Hw 2

Group 2

Problem 14: A.K.A. how to do β-decay

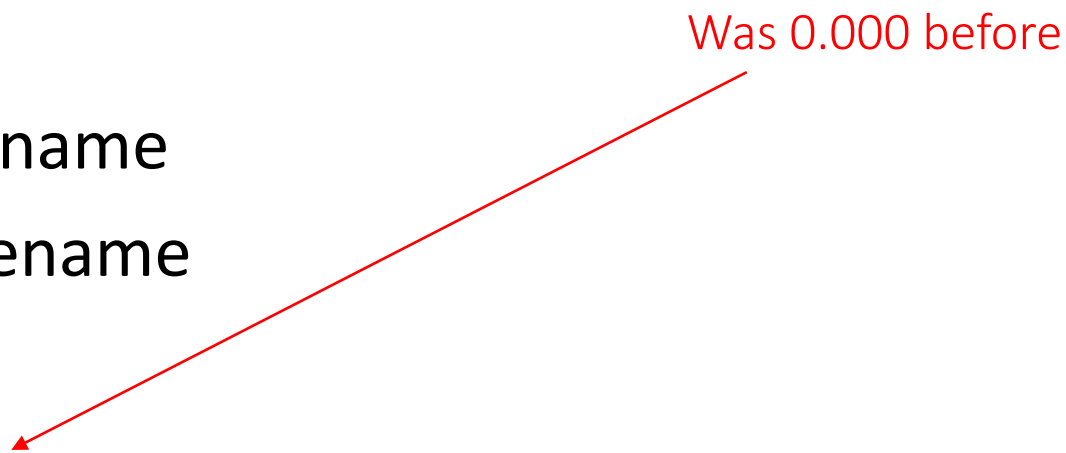
Calculate the Fermi (*F*) and Gamow-Teller (*GT*) beta decay of ^{22}O. The experimental energy of the lowest 1+ state in ^{22}F is 1.627 MeV. You will need to put this in the xxx.beq file and rerun the beta program (see the end of the xxx.bat file for how to do this). Compare the summed *B*(*F*) and *B*(*GT*) values to that expected from the sum-rules. What fraction of the *GT* sum-rule is in the transition to the lowest energy 1+ state?

```
------------------------------------------------------
lpe,   1          ! option (lpe or lan), neig (zero=10)
sd                ! model space (*.sp) name (a8)
n                 ! any restrictions (y/n)
usdb              ! interaction (*.int) name (a8)
 8                ! number of protons
 22               ! number of nucleons
 0.0, 0.0, 1.0,     ! min J, max J, del J
 0                ! parity (0 for +) (1 for -) (2 for both)
------------------------------------------------------
lpe,   0          ! option (lpe or lan), neig (zero=10)
 9                ! number of protons
 22               ! number of nucleons
 0.0, 4.0, 1.0,     ! min J, max J, del J
 0                ! parity (0 for +) (1 for -) (2 for both)
------------------------------------------------------
den               ! option
t                 ! 1, 2 or t
bb0600            ! initial file name (default from lpe above)
  1               ! max number (-1 for all)
bb1600            ! final file name (default = from lpe above)
 -1               ! max number (-1 for all)
 0.0, 0.0, 1.0,     ! min, max J, del J for bb0600
 0.0, 1.0, 1.0,     ! min, max J, del J for bb1600
y                 ! restrict coupling for operator
 0.0, 1.0,         ! min,max delta-J for operator
------------------------------------------------------
st        '       ! option
```

- ----------
- Calculation of the 22-O nucleus (8p, 14n)
- We add a 1 after lpe because we are only interested in the decay from one state.
- No restrictions
- Our g.s. is 0+, so we only need to put in 0 for our min J
- ----------
- Calculation of the 22-F nucleus (9p, 13n)
- I calculated J 0 to 4, even though only 0, 1 are needed in β decay
- ----------
- This will run the “dens” program
- T- is for the One-body transition density (OBTD)
- We put in the g.s. (00) file from 22-O
- 1 is input because we only want it from the g.s.
- This is the first file from 22-F (it will be overwritten later)
- -1 Runs all options
- g.s. of 22-O is 0+
- Range of J values allowed in 22-F

