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THE PRESENT STATUS OF THE LLNL EVALUATED CHARGED PARTICLE LIBRARY (ECPL)

Malcolm H. Mac Gregor

March 13, 1987

Lawrence
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THE PRESENT STATUS OF THE LLNL EVALUATED CHARGED PARTICLE LIBRARY (ECPL)

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March 13, 1987

The Nuclear Data Group of the Lawrence Livermore National Laboratory has for the past decade maintained an Evaluated Charged Particle Library (ECPL). This ECPL library encompasses low-Z target nuclides and low-Z incident and outgoing projectiles. Each evaluated data set extends from threshold to 20 MeV incident projectile energy, and it includes a complete set of data: total cross sections, angular distributions, energy distributions of the final-state particles, energy deposits, Maxwellian average reaction rates, and in-flight reaction cross sections. The Nuclear Data Group also maintains a reprint library of experimental papers on low-Z charged-particle reactions.

The present report is written with two purposes in mind: (1) to summarize the charged-particle reactions that presently exist in ECPL (see Table I); and (2) to list all of the low-Z charged-particle reactions for which data exist in the Livermore experimental data compilation (see reactions listed in Table II). The reactions in Table II that are underlined are presently included in ECPL. It is clear that only a small fraction of the reactions listed in Table II have as yet been included in ECPL. However, the reactions that are now in ECPL are the most important ones. Also, some of the reaction channels listed in Table II are redundant. Furthermore, although data exist for all of the reactions shown in Table II, some of these data are very fragmentary, and are not sufficient to permit an accurate evaluation to be carried out. In this regard, it should be

noted that charged particle data, by their very nature, tend in general to be incomplete, since experimentalists are usually more interested in testing nuclear models than in providing complete data sets. Thus the evaluated data sets in ECPL are drawn partly from experimental data, partly from systematics, and partly from computer modeling codes.

This report is intended primarily for users at Livermore, but it may also be of interest to workers outside of the Laboratory who are involved in fusion energy. The ECPL library and its associated processing codes are maintained on the Livermore CRAY computers. These files and codes can be made generally available on the MFECC computers to the fusion energy community.

Two comprehensive tables are given below which summarize the current status of the Livermore Evaluated Charged Particle Library. The first table lists all of the reactions which are currently included in ECPL. The second table lists all of the reactions for which data exist in the Livermore compilation of charged particle data, with the reactions underlined if they have been entered into ECPL. Also included are two auxiliary tables that contain the definitions of the incident particles (Y_i) and the reaction types (C numbers), as used in the standard Livermore ECPL notation.

*Work performed under the auspices of the U. S. Department of Energy by the Lawrence Livermore National Laboratory under contract number W-7405-ENG-48.

Table I. Reactions that are currently included in the ECPL evaluated charged particle library. The coulomb reactions are written as LACS and SI, where LACS denotes Large Angle Coulomb Scattering, and SI denotes Scattering plus Interaction (SI = total elastic scattering - LACS). The nuclear reactions are written in the form $Y_i Y_o$ with Y_i denoting the incident particle and Y_o denoting the outgoing particle (or particles) of interest.

Target particle	Incident particle	Coulomb interactions		Nuclear reactions	ECPL C-numbers
P	p	LACS	SI		8,9
	D	LACS	SI		8,9
	T	LACS	SI	T,n	8,9,11
	^3He	LACS	SI		8,9
	α	LACS	SI		8,9
D	p	LACS	SI		8,9
	D	LACS	SI	D,n D,p	8,9,11,40
	T	LACS	SI	T,n T, γ n α	8,9,11,30
	^3He	LACS	SI	$^3\text{He},p$	8,9,40
	α	LACS	SI	α,np α,pn	8,9,20,21
T	p	LACS	SI	p,n p, γ	8,9,11,46
	D	LACS	SI	D,n D, γ n α	8,9,11,30
	T	LACS	SI	T,2n	8,9,12
	^3He	LACS	SI		8,9
	α	LACS	SI		8,9
^3He	p	LACS	SI		8,9
	D	LACS	SI	D,p	8,9,40
	T	LACS	SI	T,np T,pn T,D	8,9,20,21,41
	^3He	LACS	SI		8,9
	α	LACS	SI		8,9

Table I (continued).

