AST 383 Nucleosynthesis: Assignment 5

Attempt 2 of the 4 questions
Due Thursday, March 24

1. A fundamental requirement of the cold CNO- cycles is that the unstable nuclides such as ^{13}N beta –decay rather than experience proton capture.

   For the intermediate nuclide ^{13}N in the CN01 cycle show that beta-decay is much more likely than proton capture in the core of the attached model 10 solar mass star.

   Beta-decay half-lives are given by Iliadis on page 370. For ^{13}N the half-life is 9.97 minutes.

   Take the reaction rate for ^{13}N(p, γ) ^{14}0 from the NACRE II compilation ----- http://www.astro.ulb.ac.be/nacreii/index.html?individualreaction.html

2. Again with reaction rates from NACRE II calculate the equilibrium abundance ratios ^{12}C/^{13}C, ^{12}C/^{14}N and ^{14}N/^{15}N for these participants in the CN01 cycles for temperatures T6= 10(10)50 K. Also estimate approximate uncertainties for each of the three ratios.

3. The figure below from Dearborn, Eggleton and Schramm (1976, ApJ, 203, 455) shows the interior composition of a 1 solar mass star near the end of its main- sequence evolution.

   Explain qualitatively in terms of operation of the pp---chains and the CN0 cycles the changes in composition from surface (M(R)=1) to the core (M(R)=0).

   Discuss why the enrichment of ^{3}He is relevant t the interpretation of measurements of ^{3}He^{+}/H from galactic H II regions as an indicator of ^{3}He synthesis by the Big Bang.

4. Describe the principal factors controlling the subsurface increase in the ^{3}He mass fraction in the Dearborn et al. figure, the origin of the broad peak and the sharp fall into the core. Using the attached model of a solar mass star and NACRE II rates estimate the ^{3}He mass fraction between M(R) = 0.25 and 0.75 and compare your results with the profile in the figure.

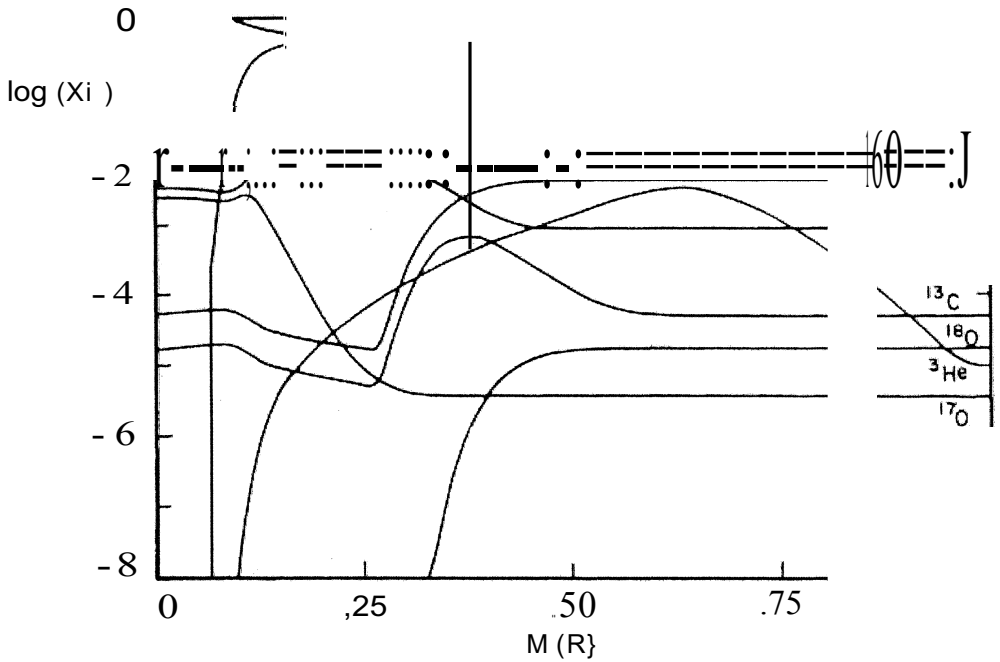

FIG. 1.—Composition of a 1 $M_\odot$ star near the end of its main-sequence evolution

