

4. EXCITED STATES

Nuclei are naturally found in their lowest energy state (ground state)

BUT, like all Q.M. systems, they have higher energy levels **with less binding energy**.

They are denoted: ${}^A_Z X^*$

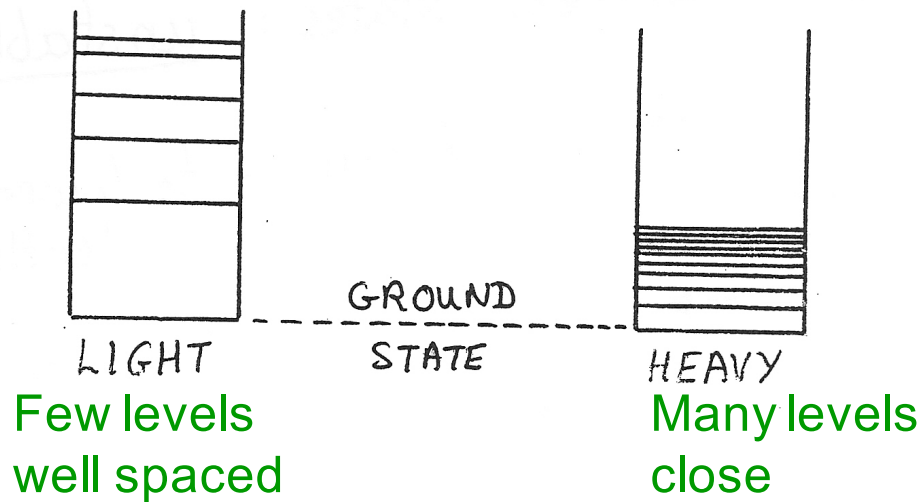
They are formed:

- after decays
- in (nuclear) reactions

Note: ${}^2_1 H$ does not have excited states for obvious reasons

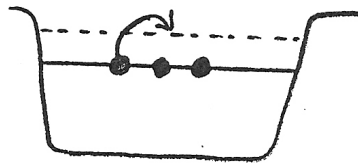
4.1. Properties of Excited States

(a) Distribution



(b) Low levels – Single nucleon excitation

shell
model



Excitation to higher levels:

involve several nucleons

not easily interpreted in terms of shell model

(c) Excited states: unstable

→ γ decay – to lower energy levels

or

→ break-up (fission)

→ lighter nuclei

γ decay

$\left\{ \begin{array}{l} \text{lifetime} \geq 10^{-16} \text{ s} \\ \text{width } \Delta E \leq \text{few eV} \end{array} \right.$

breakup

$\left\{ \begin{array}{l} \text{lifetime } 10^{-18} \text{ s} - 10^{-20} \text{ s} \\ \Delta E \leq 0.1 \text{ MeV} \end{array} \right.$

Example: excited states of $^{17}_8\text{O}$

Binding energies:

