

Final results for ^{23}Na , $^{24,25,26}\text{Mg}$ and $^{39,40,41}\text{K}(n,\gamma)$

Richard B. Firestone

Isotopes Project, Lawrence Berkeley National Laboratory,
Berkeley, CA 94720

K +1 39.0983 0.0000123%	K32	K33	K34	K35 190 ms 3/2+	K36 342 ms 2+	K37 1.226 s 3/2+	K38 7.636 m 3+	K39 3/2+	K40 1.277E+9 y 4-	K41 3/2+	K42 12.360 h 2-	K43 22.3 h 3/2+
Ar30 20 Ns 0+	Ar31 15.1 ms	Ar32 98 ms 0+	Ar33 173.0 ms 1/2+	Ar34 844.5 ms 0+	Ar35 1.775 s 3/2+	Ar36 0+	Ar37 35.04 d 3/2+	Ar38 0+	Ar39 269 y 7/2-	Ar40 0+	Ar41 109.34 m 7/2-	Ar42 32.9 y 0+
p	ECp,EC2p...	ECp	ECp	EC	EC	0.337	EC	0.063	β-	99.600	β-	β-
Cl29	Cl30	Cl31 150 ms	Cl32 298 ms 1+	Cl33 2.511 s 3/2+	Cl34 1.5264 s 0+	Cl35 3/2+	Cl36 3.01E+5 y 2+	Cl37 3/2+	Cl38 37.24 m 2-	Cl39 55.6 m 3/2+	Cl40 1.35 m 2-	Cl41 38.4 s (1/2,3/2)+
		ECp	ECp,ECα,...	EC	EC	75.77	EC,β-	24.23	β-	β-	β-	β-
S28 125 ms 0+	S29 187 ms 5/2+	S30 1.178 s 0+	S31 2.572 s 1/2+	S32 0+	S33 3/2+	S34 0+	S35 87.32 d 3/2+	S36 0+	S37 5.05 m 7/2-	S38 170.3 m 0+	S39 11.5 s (3/2,5/2,7/2)-	S40 8.8 s 0+
ECp	ECp	EC	EC	95.02	0.75	4.21	β-	0.02	β-	β-	β-	β-
P27 260 ms 1/2+	P28 270.3 ms 3+	P29 4.140 s 1/2+	P30 2.498 m 1+	P31 1/2+	P32 14.262 d 1+	P33 25.34 d 1/2+	P34 12.43 s 1+	P35 47.3 s 1/2+	P36 5.6 s	P37 2.31 s	P38 0.64 s	P39 0.16 s
ECp	ECp,ECα,...	EC	EC	100	β-	β-	β-	β-	β-	β-	β-n	β-n
Si26 2.234 s 0+	Si27 4.16 s 5/2+	Si28 0+	Si29 1/2+	Si30 0+	Si31 157.3 m 3/2+	Si32 150 y 0+	Si33 6.18 s	Si34 2.77 s 0+	Si35 0.78 s	Si36 0.45 s 0+	Si37	Si38 0+
EC	EC	92.23	4.67	3.10	β-	β-	β-	β-	β-	β-n		
Al25 7.183 s 5/2+	Al26 7.17E+5 y 5+	Al27 5/2+	Al28 2.2414 m 3+	Al29 6.56 m 5/2+	Al30 3.60 s 3+	Al31 644 ms (3/2,5/2)+	Al32 33 ms 1+	Al33	Al34 60 ms	Al35 150 ms	Al36	Al37
EC	EC	100	β-	β-	β-	β-	β-		β-n	β-n		
Mg24 0+	Mg25 5/2+	Mg26 0+	Mg27 9.458 m 1/2+	Mg28 20.91 h 0+	Mg29 1.30 s 3/2+	Mg30 335 ms 0+	Mg31 230 ms	Mg32 120 ms 0+	Mg33 90 ms	Mg34 20 ms 0+	Mg35	Mg36 0+
78.99	10.00	11.01	β-	β-	β-	β-	β-n	β-n	β-n	β-n		
Na23 3/2+	Na24 14.9590 h 4+	Na25 59.1 s 5/2+	Na26 1.072 s 3+	Na27 301 ms 5/2+	Na28 30.5 ms 1+	Na29 44.9 ms 3/2	Na30 48 ms 2+	Na31 17.0 ms 3/2+	Na32 13.2 ms (3-,4-)	Na33 8.2 ms	Na34 5.5 ms	Na35 1.5 ms
100	β-	β-	β-	β-n	β-n	β-n	β-n,β-2n,...	β-n,β-2n,...	β-n,β-2n,...	β-n,β-2n,...	β-n,β-2n,...	β-n

