feasibility of the aqueous recovery of spent fuels resulting from the operation of a nuclear reactor. This study was undertaken at the request of the Consumers Power Company of Jackson County for the Dow Chemical - Detroit Edison and Associates Atomic Power Development Project.

The aqueous recovery of spent nuclear fuels would require the use of a chemical processing plant. The design of such a facility is necessarily dependent on the physical and chemical properties of the materials to be treated. In this report are presented properties of many of the materials which are likely to be encountered in the chemical processing of spent fuels. The compilation of these data will facilitate the process design calculations which will appear in subsequent reports.

With one exception, the properties listed were obtained from the standard reference works and contemporary literature which are listed in the bibliography. The exception is that the properties of hydrofluoric acid, nitric acid, sulfuric acid, and sodium hydroxide were taken from a private communication received from Mr. A. V. Cowan.

PROPERTIES OF MATERIALS

Pertinent properties of the materials are listed on the following pages.

Aluminum Nitrate[2,3]

a. Formula	$Al(NO_3)_3 \cdot 9H_2O$
b. Molecular weight	375.14
c. Melting point	163.4°F
d. Solubility	Very soluble in cold H_2O
	Soluble in alcohol
	Soluble in CS_2

Amsco 123-15*

a. Specific gravity	0.7857
b. Density	6.541 pounds/gallon

*American Solvent Company, San Francisco, California.

Calcium[2,3]

a. Formula	Ca
b. Molecular weight	40.08
c. Specific gravity	1.55 at 68°F
d. Melting point	1490°F
e. Solubility	Slightly soluble in alcohol Soluble in acid
f. Latent heat of fusion	8.899 Btu/mole
g. Specific heat	5.31 + 0.00333T cal/gm-atom-°K, where T = °K

Chromic Sulfate[2,3]

a. Formula	$Cr_2(SO_4)_3$
b. Molecular weight	392.2
c. Specific gravity	3.012
d. Solubility	Insoluble in water Insoluble in alcohol
e. Specific heat	0.1486 Btu/mol-°F

Chromic Sulfate (Hydrate)[2,3]

a. Formula	$Cr_2(SO_4)_3 \cdot 5H_2O$
b. Molecular weight	482.28
c. Solubility	Soluble in water
	Soluble in alcohol
	Soluble in sulfuric acid

Chromic Sulfate (Hydrate)[2,3]

a. Formula	$Cr_2(SO_4)_3 \cdot 15H_2O$
b. Molecular weight	662.44
c. Specific gravity	1.867
d. Melting point	212°F
e. Solubility	Soluble in cold water
	Decomposes in water at 152.6°F
	Slightly soluble in alcohol

Chromic Sulfate (Hydrate)[2,3]

a. Formula	$Cr_2(SO_4)_3 \cdot 18H_2O$
b. Molecular weight	716.49
c. Specific gravity	1.7 at 72°F
d. Solubility	Soluble in cold water Decomposes in hot water Soluble in alcohol

Chromium[2,3]

a. Weight composition	100% Cr
b. Molecular weight	52.01
c. Specific gravity	7.1
d. Melting point	2939°F
e. Solubility	Insoluble in water Soluble in hydrochloric acid Soluble in dilute sulfuric acid Insoluble in nitric acid
f. Latent heat of fusion	15.59 Btu/mole
g. Specific heat	4.84 + 0.00295T cal/gm-atom-°K where T = °K

Chromous Sulfate (Hydrate)[2,3]

a. Formula	$CrSO_4 \cdot 7H_2O$
b. Molecular weight	274.18
c. Solubility	Soluble in water Slightly soluble in alcohol

Aqueous Hydrofluoric Acid

a. Density

Hydrofluoric Acid, weight percent	Density, g/cc	
	0°C	15°C
5	1.022	1.017
10	1.042	1.035
15	1.060	1.054
20	1.078	1.072
25	1.096	1.091
30	1.113	1.109
35	1.130	1.129
40	1.148	1.149
45	1.170	1.169
50	1.192	1.190
55	1.220	1.209
60	1.240	
65	1.253	
70	1.260	
75	1.261	
80	1.255	
85	1.234	
90	1.190	
95	1.050	

b. Partial Vapor Pressure of Hydrogen Fluoride and Water over Aqueous Hydrofluoric Acid

