SNO-STR-90-69

May 7, 1990

Tables of Primordial Radioactivity Levels in a Variety of Materials

The following tables are a compendium of many materials which have been tested for the primordial radioactivity levels of Th, U and K. It is hoped that these tables will be useful for other members of the SNO collaboration who are imagining or designing structures or components inside the SNO cavity. Not included are the specific components of the five PMTs which are candidates for the SNO detector, nor acrylic nor reflector aluminum supplied by collaboration members. Results on these are compiled in separate reports.

The tables consist of the following:

1. The first tables are materials that have been γ-counted at Guelph (and a few have been verified at LBL) specifically for the SNO collaboration.

2. The tables of Generic Materials analyzed by INAA were done many years ago at Guelph. There can be pronounced disequilibrium in both the Th and U chains in aluminum, and recently we have found large ^{228}Th enhancements over ^{232}Th and ^{228}Ra in aluminum, so that the INAA results do not necessarily represent very accurately the high energy β- and γ-rates from the samples. Caveat emptor.

3. Table of glasses and miscellaneous items γ-counted for SNO by Barton and his collaborators using the Holborn multiple γ ray counting system.

4. Tables from the work of Avignone and Brodzinski; and from Knoll's book on detectors.

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CANADA

Radioactivity Levels in SNO Materials

Jagam & Simpson
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SAMPLE TITLE	CONC Th-232 (ppb)	CONC U non Ra-226 (ppb)	CONC U via Ra-226 (ppb)	CONC K (%)
Alumina 1	65 ± 8	37 ± 19	14 ± 2	0.003 ± .0004
Alumina 2	22 ± 6	680 ± 80	12 ± 2	0.001 ± 0.0004
Alumina 3	17 ± 10	41 ± 50	12 ± 3	< 0.0001%
Borax 1	55 ± 10	3 ± 18	7 ± 2	0.006 ± .0004
Borax 2	175 ± 40	20 ± 27	46 ± 5	0.003 ± .001
Borax 3	0 ± 10	-8 ± 18	8 ± 3	0.001 ± .0004
Borax 4	123 ± 25	75 ± 75	38 ± 4	0.004 ± .0004
Borax 5	145 ± 9	19 ± 28	36 ± 3	0.004 ± 0.0004
Boric acid 1	6 ± 6	40 ± 17	8 ± 1	0.001 ± .0004
Boric acid 2	5 ± 5	24 ± 21	2 ± 2	0.001 ± 0.0004
Boric acid 3	1 ± 7	3 ± 31	2 ± 3	0.001 ± 0.0004
Cables 1	60 ± 20		4 ± 6	<0.0005
Cement 1	3120 ± 100	2800 ± 800	2350 ± 75	0.158 ± .004
Cement 2	1223 ± 68	4069 ± 541	2362 ± 54	0.236 ± 0.008
Cement 3	4242 ± 104	2012 ± 540	1091 ± 38	0.745 ± 0.013
Ceramic 1 (up bound)	156 ± 70	808 ± 72	61 ± 8	0.008 ± .002
Ceramic 2	2350 ± 150	436 ± 128	545 ± 15	0.015 ± .002
Ceramic 3	1340 ± 70	1932 ± 224	2100 ± 50	0.011 ± .002
Circuit Board 1	690 ± 90		200 ± 43	0.009 ± 0.003
Concrete 1	561 ± 15	419 ± 83	76 ± 5	0.09 ± 0.002
Concrete 2	290 ± 16	680 ± 110	512 ± 12	0.047 ± 0.002
Dolomite 1+2	5 ± 7	32 ± 17	11 ± 3	0.004 ± .0004
Dolomite 3+6	15 ± 10	22 ± 21	11 ± 3	0.004 ± .0004
Dolomite 4	325 ± 25	350 ± 100	96 ± 3	0.016 ± .001
Dolomite 7	2 ± 3	0 ± 10	4 ± 2	0.003 ± .0004
Dolomite 8	6 ± 3	29 ± 14	12 ± 2	0.005 ± .0004
Dolomite 9	2 ± 3	16 ± 14	13 ± 1	0.001 ± .0004
Dolomite 10	14 ± 6	10 ± 26	12 ± 2	0.003 ± 0.0004
Furnace Liner 1	$(1.2\pm0.3)\times10^3$		$(1.5\pm0.3)\times10^3$	0.34 ± 0.10
Furnace Liner 2	100 ± 5		105 ± 6	0.012 ± 0.0005
Furnace Liner 3	167 ± 9		185 ± 5	0.019 ± 0.002
Glass 1	600 ± 30	406 ± 147	240 ± 20	1.021 ± .011
Glass 2	400 ± 50	467 ± 108	402 ± 12	0.008 ± .001
Glass 3	425 ± 25	530 ± 129	420 ± 15	0.006 ± .001
Glass 2+3	400 ± 30	500 ± 100	380 ± 15	0.007 ± .001
Glass 4+5	297 ± 15	186 ± 51	260 ± 10	0.008 ± 0.001
Glass 5	290 ± 30	175 ± 50	275 ± 10	0.009 ± .001
Glass 8	860 ± 30	1338 ± 114	1090 ± 20	0.139 ± .002
Glass 9	840 ± 40	850 ± 200	1085 ± 10	0.007 ± .001
Glass 10	246 ± 20	101 ± 38	129 ± 5	0.03 ± 0.001
Glass 12	1150 ± 20	1500 ± 600	1500 ± 30	0.112 ± 0.002
Glass 13	63 ± 15	158 ± 62	93 ± 4	0.006 ± 0.001
Glass 14	115 ± 18	271 ± 44	201 ± 8	0.014 ± 0.001
Glass 15	604 ± 67	371 ± 120	351 ± 25	0.018 ± 0.001
Glass 16	588 ± 55	644 ± 152	357 ± 32	0.021 ± 0.002
Glass 17	615 ± 81	598 ± 149	355 ± 29	0.018 ± 0.002

