Nuclear Disintegration Energies. II.*†

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I. INTRODUCTION

THIS supplement is intended to augment the compilation, "Nuclear Disintegration Energies," [1] which included measurements of reaction energies received up to May, 1954. The data contained in the original compilation, together with other data pertaining to mass differences[2] have been of use in the preparation of tables of masses [3–5] and mass links,[6] and for the comparison of masses or mass differences obtained from nuclear reaction energies and mass-spectroscopic measurements.[3,7]

Since publication of the original compilation, there has been a considerable number of new measurements of nuclear reaction energies, e.g., measurements of some eighty previously undetermined reaction energies have been reported for $A<50$. The systematic program of precise Q-value determinations by the group at Massachusetts Institute of Technology headed by W. W. Buechner has been extended up to the mass region $A=32-60$. Together with data concerning beta-decay energies, these measurements have made possible the calculation of masses in the region from S^{32} to Ti^{45} from nuclear reaction energies only.[8]

In his systematic examination of masses and mass differences for $A<202$, Wapstra[3] pointed out several instances of Q values listed in our original compilation[1] which should be assigned to transitions to excited states, rather than ground-state transitions. He also discovered discrepancies between nuclear reaction and mass-spectroscopic data, particularly in the region of the nickel isotopes. On the basis of his analysis, he also reassigned some of the gamma rays observed from neutron capture by Kinsey and Bartholomew to other isotopes. A similar detailed analysis of (n,γ) and (γ,n) transitions has been made by Way *et al.*[6,9] in order to determine neutron binding energies in the region of $A=40-92$. More recently, Quinsenberry, Scolman, and Nier,[10] on the basis of their new mass measurements in the region Fe to Zn, have reassigned several neutron capture gamma rays to new isotopes, particularly for the nickel and zinc isotopes. It can be seen from the above brief summary that a considerable alteration of the nuclear reaction energies contained in the original compilation is now necessary.

This supplement contains new measurements of nuclear reaction energies available to the authors up to February 1, 1957. In addition, any measured values listed in the original compilation which have been revised or reassigned since its publication have been included.

II. ARRANGEMENT OF TABLE I

The arrangement of Table I of this supplement is the same as in the original compilation.[1] In Columns 1 and 2, the reactions and energy determinations are listed. In the case of a reaction shown as (n,γ,γ), the ground-state transition was not observed, and the reaction energy shown was determined from the summing of two gamma-ray energies. Some of the experimental values, designated by the superscript "a," do not appear explicitly in the reference cited, and have been calculated by the present authors from the pertinent experimental data. If it was necessary to use masses in such a calculation, those given by Wapstra[3] have been used. When there is doubt that a reported Q value represents the ground-state transition, it has been enclosed in parentheses.

In Columns 3 and 4, the method and energy standards used are listed, if stated by the authors. In Column 5, the most recent reference for each measured value is

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† This paper, and the three which follow, by H. E. Duckworth, L. J. Lidofsky, and by F. Asaro and I. Perlman, were prepared at the suggestion of the Subcommittee on Nuclear Constants of the Committee on Nuclear Science of the National Research Council. This subcommittee consists of Ward Whaling, *chairman*, and F. A. Selove, G. A. Bartholomew, H. E. Duckworth, I. Perlman, W. H. Sullivan, and D. M. Van Patter, together with L. Lidofsky as consultant.

Reprints of these four papers as a group may be obtained from the Publications Office, National Research Council, 2101 Constitution Avenue, Washington 25, D. C.

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[5] Mattauch, Waldmann, Bieri, and Everling, Z. Naturforsch. **11A**, 525 (1956).

[6] Way, King, McGinnis, and van Lieshout, "Nuclear Level Schemes," TID-5300 (USAEC September 1955).

[7] M. E. Kettner, Phys. Rev. **102**, 1065 (1956); Scolman, Quisenberry, and Nier, Phys. Rev. **102**, 1076 (1956).

[8] Endt, Buechner, Braams, Paris, and Sperduto, Phys. Rev. **105**, 1002 (1957).

[9] The authors wish to acknowledge the valuable contributions of the Nuclear Data Group under the leadership of K. Way. Their compilation "Nuclear Level Schemes," for $40\leq A\leq 92$, and their tables of ground-state Q values in *Nuclear Science Abstracts* have aided considerably the preparation of this present supplement.

[10] Quisenberry, Scolman, and Nier, Phys. Rev. **104**, 461 (1956).

TABLE I. Nuclear reaction energies.

