

Table 16.15 from (1993TI07): Resonances in  $^{12}\text{C} + \alpha$  <sup>a</sup>

No.	$E_\alpha$ (MeV $\pm$ keV)	$\Gamma_{\text{c.m.}}$ (keV)	Outgoing particles <sup>b</sup> ( $x$ )	$\Gamma_x$	$\Gamma_{\alpha_0}/\Gamma$	$^{16}\text{O}^*$ (MeV $\pm$ keV)	$J^\pi; T$
1	3.324	$480 \pm 20$	$\gamma_0$	$15.6 \pm 1.2 \text{ meV}^{\text{c}}$	$\approx 1$	8.87	$1^-$
			$\gamma_3$	$1.4 \pm 1.4 \text{ meV}^{\text{c}}$		$9.580 \pm 12$	
			$\gamma_4$	$7.8 \pm 1.6 \text{ meV}^{\text{c}}$			
			$\alpha_0$				
2	$3.5770 \pm 0.5$	$0.625 \pm 0.100$	$\gamma_0$	$5.7 \pm 0.6 \text{ meV}$	$\approx 1$	$9.8440 \pm 0.5$	$2^+$
			$\gamma_3$	$2.2 \pm 0.4 \text{ meV}$			
			$\alpha_3$				
3	4.259	$27 \pm 3$	$\gamma_0$	$\leq 0.4 \text{ meV}$	$1$	$10.356 \pm 6$	$4^+$
			$\gamma_3$	$62 \pm 6 \text{ meV}$			
			$\alpha_0$				
4	$5.245 \pm 8$	$0.28 \pm 0.05$	$\gamma_2$	$3.1 \pm 1.3 \text{ meV}$	$1$	11.094	$4^+$
			$\gamma_3$	$2.5 \pm 0.6 \text{ meV}$			
			$\alpha_0$				
5	5.47	2500	$\alpha_0$			(11.26)	(0 <sup>+</sup> )
6	$5.809 \pm 18$	$73 \pm 5$	$\gamma_0$	$0.65 \pm 0.08 \text{ eV}$	$1$	11.52	$2^+$
			$\gamma_3$	$29 \pm 7 \text{ meV}$			
			$\alpha_0$				
7	$5.92 \pm 20$	$800 \pm 100$	$\alpha_0$		$1$	11.60	$3^-$
8	$6.518 \pm 10$	$1.5 \pm 0.5$	$\alpha_0$			12.049	$0^+$
9	$7.043 \pm 4$	$99 \pm 7$	$\gamma_0$	$9.5 \pm 1.7 \text{ eV}^{\text{d}}$	$1.0$	$12.442 \pm 4$	$1^-; 0$
			$\gamma_1$	$0.12 \pm 0.06 \text{ eV}^{\text{d}}$			
			p	1.1 keV			
			$\alpha_0$	$92 \pm 8 \text{ keV}$			
			$\alpha_1$	0.025 keV			
10	$7.82 \pm 10$	$150 \pm 11$	$\gamma_0$	<sup>e</sup>	$\approx 1.0$	13.02	$2^+$
			$\alpha_0$	$150 \pm 11 \text{ keV}$			
11	$7.904 \pm 11$	$130 \pm 5$	$\gamma_0$	$44 \pm 8 \text{ eV}^{\text{f}}$		$13.088 \pm 11$	$1^-; 1$

Table 16.15 from (1993TI07): Resonances in  $^{12}\text{C} + \alpha^a$  (continued)

