Sources of Nuclear Data: General

Decay

NUCLIDE	ENERGY	INTENSITY	OTHER LINES			PRODUCTION
CD 119M	0.4115	2.0 A	0.7210	16.9	A	NFA SN122
2.20M			1.0250	23.6	A	NFI <0.01
			1.1019	9.6	A	
			1.2035	12.7	A	
			2.0214	23.1	A	
AU 198	0.4118	95.5 A	0.4118	95.5	A	NTH AU197
2.697D						NFA HG198
TL 198	0.4118	80.6 A	0.0688	22.0	A X	CHA HG198
5.3H			0.0708	40.0	A X	CHA AU197
			0.0802	13.5	A X	
			0.4118	80.6	A	
			0.6758	10.8	A	

The Gamma Rays of the Radionuclides

Tables for Applied Gamma Ray Spectrometry

Gerhard Erdtmann
Werner Soyka

Topical Presentations in Nuclear Chemistry
Kernchemie in Einzeldarstellungen
Volume 7

Verlag Chemie · Weinheim · New York · 1979

---

79 AU 198

HALF LIFE: 2.697D
GEN: NTH AU197
NFA HG198
DAU:
PAR:
REF: 77 HA 1,76 MA 1

0.00999	1.27000	A	X
0.06889	0.81000	A	X
0.07082	1.38000	A	X
0.08020	0.48000	A	X
0.08250	0.12000	A	X
0.41180	95.53000	A	
0.67588	1.06000	A	
1.08764	0.23000	A	

http://www.nndc.bnl.gov/ensdf/index.jsp

Evaluated Nuclear Structure Data File (ENSDF)

Database version of Jan 26, 2005

Experimental Unevaluated Nuclear Data List (XUNDL)

To NNDC

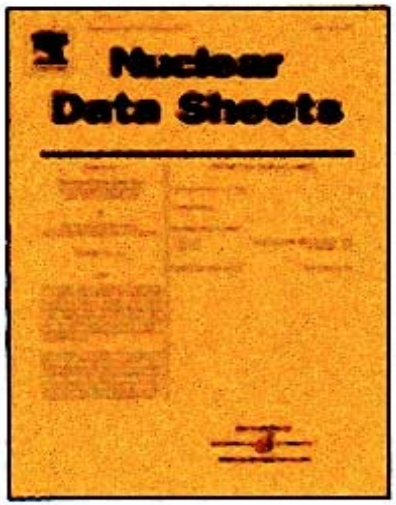
Database version of Jan 14, 2005

The **ENSDF** database contains evaluated nuclear structure and decay information for over 2900 nuclides. The file is updated on a continuous basis. New evaluations are published in *Nuclear Data Sheets*.

The **XUNDL** database contains experimental data compiled from over 1100 recent nuclear structure papers.

NUCLEAR DATA SHEETS

Description
The *Nuclear Data Sheets* are current and are published monthly. They are devoted to nuclear structure data evaluations and to nuclear structure bibliographies. The journal is produced from two computer databases: Evaluated Nuclear Structure Data File (ENSDF) and Nuclear Structure References (NSR).



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Nuclear Data Sheets 104 (2005) 1–282

Nuclear Data Sheets

www.elsevier.com/locate/nds

Nuclear Data Sheets for A = 155*

C. W. REICH

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Idaho Falls, Idaho 83415, USA

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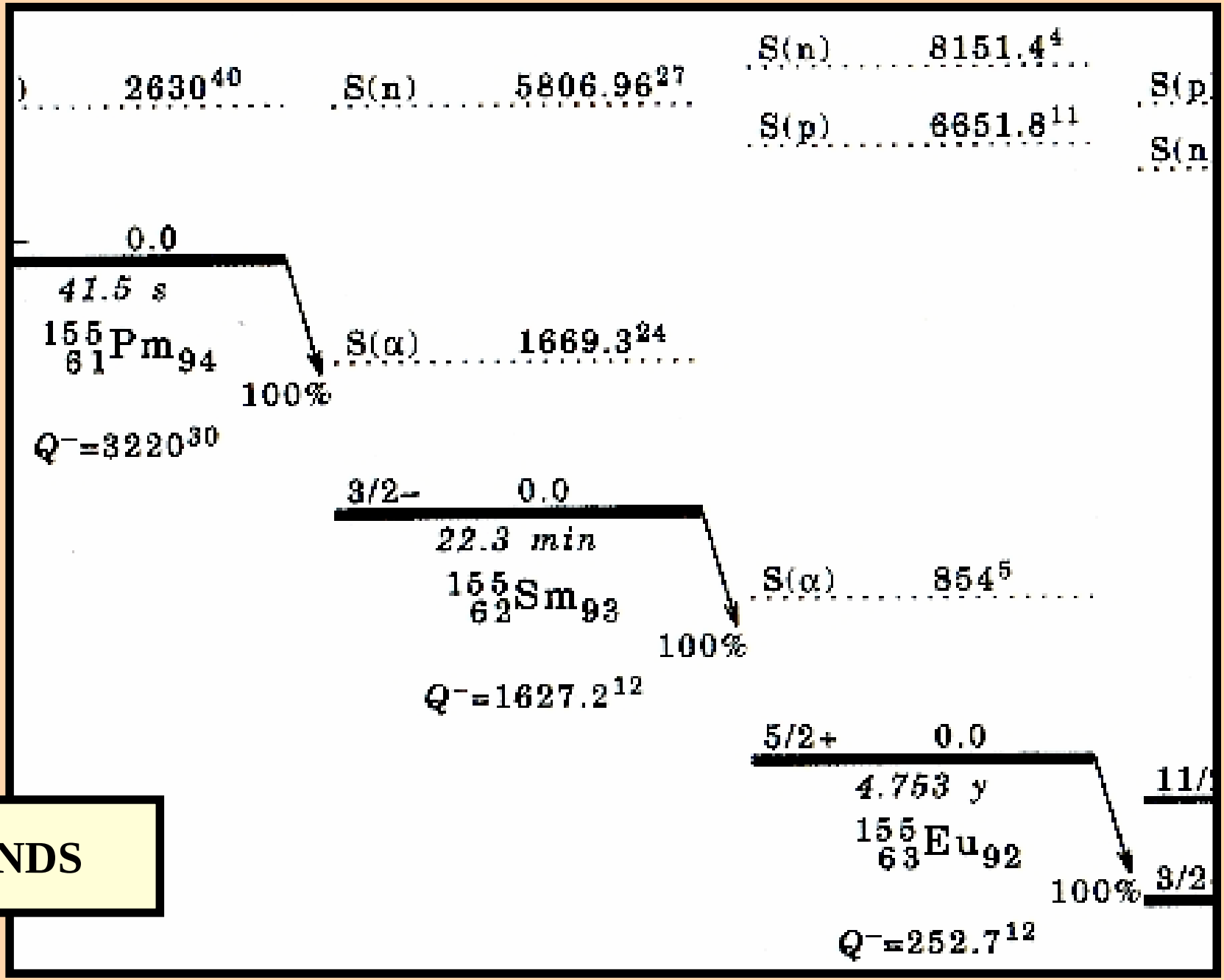
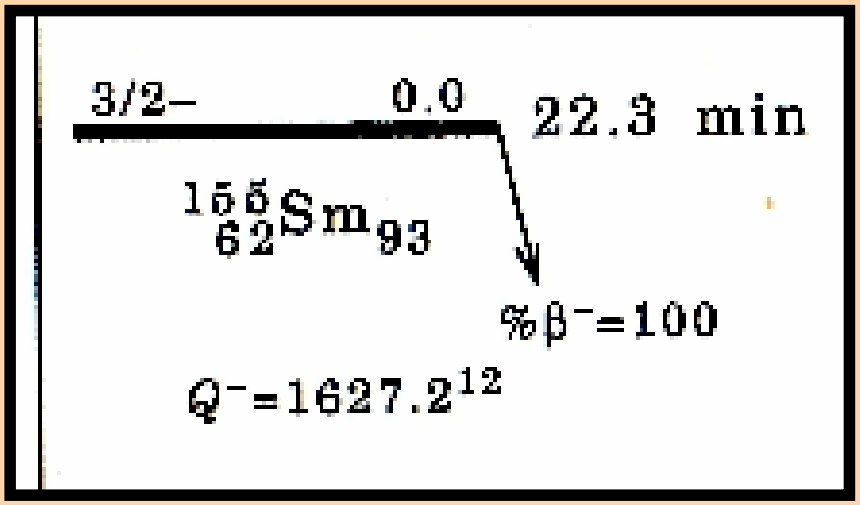
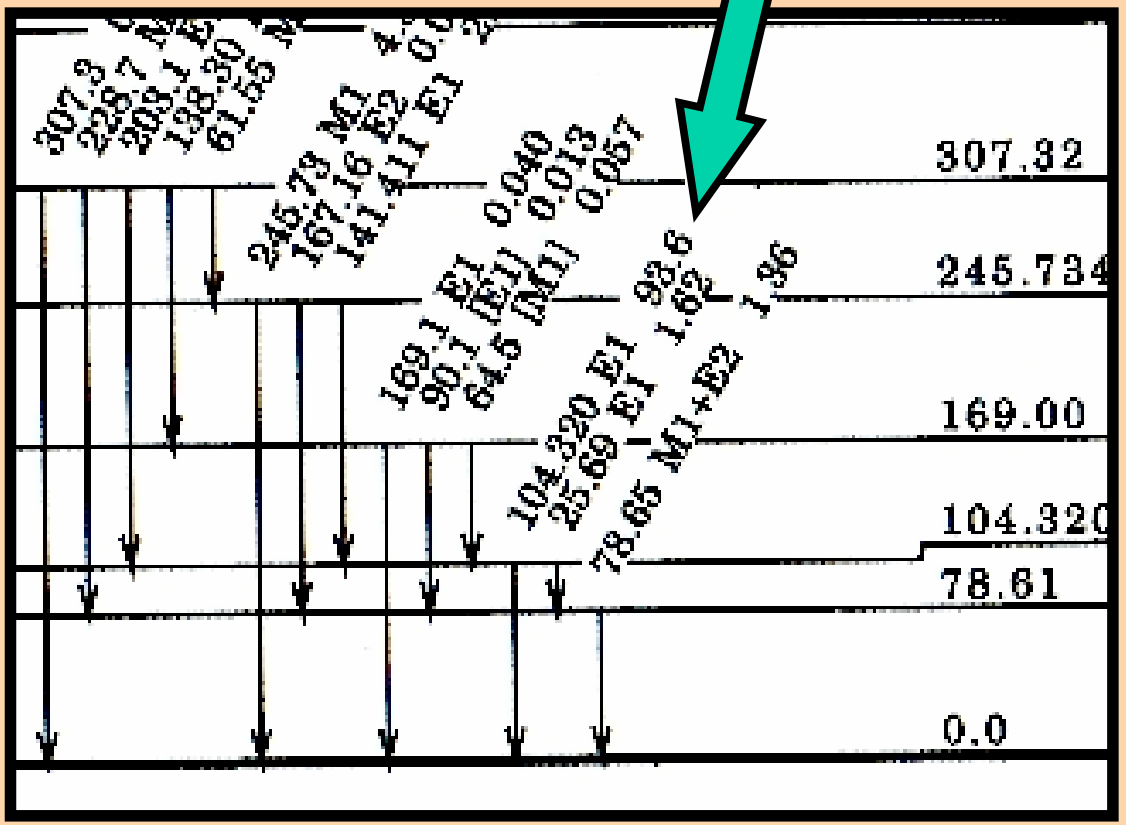
(Received December 22, 2003; Revised October 4, 2004)


S(n) 8151.4⁴
) 2630⁴⁰ S(n) 5806.96²⁷
S(p) 6651.8¹¹
S(p
S(n
0.0
41.5 s
¹⁵⁵₆₁Pm₉₄
S(α) 1669.3²⁴
100%
Q⁻=3220³⁰
3/2− 0.0
22.3 min
¹⁵⁵₆₂Sm₉₃
S(α) 854⁵
100%
Q⁻=1627.2¹²
5/2+ 0.0
4.753 y
¹⁵⁵₆₃Eu₉₂
11/
100%
3/2
Q⁻=252.7¹²

NDS


3/2−
0.0
22.3 min
$^{155}_{62}Sm_{93}$
%β⁻=100
Q⁻=1627.2¹²

NDS


307.32
245.734
169.00
104.320
78.61
0.0

NDS

^{155}Sm β$^-$ Decay 1969Un01 (continued)

γ(^{155}Eu) (continued)

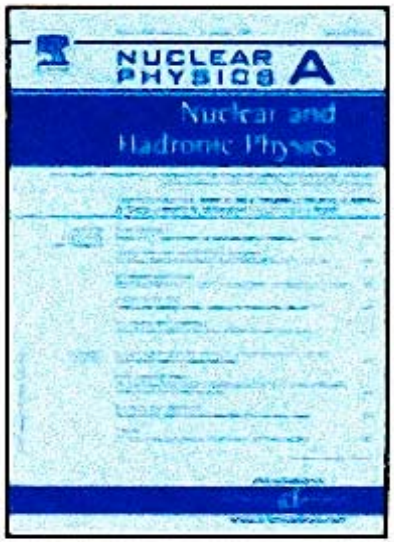
Eγ†#	E(level)	Iγ^eg	Mult.‡	δ§	α	
25.69@ 6	104.320	14 2	E1		2.11	Iγ: 1968V transi the lie
x30.5@ 5		15 1				Iγ: from by the is muc other large.
x53.1@ 4		0.40& 15				
61.55@ 6	307.32	6.0 6	M1+E2	0.29 +6-4	8.3 3	
x63.1@ 5		0.3& 1				
64.5a 5	169.00	0.20 4	[M1]		6.69	
78.65@ 7	78.61	6.8 3	M1+E2	0.60 8	4.35 12	
x80.0@ 5		0.85& 20	E1			
84.1a 5	391.38	0.061 15	M1+E2	0.115 14	3.115 6	Mult.,δ: in β$^-$
90.1a 5	169.00	0.25 6	[E1]		0.3784	
104.320b 5	104.320	2000 50	E1		0.255	Iγ: avera by 19 report