Reaction	Measured Q value (Mev)	Method	Calibration Energy standard	Reference	Average Q value (Mev)
$D^2(d,p)T^3$	4.044±0.005	el spec	$Li^7(p,n)Be^7$	Do 56a	4.038±0.005
$D^2(d,n)He^3$	3.276±0.024	ph pl	Ro 51c	Su 55	3.267±0.007
	3.271±0.011	el spec	$Li^7(p,n)Be^7$	Do 56a	
$He^4(d,p)He^5$	−3.3±0.1	ph pl		Fr 54a	−3.3±0.1
$Li^6(n,\gamma)Li^7$	7.26±0.05	pr spec		Ba 56	
$Li^6(p,d)Li^5$	−3.0±0.15	scint spec		Li 55	preliminary
$Li^6(p,\gamma)Be^7$	5.66±0.03	scint spec	$F^{19}(p,\alpha\gamma)O^{16}$	Wa 56	
$Li^6(d,He^3)He^5$	0.91±0.09	mag spec	Po α	Le 55	
$Li^6(t,\alpha)He^5$	15.15±0.04	pulse ht	Th C′ α	Cr 56a	
$Li^6(t,d)Li^7$	0.986±0.007	mag spec	$Li^6(p,\alpha)He^3$	Pe 52, Al 54*	$0.986_0\pm0.007^+$
$Li^6(t,p)Li^8$	0.790±0.011	mag spec	$Li^6(p,\alpha)$, $Li^6(t,d)Li^{7*}$	Pe 52, Al 54*	
$Li^6(He^3,n)B^8$	−1.976±0.006	threshold		Du 56	
$Li^7(p,n)Be^7$	$-1.645_2\pm0.001$	threshold	$Mg^{24}(p,p')$, $Na^{24}\gamma$, $Au^{198}\gamma$	Jo 54	$-1.644_9\pm0.000_4$
	$-1.643_7\pm0.001$	threshold	$Mg^{24}(p,p')$, $Na^{24}\gamma$, $Au^{198}\gamma$	Jo 54	
$Li^7(d,\alpha)He^5$	13.719	mag spec	$Li^6(d,p)Li^7$	Kh 55	
	14.26±0.09	mag spec	Po α	Le 55	
$Li^7(d,p)Li^8$	−0.183	mag spec	$Li^6(d,p)Li^7$	Kh 55	−0.192±0.001
$Li^7(\alpha,n)B^{10}$	−2.82±0.10	pulse ht threshold	$D^2(d,n)$, $B^{10}(\alpha,p)$	Ro 56	
$Li^7(Li^7,p)B^{13}$	5.97±0.05	range	$B^{10}(d,p)B^{11*}$	No 57	
$Be^8\rightarrow 2He^4$	0.090±0.005	ang corr		Tr 55	$0.094_1\pm0.000_7$
	$0.093_9\pm0.000_8$	mag spec		Fo 56	
$Be^9(\gamma,n)Be^8$	−1.664±0.004	threshold		Co 56	$-1.665\pm0.001_4$
$Be^9(n,\gamma)Be^{10}$	6.80	compt spec		Gr 55b	6.816±0.006
$Be^9(p,pn)Be^8$	−1.664±0.005	mag spec	Po α	Bo 56	
$Be^9(p,n)B^9$	−1.853±0.003	threshold	$Li^7(p,n)Be^7$	Ma 55b	−1.852±0.002
$Be^9(d,p)Be^{10}$	4.586±0.009	mag spec	Po α	Ju 54	4.587±0.005
$Be^9(d,n)B^{10}$	4.43±0.08	ph pl	La 47	Pr 52, Pr 53*	4.35±0.02
	4.28±0.10	ph pl		Re 54	
	4.54±0.06[c]	ph pl		Gr 55	
$Be^9(Li^7,p)C^{15}$	9.05±0.05	range	$Li^7(Li^7,p)B^{12}$	No 57	
$B^{10}(n,t)Be^8$	(0.35±0.20)	pulse ht	$D^2(d,n)$, $B^{10}(n,\alpha)Li^{7*}$	Ja 55	
$B^{10}(n,\gamma)B^{11}$	11.43±0.04	pr spec	absolute	Ba 56	
$B^{10}(p,n)C^{10}$	−4.37±0.05	threshold		Co 55	−4.37±0.05
$B^{10}(p,\gamma)C^{11}$	8.81±0.10	scint spec	$F^{19}(p,\alpha\gamma)$, $C^{13}(p,\gamma)$	Ch 56	8.81±0.10
$B^{10}(d,\alpha)Be^8$	17.829±0.010	mag spec	absolute	El 54	17.829±0.010
$B^{10}(d,t)B^9$	−2.187±0.010	mag spec	Po α	Bo 56	
$B^{10}(d,p)B^{11}$	9.227±0.006	mag spec	absolute	El 54	9.229±0.005
$B^{10}(He^2,n)N^{12}$	1.46±0.06	ph pl		Aj 57	preliminary
$B^{10}(\alpha,d)C^{12}$	1.36±0.09	scint spec	$Al^{27}(\alpha,p)Si^{30}$	Pi 56	1.341±0.002
	1.341±0.002	el spec	$Li^7(p,n)Be^7$	Do 56a	
$B^{10}(\alpha,p)C^{13}$	4.064±0.012	mag spec	Po α	Fa 55	4.064±0.012
	4.08±0.03	scint spec	$Al^{27}(\alpha,p)Si^{30}$	Pi 56	
	4.10±0.03	ph pl	Ro 51c	Pa 56	
$B^{11}(p,n)C^{11}$	$-2.83^{+0.08}_{-0.05}$	ph pl	Ro 51c	Aj 56	−2.762±0.003
$B^{11}(d,\alpha)Be^9$	8.029±0.005	mag spec	absolute	El 54	8.024±0.004
	8.015±0.010	mag spec	Po α	Bo 56	
$B^{11}(d,p)B^{12}$	1.110	spec		Kh 54	
$B^{11}(d,n)C^{12}$	13.81	ph pl		Ih 55	13.8±0.1
$B^{11}(\alpha,p)C^{14}$	0.788±0.017	mag spec	Po α	Fa 55	0.788±0.017
$B^{11}(\alpha,n)N^{14}$	0.0±0.3	pulse ht	$D^2(d,n)He^3$, $B^{10}(\alpha,p)C^{13}$	Qu 56	$0.27\pm0.06^+$
$C^{12}(p,\alpha)B^9$	−7.58±0.10	range	Be 50d, Bi 54a	Re 55	
$C^{12}(d,\alpha)B^{10}$	−1.39±0.02	range	El 51c	El 57	
$C^{12}(d,p)C^{13}$	2.717±0.010	mag spec	Po α	Sp 54	$2.721\pm0.002^+$
	2.720±0.003	mag spec	absolute	El 54	

