Explosive yields of massive stars from $Z = 0$ to $Z = Z_\odot$

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ABSTRACT

We present a new and homogeneous set of explosive yields for masses 13, 15, 20, 25, 30 and 35 $M_\odot$ and metallicities $Z = 0, 10^{-6}, 10^{-4}, 10^{-3}, 6 \cdot 10^{-3}, 2 \cdot 10^{-2}$. A wide network extending up to Mo has been used in all the computation. We show that at low metallicities ($Z \leq 10^{-4}$) the final yields do not depend significantly on the initial chemical composition of the models so that a scaled solar distribution may be safely assumed at all metallicities. Moreover, no elements above Zn are produced by any mass in the grid up to a metallicity $\sim 10^{-3}$. These yields are available for any choice of the mass cut upon request.

Subject headings: nuclear reactions, nucleosynthesis, abundances – stars: evolution – stars: supernovae

1. Introduction

A proper understanding of the chemical evolution of our galaxy and of the universe in general requires a good knowledge of the chemical composition of the matter ejected by stars of different masses and initial composition. Massive stars certainly play a pivotal role in the chemical enrichment of the interstellar medium because they are very probably responsible for the production of at least most of the intermediate mass elements (O through Ca). In spite of their central role in the general comprehension of the chemical evolution of the

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matter, only one extended set of models has been published so far: the one computed and
discussed by Woosley & Weaver (1995), hereinafter WW95, and Timmes, Woosley & Weaver
(1995), hereinafter TWW95. Their yields are based on presupernova models computed by
assuming, among the others, no mass loss, no rotation, a moderate amount of overshooting
and semiconvection, a value of the $^{12}$C($\alpha, \gamma$)$^{16}$O calibrated on preexplosive yields and a
network extending up to Ge. The explosions were computed in spherical symmetry and
the yields eventually obtained by imposing the ejecta to have a specific final kinetic energy
(their cases A, B and C). The initial chemical composition of the models at intermediate
metallicities was obtained by means of a galactic chemical evolution model (described by
TWW95).

Unfortunately, the present simulations of both the presupernova evolution and the ex-
losion are still far from being robustly established. Qualitatively (and partly quantitatively)
we know how and where the various nuclei are synthesized (see, e.g., WW95, Arnett 1996,
Thielemann, Nomoto & Hashimoto 1996, Limongi, Straniero & Chieffi 2000), but still large
uncertainties connected to both the hydrostatic evolution and the explosion of massive stars
prevent a rigorous computation of the yields. Such uncertainties are mainly related to the
efficiency of the convection (see, e.g., Chiosi & Maeder 1986, Woosley & Weaver 1988, Bazan
& Arnett 1994), the determination of the cross section of a few nuclear processes (first of
all the $^{12}$C($\alpha, \gamma$)$^{16}$O - see, e.g., Weaver & Woosley 1993 and Imbriani et al. 2001), the time
delay between the collapse of the core and the rejuvenation of the shock wave and the precise
location of the mass cut (which is the mass coordinate that separates the part of the star that
collapses in the remnant from the one that is ejected outward), even in spherical symmetry.
To further complicate the situation, also rotation, mass loss, magnetic field and asymmetric
explosions may also produce large variations in the final yields (see, e.g., Heger, Langer &
Woosley 2000 and Maeda & Nomoto 2003).

Some years ago we started a long term project devoted to the study of the evolution
of massive stars and their associated explosive yields (Chieffi, Limongi & Straniero 1998,
Limongi, Straniero & Chieffi 2000, Limongi & Chieffi 2002, Chieffi & Limongi 2002a, Limongi
& Chieffi 2003 - LC03). Since the beginning we made a strong effort to avoid the use of the
various kinds of statistical equilibrium usually adopted to determine the chemical evolution
of the matter at temperatures larger than, roughly, 3 billions degrees. Moreover we made
an effort to fully couple the integration of the physical equations to the ones describing
the evolution of the nuclear species in order to increase the numerical accuracy. Over the
years we increased progressively the nuclear network that now extends up to Molybdenum.
However, similarly to WW95, also our models are still computed by neglecting both mass
loss and rotation. In our latest paper (LC03) of the series we presented our most updated
version of the hydrostatic code (FRANEC) together to our new hydrodynamic code needed
to follow the propagation of the blast wave. We also showed that the yields produced by a given stellar mass depend mainly on the location of the mass cut rather than from the explosion energy. This means that, as a first approximation, the yields corresponding to the ejection of different amounts of $^{56}\text{Ni}$ may be obtained by assuming an explosion strong enough to eject the full mantle and imposing by hand the mass cut at the desired $^{56}\text{Ni}$ abundance. Such a finding means that one can easily explore different choices for the mass cut without the necessity of recomputing many times the explosion of the models.

By making use of the latest versions of the two codes (hydrostatic and hydrodynamic) described in LC03, here we present a wide database of yields. In particular, we present the explosive yields produced by a grid of six masses ($13, 15, 20, 25, 30$ and $35\,\text{M}_{\odot}$) and six metallicities ($Z = 0, 10^{-6}, 10^{-4}, 10^{-3}, 6 \cdot 10^{-3}, 2 \cdot 10^{-2}$).

The paper is organized as follows. The evolutionary code and the input physics adopted to compute the grid are briefly summarized in section 2. Section 3 is devoted to the discussion of the initial chemical composition used to compute the models in the intermediate metallicity range between the primordial and the solar one. A final discussion and conclusions follow.

2. The hydrostatic and the hydrodynamic codes

The presupernova evolutions have been computed by means of the latest version of the FRANEC code which has been described in LC03 (and references therein). Let us just recall here that the nuclear network extends up to Molybdenum and includes 40 isotopes (from neutrons to $^{30}\text{Si}$) in hydrogen burning, 149 isotopes (from neutrons to $^{98}\text{Mo}$) in helium burning and 267 isotopes (from neutrons to $^{98}\text{Mo}$) in all the more advanced burning phases. In total 282 isotopes (see Table 1 in LC03) and about 3000 reaction rates were explicitly included in the various nuclear burning stages. The nuclear network is fully coupled to the equations describing the physical structure of the star so that both the physical and chemical evolution due to the nuclear reactions are solved simultaneously. No nuclear statistical equilibrium (NSE) approximation has been adopted at high temperatures.

The explosive nucleosynthesis associated to the explosion of each massive star model is computed with the same procedure described in LC03. The propagation of the shock front through the mantle of the star is followed by solving the hydrodynamical equations in spherical symmetry and in lagrangean form, following the prescription of Richtmeyer & Morton (1967) and Mezzacappa & Bruenn (1993). The chemical evolution of the matter is computed by coupling the same nuclear network adopted in the hydrostatic calculations (Table 1 of LC03) to the hydrodynamical equations. The explosion is started by imparting
an initial velocity $v_0$ to a mass coordinate of $\sim 1 \text{ M}_\odot$ of the presupernova model, i.e. well inside the iron core, and by imposing the inner edge of the exploding mantle to move on a ballistic trajectory under the gravitational field of the compact remnant. $v_0$ is properly tuned in order to eject all the mass above the Fe core. By taking advantage of the fact that the final yields mainly depend on the mass cut location (see LC03), yields corresponding to different amounts of $^{56}\text{Ni}$ ejected are then easily obtained by fixing the mass cut by hand a posteriori.

3. The initial composition of the stellar models

We computed the presupernova evolution of the six massive star models, for various metallicities ranging from zero to solar. The zero metallicity models were computed by assuming an initial primordial composition ($Z=0, Y=0.23$), while the solar metallicity ones were computed starting with a scaled solar heavy elements distribution, as derived from Anders & Grevesse (1989), and an initial helium mass fraction $Y=0.285$. The initial chemical composition adopted between these two extreme metallicities requires some comments. In general, the initial composition of a star of a given metallicity is the result of the enrichment of the interstellar medium provided by the previous stellar generations; hence, its determination would involve a Galactic chemical evolution (GCE) model and therefore it would depend on the IMF, SFR, Infall, Chemical Yields, etc. Such autoconsistent procedure has been adopted by WW95 and TWW95 to determine the initial chemical composition of the models of intermediate metallicities ($0 < Z < Z_\odot$). Unfortunately models computed in this way are obviously strictly linked to the GCE model they belong to and should not be used in any other GCE simulation. Hence, the computation of the stellar models, and their associated explosive yields, should be redone for any GCE simulation, and such a procedure would obviously require an enormous amount of computer time. It is therefore crucial to understand if it is possible (or not) to compute a grid of explosive yields of general purpose and, obviously, which is the initial chemical composition that should be used: in the following we will address such a problem.

In order to study how (and if) the specific abundances of the various nuclei affect the final yields we performed two test evolutions of a 25 M$_\odot$ model having an initial global metallicity $Z = 10^{-4}$. We chose this metallicity because the largest deviations from a scaled solar distribution occur at low metallicities. In the first test we started from a scaled solar distribution and set to zero the abundances of all the nuclei but $^{12}\text{C}$, $^{14}\text{N}$, $^{16}\text{O}$ and $^{56}\text{Fe}$. The upper panel in Figure 1 shows the logarithmic ratio between the yields obtained in the test case and the standard ones (i.e. those obtained with a scaled solar composition). It is quite
evident that the two sets are in very good agreement. Co is the only element that shows a difference by a factor of 2. This test clearly demonstrates that the initial abundances of the elements initially set to zero do not influence significantly the final explosive yields. Hence, for sake of simplicity, we can adopt a scaled solar distribution for all of them.

The next step is to understand how (and if) the initial abundances of the CNO nuclei affect the final yields. Hence, we performed a second test in which, starting from a scaled solar distribution, we imposed a [O/Fe] equal to 0.4 dex and a global metallicity \( Z = 10^{-4} \). Obviously this test automatically includes also a possible variation of the initial abundances of C and/or N because the initial relative abundances among the CNO nuclei are promptly brought to their equilibrium values as soon as the star settles on the Main Sequence. This test is particularly interesting also because the global abundance of CNO controls the size of the H convective core and it is the starting point of the important chain \( ^{14}\text{N}(\alpha, \gamma)^{18}\text{F}(\beta^+)^{20}\text{O}(\alpha, \gamma)^{22}\text{Ne}(\alpha, \text{n})^{25}\text{Mg} \) that is a very important neutrons source. The lower panel in Figure 1 shows the logarithmic ratio between the yields obtained in the test and in the standard cases: once again the two sets of yields are in good agreement (within a factor of 2) even if a few elements show now some differences (largely confined, however, within a factor of 4): these elements are N, F, K, Sc, Cu and Zn. N is a typical product of the H burning and its final yield directly depends on the initial CNO abundance. Hence, it is quite obvious that a scaled solar distribution can not provide the same yield provided by an initial CNO enhanced composition. However, since probably massive stars are not the main contributors to the N production in the Galaxy, the adoption of an initial scaled solar abundance for N does not constitute a too serious problem. F is probably mostly produced by the neutrino induced reactions during the explosion (WW95). Since these processes are not presently included in our models, our current yield for F is not much reliable anyway. Also the differences obtained for K, Sc, Cu and Zn should not be considered as a big problem because, in any case, their production totally relies on the location of the mass cut (the mass location that divides the part of the star that eventually collapses in the remnant from the one that it is expelled outward) that is still a very uncertain theoretical prediction. Hence, waiting for yields based on more reliable explosive models, we conclude that at present the adoption of an initial scaled solar distribution of all the elements relative to Fe is a reasonable compromise between generality and accuracy. Therefore, we will assume in the following a scaled solar distribution (Anders & Grevesse 1989) for all the metallicities higher than zero.

The weak dependence of the elemental yields on the initial chemical composition obtained above is not surprising because the most abundant isotope of each even element is of primary origin (explosive and/or hydrostatic) while the odd elements are always produced by a combination of a primary and a secondary component; as the metallicity lowers, the secondary component drops to zero but the primary one remains obviously active. It goes
without saying, at this point, that such findings also justify (a posteriori) the use of the WW95 yields in GCE simulations other than the one (TWW95) they come from.

The grid of initial metallicities we eventually chose is: \((Z, Y) = (0, 0.23), (10^{-6}, 0.23), (10^{-4}, 0.23), (10^{-3}, 0.23), (6 \cdot 10^{-3}, 0.26)\) and \((2 \cdot 10^{-2}, 0.285)\), where \(Z\) stands for the global metallicity and \(Y\) for the initial \(^4\)He mass fraction.

4. Discussion and Conclusions

The final explosive isotopic yields in solar masses of all the computed models are reported in Table 1, available only in electronic format, once all the unstable isotopes have decayed into their stable isobars. The yields of selected radioactive isotopes at \(10^7\) s after the explosion are collected in the same table. For obvious reasons we could not present different sets of yields for different choices of the mass cut; hence we chose to present just one case, i.e. the one in which all masses eject \(0.1\) M\(_\odot\) of \(^{56}\)Ni. Any other choice is promptly available upon request.

The full set of elemental production factors (PFs) is shown in Figure 2. Each panel refers to a specific metallicity and each symbol refers to a given mass (see Figure caption). Let us remind that, in our case, the PF of any given isotope/element is defined as the ratio of each isotope's/element's mass fraction in the total ejecta divided by its corresponding initial mass fraction, i.e., \(PF = \frac{X_{\text{ejected}}}{X_{\text{ini}}}\). Note that this definition is different from the one usually adopted by WW95, where \(PF = \frac{X_{\text{ejected}}}{X_\odot}\).

Some basic properties of the present yields may be seen by looking at Figure 2. First of all the PFs of all the elements from C to Zn significantly decrease as the metallicity increases, almost independently on the initial mass - the only exceptions being N and F. The reason for this is that, regardless of the mass of the star, the yields of the elements do not vary by more than an order of magnitude within the entire range of metallicities (see Table 1), while the \(X_{\text{ini}}\) obviously scale directly with the initial global metallicity and hence they vary by several order of magnitudes. Such a strong dependence of the PFs on the metallicity simply means that the larger the metallicity, the more difficult is the further chemical enrichment.