- By running dens, we
  - create intermediary files
    - .ben – input to dens, tells where to write the output file of matrix elements, and where the OBTD files are created
    - .bei – output of dens
    - .beq – allows input of Q value, an experimental energy
  - create output file
    - .beo – beta decay final output

O_220b.beq file:



- o_220b *.bei filename
- o_220b *.beo filename
- o_220 f_220
- sd usdb
- 8., 9., 22., 0.000, 1.627, 0.60 ! zi, zf, a, q, exf, 0.60 is the quenching factor
- 0.0, 0.0, 0.0 ! texp(s), percent non-GT, texp-err(s)
- END

o_220 f_220

sd usdb

experimental q-value = 6.489 MeV

theoretical q-value = 8.437 MeV

calculated t1/2 = 0.2620E+01 sec

experimental t1/2 = 0.0000E+00 (+/-) 0.0000E+00 sec

ji,ti = 0.0 3.0

non gamow-teller br = 0.00%

ft = 6177/[qf*(1.260**2.)b(gt)+b(f)] where qf = 0.60 for the quenching factor

sum b(gt) b(f) = 3.72285 6.00000

centroid = 5.75152

sum b(gt)/3|n-z| = 0.20682 for o_220b

th [br*b(gt)/3|n-z|] = 0.04060

exp [br*b(gt)/3|n-z|] = 0.00000

					sum		sum		
jf	tf	nf	ex(MeV)	br(%)	br(%)	log(ft)	qf*b(gt)	qf*b(gt)	log(fa)	b(f)
1	2	1	1.627	21.4811	78.519	4.800	0.0616	0.0616	3.714	0.00000
1	2	2	2.605	72.4648	6.054	3.829	0.5766	0.6382	3.271	0.00000
0	2	1	3.046	0.0000	6.054	13.595	0.0000	0.6382	3.036	0.00000
1	2	3	3.313	5.2595	0.795	4.577	0.1030	0.7412	2.880	0.00000
1	2	4	4.373	0.0008	0.794	7.652	0.0001	0.7413	2.112	0.00000
1	2	5	4.832	0.7916	0.002	4.184	0.2546	0.9959	1.664	0.00000
0	2	2	5.504	0.0000	0.002	14.138	0.0000	0.9959	0.748	0.00000
1	2	6	5.694	0.0000	0.002	9.137	0.0000	0.9959	0.385	0.00000
1	2	7	6.075	0.0021	0.000	4.412	0.1508	1.1467	-0.675	0.00000
0	2	3	6.609	0.0000	0.000	15.681	0.0000	1.1467	0.000	0.00000
1	2	8	6.807	0.0000	0.000	6.858	0.0005	1.1473	0.000	0.00000
1	2	9	7.258	0.0000	0.000	4.664	0.0844	1.2317	0.000	0.00000
1	2	10	8.124	0.0000	0.000	3.589	1.0020	2.2337	0.000	0.00000
0	2	4	8.588	0.0000	0.000	14.311	0.0000	2.2337	0.000	0.00000
0	2	5	9.282	0.0000	0.000	3.013	0.0000	2.2337	0.000	6.00000
0	2	6	9.572	0.0000	0.000	16.089	0.0000	2.2337	0.000	0.00000
0	2	7	10.174	0.0000	0.000	13.669	0.0000	2.2337	0.000	0.00000
0	2	8	10.915	0.0000	0.000	16.236	0.0000	2.2337	0.000	0.00000
0	2	9	12.714	0.0000	0.000	14.127	0.0000	2.2337	0.000	0.00000
0	2	10	13.048	0.0000	0.000	15.270	0.0000	**2.2337**	0.000	0.00000

- Notice– value for B(F)= 6.. Which is exactly N-Z!! So that is okay.
- Our B(GT) = 3(N-Z), so theoretically it should be 18…. But we only get 2.2337….

- Where did the rest go?