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SAMPLE TITLE	CONC Th-232 (ppb)	CONC U non Ra-226 (ppb)	CONC U via Ra-226 (ppb)	CONC K (%)
Glass 18	635 ± 79	496 ± 139	330 ± 27	0.017 ± 0.001
Glass 19	460 ± 61	457 ± 106	377 ± 24	0.008 ± 0.001
Glass 20	454 ± 81	522 ± 159	422 ± 31	0.011 ± 0.001
Glass 21	423 ± 71	597 ± 141	315 ± 28	0.009 ± 0.001
Glass 22	441 ± 72	440 ± 148	411 ± 31	0.010 ± 0.001
Glass 23	400 ± 67	535 ± 124	341 ± 27	0.010 ± 0.001
Glass 24	244 ± 29	159 ± 72	147 ± 46	0.035 ± 0.003
Glass 25	108 ± 54	352 ± 108	88 ± 15	0.022 ± 0.003
Glass 26	382 ± 30	402 ± 107	264 ± 15	0.366 ± 0.006
Glass 27	520 ± 33	692 ± 136	968 ± 22	0.716 ± 0.007
Glass 28	688 ± 72	519 ± 283	775 ± 35	6.125 ± 0.033
Glass 29	66 ± 19		76 ± 10	0.003 ± 0.001
Glass 30	314 ± 20	304 ± 91	457 ± 15	0.008 ± 0.001
Glass 31	40 ± 5	89 ± 33	81 ± 3	0.027 ± 0.001
Glass 32	218 ± 9		265 ± 6	0.021 ± 0.001
Glass 33	211 ± 11		725 ± 11	0.107 ± 0.002
Glass 34	18 ± 4		18 ± 4	0.003 ± 0.001
Glass 35	20 ± 4		22 ± 5	0.003 ± 0.0005
Glass 36	20 ± 6		1 ± 1	<0.0005
Glass 37	72 ± 15		55 ± 7	0.002 ± 0.001
Glass Solder 1	39 ± 7		25 ± 3	0.002 ± 0.0005
Gypsum	225 ± 25	750 ± 250	725 ± 25	0.092 ± .002
Indium 1	6 ± 7	0 ± 30	1 ± 2	.001 ± .0004
$KMnO_4$ 1	30 ± 22	300 ± 190	12 ± 10	24.57 ± 0.03
Lime 1	40 ± 10	59 ± 36	40 ± 3	0.01 ± .001
MnO2 1	52 ± 9	-4 ± 14	8 ± 2	0.001 ± .0004
Mn-coated beads 1	30 ± 60		29 ± 14	4.7 ± 0.03
Nepheline syenite 1a	875 ± 50	308 ± 174	385 ± 15	3.76 ± .012
Nepheline syenite 1b	875 ± 50	1041 ± 354	355 ± 25	3.78 ± .023
Nepheline syenite 2	150 ± 10	39 ± 96	36 ± 3	7.623 ± .009
Nepheline syenite 3	200 ± 30	136 ± 117	36 ± 7	7.732 ± .009
Polymer 1	145 ± 25	118 ± 57	55 ± 5	0.025 ± .001
Polymer 2	160 ± 10	109 ± 34	50 ± 4	0.009 ± 0.0004
Quartz 1	0 ± 3	-2 ± 9	3 ± 1	0.0001 ± .0004
Residue 1	885 ± 25	501 ± 82	96 ± 6	0.001 ± .001
Rock 1	20 ± 8	21 ± 33	0 ± 2	0.001 ± .0004
Rock 2	106 ± 5	79 ± 27	66 ± 5	0.017 ± .001
Rock 3	78 ± 5	48 ± 30	23 ± 2	0.014 ± .001
SS Welding Wire 1	3 ± 1		<1	<0.0005
SS Welding Rod 1	<1		<1	<0.0005
Salt 1	3 ± 2	8 ± 15	1 ± 1	0.004 ± .0004
Salt 2	6 ± 7	4 ± 46	2 ± 4	0.008 ± 0.0001
Sand 1	2160 ± 50	442 ± 199	300 ± 25	0.12 ± .004
Sand 2	5050 ± 50	2400 ± 150	1062 ± 20	0.009 ± .001
Sand 3	415 ± 25	102 ± 70	158 ± 6	0.027 ± .001
Sand 4	790 ± 30	800 ± 100	575 ± 20	0.017 ± .001
Sand 5	20 ± 6	23 ± 16	10 ± 1	0.003 ± .0004