A second feature is the well known odd-even effect, i.e. that the difference between the PFs of the odd (Na to Sc) and the even nuclei (Ne-Ca) decreases as the metallicity increases: at the solar metallicity most of the elements show a roughly scaled solar distribution (see LC03 for a more detailed discussion of this topic). It is worth noting that, with the \(^{12}\)C(\(\alpha, \gamma\))\(^{16}\)O rate adopted in the present calculations, Ne, Mg, Si, S, Ar and Ca preserve a scaled solar distribution at all the metallicities (see Imbriani et al. 2001 for a more
comprehensive discussion of this topic).

A last feature worth mentioning here is that below $Z = 10^{-3}$ there is a cutoff in the PFs at the level of Zn, i.e., no elements heavier than Zn are produced. On the contrary, above $Z = 10^{-3}$ such a cutoff progressively reduces so that a consistent production of elements beyond Zn is obtained. Elements above Sr are not produced in a significant amount even at solar metallicity. This means that the observed abundances of elements above Zn in very metal poor stars must be attribute to stars (or, in general, to processes) outside the range presently analyzed.

Since the only other paper presenting a full set of yields is the WW95 one, we show in Figure 3 the comparison between the WW95 and the present yields, for two masses and three metallicities. Only elements up to Ge are shown because the nuclear network adopted by WW95 does not extend above this element. For this comparison we chose, for each stellar model, the mass cut that provides the ejection of the same amount of $^{56}$Ni as in the corresponding WW95 model. Note that, since the grid of metallicities computed by WW95 does not coincide exactly with the ones presented here, the comparison shown in Figure 3 refers to models having a slightly different initial metallicity. We selected the 20 and the 25 M$_\odot$ because are the ones that dominate the yields of a stellar generation having a Salpeter like IMF (see, e.g., LC03). The lower right panel in Figure 3 shows that there is a very good agreement between ours and the WW95 yields for the 25 M$_\odot$ of solar metallicity. On the contrary, all other panels disclose significant (and not systematic!) differences between the two sets of yields. In particular there are a few things worth noting: a) both sets of models produce O and C in similar amounts (within a factor of two) while the N yields tend to be similar only for $Z \geq 10^{-3}$, b) the light elements Ne, Na and Mg tend to be significantly more produced in our models than in the WW95 ones while Al is produced in quite similar amounts, c) we tend to systematically underproduce the products of the explosive oxygen burning and incomplete Si burning, i.e. Si, S, Ar and Ca by roughly a factor of two with respect to WW95 (even if the relative scaling among these elements is remarkably similar), d) also the odd elements P, Cl and K, tend to be quite largely underproduced in our models with respect to WW95 and e) the Iron peak nuclei show a quite contradictory behavior because, while Ti is always in good agreement, Co and Ni are generally overproduced and Sc often underproduced relative to WW95.

A proper understanding of the sources of such differences, though of overwhelming interest, is extremely difficult because the chemical yields are, in general, the result of a complex interplay among the various hydrostatic evolutionary phases plus the subsequent passage of the shock wave (Chieffi, Limongi & Straniero 2000). For example, elements like N and Mg are not significantly affected by the passage of the shock wave and hence their
final differences will mainly reflect a different presupernova evolution (but note that, e.g., O, that it is also a product of the hydrostatic burnings, is produced in very similar amount). Other elements are produced, vice versa, only by the explosive burnings and therefore one could think that playing with the mass cut could significantly improve the comparison. This is not the case. First of all let us note that the mass cut must be located within the region undergoing complete explosive Si burning because appreciable amounts of Sc, Co and Ni must be ejected. Hence the abundances of the elements produced by the explosive oxygen burning and/or incomplete explosive Si burning (Si, S, Ar, K, Ca, V, Cr and Mn) would not be modified by a changing of the mass cut. But also the comparison of the elements mainly produced by the complete explosive Si burning would not be improved by a changing of the mass cut because a better fit to any of the elements like Sc, Ti, Co and Ni would worsen the fit to the others.

A deeper comparison between these two sets is virtually impossible because either the two sets of models have been computed by adopting different choices for both the treatment of the convective layers and the rate of the $^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$ nuclear process, and also because the models on which the WW95 yields are based have never been published. The only possible comparisons between our presupernova models and the ones that are at the base of the WW95 yields have been presented in Limongi, Straniero & Chieffi (2000) and hence we refer the reader to that paper for such a comparison.

The differences between the WW95 and our yields are large enough that they should produce visible differences in GCE simulations and hence we strongly suggest the use of both sets of yields in the GCE modeling so to understand how alternative sets of yields influence our current understanding of the chemical evolution of the universe.

In conclusion, we provide in this paper a brand new set of yields in a wide range in both mass and initial metallicity. All the yields are freely available to the community for any choice of the mass cut (upon request). We have shown for the first time that the initial chemical composition does not affect significantly the final yields up to at least a metallicity of the order of $Z = 10^{-4}$. We have also shown that a metallicity larger than $Z = 10^{-3}$ is necessary to begin to produce elements beyond Zn up the neutron magic number $N = 50$. The present yields are quite different from the WW95 ones and the observed differences cannot be simply explained in terms of one or few causes but are certainly due to the complex interplay among various aspects of both the hydrostatic evolution and the explosion itself that are very difficult to disentangle at the moment.

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Fig. 1.— *Upper panel*: Logarithmic ratio between the explosive yields produced by a 25 M$_\odot$ of global metallicity $Z = 10^{-4}$ in which the initial abundances of all the nuclei are set to zero with the exclusion of those of $^{12}$C, $^{14}$N, $^{16}$O and $^{56}$Fe and the ones produced by a standard 25 M$_\odot$ having an initial scaled solar metallicity $Z = 10^{-4}$. *Lower panel*: Logarithmic ratio between the explosive yields produced by a 25 M$_\odot$ of global metallicity $Z = 10^{-4}$ and [O/Fe]=0.4 and those produced by the standard reference model.
Fig. 2.— Production factors of all the elements from C to Mo. The symbols refer to the 6 masses: 13 M⊙ (black filled triangles), 15 M⊙ (red crosses), 20 M⊙ (blue filled squares), 25 M⊙ (green filled circles), 30 M⊙ (cyan open triangles), 35 M⊙ (magenta asterisks). Each panel refers to the metallicity reported in the upper right corner.
Fig. 3.— Comparison between the elemental yields provided by WW95 and the present ones for two masses, 20 and 25 M\(_\odot\), and for three selected metallicities, \(Z = 10^{-6}\) (upper panels), \(Z = 10^{-3}\) (middle panels) and \(Z = 2 \cdot 10^{-2}\) (lower panels).
Table 1. Explosive yields

| Mass | 13  | 15  | 20  | 25  | 30  | 35  |
|------|-----|-----|-----|-----|-----|-----|
| \(M_{\text{ejected}}\) | 11.79 | 13.53 | 18.33 | 23.40 | 27.93 | 32.97 |
| \(M_{\text{remnant}}\) | 1.21 | 1.47 | 1.67 | 1.60 | 2.07 | 2.03 |
| \(^{56}\text{Ni}\) | 0.0913 | 0.1000 | 0.1000 | 0.1000 | 0.1000 | 0.1000 |
| \(^{1}\text{H}\) | 6.86(+00) | 7.77(+00) | 9.74(+00) | 1.16(+01) | 1.32(+01) | 1.47(+01) |
| \(^{2}\text{H}\) | 6.55(-17) | 5.95(-17) | 6.34(-17) | 1.77(-16) | 9.76(-16) | 3.05(-16) |
| \(^{3}\text{He}\) | 3.07(-05) | 3.01(-05) | 2.90(-05) | 2.77(-05) | 2.72(-05) | 2.71(-05) |
| \(^{4}\text{He}\) | 4.05(+00) | 4.65(+00) | 6.26(+00) | 7.78(+00) | 9.33(+00) | 1.07(+01) |
| \(^{6}\text{Li}\) | 5.22(-19) | 1.16(-18) | 3.20(-18) | 1.88(-16) | 6.86(-16) | 1.73(-16) |
| \(^{7}\text{Li}\) | 4.15(-11) | 1.19(-10) | 2.16(-10) | 2.40(-10) | 2.60(-10) | 2.42(-10) |
| \(^{9}\text{Be}\) | 1.15(-59) | 1.33(-59) | 1.80(-59) | 4.11(-30) | 5.25(-29) | 2.89(-30) |
| \(^{10}\text{B}\) | 4.65(-18) | 1.06(-17) | 6.22(-17) | 2.16(-15) | 6.79(-15) | 1.59(-14) |
| \(^{11}\text{B}\) | 9.11(-16) | 1.55(-15) | 3.01(-15) | 3.85(-13) | 1.29(-12) | 2.02(-12) |
| \(^{12}\text{C}\) | 7.87(-02) | 1.39(-01) | 3.35(-01) | 4.01(-01) | 7.16(-01) | 7.48(-01) |
| \(^{13}\text{C}\) | 3.66(-09) | 5.10(-10) | 2.31(-08) | 8.30(-03) | 9.15(-03) | 1.55(-04) |
| \(^{14}\text{N}\) | 3.71(-08) | 2.95(-07) | 2.05(-06) | 5.26(-02) | 6.95(-02) | 1.17(-04) |
| \(^{15}\text{N}\) | 1.10(-09) | 9.77(-10) | 3.24(-09) | 4.32(-06) | 4.51(-06) | 1.29(-07) |
| \(^{16}\text{O}\) | 1.60(-01) | 3.46(-01) | 1.00(+00) | 2.03(+00) | 3.04(+00) | 4.39(+00) |
| \(^{17}\text{O}\) | 4.35(-09) | 2.14(-08) | 1.70(-07) | 1.58(-04) | 1.99(-04) | 5.07(-05) |
| \(^{18}\text{O}\) | 6.83(-09) | 8.80(-09) | 2.52(-08) | 7.55(-05) | 8.47(-05) | 2.24(-06) |
| \(^{19}\text{F}\) | 4.64(-11) | 7.00(-11) | 2.47(-10) | 4.14(-07) | 7.62(-07) | 1.90(-07) |
| \(^{20}\text{Ne}\) | 3.08(-02) | 1.15(-01) | 2.22(-01) | 6.73(-01) | 3.43(-01) | 1.08(+00) |
| \(^{21}\text{Ne}\) | 1.19(-06) | 3.31(-06) | 1.46(-05) | 6.30(-05) | 4.70(-05) | 4.69(-05) |
| \(^{22}\text{Ne}\) | 2.97(-07) | 1.46(-06) | 6.28(-06) | 6.15(-05) | 8.76(-05) | 3.74(-05) |
| \(^{23}\text{Na}\) | 1.51(-04) | 5.79(-04) | 1.32(-03) | 4.00(-03) | 1.85(-03) | 3.31(-03) |
| \(^{24}\text{Mg}\) | 2.85(-02) | 4.98(-02) | 1.02(-01) | 1.36(-01) | 1.71(-01) | 2.09(-01) |
| \(^{25}\text{Mg}\) | 7.56(-05) | 8.97(-05) | 2.92(-04) | 5.17(-04) | 3.51(-04) | 2.61(-04) |
| \(^{26}\text{Mg}\) | 1.22(-04) | 1.96(-04) | 4.73(-04) | 7.40(-04) | 4.68(-04) | 4.61(-04) |
| \(^{27}\text{Al}\) | 4.07(-04) | 8.66(-04) | 1.50(-03) | 2.20(-03) | 1.47(-03) | 2.01(-03) |
| \(^{28}\text{Si}\) | 4.63(-02) | 5.30(-02) | 1.38(-01) | 1.15(-01) | 2.78(-01) | 1.90(-01) |
| \(^{29}\text{Si}\) | 2.72(-04) | 2.57(-04) | 7.41(-04) | 5.13(-04) | 1.17(-03) | 5.38(-04) |
| \(^{30}\text{Si}\) | 2.55(-04) | 1.84(-04) | 5.05(-04) | 2.81(-04) | 5.63(-04) | 1.78(-04) |
| Mass | 13   | 15   | 20   | 25   | 30   | 35   |
|------|------|------|------|------|------|------|
| $^{31}$P | 1.02(-04) | 9.72(-05) | 2.30(-04) | 1.46(-04) | 3.10(-04) | 1.25(-04) |
| $^{32}$S | 1.98(-02) | 2.15(-02) | 6.13(-02) | 5.27(-02) | 1.30(-01) | 9.18(-02) |
| $^{33}$S | 4.73(-05) | 5.04(-05) | 1.29(-04) | 9.38(-05) | 2.28(-04) | 1.12(-04) |
| $^{34}$S | 2.93(-04) | 1.94(-04) | 5.49(-04) | 2.62(-04) | 6.10(-04) | 1.53(-04) |
| $^{35}$S | 3.1(-04) | 7.01(-04) | 1.52(-03) | 7.23(-03) | 1.54(-02) | 3.79(-02) |
| $^{36}$S | 1.0(-04) | 2.04(-04) | 9.52(-04) | 2.72(-04) | 5.24(-04) | 4.23(-10) |
| $^{37}$S | 4.73(-05) | 5.04(-05) | 1.29(-04) | 9.38(-05) | 2.28(-04) | 1.12(-04) |
| $^{38}$S | 2.93(-04) | 1.94(-04) | 5.49(-04) | 2.62(-04) | 6.10(-04) | 1.53(-04) |
| $^{39}$S | 8.74(-09) | 2.04(-09) | 9.52(-09) | 2.72(-09) | 5.24(-09) | 4.23(-10) |
| $^{40}$Cl | 2.26(-05) | 2.61(-05) | 4.35(-05) | 3.39(-05) | 2.28(-04) | 1.12(-04) |
| $^{41}$Cl | 2.44(-06) | 2.66(-06) | 7.10(-06) | 5.91(-06) | 1.37(-05) | 8.82(-06) |
| $^{42}$Cl | 3.88(-03) | 4.12(-03) | 1.18(-02) | 1.05(-02) | 2.56(-02) | 1.87(-02) |
| $^{43}$Cl | 4.62(-05) | 5.52(-11) | 2.02(-10) | 5.16(-11) | 8.51(-11) | 8.82(-12) |
| $^{44}$Cl | 9.50(-06) | 1.13(-06) | 2.13(-06) | 1.34(-06) | 2.73(-06) | 1.54(-06) |
| $^{45}$Cl | 6.86(-09) | 2.58(-09) | 6.24(-09) | 3.13(-09) | 6.41(-09) | 1.60(-09) |
| $^{46}$Cl | 6.88(-07) | 7.79(-07) | 1.54(-06) | 1.47(-06) | 3.06(-06) | 2.07(-06) |
| $^{47}$Cl | 3.74(-03) | 3.83(-03) | 1.07(-02) | 9.82(-03) | 2.31(-02) | 1.70(-02) |
| $^{48}$Cl | 9.50(-06) | 1.13(-06) | 2.13(-06) | 1.34(-06) | 2.73(-06) | 1.54(-06) |
| $^{49}$Cl | 1.81(-06) | 3.77(-07) | 1.14(-07) | 9.92(-08) | 4.37(-09) | 1.56(-09) |
| $^{50}$Cl | 6.94(-05) | 5.94(-05) | 3.00(-05) | 5.73(-05) | 1.18(-05) | 1.03(-05) |
| $^{51}$Cl | 4.62(-13) | 5.52(-14) | 3.23(-13) | 5.74(-14) | 1.94(-13) | 3.96(-15) |
| $^{52}$Cl | 1.29(-18) | 4.04(-19) | 3.70(-18) | 3.68(-18) | 2.13(-18) | 1.49(-15) |
| $^{53}$Cl | 1.28(-06) | 5.50(-08) | 7.93(-08) | 8.40(-08) | 1.63(-07) | 1.05(-07) |
| $^{54}$Cl | 5.97(-06) | 1.24(-06) | 1.36(-06) | 1.09(-06) | 1.55(-06) | 1.02(-06) |
| $^{55}$Cl | 6.11(-06) | 9.57(-07) | 3.60(-07) | 4.52(-07) | 5.33(-08) | 4.13(-08) |
| $^{56}$Cl | 1.99(-04) | 1.70(-04) | 1.85(-04) | 2.11(-04) | 2.27(-04) | 1.94(-04) |
| $^{57}$Cl | 5.87(-06) | 2.81(-06) | 5.52(-06) | 5.40(-06) | 9.81(-06) | 8.86(-06) |
| $^{58}$Cl | 4.83(-12) | 1.66(-12) | 4.40(-12) | 1.02(-12) | 2.13(-12) | 1.89(-13) |
| $^{59}$Cl | 4.79(-10) | 1.21(-11) | 3.07(-11) | 9.79(-12) | 2.34(-11) | 6.60(-12) |
| $^{60}$Cl | 1.26(-05) | 5.32(-06) | 6.70(-06) | 9.42(-06) | 1.30(-05) | 1.06(-05) |
| $^{61}$Cl | 1.62(-05) | 8.49(-06) | 1.00(-05) | 1.35(-05) | 1.90(-05) | 1.35(-05) |
| $^{62}$Cl | 1.13(-03) | 9.22(-04) | 2.32(-03) | 1.89(-03) | 4.00(-03) | 3.43(-03) |
| $^{63}$Cl | 7.63(-05) | 6.52(-05) | 1.24(-04) | 1.22(-04) | 2.22(-04) | 2.00(-04) |
| $^{64}$Cl | 1.37(-09) | 1.23(-10) | 3.35(-10) | 1.62(-10) | 3.75(-10) | 2.15(-10) |
| $^{65}$Cl | 3.16(-04) | 3.02(-04) | 3.54(-04) | 5.11(-04) | 7.06(-04) | 5.89(-04) |
| $^{66}$Cl | 1.17(-03) | 1.06(-03) | 1.03(-03) | 1.61(-03) | 2.18(-03) | 1.59(-03) |
Table 1—Continued