Evaluation of Z<20 Nuclei

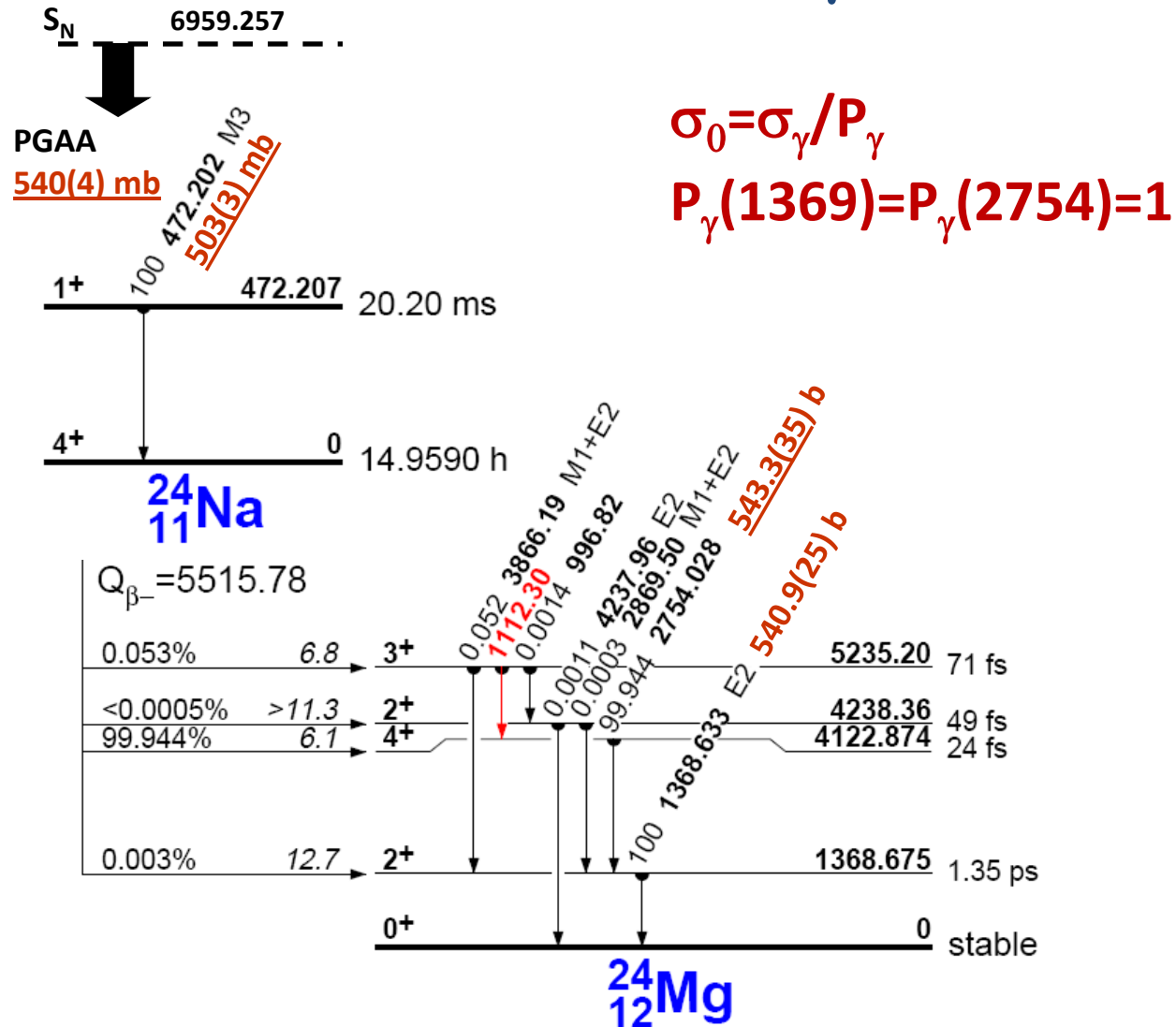
- Data are from thermal/cold guided neutron beam measurements at the Budapest and Garching FRM-II reactors, except as noted.
- Capture γ -ray decay schemes are “complete”.
- Total radiative cross sections

$$\sigma_0 = \sum \sigma_\gamma(\text{GS}) = \sum \sigma_\gamma(\text{CS})$$

- Decay scheme normalizations/ σ_0 from decay data

$$P_\gamma = \sigma_\gamma / \sigma_0$$

Determination of σ_0/P_γ : $^{23}\text{Na}(n,\gamma)$



$$\sigma_0 = \sigma_\gamma / P_\gamma$$

$$P_\gamma(1369) = P_\gamma(2754) = 1$$

²³ Na	Author (year)	$\sigma_0 \pm \Delta\sigma$ (b)
	Coltman (1946)	0.47±0.04
	Pomerance (1951)	0.470±0.024
	Meadows (1961)	0.47±0.06
	Brooksbank (1955)	0.50±0.05
	Koehler (1963)	0.50±0.02
	Yamamuro (1970)	0.50±0.03
	Harris (1953)	0.503±0.005
	Grimeland (1955)	0.51±0.03
	De Corte (2003)	0.513±0.006
	Kennedy (2003)	0.515±0.021
	Heft (1978)	0.523±0.005
	Ryves (1970)	0.527±0.005
	Szentmiklosi (2006)	0.527±0.008
	Bartholomew (1953)	0.530±0.032
	Wolf (1960)	0.531±0.008
	Cocking (1958)	0.536±0.006
	Jowitt (1959)	0.536±0.008
	Rose (1959)	0.539±0.008
	Gleason (1975)	0.54±0.02
	Kaminishi (1963)	0.577±0.008
	Seren (1947)	0.63±0.13
	Atlas	0.517±0.004
	EGAF - Primary	0.534±0.003
	EGAF - Secondary	0.540±0.004
	EGAF - Activation	0.542±0.003