No.	$E_\alpha$ (MeV $\pm$ keV)	$\Gamma_{\text{c.m.}}$ (keV)	Outgoing particles <sup>b</sup> ( $x$ )	$\Gamma_x$	$\Gamma_{\alpha_0}/\Gamma$	$^{16}\text{O}^*$ (MeV $\pm$ keV)	$J^\pi; T$
12	$7.960 \pm 10$	$110 \pm 30$	$\gamma_4$	$1.35 \pm 0.4$ eV	0.3	13.129	$3^-; 0$
			p	100 keV			
			$\alpha_0$	$45 \pm 18$ keV			
			$\alpha_1$	1 keV			
			$\gamma_0$	$> 0.01$ eV			
13	$8.130 \pm 15$	$26 \pm 7$	p	1 keV	0.7	13.257	$3^-; 1$
			$\alpha_0$	$90 \pm 14$ keV			
			$\alpha_1$	$\approx 20$ keV			
			$\gamma$				
			p	4.5 keV			
14	$8.960 \pm 10$	$75 \pm 7$	$\alpha_0$	9 $\pm$ 4 keV	$0.65 \pm 0.05$	$13.879 \pm 8$	$4^+$
			$\alpha_1$	7.5 keV			
			$\gamma_{4.4}$				
			$\alpha_0$	49 keV			
			$\alpha_1$	23 keV			
15	9.1	4800	$\alpha_0$			(14.0)	( $0^+$ )
16	$9.164 \pm 15$	$200 \pm 15$	$\alpha_0$	$\approx 200$ keV	$> 0.9$	14.032	$0^+$
17	$9.3 \pm 100$	$750 \pm 200$	$\alpha_0$		$0.2 \pm 0.1$	14.1	$3^-$
			$\alpha_1$				
			$\alpha_0$		$0.8^h$	$14.620 \pm 11^g$	( $4^+$ )
18	9.948	$487 \pm 12$	$\alpha_0$				
			$\alpha_1$				
			$\alpha_0$		0.94	$14.660 \pm 11^g$	$5^-$
19	10.002	$672 \pm 11$	$\alpha_0$				
			$\alpha_1$				
			$\alpha_0$				
20	$10.195 \pm 7$	$70 \pm 8$	$\alpha_0$	22 keV	$0.45 \pm 0.05$	14.805	$6^+$
			$\alpha_1$	48 keV			
21	10.544	$166 \pm 30$	$\alpha_0, \alpha_1, p_0$		0.35	$15.066 \pm 11$	$0^+$
22	10.999	$133 \pm 7$	$\alpha_0, \alpha_1, p_0$		0.58	$15.408 \pm 2$	$3^-$
23	11.560	$703 \pm 113$	$\alpha_0, (\alpha_1), \gamma_{4.4}$		0.21	$15.828 \pm 30$	$3^-$

Table 16.15 from (1993TI07): Resonances in  $^{12}\text{C} + \alpha^a$  (continued)