| Mass | 13   | 15   | 20   | 25   | 30   | 35   |
|------|------|------|------|------|------|------|
| $^{56}$Fe | 9.12(-02) | 1.00(-01) | 1.00(-01) | 1.00(-01) | 1.00(-01) | 1.00(-01) |
| $^{57}$Fe | 3.72(-03) | 3.43(-03) | 1.98(-03) | 2.41(-03) | 8.51(-04) | 1.07(-03) |
| $^{58}$Fe | 4.02(-08) | 5.51(-11) | 1.24(-10) | 8.14(-11) | 2.00(-10) | 1.34(-10) |
| $^{59}$Co | 2.74(-03) | 2.14(-04) | 8.04(-05) | 8.58(-05) | 4.26(-06) | 7.58(-06) |
| $^{58}$Ni | 1.27(-01) | 3.03(-03) | 1.31(-03) | 6.56(-04) | 3.34(-04) | 3.24(-04) |
| $^{60}$Ni | 1.67(-02) | 2.87(-03) | 1.47(-03) | 2.36(-03) | 1.37(-04) | 3.06(-04) |
| $^{61}$Ni | 1.41(-03) | 1.53(-04) | 6.55(-05) | 9.64(-05) | 2.50(-06) | 6.29(-06) |
| $^{62}$Ni | 1.79(-02) | 8.48(-04) | 3.01(-04) | 3.31(-04) | 3.77(-06) | 7.66(-06) |
| $^{64}$Ni | 5.81(-09) | 2.16(-16) | 1.40(-18) | 4.30(-16) | 2.32(-15) | 2.12(-15) |
| $^{63}$Cu | 6.07(-04) | 2.17(-06) | 7.73(-07) | 2.00(-06) | 5.25(-07) | 2.21(-06) |
| $^{65}$Cu | 4.07(-05) | 1.79(-06) | 6.52(-07) | 9.84(-07) | 1.84(-08) | 5.93(-08) |
| $^{64}$Zn | 1.03(-02) | 2.68(-05) | 1.34(-05) | 3.49(-05) | 1.90(-06) | 7.30(-06) |
| $^{66}$Zn | 1.68(-04) | 2.32(-05) | 7.78(-06) | 9.06(-06) | 4.20(-08) | 1.45(-07) |
| $^{67}$Zn | 3.41(-05) | 5.47(-08) | 1.30(-08) | 1.28(-08) | 1.72(-11) | 6.29(-11) |
| $^{68}$Zn | 7.93(-04) | 1.00(-08) | 2.19(-09) | 2.52(-09) | 4.54(-12) | 1.69(-11) |
| $^{70}$Zn | 5.87(-21) | 1.44(-20) | 9.50(-24) | 8.71(-20) | 5.62(-20) | 9.80(-20) |
| $^{69}$Ga | 1.15(-06) | 1.92(-12) | 2.89(-13) | 2.44(-13) | 1.80(-15) | 2.75(-15) |
| $^{71}$Ga | 1.20(-06) | 2.69(-14) | 3.60(-15) | 2.43(-15) | 9.19(-17) | 5.36(-16) |
| $^{70}$Ge | 6.17(-06) | 2.43(-16) | 7.85(-17) | 8.86(-15) | 8.18(-14) | 1.19(-13) |
| $^{72}$Ge | 2.15(-09) | 5.39(-17) | 3.29(-16) | 4.65(-14) | 4.24(-13) | 5.23(-13) |
| $^{73}$Ge | 1.08(-08) | 1.00(-17) | 7.15(-19) | 3.39(-16) | 1.86(-15) | 3.79(-15) |
| $^{74}$Ge | 2.41(-11) | 4.04(-17) | 9.14(-19) | 1.09(-15) | 8.49(-16) | 1.37(-14) |
| $^{76}$Ge | 3.71(-21) | 1.35(-20) | 2.71(-22) | 2.76(-19) | 3.98(-19) | 1.86(-18) |
| $^{75}$As | 1.97(-08) | 5.07(-14) | 8.92(-15) | 1.32(-14) | 1.32(-15) | 3.54(-15) |
| $^{74}$Se | 1.20(-06) | 1.64(-15) | 3.90(-16) | 2.47(-14) | 2.50(-13) | 3.84(-13) |
| $^{76}$Se | 7.31(-10) | 1.27(-16) | 6.55(-16) | 8.66(-14) | 9.13(-13) | 1.26(-12) |
| $^{77}$Se | 2.26(-09) | 6.84(-18) | 5.90(-19) | 3.02(-16) | 8.60(-16) | 5.72(-15) |
| $^{78}$Se | 1.34(-11) | 2.59(-17) | 4.76(-17) | 7.08(-15) | 5.19(-14) | 7.15(-14) |
| $^{80}$Se | 1.39(-15) | 4.23(-17) | 9.22(-17) | 5.43(-15) | 1.66(-13) | 2.21(-13) |
| $^{82}$Se | 1.10(-19) | 2.92(-20) | 1.07(-19) | 2.36(-18) | 2.00(-16) | 2.90(-17) |
| $^{79}$Br | 1.08(-09) | 1.37(-14) | 2.52(-15) | 5.92(-15) | 8.06(-15) | 1.70(-14) |
| $^{81}$Br | 1.81(-09) | 1.33(-17) | 2.62(-17) | 2.97(-15) | 4.33(-14) | 6.17(-14) |
| $^{78}$Kr | 1.88(-07) | 2.34(-15) | 4.17(-16) | 1.10(-14) | 1.18(-13) | 1.89(-13) |
### Table 1—Continued

| Mass | 13  | 15  | 20  | 25  | 30  | 35  |
|------|-----|-----|-----|-----|-----|-----|
| $^{80}$Kr | 5.06(-09) | 7.96(-17) | 2.08(-15) | 2.62(-13) | 3.01(-12) | 4.44(-12) |
| $^{82}$Kr | 1.09(-11) | 5.36(-17) | 6.20(-16) | 7.01(-14) | 1.47(-12) | 1.57(-12) |
| $^{83}$Kr | 1.50(-11) | 1.42(-17) | 1.17(-16) | 1.74(-14) | 4.15(-13) | 2.40(-13) |
| $^{84}$Kr | 9.49(-13) | 8.72(-17) | 1.15(-15) | 4.54(-13) | 1.21(-12) | 3.98(-11) |
| $^{86}$Kr | 5.67(-17) | 5.08(-16) | 2.62(-16) | 9.55(-14) | 1.33(-13) | 7.46(-12) |
| $^{85}$Rb | 4.99(-11) | 1.27(-17) | 1.31(-15) | 1.55(-13) | 6.43(-13) | 1.18(-11) |
| $^{87}$Rb | 3.18(-17) | 9.64(-17) | 1.64(-16) | 1.39(-14) | 4.89(-14) | 6.00(-13) |
| $^{84}$Sr | 8.95(-10) | 1.87(-17) | 2.05(-15) | 2.37(-13) | 2.98(-12) | 4.33(-12) |
| $^{86}$Sr | 3.12(-11) | 7.90(-17) | 1.40(-14) | 1.52(-12) | 1.06(-11) | 1.35(-10) |
| $^{88}$Sr | 1.23(-10) | 2.68(-17) | 1.27(-14) | 1.42(-12) | 1.04(-12) | 1.46(-10) |
| $^{89}$Y | 1.91(-13) | 1.46(-16) | 1.52(-14) | 2.46(-12) | 4.94(-11) | 1.45(-10) |
| $^{90}$Zr | 9.60(-11) | 4.91(-16) | 9.36(-14) | 1.80(-11) | 1.61(-10) | 4.08(-10) |
| $^{91}$Zr | 6.04(-11) | 3.01(-17) | 1.27(-14) | 9.38(-12) | 3.57(-11) | 6.01(-11) |
| $^{92}$Zr | 9.06(-14) | 5.68(-17) | 2.45(-14) | 8.03(-12) | 4.41(-11) | 3.88(-10) |
| $^{94}$Zr | 9.74(-14) | 6.23(-17) | 3.10(-13) | 1.19(-10) | 3.84(-10) | 2.29(-09) |
| $^{96}$Zr | 3.29(-16) | 1.49(-19) | 2.24(-16) | 2.32(-13) | 5.16(-13) | 2.92(-12) |
| $^{93}$Nb | 5.14(-12) | 2.85(-17) | 1.08(-14) | 2.08(-12) | 6.87(-12) | 1.97(-10) |
| $^{92}$Mo | 4.24(-09) | 1.71(-16) | 1.04(-14) | 2.22(-12) | 2.01(-11) | 4.27(-11) |
| $^{94}$Mo | 9.45(-13) | 1.74(-16) | 1.19(-14) | 2.62(-12) | 2.00(-11) | 4.83(-11) |
| $^{95}$Mo | 1.33(-14) | 1.09(-17) | 3.64(-14) | 1.61(-11) | 4.33(-11) | 2.67(-10) |
| $^{96}$Mo | 6.07(-14) | 4.62(-16) | 1.42(-13) | 5.85(-11) | 1.98(-10) | 9.33(-10) |
| $^{97}$Mo | 9.05(-15) | 1.31(-15) | 4.36(-14) | 2.20(-11) | 1.75(-10) | 1.15(-09) |
| $^{98}$Mo | 5.97(-14) | 1.43(-15) | 4.11(-14) | 2.29(-11) | 7.88(-11) | 4.40(-10) |