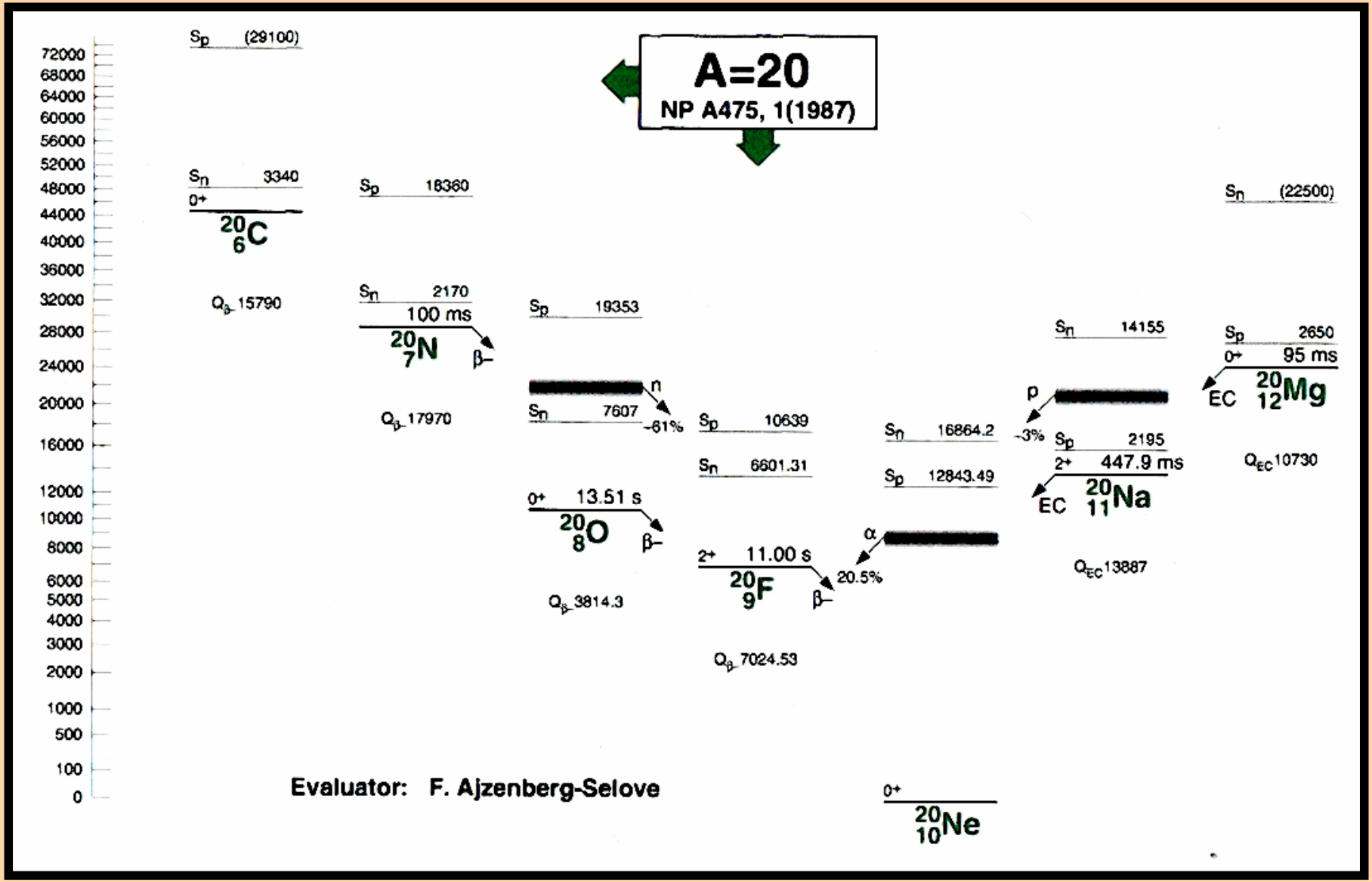
g For absolute intensity per 100 decays, multiply by 0.0373 2.

A ≤ 20

NUCLEAR PHYSICS A

Nuclear and Hadronic Physics




A=20
NP A475, 1(1987)
72000
68000
64000
60000
56000
52000
48000
44000
40000
36000
32000
28000
24000
20000
16000
12000
10000
8000
6000
5000
4000
3000
2000
1000
500
100
0
Sp (29100)
Sn 3340
0+
20 6C
Qβ- 15790
Sp 18360
Sn 2170
100 ms
20 7N
β-
Qβ- 17970
Sp 19353
n
Sn 7607
~61%
0+ 13.51 s
20 8O
β-
Qβ- 3814.3
Sp 10639
Sn 6601.31
2+ 11.00 s
20 9F
β-
20.5%
α
Qβ- 7024.53
Sn 16864.2
Sp 12843.49
0+
20 10Ne
Sn 14155
p
~3%
Sp 2195
2+ 447.9 ms
EC 20 11Na
QEC 13887
Sn (22500)
Sp 2650
0+ 95 ms
EC 20 12Mg
QEC 10730
Evaluator: F. Ajzenberg-Selove

$^{20}_{9}F$ (continued)

6647.5 *4*, 1⁻, Γ=1.59 *10* keV, *[IJ]*,
%IT=0.101 *20*, %n=99.899 *20*,
Γ_γ=1.6 *3* eV
γ_{3488} ***3158.7*** *4* ($\dagger_\gamma$24 *9*)
γ_{2044} ***4602.9*** *4* ($\dagger_\gamma$100 *10*)
γ_{1057} ***5589.8*** *4* ($\dagger_\gamma$15 *7*)
γ_{984} ***5662.9*** *4* ($\dagger_\gamma$31 *7*)

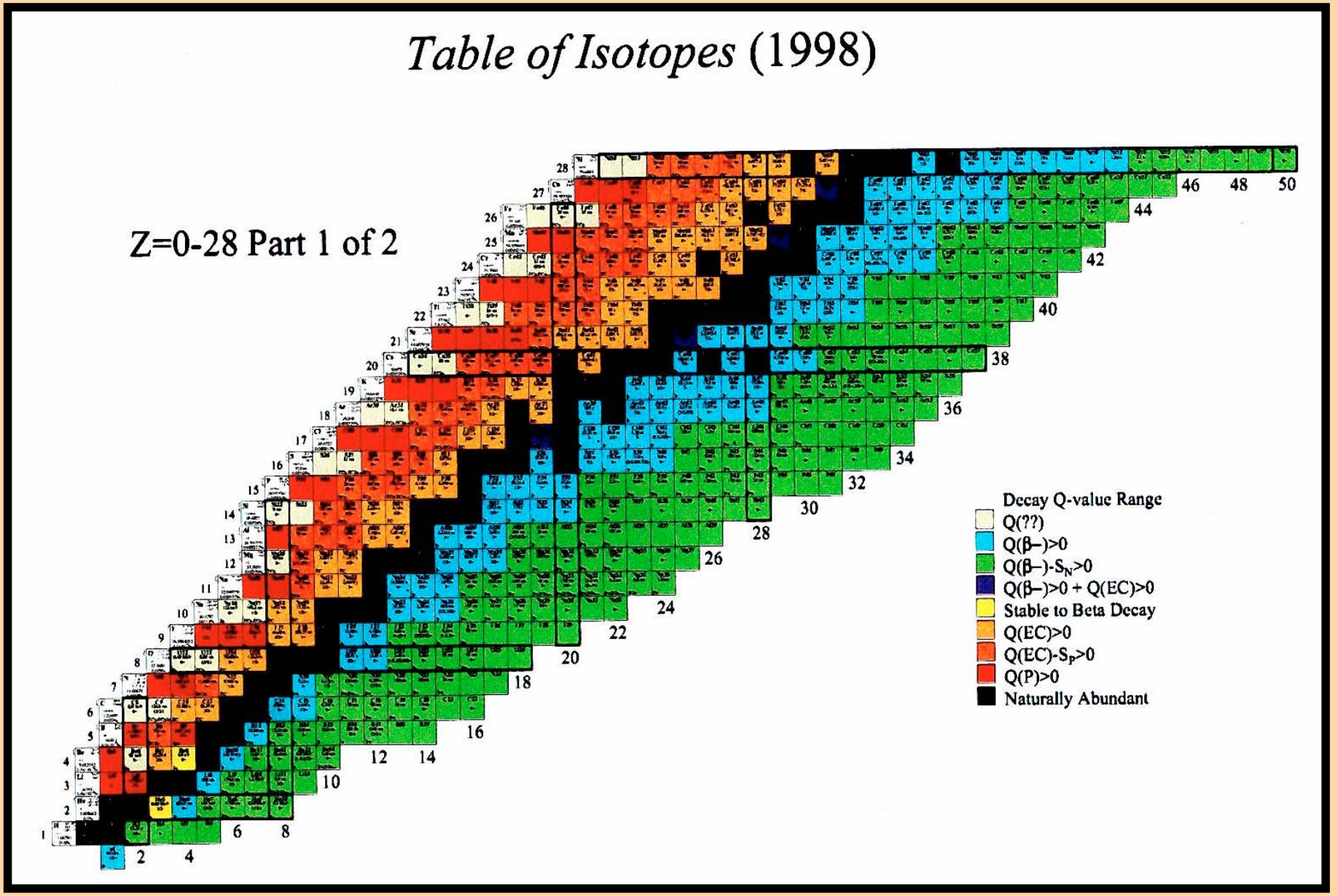
6693.4 *6*, 1⁻, Γ=13.8 *8* keV, *[EIJ]*, %IT=?,

NP A

γ(*^{20}Ne*) from ^{20}F (11.00 s) β⁻ decay <*for Iγ%*
multiply by 1.0>

1633.602 *15* ($\dagger_\gamma$100)
3332.54 *20* ($\dagger_\gamma$0.0082 *6*)
4965.85 *20* ($\dagger_\gamma$0.00005 *2*)

http://ie.lbl.gov/toi/pdf/chart.pdf



Welcome to the *Table of Isotopes* home page

ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

Isotopes Project, Nuclear Science Division

The 8th edition of the Table of Isotopes, book and CD-ROM, by Richard B. Firestone, Virginia S. Shirley*, Coral M. Baglin, S.Y. Frank Chu, and Jean Zipkin. Published by John Wiley & Sons, Inc., 1996.

1998 Update to the 8th edition of the Table of Isotopes, 138-page book and updated CD-ROM, by Richard B. Firestone, S.Y.Frank Chu, and Coral M. Baglin. Published by John Wiley & Sons, Inc., 1998.

1999 Update to the 8th edition of the Table of Isotopes, Booklet and updated CD-ROM, by Richard B. Firestone, S.Y.Frank Chu, and Coral M. Baglin. Published by John Wiley & Sons, Inc., 1999.

http://ie.lbl.gov/toibook.html

LBNL Isotopes Project - LUNDS Universitet

WWW Table of Radioactive Isotopes

Version 2.1, January 2004

R.B. Firestone[1] and L.P. Ekström[1,2]

[1] LBNL, Berkeley, USA
[2] Department of Physics, Lund University, Sweden

Notice: We have been experiencing problems with TORI crashes on the LBNL site that are apparently linked to Windows problems and high usage. If your search fails, please try the Lund site. Please bear with us while we are working on this problem.