- The reason is 2-fold
  - Recall we have a quenching factor of 0.6
  - Also, we have only calculated 10 states (the automatic input)– this value changes as we change lpe, 0 to lpe, 50 or lpe, 100

Spectroscopic Factor Problems 7

Calculate the spectroscopic factors from the ground state of ^{23}O to all states in ^{22}O in the full 1*s*0*d* model space. Use the sum rule to obtain the orbital occupations in 23O for $0d_{5/2}$, $1s_{1/2}$ and $0d_{3/2}$. Compare these to those given in the so-called xxx.occ file.

```
lpe,   0          ! option (lpe or lan), neig (zero=10)
sd                ! model space (*.sp) name (a8)
n                 ! any restrictions (y/n)
usdb              ! interaction (*.int) name (a8)
 8                ! number of protons
 23               ! number of nucleons
 0.5, 0.5, 1.0,   ! min J, max J, del J
 0                ! parity (0 for +) (1 for -) (2 for both)
---------------------------------------------------
lpe,   0          ! option (lpe or lan), neig (zero=10)
 8                ! number of protons
 22               ! number of nucleons
 0.0, 4.0, 1.0,   ! min J, max J, del J
 0                ! parity (0 for +) (1 for -) (2 for both)
---------------------------------------------------
den               ! option
1                 ! 1, 2 or t
bb0600            ! initial file name (default from lpe above)
 -1               ! max number (-1 for all)
bb0701            ! final file name (default = from lpe above)
  1               ! max number (-1 for all)
 0.0, 4.0, 1.0,   ! min, max J, del J for bb0600
 0.5, 0.0, 1.0,   ! min, max J, del J for bb0701
n                 ! restrict coupling for operator
---------------------------------------------------
st                ! option
```

23-O input

Only interested in g.s.

Here, we have 22-O

---

st ! option

23O.ans

For occupation sum rule--- we can take the direct sum from C^{2S}

(Ai Tzi)	(Af Tzf)	(type n,l,2j)	Ji	Jf	ni	nf	C^2S	Ei	Ef	C^2S*(Ef-Ei)	Exi	Exf	
(22 3.0)	(23 3.5)	(n 2 0 1)	0.0+	0.5+	1	1	0.7823	-34.498	-37.079	-2.019	0.000	0.000	
		sum	**0.9389**					-3.213					1.02 in s1/2
(22 3.0)	(23 3.5)	(n 2 0 1)	1.0+	0.5+	10	1	0.0003	-14.893	-37.079	-0.007	19.605	0.000	
		sum	**0.0801**					-4.293					
(22 3.0)	(23 3.5)	(n 1 2 3)	1.0+	0.5+	10	1	0.0004	-14.893	-37.079	-0.009	19.605	0.000	
		sum	**0.0381**					-4.846					0.170 in d3/2
(22 3.0)	(23 3.5)	(n 1 2 3)	2.0+	0.5+	10	1	0.0004	-19.966	-37.079	-0.007	14.532	0.000	
		sum	**0.1315**					-6.249					
(22 3.0)	(23 3.5)	(n 1 2 5)	2.0+	0.5+	10	1	0.0064	-19.966	-37.079	-0.110	14.532	0.000	
		sum	**2.4565**					-22.031					5.80 in d5/2
(22 3.0)	(23 3.5)	(n 1 2 5)	3.0+	0.5+	10	1	0.0008	-18.102	-37.079	-0.015	16.396	0.000	
		sum	**3.3424**					-47.421					

Compare with o_23b.occ (starting nucleus)

					Protons			Neutrons		
N	NJ	Ex	2J	P	0d3	0d5	1s1	0d3	0d5	1s1
1	1	0.000	1	1	0.00	0.00	0.00	0.17	5.81	1.02
2	1	2.593	5	1	0.00	0.00	0.00	0.16	4.89	1.95
3	1	4.001	3	1	0.00	0.00	0.00	1.10	5.63	0.27
4	2	6.943	5	1	0.00	0.00	0.00	1.09	4.76	1.14
5	2	7.034	3	1	0.00	0.00	0.00	1.16	4.80	1.04

Compare this with the summed values from the previous slide…

8.

Calculate the spectroscopic factors from the ground state of ^{23}O to all states in ^{24}O in the full 1*s*0*d* model space. Use the sum rule to obtain the number of holes in those three orbits in ^{23}O. Compare these to those given in the xxx.occ file.