Radioactive isotopes at $t = 10^7$ s

|     |     |     |     |     |     |     |
|-----|-----|-----|-----|-----|-----|-----|
| $^3$H | 1.35(-29) | 5.76(-27) | 2.57(-28) | 1.40(-22) | 3.77(-21) | 1.01(-22) |
| $^{14}$C | 4.16(-11) | 2.09(-10) | 3.82(-09) | 6.09(-03) | 6.59(-03) | 5.87(-05) |
| $^{22}$Na | 1.01(-07) | 3.16(-07) | 3.75(-07) | 1.76(-06) | 2.98(-06) | 1.10(-05) |
| $^{26}$Al | 6.35(-07) | 6.77(-07) | 2.05(-06) | 1.71(-06) | 4.20(-06) | 1.57(-06) |
| $^{32}$Si | 3.30(-11) | 7.42(-12) | 3.67(-11) | 1.25(-11) | 1.98(-11) | 2.67(-12) |
| $^{36}$Cl | 6.73(-08) | 3.76(-08) | 1.10(-07) | 5.13(-08) | 1.03(-07) | 2.43(-08) |
| $^{39}$Ar | 1.11(-09) | 5.86(-10) | 1.38(-09) | 6.58(-10) | 1.29(-09) | 2.56(-10) |
| $^{41}$Ca | 6.72(-07) | 7.79(-07) | 1.54(-06) | 1.48(-06) | 3.06(-06) | 2.07(-06) |
Table 1—Continued

| Mass  | 13     | 15     | 20     | 25     | 30     | 35     |
|-------|--------|--------|--------|--------|--------|--------|
| $^{45}$Ca | 2.49(-12) | 5.65(-13) | 2.12(-12) | 5.17(-13) | 9.15(-13) | 7.22(-14) |
| $^{44}$Ti | 6.94(-05) | 5.95(-05) | 3.01(-05) | 5.73(-05) | 1.19(-05) | 1.03(-05) |
| $^{49}$V | 5.86(-06) | 2.80(-06) | 5.50(-06) | 5.38(-06) | 9.78(-06) | 8.84(-06) |
| $^{53}$Mn | 7.64(-05) | 6.53(-05) | 1.25(-04) | 1.23(-04) | 2.22(-04) | 2.01(-04) |
| $^{54}$Mn | 1.37(-09) | 1.23(-10) | 3.35(-10) | 1.62(-10) | 3.75(-10) | 2.16(-10) |
| $^{55}$Fe | 5.43(-05) | 5.15(-05) | 6.11(-05) | 8.71(-05) | 1.21(-04) | 1.00(-04) |
| $^{60}$Fe | 2.95(-20) | 7.31(-18) | 5.55(-21) | 5.67(-18) | 3.22(-15) | 1.31(-15) |
| $^{57}$Co | 1.97(-04) | 1.79(-04) | 1.04(-04) | 1.24(-04) | 4.37(-05) | 5.51(-05) |
| $^{60}$Co | 2.69(-13) | 6.80(-17) | 2.10(-16) | 1.25(-16) | 3.67(-16) | 2.86(-16) |
| $^{56}$Ni | 9.13(-02) | 1.00(-01) | 1.00(-01) | 1.00(-01) | 1.00(-01) | 1.00(-01) |
| $^{57}$Ni | 3.53(-03) | 3.26(-03) | 1.88(-03) | 2.30(-03) | 8.08(-04) | 1.02(-03) |
| $^{59}$Ni | 2.75(-03) | 2.14(-04) | 8.04(-05) | 8.59(-05) | 4.27(-06) | 7.58(-06) |
| $^{63}$Ni | 2.20(-12) | 5.34(-18) | 8.84(-19) | 1.58(-18) | 4.48(-16) | 3.81(-18) |
| $^{65}$Zn | 4.07(-05) | 1.79(-06) | 6.53(-07) | 9.84(-07) | 1.84(-08) | 5.93(-08) |
| $^{68}$Ge | 7.93(-04) | 1.00(-08) | 2.19(-09) | 2.53(-09) | 4.53(-12) | 1.70(-11) |
| $^{79}$Se | 5.24(-18) | 2.41(-18) | 6.81(-20) | 1.50(-16) | 4.20(-17) | 1.82(-15) |
| $^{81}$Kr | 1.14(-09) | 2.59(-18) | 8.32(-18) | 1.52(-15) | 1.14(-14) | 1.95(-14) |
| $^{85}$Kr | 1.13(-17) | 2.29(-18) | 3.02(-17) | 2.02(-14) | 3.27(-14) | 8.86(-13) |
| $^{90}$Sr | 1.12(-19) | 3.82(-20) | 1.03(-17) | 2.04(-15) | 3.83(-14) | 2.96(-14) |
| $^{93}$Zr | 6.68(-16) | 1.26(-17) | 7.72(-15) | 1.61(-12) | 4.20(-12) | 1.66(-10) |

Metallicity $Z = 10^{-6}$

| $M_{\text{ejected}}$ | 11.56 | 13.55 | 18.34 | 23.22 | 28.07 | 32.87 |
|-----------------------|-------|-------|-------|-------|-------|-------|
| $M_{\text{remnant}}$  | 1.44  | 1.45  | 1.66  | 1.78  | 1.93  | 2.13  |
| $^{56}$Ni             | 0.1000| 0.1000| 0.1000| 0.1000| 0.1000| 0.1000|
| $^1$H                 | 6.83(+00) | 7.70(+00) | 9.70(+00) | 1.14(+01) | 1.31(+01) | 1.47(+01) |
| $^2$He                | 1.61(-16) | 1.29(-16) | 1.12(-16) | 1.27(-16) | 1.46(-16) | 1.68(-16) |
| $^3$He                | 7.04(-05) | 6.41(-05) | 5.50(-05) | 4.97(-05) | 4.66(-05) | 4.45(-05) |
| $^4$He                | 3.88(+00) | 4.51(+00) | 6.04(+00) | 7.51(+00) | 8.91(+00) | 1.03(+01) |
| $^6$Li                | 7.86(-15) | 6.68(-15) | 4.60(-15) | 2.81(-15) | 9.18(-16) | 1.32(-17) |
| $^7$Li                | 3.97(-16) | 2.89(-12) | 2.66(-11) | 3.97(-11) | 4.66(-11) | 5.37(-11) |
| $^9$Be                | 2.04(-15) | 1.70(-15) | 1.18(-15) | 7.22(-16) | 3.10(-16) | 3.23(-59) |
Table 1—Continued

| Mass |  13 |  15 |   20 |   25 |   30 |   35 |
|------|-----|-----|------|------|------|------|
|  10B | 1.43(-14) | 1.27(-14) | 9.92(-15) | 6.53(-15) | 3.82(-15) | 8.19(-16) |
|  11B | 1.27(-13) | 1.32(-13) | 1.49(-13) | 1.63(-13) | 1.75(-13) | 1.88(-13) |
|  12C | 1.04(-01) | 1.61(-01) | 3.69(-01) | 4.91(-01) | 7.18(-01) | 7.57(-01) |
|  13C | 3.92(-08) | 3.84(-08) | 6.48(-08) | 5.97(-08) | 7.81(-08) | 3.26(-08) |
|  14N | 4.58(-06) | 5.42(-06) | 1.27(-05) | 2.59(-05) | 3.98(-05) | 6.45(-05) |
|  15N | 8.62(-10) | 1.47(-09) | 7.16(-09) | 3.30(-08) | 3.10(-08) | 9.69(-08) |
| 16O  | 2.31(-01) | 4.64(-01) | 1.18(+00) | 2.18(+00) | 3.45(+00) | 4.67(+00) |
| 17O  | 4.63(-08) | 6.28(-08) | 5.23(-07) | 8.11(-07) | 1.38(-05) | 3.47(-05) |
| 18O  | 4.69(-08) | 6.96(-08) | 9.00(-08) | 1.94(-07) | 1.92(-07) | 9.14(-07) |
| 19F  | 1.21(-10) | 1.74(-10) | 4.24(-10) | 1.21(-09) | 1.42(-08) | 3.54(-07) |
| 20Ne | 4.31(-02) | 1.55(-01) | 2.59(-01) | 6.57(-01) | 6.68(-01) | 1.05(+00) |
| 21Ne | 1.87(-06) | 4.74(-06) | 4.11(-05) | 4.14(-05) | 5.24(-05) | 4.35(-05) |
| 22Ne | 8.60(-07) | 2.87(-06) | 1.96(-05) | 3.23(-05) | 3.65(-05) | 3.99(-05) |
| 23Na | 2.38(-04) | 7.59(-04) | 1.85(-03) | 2.88(-03) | 3.16(-03) | 2.95(-03) |
| 24Mg | 3.58(-02) | 6.13(-02) | 1.04(-01) | 1.37(-01) | 1.82(-01) | 2.06(-01) |
| 25Mg | 1.03(-04) | 1.09(-04) | 2.89(-04) | 3.21(-04) | 3.11(-04) | 2.14(-04) |
| 26Mg | 1.64(-04) | 2.46(-04) | 3.67(-04) | 5.16(-04) | 4.43(-04) | 3.68(-04) |
| 27Al | 4.96(-04) | 1.08(-03) | 1.49(-03) | 1.74(-03) | 1.83(-03) | 1.73(-03) |
| 28Si | 5.74(-02) | 7.65(-02) | 1.54(-01) | 1.41(-01) | 2.33(-01) | 2.23(-01) |
| 29Si | 3.49(-04) | 3.00(-04) | 6.98(-04) | 4.53(-04) | 8.37(-04) | 5.64(-04) |
| 30Si | 3.07(-04) | 2.12(-04) | 4.25(-04) | 2.13(-04) | 3.38(-04) | 1.64(-04) |
| 31P  | 1.24(-04) | 1.08(-04) | 2.13(-04) | 1.31(-04) | 2.05(-04) | 1.22(-04) |
| 32S  | 2.47(-02) | 3.50(-02) | 6.62(-02) | 6.76(-02) | 1.09(-01) | 1.11(-01) |
| 33S  | 6.13(-05) | 6.20(-05) | 1.45(-04) | 1.00(-04) | 1.72(-04) | 1.27(-04) |
| 34S  | 3.56(-04) | 2.55(-04) | 5.04(-04) | 2.40(-04) | 3.24(-04) | 1.62(-04) |
| 36S  | 1.02(-08) | 2.49(-09) | 4.91(-09) | 1.17(-09) | 1.93(-09) | 4.84(-10) |
| 35Cl | 2.86(-05) | 3.13(-05) | 4.89(-05) | 3.16(-05) | 4.59(-05) | 2.82(-05) |
| 37Cl | 3.34(-06) | 6.01(-06) | 8.29(-06) | 7.29(-06) | 1.26(-05) | 1.06(-05) |
| 36Ar | 4.76(-03) | 6.78(-03) | 1.23(-02) | 1.36(-02) | 2.15(-02) | 2.29(-02) |
| 38Ar | 7.68(-05) | 1.32(-04) | 1.26(-04) | 1.03(-04) | 9.88(-05) | 7.87(-05) |
| 40Ar | 2.52(-10) | 7.14(-11) | 1.34(-10) | 5.14(-11) | 9.37(-11) | 6.14(-10) |
| 39K  | 2.16(-05) | 3.23(-05) | 1.95(-05) | 1.56(-05) | 1.97(-05) | 1.66(-05) |
| 40K  | 4.81(-09) | 3.02(-09) | 5.98(-09) | 2.58(-09) | 3.38(-09) | 1.76(-09) |
| Mass | 13  |
|------|-----|
| K    | 8.85(-07) | 1.86(-06) | 1.69(-06) | 1.69(-06) | 2.98(-06) | 2.55(-06) |
| Ca   | 4.47(-03) | 5.92(-03) | 1.08(-02) | 1.24(-02) | 1.95(-02) | 2.09(-02) |
| Ca   | 1.78(-06) | 4.54(-06) | 2.24(-06) | 2.52(-06) | 1.90(-06) | 1.67(-06) |
| Ca   | 3.34(-07) | 2.25(-07) | 4.38(-08) | 6.57(-09) | 2.65(-09) | 2.44(-09) |
| Ca   | 7.92(-05) | 5.17(-05) | 3.75(-05) | 2.06(-05) | 1.51(-05) | 1.17(-05) |
| Ca   | 2.14(-12) | 1.94(-12) | 2.67(-12) | 3.18(-12) | 1.12(-11) | 3.75(-10) |
| Ca   | 7.95(-11) | 9.27(-11) | 1.24(-10) | 1.54(-10) | 1.85(-10) | 2.10(-10) |
| Sc   | 5.64(-08) | 1.05(-07) | 8.60(-08) | 9.35(-08) | 1.35(-07) | 1.38(-07) |
| Ti   | 1.72(-06) | 4.25(-06) | 1.36(-06) | 1.79(-06) | 1.18(-06) | 1.07(-06) |
| Ti   | 9.59(-07) | 6.51(-07) | 2.40(-07) | 6.92(-08) | 4.05(-08) | 4.24(-08) |
| Ti   | 2.20(-04) | 1.59(-04) | 1.85(-04) | 1.86(-04) | 1.95(-04) | 2.28(-04) |
| Ti   | 2.81(-06) | 5.38(-06) | 6.18(-06) | 8.09(-06) | 8.00(-06) | 9.56(-06) |
| Ti   | 1.03(-10) | 1.17(-10) | 1.61(-10) | 2.03(-10) | 3.32(-10) | 6.35(-10) |
| V    | 2.90(-11) | 3.82(-11) | 3.05(-11) | 2.08(-11) | 1.38(-11) | 1.86(-11) |
| V    | 3.96(-06) | 1.29(-05) | 1.09(-05) | 1.20(-05) | 9.78(-06) | 1.10(-05) |
| Cr   | 7.15(-06) | 4.39(-05) | 1.88(-05) | 2.10(-05) | 1.18(-05) | 1.31(-05) |
| Cr   | 1.10(-03) | 1.27(-03) | 2.13(-03) | 2.81(-03) | 3.29(-03) | 4.04(-03) |
| Cr   | 6.11(-05) | 1.16(-04) | 1.41(-04) | 1.82(-04) | 1.78(-04) | 2.17(-04) |
| Cr   | 6.72(-10) | 3.29(-09) | 8.84(-10) | 1.60(-09) | 1.47(-09) | 2.30(-09) |
| Mn   | 1.94(-04) | 5.54(-04) | 5.73(-04) | 6.16(-04) | 5.46(-04) | 6.33(-04) |
| Fe   | 6.25(-04) | 3.45(-03) | 2.05(-03) | 2.18(-03) | 1.42(-03) | 1.62(-03) |
| Fe   | 1.00(-01) | 1.00(-01) | 1.00(-01) | 1.00(-01) | 1.00(-01) | 1.00(-01) |
| Fe   | 3.23(-03) | 3.13(-03) | 2.02(-03) | 1.65(-03) | 1.07(-03) | 8.15(-04) |
| Fe   | 3.61(-09) | 5.48(-09) | 7.29(-09) | 9.33(-09) | 3.22(-08) | 7.62(-08) |
| Co   | 1.80(-04) | 1.62(-04) | 5.36(-05) | 8.58(-06) | 7.12(-06) | 4.23(-06) |
| Ni   | 1.79(-03) | 1.90(-03) | 5.74(-04) | 3.76(-04) | 3.39(-04) | 2.93(-04) |
| Ni   | 3.36(-03) | 2.55(-03) | 1.68(-03) | 1.17(-03) | 4.26(-04) | 1.19(-04) |
| Ni   | 1.66(-04) | 1.14(-04) | 6.33(-05) | 3.60(-05) | 9.13(-06) | 2.12(-06) |
| Ni   | 7.89(-04) | 5.52(-04) | 1.94(-04) | 6.25(-05) | 1.29(-05) | 3.31(-06) |
| Ni   | 4.33(-10) | 5.07(-10) | 6.82(-10) | 8.71(-10) | 1.22(-09) | 7.83(-09) |
| Cu   | 6.56(-06) | 1.82(-06) | 1.37(-06) | 1.50(-05) | 3.35(-06) | 3.09(-07) |
| Cu   | 2.09(-06) | 1.13(-06) | 6.06(-07) | 4.10(-07) | 1.12(-07) | 1.02(-08) |
| Zn   | 5.22(-05) | 2.47(-05) | 2.49(-05) | 4.33(-05) | 1.31(-05) | 9.05(-07) |
Table 1—Continued