Radiation search - search for γ-rays/α,β-particles by energy range and/or parent properties.
Nuclide search - search for nuclides by A, Z, N, and/or half-life range.
Atomic data - search for X-rays and Auger electrons
Periodic table interface to the nuclides
Summary drawings for A=1-277 (PDF)
Chart of the Nuclides (PDF)
Database status

About this service

http://ie.lbl.gov/toi/

Nuclear Data Dissemination home page

Lund Table of Radioactive Isotopes Server

Reference: L.P. Ekström and R.B. Firestone, WWW Table of Radioactive Isotopes, database version 2/28/99 from URL http://ie.lbl.gov/toi/index.htm
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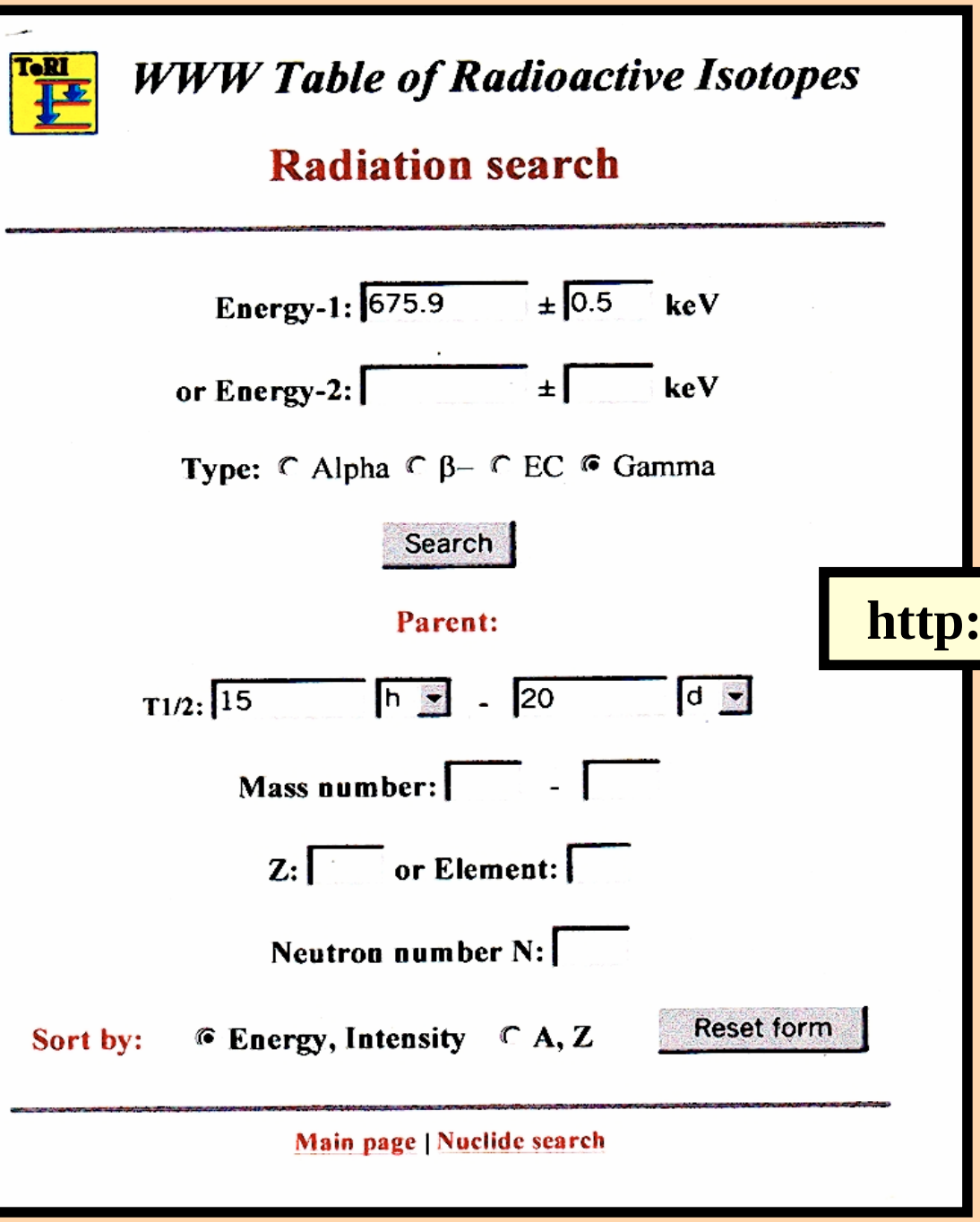
For more information contact
Richard B. Firestone, e-mail: rbf@lbl.gov
Ernest O. Lawrence Berkeley National Laboratory
MailStop 88R0192
1 Cyclotron Road
Berkeley, CA 94720
Phone: 510-486-7646
Fax: 510-486-5757



http://ie.lbl.gov/toi/

http://ie.lbl.gov/toi/

WWW Table of Radioactive Isotopes

Gamma energy search

Eγ between 675.4 and 676.4 keV and $T_{1/2}$(parent) ≥ 15 h and $T_{1/2}$(parent) ≤ 20 d

Eγ (keV)	Iγ (%)	Decay mode	Half life	Parent
675.45 *20*	0.0111 *7*	$\varepsilon+\beta^+$	2.012 d *20*	^{170}Lu
675.5 *5*	0.0009 *4*	β^-	33.039 h *6*	^{143}Ce
675.8836 *7*	0.804 *3*	β^-	2.69517 d *21*	^{198}Au
675.90 *11*	0.075 *9*	$\varepsilon+\beta^+$	34.06 h *5*	^{169}Lu
676.13 *10*	0.14	$\varepsilon+\beta^+$	5.35 d *10*	^{156}Tb
676.14 *11*	<0.015	$\varepsilon+\beta^+$	5.35 d *10*	^{156}Tb
676.17 *10*	0.0172 *19*	$\varepsilon+\beta^+$	8.24 d *3*	^{171}Lu

Main page | Radiation search | Nuclide search

Table of Isotopes decay data

http://ie.lbl.gov/toi/

WWW Table of Radioactive Isotopes

$^{198}_{79}Au_{119}$

Half life:	2.69517 d *21*
Jπ:	2-
S_n (keV):	6512.34 *11*
S_p (keV):	6448.9 *6*
Prod. mode:	Fast neutron activation Thermal neutron activation
ENSDF citation:	NDS 74,259 (1995)
Literature cut-off date:	1-Nov-1994
Author(s):	Zhou Chunmei
References since cut-off:	^{198}Au decay from 1994-98 (NSR)

Decay properties:

Mode	Branching (%)	Q-value (keV)	References
β^-	100	1372.5 *5*	94HeZZ 91BaZS 80Iw03

Most Recent ENSDF Data (12/2002)

Mode	Data set name	Display data
β^-	198AU B- DECAY (2.69517 D)	
	Tables:	Levels Gammas Betas
	ENSDF data:	Data
	Java applets:	Level scheme Beta spectrum

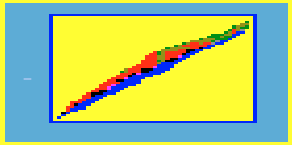
http://ie.lbl.gov/toi/

^{198}Hg:^{198}Au β^- decay (2.69517 d)

E_γ	E_{level}	$J\pi_i$	$J\pi_f$	Mult	δ	I_γ†	$T_{1/2}$	α
411.80205 *17*	411.80249 *17*	2+	0+	E2		100	23.16 ps *12*	0.0443
675.8836 *7*	1087.6873 *7*	2+	2+	M1+E2	+1.07 *14*	0.841 *3*	2.5 ps *2*	0.0276 *21*
1087.684 *3*	1087.6873 *7*	2+	0+	E2		0.1664 *21*	2.5 ps *2*	0.00517

†: For absolute intensity per 100 decays, multiply by 0.9558 *12*.

Feedback to S.Y.Frank Chu



Isotope Explorer

V 2.23, 1999

"Nuclear data a mouse-click away“

S Y F Chu*, L P Ekström[#] and R B Firestone*

** Isotopes Project, LBNL, Berkeley*

[#] Department of Physics, Lund University

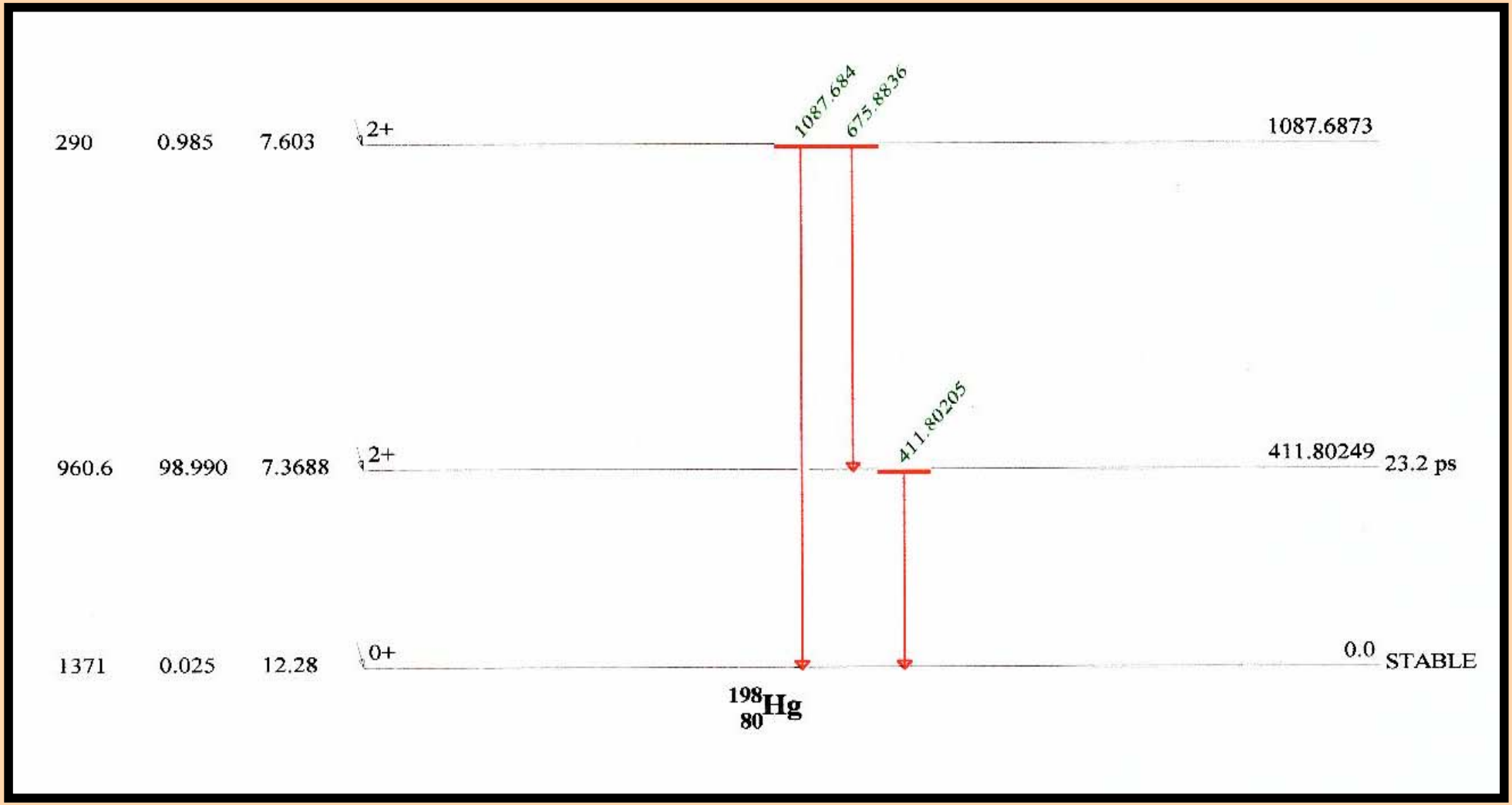
Isotope Explorer is a Windows application to interactively access and display nuclear data and to search for literature references. Isotope Explorer can retrieve data via the Internet or it can use data stored locally.

The program can display **level drawings**, **coincidences**, **tables**, **band plots**, **nuclear charts**, **chart data** and literature **references** - see figures on the left.

Isotope Explorer supports a **nuclear chart interface**, it can display systematics of nuclear properties by color coding a nuclear chart, and it can perform complex searches and calculations with the built-in **script language**.

http://www-nds.iaea.or.at/pgaa/isoexpl/isoexpl.htm

IE 2.23: Au-198 gamma decay scheme



Gammas for ^{198}Hg:^{198}Au β^- decay (2.69517 d) – (continued)

General Comments

G absolute intensity ratios: IG(411G):IG(676G):IG(1088G)=0.9556 65:0.00805 9:0.001595 26 (1992HA02)
I(XKA)/IG(411.8G)=0.0229 5, I(XKB)/IG(411.8G)=0.00635 15 (1975CA15); I(XK) value is consistent with decay
1952FA14, 1952HU01, 1952MU45, 1955BI24, 1956CO28, 1958BA33, 1958KA01, 1958RE22, 1960DE17, 19
Branching IG(1087G)/IG(676G): 0.22 2 (1968DE30), 0.20 2 (1954EL04), 0.23 2 (1955DZ41), 0.23 5 (1951CA24)

E_γ‡	E_{level}	$J\pi_i$	$J\pi_f$	Mult#	δ	I_γ†§	$T_{1/2}$	α	Comments
411.80205 *17*	411.80249 *17*	2+	0+	E2		100	23.2 ps *1*	0.044 *2*	E_γ: others: 411.804 1965MU03 ree EKC=0.0302 3 fro ECC=0.0445 9 0.0302 4 (1965 For other EKC depe 1964PA20, 196 Other recommende K:L1:L2:L3=673 1 (1969MAZU); 15:100:3 2, O/N 1965PE05 deduced 1965RA07 measure
675.8836 *7*	1087.6873 *7*	2+	2+	M1+E2	+1.07 *14*	0.841 *3*		0.0276 *21*	GG(THETA): A2=-

Footnotes

†: For absolute intensity per 100 decays, multiply by 0.9558 *12*.

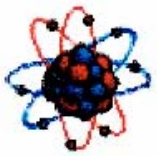
IE 2.23: Au-198 decay gammas

http://id.inel.gov/gamma/

Security/Privacy

Idaho National Engineering & Environmental Laboratory

Welcome to the γ-RAY SPECTROMETRY CENTER



The Idaho National Engineering & Environmental Laboratory (INEEL), capitalizing on its extensive experience, equipment resources, and extended scientific database, has established the INEEL Gamma-Ray Spectrometry Center. The purpose of the Center is to provide specialized data and technical services in the field of Gamma-ray Spectrometry for radiation measurements in many disciplines.