Table 9.3(*c*) (*continued*).

r/R^a	M_r/M^b	L_r/L^c	$\log(\rho)$	$\log(P)$	$\log[T(\mathrm{K})]$	κ^d
0.92	0.999	1.000	−1.463	12.392	5.733	241.88*
0.95	1.000	1.000	−1.820	11.785	5.488	965.14*
0.97	1.000	1.000	−2.123	11.285	5.297	
0.98	1.000	1.000	−2.753	10.285	4.947	
1.00	1.000	1.000	−6.273	5.285	3.754	0.33

Notes:
[a] $R = 6.07 \cdot 10^{10}$ cm
[b] $M = 1.0 \cdot 1.99 \cdot 10^{33}$ gm
[c] $L = 2.72 \cdot 10^{33}$ ergs/sec
P and ρ in cgs units.
[d] Opacity in $\mathrm{cm}^2/\mathrm{gm}$. The asterisk means the stellar temperature gradient is adiabatic.
Age = 0.042 Gyr, $X = 0.702, Z = 0.019$.

Table 9.3(*c*). *Model of a 1 Solar Mass Main-Sequence Star*

r/R^a	M_r/M^b	L_r/L^c	$\log(\rho)$	$\log(P)$	$\log[T(\mathrm{K})]$	κ^d
0.03	0.001	0.021	1.891	17.158	7.133	1.46*
0.04	0.002	0.046	1.888	17.151	7.131	1.47*
0.06	0.008	0.135	1.876	17.132	7.123	1.51*
0.08	0.018	0.257	1.860	17.106	7.113	1.55*
0.10	0.035	0.390	1.839	17.071	7.099	1.61*
0.12	0.058	0.510	1.814	17.029	7.082	1.69*
0.14	0.088	0.642	1.783	16.978	7.062	1.79
0.16	0.126	0.769	1.746	16.919	7.041	1.90
0.18	0.170	0.868	1.702	16.853	7.018	2.03
0.20	0.219	0.931	1.653	16.780	6.993	2.17
0.22	0.272	0.967	1.597	16.698	6.968	2.33
0.24	0.327	0.987	1.536	16.612	6.943	2.50
0.26	0.385	0.999	1.468	16.518	6.918	2.68
0.28	0.442	1.005	1.395	16.419	6.892	2.88
0.30	0.496	1.008	1.319	16.317	6.868	3.10
0.32	0.550	1.008	1.234	16.207	6.842	3.33
0.34	0.596	1.008	1.155	16.104	6.819	3.57
0.36	0.646	1.007	1.059	15.981	6.793	3.86
0.38	0.684	1.006	0.976	15.877	6.771	4.14
0.40	0.725	1.004	0.878	15.753	6.746	4.53
0.42	0.759	1.003	0.784	15.637	6.724	4.93
0.44	0.785	1.002	0.703	15.536	6.704	5.31
0.46	0.813	1.001	0.608	15.418	6.682	5.80
0.48	0.832	1.001	0.536	15.329	6.665	6.20
0.51	0.860	1.000	0.415	15.180	6.637	7.04
0.53	0.876	1.000	0.335	15.081	6.618	7.65
0.54	0.891	1.000	0.254	14.981	6.599	8.30
0.56	0.904	0.999	0.174	14.881	6.579	9.00
0.58	0.916	0.999	0.094	14.781	6.559	9.75
0.60	0.927	0.999	0.014	14.681	6.539	10.56
0.63	0.940	0.999	−0.104	14.531	6.508	11.72
0.65	0.948	0.999	−0.182	14.432	6.486	12.58
0.67	0.955	0.999	−0.259	14.332	6.464	13.58
0.69	0.962	0.999	−0.336	14.232	6.440	14.81
0.71	0.967	0.999	−0.409	14.133	6.415	16.44
0.72	0.972	0.999	−0.479	14.033	6.385	18.85
0.74	0.976	0.999	−0.539	13.939	6.351	22.62*
0.77	0.981	1.000	−0.629	13.790	6.291	31.05*
0.78	0.984	1.000	−0.688	13.690	6.251	37.75*
0.80	0.988	1.000	−0.778	13.540	6.191	47.30*
0.83	0.991	1.000	−0.868	13.390	6.132	58.07*
0.84	0.993	1.000	−0.958	13.241	6.072	70.94*
0.86	0.995	1.000	−1.048	13.091	6.012	85.54*
0.88	0.997	1.000	−1.168	12.891	5.932	110.36*
0.90	0.998	1.000	−1.316	12.641	5.832	158.13*