Partial Pressure, mm Hg		Weight Percent of Hydrofluoric Acid							
		5	10	15	20	25	30	35	40
25°C	HF:				0.61	1.24	2.35	3.82	5.75
	H_2O:				14.0	10.4	10.1	10.1	
40°C	HF:	0.11	0.53	0.94	1.35				
	H_2O:	49.5	45.7	42.0	38.4				
50°C	HF:	0.2	0.85	1.80	3.1	5.1	8.6	15.6	24.0
	H_2O:	84.7	75.0	65.0	55.0	45.7	39.2	35.7	33.2
60°C	HF:	0.49	1.52	2.6	5.2	8.7	12.8		
	H_2O:	131	119	107	95	83	71.3		
75°C	HF:	1.97	3.78	7.2	12.0	20.0	29.8		
	H_2O:	267	245.5	227	204	173	133		

c. Specific Gravity of Aqueous Hydrofluoric Acid Solution at 0°C/4°C

Be'	Specific Gravity	Percent HF	Grams per liter	Lbs per cu ft	Lbs per gallon
2.8	1.020	5	51.00	3.184	0.4256
5.6	1.040	10	104.0	6.492	0.8679
8.2	1.060	15	159.0	9.926	1.327
10.7	1.080	20	216.0	13.48	1.803
13.1	1.099	25	274.8	17.15	2.293
15.4	1.119	30	335.7	20.96	2.801
17.7	1.139	35	398.7	24.89	3.327
19.9	1.159	40	463.6	28.94	3.869
21.9	1.178	45	530.1	33.09	4.424
24.0	1.198	50	599.0	37.39	4.999
25.9	1.217	55	669.4	41.78	5.586
27.6	1.235	60	741.0	46.26	6.184
28.8	1.248	65	811.2	50.64	6.770
29.7	1.258	70	880.6	54.97	7.349
30.0	1.261	72	907.9	56.68	7.577
30.1	1.262	74	933.9	58.30	7.793
30.1	1.262	76	959.1	59.87	8.004
30.0	1.261	78	983.6	61.40	8.208
29.8	1.259	80	1007	62.88	8.405
29.5	1.255	82	1029	64.24	8.588
28.6	1.246	84	1047	65.34	8.734
27.4	1.233	86	1060	66.20	8.849
25.5	1.213	88	1067	66.64	8.908
21.9	1.178	90	1060	66.18	8.848
11.9	1.089	95	1035	64.58	8.633
0.07	1.0005	100	1001	62.46	8.349

d. Specific Gravity of Aqueous Hydrofluoric Acid Solution at 20°C/4°C

Be'	Specific Gravity	Percent HF	Grams per liter	Lbs per cu ft	Lbs per gallon
2.4	1.017	5	50.85	3.174	0.4244
4.9	1.035	10	103.5	6.461	0.8637
7.3	1.053	15	158.0	9.860	0.318
9.5	1.070	20	214.0	13.36	1.786
11.5	1.086	25	271.5	16.95	2.266
13.3	1.101	30	330.3	20.62	2.756
15.1	1.116	35	390.6	24.38	3.260
16.7	1.130	40	452.0	28.22	3.772
18.1	1.143	45	514.4	32.11	4.292
19.5	1.155	50	577.5	36.05	4.819

e. Surface Tension of Aqueous Hydrofluoric Acid at 25°C

Molarity of HF	Surface Tension, dynes/cm
0	71.0
7.5	57.7
13.0	52.4
27.0	42.6

f. Specific Conductivity of Aqueous Hydrofluoric Acid Solutions

Weight Percent of HF	Molarity of HF at 0°C	Specific Conductivity, $ohm^{-1}cm^{-1}$	
		0°C	18°C
5	2.55	0.051	0.064
10	5.2	0.102	0.122
15	8.0	0.153	0.176
20	10.8	0.204	0.233
25	13.7	0.255	0.288
30	16.8	0.305	0.345
35	19.8	0.355	
40	23.1	0.405	
45	26.5	0.460	
50	30.0	0.517	
55	33.5	0.577	
60	37.0	0.620	
65	40.5	0.654	
70	44.0	0.676	
75	47.1	0.680	
80	50.3	0.662	
85	52.7	0.616	
90	53.0	0.340	
95	51.7	0.175	

g. Solubility of Hydrofluoric Acid in Water and Boiling Points of Aqueous Hydrofluoric Acid at Atmospheric Pressure