| Mass |  13   |  15   |  20   |  25   |  30   |  35   |
|------|-------|-------|-------|-------|-------|-------|
| Zn   | 2.53(-05) | 1.32(-05) | 5.08(-06) | 2.25(-06) | 3.31(-07) | 2.51(-08) |
| Zn   | 6.14(-08) | 2.47(-08) | 6.22(-09) | 1.61(-09) | 3.04(-10) | 3.19(-10) |
| Zn   | 1.03(-08) | 5.80(-09) | 1.60(-09) | 9.51(-10) | 6.87(-10) | 1.33(-09) |
| Zn   | 7.87(-12) | 9.17(-12) | 1.22(-11) | 1.55(-11) | 1.76(-11) | 1.98(-11) |
| Ga   | 2.79(-11) | 3.15(-11) | 4.31(-11) | 5.54(-11) | 7.48(-11) | 1.63(-10) |
| Ga   | 1.62(-11) | 1.90(-11) | 2.60(-11) | 3.35(-11) | 4.61(-11) | 9.62(-11) |
| Ge   | 2.82(-11) | 3.40(-11) | 4.94(-11) | 6.26(-11) | 9.09(-11) | 2.09(-10) |
| Ge   | 3.50(-11) | 4.08(-11) | 5.53(-11) | 6.95(-11) | 9.27(-11) | 2.04(-10) |
| Ge   | 9.89(-12) | 1.16(-11) | 1.56(-11) | 2.00(-11) | 2.61(-11) | 5.79(-11) |
| Ge   | 4.72(-11) | 5.52(-11) | 7.41(-11) | 9.43(-11) | 1.17(-10) | 2.43(-10) |
| Ge   | 1.01(-11) | 1.17(-11) | 1.55(-11) | 1.97(-11) | 2.22(-11) | 2.52(-11) |
| As   | 7.12(-12) | 8.21(-12) | 1.10(-11) | 1.37(-11) | 1.70(-11) | 2.90(-11) |
| Se   | 6.78(-13) | 8.33(-13) | 1.32(-12) | 1.63(-12) | 2.24(-12) | 2.81(-12) |
| Se   | 7.63(-12) | 9.26(-12) | 1.33(-11) | 1.73(-11) | 2.30(-11) | 5.90(-11) |
| Se   | 5.42(-12) | 6.41(-12) | 8.70(-12) | 1.14(-11) | 1.40(-11) | 2.86(-11) |
| Se   | 1.71(-11) | 2.01(-11) | 2.72(-11) | 3.48(-11) | 4.43(-11) | 9.27(-11) |
| Se   | 3.53(-11) | 4.10(-11) | 5.46(-11) | 7.01(-11) | 8.73(-11) | 1.80(-10) |
| Se   | 6.80(-12) | 7.95(-12) | 1.06(-11) | 1.35(-11) | 1.58(-11) | 1.78(-11) |
| Br   | 6.57(-12) | 7.62(-12) | 1.01(-11) | 1.27(-11) | 1.69(-11) | 3.57(-11) |
| Br   | 7.09(-12) | 8.34(-12) | 1.13(-11) | 1.49(-11) | 1.72(-11) | 3.24(-11) |
| Kr   | 1.77(-13) | 2.09(-13) | 2.96(-13) | 3.82(-13) | 4.43(-13) | 6.70(-13) |
| Kr   | 1.94(-12) | 2.46(-12) | 3.82(-12) | 5.37(-12) | 5.45(-12) | 9.54(-12) |
| Kr   | 7.93(-12) | 9.88(-12) | 1.43(-11) | 1.97(-11) | 2.47(-11) | 6.82(-11) |
| Kr   | 6.06(-12) | 7.06(-12) | 9.56(-12) | 1.21(-11) | 1.53(-11) | 3.15(-11) |
| Kr   | 3.15(-11) | 3.68(-11) | 4.99(-11) | 6.84(-11) | 7.87(-11) | 1.65(-10) |
| Kr   | 9.91(-12) | 1.16(-11) | 1.56(-11) | 1.99(-11) | 2.71(-11) | 8.25(-11) |
| Rb   | 6.48(-12) | 7.59(-12) | 1.02(-11) | 1.36(-11) | 1.77(-11) | 5.08(-11) |
| Rb   | 2.76(-12) | 3.19(-12) | 4.38(-12) | 5.50(-12) | 8.15(-12) | 3.18(-11) |
| Sr   | 1.76(-13) | 2.00(-13) | 2.89(-13) | 4.17(-13) | 4.12(-13) | 8.57(-13) |
| Sr   | 4.01(-12) | 5.04(-12) | 7.39(-12) | 1.06(-11) | 1.20(-11) | 3.14(-11) |
| Sr   | 2.16(-12) | 2.63(-12) | 3.71(-12) | 2.24(-11) | 6.28(-12) | 5.83(-11) |
| Sr   | 2.56(-11) | 3.00(-11) | 4.07(-11) | 5.97(-11) | 6.51(-11) | 1.19(-10) |
| Y    | 6.16(-12) | 7.25(-12) | 9.90(-12) | 1.52(-11) | 1.57(-11) | 2.32(-11) |
Table 1—Continued

| Mass | 13   | 15   | 20   | 25   | 30   | 35   |
|------|------|------|------|------|------|------|
| Zr   | 8.18(−12) | 9.62(−12) | 1.34(−11) | 2.03(−11) | 2.09(−11) | 3.42(−11) |
| Zr   | 1.71(−12) | 2.01(−12) | 2.71(−12) | 4.00(−12) | 4.31(−12) | 1.01(−11) |
| Zr   | 2.66(−12) | 3.13(−12) | 4.23(−12) | 6.14(−12) | 6.68(−12) | 1.05(−11) |
| Zr   | 2.69(−12) | 3.15(−12) | 4.20(−12) | 3.84(−11) | 6.51(−12) | 4.89(−11) |
| Zr   | 3.93(−13) | 4.47(−13) | 5.75(−13) | 7.79(−13) | 9.35(−13) | 2.75(−12) |
| Nb   | 9.36(−13) | 1.09(−12) | 1.47(−12) | 1.94(−12) | 2.30(−12) | 3.12(−12) |
| Mo   | 6.32(−13) | 7.44(−13) | 1.18(−12) | 1.62(−12) | 1.83(−12) | 2.60(−12) |
| Mo   | 4.97(−13) | 6.27(−13) | 1.05(−12) | 1.59(−12) | 1.68(−12) | 2.19(−12) |
| Mo   | 5.63(−13) | 6.60(−13) | 8.85(−13) | 4.14(−12) | 1.34(−12) | 6.79(−12) |
| Mo   | 8.35(−13) | 1.02(−12) | 1.58(−12) | 5.79(−12) | 2.79(−12) | 2.35(−11) |
| Mo   | 4.42(−13) | 5.45(−13) | 7.76(−13) | 6.13(−12) | 2.08(−12) | 1.24(−11) |
| Mo   | 7.74(−11) | 9.08(−11) | 1.21(−10) | 1.59(−10) | 1.86(−10) | 2.22(−10) |

Radioactive isotopes at $t = 10^7$ s

|          | 3H   | 14C  | 22Na | 26Al | 32Si | 36Cl  | 39Ar  | 41Ca  | 45Ca  | 44Ti  | 49V   | 53Mn  | 54Mn  | 55Fe  | 60Fe  | 57Co  | 60Co  | 56Ni  | 57Ni  | 59Ni  |
|----------|------|------|------|------|------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
|         | 1.14(−59) | 1.33(−59) | 2.35(−30) | 4.55(−29) | 3.97(−27) | 3.97(−27) | 1.10(−25) | 1.41(−10) | 2.87(−10) | 1.45(−08) | 1.69(−08) | 1.87(−06) | 3.13(−05) | 1.03(−07) | 6.40(−07) | 5.87(−07) | 7.42(−06) | 1.34(−06) | 1.21(−05) |
|         | 8.61(−07) | 7.35(−07) | 2.35(−06) | 1.55(−06) | 2.85(−06) | 1.64(−06) | 8.61(−07) | 7.35(−07) | 2.35(−06) | 1.55(−06) | 2.85(−06) | 1.64(−06) | 3.83(−11) | 8.94(−12) | 1.79(−11) | 5.65(−12) | 7.58(−12) | 1.80(−12) | 8.14(−08) | 4.27(−08) | 9.10(−08) | 3.77(−08) | 5.35(−08) | 2.38(−08) | 1.19(−09) | 5.99(−10) | 1.29(−09) | 4.66(−10) | 7.83(−10) | 1.31(−09) | 8.85(−07) | 1.87(−06) | 1.70(−06) | 1.69(−06) | 2.98(−06) | 2.56(−06) | 2.81(−12) | 6.88(−13) | 1.57(−12) | 9.31(−13) | 1.38(−11) | 3.81(−10) | 7.93(−05) | 5.18(−05) | 3.76(−05) | 2.06(−05) | 1.52(−05) | 1.17(−05) | 2.81(−06) | 5.37(−06) | 6.16(−06) | 8.07(−06) | 7.98(−06) | 9.53(−06) | 6.12(−05) | 1.16(−04) | 1.42(−04) | 1.83(−04) | 1.79(−04) | 2.17(−04) | 3.56(−10) | 2.90(−09) | 3.23(−10) | 8.46(−10) | 2.19(−10) | 2.31(−10) | 3.33(−05) | 1.00(−04) | 9.78(−05) | 1.06(−04) | 9.29(−05) | 1.08(−04) | 1.30(−13) | 1.47(−13) | 3.10(−13) | 3.17(−13) | 4.62(−10) | 2.33(−08) | 1.62(−04) | 1.61(−04) | 1.03(−04) | 8.42(−05) | 5.44(−05) | 4.17(−05) | 5.94(−12) | 2.94(−12) | 1.07(−11) | 7.25(−12) | 4.88(−10) | 4.17(−09) | 1.00(−01) | 1.00(−01) | 1.00(−01) | 1.00(−01) | 1.00(−01) | 1.80(−04) | 1.63(−04) | 5.37(−05) | 8.57(−06) | 7.12(−06) | 4.20(−06) | 3.07(−03) | 2.98(−03) | 1.92(−03) | 1.57(−03) | 1.02(−03) | 7.74(−04) | 3.07(−03) | 2.98(−03) | 1.92(−03) | 1.57(−03) | 1.02(−03) | 7.74(−04) | 3.07(−03) | 2.98(−03) | 1.92(−03) | 1.57(−03) | 1.02(−03) | 7.74(−04) |
Table 1—Continued

| Mass | 13    | 15    | 20    | 25    | 30    | 35    |
|------|-------|-------|-------|-------|-------|-------|
| $^{63}$Ni | 1.93(-12) | 3.63(-12) | 7.09(-12) | 1.74(-11) | 4.72(-10) | 4.99(-09) |
| $^{65}$Zn | 2.09(-06) | 1.13(-06) | 6.07(-07) | 4.10(-07) | 1.12(-07) | 8.72(-09) |
| $^{68}$Ge | 1.01(-08) | 5.53(-09) | 1.22(-09) | 4.66(-10) | 4.42(-11) | 3.93(-12) |
| $^{70}$Se | 4.20(-14) | 9.90(-14) | 1.13(-13) | 6.51(-13) | 2.99(-12) | 1.98(-11) |
| $^{81}$Kr | 2.84(-13) | 4.06(-13) | 6.52(-13) | 1.10(-12) | 5.61(-13) | 1.09(-12) |
| $^{85}$Kr | 3.10(-14) | 5.17(-14) | 1.47(-13) | 5.40(-13) | 3.49(-12) | 2.02(-11) |
| $^{90}$Sr | 1.01(-16) | 1.28(-16) | 3.60(-16) | 1.38(-15) | 1.14(-13) | 2.10(-12) |
| $^{93}$Zr | 4.95(-14) | 7.68(-14) | 1.40(-13) | 2.57(-13) | 4.47(-13) | 9.20(-13) |