TABLE I.—*Continued.*

Reaction	Measured Q value (Mev)	Method	Calibration energy standard	Reference	Average Q value (Mev)
$C^{12}(He^3,n)O^{14}$	$-1.147\pm0.002_4$[a]	threshold		Bu 56a	-1.152 ± 0.005
	$-1.158_5\pm0.003$	threshold	$Li^7(p,n)Be^7$, $Li^7(\alpha,\gamma)B^{11}$	Br 56a	
$C^{13}(p,d)C^{12}$	-2.718	mag spec	Po α	Sp 56a	$-2.721\pm0.002^+$
$C^{13}(d,p)C^{14}$	5.942 ± 0.011	mag spec	Po α	Sp 54	5.943 ± 0.003
	5.953 ± 0.010	mag spec	ThC α	Ah 54d	
$C^{13}(d,n)N^{14}$	5.40 ± 0.10	ph pl	Ri 51	Be 52	5.35 ± 0.03
	5.41 ± 0.06	ph pl		Gr 55	
	5.325 ± 0.04	ph pl		Bi 55	
$C^{14}(p,n)N^{14}$	$-0.626_4\pm0.000_5$	threshold	$Li^7(p,n)Be^7$	Sa 56	$-0.626_4\pm0.000_5^+$
$C^{14}(d,\alpha)B^{12}$	$0.362\pm0.001_5$	el spec	$Li^7(p,n)Be^7$	Do 56a	
$C^{14}(d,p)C^{15}$	-1.007 ± 0.001	el spec	$Li^7(p,n)Be^7$	Do 56a	
$C^{14}(\alpha,n)O^{17}$	-1.820 ± 0.002	threshold	$Li^7(p,n)Be^7$	Sa 56	
$N^{14}(n,p)C^{14}$	0.609 ± 0.005[c]	pulse ht		Is 50	$0.626_4\pm0.000_5^+$
$N^{14}(d,n)O^{15}$	5.21 ± 0.07	ph pl		No 56	5.14 ± 0.03
$N^{14}(\alpha,p)O^{17}$	-1.16	ph pl		Hj 53, Hj 53a	-1.16 ± 0.04
$N^{14}(\alpha,n)F^{17}$	-4.76 ± 0.07	threshold, pulse ht	Be 49	Do 56	-4.76 ± 0.07
$N^{15}(p,n)O^{15}$	-3.539 ± 0.008	threshold	(p,n) threshs, (p,γ) resonances	Ki 55	-3.5432 ± 0.0015
	-3.5432 ± 0.0015	threshold	$Li^7(p,n)Be^7$, $E_T=1.8811$	Li 57	preliminary
$N^{15}(d,p)N^{16}$	0.286	mag spec		Wh 55	
$O^{16}(d,p)O^{17}$	1.915 ± 0.010	mag spec	Po α	Sp 54	1.918 ± 0.004
$O^{16}(d,n)F^{17}$	-1.622 ± 0.004	threshold	$Li^7(p,n)Be^7$	Bo 51, Ma 55a*	-1.623 ± 0.003
	-1.626 ± 0.004	threshold	(p,n) thresholds	Ma 55a	
$O^{17}(d,\alpha)N^{15}$	9.807 ± 0.012	mag spec	$F^{19}(d,\alpha)O^{17}$, $N^{14}(d,\alpha)C^{12}$	Pa 54a	
$O^{17}(d,p)O^{18}$	5.821 ± 0.010	mag spec	ThC α	Ah 54c, Ah 54d	
$O^{18}(p,\alpha)N^{15}$	3.967 ± 0.009	mag spec	$F^{19}(p,\alpha\gamma)O^{16}$, $N^{15}(p,\alpha)C^{12}$	Mi 54, Ah 54d*	3.967 ± 0.009
$O^{18}(p,n)F^{18}$	-2.447 ± 0.010	threshold	$Li^7(p,n)Be^7$	Ma 56a	-2.452 ± 0.004
$O^{18}(d,\alpha)N^{16}$	4.237 ± 0.009	mag spec	$C^{12}(d,p)C^{13}$, $N^{14}(d,p)N^{15}$*	Pa 55a	