24Ospec.ans

```
-------------------------------------------------
lpe,   0          ! option (lpe or lan), neig (zero=10)
sd                ! model space (*.sp) name (a8)
n                 ! any restrictions (y/n)
usdb              ! interaction (*.int) name (a8)
 8                ! number of protons
 23               ! number of nucleons
 0.5, 3.5, 1.0,      ! min J, max J, del J
 0                ! parity (0 for +) (1 for -) (2 for both)
-------------------------------------------------
lpe,   0          ! option (lpe or lan), neig (zero=10)
 8                ! number of protons
 24               ! number of nucleons
 0.0, 4.0, 1.0,      ! min J, max J, del J
 0                ! parity (0 for +) (1 for -) (2 for both)
-------------------------------------------------
den               ! option
1                 ! 1, 2 or t
bb0701            ! initial file name (default from lpe above)
  1               ! max number (-1 for all)
bb0800            ! final file name (default = from lpe above)
 -1               ! max number (-1 for all)
 0.5, .5, 1.0,      ! min, max J, del J for bb0701
 0.0, 4.0, 1.0,      ! min, max J, del J for bb0800
n                 ! restrict coupling for operator
-------------------------------------------------
st                ! option
```

24Ospecb.lsf: output with spectroscopic factors

! model space = sd
! interaction = usdb

(Ai Tzi)	(Af Tzf)	(type n,l,2j)	Ji	Jf	ni	nf	C^2S	Ei	Ef	C^2S*(Ef-Ei)	Exi	Exf
(23 3.5)	(24 4.0)	(n 2 0 1)	0.5+	0.0+	1	1	1.8103	-37.079	-41.225	-7.506	0.000	0.000
…….												
(23 3.5)	(24 4.0)	(n 2 0 1)	0.5+	0.0+	1	9	0.0000	-37.079	-12.011	0.000	0.000	29.214
					sum		1.8587			-7.326		# holes **0.929**

(Ai Tzi)	(Af Tzf)	(type n,l,2j)	Ji	Jf	ni	nf	C^2S	Ei	Ef	C^2S*(Ef-Ei)	Exi	Exf
(23 3.5)	(24 4.0)	(n 2 0 1)	0.5+	1.0+	1	1	0.0001	-37.079	-35.266	0.000	0.000	5.959
……												
(23 3.5)	(24 4.0)	(n 2 0 1)	0.5+	1.0+	1	10	0.0000	-37.079	-17.220	0.000	0.000	24.005
					sum		0.0342			-7.120		# holes **0.051**

(Ai Tzi)	(Af Tzf)	(type n,l,2j)	Ji	Jf	ni	nf	C^2S	Ei	Ef	C^2S*(Ef-Ei)	Exi	Exf
(23 3.5)	(24 4.0)	(n 1 2 3)	0.5+	1.0+	1	1	0.9277	-37.079	-35.266	1.682	0.000	5.959
…..												
(23 3.5)	(24 4.0)	(n 1 2 3)	0.5+	1.0+	1	10	0.0001	-37.079	-17.220	0.002	0.000	24.005
					sum		0.9391			-5.344		# holes **2.347**

(Ai Tzi)	(Af Tzf)	(type n,l,2j)	Ji	Jf	ni	nf	C^2S	Ei	Ef	C^2S*(Ef-Ei)	Exi	Exf
(23 3.5)	(24 4.0)	(n 1 2 3)	0.5+	2.0+	1	1	0.9448	-37.079	-36.182	0.847	0.000	5.043
…..												
(23 3.5)	(24 4.0)	(n 1 2 3)	0.5+	2.0+	1	10	0.0001	-37.079	-23.506	0.001	0.000	17.719
					sum		0.9671			-4.372		# holes **2.417**

(Ai Tzi)	(Af Tzf)	(type n,l,2j)	Ji	Jf	ni	nf	C^2S	Ei	Ef	C^2S*(Ef-Ei)	Exi	Exf
(23 3.5)	(24 4.0)	(n 1 2 5)	0.5+	2.0+	1	1	0.0106	-37.079	-36.182	0.010	0.000	5.043
….												
(23 3.5)	(24 4.0)	(n 1 2 5)	0.5+	2.0+	1	10	0.0006	-37.079	-23.506	0.008	0.000	17.719
					sum		0.0476			-4.102		# holes **0.119**