Target particle	Incident particle	Coulomb interactions	Nuclear reactions	ECPL C-numbers
α	p	LACS SI		8,9
	D	LACS SI		8,9
	T	LACS SI		8,9
	^3He	LACS SI		8,9
	α	LACS SI		8,9
^6Li	p	LACS	p, ^3He	8,44
	D	LACS	D,n D,n ^3He D,Tp D,p D, α	8,11,25,39,40,45
	T	LACS	T,2n T,n α T,D	8,12,26,41
	^3He	LACS	^3He ,D ^3He ,p α	8,41,48
	α	LACS	α ,p α ,D α	8,40,47
^7Li	p	LACS	p,n p, α	8,11,45
	D	LACS	D,2n D,n α	8,12,26
	T	LACS	T,n T,3n T,2n α	8,11,13,33
	^3He	LACS	^3He ,np α ^3He ,p ^3He ,T ^3He , α	8,34,40,42,45,47
	α	LACS	^3He ,D α	8
^7Be	p	LACS		8
	D	LACS	D,p α	8,48
	T	LACS	T,np α T,D α	8,34,47
	^3He	LACS	^3He ,2p α	8,49
	α	LACS		8
^9Be	p	LACS		8
	D	LACS		8
	T	LACS		8
	^3He	LACS		8
	α	LACS	α ,n α ,n2 α α ,Xy	8,11,27,55

Table I (continued)

Target particle	Incident particle	Coulomb interactions	Nuclear reactions	ECPL C-numbers
^{10}B	p	LACS	p, α ^3He p, α	8,38,45
	D	LACS	D, n $D, 3\alpha$ D, p	8,11,37,40
	T	LACS		8
	^3He	LACS		8
	α	LACS		8
^{11}B	p	LACS	p, n $p, 3\alpha$	8,11,37
	D	LACS	D, n D, p	8,11,40
	T	LACS		8
	^3He	LACS		8
	α	LACS		8
^{12}C	p	LACS		8
	D	LACS		8
	T	LACS		8
	^3He	LACS		8
	α	LACS		8
^{14}N	p	LACS		8
	D	LACS		8
	T	LACS		8
	^3He	LACS		8
	α	LACS		8
^{16}O	p	LACS		8
	D	LACS		8
	T	LACS		8
	^3He	LACS		8
	α	LACS		8
^{89}Y	p		p, n	11

Table II. Charged-particle reactions for which experimental data exist in the Livermore data compilation. Reactions that have been entered into ECPL are underlined. The Y_i and C descriptors are defined in Tables A1 and A2.

ZA	Y_i	C
1001	2	<u>8+9</u> , 46
	3	11, 20
	4	<u>8+9</u> , <u>11</u>
1002	2	<u>8+9</u> , 11, 21, 40, 46
	3	<u>8+9</u> , <u>11</u> , 20, <u>40</u> , 42, 44, 46
	4	<u>8+9</u> , 45
	5	<u>40</u> , 46
	6	<u>9+9</u> , 11, <u>21</u> , 40, 45, 46
1003	2	<u>8+9</u> , <u>11</u> , 44, <u>46</u>
	3	<u>8+9</u> , <u>11</u> , 12, 20, <u>30</u> , 40, 46
	4	<u>8+9</u> , <u>12</u>
	5	<u>8+9</u> , 11, 40, 41, 46
	6	11, 46
2003	2	<u>8+9</u>
	3	<u>8+9</u> , 11, <u>40</u> , 45, 46
	4	<u>8+9</u> , 11, 40, <u>41</u>
	5	<u>8+9</u> , 40, 45, 46
	6	40, 46
2004	2	<u>8+9</u> , 20, 41, 42, 46
	3	<u>8+9</u> , 11, 20, 40, 41
	4	<u>8+9</u> , 40
	5	<u>8+9</u> , 40, 45, 46
	6	<u>8+9</u>

Table II (continued).

ZA	Y_i	C
3006	2	<u>8+9</u> , 11, 20, 40, 41, 42, <u>44</u> , 45, 46
	3	<u>8+9</u> , <u>11</u> , <u>25</u> , <u>39</u> , <u>40</u> , 41, 42, 44, <u>45</u> , 46
	4	11, <u>12</u> , 40, <u>41</u>
	5	<u>8+9</u> , 11, 40, <u>41</u> , 42, 43, 44, 45
	6	<u>8+9</u> , 11, <u>40</u> , 41, 42, 45, 46
3007	2	<u>8+9</u> , <u>11</u> , 25, 40, 41, 42, <u>45</u> , 46, 55
	3	<u>8+9</u> , 11, <u>12</u> , 40, 41, 42, 45, 46
	4	<u>11</u> , 12, 40, 45, 46
	5	<u>8+9</u> , 11, 21, <u>40</u> , 41, <u>42</u> , 44, <u>45</u> , 46, 55
	5	<u>8+9</u> , 11, 40, 42, 45, 46
4007	2	46
	3	40
4009	2	<u>8+9</u> , 11, 12, 21, 40, 41, 42, 45, 46, 55
	3	<u>8+9</u> , 11, 40, 41, 42, 45, 46, 55
	4	<u>8+9</u> , 11, 40, 41, 45
	5	<u>8+9</u> , 11, 12, 37, 40, 41, 42, 45, 46, 55
	6	<u>8+9</u> , <u>11</u> , 12, 41, 45, <u>55</u>
4010	2	<u>8+9</u> , 40, 46
	3	<u>8+9</u> , 40, 42, 45, 46
5010	2	<u>8+9</u> , 11, 40, 41, 44, <u>45</u> , 46, 55
	3	<u>8+9</u> , <u>11</u> , <u>37</u> , <u>40</u> , 41, 42, 44, 45
	4	<u>8+9</u> , 40, 41, 45
	5	<u>8+9</u> , 11, 40, 41, 42, 44, 45, 46
	6	<u>8+9</u> , 11, 40, 41, 42, 45, 55