$O^{18}(d,p)O^{19}$	1.730 ± 0.008	mag spec	$B^{10}(d,p)B^{11}$*, $F^{19}(p,\alpha\gamma)O^{16}$	Ah 54b, Mi 54b	1.732 ± 0.005
	1.732 ± 0.008	mag spec		Th 54	
	1.735 ± 0.008	mag spec		Ho 55	
$F^{19}(n,\gamma)F^{20}$	6.599 ± 0.011	pr spec	absolute	Ca 56	6.599 ± 0.011
$F^{19}(p,\alpha)O^{16}$	8.110 ± 0.010	mag spec	Po α	Sq 56	8.114 ± 0.007
$F^{19}(p,n)Ne^{19}$	-4.029 ± 0.008	threshold	$F^{19}(p,\alpha\gamma)O^{16}$	Wi 52, Ki 55*	-4.025 ± 0.004
	-4.027 ± 0.008	threshold	(p,n)threshs, (p,γ)resonances	Ki 55	
	-4.022 ± 0.005	threshold	$Li^7(p,n)Be^7$	Ma 55b	
$F^{19}(d,p)F^{20}$	4.38 ± 0.03	range	El 51c	El 56	4.373 ± 0.007
$F^{19}(d,t)F^{18}$	-4.17 ± 0.02	range	El 51c	El 57	
$F^{19}(t,p)F^{21}$	6.200 ± 0.025	mag spec	$O^{16}(t,\alpha)N^{15}$	Ja 56	6.200 ± 0.025
	6.03 ± 0.1[a]	ph pl		Bi 55a	preliminary
$F^{19}(\alpha,p)Ne^{22}$	1.673 ± 0.011	mag spec	Po α	Fa 55	1.673 ± 0.011
$F^{19}(\alpha,n)Na^{22}$	-2.0 ± 0.2	pulse ht	$D^2(d,n)He^3$, $B^{10}(\alpha,p)C^{13}$	Qu 56	-2.0 ± 0.2
$Ne^{20}(n,\alpha)O^{17}$	-0.70 ± 0.02	pulse ht		Fl 53	-0.71 ± 0.02
$Ne^{20}(d,\alpha)F^{18}$	2.810 ± 0.009	mag spec	$F^{19}(p,\alpha\gamma)O^{16}$, $O^{16}(d,p)O^{17}$	Mi 54a, Mi 56*	2.810 ± 0.009
$Ne^{22}(d,p)Ne^{23}$	2.968 ± 0.008	mag spec	$C^{12}(d,p)C^{13}$	Ah 54a	2.966 ± 0.005
$Na^{23}(n,\gamma,\gamma)Na^{24}$	6.96 ± 0.03	compt spec		Gr 55b	
$Na^{23}(p,\alpha)Ne^{20}$	2.370 ± 0.008	mag spec	Po α	Bu 56c	2.377 ± 0.003
$Na^{23}(p,n)Mg^{23}$	-4.849 ± 0.010	threshold	$F^{19}(p,\alpha\gamma)O^{16}$	Wi 52a, Ki 55*	-4.845 ± 0.007
	-4.841 ± 0.010	threshold	(p,n)threshs, (p,γ)resonances	Ki 55	
$Na^{23}(\alpha,n)Al^{26}$	-2.9 ± 0.2	pulse ht	Be 49	Do 56	
	$\geq -2.970\pm0.004$	threshold	$Li^7(p,n)Be^7$	Bu 56b	preliminary
$Mg^{24}(p,\gamma)Al^{25}$	2.26 ± 0.03[a]	scint spec	$F^{19}(p,\alpha\gamma)O^{16}$, (p,γ)reactions	Gr 55a	$2.28\pm0.01_5$
	2.29 ± 0.02[a]	scint spec	$Pr^{144}\gamma$, $Cs^{137}\gamma$, $Na^{22}\gamma$	Cr 56	
	2.29 ± 0.02[a]	scint spec	$Zn^{65}\gamma$, $Co^{60}\gamma$, ThC$''\gamma$	Ag 56	
$Mg^{24}(d,\alpha)Na^{22}$	1.953 ± 0.012	mag spec	Po α	Br 55, Br 55a*	preliminary
$Mg^{24}(d,p)Mg^{25}$	5.02 ± 0.02[c]	spec		Kh 53	5.097 ± 0.007