(Ai Tzi)	(Af Tzf)	(type n,l,2j)	Ji	Jf	ni	nf	C^2S	Ei	Ef	C^2S*(Ef-Ei)	Exi	Exf
(23 3.5)	(24 4.0)	(n 1 2 5)	0.5+	3.0+	1	1	0.0057	-37.079	-33.166	0.022	0.000	8.059
…….												
(23 3.5)	(24 4.0)	(n 1 2 5)	0.5+	3.0+	1	10	0.0000	-37.079	-19.366	0.000	0.000	21.859
					sum		0.0206			-3.937		# holes 0.0721

total sum 3.8467

We have the sums of the spectroscopic factors in each orbital… must multiply this by $(2J_f+1)/(2J_i+1)$ to find out num of holes (Ch 40 Brown notes eq. 40.12)

Compare with o_23b.occ (starting nucleus)

					Protons			Neutrons		
N	NJ	Ex	2J	P	0d3	0d5	1s1	0d3	0d5	1s1
1	1	0.000	1	1	0.00	0.00	0.00	0.17	5.81	1.02
2	1	2.593	5	1	0.00	0.00	0.00	0.16	4.89	1.95
3	1	4.001	3	1	0.00	0.00	0.00	1.10	5.63	0.27
4	2	6.943	5	1	0.00	0.00	0.00	1.09	4.76	1.14
5	2	7.034	3	1	0.00	0.00	0.00	1.16	4.80	1.04

So we have 0.19 holes in this $d_{5/2}$

The allowed in $d_{5/2}$ is:
0.5+ 2.0+ and 0.5+ 3.0+
So we add the two sum Numbers from before…
0.119 + 0.0721 = 0.1911

This works!

Similarily, adding the two values from the spec. factor page– we get 0.929+0.051 for the $1s_{1/2}$ and get 0.98 holes, which is what we would expect since the occ file has an occupancy of 1.02

9.

Calculate the ^{23}O $5/2^+$ to ^{22}O 0^+ spectroscopic factor. Explain why it is so small.

23Ofivb.lsf

! model space = sd

! interaction = usdb

We see how small the sum is of the spectroscopic factor… This indeed makes sense. We are going from a $(0d5/2+)^5(1s1/2)^2$ to a $(0d5/2)^6(1s1/2)^0$ g.s…. Meaning that we would lose one d5/2 and de-promote the two 1s1/2 neutrons to fill the 0d5/2 state. So neutron would have to have a high L.

(Ai Tzi)	(Af Tzf)	(type n,l,2j)	Ji	Jf	ni	nf	C^2S	Ei	Ef	C^2S*(Ef-Ei)	Exi	Exf
(22 3.0)	(23 3.5)	(n 1 2 5)	0.0+	2.5+	1	1	0.0590	-34.498	-34.486	0.001	0.000	0.000
(22 3.0)	(23 3.5)	(n 1 2 5)	0.0+	2.5+	2	1	0.2708	-29.736	-34.486	-1.286	4.762	0.000
(22 3.0)	(23 3.5)	(n 1 2 5)	0.0+	2.5+	3	1	0.0024	-24.849	-34.486	-0.023	9.649	0.000
(22 3.0)	(23 3.5)	(n 1 2 5)	0.0+	2.5+	4	1	0.0002	-22.361	-34.486	-0.002	12.137	0.000
(22 3.0)	(23 3.5)	(n 1 2 5)	0.0+	2.5+	5	1	0.0014	-19.986	-34.486	-0.020	14.512	0.000
(22 3.0)	(23 3.5)	(n 1 2 5)	0.0+	2.5+	6	1	0.0000	-16.492	-34.486	-0.000	18.006	0.000
(22 3.0)	(23 3.5)	(n 1 2 5)	0.0+	2.5+	7	1	0.0002	-16.341	-34.486	-0.004	18.157	0.000
(22 3.0)	(23 3.5)	(n 1 2 5)	0.0+	2.5+	8	1	0.0000	-14.791	-34.486	-0.000	19.707	0.000
(22 3.0)	(23 3.5)	(n 1 2 5)	0.0+	2.5+	9	1	0.0000	-13.558	-34.486	-0.000	20.940	0.000
(22 3.0)	(23 3.5)	(n 1 2 5)	0.0+	2.5+	10	1	0.0000	-11.207	-34.486	-0.000	23.291	0.000
							sum 0.3340			-1.335		

total sum 0.0000

10.