Comparison with Previous Measurements

^{23m} Na	Author (year)	$\sigma_0 \pm \Delta\sigma$ (b)
	Alexander	0.40±0.03
	Groshev	0.39±0.06
	Matsue	0.476±0.011
	Atlas	0.40±0.03
	EGAF - Feeding	0.506±0.004
	EGAF - Deexciting	0.501±0.003

The Atlas value was based on De Corte (2003). It was likely affected by summing (private communication).

Intensity balance through $^{24}\text{Mg}(n,\gamma)$ decay scheme

Level Energy	J^π	σ_γ (feeding)	σ_γ (deexciting)	Net Feeding
0	5/2+	0.0539(20)		
585.074(25)	1/2+	0.0403(14)	0.0400(19)	0
974.81(3)	3/2+	0.0158(5)	0.0158(5)	0
1964.71(14)	5/2+	0.00034(6)	0.00034(4)	0
2563.43(5)	1/2+	0.00204(10)	0.00190(10)	-0.00014(14)
2801.67(14)	3/2+	0.00037(6)	0.00046(5)	0.00009(8)
3413.43(3)	3/2-	0.0403(19)	0.0412(14)	0.0009(24)
4276.49(4)	1/2-	0.0105(5)	0.0108(4)	0.0003(6)
4358.3(6)	3/2+	0.00009(3)	0.00009(3)	0
5116.62(23)	1/2-	0.00029(5)	0.00023(3)	0.00006(6)
7330.66(4)	1/2+		0.0530(20)	

$^{24}\text{Mg}(n,\gamma)$

Literature values

Author (Year)	$\sigma_0 \pm \Delta\sigma$ (mb)
Pomerance(1952)	0.033 \pm 0.010
Prestwich(1990)	0.0515 \pm 0.0025
Walkiewicz(1992)	0.0541 \pm 0.0013
Spilling(1967)	0.052 \pm 0.013
Selin(1970)	0.041 \pm 0.010
Atlas	0.0538\pm0.0013

Intensity balance through $^{25}\text{Mg}(n,\gamma)$ decay scheme

$^{25}\text{Mg}(n,\gamma)$

Level Energy	J^π	σ_γ (feeding)	σ_γ (deexciting)	Net Feeding
0	0+	0.196(8)		
1808.74(3)	2+	0.183(5)	0.181(8)	0
2938.33(3)	2+	0.0977(24)	0.099(4)	0
3588.57(8)	0+	0.00090(7)	0.00127(6)	0.00037(9)
3941.54(4)	3+	0.0247(10)	0.0252(9)	0.0005(14)
4318.89(5)	4+	0.0089(6)	0.0057(4)	-0.0032(7)
4332.57(5)	2+	0.0139(8)	0.0123(6)	-0.0017(10)
4350.08(4)	3+	0.0248(10)	0.0287(11)	0.0039(15)
4835.15(4)	2+	0.0107(5)	0.0130(7)	0.0023(9)
4901.30(8)	4+	0.0050(4)	0.00265(23)	-0.0024(5)
4972.30(5)	0+	0.00044(5)	0.00067(15)	0.00023(16)
5291.74(5)	2+	0.0037(3)	0.0049(3)	0.0012(5)
5476.12(7)	4+	0.00084(7)	0.00208(13)	0.00124(15)
5691.11(17)	1	0.00039(4)	0.00090(8)	0.00051(9)
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10718.75(6)		0.00026(8)	0	-0.00026(8)
10745.98(9)		0.00011(20)	0.00141(20)	0.00130(20)
10805.8(4)		0.00005(20)	0.00005(10)	-0.00005(22)
11093.18(3)	2+,3+		0.187(4)	

Literature values

Author (Year)	$\sigma_0 \pm \Delta\sigma$ (mb)
Pomerance(1952)	0.27±0.08
Prestwich(1990)	0.201±0.009
Walkiewicz(1992)	0.200±0.003
Spilling(1967)	0.181±0.050
Selin(1970)	0.125±0.030
Atlas	0.199±0.003