TABLE I.—*Continued.*

Reaction	Measured Q value (Mev)	Method	Calibration energy standard	Reference	Average Q value (Mev)
$Mg^{25}(\gamma,p)Na^{24}$	−12.1	threshold		Ka 54	
$Mg^{25}(\gamma,n)Mg^{24}$	−7.2	threshold		Ka 54	
$Mg^{25}(n,\gamma)Mg^{26}$	11.086±0.025	pr spec	absolute	Ca 56	
$Mg^{25}(p,\alpha)Na^{22}$	−3.15	mag spec	Po α	Br 55a	preliminary
$Mg^{25}(p,n)Al^{25}$	−5.084±0.024	threshold	(p,n)threshs, (p,γ)resonances	Ki 55	
$Mg^{25}(p,\gamma)Al^{26}$	6.35±0.08	scint spec	$F^{19}(p,\alpha\gamma)$, $Be^{9}(\alpha,n\gamma)$, $C^{13}(p,\gamma)$	Kl 54	
$Mg^{25}(\alpha,p)Al^{28}$	−1.29±0.04	pulse ht	$Al^{27}(p,\alpha)Mg^{24}$	Gr 57	
$Mg^{26}(\gamma,p)Na^{25}$	−14.3	threshold		Ka 54	
$Mg^{26}(\gamma,n)Mg^{24}$	−11.1	threshold		Ka 54	
$Mg^{26}(p,n)Al^{26}$	−4.83±0.1[a]	threshold		Sc 54|En 54, Ka	−4.778±0.015
	−4.778±0.015[a]	threshold	(p,n)threshs, (p,γ)resonances	Ki 55| 55	
$Mg^{26}(\alpha,p)Al^{29}$	−2.90±0.04	pulse ht	$Al^{27}(p,\alpha)Mg^{24}$	Gr 57	
$Al^{27}(\gamma,n)Al^{26}$	−13.4±0.2	threshold	$Cu^{63}(\gamma,n)Cu^{62}$	Ha 54	−13.1+0.3
$Al^{27}(p,\alpha)Mg^{24}$	1.61±0.04	ph pl		Gr 54	1.595±0.002+
	1.596±0.006	mag spec	$Li^{7}(p,n)Be^{7}$, Po α	Va 57	
$Al^{27}(p,n)Si^{27}$	−5.581±0.010	threshold	$F^{19}(p,\alpha\gamma)O^{16}$	Ki 53d, Ki 55*	−5.593±0.009
	−5.584±0.010	threshold	(p,n)threshs, (p,γ)resonances	Ki 55	
	−5.607±0.008	threshold	$Li^{7}(p,n)Be^{7}$, $E_T=1.8811$	Ma 55b	
$Al^{27}(d,p)Al^{28}$	5.475	spec		Kh 54	5.498±0.007
	5.502±0.010	mag spec	Po α	Bu 56	
$Al^{27}(\alpha,p)Si^{30}$	2.38±0.03	scint spec pulse ht ph pl		Ha 56	2.38±0.03
$Al^{27}(\alpha,n)P^{30}$	≥−2.662±0.004	threshold	$Li^{7}(p,n)Be^{7}$	Bu 56b	preliminary
$Si^{28}(n,\gamma)Si^{29}$	8.482±0.015	compt spec		Ad 56a	8.471±0.007
$Si^{28}(d,\alpha)Al^{26}$	1.416±0.008	mag spec	Po α	Br 54c	
$Si^{29}(\gamma,p)Al^{28}$	−12.3	threshold		Ka 54	
$Si^{29}(\gamma,n)Si^{28}$	−8.5	threshold		Ka 54	
$Si^{29}(n,\gamma)Si^{30}$	10.59±0.03	compt spec		Ad 56a	10.600±0.010
$Si^{29}(p,\gamma)P^{30}$	5.55±0.06	scint spec	$Be^{9}(\alpha,n\gamma)C^{12}$, $F^{19}(p,\alpha\gamma)O^{16}$	En 54a	
$Si^{30}(\gamma,p)Al^{29}$	−12.9	threshold		Ka 54	
$Si^{30}(\gamma,n)Si^{29}$	−10.6	threshold		Ka 54	
$P^{31}(\gamma,n)P^{30}$	−12.33±0.05	threshold	(γ,n)thresholds	Ba 55a	−12.32±0.05
$P^{31}(p,\alpha)Si^{28}$	1.911±0.005	mag spec	$Li^{7}(p,n)$, $Al^{27}(p,\alpha)$, Po α	Va 56	1.910±0.004
	1.909±0.010	mag spec	Po α	En 57	
$P^{31}(p,n)S^{31}$	−6.06±0.2	ph pl	Gi 54	Ru 56	
$P^{31}(d,n)S^{32}$	6.63±0.08	ph pl	El 51d	El 52, El 55*	6.63±0.08
$P^{31}(\alpha,p)S^{34}$	0.7±0.1	scint spec	$Al^{27}(\alpha,p)Si^{30}$	St 56	0.7±0.1
$P^{31}(\alpha,n)Cl^{34}$	−5.7±0.2	threshold	$D^{2}(d,n)He^{3}$, $B^{10}(\alpha,p)C^{13}$	Qu 56	−5.7±0.2
$S^{32}(n,\gamma)S^{33}$	8.63±0.04	compt spec		Gr 55b	8.64±0.02
$S^{32}(p,\gamma)Cl^{33}$	2.285±0.012	scint spec	$Na^{24}\gamma$	Va 56a	
$S^{32}(d,\alpha)P^{30}$	4.831±0.013	mag spec		Le 56	
$S^{32}(d,p)S^{33}$	6.408±0.020	mag spec		Le 56	6.419±0.010
$S^{32}(\alpha,p)Cl^{35}$	−2.3	scint spec	$Al^{27}(\alpha,p)Si^{30}$	Pi 55	−1.861±0.004+
$S^{34}(p,n)Cl^{34}$	(−6.1)	ph pl		Aj 55	preliminary
$S^{34}(d,\alpha)P^{32}$	5.04±0.02	mag spec		Le 56	
$Cl^{35}(\gamma,n)Cl^{34}$	−12.35±0.035	threshold	C^{12}, N^{14}, $O^{16}(\gamma,n)$threshs	De 55	
$Cl^{35}(n,\gamma)Cl^{36}$	8.55±0.04	compt spec		Gr 55b	8.56±0.02
$Cl^{35}(p,\alpha)S^{32}$	1.865±0.015	mag spec		Al 55	1.861±0.004+
	1.863±0.008	mag spec	Po α	En 56	
	1.860±0.005	mag spec	$Li^{7}(p,n)Be^{7}$, Po α	Va 56, Va 57*	
$Cl^{35}(d,\alpha)S^{33}$	8.277±0.010	mag spec	Po α	Pa 55	8.277±0.010
$Cl^{35}(d,p)Cl^{36}$	6.354±0.008	mag spec	Po α	Pa 55	6.354±0.008
$Cl^{37}(p,\alpha)S^{34}$	3.015±0.015	mag spec		Al 55	3.026±0.005
	3.026±0.008	mag spec	Po α	En 56	
	3.028±0.006	mag spec	$Li^{7}(p,n)Be^{7}$, Po α	Va 56, Va 57*	