Boiling Point of HF at Atmospheric Pressure, °C	Weight Percent of HF	Solubility of HF in H_2O	
		Temperature, °C	Solid Phase
100.053	0.20		
100.262	1.10		
100.464	1.99		
100.743	2.98		
100.925	3.54		
101.496	5.78		
	9.3	- 10	Ice
102.516	9.62		
103.754	12.59		
	14.8	- 20	Ice
105.216	15.00		
108.80	18.65		
	19.0	- 30	Ice
111.56	22.44		
	22.75	- 40	Ice
	25.5	- 50	Ice
113.83	27.19		
	27.5	- 60	Ice
	29.75	- 70.2	Eutectic
114.85	30.70		
	34.0	- 60	$HF \cdot H_2O$
115.18	35.37		
	39.0	- 50	$HF \cdot H_2O$
113.21	43.17		
	45.8	- 40	$HF \cdot H_2O$
	52.62	- 35.4	M.P. $HF \cdot H_2O$
63.75	56.04		
	58.5	- 40	$HF \cdot H_2O$
55.70	58.85		
50.44	61.43		
	64.5	- 50	$HF \cdot H_2O$
43.60	65.54		
	68.2	- 60	$HF \cdot H_2O$
	70.0	- 70	$HF \cdot H_2O$
	70.71	- 75.2	$HF \cdot H_2O + 2HF$
	75.5	- 80	$2HF \cdot H_2O$
	78.3	- 90	$2HF \cdot H_2O$
	79.2	-100	$2HF \cdot H_2O$
	79.39	-101.4	Eutectic
	81.62	-100.3	M.P. $4HF \cdot H_2O$
	89.1	-110	$4HF \cdot H_2O$
	92.0	-100	HF
28.95	92.51		
27.89	93.28		
26.89	94.07		
24.89	95.69		
	96.0	- 90	HF
22.87	97.37		
20.81	99.11		
19.54	100.00	- 83.01	M.P. HF

Hydrogen[2,3]

a. Formula — H_2

b. Molecular weight — 2.016

c. Specific gravity of liquid — 0.0709 at -423°F

0.06948 referred to air at 1.00000

d. Melting point — -434°F

e. Solubility — Slightly soluble in H_2O

Slightly soluble in Fe, Pd, and Pt

f. Latent heat of fusion — 0.111 Btu/mole

g. Thermal conductivity

°F	K, Btu/(hr)(ft^2)(°F/ft)
32	0.100
122	0.115
212	0.129
572	0.178

h. Specific heat — 6.62 + 0.00081T cal/mole-°K

where T = °K

Hydrogen Peroxide[2,3]

a. Formula	H_2O_2
b. Molecular weight	34.02
c. Specific gravity	1.438
d. Melting point	30.4°F
e. Boiling point	304.52°F
f. Solubility	Infinitely soluble in water Soluble in alcohol
g. Latent heat of fusion	10 Btu/mole

Iodine[2,3]

a. Formula	I_2
b. Molecular weight	253.84
c. Specific gravity	4.93 at 68°F
d. Melting point	234.1°F
e. Boiling point	364°F
f. Solubility	Slightly soluble in hot water Soluble in alcohol Soluble in KI
g. Latent heat of fusion	14.48 Btu/mole
h. Specific heat	0.0198 Btu/mole-°F

Iron[2,3]

a. Weight composition	100% Fe
b. Molecular weight	55.85
c. Specific gravity	7.86 at 68°F
d. Melting point	2795°F
e. Solubility	Insoluble in water Soluble in alcohol Insoluble in alkali
f. Latent heat of fusion	14.13 Btu/mole
g. Thermal conductivity	34.9 Btu/(hr)(ft^2)(°F/ft) at 64°F 36.6 Btu/(hr)(ft^2)(°F/ft) at 212°F
h. Specific heat	6.12 + 0.00336T cal/gm atom-°K where T = °K

Isopropyl Alcohol[2,3]

a. Formula	$(CH_3)_2CHOH$
b. Molecular weight	60.09
c. Boiling point	180.5°F at 1 atmosphere
d. Specific heat of liquid	0.52 Btu/lb-°F at -4°F
e. Specific gravity	0.789 at 87°F
f. Latent heat of vaporization	286.2 Btu/lb

Magnesium[2,3]

a. Weight composition	100% Mg
b. Molecular weight	24.32
c. Specific gravity	1.74 at 68°F
d. Melting point	1203.8°F
e. Solubility	Slightly soluble in hot water Soluble in acid
f. Latent heat of fusion	8.57 Btu/mole
g. Specific heat	$6.20 + 0.00133T - 67{,}800/T^2$ cal/gm atom-°K where T = °K
h. Thermal conductivity	92.0 Btu/(hr)(ft^2)(°F/ft)