SAMPLE TITLE	CONC Th-232 (ppb)	CONC U non Ra-226 (ppb)	CONC U via Ra-226 (ppb)	CONC K (%)
Sand 6	390 ± 10	200 ± 75	140 ± 3	0.038 ± .001
Sand 7	43 ± 10	20 ± 18	15 ± 2	0.002 ± 0.0004
Sand 8	320 ± 15	258 ± 60	140 ± 7	0.005 ± 0.001
Sand 9	322 ± 14	373 ± 21	263 ± 11	< 0.0001
Sand 10	255 ± 12	107 ± 37	130 ± 5	0.007 ± 0.0004
Sand 11	249 ± 10	125 ± 31	122 ± 4	0.009 ± 0.0004
Sand 12	22 ± 7	36 ± 17	6 ± 2	0.014 ± 0.001
Scintillator Paint 1	19 ± 60		40 ± 30	0.008 ± 0.004
Silica 1	2650 ± 100	753 ± 257	440 ± 20	0.143 ± .006
Silica 2	560 ± 25	194 ± 145	200 ± 15	0.055 ± .003
Silica 3	375 ± 25	785 ± 215	200 ± 15	4.38 ± .017
Sulphur 1	2 ± 5	19 ± 13	2 ± 1	0.001 ± .0004
Sulphur 2	20 ± 4	16 ± 15	9 ± 1	0.002 ± 0.0004
ZnS 1	23 ± 6	753 ± 57	15 ± 3	0.002 ± 0.0005
ZnS 2	130 ± 80		140 ± 40	0.013 ± 0.005