able *9.3(a). Model of a 10 Solar M ass M ain-Sequencer§tar*

R⁰	*Mr / M b*	*Lr / V*	log(p)	log(P)	log[T(K)]	*Kd*
03	0.001	0.029	0.949	16.598	7.495	0.37*
04	0.002	0.062	0.945	16.592	7.493	0.37*
06	0.008	0.183	0.934	16.574	7.486	0.37*
08	0.018	0.356	0.919	16.550	7.478	0.37*
10	0.034	0.545	0.899	16.518	7.467	0.38*
12	0.057	0.709	0.875	16.480	7.453	0.38*
14	0.087	0.832	0.846	16.434	7.437	0.38*
16	0.124	0.909	0.813	16.381	7.419	0.39*
18	0.168	0.950	0.776	16.322	7.398	0.40*
20	0.219	0.970	0.734	16.254	7.373	0.41*
22	0.275	0.977	0.687	16.178	7.346	0.41*
24	0.335	0.982	0.635	16.095	7.316	0.42
26	0.398	0.997	0.577	16.004	7.285	0.44
28	0.462	1.000	0.511	15.904	7.252	0.44
30	0.525	1.000	0.439	15.798	7.218	0.45
32	0.582	1.000	0.365	15.691	7.187	0.45
34	0.638	1.000	0.281	15.574	7.153	0.45
36	0.691	1.000	0.188	15.447	7.119	0.45
38	0.741	1.000	0.086	15.311	7.085	0.46
40	0.785	1.000	–0.022	15.169	7.052	0.47
43	0.822	1.000	–0.131	15.028	7.019	0.49
44	0.851	1.000	–0.231	14.899	6.990	0.52
47	0.879	1.000	–0.347	14.750	6.956	0.56
48	0.895	1.000	–0.424	14.650	6.933	0.58
50	0.915	1.000	–0.541	14.500	6.899	0.62
52	0.932	1.000	–0.657	14.350	6.865	0.65
54	0.946	1.000	–0.772	14.200	6.830	0.68
56	0.957	1.000	–0.888	14.050	6.795	0.71
58	0.966	1.000	–1.003	13.900	6.761	0.73
60	0.973	1.000	–1.119	13.750	6.726	0.75
62	0.979	1.000	–1.236	13.600	6.692	0.76
64	0.984	1.000	–1.353	13.450	6.659	0.78
66	0.988	1.000	–1.510	13.250	6.615	0.84
68	0.991	1.000	–1.627	13.100	6.581	0.89
71	0.994	1.000	–1.782	12.900	6.536	0.94
72	0.995	LOOO	–1.898	12.750	6.501	0.98
74	0.997	1.000	–2.053	12.550	6.455	1.02
76	0.998	1.000	–2.206	12.350	6.407	1.07
78	0.998	1.000	–2.357	12.150	6.359	1.11
81	0.999	1.000	–2.558	11.884	6.293	1.14
82	0.999	1.000	–2.708	11.684	6.242	1.15
84	1.000	1.000	–2.933	11.384	6.168	1.12
86	1.000	1.000	-3.162	11.084	6.096	1.10
89	1.000	1.000	–3.473	10.684	6.005	1.15
90	1.000	1.000	-3.785	10.284	5.915	1.27