TABLE I.—*Continued.*

Reaction	Measured Q value (Mev)	Method	Calibration energy standard	Reference	Average Q value (Mev)
$Cl^{37}(d,\alpha)S^{35}$	7.783±0.012	mag spec	Po α	Pa 55	
$Cl^{37}(d,p)Cl^{38}$	3.877±0.008	mag spec	Po α	Pa 55	3.877±0.008
$A^{36}(\alpha,p)K^{39}$	−1.28±0.03	ph pl	$N^{14}(\alpha,p)O^{17}$	Sc 56a	−1.283±0.008+
$A^{40}(\gamma,n)A^{39}$	−9.85±0.15	threshold	C^{12}, Mn^{55}, $Bi^{209}(\gamma,n)$threshs	Ha 54a	
$A^{40}(n,\alpha)S^{37}$	−2.5±0.1	pulse ht	Po α	Be 55	
$A^{40}(\alpha,p)K^{43}$	−3.36±0.03	ph pl	$N^{13}(\alpha,p)O^{17}$	Sc 56a	preliminary
$K^{39}(\gamma,n)K^{38}$	−13.00	threshold	C^{12}, N^{14}, $O^{16}(\gamma,n)$threshs	De 55	
$K^{39}(n,\gamma,\gamma)K^{40}$	7.795±0.010	compt spec		Ad 56, Bu 53	7.791±0.006
$K^{39}(n,\alpha)Cl^{36}$	1.25±0.20	scint spec	Po α, $K^{39}(n,p)A^{39}$	Sc 56	
$K^{39}(p,\alpha)A^{36}$	1.267±0.020	mag spec		Al 55	1.283±0.008+
	1.286±0.008	mag spec	Po α	Sp 55, Sp 56a*	
$K^{39}(\alpha,p)Ca^{42}$	−0.19±0.07	range		Sc 55	−0.118±0.007+
$K^{41}(p,\alpha)A^{38}$	4.002±0.015	mag spec	mag spec	Al 55	
$K^{41}(\alpha,p)Ca^{44}$	0.98±0.10	range		Sc 55	1.057±0.010+
$Ca^{40}(n,\gamma,\gamma)Ca^{41}$	8.37±0.03	pr spec	absolute	Ki 52, Br 56b	8.355±0.014
	8.350±0.017	compt spec		Ad 56	
$Ca^{40}(d,\alpha)K^{38}$	4.650±0.010	mag spec	Po α	Br 56	
$Ca^{40}(d,p)Ca^{41}$	6.140±0.009	mag spec	Po α	Br 54, Br 56b*	6.140±0.009
$Ca^{40}(d,n)Sc^{14}$	−0.60±0.05	range		Pl 55	preliminary
$Ca^{42}(p,\alpha)K^{39}$	0.118±0.007	mag spec	Po α	Br 56	0.118±0.007+
$Ca^{42}(d,p)Ca^{43}$	5.711±0.010	mag spec	Po α	Br 54b, Br 56*	
$Ca^{43}(p,\alpha)K^{40}$	−0.014±0.008	mag spec	Po α	Br 56	
$Ca^{43}(d,p)Ca^{44}$	9.07±0.07	range		Sc 55	8.913±0.014
	8.913±0.014	mag spec	Po α	Br 56	
$Ca^{44}(p,\alpha)K^{41}$	−1.057±0.010	mag spec	Po α	Br 56	−1.057±0.010+
$Ca^{44}(d,p)Ca^{45}$	5.188±0.010	mag spec	Po α	Br 54b, Br 56*	
$Ca^{48}(d,p)Ca^{49}$	2.916±0.006	mag spec	Po α	Br 56	2.916±0.006
$Sc^{45}(p,n)Ti^{45}$	−2.844±0.004	threshold	$Li^7(p,n)Be^7$, $E_T=1.8811$	Br 55b	
$Ti^{47}(n,\gamma,\gamma)Ti^{48}$	(11.609±0.02)			Ba 56a	
	[10.619 γ transition (Ba 56a) to 0.990±0.015 state (He 55)]				
	(11.51±0.05)			Ki 53, Wa 55	
$Ti^{47}(d,p,\gamma)Ti^{48}$	9.13±0.05			Pi 52a, Wa 55	9.13±0.05
$Ti^{48}(n,\gamma,\gamma)Ti^{49}$	8.141±0.008			Ba 56a	8.145±0.006
	[6.756±0.006 γ transition (Ki 53) to 1.385±0.005 state (Mo 54)]				
	8.14±0.02			Ki 53, Wa 55	
	8.153±0.010			Ad 56a	
$Ti^{49}(n,\gamma,\gamma)Ti^{50}$	10.97±0.07			Ki 53, Wa 55	
$V^{51}(p,\alpha)Ti^{48}$	1.161±0.010	mag spec	Po α	Bu 55	
$V^{51}(p,n)Cr^{51}$	−1.535±0.001	threshold	$Li^7(p,n)Be^7$	Gi 55	−1.535±0.001
	−1.536	threshold	$Li^7(p,n)Be^7$, $E_T=1.8811$	Ma 56	
$Cr^{50}(n,\gamma,\gamma)Cr^{51}$	9.25±0.01			Ki 53, Wa 55	
	[8.499±0.007 γ transition (Ki 53) to 0.750±0.011 state (He 55)]				
$Cr^{52}(d,p)Cr^{53}$	5.74	range Al		El 56a	preliminary
$Cr^{53}(d,p)Cr^{54}$	7.55	range Al		El 56a	preliminary
$Cr^{54}(p,n)Mn^{54}$	−2.162±0.005	threshold	$Li^7(p,n)Be^7$	Lo 52	
$Mn^{55}(p,n)Fe^{55}$	−1.015±0.003	threshold		Jo 56	−1.014±0.003
$Fe^{54}(\gamma,n)Fe^{53}$	(−13.7±0.2)	threshold		Ka 51	
	(−13.65±0.05)	threshold	C^{12}, O^{16}, Cu^{63}, $Ag^{109}(\gamma,n)$ thresholds	Ba 55	
	−11.90±0.07	threshold	C^{12}, N^{14}, $O^{16}(\gamma,n)$thresholds	De 55	
$Fe^{54}(n,\gamma)Fe^{55}$	9.295±0.015	compt spec		Ad 56a	9.297±0.006
$Fe^{54}(d,p)Fe^{55}$	7.073	mag spec	Po α	Sp 56	
$Fe^{56}(n,\gamma)Fe^{57}$	7.636±0.010	compt spec		Ad 56a	7.638±0.004
$Fe^{56}(d,p)Fe^{57}$	5.418	mag spec	Po α	Sp 56	
	5.53	range		Mc 55	preliminary
$Fe^{57}(d,p)Fe^{58}$	7.808	mag spec	Po α	Sp 56	
	7.89	range		Mc 55	preliminary