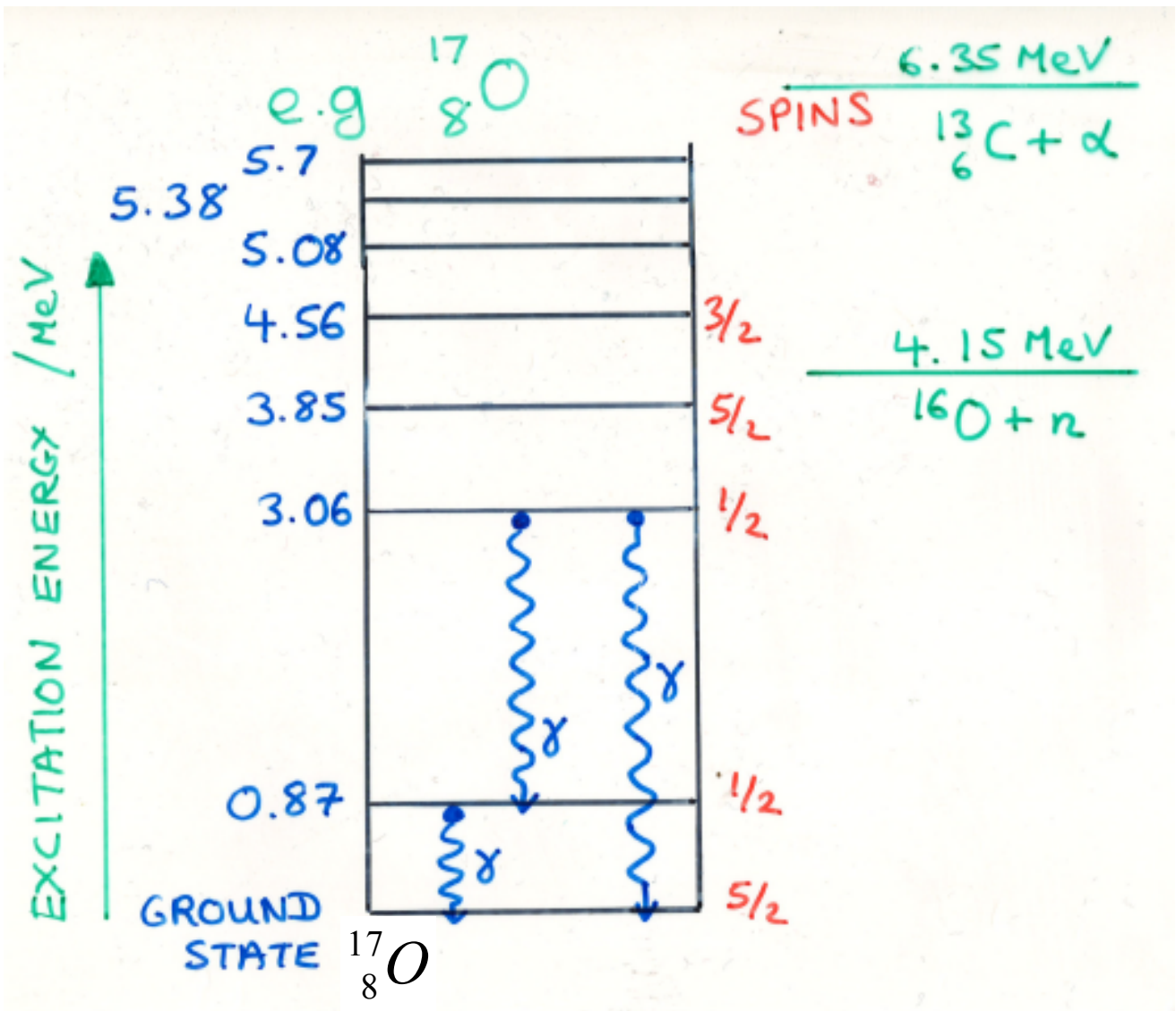
$^{17}_8\text{O}$	131.76 MeV	
$^{16}_8\text{O} + n$	127.62 MeV	(a)
$^{13}_6\text{C} + \alpha$	125.41 MeV	(b)

(a) is 4.15 MeV above ground state of $^{17}_8\text{O}$

(b) is 6.35 MeV above ground state of $^{17}_8\text{O}$

Let us look at the energy levels ...

No spin-orbit coupling		With spin-orbit coupling		MAGIC NUMBERS					
1i	—	<div>126</div>	1i _{13/2} 14	126	82	12	1h _{11/2}	<div>82</div>	
	—		3p _{1/2} 2						
3p	—		3p _{3/2} 4			2	3s _{1/2}	—	
	—		2f _{5/2} 6						
2f	—		2f _{7/2} 8			4	2d _{3/2}	—	
	—		1h _{9/2} 10						
1h	—	<div>82</div>				6	2d _{5/2}	—	
	—		1h _{11/2} 12	82		8	1g _{7/2}	—	
3s	—		3s _{1/2} 2						
	—		2d _{3/2} 4					<div>50</div>	
2d	—		2d _{5/2} 6		50	10	1g _{9/2}	—	
	—		1g _{7/2} 8			2	2p _{1/2}	—	
1g	—	<div>50</div>				6	1f _{5/2}	—	
	—		1g _{9/2} 10	50		4	2p _{3/2}	—	
	—		2p _{1/2} 2					<div>28</div>	
2p	—		1f _{5/2} 6						
	—		2p _{3/2} 4		28	8	1f _{7/2}	—	
1f	—	<div>28</div>						<div>20</div>	
	—		1f _{7/2} 8	28					
	—	<div>20</div>			20	4	1d _{3/2}	—	
	—		1d _{3/2} 4	20					
	—		2s _{1/2} 2			2	2s _{1/2}	—	
2s	—								
1d	—		1d _{5/2} 6			6	1d _{5/2}	—	
	—	<div>8</div>						<div>8</div>	
	—		1p _{1/2} 2	8	8	2	1p _{1/2}	—	
1p	—		1p _{3/2} 4			4	1p _{3/2}	—	
	—	<div>2</div>						<div>2</div>	
1s	—		1s _{1/2} 2	2	2	2	1s _{1/2}	—	
NEUTRON LEVELS				MAGIC NUMBERS		PROTON LEVELS *			



➤ all excited states above

- 4.15 MeV can break up into $^{16}_8\text{O} + n$
- 6.35 MeV can also break up into $^{13}_6\text{C} + \alpha$