Table II (continued).

ZA	γ_i	C
5011	2	<u>8+9</u> , <u>11</u> , 26, <u>37</u> , 40, 41, 45, 46
	3	<u>8+9</u> , <u>11</u> , 12, 27, <u>40</u> , 42, 45, 46
	4	<u>8+9</u> , 40, 45
	5	<u>8+9</u> , 11, 40, 41, 42, 45, 46
	6	<u>8+9</u> , 11, 40, 41, 42, 46, 55
6012	2	<u>8+9</u> , 45, 46, 55
	3	<u>8+9</u> , 11, 40, 41, 42, 45
	4	<u>8+9</u> , 40, 41, 45
	5	<u>8+9</u> , 11, 40, 41, 42, 44, 45
	6	<u>8+9</u> , 11, 40, 45, 46
6013	2	11, 46
	3	8+9, 11, 40, 42, 45, 46
	4	41
	5	8+9, 11, 40, 42, 45
	6	11, 42, 55
6014	2	41, 42
	3	40, 45
	5	8+9
7014	2	<u>8+9</u> , 45, 46, 55
	3	<u>8+9</u> , 40, 41, 45, 46
	5	<u>8+9</u> , 41, 45
	6	40
7015	2	11, 45
	3	11
	5	11

Table II (continued).

ZA	Y_i	C
8016	2	<u>8</u> +9, 40, 41, 42, 45, 55
	3	<u>8</u> +9, 11, 40, 41, 45
	4	40, 45
	5	<u>8</u> +9, 40, 45
	6	<u>8</u> +9
8017	2	45
8018	2	11, 41, 42, 45
	3	40
	5	11
9019	2	8+9, 11, 40, 45, 46
	3	9+9, 11
	5	8+9, 11, 44, 45
10022	5	11
11023	2	8+9
	5	8+9
	6	8+9, 11
12024	3	41
	5	12
13027	2	8+9, 11, 46
	3	41
	5	12, 44, 45
15031	2	8+9, 40
17035	5	8+9

Table A1. Definitions of Y_i particle descriptors.

yi,yo no.	particle description
00	not applicable or none
01	neutron
02	proton
03	deuteron
04	triton
05	he-3
06	alpha
07	gamma ray
08	beta
09	beta-
10	electron
11	neutron as recoil nucleus
12	proton as recoil nucleus
13	deuteron as recoil nucleus
14	triton as recoil nucleus
15	he-3 as recoil nucleus
16	alpha as recoil nucleus

Table A2. Definitions of C reaction descriptors.

c no.	reaction type	c no.	reaction type
8	large angle coulomb scat	43	y,ta
9	scatt:int	44	y,he3
10	elastic	45	y,a
11	y,n	46	y,gamma
12	y,2n	47	y,da
13	y,3n	48	y,pa
14	y,4n	49	y,2pa
15	y,t	50	y,xp
16		51	y,xd
17		52	y,xt
18		53	y,xhe3
19		54	y,xa
20	y,n'p	55	y,xgamma
21	y,pn	56	y,xh
22	y,n'd	57	y,xg
23	y,n'da	58	
24	y,n't	59	
25	y,n'he3	60	
26	y,n'a	61	
27	y,n'2a	62	
28	y,n'ta	63	
29	y,2np	64	
30	y,gna	65	activat.
31	y,2npa	66	yield
32	y,2nd	67	to (z2,a2)
33	y,2n'a	68	
34	y,npa	69	
35	y,dn	70	total
36		71	coherent scattering
37	y,3a	72	incoherent scatter
38	y,he3,a	73	photo electric
39	y,3p	74	pair product.
40	y,p	75	pair prod.(electronic)
41	y,d	76	photo nuclear
42	y,t	77	

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