Nitric Acid

a. Specific Gravity at 60°F/60°F

Be'	Specific Gravity	Percent HNO_3
10.0	1.0741	12.86
11.0	1.0821	14.13
12.0	1.0902	15.41
13.0	1.0985	16.72
14.0	1.1069	18.04
15.0	1.1154	19.36
16.0	1.1240	20.69
17.0	1.1328	22.04
18.0	1.1417	23.42
19.0	1.1508	24.82
20.0	1.1600	26.42
21.0	1.1694	27.67
22.0	1.1789	29.07
23.0	1.1885	30.49
24.0	1.1983	31.94
25.0	1.2083	33.42
26.0	1.2185	34.94
27.0	1.2288	36.48
28.0	1.2393	38.06
29.0	1.2500	39.66
30.0	1.2609	41.30
31.0	1.2719	43.00
32.0	1.2832	44.78
33.0	1.2946	46.58
34.0	1.3063	48.42
35.0	1.3182	50.32
36.0	1.3303	52.30
37.0	1.3426	54.36
38.0	1.3551	56.52
39.0	1.3679	58.82
40.0	1.3810	61.38
41.0	1.3942	64.20
42.0	1.4078	67.18
43.0	1.4216	70.33
44.0	1.4356	73.67
45.0	1.4500	77.17
46.0	1.4646	81.08
47.0	1.4796	85.70
48.0	1.4948	91.35

Nitric Oxide[2,3]

a. Formula	NO
b. Molecular weight	30.01
c. Specific gravity	1.0367 referred to air at 1.0000
d. Melting point	-257.8°F
e. Solubility	Soluble in water Soluble in alcohol Soluble in sulfuric acid
f. Latent heat of fusion	2.18 Btu/mole
g. Thermal conductivity	0.0138 Btu/(hr)(ft^2)(°F/ft) at 32°F
h. Specific heat	8.05 + 0.000233T - 156,300/T^2 cal/mole-°K where T = °K

Nitrogen[2,3]

a. Formula — N_2

b. Molecular weight — 28.02

c. Specific gravity — 12.5 at 32°F referred to H at 1.0

d. Solubility — Soluble in water

Slightly soluble in alcohol

e. Latent heat of fusion — 0.683 Btu/mole

f. Thermal conductivity — 0.0140 Btu/(hr)(ft^2)(°F/ft) at 32°F

0.0160 Btu/(hr)(ft^2)(°F/ft) at 122°F

0.0180 Btu/(hr)(ft^2)(°F/ft) at 212°F

h. Specific heat — 6.50 + 0.00100T cal/mole-°K

where T = °K

i. Vapor pressure

Temperature, °F	Pressure, Atmospheres
-320	1
-308	2
-290	5

Nitrogen Dioxide[2,3]

a. Formula	NO_2
b. Molecular weight	46.01
c. Specific gravity	1.448 at 68°F
d. Melting point	30.14°F
e. Boiling point	70.34°F
f. Solubility	Decomposes in water
	Soluble in nitric acid
	Soluble in sulfuric acid
	Soluble in carbon disulfide

Nitrous Oxide[2,3]

a. Formula	N_2O
b. Molecular weight	44.02
c. Specific gravity	1.530 referred to air at 1.000
d. Melting point	-152.14°F
e. Solubility	Soluble in water Soluble in sulfuric acid Soluble in alcohol
f. Latent heat of fusion	6.20 Btu/mole
g. Thermal conductivity	0.0087 Btu/(hr)(ft^2)(°F/ft) at 32°F 0.0128 Btu/(hr)(ft^2)(°F/ft) at 212°F

Potassium[2,3]

a. Weight composition	100% K
b. Molecular weight	39.10
c. Specific gravity	0.86 at 68°F
d. Melting point	144.14°F
e. Solubility	Decomposes in water Soluble in alcohol Soluble in acid
f. Latent heat of fusion	2.28 Btu/mole
g. Specific heat	5.24 + 0.00555T cal/gm atom-°K where T = °K