Acrylic	1	Acrylic (UUT)	Chalk River
Alumina	1	Calcined Alumina	Alcan
	2	Hamamatsu Alumina	HBM
	3	CERA Hydrate	HBM
Borax	1	Anhydrous Borax	HBM
	2	US Anhydrous Borax	Peter Doe
	3	US Borax Gran Sq.	Peter Doe
	4	US Anhydrous Borax	WFD
	5	Borax	HBM
Boric Acid	1	US Anhydrous Boric Acid HP	WFD
	2	Hamamatsu Boric Acid	HBM
	3	Boric Acid	HBM
Cables	1	Coaxial cables	
Cement	1	White Portland Cement Type 10	Federal White Cement
	2	Richmond Cement, D. Hallman	
	3	Bath Cement, D. Hallman	
Ceramic	1	Dynode Ceramic Squares	RCA
	2	Mauve Ceramic Ring	RCA
	3	White Ceramic Ring	RCA
Circuit Board	1	Flexible circuit board	
Concrete	1	Bath Concrete, D. Hallman	
	2	Borated Concrete, D. Hallman	
Dolomite	1	Whitish-grey Dolomite (bag #1)	Haley
	2	Whitish-grey Dolomite (bag #2)	Haley
	3	Sandy-stained Dolomite (bag #3)	Haley
	4	Bluish Dolomite (bag #4)	Haley
	5	Whitish-grey Dolomite (bag #5)	Haley
	6	Sandy-stained Dolomite (bag #6)	Haley
	7	West Dolomite	Haley
	8	Middle Dolomite	Haley
	9	East Dolomite	Haley
	10	Dolomite used in Sulfurcrete	WFD
Furnace Liner	1	"ZAC-stone", Schott	
	2	Special liner, Schott	
	3	Crushed liner	
Glass	1	RCA Glass Slides	RCA (Erie Glass)
	2	ZW3468 dark PMT glass, Hamamatsu	HBM
	3	ZW3468 clear PMT glass, Hamamatsu	HBM
	4	ZW4693 dark PMT glass, Hamamatsu	HBM
	5	ZW4693 clear PMT glass, Hamamatsu	HBM
	6	ZW4751 dark PMT glass, Hamamatsu	HBM
	7	ZW4751 clear PMT glass, Hamamatsu	HBM
	8	Schott Glass 8245	Schott via Burle

9	Schott Glass 8020	Schott
10	2 Gencom glass plates	Thorn EMI Gencom
11	Cullet glass	Kimble
12	Philips Glass	JRL
13	Schott Glass 8246-1	Burle
14	Low-Rad Glass Type 1001, EMI	HBM
15	IWAKI 7740	1988.6.8 SMPL 1
16	"	1988.6.27 SMPL 2
17	"	1988.7.7 SMPL 3
18	"	1988.7.26 SMPL 4
19	H-32, Hamamatsu	1988.6.24 SMPL 1
20	"	1988.7.1 SMPL 2
21	"	1988.7.8 SMPL 3
22	"	1988.7.15 SMPL 4
23	"	1988.7.23 SMPL 5
24	Philips Glass 6	
25	Philips Glass 211	
26	Hamamatsu Glass H-50	
27	Hamamatsu Glass HS-50	
28	Burle Shott 8250	
29	Schott 8246-2	
30	ACMI UV1008, CIRCON Corp.	
31	ACMI B472, CIRCON Corp.	
32	K-7003-D (Iwaki), from Hamamatsu	
33	SKS-48 (Akagawa), from Hamamatsu	
34	Schott 8246-3	
35	Schott 8246-4	
36	Glass 300	
37	Russian Glass, Philips	