$^{26}\text{Mg}(n,\gamma)$

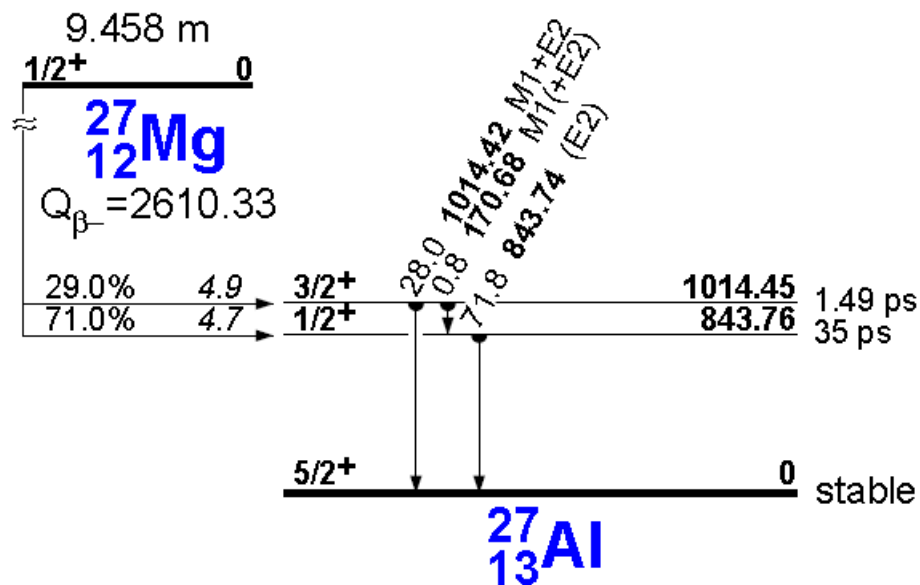
Intensity balance through $^{26}\text{Mg}(n,\gamma)$ decay scheme

Level Energy	J^π	$\sigma_\gamma(\text{feeding})$	$\sigma_\gamma(\text{deexciting})$	Net Feeding
0	1/2+	0.0381(14)		
984.92(3)	3/2+	0.0063(4)	0.0058(4)	-0.0004(5)
1698.62(4)	5/2+	0.00108(6)	0.00107(18)	0
1940.37(7)	5/2+	0.00029(4)	0.00037(5)	0.00008(6)
3476.35(6)	1/2+	0.00124(13)	0.0014(3)	0.00010(3)
3491.43(15)	(3/2,5/2)+	0.00038(11)	0.00037(4)	0
3561.55(3)	3/2-	0.0257(14)	0.0249(12)	-0.0008(18)
3787.37(5)	3/2+	0.00120(17)	0.00133(8)	0.00013(19)
4828.17(4)	(1/2,3/2)-	0.0064(4)	0.0060(4)	-0.0004(6)
5028.57(15)	1/2+	0.00016(3)	0.00014(3)	-0.00003(4)
5925.93(18)		0.00022(3)	0.00021(3)	0
6443.38(3)	1/2+		0.0395(15)	0.0395(15)

$^{26}\text{Mg}(n,\gamma)$ Reaction and Decay

Literature values

Author (Year)	$\sigma_0 \pm \Delta\sigma$ (mb)
Gleason(1975)	0.034±0.002
Seren(1947)	0.048±0.010
Pomerance(1952)	0.06±0.06
Heft(1978)	0.0365±0.0010
Walkiewicz(1992)	0.0392±0.0010
Spilling(1967)	0.034±0.010
Gryntakis(1976)	0.035±0.020
Ryves(1970)	0.0382±0.0008
De Corte	0.0371±0.0005
Atlas	0.0384±0.0006
EGAF – primary	0.0395±0.0015
EGAF - secondary	0.0381±0.0014



$E(\gamma)$	P_γ (ENSDF)	σ_γ (b)	σ_0 (b)	P_γ (EGAF)
170.63(12)	0.0086(2)	0.00032 (7)	0.037(8)	0.0093(20)
843.71(3)	0.7180(2)	0.0285(14)	0.0397(19)	0.72(5)
1014.30(4)	0.2820(2)	0.0112(5)	0.0396(18)	0.282(19)

Potassium Data

In addition to the EGAF measurements at the Budapest Reactor we used the Grenoble measurements of von Egidy, Krause, et al to complete the level schemes.

- [3] T. von Egidy, H. Daniel, P. Hungerford, H. Schmidt, K. Lieb, B. Krusche, S. Kerr, G. Barreau, H. Borner, R. Brissot, et al., *J. Phys. G. Nucl. Phys.* **10**, 221 (1984).
- [4] B. Krusche, K. Lieb, L. Ziegler, H. Daniel, T. von Egidy, R. Rascher, G. Barreau, H. Borner, and D. Warner, *Nucl. Phys. A* **417**, 231 (1984).
- [5] B. Krusche, C. Winter, K. Lieb, P. Hungerford, H. Schmidt, T. von Egidy, H. Scheerer, S. Kerr, and H. Borner, *Nucl. Phys. A* **439**, 219 (1985).