TABLE I.—*Continued.*

Reaction	Measured Q value (Mev)	Method	Calibration energy standard	Reference	Average Q value (Mev)
$Fe^{58}(d,p)Fe^{59}$	4.350	mag spec	Po α	Sp 56	
$Co^{59}(p,n)Ni^{59}$	-1.84	range ph pl		St 52	-1.858 ± 0.002
	-1.858 ± 0.004	threshold		Bu 56d	preliminary
	-1.862 ± 0.005[b]	threshold	$Li^7(p,n)Be^7$, $E_T=1.8811$	Ch 57	
$Co^{59}(d,p)Co^{60}$	5.283 ± 0.008	mag spec	Po α	Fo 54	5.283 ± 0.008
$Ni^{58}(\gamma,n)Ni^{57}$	-12.0	threshold		Ka 51	
$Ni^{58}(n,\gamma)Ni^{59}$	8.996 ± 0.010	compt spec		Ad 56	8.997 ± 0.004
$Ni^{58}(p,\gamma)Cu^{59}$	3.42 ± 0.02	scint spec		Go 57a	
$Ni^{58}(d,p)Ni^{59}$	6.70 ± 0.1	range ph pl		Pr 54	6.74 ± 0.07
$Ni^{60}(n,\gamma)Ni^{61}$	(7.817 ± 0.008)	pr spec	absolute	Ki 53, Qu 56a	tgt isotope uncertain
	(7.825 ± 0.020)	compt spec		Ad 56, Qu 56a	tgt isotope uncertain
$Ni^{60}(p,\gamma)Cu^{61}$	4.81 ± 0.03	scint spec		Go 57a	preliminary
$Ni^{60}(p,n)Cu^{60}$	-6.6 ± 0.4	threshold		Co 54a	-6.6 ± 0.4
$Ni^{60}(d,p)Ni^{61}$	(5.55 ± 0.1)	range ph pl		Pr 54	
$Ni^{61}(p,\gamma)Cu^{62}$	6.03 ± 0.06	scint spec		Go 57a	preliminary
$Ni^{62}(p,\gamma)Cu^{63}$	6.13 ± 0.03	scint spec		Go 57a	
$Ni^{64}(p,\gamma)Cu^{65}$	7.42 ± 0.03	scint spec		Go 57a	
$Cu^{63}(\gamma,n)Cu^{62}$	-10.78 ± 0.05	threshold	D^2, F^{19}, $O^{16}(\gamma,n)$thresholds	Be 56	-10.65 ± 0.06
	-10.73 ± 0.05	threshold	N^{14}, $F^{19}(\gamma,n)$thresholds	Ro 55	
	-10.54 ± 0.04	threshold	C^{12},N^{14}, $O^{16}(\gamma,n)$thresholds	De 55	
$Cu^{63}(\gamma,2n)Cu^{61}$	-20.0 ± 0.5	threshold		Be 54	
$Cu^{63}(p,\gamma)Zn^{64}$	7.69 ± 0.04	scint spec		Go 57	preliminary
$Cu^{63}(p,n)Zn^{63}$	-4.147 ± 0.008	threshold	$Li^7(p,n)Be^7$	Ki 55	-4.149 ± 0.004
	-4.149 ± 0.004	threshold	$Li^7(p,n)Be^7$, $E_T=1.8811$	Br 55b	
$Cu^{65}(\gamma,n)Cu^{64}$	-9.94 ± 0.08	threshold	D^2, O^{16}, $F^{19}(\gamma,n)$thresholds	Be 56	-9.95 ± 0.08
$Cu^{65}(n,\gamma)Cu^{66}$	(7.01 ± 0.02)	pr spec	absolute	Ba 53, Qu 56a	(7.01 ± 0.02) tgt isotope uncertain
$Cu^{65}(p,\gamma)Zn^{66}$	8.85 ± 0.04	scint spec		Go 57	
$Cu^{65}(p,n)Zn^{65}$	-2.137 ± 0.005	threshold	$Li^7(p,n)Be^7$	Ki 55	$-2.132_7\pm0.001_3$
	-2.136 ± 0.004	threshold	$Li^7(p,n)Be^7$, $E_T=1.8811$	Br 55b	
	-2.131 ± 0.005	resonance	$Li^7(p,n)Be^7$	Ma 56	
	$-2.132_2\pm0.001_5$	threshold	$Li^7(p,n)Be^7$, $E_T=1.8811$	Ma 56b	
$Zn^{64}(\gamma,2n)Zn^{62}$	-20.35 ± 0.35	threshold	C^{12}, N^{14}, $O^{16}(\gamma,n)$thresholds	De 55	
$Zn^{64}(\gamma,n)Zn^{63}$	-11.6	threshold		Ka 51	-11.60 ± 0.06
	-11.58 ± 0.06	threshold	C^{12}, N^{14}, $O^{16}(\gamma,n)$thresholds	De 55	
$Zn^{64}(n,\gamma,\gamma)Zn^{65}$	(7.928 ± 0.007)			Ki 53, Wa 55	tgt isotope
	(7.990 ± 0.008)			Ki 53, Qu 56a	uncertain
$Zn^{66}(n,\gamma,\gamma)Zn^{67}$	(7.03 ± 0.02)			Ki 53, Qu 56a	tgt isotope uncertain
$Zn^{67}(n,\gamma,\gamma)Zn^{68}$	(10.22 ± 0.01)			Wa 55, Qu 56a	tgt isotope uncertain
$Zn^{67}(p,n)Ga^{67}$	-1.777 ± 0.005[b]	threshold	$Li^7(p,n)Be^7$, $E_T=1.8811$	Ch 57	-1.781 ± 0.003
$Zn^{68}(n,\gamma)Zn^{69}$	(6.49 ± 0.02)			Ki 53, Qu 56a	tgt isotope uncertain
$Zn^{68}(p,n)Ga^{68}$	-3.694 ± 0.006	threshold	$Li^7(p,n)Be^7$, $E_T=1.8811$	Br 55b	-3.700 ± 0.005
	-3.704 ± 0.005[b]	threshold	$Li^7(p,n)Be^7$, $E_T=1.8811$	Ch 57	
$Ga^{69}(n,\gamma)Ga^{70}$	7.733 ± 0.020	pr spec	absolute	Ba 56a	
$Ge^{70}(\gamma,n)Ge^{69}$	-12.1 ± 0.2	threshold	C^{12}, N^{14}, $O^{16}(\gamma,n)$thresholds	De 55	
$Ge^{76}(\gamma,n)Ge^{75}$	-9.3	threshold	C^{12}, N^{14}, $O^{16}(\gamma,n)$thresholds	De 55	
$Kr^{78}(d,p)Kr^{79}$	5.98 ± 0.05	range ph pl	$N^{14}(d,p)N^{15}$	Bl 56	
$Kr^{80}(d,p)Kr^{81}$	5.63 ± 0.10	range ph pl	$N^{14}(d,p)N^{15}$	Bl 56	
$Rb^{85}(\gamma,n)Rb^{84}$	-9.26 ± 0.15	threshold	O^{16}, $F^{19}(\gamma,n)$thresholds	To 56	
$Rb^{87}(\gamma,n)Rb^{86}$	-10.14 ± 0.15	threshold	O^{16}, $F^{19}(\gamma,n)$thresholds	To 56	
$Sr^{86}(\gamma,n)Sr^{85}$	-11.5	threshold		Ye 55	
$Sr^{86}(n,\gamma,\gamma)Sr^{87}$	8.417 ± 0.018			Wa 55	$8.417\pm0.018^+$
$Sr^{87}(n,\gamma,\gamma)Sr^{88}$	11.14 ± 0.05			Wa 55	$11.14\pm0.05^+$
$Y^{89}(d,p)Y^{90}$	4.41 ± 0.05	scint spec		Wa 54	
$Zr^{90}(\gamma,n)Zr^{89}$	-11.78 ± 0.09		$Cu^{63}(\gamma,n)Cu^{62}$, $E_T=10.73$	Ax 56	-11.78 ± 0.09

The Q values for this reaction in reference (1) are now attributed to excitation of the 0.588 level in Zr^{89} (Ax 56).