Use the interaction wspot to obtain the single-particle decay width for the ^{23}O $5/2_1^+$ state using the experimental neutron separation energy as a constraint. Combine this with the result of the last problem to obtain its neutron decay width. Compare to experiment.

Neutron separation energy is 2.733 for GROUND STATE

For the $5/2_1^+$ it is 40 keV

Wspot (brown Ch 23)

- Obtain single-particle energies and single-particle radial wavefunctions for bound states of Woods-Saxon potential
- Used to calculate neutron scattering cross section for given *l* and *j*
- Input file is *.dai (you make on your own)

22 8 1 0: A, Z, neutron (1 0) proton (1 1)

0 0 1: nr, l, 2j

…

0 2 3

Output: nr, l, 2j, spe,

-ke (<T> expectation value of kinetic energy),

-ket ($\Sigma_i(2j_i+1)\langle T\rangle_i$), rms, (sqrt($\langle r^2\rangle$)), rmst [sqrt(($\Sigma_i(2j_i+1)\langle r^2\rangle_i$ /Sum over I $(2j_i+1)$)]– total rms radius for all orbits up to current

Wspot for UNBOUND states

- L, j given, we can calc the phase shift δ(E) and scattering cross section σ(E)

22 8 1 1: A Z proton (neutron would be 1 0)
0.1 10: shows the E_{min} and E_{max} range to look for resonance
0 2 5: n_r, l, 2j

This is in 23O.dai
22 8 1 0
0.04 0.04 .1 4. Here we have input the neutron sep energy.. 40 keV…
0 2 5

Type in wspot 23O

G=Γ= fwhm width at resonance energy.

The output is found in 23o.dao

input: iat,izt,iap,izp = 22 8 1 0

input: emin,emax,vnmin,vnmax = 0.040 0.040 0.100 4.000

defaults: vn,adif,rr0,vnls = 1.0000 0.6500 1.2500 1.0000

input: vn,adif,rr0,vnls = 0.0000 0.0000 0.0000 0.0000

resonance at vn = 1.953

resonance at vn = 1.953

resonance at vn = 1.953

resonance at vn = 1.953

resonance at vn = 1.953

resonance at ei = 0.040 with G = 0.00150 MeV

resonance at ei = 0.040 with G = 0.18000 keV

resonance at ei = 0.040 with G = 0.12960 keV

resonance at ei = 0.040 with G = 0.12960 keV

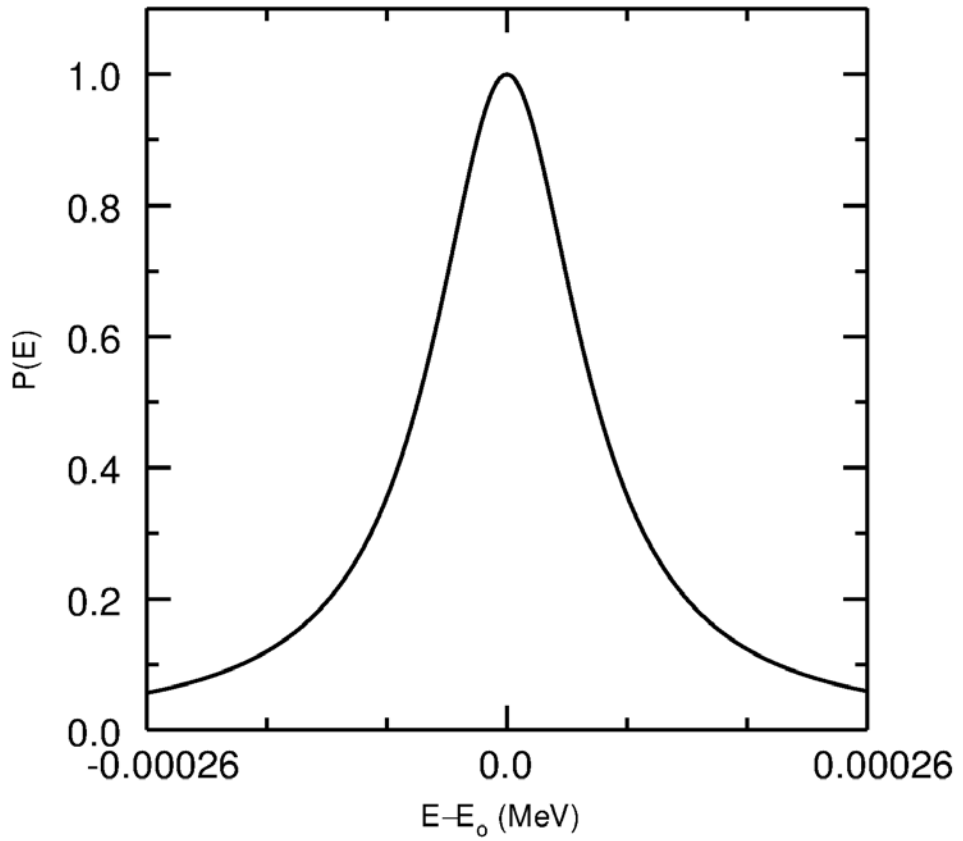
This is the important one… the other ones are just converging here.