No.	$E_\alpha$ (MeV $\pm$ keV)	$\Gamma_{\text{c.m.}}$ (keV)	Outgoing particles <sup>b</sup> ( $x$ )	$\Gamma_x$	$\Gamma_{\alpha_0}/\Gamma$	$^{16}\text{O}^*$ (MeV $\pm$ keV)	$J^\pi; T$
24	11.6	$\approx 600$	$\gamma_0$	$\Gamma_\alpha \Gamma_\gamma / \Gamma \approx 0.4 \text{ eV}$		15.9	$2^+$
25	12.156	$422 \pm 14$	$\alpha_0$		0.93	$16.275 \pm 7$	$6^+$
26	12.272	$65 \pm 45$	$\alpha_0, (\alpha_1, \alpha_2), p_0$		0.07	$16.362 \pm 20$	$(0^+, 1^-)$
27	12.380	$22 \pm 3$	$\gamma_0, n, p_0, \alpha_0, \alpha_1, \alpha_2, \gamma_{4.4}$	$\Gamma_\alpha \Gamma_\gamma / \Gamma = 0.45 \text{ eV}$	0.28	$16.443 \pm 2$	$2^+; (1)$
28	12.5	730	$p_0, \alpha_0$			(16.5)	
29	12.915	$567 \pm 60$	$\alpha_0$		0.28	$16.844 \pm 21$	$4^+$
30	13.0	700	$\alpha_0$			(16.9)	$5^-$
31	13.05	$\approx 280$	$\alpha_2, ^8\text{Be}$			16.94	$2^+$
32	13.296	$107 \pm 14$	$n, p_0, \alpha_0, \alpha_1, \gamma_{4.4}$		0.37	$17.129 \pm 5$	$2^+$
33	13.32	$36 \pm 5$	$\alpha_0, \alpha_1$			17.15	
34	13.35	$160 \pm 60$	$\alpha_2, ^8\text{Be}$			17.17	$2^+$
35	13.50	$< 100$	$n$			17.28	
36	13.805	$182 \pm 56$	$\alpha_0, (\alpha_1), \alpha_2$		0.16	$17.510 \pm 26$	$1^-$
37	13.865	$178 \pm 66$	$n, (\alpha_0, \alpha_1)$		0.07	$17.555 \pm 21$	$(6^+)$
38	13.948	$175 \pm 55$	$p_0, \alpha_0$		0.32	$17.618 \pm 20$	$(0^+, 1^-)$
39	14.08	$(\approx 75)$	$(p_0), ^8\text{Be}$			17.72	$(0^+, 2^+)$
40	14.170	$396 \pm 41$	$n, \alpha_0, \alpha_1, \gamma_{4.4}, ^8\text{Be}$		0.34	$17.784 \pm 15$	$4^+$
41	14.480	$14 \pm 2$	$(n), p_0, \alpha_0, \alpha_1, \gamma_{4.4}, ^8\text{Be}$		0.36	$18.016 \pm 1$	$4^+; (0)$
42	14.577	$248 \pm 90$	$(\gamma_0), n_0, p_0, \alpha_0$		0.31	$18.089 \pm 25$	$(0^+)$
43	(14.62)	$(\approx 45)$	$\alpha_0$			(18.12)	$(\neq 4^+)$
44	14.85	$\approx 380$	$\gamma_0, p_0, (\alpha_1, \gamma_{4.4})$	$\Gamma_\alpha \Gamma_\gamma / \Gamma = 0.95 \text{ eV}$		18.29	
45	14.997	$544 \pm 39$	$\alpha_0$		0.40	$18.404 \pm 12$	$5^-$
46	15.2	$\approx 150$	$\alpha_0, \alpha_1, \alpha_2, \gamma_{4.4}$			18.6	$(1^-, 5^-)$
47	15.2	$\approx 300$	$\alpha_2, ^8\text{Be}$			18.6	$(4^+)$
48	15.490	$215 \pm 45$	$p_0, \alpha_0$		0.26	$18.773 \pm 22$	$1^-$
49	15.506	$260 \pm 16$	$n, p_0, \alpha_0, (\alpha_1), ^8\text{Be}$		0.48	$18.785 \pm 6$	$4^+$
50	15.8	$\approx 550$	$(\alpha_0), \alpha_1, \gamma_{4.4}$			19.0	$(5^-)$
51	15.96	41	$(n), \alpha_0$			(19.12)	$(2^+, 4^+)$

Table 16.15 from (1993TI07): Resonances in  $^{12}\text{C} + \alpha^a$  (continued)