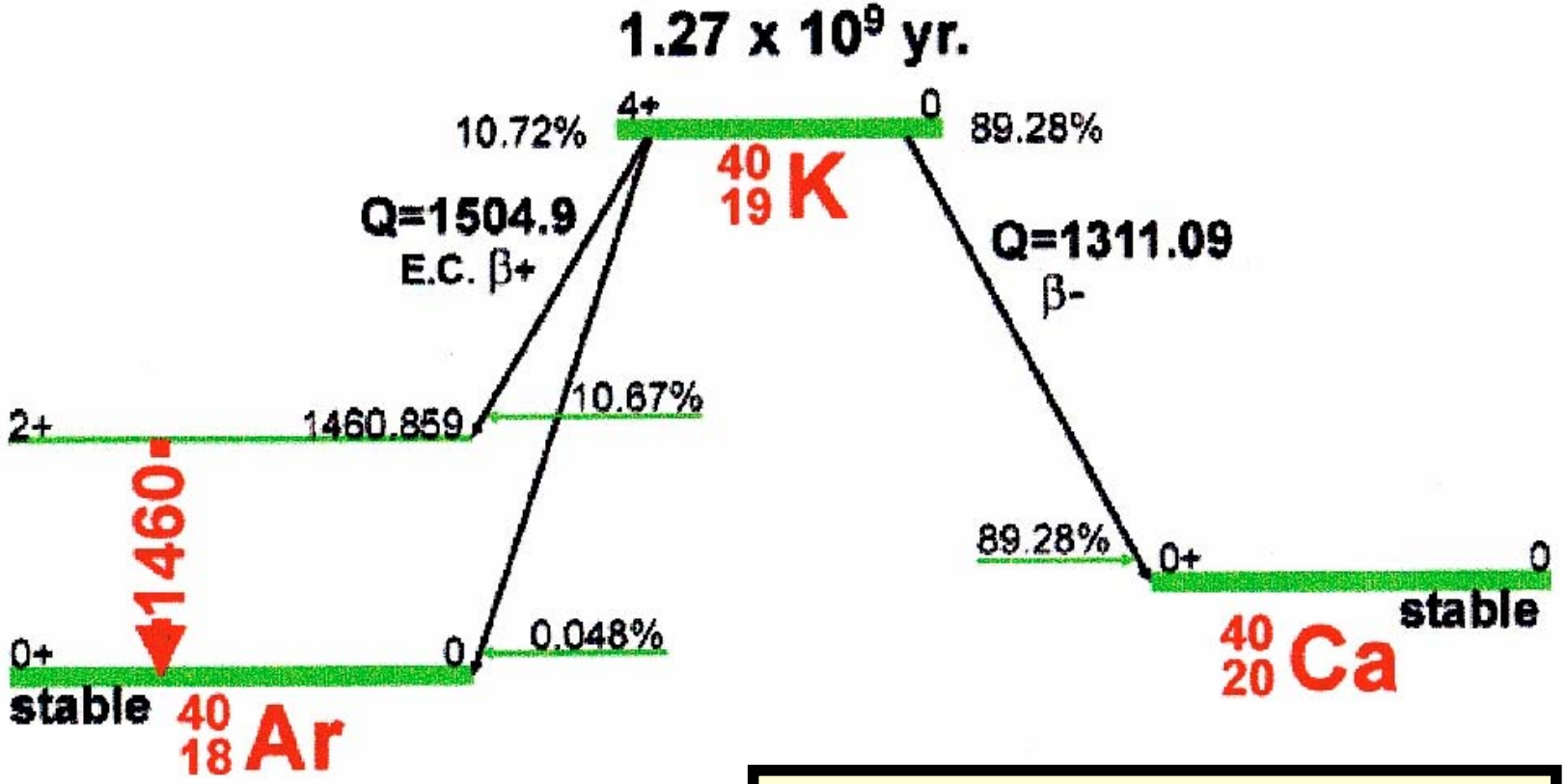
This site includes integrated technical reference material of gamma energies, decay spectra and actual spectral Data in catalog form, history of gamma-ray Spectrometry at the INEEL, and Links to other sources of nuclear data. We hope this information is useful for educating and supporting users who are applying Gamma-ray Spectrometry to an expanding experimental and application based environment.

Home | Spectrometry | Data | Links | Disclaimer

Last Updated Monday, November 26, 2001 by J. R. Davidson

Radionuclide decay scheme for the radioisotope K-40

Specialized spectroscopy format incorporating ENSDF data

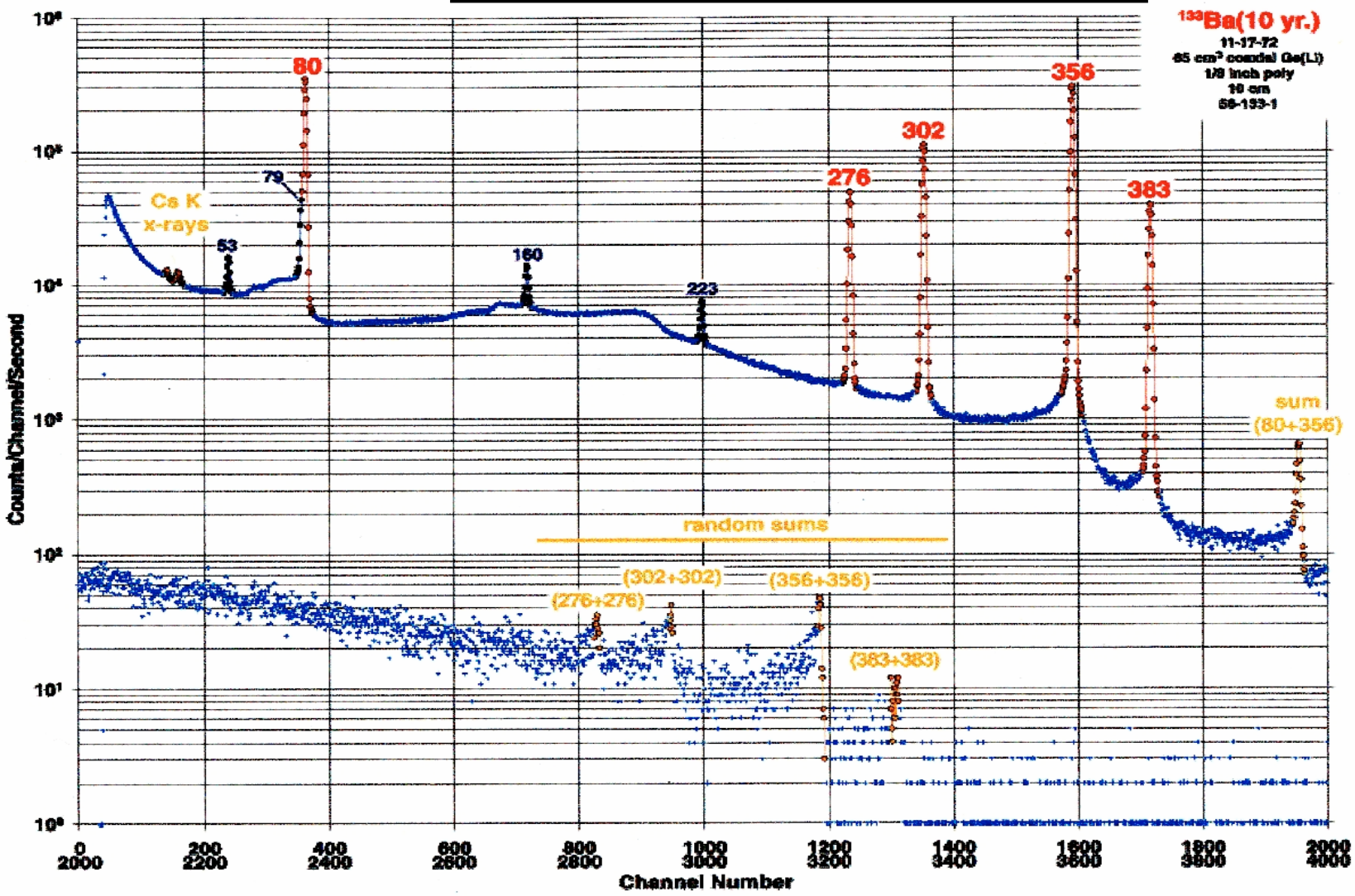


http://id.inel.gov/gamma/

Last Updated Thursday, March 23, 2000 by J. R. Davidson

Spectrum Catalogue Barium-133 Sample

http://id.inel.gov/gamma/



revious Page

http://iaeand.iaea.org/nudat/

Nuclear Data from NuDat

Tables of nuclear data will be produced for the specified type of nuclear data and the nuclides specified by the user. A brief description may be found in the Abstract and a full desciption including examples may be found in the document "The NuDat Program for Nuclear Data on the Web".

Data Base Last Updated On January 15, 2003

	Type of Nuclear Data
LEVELS	Adopted levels from ENSDF
GAMMAS	Adopted gammas rays from ENSDF
LEVELS AND GAMMAS	Adopted levels and gamma rays from ENSDF
WALLET CARDS	Ground and Metastable State Properties
DECAY RADIATIONS	ENSDF decay data processed by RADLIST
NEUTRON DATA	Thermal Data and Resonance Integrals from BNL325

Updated by: TWB (May 17, 2002).

http://www.nndc.bnl.gov/nudat2/index.jsp

NuDat 2

Is a software product that allows to search and plot nuclear structure and nuclear decay data interactively.

It was developed by the NNDC.

It provides an interface between web users and several databases containing nuclear structure, nuclear decay and some neutron-induced nuclear reaction information.

http://www.nndc.bnl.gov/nudat2/index.jsp

The sections of NuDat 2 related to levels, gammas and decay are obtained from the Evaluated Nuclear Structure Data File (ENSDF). Physicists from around the world have been contributing to this effort. The management and location of ENSDF resides at the NNDC. NuDat 2 is periodically updated to reflect changes in ENSDF.

http://www.nndc.bnl.gov/ensdf/index.jsp

http://www.nndc.bnl.gov/nudat2/index.jsp

Search Options:

LEVELS AND GAMMAS

Search on ground and excited states level properties (energy, half-life, spin and parity, decay modes) and gamma-ray information (energy, branching ratio, multipolarity)

NUCLEAR WALLET CARDS

Search on ground and isomeric states level properties, neutron resonance parameters and thermal cross sections

Nuclear Wallet Cards

Nuclear Wallet Cards present properties for ground and isomeric states of all known nuclides. Properties given are:

- Spin and parity assignments
- Nuclear mass excesses
- Half-life, isotopic abundances
- Decay modes

Sixth Edition
2000

Appendices contain properties of elements, fundamental constants and other userful information. Nuclear Wallet Cards booklet is published by the National Nuclear Data Center and its electronic (current) version is periodically updated by Dr. Jagdish K. Tuli. Nuclear Wallet Cards are distributed as a booklet as well as in PDA-adaptable Palm Pilot format, ASCII version is available upon request. A web-based version of Nuclear Wallet Cards provides **search** capabilities on ground and isomeric states level properties. For additional nuclear properties see **NuDat 2.0**.

http://www.nndc.bnl.gov/wallet/index.html

Sources of Nuclear Data

k_0-NAA

ACADEMIC PRESS

Available online at www.sciencedirect.com

SCIENCE DIRECT®

Atomic Data and Nuclear Data Tables 85 (2003) 47–67

Atomic Data AND Nuclear Data Tables

www.elsevier.com/locate/adt

Recommended nuclear data for use in the k_0 standardization of neutron activation analysis☆,☆☆

Frans De Corte[a,*] and András Simonits[b]

[a] *Laboratory of Analytical Chemistry, Institute for Nuclear Sciences (INW), Ghent University, Proeftuinstraat 86, Gent B-9000, Belgium*

[b] *Materials Science Department (ASzI), MTA-KFKI-Atomic Energy Research Institute (AEKI), H-1525 Budapest 114, P.O. Box 49, Hungary*

Abstract

k_0 factors (composite nuclear constants) for use in the k_0 standardization of reactor neutron activation analysis were experimentally measured with great care in several laboratories. The recommended values thus obtained for the relevant gamma rays of 144 analytically interesting radionuclides are tabulated, together with evaluated values for their associated parameters such as resonance integral to thermal cross-section ratios and effective resonance energies. A classification is also given of the various activation-decay types, to which the data are strictly correlated.