Sodium[2,3,4]

a. Weight composition — 100% Na

b. Molecular weight — 22.997

c. Melting point — 208.06°F

d. Density — 60.6 lbs/ft^3 at 32°F

e. Latent heat of fusion — 2.47 Btu/mole

f. Specific heat

C_p(solid) = 9.93555 - 0.028053T + 0.000057883T^2 cal/gm atom-°K

C_p(liquid) = 8.9581 - 0.0045788T + 0.0000025409T^2 cal/gm atom-°K

where T = °K

g. Thermal conductivity

State	Temperature, °F	K, Btu/(hr)(ft^2)(°F/ft)
Solid	32	78.5
	104	74.6
	176	70.7
	208.06	69.0
Liquid	482	45.5
	752	41.2
	1022	37.0

h. Viscosity

Temperature, °F	Viscosity, lb/ft-sec
320	3.49
500	2.53
752	1.88

i. Solubility — Decomposes in water and forms NaOH

Insoluble in benzene

Decomposes in alcohol

Sodium Hydroxide

a. Specific Gravity of Aqueous Sodium Hydroxide Solutions at 20°C/4°C

Percent of NaOH	Specific Gravity	Concentration of Sodium Hydroxide gm/liter	lbs/ft3	lbs/gal
1	1.0095	10.10	0.6302	0.0842
2	1.0207	20.41	1.274	0.1704
3	1.0318	30.95	1.932	0.2583
4	1.0428	41.71	2.604	0.3481
5	1.0538	52.69	3.289	0.4397
6	1.0648	63.89	3.988	0.5332
7	1.0758	75.31	4.701	0.6284
8	1.0869	86.95	5.428	0.7256
9	1.0979	98.81	6.168	0.8246
10	1.1089	110.9	6.923	0.9254
12	1.1309	135.7	8.472	1.113
14	1.1530	161.4	10.08	1.347
16	1.1751	188.0	11.74	1.569
18	1.1972	215.5	13.45	1.798
20	1.2191	243.8	15.22	2.035
22	1.2411	273.0	17.05	2.279
24	1.2629	303.1	18.92	2.529
26	1.2848	334.0	20.85	2.788
28	1.3064	365.8	22.84	3.053
30	1.3279	398.4	24.87	3.324
32	1.3490	431.7	26.95	3.602
34	1.3696	465.7	29.07	3.886
36	1.3900	500.4	31.24	4.176
38	1.4101	535.8	33.45	4.472
40	1.4300	572.0	35.71	4.773
42	1.4494	608.7	38.00	5.080
44	1.4685	646.1	40.34	5.392
46	1.4873	684.2	42.71	5.709
48	1.5065	723.1	45.14	6.035
50	1.5253	762.7	47.61	6.364

b. Surface Tension of Aqueous Solutions of Sodium Hydroxide Against Air, 18°C

Gram Formula Weights per 1000 gm of Solvent	Surface Tension, dynes/cm Less that for water at 18°C.
0.7	1.3
1.5	2.8
5.0	10.0
11.0	23.0
14.0	28.0