n, e, phi, sig=sin(phi)**2/k, vnorm

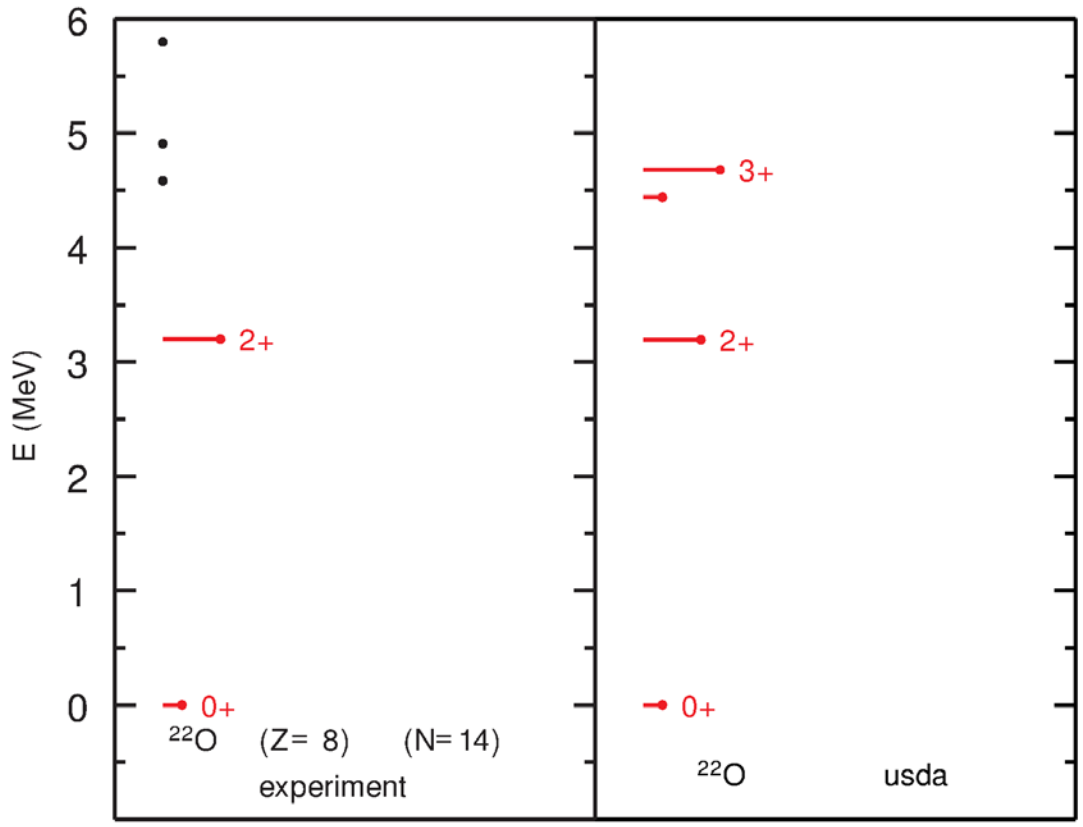
1 0.03974 0.239 0.1839E+04 1.95307

0.1296 * 0.059 (our Spectroscopic Factor)= 0.0073 keV= 7.3 eV Versus 10 eV experimental value

- The output for the cross section vs E is given in the output le 23O.dao. Also a 23O.top file is made. Typing cps 23O will produce an 23O.eps file that shows a picture of the resonance.