Glass Solder 1			
Indium 1	Indium		Aptec
$KMnO_4$ 1	University of Guelph		
Lime 1	CaOMgO Lime		Haley
Mn-coated beads	1	Acrylic beads, Secam Canada	
MnO_2	Manganese Oxide		
Nepheline syenite 1	Indusmin Neph. syen.		WFD
2	North Cape Neph. sy. (bag #1)		WFD
3	North Cape Neph. sy. (bag #2)		WFD
PVC 1	PVC, Guelph		Physics Machine Shop
Polymer 1	SRX polymer		
2	SRX Polymer used in Sulfurcrete Sample		WFD
Quartz 1	Minnor XLA01 Quartz		R. Storey
Residue 1	Air-cooled Residue		Chromasco

Rock 1	Russian black rubble	WFD
2	Russian aggregate	WFD
3	Serpentinised Mg pyroxide	Ward Chesworth
SS Welding Wire 1	from K. McFarlane, CRNL	
SS Welding Rod 1	316L, from K. McFarlane, CRNL	
Salt 1	Windsor Ionized Table Salt	Miracle Mart
2	Coarse Pickling Salt	PJ
Sand 1	Midland Treated Sand	Indusmin
2	Fine FeSi	WFD
3	Flint	Indusmin
4	Fluorspar	WFD
5	Corning sand	
6	Russian binder material	WFD
7	Hamamatsu Boric Sand	HBM
8	Silicic Sand Hamamatsu	HBM
9	Acid Washed Quintus Sand	HBM
10	German Sand	HBM
11	Sand (MAM2)	HBM
12	Quartz Sand, Doug Hallman	
Scintillator Paint 1		from R. Kouzes, Princeton
Silica 1	Midland-Silica-325M	WFD
2	St. Canut Silica-325M	WFD
3	Minex-4	WFD
Sulfurcrete 1	Sulfurcrete	Sulfurcrete Prod's Inc.
Sulphur 1	Yellow sulphur disks	
2	Sulphur used in Sulfurcrete	WFD
ZnS 1	BHD ZnS	
2	from R. Kouzes, Princeton	

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Some Generic Materials by INAA

	Th (ppb)	U(Ra) (ppb)
Aluminum Alloys		
1100	200	
2011	150-322	630-870
2024	100-180	511
3002	<1000	1000
5252	<200	3100
5657	<200	1300
6061	100-170	930
Cominco 6 9's	4	14
MRC UHP	0.5-4	1-3
Kingston Ind., NY	<200	2300
Plastics		
Acrylic	1	N/D
Fiber Glass	5000	N/A
Polycarbonate	1	<1.5
Vespel	2	1
Teflon Rod	0.6	0.7
Sheet	0.2	0.2
Powder	<1	N/D
Nylon Rod	0.6	N/D
Synthetic		
Neoprene	162	N/D
Viton	80	162
Epoxy (brown)	2325	350
(white)	61	150

Miscellaneous

	Activated Charcoal	<2-18	1-11
	Concrete 1	651	320
	2	3675	1480
	Rock Salt	2.6	<65
	Boron Nitride	470	N/D
110 Cu		<1	<20
OFHC Cu		<1	<20
Te-Cu		<24	N/D
Mg		<0.6	N/A
Ti		<14	N/A
Pb		<1	<9