No.	$E_\alpha$ (MeV $\pm$ keV)	$\Gamma_{\text{c.m.}}$ (keV)	Outgoing particles <sup>b</sup> ( $x$ )	$\Gamma_x$	$\Gamma_{\alpha_0}/\Gamma$	$^{16}\text{O}^*$ (MeV $\pm$ keV)	$J^\pi; T$
52	16.130	$50 \pm 45$	(n), ( $\alpha_0$ )		0.04	$19.253 \pm 30$	(5 <sup>-</sup> )
53	16.137	$155 \pm 23$	$p_0, \alpha_0, (\alpha_1)$		0.34	$19.257 \pm 9$	2 <sup>+</sup>
54	16.219	$63 \pm 33$	$p_0, (\alpha_0), \alpha_1, \alpha_2, ^8\text{Be}$		0.07	$19.319 \pm 14$	(6 <sup>+</sup> )
55	16.293	$23 \pm 4$	$p_0, \alpha_0, \alpha_1, \alpha_2$		0.23	$19.375 \pm 2$	4 <sup>+</sup>
56	16.496	$255 \pm 75$	(n), $\alpha_0, (\alpha_1, \alpha_2)$		0.20	$19.527 \pm 26$	2 <sup>+</sup>
57	16.799	$286 \pm 44$	$p_0, \alpha_0, \alpha_1$		0.29	$19.754 \pm 16$	2 <sup>+</sup>
58	(16.92)	( $\approx 175$ )	$\alpha_2$			(19.85)	
59	(17.05)	( $\approx 30$ )	( $\alpha_0$ )			(19.94)	( $\neq 3^-$ )
60	17.201	$432 \pm 40$	$\gamma_0, \text{n}, (p_0), \alpha_0, (\alpha_1)$		0.43	$20.055 \pm 13$	2 <sup>+</sup>
61	(17.27)	( $\approx 45$ )	( $\alpha_0$ )			(20.11)	( $\neq 3^-$ )
62	17.5	$\approx 1500$	$p_0$			(20.3)	
63	(17.66)	( $\approx 150$ )	$\text{n}, (p_0), \alpha_0, \alpha_2$			(20.40)	(4 <sup>+</sup> )
64	(17.8)	( $\approx 300$ )	( $\alpha_0$ ), $\alpha_1$			(20.5)	
65	17.849	$11 \pm 2$	$p_0, \alpha_0, \alpha_1, \alpha_2$		$0.14 \pm 0.02$	$20.541 \pm 2$	5 <sup>-</sup>
66	17.875	$< 5$	$\alpha_0$			$20.560 \pm 2$	even
67	17.948	$< 10$	$\alpha_0$			$20.615 \pm 3$	even
68	(18.2)	( $\approx 60$ )	$\text{n}, (p_0)$			(20.8)	
69	18.271	$904 \pm 55$	$\alpha_0$		0.60	$20.857 \pm 14$	7 <sup>-</sup>
70	(18.3)		$\alpha_0$			(20.9)	2 <sup>+</sup>
71	(18.48)	( $\approx 50$ )	$\text{n}, p_0, (\alpha_0)$			(21.01)	
72	$18.50 \pm 25$	$240 \pm 80$	$\gamma_0, (\alpha_0, \alpha_1)$		0.20	21.03	(1 <sup>-</sup> )
73	18.5	900	$\alpha_0$		i	(21.0)	5 <sup>-</sup>
74	18.531	$205 \pm 14$	$\alpha_0$		0.50	$21.052 \pm 6$	6 <sup>+</sup>
75	18.593	$306 \pm 46$	( $\alpha_0$ )		0.20	(21.098)	4 <sup>+</sup>
76	19.294	$61 \pm 32$	$\text{n}, p_0, \alpha_0, \alpha_2$		$< 0.05$	$21.623 \pm 11$	7 <sup>-</sup>
77	$19.327^j$	$115 \pm 8$	$\text{n}, \alpha_0, \alpha_1, \alpha_2$		0.41	$21.648 \pm 3$	6 <sup>+</sup>
78	$19.498^j$	$43 \pm 20$	$\text{n}, p_0, \alpha_0, \alpha_1, \alpha_2$		0.07	$21.776 \pm 9$	3 <sup>-</sup>
79	19.85	60	n			22.04	

Table 16.15 from (1993TI07): Resonances in  $^{12}\text{C} + \alpha^a$  (continued)

No.	$E_\alpha$ (MeV $\pm$ keV)	$\Gamma_{\text{c.m.}}$ (keV)	Outgoing particles <sup>b</sup> ( $x$ )	$\Gamma_x$	$\Gamma_{\alpha_0}/\Gamma$	$^{16}\text{O}^*$ (MeV $\pm$ keV)	$J^\pi; T$
80	19.89	340	n			22.07	
81	19.95	< 150	n, $^8\text{Be}$			22.11	
82	20.49	375	n			22.52	
83	20.71	60	n, $^8\text{Be}$			22.68	
84	$20.760 \pm 5$	$12.5 \pm 2.5$	$n_0, p_0, \alpha_0, \alpha_2$			22.721	$0^+; T = 2$
85	21.28	$\approx 20$	$\alpha_1, \alpha_2, ^8\text{Be}$			23.11	
86	21.3	$\leq 500$	$^8\text{Be}$			23.1	$6^+$
87	21.67	< 40	n, $\alpha_0, \alpha_2$		$\approx 0.31$	23.40	$(5^-)$
88	21.85	300	$\alpha_0, \alpha_1$			23.54	
89	22.0	1500	$\gamma_{12.71}$			23.6	
90	22.14	120	n			23.75	
91	$22.306 \pm 6$	$26 \pm 4$	$p_0, \alpha_0, \alpha_1, \alpha_2, ^8\text{Be}$	<sup>k</sup>	$0.06 \pm 0.02$	23.879	$6^+$
92	22.37	165	n			23.93	
93 <sup>m</sup>	22.75	$\leq 500$	$^8\text{Be}$			24.21	
94	23.2	750	$\gamma_{12.71}, \gamma_{15.11}$			24.5	$T = 1$
95	24.1	450	$\gamma_{15.11}$			25.2	$T = 1$
96	24.6	450	$\gamma_{15.11}$			25.6	$T = 1$
97	25.5	450	$\gamma_{15.11}$			26.3	$T = 1$
98	25.6	1200	$\alpha_0, \gamma_{12.71}$	$\Gamma_\alpha \Gamma_\gamma / \Gamma = 1.2 \text{ eV}$		26.3	$2^+$
99	28.1	1000	$\alpha_0$		0.35	28.2	$7^-$
100	29.1	1000	$\alpha_0, \alpha_1, p_3$		0.35	29.0	$7^-$
101	35.8	2300	$\alpha_0, \alpha_2$		$0.1^1$	34.0	$10^+; (9^-)$