Element	Target isotope	Q_0 (s, %)	$\overline{E}_r$, eV	Formed isotope (Activation /decay code)	T½	E_γ, keV	Measured $k_{0,Au}$ (s, %)	Notes
Si	^{30}Si	1.11 (6.)	2280	^{31}Si (I)	2.622 h	1266.2	1.45E-7 (0.7)	
S	^{36}S	1.12 (-)	-	^{37}S (I)	5.05 min	3103.4	1.96E-6 (1.8)	no resonance data; large terrestrial variation in θ
Cl	^{37}Cl	0.69 (-)	13700	^{38}Cl (IVb)	37.24 min	1642.7 2167.4	1.97E-3 (1.4) 2.66E-3 (1.3)	data for m+g (m=715 ms)
Ar	^{40}Ar	0.63	31000	^{41}Ar (I)	1.822 h	1293.6	3.32E-2 (-)	Q_0 adopted
K	^{41}K	0.97 (-)	2960	^{42}K (I)	12.36 h	312.7 1524.7	1.59E-5 (1.1) 9.46E-4 (0.6)	
Ca	^{46}Ca	1.3	-	^{47}Ca (I) ↓ ^{47}Sc (IIa)	4.536 d 3.349 d	489.2 807.9 1297.1 159.4	9.14E-8 (1.8) 9.20E-8 (0.2) 9.54E-7 (1.7) 8.57E-7 (1.6)	no resonance data; Q_0 adopted; large terrestrial variation in θ

ADNDT, 2003: Excerpt

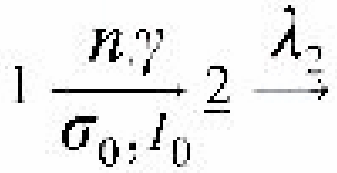
ADNDT, 2003

k_0-NAA:

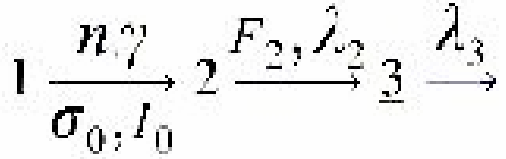
Classification of

Activation/decay schemes

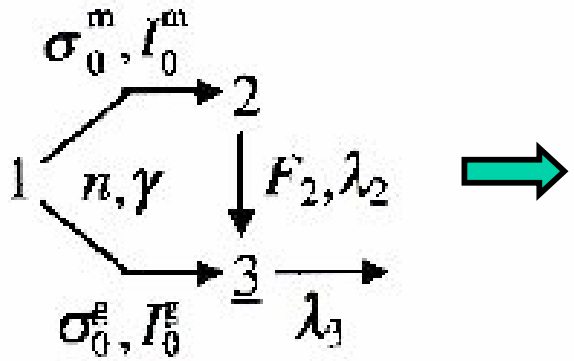
Activation/decay code I



Activation/decay code IIa



Activation/decay code IVa



Activation/decay code IVb

Special case of IVa: $\lambda_2 \gg \lambda_3$ and $D_2 = 0$

Pure Appl. Chem., Vol. 76, No. 10, pp. 1921–1925, 2004.

INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY

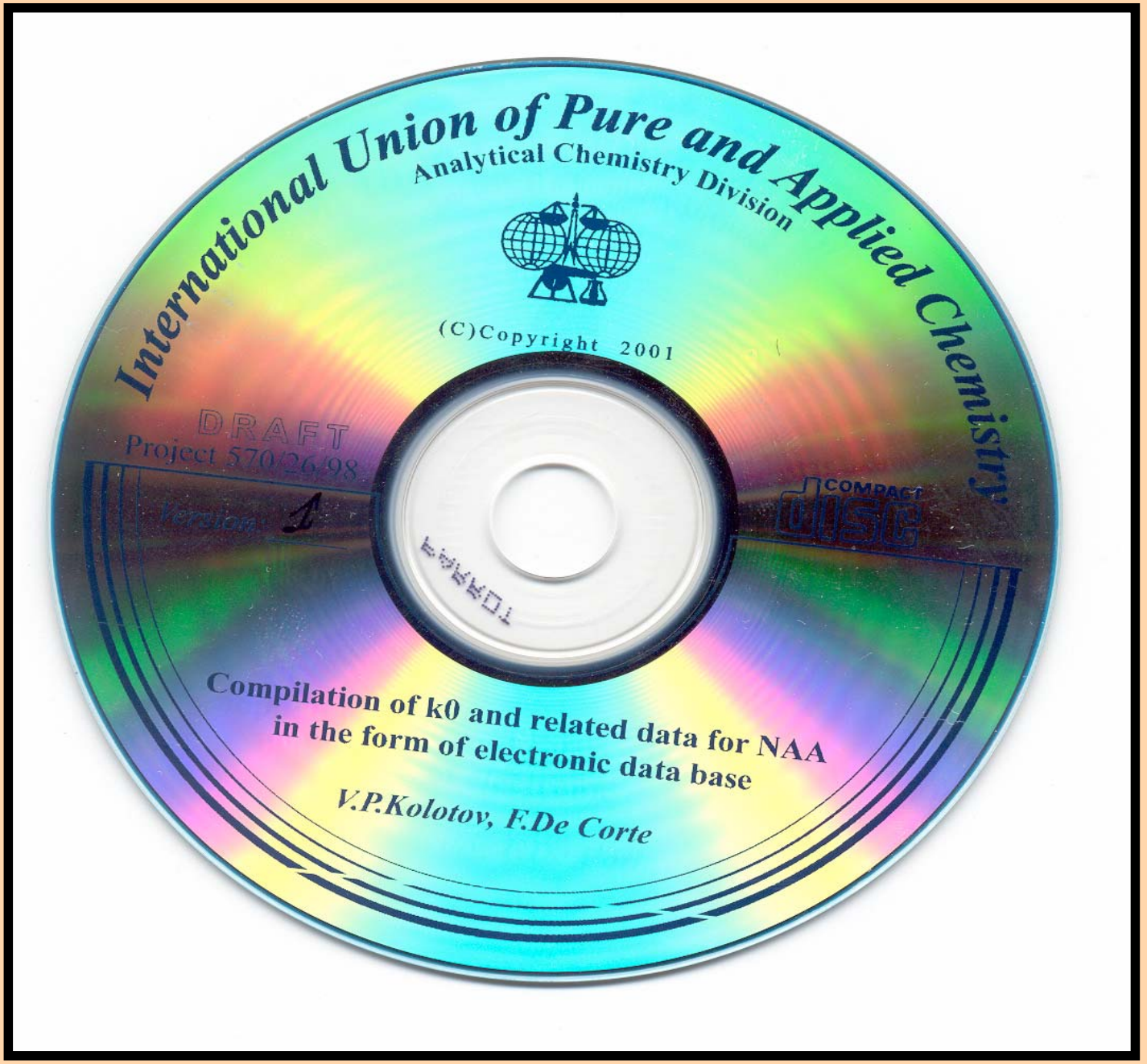
ANALYTICAL CHEMISTRY DIVISION*

COMPILATION OF k_0 AND RELATED DATA FOR NEUTRON-ACTIVATION ANALYSIS (NAA) IN THE FORM OF AN ELECTRONIC DATABASE**

(IUPAC Technical Report)

Prepared for publication by
V. P. KOLOTOV[1,‡] AND F. DE CORTE[2]

[1]Vernadsky Institute of Geochemistry and Analytical Chemistry of Russian Academy of Sciences, Moscow, Russia; [2]Laboratory of Analytical Chemistry, Institute for Nuclear Sciences, Ghent University, Belgium (Fund for Scientific Research, Flanders)


International Union of Pure and Applied Chemistry
Analytical Chemistry Division
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DRAFT
Project 570/26/98
Version 1
COMPACT
disc
Compilation of k0 and related data for NAA
in the form of electronic data base
V.P.Kolotov, F.De Corte

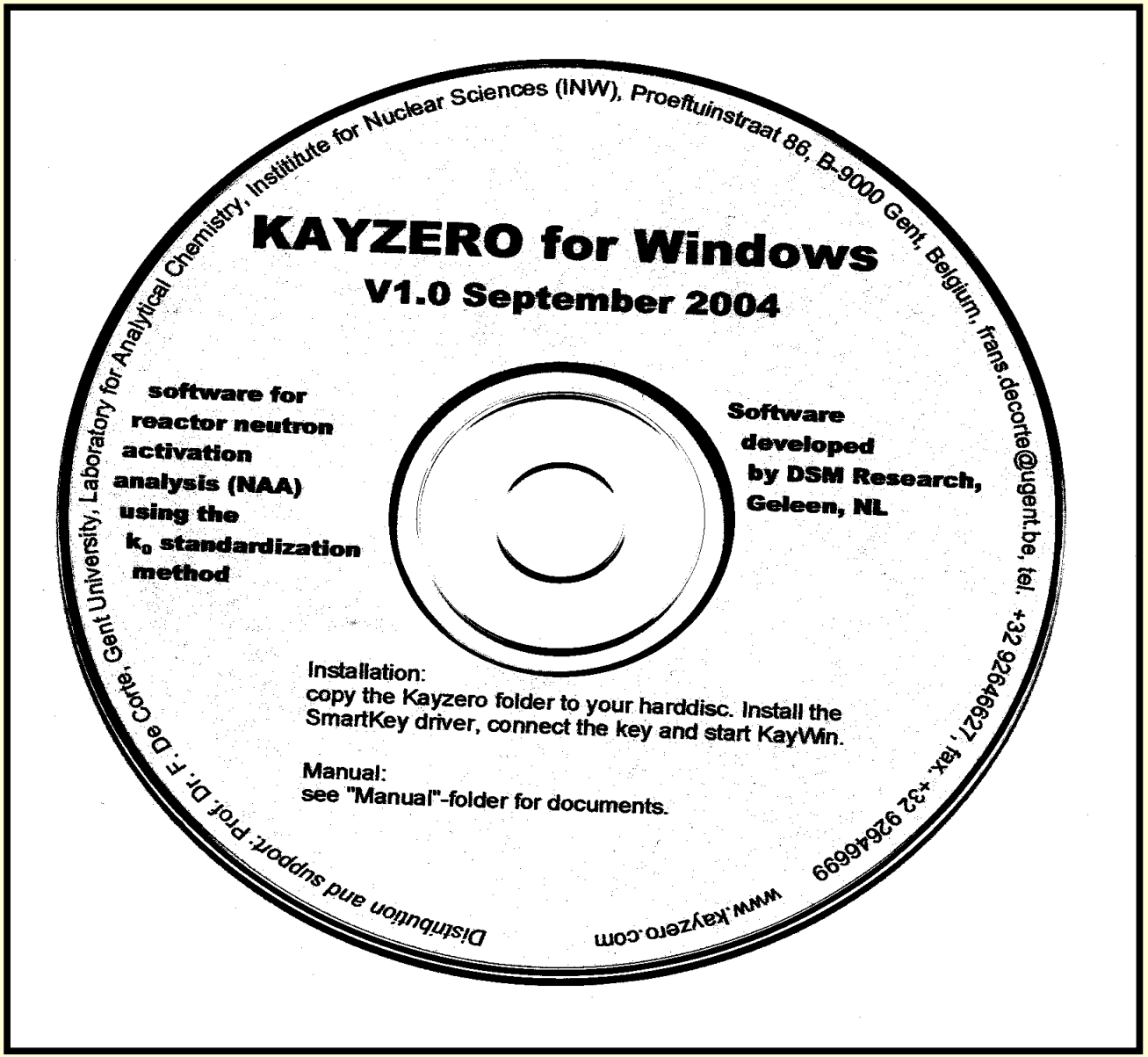
Contains library with

“recommended” k_0

and related nuclear

data for use

in k_0-NAA



Appendix 10: KAYZERO Library: Gamma line listing

PRINT OF THE GAMMA-LINES IN THE KAYZERO LIBRARY : VER4_0 16/12/1996

T 1/2 : 0.0 > T 1/2 > 10000000000. minutes

Energy keV	Isotope	Element	T 1/2 min.	yield %	k0-code
58.6	Co-60m	Co*	10.5	2.089	2
63.1	Yb-169	Yb*	46117.4	44.213	2
63.6	Re-188m	Re	18.6	22.583	3
67.8	Ta-182	Ta	164779.0	41.217	2
69.7	Sm-153	Sm	2776.2	4.312	1
70.4	Pd-111m	Pd*	330.0	30.641	3
74.7	U-239	U	23.5	48.101	1
75.4	Pa-233	Th	38832.5	1.408	3
80.2	I-131	Te	11549.8	2.331	2
80.6	Ho-166	Ho	1609.8	6.330	1
80.9	Mo-101	Mo	14.6	4.771	2
84.3	Tm-170	Tm	185184.0	3.260	1
86.8	Pa-233	Th	38832.5	1.991	3
86.8	Tb-160	Tb	104112.0	13.380	1
88.0	Ag-109m	Pd*	822.1	3.610	2
88.4	Lu-176m	Lu	218.1	8.899	1
89.4	Hf-175	Hf	100800.0	2.354	3
89.7	Cd-117	Cd	149.4	4.071	2
90.1	Eu-152	Eu*	7122670.0	13.477	(double escape peak)
91.1	Nd-147	Nd	15811.2	27.899	1
92.2	Br-82	Br	2118.0	0.760	3
92.4	Re-188m	Re	18.6	5.606	1
93.3	Hf-180m	Hf	330.0	17.311	1
93.5	Ni-65	Ni	151.0	15.119	(double escape peak)
93.5	Zn-65	Zn	351734.4	50.619	(double escape peak)

Appendix 9: KAYZERO Library: Full listing

PRINT OF THE KAYZERO LIBRARY : VER4_0 (16/12/1996) 16/12/1996 - 1-

Isotope:	F-20	Element:	F*	M/D rel:	1		
Q0-1 :	1.500	Q0-2 :	0.000	Eres :	44700.0	eV	
T1/2(2):	0.183	T1/2(3):	0.000	T1/2(4):	0.000	[min]	
F1 :	0.000	F2 :	0.000	F3 :	0.000		
F4 :	0.000	F5 :	0.000				