c. Vapor Pressure of Sodium Hydroxide

Pressure, mm Hg	Temperature, °C
1	739
10	897
40	1017
100	1111
400	1286
760	1378

d. Melting Point of Sodium Hydroxide 318°C

Sulfuric Acid

a. Specific Gravity of Aqueous Sulfuric Acid Solutions at 20°C/4°C

Percent H_2SO_4	Specific Gravity	Baume'	Gm/liter	Lbs/ft^3	Lbs/gal
2	1.0118	1.7	20.24	1.263	0.1689
4	1.0250	3.5	41.00	2.560	0.3422
6	1.0385	5.4	62.31	3.890	0.5200
8	1.0522	7.2	84.18	5.255	0.7025
10	1.0661	9.0	106.6	6.655	0.8897
12	1.0802	10.8	129.6	8.092	1.082
14	1.0947	12.5	153.3	9.567	1.279
16	1.1094	14.3	177.5	11.08	1.481
18	1.1243	16.0	202.4	12.63	1.689
20	1.1394	17.7	227.9	14.23	1.902
22	1.1548	19.4	254.1	15.86	2.120
24	1.1704	21.1	280.9	17.54	2.344
26	1.1862	22.8	308.4	19.25	2.574
28	1.2023	24.4	336.6	21.02	2.809
30	1.2185	26.0	365.6	22.82	3.051
32	1.2349	27.6	395.2	24.67	3.298
34	1.2515	29.1	425.5	26.56	3.551
36	1.2684	30.7	456.6	28.51	3.811
38	1.2855	32.2	488.5	30.49	4.077
40	1.3028	33.7	521.1	32.53	4.349
42	1.3205	35.2	554.6	34.62	4.628
44	1.3384	36.7	588.9	36.76	4.914
46	1.3569	38.1	624.2	38.97	5.209
48	1.3758	39.6	660.4	41.23	5.551
50	1.3951	41.1	697.6	43.55	5.821
52	1.4148	42.5	735.7	45.93	6.140
54	1.4350	44.0	774.9	48.37	6.467
56	1.4557	45.4	815.2	50.89	6.803
58	1.4768	46.8	856.5	53.47	7.148
60	1.4983	48.2	899.0	56.12	7.502
62	1.5200	49.6	942.4	58.84	7.865
64	1.5421	51.0	986.9	61.61	8.236
66	1.5646	52.3	1033	64.46	8.618
68	1.5874	53.7	1079	67.39	9.008
70	1.6105	55.0	1127	70.38	9.408
72	1.6338	56.3	1176	73.44	9.817
74	1.6574	57.5	1226	76.57	10.24
76	1.6810	58.7	1278	79.75	10.66
78	1.7043	59.9	1329	82.99	11.09
80	1.7272	61.1	1382	86.26	11.53
82	1.7491	62.1	1434	89.54	11.97
84	1.7693	63.0	1486	92.78	12.40
86	1.7872	63.9	1537	95.95	12.83
88	1.8022	64.5	1586	99.01	13.23
90	1.8144	65.1	1633	101.9	13.63
92	1.8240	65.5	1678	104.8	14.00
94	1.8312	65.8	1721	107.5	14.36
96	1.8355	66.0	1762	110.0	14.70
98	1.8361	66.0	1799	112.3	15.02
100	1.8305	65.8	1831	114.3	15.28

b. Electrical Conductivity of Sulfuric Acid

Temperature, °C	Conductivity, $ohm^{-1}cm^{-1}$
0	0.5184
5	0.5792
10	0.6408
15	0.7028
16	0.7151
17	0.7275
18	0.7398
19	0.7522
20	0.7645
21	0.7768
22	0.7890
23	0.8013
24	0.8135
25	0.8257
26	0.8378
27	0.8499
28	0.8620
29	0.8740
30	0.8860

Test solution was prepared by dissolving 378 gm of 97% acid in pure water and diluting to 1 liter.

Density at 18°C, 1.223.

c. Viscosity of Sulfuric Acid

Temperature, °C	Viscosity, centipoises
0	48.4
15	32.8
20	25.4
30	15.7
40	11.5
50	8.82
60	7.72
70	6.09
80	5.19

d. Vapor Pressure of Sulfuric Acid

Temperature, °C	Vapor Pressure, mm Hg
145.8	1
194.2	10
229.7	40
257.0	100
305.0	400
330.0	760

e. Boiling Point of Aqueous Sulfuric Acid

Be', °	Boiling Temperature, °F	Specific Gravity	Boiling Temperature, °C
50	295	1.525	136
60	386	1.708	197
61	400	1.725	204
62	415	1.747	213
63	432	1.769	222
64	451	1.790	233
65	485	1.812	252
66	538	1.836	281

TBP*

a. Density, Surface Tension, and Viscosity of TBP in Amsco 123-15 Solutions

Temperature, °C	Volume % of TBP in Amsco	Molarity in Solvent HNO_3	Molarity in Solvent UNH	Density, gm/cc	Surface Tension, dynes/cm	Viscosity, centipoises
	0			0.7757	31.9	1.099
25	5			0.7847	31.5	1.137
	10			0.7944	31.2	1.186
	15			0.8030	30.9	1.229
	5	0.2		0.7895	31.3	1.162
25	10	0.2		0.8005	31.0	1.234
	5	0.2	0.01	0.7923	31.2	1.172
25	10	0.2	0.01	0.8029	30.6	1.259
20	5			0.7885		1.304
30	5			0.7811		1.097
20	10			0.7980		1.239
30	10			0.7904		1.052
25	100			0.983	26.7	

*Courtesy of the Chemical Section, Atomic Energy Division, American Cyanamid Company.