	Potassium (ppm)	Uranium (ppm)	Thorium (ppm)
Glasses			
1. Pyrex (E.M.I.)	-50 +- 20	0.58 +- .03	0.37 +- .04
2. Soveril	22800 +- 50	0.09 +- .04	0.07 +- .07
3. Duran 8830	2000 +- 30	0.95 +- .05	2.98 +- .11
4. B47.2	180 +- 20	0.16 +- .03	0.24 +- .05
5. Newcastle	870 +- 30	0.32 +- .04	1.02 +- .07
6. Schott 8245	290 +- 50	1.05 +- .09	0.82 +- .14
7. Schott 8246	-50 +- 20	0.01 +_ .02	0.00 +- .04
Miscellaneous			
8. Quartz powder	-110 +- 30	-0.03 +- .04	-0.01 +- .06
9. Limestone	-70 +- 20	0.00 +- .03	-0.01 +- .05
10. Granite	16200 +- 50	2.96 +- .09	19.42 +- .28
11. Furnace lining	6560 +- 50	8.95 +- .15	27.07 +- .39
12 Aluminium block	-120 +- 20	0.00 +- .04	0.33 +- .07
13. Aluminium sheet	-70 +- 30	-0.06 +- .05	0.12 +- .07
14. CsI crystal	-20 +- 10	-0.02 +- .01	0.00 +- .02
15. CsI(Tl) crystal	-30 +- 10	0.01 +_ .01	0.01 +- .02
16. Brazil nuts	2370 +- 60	2.53 +- .13	6.98 +- .28

Materials	Radionuclide concentration (dpm/kg)		
	^{208}Tl	^{214}Bi	^{40}K
Aluminum	7-200	<4-2000	<20-1000
Beryllium	10	700	<1000
Copper	<0.3	<0.8-3	<10
Copper (grade 101)	<0.03	<0.05	<0.5
Copper (OFHC)	<0.3	<0.8-10	<10
Epoxy	50-4000	80-53000	<1000-72000
Grease, high vacuum	<1	<7	<8
Indium	<1	<3	<20
Lead	<0.02	<0.04	<0.1
Molecular sieve	400-500	1000-3000	8000-9000
Mylar, aluminized	100	200	<2000
Oil, cutting	<0.4	<3	<20
Plastic tubing	4	<4	<800
Printed circuit board	2000	4000	4000
Quartz	6-60	<20-1000	<200
Reflector materials	<0.1-100	<0.7-200	<5-300
Rubber, sponge	50-200	80-1200	<400-2000
Silica, fused	<20	<10	<100
Silicone, foam	20	50	<200
Sodium iodide (Tl)	<3	<4	<30
Solder	<0.3	<0.8	<10
Steel, stainless	<2	<6	<200
Steel, pre-WWII	<0.5	<0.9	<10
Teflon	<0.3	<1-7	<20
Wire, Teflon coated	<4	<1	<20

from Knoll

TABLE 20-1. Levels of Activities from Natural Sources in Common Construction Materials

Material	Disintegrations/min per Gram of Material ^{232}Th(583 keV)	^{238}U	^{40}K
Aluminum (6061 from Harshaw)	0.42	0.04	<0.05
Aluminum (1100 from Harshaw)	0.24	<0.017	<0.06
Aluminum (1100 from ALCOA)	0.08	<0.026	<0.11
Aluminum (3003 from ALCOA)	0.10	<0.026	0.56
Stainless steel (304)	<0.006	<0.007	<0.06
Stainless steel (304-L)	<0.005	<0.005	<0.02
Magnesium (rod)	0.06	<0.04	0.1
Magnesium (ingot)	<0.01	<0.002	<0.02
Magnesium (4"Ø×4" from Dow)	<0.005	<0.002	<0.02
Magnesium (from PGT)	<0.05	<0.03	<0.05
Beryllium copper alloy	<0.02	<0.06	<0.2
Copper (sheet)	<0.05	<0.06	<0.2
Pyrex window	0.45	0.27	3.8
Quartz window	<0.018	<0.018	<0.07
Molecular sieve	4.4	3.0	9.0
Neoprene	<0.008	<0.01	0.36
Rubber	0.12	1.0	2.0
Apiezon Q	4.5	4.5	2.7
Electrical tape - 3M	<0.04	<0.06	<0.1
Cement (Portland)	0.25	1.3	4.5
Epoxy	0.006	0.01	0.19
Lacquer	0.002	0.005	0.04

From Camp, Gatrousis, and Maynard[2].