Metallicity $Z = 10^{-4}$

| $M_{\text{ejected}}$ | 11.67 | 13.35 | 18.45 | 23.14 | 28.16 | 32.86 |
| $M_{\text{remnant}}$ | 1.33  | 1.65  | 1.55  | 1.86  | 1.84  | 2.14  |
| $^{56}$Ni | 0.1000 | 0.1000 | 0.1000 | 0.1000 | 0.1000 | 0.1000 |
| $^{1}$H | 6.74(+00) | 7.61(+00) | 9.61(+00) | 1.14(+01) | 1.31(+01) | 1.47(+01) |
| $^{2}$H | 1.64(-16) | 1.81(-16) | 2.20(-16) | 2.54(-16) | 2.85(-16) | 3.17(-16) |
| $^{3}$He | 9.01(-05) | 8.27(-05) | 7.10(-05) | 6.48(-05) | 6.13(-05) | 5.92(-05) |
| $^{4}$He | 3.83(+00) | 4.43(+00) | 5.85(+00) | 7.14(+00) | 8.50(+00) | 9.85(+00) |
| $^{6}$Li | 2.16(-12) | 2.28(-12) | 2.21(-12) | 2.40(-12) | 2.27(-12) | 2.40(-12) |
| $^{7}$Li | 4.53(-17) | 1.03(-15) | 3.45(-13) | 1.82(-12) | 3.29(-12) | 4.43(-12) |
| $^{9}$Be | 5.96(-13) | 5.85(-13) | 6.37(-13) | 6.18(-13) | 6.35(-13) | 6.15(-13) |
| $^{10}$B | 4.17(-12) | 4.33(-12) | 4.51(-12) | 4.53(-12) | 4.69(-12) | 4.71(-12) |
| $^{11}$B | 3.16(-11) | 3.46(-11) | 4.15(-11) | 4.76(-11) | 5.34(-11) | 5.88(-11) |
| $^{12}$C | 1.09(-01) | 2.00(-01) | 3.01(-01) | 5.43(-01) | 6.24(-01) | 8.14(-01) |
| $^{13}$C | 4.37(-06) | 4.98(-06) | 6.40(-06) | 7.60(-06) | 8.92(-06) | 1.02(-05) |
| $^{14}$N | 2.99(-04) | 3.37(-04) | 4.17(-04) | 5.21(-04) | 6.21(-04) | 7.22(-04) |
| $^{15}$N | 6.07(-08) | 6.76(-08) | 8.35(-08) | 1.34(-07) | 1.24(-07) | 1.54(-07) |
| $^{16}$O | 3.17(-01) | 4.59(-01) | 1.37(+00) | 2.38(+00) | 3.75(+00) | 4.97(+00) |
| $^{17}$O | 3.89(-06) | 3.98(-06) | 4.39(-06) | 5.32(-06) | 5.45(-06) | 5.09(-06) |
| $^{18}$O | 4.47(-06) | 7.13(-06) | 6.55(-06) | 3.31(-06) | 1.46(-06) | 1.41(-06) |
| $^{19}$F | 1.58(-08) | 1.87(-08) | 3.71(-08) | 5.84(-08) | 7.29(-08) | 1.06(-07) |
| $^{20}$Ne | 1.33(-01) | 4.24(-02) | 4.89(-01) | 6.77(-01) | 1.05(+00) | 1.19(+00) |
| $^{21}$Ne | 6.85(-06) | 5.93(-06) | 2.98(-05) | 5.12(-05) | 8.11(-05) | 7.75(-05) |
Table 1—Continued

| Mass | 13   | 15   | 20   | 25   | 30   | 35   |
|------|------|------|------|------|------|------|
| $^{22}\text{Ne}$ | 6.27(-05) | 9.50(-05) | 2.09(-04) | 3.11(-04) | 3.68(-04) | 4.17(-04) |
| $^{23}\text{Na}$ | 7.83(-04) | 1.84(-04) | 1.83(-03) | 3.06(-03) | 4.48(-03) | 3.99(-03) |
| $^{24}\text{Mg}$ | 5.12(-02) | 5.41(-02) | 1.70(-01) | 1.43(-01) | 2.23(-01) | 2.22(-01) |
| $^{25}\text{Mg}$ | 1.52(-04) | 1.67(-04) | 6.55(-04) | 3.25(-04) | 4.88(-04) | 3.25(-04) |
| $^{26}\text{Mg}$ | 3.15(-04) | 2.33(-04) | 1.17(-03) | 5.33(-04) | 9.11(-04) | 6.07(-04) |
| $^{27}\text{Al}$ | 1.18(-03) | 5.50(-04) | 2.97(-03) | 1.84(-03) | 3.05(-03) | 2.40(-03) |
| $^{28}\text{Si}$ | 7.48(-02) | 1.14(-01) | 1.71(-01) | 1.11(-01) | 1.69(-01) | 2.33(-01) |
| $^{29}\text{Si}$ | 2.84(-04) | 6.55(-04) | 7.31(-04) | 5.07(-04) | 7.39(-04) | 6.35(-04) |
| $^{30}\text{Si}$ | 2.50(-04) | 5.33(-04) | 5.30(-04) | 2.35(-04) | 3.47(-04) | 2.27(-04) |
| $^{31}\text{P}$ | 1.12(-04) | 2.21(-04) | 2.20(-04) | 1.49(-04) | 2.00(-04) | 1.56(-04) |
| $^{32}\text{S}$ | 3.64(-02) | 4.90(-02) | 4.41(-02) | 8.22(-02) | 7.43(-02) | 1.15(-01) |
| $^{33}\text{S}$ | 6.75(-05) | 1.29(-04) | 8.88(-05) | 1.23(-04) | 1.33(-04) | 1.47(-04) |
| $^{34}\text{S}$ | 3.75(-04) | 7.53(-04) | 3.36(-04) | 3.09(-04) | 2.84(-04) | 2.53(-04) |
| $^{36}\text{S}$ | 1.04(-08) | 2.33(-08) | 1.40(-08) | 1.10(-08) | 1.40(-08) | 1.40(-08) |
| $^{35}\text{Cl}$ | 3.49(-05) | 5.04(-05) | 3.42(-05) | 3.95(-05) | 3.81(-05) | 3.73(-05) |
| $^{37}\text{Cl}$ | 1.00(-05) | 8.03(-06) | 5.06(-06) | 1.05(-05) | 9.78(-06) | 1.36(-05) |
| $^{36}\text{Ar}$ | 7.00(-03) | 8.94(-03) | 8.34(-03) | 1.61(-02) | 1.46(-02) | 2.33(-02) |
| $^{38}\text{Ar}$ | 2.92(-04) | 1.93(-04) | 7.28(-05) | 1.49(-04) | 8.05(-05) | 1.17(-04) |
| $^{40}\text{Ar}$ | 1.63(-09) | 2.16(-09) | 2.50(-09) | 2.85(-09) | 3.52(-09) | 3.88(-09) |
| $^{39}\text{K}$ | 3.74(-05) | 1.96(-05) | 2.18(-05) | 2.39(-05) | 1.64(-05) | 2.33(-05) |
| $^{40}\text{K}$ | 6.38(-09) | 1.25(-08) | 9.40(-09) | 1.25(-08) | 1.91(-08) | 2.25(-08) |
| $^{41}\text{K}$ | 2.77(-06) | 1.67(-06) | 1.32(-06) | 2.52(-06) | 2.43(-06) | 3.52(-06) |
| $^{40}\text{Ca}$ | 6.08(-03) | 7.71(-03) | 7.53(-03) | 1.42(-02) | 1.36(-02) | 2.11(-02) |
| $^{42}\text{Ca}$ | 1.01(-05) | 3.62(-06) | 1.58(-06) | 3.53(-06) | 1.64(-06) | 2.60(-06) |
| $^{43}\text{Ca}$ | 3.13(-07) | 3.40(-08) | 1.96(-07) | 2.43(-08) | 3.80(-08) | 4.64(-08) |
| $^{44}\text{Ca}$ | 1.74(-05) | 4.12(-05) | 6.70(-05) | 1.85(-05) | 2.78(-05) | 1.20(-05) |
| $^{46}\text{Ca}$ | 1.62(-10) | 2.00(-10) | 2.54(-10) | 3.11(-10) | 3.75(-10) | 4.29(-10) |
| $^{48}\text{Ca}$ | 7.99(-09) | 9.03(-09) | 1.23(-08) | 1.52(-08) | 1.85(-08) | 2.10(-08) |
| $^{45}\text{Sc}$ | 1.31(-07) | 7.54(-08) | 7.66(-08) | 1.34(-07) | 1.20(-07) | 1.85(-07) |
| $^{46}\text{Ti}$ | 8.04(-06) | 2.23(-06) | 1.40(-06) | 2.42(-06) | 1.00(-06) | 1.60(-06) |
| $^{47}\text{Ti}$ | 6.59(-07) | 1.43(-07) | 7.30(-07) | 9.63(-08) | 8.28(-08) | 7.80(-08) |
| $^{48}\text{Ti}$ | 1.22(-04) | 1.83(-04) | 2.07(-04) | 1.83(-04) | 1.83(-04) | 2.22(-04) |
| $^{49}\text{Ti}$ | 7.29(-06) | 4.88(-06) | 5.52(-06) | 8.12(-06) | 5.99(-06) | 9.27(-06) |
| Mass | 13  | 15  | 20  | 25  | 30  | 35  |
|------|-----|-----|-----|-----|-----|-----|
| Ti   | 1.01(-08) | 1.15(-08) | 1.77(-08) | 2.40(-08) | 3.38(-08) | 4.32(-08) |
| V    | 2.56(-10) | 2.86(-10) | 3.72(-10) | 7.89(-10) | 7.75(-10) | 2.06(-09) |
| Cr   | 2.10(-05) | 8.02(-06) | 1.16(-05) | 1.30(-05) | 7.56(-06) | 1.19(-05) |
| Cr   | 7.65(-05) | 1.57(-05) | 2.46(-05) | 2.54(-05) | 8.63(-06) | 1.59(-05) |
| Cr   | 1.76(-03) | 1.79(-03) | 1.57(-03) | 2.84(-03) | 2.51(-03) | 4.03(-03) |
| Cr   | 1.72(-04) | 1.10(-04) | 1.18(-04) | 1.81(-04) | 1.35(-04) | 2.14(-04) |
| Cr   | 4.32(-08) | 3.93(-08) | 6.62(-08) | 9.43(-08) | 1.36(-07) | 1.75(-07) |
| Mn   | 9.35(-04) | 3.99(-04) | 5.22(-04) | 6.50(-04) | 4.37(-04) | 7.01(-04) |
| Fe   | 5.58(-03) | 1.43(-03) | 2.43(-03) | 2.42(-03) | 1.06(-03) | 1.87(-03) |
| Fe   | 1.00(-01) | 1.00(-01) | 1.00(-01) | 1.00(-01) | 1.00(-01) | 1.00(-01) |
| Fe   | 3.37(-03) | 2.29(-03) | 2.93(-03) | 1.54(-03) | 1.65(-03) | 7.77(-04) |
| Fe   | 4.15(-07) | 5.42(-07) | 1.17(-06) | 1.89(-06) | 3.48(-06) | 5.06(-06) |
| Co   | 2.37(-04) | 3.50(-05) | 1.24(-04) | 1.24(-05) | 1.53(-05) | 5.97(-06) |
| Ni   | 8.91(-03) | 3.11(-04) | 1.15(-03) | 3.70(-04) | 2.76(-04) | 3.13(-04) |
| Ni   | 1.88(-03) | 2.35(-03) | 2.61(-03) | 1.05(-03) | 1.33(-03) | 8.04(-05) |
| Ni   | 1.50(-04) | 8.92(-05) | 1.20(-04) | 3.03(-05) | 4.09(-05) | 1.47(-06) |
| Ni   | 1.98(-03) | 2.08(-04) | 4.62(-04) | 5.52(-05) | 6.59(-05) | 2.83(-06) |
| Ni   | 4.43(-08) | 4.94(-08) | 7.14(-08) | 8.94(-08) | 1.14(-07) | 1.37(-07) |
| Cu   | 3.05(-06) | 1.68(-05) | 2.24(-06) | 1.13(-05) | 1.25(-05) | 1.53(-07) |
| Cu   | 1.91(-06) | 1.00(-06) | 1.29(-06) | 3.90(-07) | 7.05(-07) | 8.23(-08) |
| Zn   | 1.45(-05) | 7.01(-05) | 3.31(-05) | 3.57(-05) | 6.38(-05) | 3.39(-07) |
| Zn   | 5.96(-05) | 7.71(-06) | 1.28(-05) | 1.82(-06) | 3.24(-06) | 1.16(-07) |
| Zn   | 1.51(-07) | 1.34(-08) | 3.23(-08) | 1.27(-08) | 1.73(-08) | 1.82(-08) |
| Zn   | 1.12(-07) | 2.93(-08) | 4.35(-08) | 5.08(-08) | 6.48(-08) | 7.72(-08) |
| Zn   | 7.89(-10) | 9.57(-10) | 1.21(-09) | 1.48(-09) | 1.76(-09) | 2.01(-09) |
| Zn   | 2.60(-09) | 3.03(-09) | 4.43(-09) | 5.74(-09) | 7.53(-09) | 9.12(-09) |
| Ga   | 1.66(-09) | 1.90(-09) | 2.86(-09) | 3.76(-09) | 5.02(-09) | 6.19(-09) |
| Ge   | 2.85(-09) | 3.36(-09) | 5.07(-09) | 7.10(-09) | 9.27(-09) | 1.17(-08) |
| Ge   | 3.53(-09) | 4.10(-09) | 5.69(-09) | 7.21(-09) | 9.23(-09) | 1.10(-08) |
| Ge   | 1.00(-09) | 1.13(-09) | 1.64(-09) | 2.07(-09) | 2.64(-09) | 3.18(-09) |
| Ge   | 4.76(-09) | 5.39(-09) | 7.53(-09) | 9.39(-09) | 1.15(-08) | 1.36(-08) |
| Ge   | 1.01(-09) | 1.16(-09) | 1.54(-09) | 1.87(-09) | 2.19(-09) | 2.49(-09) |
| As   | 7.09(-10) | 8.39(-10) | 1.11(-09) | 1.37(-09) | 1.68(-09) | 1.95(-09) |
| Mass |  13  |  15  |   20  |   25  |   30  |   35  |
|------|------|------|-------|-------|-------|-------|
| 74Se | 6.55(-11) | 8.93(-11) | 1.09(-10) | 1.84(-10) | 2.05(-10) | 3.07(-10) |
| 76Se | 7.65(-10)  | 8.93(-10)  | 1.32(-09)  | 1.76(-09)  | 2.27(-09)  | 2.76(-09)  |
| 77Se | 5.48(-10)  | 6.29(-10)  | 9.06(-10)  | 1.14(-09)  | 1.42(-09)  | 1.67(-09)  |
| 78Se | 1.73(-09)  | 1.96(-09)  | 2.82(-09)  | 3.58(-09)  | 4.50(-09)  | 5.31(-09)  |
| 80Se | 3.54(-09)  | 4.02(-09)  | 5.37(-09)  | 6.49(-09)  | 7.60(-09)  | 8.58(-09)  |
| 82Se | 6.84(-10)  | 7.86(-10)  | 1.06(-09)  | 1.32(-09)  | 1.59(-09)  | 1.83(-09)  |
| 79Br | 6.62(-10)  | 7.52(-10)  | 1.03(-09)  | 1.29(-09)  | 1.56(-09)  | 1.81(-09)  |
| 81Br | 7.14(-10)  | 8.20(-10)  | 1.14(-09)  | 1.42(-09)  | 1.73(-09)  | 2.01(-09)  |
| 78Kr | 1.72(-11)  | 2.10(-11)  | 2.60(-11)  | 3.90(-11)  | 4.08(-11)  | 5.92(-11)  |
| 80Kr | 2.00(-10)  | 2.50(-10)  | 4.03(-10)  | 5.99(-10)  | 8.32(-10)  | 1.07(-09)  |
| 82Kr | 8.04(-10)  | 9.08(-10)  | 1.57(-09)  | 2.23(-09)  | 3.08(-09)  | 3.85(-09)  |
| 83Kr | 6.23(-10)  | 7.17(-10)  | 1.06(-09)  | 1.39(-09)  | 1.80(-09)  | 2.17(-09)  |
| 84Kr | 3.20(-09)  | 3.65(-09)  | 5.17(-09)  | 6.57(-09)  | 8.35(-09)  | 9.99(-09)  |
| 86Kr | 9.99(-10)  | 1.14(-09)  | 1.58(-09)  | 1.96(-09)  | 2.39(-09)  | 2.76(-09)  |
| 85Rb | 6.51(-10)  | 7.44(-10)  | 1.02(-09)  | 1.27(-09)  | 1.59(-09)  | 1.88(-09)  |
| 87Rb | 2.75(-10)  | 3.33(-10)  | 4.37(-10)  | 5.41(-10)  | 6.58(-10)  | 7.60(-10)  |
| 84Sr | 1.71(-11)  | 2.34(-11)  | 2.64(-11)  | 3.84(-11)  | 4.21(-11)  | 5.68(-11)  |
| 86Sr | 4.10(-10)  | 4.67(-10)  | 8.25(-10)  | 1.18(-09)  | 1.67(-09)  | 2.19(-09)  |
| 87Sr | 2.25(-10)  | 2.54(-10)  | 4.39(-10)  | 6.25(-10)  | 9.03(-10)  | 1.17(-09)  |
| 88Sr | 2.58(-09)  | 2.97(-09)  | 4.20(-09)  | 5.34(-09)  | 6.80(-09)  | 8.17(-09)  |
| 89Y  | 6.22(-10)  | 7.17(-10)  | 1.00(-09)  | 1.29(-09)  | 1.60(-09)  | 1.92(-09)  |
| 90Zr | 8.18(-10)  | 9.72(-10)  | 1.31(-09)  | 1.68(-09)  | 2.07(-09)  | 2.44(-09)  |
| 91Zr | 1.73(-10)  | 1.99(-10)  | 2.82(-10)  | 3.57(-10)  | 4.43(-10)  | 5.22(-10)  |
| 92Zr | 2.69(-10)  | 3.06(-10)  | 4.33(-10)  | 5.47(-10)  | 6.81(-10)  | 8.05(-10)  |
| 94Zr | 2.71(-10)  | 3.07(-10)  | 4.25(-10)  | 5.31(-10)  | 6.51(-10)  | 7.67(-10)  |
| 96Zr | 3.75(-11)  | 4.38(-11)  | 5.49(-11)  | 6.61(-11)  | 7.71(-11)  | 8.77(-11)  |
| 93Nb | 9.42(-11)  | 1.07(-10)  | 1.50(-10)  | 1.88(-10)  | 2.33(-10)  | 2.73(-10)  |
| 92Mo | 6.03(-11)  | 8.32(-11)  | 1.02(-10)  | 1.32(-10)  | 1.51(-10)  | 1.81(-10)  |
| 94Mo | 4.93(-11)  | 6.47(-11)  | 9.15(-11)  | 1.22(-10)  | 1.47(-10)  | 1.60(-10)  |
| 95Mo | 5.66(-11)  | 6.47(-11)  | 8.88(-11)  | 1.09(-10)  | 1.29(-10)  | 1.48(-10)  |
| 96Mo | 8.52(-11)  | 1.10(-10)  | 1.59(-10)  | 2.11(-10)  | 2.75(-10)  | 3.20(-10)  |
| 97Mo | 4.53(-11)  | 5.12(-11)  | 8.48(-11)  | 1.32(-10)  | 2.01(-10)  | 2.91(-10)  |
| 98Mo | 7.80(-09)  | 8.84(-09)  | 1.23(-08)  | 1.54(-08)  | 1.88(-08)  | 2.20(-08)  |
Table 1—Continued