Energy	k0 factor	code	- interfering nuclides
1633.6	1.010E-3	2	-

Isotope:	Na-24	Element:	Na	M/D rel:	10		
Q0-1 :	0.590	Q0-2 :	0.000	Eres :	3380.0	eV	
T1/2(2):	3.370E-4	T1/2(3):	897.540	T1/2(4):	0.000	[min]	
F1 :	0.000	F2 :	0.000	F3 :	0.000		
F4 :	0.000	F5 :	0.000				

Energy	k0 factor	code	- interfering nuclides
346.6	4.680E-2	5	-
857.6	4.680E-2	4	-
1368.6	4.680E-2	1	- Sb-124
1732.0	4.620E-2	5	-
2243.0	4.620E-2	4	-
2754.0	4.620E-2	1	-

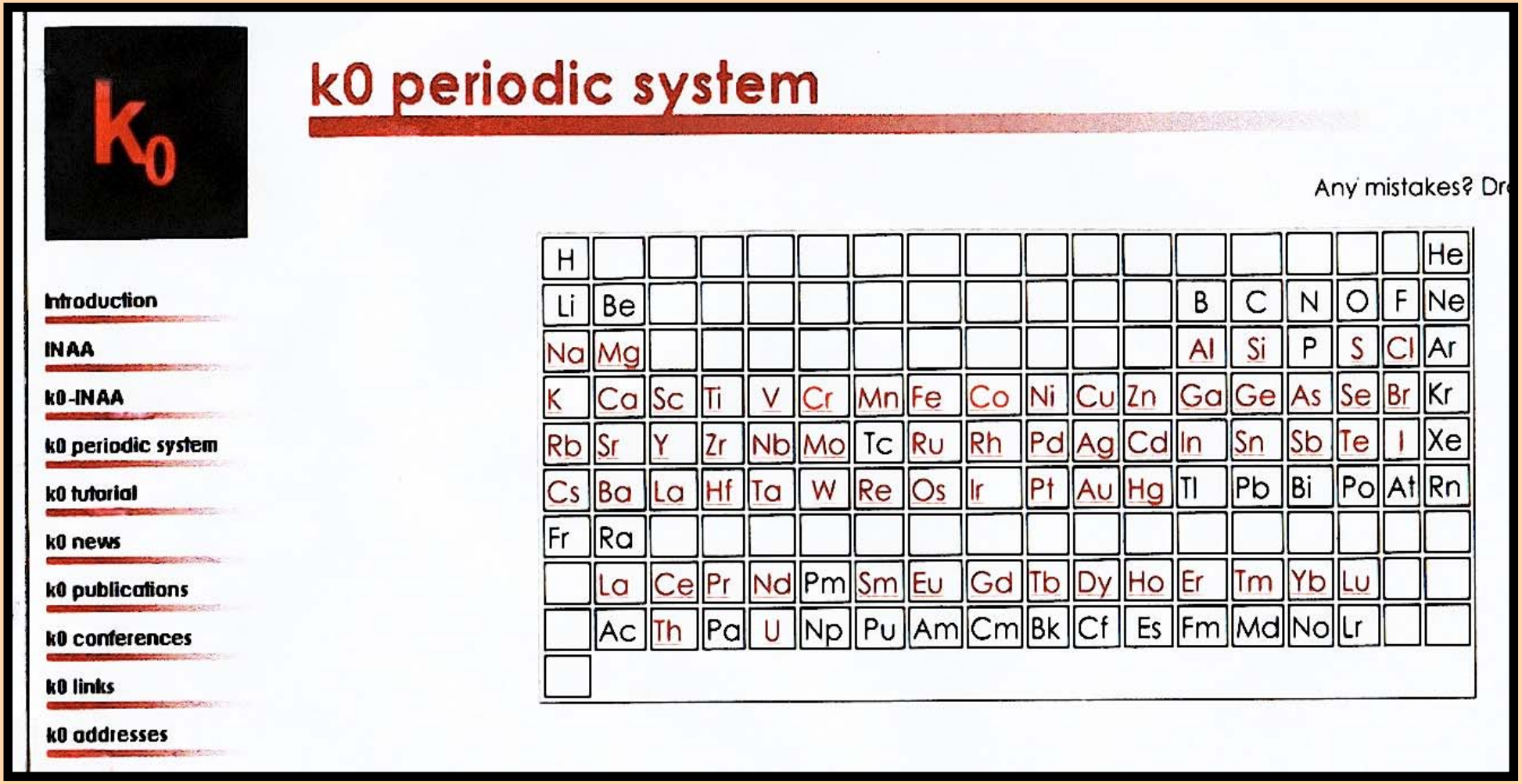
http://iriaxp.iri.tudelft.nl/~rc/fmr/k0www3

Welcome to the Official

k_0 Instrumental Neutron Activation Analysis

WebSite

Created on: 07/15/2004 10:21:44



k0 INAA Website

Cobalt , Co

k0 INAA Website

Z =	27
Mass (g/mol) =	58.93

Stable Isotopes

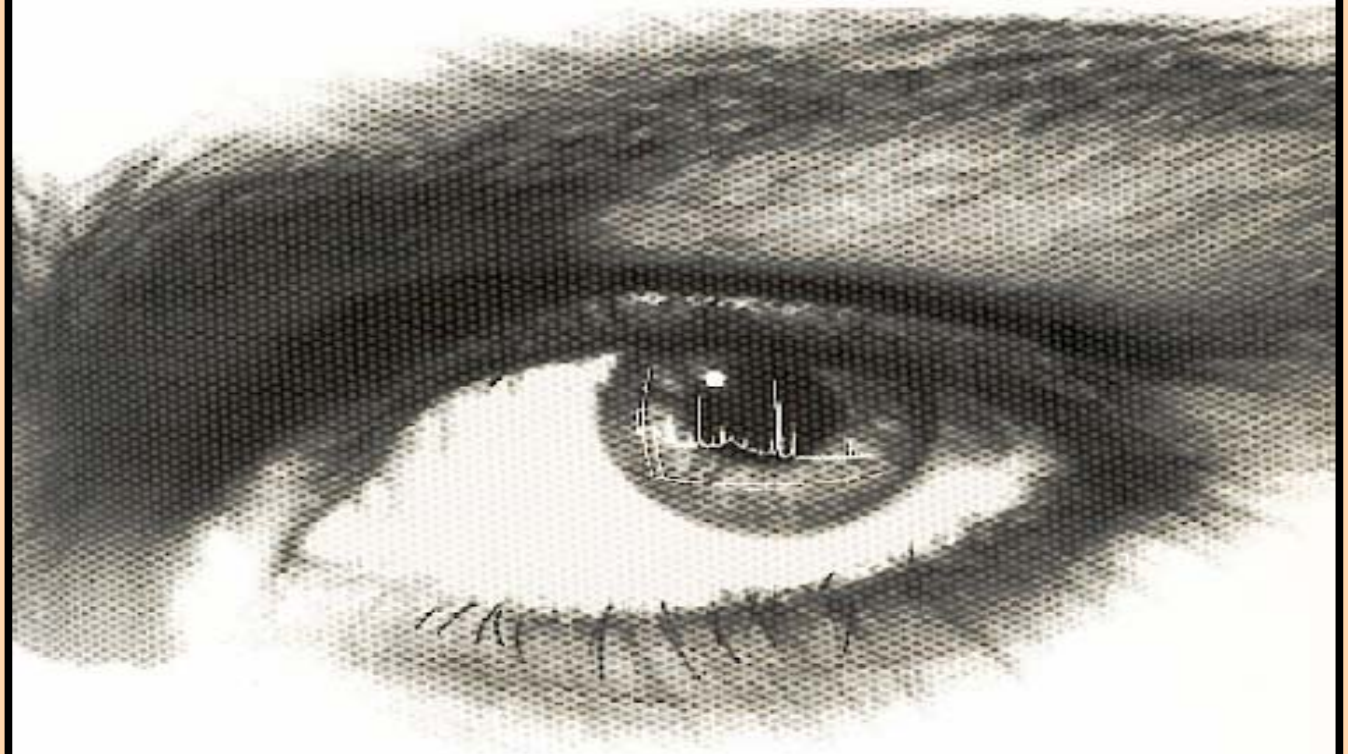
	Abundance (%)	X-sect. (b)	Q0	F-cd	Er (eV)
59Co	100	37.1	1.993	1	136

Parent	M/D	Isotope to Monitor	F1	F2	F3	F4	F5
59Co	IVb	60Co	0	0	0	0	0

k0 values

Measured	T1/2				
60Co	5.271 y	*E (keV)*	*Intensity (abs)*	*K0*	*Comment*
		1173.2	9.990E-01	1.320E+00	K0
		1332.5	9.998E-01	1.320E+00	

The k_0-Consistent IRI Gamma-ray Catalogue for INAA



Menno Blaauw

TABLE I: Activation Reactions and Subsequent Decay

O
M: 16.00
Reactions:
O-18 -> O-19 (26.91 s)
(Θ: 2.00E-03, σ_0: 1.60E-04 b, Q_0: 5.1, E_r: 1.0 eV)

F
M: 19.00
Reactions:
F-19 -> O-19 (26.91 s)
(Θ: 1.00E+00, sF: 1.35E+00 mb)
F-19 -> F-20 (11.03 s)
(Θ: 1.00E+00, σ_0: 9.50E-03 b, Q_0: 4.1, E_r: 1.0 eV)

Ne
M: 20.18
Reactions:
Ne-22 -> Ne-23 (37.24 s)
(Θ: 9.20E-02, σ_0: 4.80E-02 b, Q_0: 0.4, E_r: 1.0 eV)

IRI k0-consistent gamma catalogue

TABEL II: The Gamma-Ray Spectra of the Radionuclides

Be-7 (53.3 d)
Peaks:
 477.61 keV: 10.4 *

O-19 (26.91 s)
    (O-18 -> O-19 (-6))
    (F-19 -> O-19 (-4))
Peaks:
 109.90 keV: 3.10
 197.10 keV: 95.9 *
1356.90 keV: 55.8
1444.10 keV: 3.06
1554.00 keV: 1.43
1598.00 keV: 0.287

F-20 (11.03 s)
    (F-19 -> F-20 (-2))
    (Na-23 -> F-20 (-4))
Peaks:
1633.60 keV: 100 *

Mg-28 (20.9 h)
    (Si-29 -> Mg-28 (-1l))
Main daughter: Al-28
Peaks:
 320.15 keV: (E)
 350.79 keV: (E)
 400.59 keV: 36.0
 431.23 keV: (S)
 567.45 keV: (E)
 647.89 keV: 0.0850
 831.15 keV: (E)
 861.79 keV: (E)
 941.56 keV: 36.2
 972.20 keV: (S)
1078.45 keV: (E)
1342.15 keV: 54.1 *
1372.79 keV: 4.75
1589.45 keV: 4.59
1620.09 keV: 0.300

IRI k0-consistent gamma catalogue

TABLE III: The Gamma-Rays

IRI k0-consistent gamma catalogue

Energy (keV)	Nuclid	$t_{1/2}$	int (%)	E1 (keV)	int (%)	E2 (keV)	int (%)
366.38	Ni-65	2.52 h	4.61	1481.90	23.5	1115.52	14.7
366.42	Mo-99	2.7477 d	1.15	739.50	12.0	181.07	6.07
366.47	Eu-152	13.33 y	(S)	121.78	28.3	344.29	26.0
366.48	Nd-147	10.98 d	(S)	91.10	27.9	531.01	13.1
366.63	Nd-149	1.73 h	0.662	211.29	27.2	114.31	18.7
366.69	Pt-191	2.9 d	(S)	538.91	13.7	409.48	8.00
366.93	Cd-117m	3.36 h	6.24	1065.98	30.0	1997.31	26.2
367.37	Ge-77	11.3 h	13.3	264.42	50.9	211.01	29.1
367.43	Lu-177m	160.9 d	2.89	413.66	17.1	319.03	10.1
367.80	Eu-152	13.33 y	0.858	121.78	28.3	344.29	26.0
368.09	Th-233	22.3 m	4.70E-3	108.40	0.301	459.32	1.39
368.21	U-235	7.0E+8 y	(S)	185.71	48.7	194.93	12.2
368.92	Ba-131	11.5 d	0.0299	496.26	43.7	123.78	29.1
370.78	Eu-154	8.8 y	(S)	123.10	40.4	1274.54	35.4
370.86	Yb-169	32.022 d	6.63E-3	197.96	34.9	177.22	21.4
370.97	Eu-154	8.8 y	(S)	123.10	40.4	1274.54	35.4
371.07	Eu-154	8.8 y	(S)	123.10	40.4	1274.54	35.4
371.30	Ce-143	1.375 d	0.0210	293.28	42.0	664.58	5.25
371.70	Ra-223	11.43 d	0.490	269.39	13.6	154.19	5.58
371.98	Er-171	7.52 h	0.256	308.33	64.4	295.67	28.9
373.01	La-140	1.678 d	(S)	1596.54	95.3	487.02	45.9

Journal of Radioanalytical and Nuclear Chemistry, Vol. 257, No. 3 (2003) 493–499

The updated NAA nuclear data library derived from the Y2K k_0-database

F. De Corte*

Laboratory of Analytical Chemistry, Institute for Nuclear Sciences, Proeftuinstraat 86, B-9000 Gent, Belgium

(Received February 15, 2003)

Values of 2200 $m \cdot s^{-1}$ cross sections, together with the associated nuclear data, are tabulated for 128 (n, γ) reactions of interest in NAA. The values are derived from the Y2K database of experimentally measured k_0-factors.