Uranium[1,2,3]

a. Weight composition — 100% U

b. Molecular weight — 238.07

c. Specific gravity — 18.485

d. Melting point — 2102°F

e. Solubility — Insoluble in water; Soluble in acid; Insoluble in alcohol

f. Specific heat

For α, $C_p = 3.15 + 8.44 \times 10^{-3} T + 0.80 \times 10^{5} T^{-2}$ cal/gm atom-°K

For β, $C_p = 10.38$ cal/gm atom-°K

For γ, $C_p = 9.10$ cal/gm atom-°K

where T = °K

Enthalpy for α:

$$H_T - H_{298.16} = 3.15\,T + 4.22 \times 10^{-3} T^2 - 0.80 \times 10^{5} T^{-1} - 1046$$ cal/gm atom

where T = °K

g. Heat of fusion — 4950 Btu/lb-atom

h. Thermal conductivity — 14.5 Btu/(hr)(ft^2)(°F/ft) at 68°F

Uranium Dioxide[1,2,3]

a. Formula — UO_2

b. Molecular weight — 270.07

c. Specific gravity — 10.9

d. Melting point — 3948°F

e. Solubility — Insoluble in water
Soluble in nitric acid
Soluble in concentrated sulfuric acid

f. Specific heat

$$C_p = 19.20 + 1.62 \times 10^{-3} T - 3.95 \times 10^{5} T^{-2} \text{ cal/mole-°K} \quad \text{where } T = °K$$

g. Enthalpy

$$H_T - H_{298.16} = 19.20T + 0.81 \times 10^{-3}T^2 + 3.95 \times 10^{5}T^{-1} - 7124 \text{ cal/mole}$$

where T = °K

h. Thermal conductivity — 0.082 Btu/(hr)(ft^2)(°F/ft) at 68-437°F
0.046 Btu/(hr)(ft^2)(°F/ft) at 518-1130°F

i. Heat of formation — -1020 Btu/mole at 77°F

Uranium Oxide[1,2,3]

a. Formula — U_3O_8

b. Molecular weight — 842.21

c. Specific gravity — 7.31

d. Solubility — Insoluble in water
Soluble in nitric acid
Soluble in sulfuric acid

e. Specific heat

$$C_p = 62.6 + 6.6 \times 10^{-3} T - 2.5 \times 10^{5} T^{-2} \text{ cal/mole-°K}$$ where T = °K

f. Enthalpy

Temperature, °F	$H_T - H_{298}$, Btu/mole
77	0
440	47.6
1340	167.0
2240	322.0

g. Heat of formation — -3360 Btu/mole at 77°F

Uranium Tetrachloride[1]

a. Formula UCl_4

b. Molecular weight 379.93

c. Specific gravity 4.87

d. Melting point 1094°F

e. Heat of formation -996.1 Btu/mole

f. Specific heat

$$C_p = 0.07608 + 2.88 \times 10^{-5}\, t - 1.3\, (t+41)^{-2} \text{ cal/mole-°C}$$ where t = °C

g. Enthalpy

$$H_t - H_{0°C} = 0.07608\, t + 1.44 \times 10^{-5}\, t^2 - 0.032 + 1.3\, (t+41) \text{ cal/mole}$$

where t = °C

Uranium Tetrafluoride[1]

a. Formula	UF_4
b. Molecular weight	314.11
c. Specific gravity	6.70
d. Melting point	1760°F
e. Solubility	Insoluble in water
f. Heat of formation	-1770 Btu/mole
g. Thermal conductivity	1.13 Btu/(hr)(ft^2)(°F/ft)

Uranium Trioxide[1,2,3]

a. Formula UO_3

b. Molecular weight 286.07

c. Specific gravity 7.54

d. Specific heat

$$C_p = 22.09 + 2.54 \times 10^{-3} T - 2.973 \times 10^{5} T^{-2} \text{ cal/mole-°K}$$

where T = °K

e. Enthalpy

$$H_T - H_{298.16} = 22.09\ T + 1.27 \times 10^{-3} T^2 + 2.973 \times 10^{5} T^{-1} - 7696 \text{ cal/mole}$$

where T = °K

f. Thermal conductivity

Temperature, °F	K, Btu/(hr)(ft^2)(°F/ft)
77 - 302	0.16
320 - 644	0.15
590 - 1112	0.15

Uranyl Nitrate, Hexahydrate[2,3]

a. Formula	$UO_2(NO_3)_2 \cdot 6H_2O$
b. Molecular weight	502.18
c. Specific gravity	2.807
d. Melting point	140.4°F
e. Boiling point	234.4°F
f. Soluble	Very soluble in water
	Very soluble in alcohol
	Very soluble in ether

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