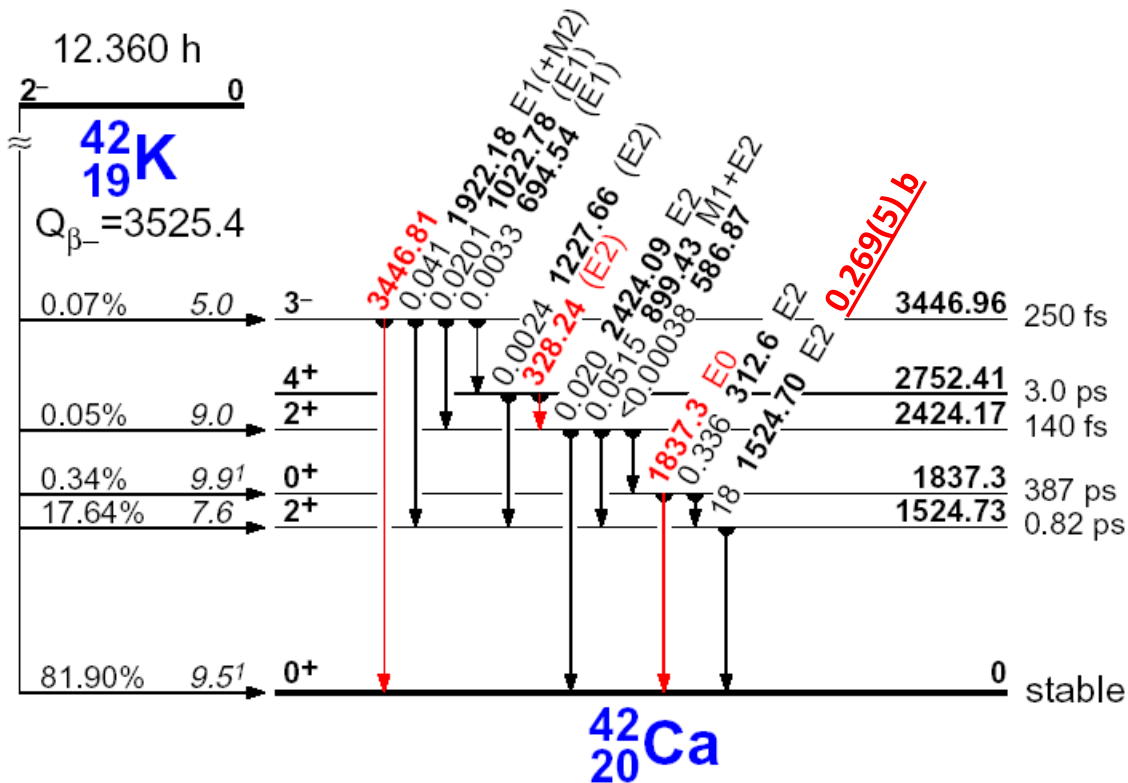
Determination of $\sigma_0/P_\gamma: {}^{41}\text{K}$