JRNC, 2003: 2200 ms^{-1} cross-section for 128 (n,γ) reactions,

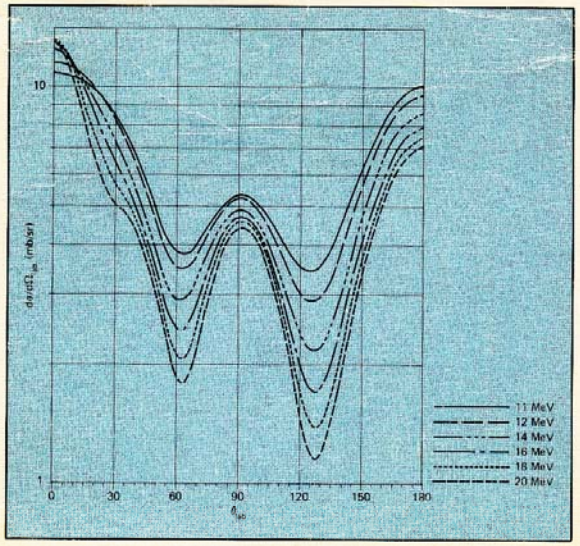
derived from activation method (k_0-factors),

together with associated nuclear data (θ, Q_0, $\bar{E}_r$, $T_{½}$, γ)

F. De Corte, JRNC 2003

Table 1. Y2K compilation of 2200 m.s^{-1} cross sections derived from k_0-factors, together with input data

Target isotope	θ, %	Q_0	E_r, eV	Formed isotope	$T_{1/2}$	E_γ, keV (absol.intens.,%)	σ_0, barn (%s)
^{19}F	100	2.2	44700	^{20}F	11.163 s	1633.6(100.0)	0.0090(1.2)
^{23}Na	100	0.59	3380	$^{24(m+g)}$Na	14.9590 h	1368.6(100.0); 2754.0(99.944)	0.512(0.6)
^{26}Mg	11.01	0.64	257000	^{27}Mg	9.462 min	170.7(0.8); 843.8(71.8); 1014.4(28.0)	0.038(4.4)
^{27}Al	100	0.71	11800	^{28}Al	2.2414 min	1778.9(100.)	0.226(0.8)
^{30}Si	3.0872	1.11	2280	^{31}Si	2.622 h	1266.2(0.07)	0.090(>0.8)
^{36}S	0.02	1.12	-	^{37}S	5.05 min	3103.4(94.0)	0.16(50.)
^{37}Cl	24.22	0.69	13700	$^{38(m+g)}$Cl	37.24 min	1642.7(31.9); 2167.4(42.4)	0.437(2.2)
^{40}Ar	99.6003	0.63	31000	^{41}Ar	1.822 h	(1293.6(99.1))	(0.64)
^{41}K	6.7302	0.97	2960	^{42}K	12.360 h	312.6(0.336); 1524.7(18.08)	1.39(5.)
^{46}Ca	0.004	1.3	-	^{47}Ca	4.536 d	489.2(6.25); 807.9(6.25); 1297.1(71.)	0.643(75.)
				↓ *1.00*			
				^{47}Sc	3.3492 d	159.4(68.3)	
^{48}Ca	0.187	0.45	1330000	^{49}Ca	8.718 min	3084.4(92.1)	1.13(11.)
^{45}Sc	100	0.43	5130	$^{46(m+g)}$Sc	83.83 d	889.3(99.984); 1120.5(99.987)	26.3(0.6)
^{50}Ti	5.18	0.67	63200	^{51}Ti	5.76 min	320.1(93.1); 928.6(6.9)	0.174(2.8)
^{51}V	99.75	0.55	7230	^{52}V	3.75 min	1434.1(100.)	4.79(1.8)
^{50}Cr	4.345	0.53	7530	^{51}Cr	27.7025 d	320.1(9.92)	15.1(0.8)
^{55}Mn	100	1.053	468	^{56}Mn	2.5789 h	846.8(98.87); 1810.7(27.2); 2113.1(14.3)	13.2(1.4)
^{58}Fe	0.282	0.975	637	^{59}Fe	44.503 d	142.7(1.02); 1099.3(56.5); 1291.6(43.2)	1.28(3.0)
^{59}Co	100	2.0	136	^{60m}Co	10.467 min	58.6(2.0); 1332.5(0.24)	20.7(6.)
		2.0	136	^{60}Co	5.2714 y	1332.5(99.97) (m/g=1.23)	(16.8)
		1.993	136	$^{60(F2m+g)}$Co	5.2714 y	1173.2(99.97); 1332.5(99.99)	37.1(0.4)
^{64}Ni	0.9256	0.67	14200	^{65}Ni	2.51719 h	366.3(4.81); 1115.5(15.4); 1481.8(23.6)	1.60(1.5)
^{63}Cu	69.17	1.14	1040	^{64}Cu	12.700 h	1345.8(0.467)	4.69(2.3)
^{65}Cu	30.83	1.06	766	^{66}Cu	5.120 min	1039.2(9.23)	1.99(1.1)
^{64}Zn	48.63	1.908	2560	^{65}Zn	244.26 d	1115.5(50.60)	0.728(1.4)
^{68}Zn	18.75	3.19	590	^{69m}Zn	13.76 h	438.6(94.8)	0.0701(2.8)
^{70}Zn	0.62	7.9	17	^{71}Zn	2.45 min	121.5(3.0); 511.6(32.)	0.021(7.)
^{71}Ga	39.892	6.69	154	$^{72(m+g)}$Ga	14.10 h	834.0(95.6); 894.3(9.88); 1050.7(6.91); 2201.7(25.9); 2491.0(7.68); 2501.8 E_{eff}(20.7); 2507.9 E_{eff}(13.0)	4.65(0.8)
^{74}Ge	36.28	2.38	3540	^{75m}Ge	47.7 s	139.7(38.8)	0.139(3.)
		1.57	3540	$^{75(F2m+g)}$Ge	82.78 min	(198.6(1.19)); (468.8(0.223))	(0.51)
^{76}Ge	7.61	8.75	583	^{77m}Ge	52.9 s	159.7(10.3)	0.109(11.)
		12.9	583	$^{77(F2m+g)}$Ge	11.30 h	(211.0(30.8)); (215.5(28.6)); (264.4(53.9)); (367.4(14.0)); (416.3(21.8)); (558.0(16.1));	(0.064)



TECHNICAL REPORTS SERIES No. 273

Reprinted 1995

Handbook
on Nuclear Activation Data

INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 1987

TABLE A–I. CALCULATED $\bar{E}_r$ VALUES FOR THE (n, γ) REACTION ON 128 TARGET ISOTOPES

Target isotope	$\bar{E}_r$ (eV)	Target isotope	$\bar{E}_r$ (eV)
^{18}O	1 140 000 ± 80 000	^{80}Se	2940 ± 410
^{19}F	44 700 ± 2200	^{82}Se	8540 ± [b]
^{23}Na	3380 ± 370	^{79}Br	69.3 ± 6.2
^{26}Mg	257 000 ± 33 000	^{81}Br	152 ± 14
^{27}Al	11 800 ± 700	^{85}Rb	839 ± 50
^{30}Si	2280 ± 10	^{87}Rb	364 ± 11
^{31}P	38 500 ± 6900	^{84}Sr	469 ± 33
^{36}S	[a]	^{86}Sr	795 ± 16
^{37}Cl	13 700 ± 1900	^{89}Y	4300 ± 340
^{40}Ar	31 000 ± 5600	^{94}Zr	6260 ± 250

GRYNTAKIS et al.

Annex

EFFECTIVE RESONANCE ENERGY VALUES

F. De Corte
Rijksuniversiteit Gent, Gent, Belgium

k_0-PGAA

k_0-PGAA

launch at 1st International k_0 Users Workshop, Gent, 1992

Lindstrom, Fleming, Paul, Mackey (NIST):

"The k_0 approach in cold-neutron prompt-gamma activation analysis"

Rossbach (KFA-Jülich), De Corte (INW, Gent):

"Introducing the k_0-concept into prompt gamma cold neutron activation analysis (PGCNAA)"

Basic PGAA equation (a = analyte; m = monitor):

$$(conc)_a = \frac{\left(\frac{N_p / t_m}{W}\right)_a}{\left(\frac{N_p / t_m}{w}\right)_m} \frac{1}{\frac{M_m \theta_a \gamma_a \sigma_{0,a}}{M_a \theta_m \gamma_m \sigma_{0,m}}} \frac{\varepsilon_{p,m}}{\varepsilon_{p,a}}$$

prompt: no SDC !!

Thermal / cold neutron beam: no term for epithermals !!

M = atomic weight
θ = isotopic abundance
γ = gamma-intensity
σ_0 = thermal cross-section

Immediately after launch of PGAA:

measurement of k_0's in thermal and/or cold neutron beams

with tackling of special problems:

neutron scattering / change of neutron spectrum (neutron absorption):
→ internal comparator

Ge gamma-ray spectrometry:
wide energy-range (50 keV - 12 MeV) efficiency calibration
→ multi-gamma sources and capture reactions

gamma-spectrum deconvolution and peak integration:
→ (Budapest) Hypermet-PC software [< Hypermet algorithm]

Since serious problems with neutron scattering and absorption:

$$\left(conc\right)_{\frac{a}{IC}} = \frac{\left(N_p\right)_a}{\left(N_p\right)_{IC}} \frac{k_{0,m}\left(IC\right)}{k_{0,m}\left(a\right)} \frac{\varepsilon_{p,IC}}{\varepsilon_{p,a}}$$

Concentration ratio vs suitable IC element
m = ultimate monitor

Co-ordination needed → IAEA-CRP 1999 - 2002

"DATABASE OF PROMPT GAMMA RAYS FROM SLOW NEUTRON CAPTURE FOR ELEMENTAL ANALYSIS"

H.D. Choi (Seoul, Korea)
R.B. Firestone (Berkeley, CA, USA)
S.C. Frankle (Los Alamos, NM, USA)
A. Goswani (Mumbai, India)
R.M. Lindstrom (Gathersburg, MD, USA)
M.A. Lone (Chalk River, Canada)
G.L. Molnár (Budapest, Hungary)
S.F.Mughabghab (Upton, NY, USA)
Nguyen Canh Hai (Dalat, Vietnam)
A.V.R. Reddy (Mumbai, India)
Zs. Révay (Budapest, Hungary)
Chunmei Zhou (Beijing, PR China)

IAEA-CRP 1999 - 2002

labs participating in k_0-determination

Institute	Location	Researchers
NIST – National Institute of Standards and Technology, Analytical Chemistry Division	Gaithersburg, MD, USA	Lindstrom, Paul et al.
Bhaba Atomic Research Centre	Trombay, Mumbai, India	Reddy, Acharya et al.
Seoul National University, Korea Atomic Energy Research Institute	Seoul, Korea	Choi et al.
Vietnam Atomic Energy Commission	Hanoi, Vietnam	Tan et al.
Institute of Isotope and Surface Chemistry, Chemical Research Centre	Budapest, Hungary	Molnár, Révay et al.

IAEA CRP: Final Report

k_0 versus Cl: Comparison of adopted with other measurements

Table V. Comparison of library $k_{0,Cl}$-factors with other measurements for the most prominent γ rays of selected elements.

Z	Target Isotope	E(dE)	Adopted	Dalat thermal beam [31]	BARC thermal guide [28]	SNU diffraction beam [7]	NIST-thermal beam [33]	JAERI thermal guide [34, 35]	NIST cold guide [33]	JAERI cold guide [34, 35]	Budapest thermal guide [32]
1	1-H	2223.25	1.848(11)		1.800(16)		2.00(10)	1.80(6)	2.05(11)	1.86(6)	1.803(10)
3	7-Li	2032.30(4)	0.0307(8)	0.0230(5)*							
5	10-B	477.595(3)	369.5(23)		312(22)			371(31)		380(32)	360(3)
6	12-C	1261.765(9)	0.000579(15)	0.00041(1)*				0.000573(5)		0.000551(6)	0.000546(9)
	12-C	4945.301(3)	0.001218(25)					0.00124(3)		0.001160(17)	0.001192(13)
7	14-N	1884.821(16)	0.00588(8)	0.00567(11)				0.005800(13)		0.005890(18)	0.00569(4)
11	23-Na	472.202(9)	0.1165(11)				0.105(4)	0.11600(41)	0.105(4)	0.1160(25)	0.1181(13)
12	25-Mg	585.00(3)	0.0072(3)				0.0065(2)		0.0064(3)		
13	27-Al	1778.92(3)	0.0482(10)				0.0467(18)	0.0440(4)	0.0463(21)	0.0433(14)	0.0472(9)
14	28-Si	2092.902(18)	0.00660(13)	0.00603(11)							
	28-Si	3538.966(22)	0.0237(4)				0.0214(7)	0.02180(10)	0.0216(9)	0.02110(11)	0.0231(5)
15	31-P	636.663(21)	0.0056(3)					0.00572(9)		0.00570(9)	0.0055(3)
16	32-S	840.993(13)	0.0606(11)	0.0603(15)			0.0558(18)	0.0554(10)	0.0562(23)	0.0570(12)	0.0608(13)
17	35-Cl	786.3020(10)	0.540(3)		1.30(3)&		1.28(6)&	1.330(45)&	1.26(7)&	1.350(44)&	
	35-Cl	788.4280(10)	0.856(9)		1.30(3)&		1.28(6)&	1.330(45)&	1.26(7)&	1.350(44)&	
	35-Cl	1951.1400(20)	1	1	1	1		1		1	1
19	39-K	770.3050(20)	0.1294(18)		0.116(4)		0.126(4)	0.127(4)	0.122(5)	0.128(4)	0.127(3)
20	40-Ca	1942.67(3)	0.0492(10)		0.045(2)		0.0461(16)	0.047(2)	0.0459(19)	0.0464(16)	0.0463(14)
22	48-Ti	341.706(5)	0.215(3)		0.187(6)*			0.211(3)		0.2250(16)	
	48-Ti	1381.745(5)	0.606(15)	0.433(10)*	0.604(13)		0.582@	0.582(6)	0.591@	0.591(6)	0.591(7)
	48-Ti	1585.941(5)	0.0730(10)		0.056(3)*						
24	50-Cr	749.09(3)	0.0614(10)		0.065(8)			0.0562(20)		0.0601(25)	
	50-Cr	834.849(22)	0.149(3)		0.138(8)			0.141(5)		0.142(5)	0.145(2)
	50-Cr	7938.46(23)	0.0457(11)		0.048(3)						
25	55-Mn	314.398(20)	0.1488(22)					0.152(5)		0.149(8)	0.150(3)
26	56-Fe	352.347(12)	0.0274(3)				0.0253(9)	0.0273(10)	0.0248(10)	0.0269(11)	
	56-Fe	7631.136(14)	0.0654(13)					0.0568(24)*		0.0537(27)*	0.0676(14)