O_22a.eps



Calculate the gamma decay of ^{22}O for levels up to 6 MeV and compare to experiment. Calculate the B(E2) for Coulex to the 2_1^+ state in ^{22}O and compare with experiment.

NNDC has the B(E2) values tabulated in the ENSDF file– notice units are Weiskopf units

$\gamma(^{22}O)$

E_i(level)	J_i^π	E_γ †	I_γ †	E_f	J_f^π	Mult.	Comments
3199	2^+	3199 *8*	100	0.0	0^+	E2	B(E2)(W.u.)=1.2 *5* Mult.: Assigned by evaluator based on B(E2)↑ in $^{197}Au(^{22}O,^{22}O')$ (2000Th11).
4584	(3^+)	1385 *3*	100	3199	2^+		E_γ: Weighted average of data from $(^{36}S,X)$,$(^{23}O,xn\gamma)$ and ^{22}N β^- decay.

Continued on next page (footnotes at end of table)

O_220b.deo

gamma decay for o_220b.deo BR greater than 0.688 4.05 ---------- 0.000

! model space = sd

! interaction = usdb

! e_p = 1.360 e_n = 0.450 E2

! g_sp = 5.000 g_sn = -3.440 M1 spin

! g_lp = 1.174 g_ln = -0.110 M1 orbital

! g_pp = 0.240 g_pn = -0.160 M1 tensor

Ei (MeV)	Ji	ni	T_(1/2) (psec)	width (eV)	M1 moment (u_N)	Q moment (e^2 fm^2)
3.158	2+	1	0.453864	0.1005E-02	-	

Ef	Jf	nf	BR	Eg	del	B(1)	B(2)	A_p	A_n
0.000	0+	1	100.0000	3.158	999.00	0.0000E+00	0.3968E+01	0.000	-9.898
4.762	0+	2	16.153395	0.2824E-04		0.000	0.00	----------	

Ef	Jf	nf	BR	Eg	del	B(1)	B(2)	A_p	A_n
3.158	2+	1	100.0000	1.604	999.00	0.0000E+00	0.3298E+01	0.000	-4.036
4.795	3+	1	0.037344	0.1221E-01	-	2.449	3.74	----------	

- Use the monopole interactions to calculate the energies for the ground states of the four nuclei 22−25O assuming a single Slater determinant for each. The USDB two-body matrix elements are assumed to scale like $(18/A)^{0.3}$.

- Go to usdb.int in folder (Hamiltonian of usdb)
- Find Tz=1 for neutrons (6th column)
- Chapter 35 in notes
- We need identical matrix elements <kakb|== |kakb (so take out all the other stuff

The average (monopole) interaction energy between two k orbits is defined as:

$$\bar{V}_{k_a k_b} = \frac{\sum_J (2J+1) < k_a k_b J \mid V \mid k_a k_b J >}{\sum_J (2J+1)}. \qquad (35.10)$$

Table 35.1: Values of the some V_{lowk} and Coulomb two-body matrix elements used in this section. The orbits are labeled by $k = 1$ for $0s_{1/2}$ $k = 2$ for $0p_{3/2}$, $k = 3$ for $0p_{1/2}$, and $k = 4$ for $0d_{5/2}$. The average values is the $(2J+1)(2T+1)$ monopole weighted value.

k_1	k_2	k_3	k_4	J T	V_{lowk}	V_{coul}
1	1	1	1	1 0	-7.86	
1	1	1	1	0 1	-6.72	0.67

$$E_K(C) = \sum_{k_a,m_a} < k_a m_a \mid T \mid k_a m_a >= \sum_{k_a} N'_a < k_a \mid T \mid k_a >, \tag{35.16}$$

the closed-shell interaction energy is:

$$E_I(C) = \sum_{k_a \leq k_b} \sum_{J,T} (2T+1)(2J+1) < k_a k_b JT \mid V \mid k_a k_b JT >, \tag{35.17}$$

$$E = E_I + E_K$$

Label.dat

- Shows model-space
- Sd.sp –single particle state file
- Later we see a sdpn.sp--- which is just the pn file--- our Hamiltonian has 4 labels in it, so sdpn has 1,3 are protons and 2,4 are neutrons (can also be seen in usdbpn.int)