TABLE I.—*Continued.*

Reaction	Measured Q value (Mev)	Method	Calibration energy standard	Reference	Average Q value (Mev)
$Nb^{93}(p,n)Mo^{93}$	-1.27 ± 0.04	ph pl		Pa 54	-1.27 ± 0.04
	Value quoted in reference 1 is not ground-state transition.				
$Mo^{92}(\gamma,n)Mo^{91}$	(-13.5 ± 0.4)	threshold		Ba 45	-13.1 ± 0.1
	(-13.28 ± 0.15)	threshold		Ha 49a	
	-13.1 ± 0.1	threshold		Ka 53, Ka 53a	
$Mo^{92}(n,2n)Mo^{91}$	-12.34	threshold		Br 53	
$Rh^{103}(p,n)Pd^{103}$	(-1.53)	ph pl		Pa 54	
$Ag^{107}(\gamma,n)Ag^{106}$	-9.45 ± 0.05	threshold	D^2, F^{19}, $O^{16}(\gamma,n)$ thresholds	Be 56	-9.50 ± 0.06
	-9.57 ± 0.06	threshold	C^{12}, O^{16}, Cu^{63}, $Ag^{109}(\gamma,n)$-thresholds	Ba 55	
$Ag^{109}(\gamma,n)Ag^{108}$	-9.17 ± 0.06	threshold	D^2, F^{19}, $O^{16}(\gamma,n)$thresholds	Be 56	-8.90 ± 0.18
	-8.78 ± 0.04	threshold		De 55	
$Cd^{111}(p,n)In^{111}$	-2.37 ± 0.20	threshold		Mc 51c	
$Cd^{113}(n,\gamma)Cd^{114}$	9.04 ± 0.03	compt spec		Ad 55	9.046 ± 0.008
$Ba^{138}(d,p)Ba^{139}$	2.493 ± 0.010			Pa 55	2.493 ± 0.010
$Ba^{138}(n,\gamma)Ba^{139}$	(4.70 ± 0.03)	pr spec	absolute	Ki 53c, Pa 55	tgt isotope uncertain
$Pr^{141}(d,p)Pr^{142}$	3.42 ± 0.30	scint spec		Wa 54	
$Sm^{144}(\gamma,n)Sm^{143}$	-9.60 ± 0.05	threshold	C^{12}, N^{14}, $O^{16}(\gamma,n)$thresholds	De 55	
	-9.6	threshold		Si 56	
$Sm^{149}(n,\gamma,\gamma)Sm^{150}$	8.00 ± 0.03			Ad 55	8.00 ± 0.03
$Gd^{155}(n,\gamma)Gd^{156}$	(7.78 ± 0.05)	pr spec	absolute	Ki 53c	tgt isotope uncertain
$Gd^{157}(n,\gamma)Gd^{158}$	(7.36 ± 0.05)	pr spec	absolute	Kr 53c	tgt isotope uncertain
$Hf^{177}(\gamma,n)Hf^{176}$	-6.70 ± 0.09	threshold	O^{16}, $F^{19}(\gamma,n)$thresholds	To 56	
$Hf^{179}(\gamma,n)Hf^{178}$	-6.52 ± 0.12	threshold	O^{16}, $F^{19}(\gamma,n)$thresholds	To 56	
$Pt^{194}(n,\gamma)Pt^{195}$	(6.07 ± 0.04)	pr spec	absolute	Ki 53c	tgt isotope uncertain
$Hg^{199}(n,\gamma)Hg^{200}$	8.03 ± 0.03			Ad 55	8.03 ± 0.03
$Bi^{209}(p,2n)Po^{208}$	-9.65 ± 0.08	threshold	range Al, Sm 47	An 56	

[a] This Q value has been calculated specifically for this compilation from the experimental data, using accurate masses.
[b] This Q value has been corrected for the $Li^7(p,n)Be^7$ threshold energy of 1.8811 Mev.
[c] This Q value has been omitted from the weighted average.
* This average contains a later correction to the value originally reported.
+ This average value was calculated by including the measured Q value for the inverse reaction.

List of abbreviations used for experimental methods.

ang corr	angular correlation	ph pl	range in photographic plates
compt spec	Compton electron spectrometer	pr spec	pair spectrometer
el spec	electrostatic spectrometer	pulse ht	pulse height
E_T	threshold energy	range Al	range in aluminum
mag spec	magnetic spectrometer	scint spec	scintillation spectrometer

given. When a correction to the original value has been reported by another author, a second reference with an asterisk has been added. For some measurements, such as a (n,γ,γ) reaction, two references are given. The first reference contains the measurements of the neutron capture gamma rays, while the second contains the assignment of the gamma rays to transitions for specific isotopes, and, also, other determinations of level energies if necessary for the calculation of the energy of the ground-state transition (e.g., see references 6 and 10).

In Column 6 are listed the weighted average values, calculated in the same manner as before. Measured values listed in the original compilation are included in the calculations of the weighted average values given in this supplement. Following the bibliography, a few additional corrections to the original compilation are listed, if not already included in this supplement. No attempt has been made to list revised references for those given previously if no alteration in the Q values reported were made in the later reference. However, all references listed in Table I of this supplement are included in the bibliography for the sake of completeness.

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$Li^7(p,\alpha)He^4$	The average Q value should read 17.345±0.006 Mev.
$Si^{28}(p,n)P^{28}$	The Q value measured by Br 54a should be −14.9 ±0.6 Mev. The average Q value should read −15.0±0.4 Mev.
$Cr^{54}(p,n)Mn^{54}$	The Q value measured by Lo 52 should read −2.162±0.005 Mev.
$Cu^{65}(n,\gamma)Cu^{66}$	Assignment of 7.634 Mev γ to this reaction is now thought to be incorrect (Qu 56a, Wa 55).

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