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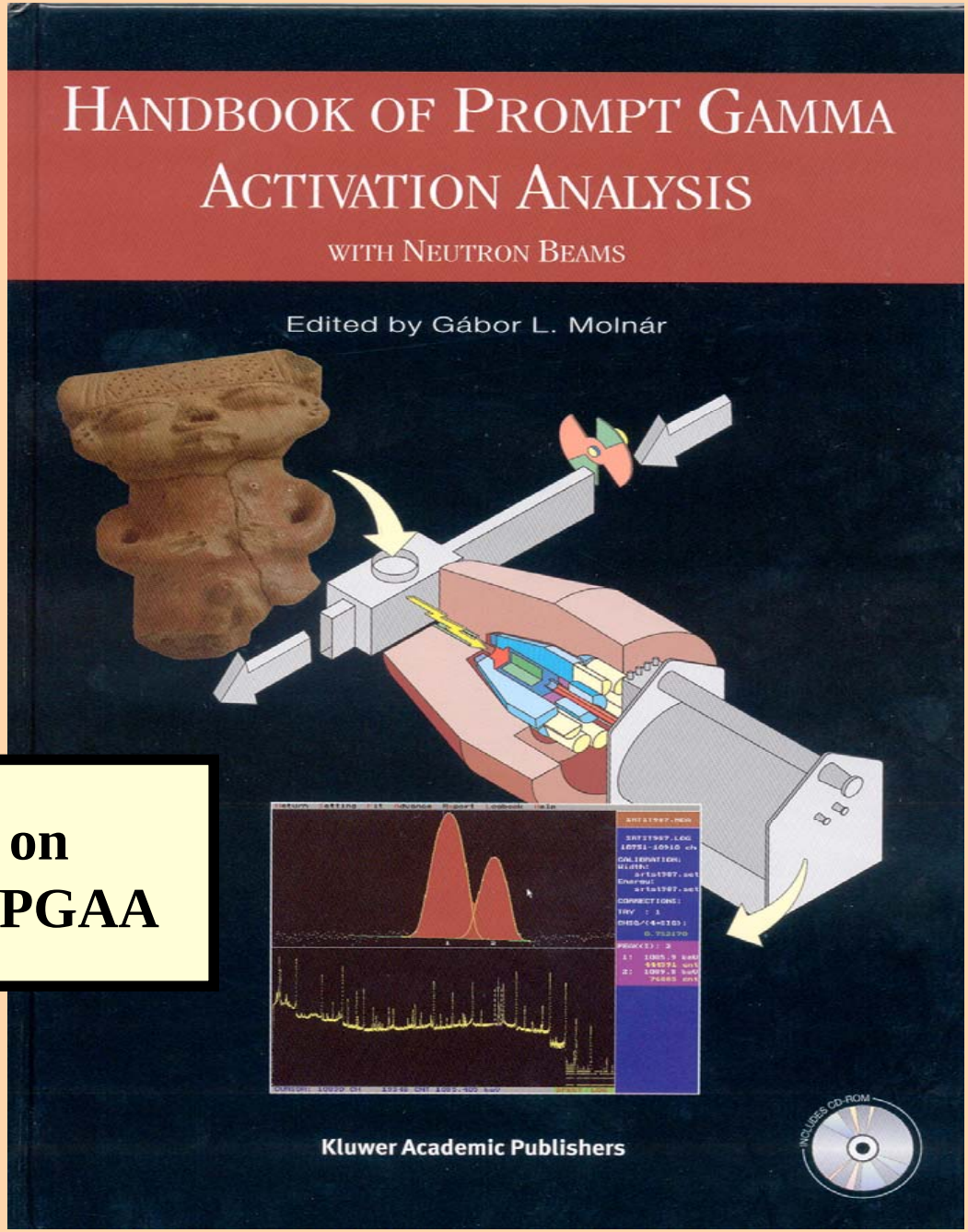
k_0 versus H: adopted

Table III. Adopted Prompt and Decay Gamma [illegible] from Thermal Neutron Capture for all Elements

^{A}Z	E_γ-keV	$\sigma_\gamma^z(E_\gamma)$-barns	k_0
Hydrogen (Z=1), *At.Wt.*=1.00794(7), σ_γ^z =0.3326(7)			
^{1}H	**2223.24835(9)**	**0.3326(7)**	**1.0000(21)**
^{2}H	6250.243(3)	0.000519(7)(a)	0.001560(21)
Helium (Z=2), *At.Wt.*=4.002602(2), σ_γ^z =4.2E-11(12)			
^{3}He	**20520.46**	**4.2(12)E-11**	**3.2(9)E-11**
Lithium (Z=3), *At.Wt.*=6.941(2), σ_γ^z =0.045(3)			
		σ_α^z (^{6}Li)=71.3(5)	
^{6}Li	477.595(3)	0.00153(8)	0.00067(4)
^{7}Li	**980.53(7)**	**0.00415(13)**	**0.00181(6)**
^{7}Li	**1051.90(7)**	**0.00414(12)**	**0.00181(5)**
^{7}Li	**2032.30(4)**	**0.0381(8)**	**0.0166(4)**
^{6}Li	6768.81(4)	0.00151(9)	0.00066(4)
^{6}Li	7245.91(4)	0.00247(14)	0.00108(6)
Beryllium (Z=4), *At.Wt.*=9.012182(3), σ_γ^z =0.0088(4)			
^{9}Be	**853.630(12)**	**0.00208(24)**	**0.00070(8)**
^{9}Be	**2590.014(19)**	**0.00191(15)**	**0.00064(5)**
^{9}Be	**3367.448(25)**	**0.00285(22)**	**0.00096(7)**

^{A}Z	E_γ-keV	$\sigma_\gamma^z(E_\gamma)$-barns	k_0
^{16}O	**870.68(6)**	**1.77(11)E-4**	**3.35(21)E-5**
^{16}O	**1087.75(6)**	**1.58(7)E-4**	**2.99(13)E-5**
^{17}O	1981.95(9)	2.0(4)E-7	3.8(8)E-8
^{16}O	**2184.42(7)**	**1.64(7)E-4**	**3.11(13)E-5**
^{16}O	**3272.02(8)**	**3.53(23)E-5**	**6.7(4)E-6**
Fluorine (Z=9), *At.Wt.*=18.9984032(5), σ_γ^z =0.0096(5)			
^{19}F	**166.700(20)**	**0.000413(18)**	**6.6(3)E-5**
^{19}F	325.606(24)	4.0(3)E-5	6.4(5)E-6
^{19}F	556.40(4)	2.01(8)E-4	3.21(13)E-5
^{19}F	**583.561(16)**	**0.00356(12)**	**0.000568(19)**
^{19}F	**656.006(18)**	**0.00197(7)**	**0.000314(11)**
^{19}F	661.647(21)	2.24(14)E-4	3.57(22)E-5
^{19}F	662.25(10)	1.02(15)E-4	1.63(24)E-5
^{19}F	**665.207(18)**	**0.00149(6)**	**2.38(10)E-4**
^{19}F	822.700(19)	2.20(9)E-4	3.51(14)E-5
^{19}F	978.19(5)	6.8(6)E-5	1.08(10)E-5
^{19}F	**983.538(20)**	**0.00116(4)**	**1.85(6)E-4**
^{19}F	1045.98(3)	1.79(8)E-4	2.86(13)E-5
^{19}F	**1056.776(17)**	**0.00095(3)**	**1.52(5)E-4**



Detailed info on nuclear data for PGAA

Note on Inconsistencies

<u>WARNING FOR INCONSISTENCIES:</u>

mostly, σ_0 is determined from the activation method ("k_0"),

with the introduction of data for the isotopic abundance θ

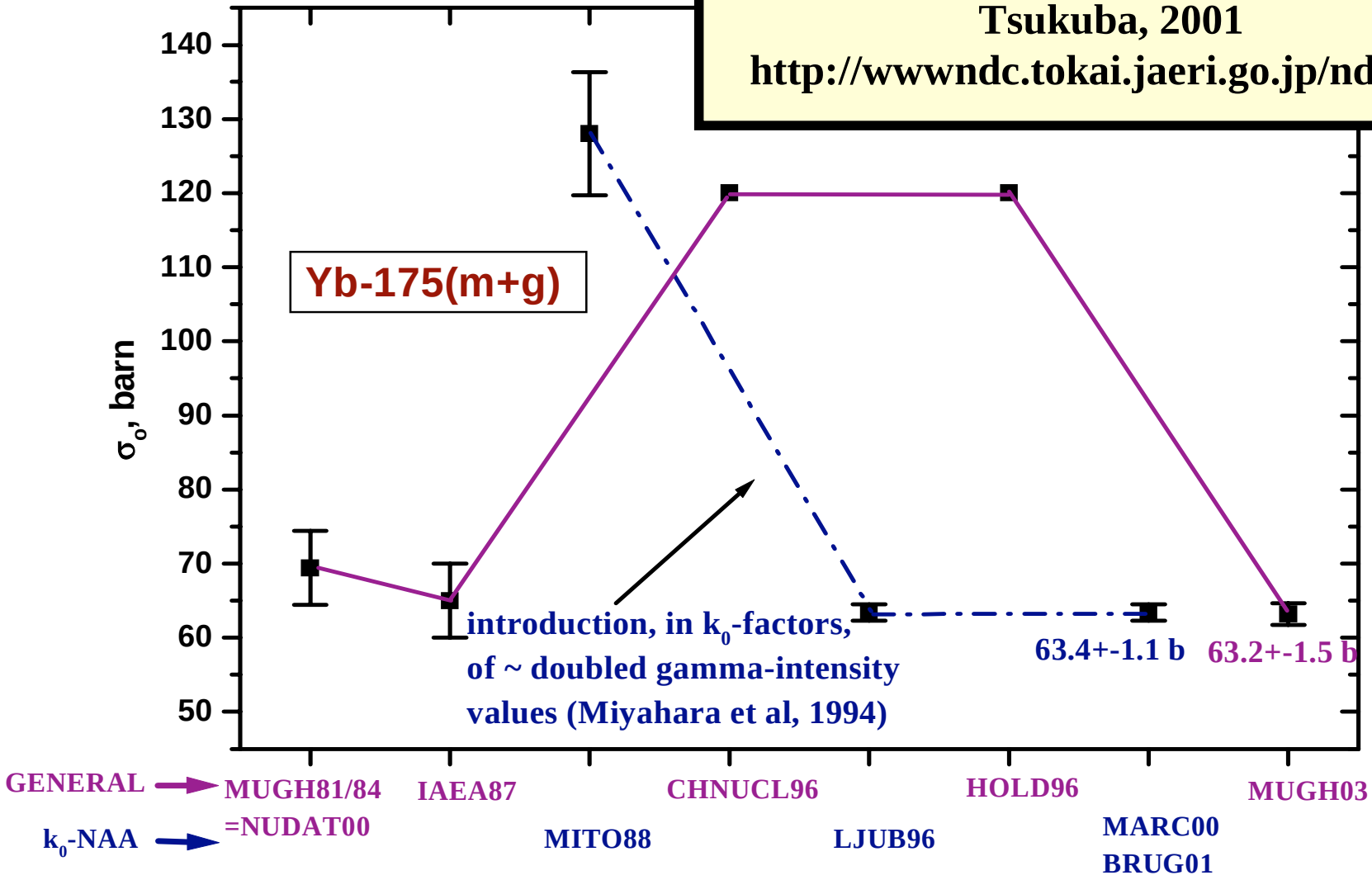
and the gamma-intensity γ;

modification of the latter without changing the compiled σ_0,

leads to inconsistencies (loss of traceability)

Remarkable case of inconsistency

F. De Corte, in:
ND in Sci.&Technol.,
Tsukuba, 2001
http://wwwndc.tokai.jaeri.go.jp/nd2001/



End of walk through Nuclear Data in NAA

(F. De Corte, UGent)