S_N 7533.80

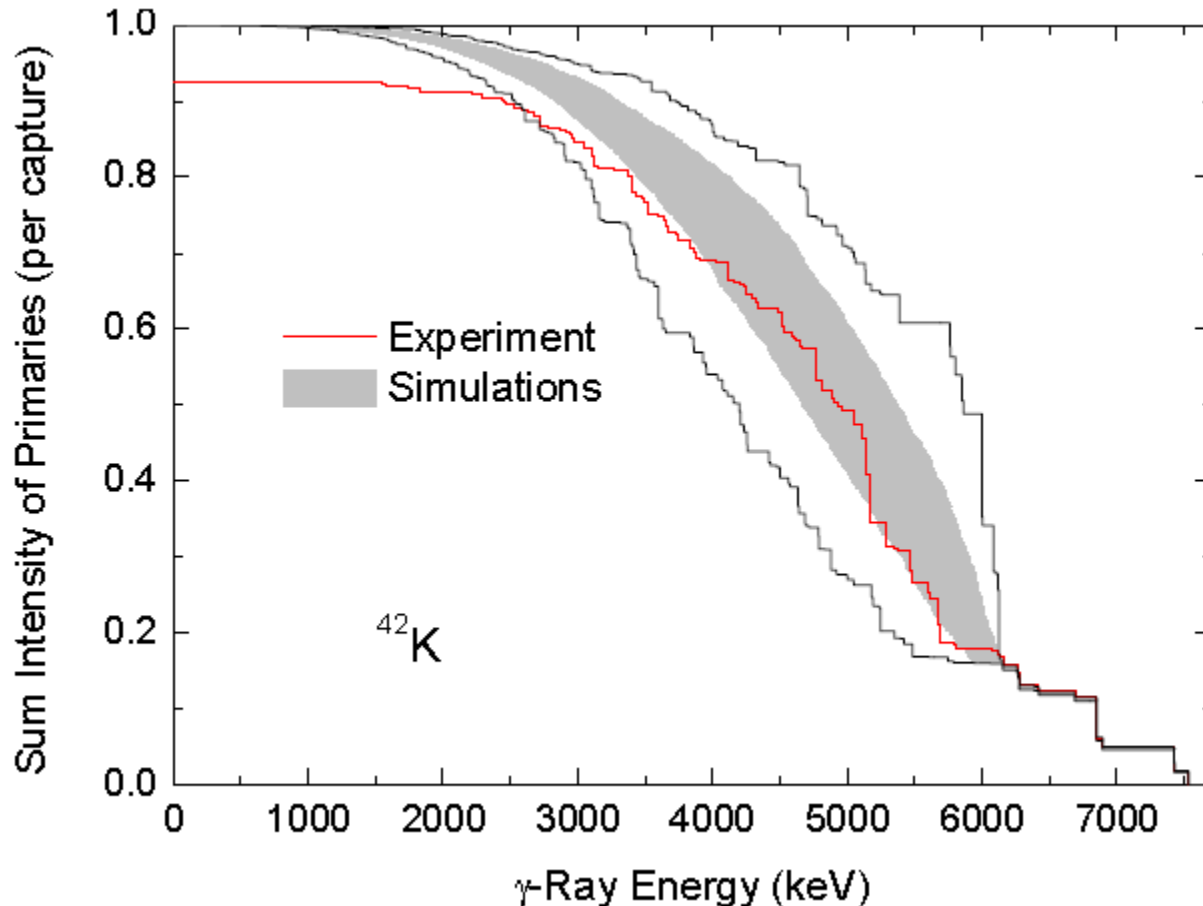


PGAA

1.62(3) b

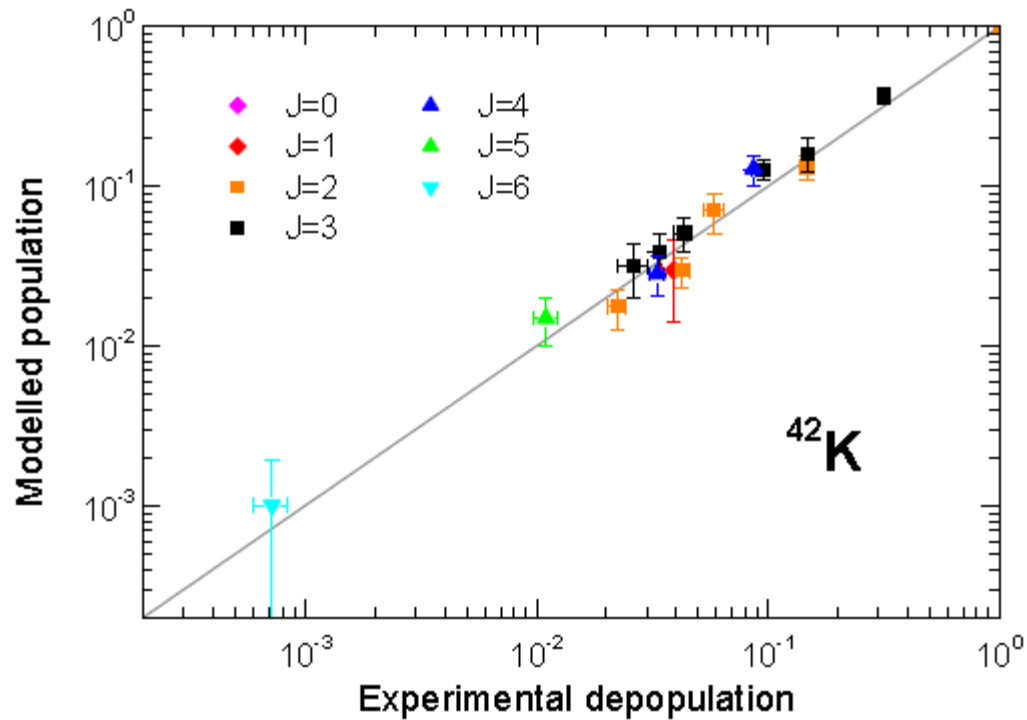


Statistical Model Simulation



Simulation of primary γ -ray intensities. 100 simulations were performed, 68% fall in the gray area. Experimental primary γ -ray are complete >4 MeV and 92% of primary intensity is observed.

Population/Depopulation Plot



Best fit population/depopulation plot. $E_{\text{crit}} = 1.4 \text{ MeV}$ (17 levels).

$^{41}\text{K}(n,\gamma)$ Cross Section

Method 1:

$$\Sigma\sigma_{\gamma}(\text{GS})^{\text{EXPT}}=1.604\pm 0.023 \text{ b}$$

$$\Sigma\sigma_{\gamma}(\text{GS})^{\text{CALC}}<0.035 \text{ b } (E_{\gamma}>4 \text{ MeV})$$

$$\sigma_0(^{41}\text{K})=1.62\pm 0.03 \text{ b}$$

Method 2:

$$\Sigma\sigma_{\gamma}(\text{GS})^{E<E_{\text{crit}}}=1.185\pm 0.019 \text{ b (experiment)}$$

$$\Sigma\sigma_{\gamma}(\text{GS})^{E>E_{\text{crit}}}=0.37\pm 0.11 \text{ b (calculated)}$$

$$\sigma_0(^{41}\text{K})=1.56\pm 0.11 \text{ b}$$

$^{41}\text{K}(n,\gamma)$: Comparison with Previous Measurements

Author (Year)	$\sigma_0 \pm \Delta\sigma$ (mb)	$\sigma_\gamma(1525)$
Seren (1947)	1.0 \pm 0.2	
Pomerance (1952)	1.19 \pm 0.10	
Koehler (1967)	1.2 \pm 0.1	
Gryntakis (1976)	1.28 \pm 0.06	
De Corte (2003)	1.42 \pm 0.02	0.263(2)
Gleason (1975)	1.43 \pm 0.03	0.257(5)
Heft (1978)	1.43 \pm 0.03	0.252(5)
Lyon (1960)	1.45	
Ryves (1970)	1.46 \pm 0.03	
Kappe (1966)	1.49 \pm 0.03	0.266(8)
Kaminishi (1982)*	1.57 \pm 0.17	
EGAF	1.62\pm0.03	0.269(5)
Atlas	1.46\pm0.03	

Bad agreement with previous results!