| Mass | 13       | 15       | 20       | 25       | 30       | 35       |
|------|----------|----------|----------|----------|----------|----------|
|      |          |          |          |          |          |          |
| $^3$H | 1.15(-59)| 1.31(-59)| 1.81(-59)| 2.28(-59)| 2.77(-59)| 3.23(-59)|
| $^{14}$C | 1.45(-09)| 3.97(-09)| 1.05(-08)| 2.40(-08)| 2.52(-08)| 1.64(-08)|
| $^{22}$Na | 2.73(-07)| 2.96(-07)| 1.17(-06)| 8.98(-06)| 2.48(-06)| 1.51(-05)|
| $^{26}$Al | 7.00(-07)| 2.05(-06)| 1.65(-06)| 1.87(-06)| 2.17(-06)| 2.11(-06)|
| $^{32}$Si | 2.09(-11)| 6.04(-11)| 8.93(-11)| 4.89(-12)| 9.86(-12)| 3.07(-12)|
| $^{36}$Cl | 5.66(-08)| 1.56(-07)| 7.24(-08)| 4.70(-08)| 5.73(-08)| 4.43(-08)|
| $^{39}$Ar | 1.10(-09)| 3.03(-09)| 1.82(-09)| 1.86(-09)| 2.64(-09)| 3.02(-09)|
| $^{41}$Ca | 2.76(-06)| 1.65(-06)| 1.30(-06)| 2.50(-06)| 2.39(-06)| 3.48(-06)|
| $^{45}$Ca | 1.08(-11)| 9.77(-11)| 6.99(-11)| 1.03(-10)| 6.66(-11)| 2.41(-10)|
| $^{44}$Ti | 1.74(-05)| 4.12(-05)| 6.70(-05)| 1.84(-05)| 2.77(-05)| 1.18(-05)|
| $^{49}$V | 7.27(-06)| 4.86(-06)| 5.48(-06)| 8.07(-06)| 5.92(-06)| 9.18(-06)|
| $^{53}$Mn | 1.72(-04)| 1.10(-04)| 1.18(-04)| 1.81(-04)| 1.36(-04)| 2.15(-04)|
| $^{54}$Mn | 1.06(-08)| 1.95(-09)| 1.35(-09)| 2.45(-09)| 2.05(-09)| 2.68(-09)|
| $^{55}$Fe | 1.72(-04)| 6.91(-05)| 8.85(-05)| 1.13(-04)| 7.43(-05)| 1.19(-04)|
| $^{60}$Fe | 3.10(-11)| 1.99(-09)| 1.60(-10)| 1.45(-10)| 1.59(-10)| 2.29(-10)|
| $^{57}$Co | 1.72(-04)| 1.15(-04)| 1.47(-04)| 7.81(-05)| 8.39(-05)| 3.99(-05)|
| $^{60}$Co | 3.93(-10)| 3.39(-09)| 1.41(-09)| 1.80(-09)| 2.01(-09)| 3.95(-09)|
| $^{56}$Ni | 1.00(-01)| 1.00(-01)| 1.00(-01)| 1.00(-01)| 1.00(-01)| 1.00(-01)|
| $^{57}$Ni | 3.20(-03)| 2.18(-03)| 2.78(-03)| 1.46(-03)| 1.57(-03)| 7.28(-04)|
| $^{59}$Ni | 2.37(-04)| 3.47(-05)| 1.24(-04)| 1.17(-05)| 1.43(-05)| 4.63(-06)|
| $^{63}$Ni | 7.50(-10)| 1.88(-09)| 2.95(-09)| 4.60(-09)| 7.48(-09)| 8.89(-09)|
| $^{65}$Zn | 1.90(-06)| 9.85(-07)| 1.26(-06)| 3.47(-07)| 6.44(-07)| 6.52(-09)|
| $^{68}$Ge | 8.78(-08)| 1.75(-09)| 3.90(-09)| 4.59(-10)| 6.76(-10)| 1.73(-10)|
| $^{79}$Se | 1.13(-11)| 1.78(-11)| 5.61(-11)| 1.11(-10)| 1.17(-10)| 1.93(-10)|
| $^{81}$Kr | 3.29(-11)| 3.66(-11)| 9.24(-11)| 1.37(-10)| 1.90(-10)| 2.30(-10)|
| $^{85}$Kr | 8.36(-12)| 1.79(-11)| 3.80(-11)| 5.40(-11)| 8.52(-11)| 9.60(-11)|
| $^{90}$Sr | 1.78(-14)| 7.11(-13)| 8.57(-14)| 1.06(-13)| 1.15(-13)| 1.45(-13)|
| $^{93}$Zr | 6.14(-12)| 7.68(-12)| 2.19(-11)| 3.56(-11)| 5.66(-11)| 7.46(-11)|