- <sup>a</sup> References are listed in [Tables 16.11 \(1971AJ02\)](#), [16.12 \(1977AJ02\)](#), [16.13 \(1982AJ01\)](#), and [16.12 \(1986AJ04\)](#).
- <sup>b</sup>  $p_0$  corresponds to  $^{15}\text{N}(0)$ .  $\alpha_0, \alpha_1$  corresponds to  $^{12}\text{C}^*(0, 4.4)$  and  $\gamma_{4.4}$  corresponds to the  $\gamma$ -ray from the decay of  $^{12}\text{C}^*(4.4)$ ;  $\gamma_0, \gamma_1, \gamma_2, \gamma_3, \gamma_4$  correspond to the transitions to  $^{16}\text{O}^*(0, 6.05, 6.13, 6.92, 7.12)$ .
- <sup>c</sup> These are observed widths from [\(1987RE02\)](#). We are indebted to Dr. F.C. Barker who informed us of these and other recent observed width determinations.  $\Gamma_{\gamma_3}^0 = 2.4 \pm 1.4$  meV ([1987RE02](#)),  $\Gamma_{\gamma_3} = 2.4$  meV,  $\Gamma_{\gamma_4} = 8.0$  meV ([1991BA1K](#)),  $\Gamma_{\gamma_0} = 16.4$  meV (*R*-matrix fit by [\(1991HU10\)](#)).
- <sup>d</sup> Branching ratios to  $^{16}\text{O}^*(0, 6.05) = 98.8\%, 1.2\%$ .
- <sup>e</sup>  $\Gamma_{\gamma_0} = 0.7 \pm 0.2$  eV, based on  $\Gamma_{\alpha_0}/\Gamma = 1.0$  and  $\Gamma_{\text{c.m.}} = 190 \pm 40$  keV.
- <sup>f</sup>  $\Gamma_{\alpha_0}\Gamma_{\gamma_0}/\Gamma^2 = (1.49 \pm 0.17) \times 10^{-4}$ .
- <sup>g</sup> Uncertainties in  $E_x$  may be larger.
- <sup>h</sup> For this and the states below  $\Gamma_{\alpha}/\Gamma$  is  $\pm 0.10$  for isolated narrow levels.
- <sup>i</sup>  $\Gamma_{\alpha_2}/\Gamma = 0.16$  ([1982KA30](#)).
- <sup>j</sup> A resonance is reported at  $E_{\alpha} = 19.4$  MeV:  $4^+$  is dominant,  $\Gamma_{\alpha}/\Gamma \ll 1$ ,  $\Gamma \geq 0.48$  ([1982KA30](#)).
- <sup>k</sup>  $\Gamma_{8\text{Be}}, \Gamma_{\alpha_0}$ , and  $\Gamma_{\alpha_2} \approx 3.5, 1.5 \pm 0.5$  and  $\approx 6$  keV, respectively.
- <sup>l</sup>  $\Gamma_{\alpha_2}/\Gamma = 0.2$  ([1983AR12](#)).
- <sup>m</sup> Broad maxima are reported in the activation cross section at  $E_{\alpha} = 22.8, 24.3, 25.3$  and  $26.9$  MeV ([1983KOZD](#); prelim.).
- <sup>n</sup> See [\(1981SA07\)](#) for  $(\alpha, \gamma_{14.8})$  measurements which indicate an  $8^+$  GQR built on the  $6_1^+$  state  $^{16}\text{O}^*(14.82)$ .