$^{41}\text{K}(n,\gamma)$: Determination of P_γ

$$P_\gamma = \sigma_\gamma / \sigma_0$$

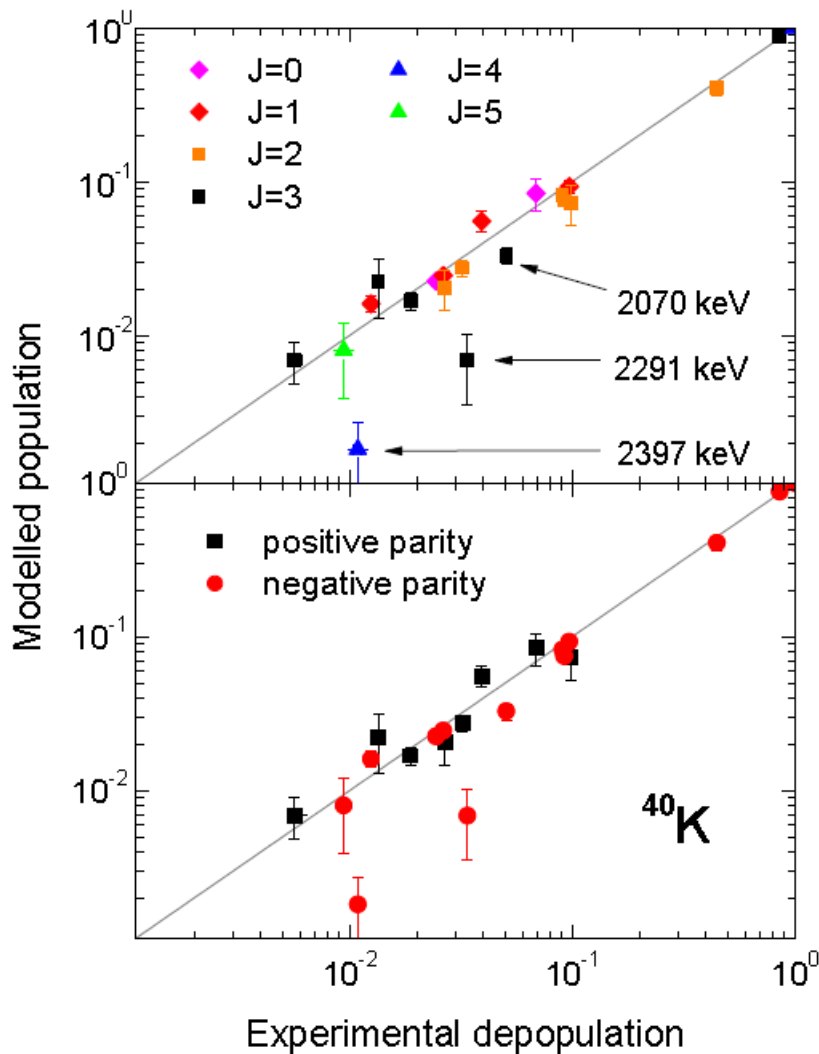
$\sigma_\gamma = 0.269 \pm 0.005$ b, $\sigma_0 = 1.62 \pm 0.03$ b from same spectrum

Author (Year)	P_g (1566)
Miyahara (1990)*	0.1808(9)
Simoës (2001)*	0.1813(14)
Kaminishi (1982)#	0.171(12)
EGAF	0.166(4)

* $4\pi\beta\text{-}\gamma$ measurements not corrected for self-absorption in the target.

$4\pi\beta\text{-}\gamma$ measurement corrected for self-absorption in the target.

$^{39}\text{K}(n,\gamma)$



Population/depopulation plot. For selected levels where direct reactions dominate. Confirmed in (d,p).

$E_{\text{crit}} = 2.82 \text{ MeV}$ (21 levels),

30 keV level not observed

Method 1:

$$\Sigma \sigma_{\gamma}(\text{GS}+30)^{\text{EXPT}} = 2.252 \pm 0.016 \text{ b}$$

$$\Sigma \sigma_{\gamma}(\text{GS}+30)^{\text{CALC}} < 0.056 \text{ b}$$

$$\sigma_0(^{39}\text{K}) = 2.28 \pm 0.04 \text{ b}$$

Method 2:

$$\Sigma \sigma_{\gamma}(\text{GS}+30)^{E < E_{\text{crit}}} = 1.836 \pm 0.014 \text{ b}$$

$$\Sigma \sigma_{\gamma}(\text{GS}+30)^{E > E_{\text{crit}}} = 0.52 \pm 0.12 \text{ b}$$

$$\sigma_0(^{39}\text{K}) = 2.35 \pm 0.15 \text{ b}$$

Author (Year)	$\sigma_0 \pm \Delta\sigma$ (mb)
Hansen (1949)	3.0 ± 1.5
Pomerance (1952)	1.9 ± 0.2
Gillette (1966)	1.4
Atlas	2.1 ± 0.2

$^{40}\text{K}(n,\gamma)$

Population/depopulation plot.

$E_{\text{crit}} = 2.60 \text{ MeV (16 levels)}$

Method 1:

$$\Sigma \sigma_{\gamma}(\text{GS})^{\text{EXPT}} = 86 \pm 7 \text{ b}$$

$$\Sigma \sigma_{\gamma}(\text{GS})^{\text{CALC}} < 7 \text{ b}$$

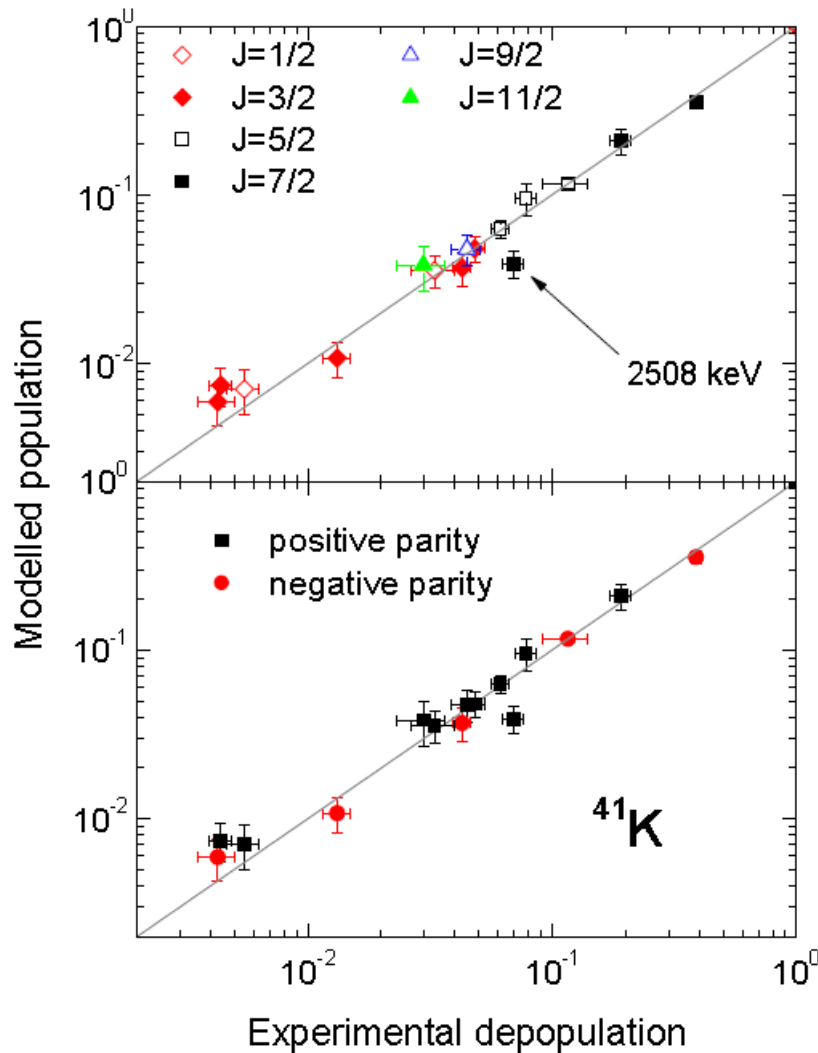
$$\sigma_0(^{40}\text{K}) = 90 \pm 8 \text{ b}$$

Method 2:

$$\Sigma \sigma_{\gamma}(\text{GS})^{E < E_{\text{crit}}} = 75 \pm 4 \text{ b}$$

$$\Sigma \sigma_{\gamma}(\text{GS})^{E > E_{\text{crit}}} = 15 \pm 5 \text{ b}$$

$$\sigma_0(^{40}\text{K}) = 90 \pm 7 \text{ b}$$



Author (Year)	$\sigma_0 \pm \Delta\sigma$ (mb)
Pomerance (1952)	66 ± 30
Gillette (1966)	≈ 70
Beckstrand (1971)	30 ± 8
Atlas	30 ± 8

Summary of results

Isotope	σ_0 (Atlas) b	σ_0 (EGAF) b
$^{23}\text{Na-0}$	0.517 ± 0.004	0.541 ± 0.003
$^{23}\text{Na-478}$	0.40 ± 0.03	0.503 ± 0.003
^{24}Mg	0.0538 ± 0.013	0.0539 ± 0.020
^{25}Mg	0.199 ± 0.003	0.196 ± 0.008
^{26}Mg	0.0384 ± 0.006	0.0387 ± 0.014
^{39}K	2.1 ± 2	2.28 ± 0.04
^{40}K	30 ± 8	90 ± 7
^{41}K	1.46 ± 0.03	1.62 ± 0.03
	P_γ (ENSDF)	P_γ (EGAF)
$^{42}\text{K-1525}\gamma$	0.1809 ± 0.0009	0.166 ± 0.004