Metallicity $Z = 10^{-3}$

$M_{\text{ejected}}$ 11.55 13.47 18.45 22.93 28.20 32.95
| Mass | 13 | 15 | 20 | 25 | 30 | 35 |
|------|----|----|----|----|----|----|
| $^56\text{Ni}$ | 0.1000 | 0.1000 | 0.1000 | 0.1000 | 0.1000 | 0.1000 |
| $^1\text{H}$ | 6.76 (+00) | 7.64 (+00) | 9.63 (+00) | 1.14 (+01) | 1.30 (+01) | 1.45 (+01) |
| $^2\text{H}$ | 1.73 (-16) | 1.88 (-16) | 2.29 (-16) | 2.73 (-16) | 3.13 (-16) | 3.43 (-16) |
| $^3\text{He}$ | 1.12 (-04) | 1.07 (-04) | 1.00 (-04) | 9.83 (-05) | 9.90 (-05) | 1.00 (-04) |
| $^4\text{He}$ | 3.81 (+00) | 4.39 (+00) | 5.79 (+00) | 7.11 (+00) | 8.55 (+00) | 1.00 (+01) |
| $^6\text{Li}$ | 3.09 (-11) | 3.32 (-11) | 3.60 (-11) | 3.73 (-11) | 3.74 (-11) | 3.87 (-11) |
| $^7\text{Li}$ | 2.44 (-17) | 1.44 (-16) | 5.85 (-14) | 7.06 (-13) | 1.96 (-12) | 3.57 (-12) |
| $^9\text{Be}$ | 8.48 (-12) | 8.49 (-12) | 9.23 (-12) | 9.77 (-12) | 9.59 (-12) | 9.94 (-12) |
| $^{10}\text{B}$ | 5.99 (-11) | 6.34 (-11) | 7.01 (-11) | 7.37 (-11) | 7.86 (-11) | 8.10 (-11) |
| $^{11}\text{B}$ | 4.52 (-10) | 5.01 (-10) | 6.11 (-10) | 7.08 (-10) | 7.98 (-10) | 8.84 (-10) |
| $^{12}\text{C}$ | 1.07 (-01) | 1.84 (-01) | 2.89 (-01) | 5.30 (-01) | 6.13 (-01) | 8.38 (-01) |
| $^{13}\text{C}$ | 5.02 (-05) | 5.73 (-05) | 7.37 (-05) | 8.86 (-05) | 1.04 (-04) | 1.20 (-04) |
| $^{14}\text{N}$ | 2.65 (-03) | 2.99 (-03) | 3.68 (-03) | 4.56 (-03) | 5.63 (-03) | 6.80 (-03) |
| $^{15}\text{N}$ | 7.68 (-07) | 8.55 (-07) | 1.05 (-06) | 1.33 (-06) | 1.37 (-06) | 1.60 (-06) |
| $^{16}\text{O}$ | 2.91 (-01) | 5.27 (-01) | 1.41 (+00) | 2.28 (+00) | 3.75 (+00) | 4.88 (+00) |
| $^{17}\text{O}$ | 1.58 (-05) | 1.61 (-05) | 1.46 (-05) | 1.43 (-05) | 1.17 (-05) | 1.11 (-05) |
| $^{18}\text{O}$ | 5.38 (-05) | 8.30 (-05) | 7.01 (-05) | 2.24 (-05) | 1.78 (-05) | 1.67 (-05) |
| $^{19}\text{F}$ | 1.92 (-07) | 2.28 (-07) | 4.77 (-07) | 9.46 (-07) | 9.30 (-07) | 1.30 (-06) |
| $^{20}\text{Ne}$ | 9.31 (-02) | 1.21 (-01) | 5.42 (-01) | 5.28 (-01) | 1.14 (+00) | 1.32 (+00) |
| $^{21}\text{Ne}$ | 1.57 (-05) | 2.50 (-05) | 6.93 (-05) | 9.54 (-05) | 1.95 (-04) | 2.11 (-04) |
| $^{22}\text{Ne}$ | 5.63 (-04) | 9.16 (-04) | 1.95 (+03) | 2.76 (+03) | 3.30 (+03) | 3.69 (+03) |
| $^{23}\text{Na}$ | 7.20 (-04) | 1.05 (-03) | 3.15 (-03) | 3.61 (-03) | 7.67 (-03) | 8.71 (-03) |
| $^{24}\text{Mg}$ | 4.52 (-02) | 6.37 (-02) | 1.57 (-01) | 1.52 (-01) | 2.27 (-01) | 2.30 (-01) |
| $^{25}\text{Mg}$ | 2.87 (-04) | 4.43 (-04) | 1.16 (-03) | 7.74 (-04) | 1.38 (-03) | 1.36 (-03) |
| $^{26}\text{Mg}$ | 4.46 (-04) | 6.08 (-04) | 1.97 (-03) | 1.38 (-03) | 2.71 (-03) | 2.84 (-03) |
| $^{27}\text{Al}$ | 1.11 (-03) | 1.52 (-03) | 4.41 (-03) | 3.70 (-03) | 6.71 (-03) | 7.58 (-03) |
| $^{28}\text{Si}$ | 5.30 (-02) | 1.04 (-01) | 1.05 (-01) | 2.41 (-01) | 1.61 (-01) | 2.22 (-01) |
| $^{29}\text{Si}$ | 4.08 (-04) | 6.78 (-04) | 8.81 (-04) | 9.94 (-04) | 1.06 (-03) | 9.87 (-04) |
| $^{30}\text{Si}$ | 3.71 (-04) | 5.84 (-04) | 7.30 (-04) | 6.40 (-04) | 7.51 (-04) | 6.65 (-04) |
| $^{31}\text{P}$ | 1.46 (-04) | 2.38 (-04) | 2.63 (-04) | 3.36 (-04) | 3.37 (-04) | 3.23 (-04) |
| $^{32}\text{S}$ | 2.21 (-02) | 4.60 (-02) | 4.43 (-02) | 1.13 (-01) | 6.98 (-02) | 1.07 (-01) |
| $^{33}\text{S}$ | 6.46 (-05) | 1.22 (-04) | 1.05 (-04) | 2.38 (-04) | 1.77 (-04) | 2.06 (-04) |
Table 1—Continued

| Mass | 13     | 15       | 20       | 25       | 30       | 35       |
|------|--------|----------|----------|----------|----------|----------|
| $^{34}\text{S}$ | 3.84(-04) | 7.16(-04) | 5.27(-04) | 8.33(-04) | 6.23(-04) | 6.11(-04) |
| $^{36}\text{S}$ | 6.83(-08) | 8.54(-08) | 1.12(-07) | 1.15(-07) | 1.52(-07) | 1.61(-07) |
| $^{35}\text{Cl}$ | 3.47(-05) | 5.65(-05) | 4.00(-05) | 8.72(-05) | 6.49(-05) | 7.46(-05) |
| $^{37}\text{Cl}$ | 4.14(-06) | 8.16(-06) | 7.04(-06) | 2.00(-05) | 1.70(-05) | 2.15(-05) |
| $^{36}\text{Ar}$ | 4.18(-03) | 8.65(-03) | 8.66(-03) | 2.14(-02) | 1.34(-02) | 2.12(-02) |
| $^{38}\text{Ar}$ | 8.78(-05) | 1.82(-04) | 1.08(-04) | 3.09(-04) | 1.75(-04) | 2.10(-04) |
| $^{40}\text{Ar}$ | 1.74(-08) | 2.04(-08) | 2.91(-08) | 3.39(-08) | 4.68(-08) | 5.60(-08) |
| $^{39}\text{K}$ | 3.09(-05) | 3.02(-05) | 1.90(-05) | 3.85(-05) | 2.84(-05) | 3.42(-05) |
| $^{40}\text{K}$ | 2.85(-08) | 4.73(-08) | 1.12(-07) | 1.73(-07) | 3.05(-07) | 3.88(-07) |
| $^{41}\text{K}$ | 1.28(-06) | 2.05(-06) | 1.98(-06) | 4.94(-06) | 4.78(-06) | 6.17(-06) |
| $^{40}\text{Ca}$ | 3.86(-03) | 7.65(-03) | 7.93(-03) | 1.86(-02) | 1.23(-02) | 1.88(-02) |
| $^{42}\text{Ca}$ | 2.24(-06) | 3.75(-06) | 2.98(-06) | 7.97(-06) | 6.92(-06) | 8.80(-06) |
| $^{43}\text{Ca}$ | 6.21(-07) | 3.34(-07) | 4.10(-07) | 5.92(-07) | 1.21(-06) | 1.63(-06) |
| $^{44}\text{Ca}$ | 7.84(-05) | 5.76(-05) | 4.64(-05) | 1.24(-05) | 4.59(-05) | 1.57(-05) |
| $^{46}\text{Ca}$ | 1.81(-09) | 2.21(-09) | 2.66(-09) | 3.39(-09) | 4.00(-09) | 4.82(-09) |
| $^{48}\text{Ca}$ | 7.93(-08) | 9.16(-08) | 1.24(-07) | 1.50(-07) | 1.86(-07) | 2.14(-07) |
| $^{45}\text{Sc}$ | 9.88(-08) | 1.27(-07) | 1.74(-07) | 3.71(-07) | 5.68(-07) | 8.82(-07) |
| $^{46}\text{Ti}$ | 1.99(-06) | 2.53(-06) | 1.49(-06) | 3.74(-06) | 2.64(-06) | 3.23(-06) |
| $^{47}\text{Ti}$ | 1.47(-06) | 9.22(-07) | 5.35(-07) | 3.51(-07) | 4.87(-07) | 5.32(-07) |
| $^{48}\text{Ti}$ | 2.16(-04) | 1.99(-04) | 1.77(-04) | 2.05(-04) | 2.00(-04) | 2.02(-04) |
| $^{49}\text{Ti}$ | 2.84(-06) | 5.53(-06) | 5.58(-06) | 1.03(-05) | 6.34(-06) | 9.99(-06) |
| $^{50}\text{Ti}$ | 1.11(-07) | 1.38(-07) | 2.86(-07) | 4.15(-07) | 7.17(-07) | 9.39(-07) |
| $^{51}\text{V}$ | 1.46(-09) | 2.24(-09) | 4.12(-09) | 6.80(-09) | 7.65(-09) | 1.16(-08) |
| $^{51}\text{V}$ | 5.17(-06) | 1.09(-05) | 1.07(-05) | 1.72(-05) | 9.52(-06) | 1.46(-05) |
| $^{50}\text{Cr}$ | 9.31(-06) | 2.04(-05) | 2.09(-05) | 3.08(-05) | 1.55(-05) | 2.44(-05) |
| $^{52}\text{Cr}$ | 9.45(-04) | 1.66(-03) | 1.57(-03) | 3.61(-03) | 2.28(-03) | 3.59(-03) |
| $^{53}\text{Cr}$ | 5.90(-05) | 1.26(-04) | 1.15(-04) | 2.29(-04) | 1.34(-04) | 2.18(-04) |
| $^{54}\text{Cr}$ | 3.57(-07) | 4.59(-07) | 9.81(-07) | 1.40(-06) | 2.35(-06) | 3.02(-06) |
| $^{55}\text{Mn}$ | 2.55(-04) | 5.77(-04) | 4.92(-04) | 8.79(-04) | 4.99(-04) | 7.91(-04) |
| $^{54}\text{Fe}$ | 9.53(-04) | 2.25(-03) | 2.15(-03) | 3.15(-03) | 1.64(-03) | 2.62(-03) |
| $^{56}\text{Fe}$ | 1.00(-01) | 1.00(-01) | 1.01(-01) | 1.01(-01) | 1.01(-01) | 1.01(-01) |
| $^{57}\text{Fe}$ | 3.68(-03) | 2.85(-03) | 2.77(-03) | 1.13(-03) | 2.00(-03) | 1.13(-03) |
| $^{58}\text{Fe}$ | 6.76(-06) | 1.04(-05) | 3.59(-05) | 5.74(-05) | 1.09(-04) | 1.43(-04) |
Table 1—Continued

| Mass | 13     | 15     | 20     | 25     | 30     | 35     |
|------|--------|--------|--------|--------|--------|--------|
| $^{59}$Co | 2.51(-04) | 1.50(-04) | 1.15(-04) | 3.54(-05) | 6.02(-05) | 5.96(-05) |
| $^{58}$Ni | 3.54(-03) | 2.03(-03) | 8.34(-04) | 5.05(-04) | 3.56(-04) | 4.46(-04) |
| $^{60}$Ni | 3.25(-03) | 2.31(-03) | 2.32(-03) | 2.58(-04) | 1.82(-03) | 3.41(-04) |
| $^{61}$Ni | 1.86(-04) | 1.13(-04) | 9.75(-05) | 9.98(-06) | 7.19(-05) | 2.05(-05) |
| $^{62}$Ni | 1.07(-03) | 5.44(-04) | 3.36(-04) | 2.51(-05) | 1.68(-04) | 5.51(-05) |
| $^{64}$Ni | 4.92(-07) | 5.86(-07) | 1.11(-06) | 1.77(-06) | 3.67(-06) | 5.46(-06) |
| $^{63}$Cu | 3.19(-06) | 2.03(-06) | 3.27(-06) | 2.14(-06) | 1.43(-05) | 5.89(-06) |
| $^{65}$Cu | 2.60(-06) | 1.47(-06) | 1.51(-06) | 1.32(-06) | 3.73(-06) | 4.62(-06) |
| $^{64}$Zn | 3.24(-05) | 2.18(-05) | 3.20(-05) | 3.22(-06) | 5.98(-05) | 7.08(-06) |
| $^{66}$Zn | 3.22(-05) | 1.44(-05) | 9.12(-06) | 1.66(-06) | 7.86(-06) | 4.35(-06) |
| $^{67}$Zn | 1.49(-07) | 9.89(-08) | 1.46(-07) | 2.30(-07) | 5.00(-07) | 7.66(-07) |
| $^{68}$Zn | 2.69(-07) | 3.08(-07) | 5.14(-07) | 8.03(-07) | 1.59(-06) | 2.44(-06) |
| $^{70}$Zn | 7.78(-09) | 8.92(-09) | 1.16(-08) | 1.38(-08) | 1.61(-08) | 1.84(-08) |
| $^{69}$Ga | 2.75(-08) | 3.40(-08) | 6.12(-08) | 1.09(-07) | 2.11(-07) | 3.27(-07) |
| $^{71}$Ga | 1.79(-08) | 2.20(-08) | 4.14(-08) | 6.60(-08) | 1.37(-07) | 2.16(-07) |
| $^{70}$Ge | 3.12(-08) | 3.98(-08) | 7.43(-08) | 1.60(-07) | 2.73(-07) | 4.48(-07) |
| $^{72}$Ge | 3.75(-08) | 4.54(-08) | 7.52(-08) | 1.17(-07) | 2.09(-07) | 3.14(-07) |
| $^{73}$Ge | 1.05(-08) | 1.25(-08) | 2.20(-08) | 3.29(-08) | 6.08(-08) | 9.18(-08) |
| $^{74}$Ge | 4.86(-08) | 5.70(-08) | 8.76(-08) | 1.23(-07) | 2.04(-07) | 2.92(-07) |
| $^{76}$Ge | 9.97(-09) | 1.13(-08) | 1.46(-08) | 1.73(-08) | 2.01(-08) | 2.29(-08) |
| $^{75}$As | 7.29(-09) | 8.66(-09) | 1.31(-08) | 1.93(-08) | 2.93(-08) | 4.03(-08) |
| $^{74}$Se | 7.05(-10) | 9.61(-10) | 1.36(-09) | 4.20(-09) | 3.97(-09) | 7.26(-09) |
| $^{76}$Se | 7.93(-09) | 9.81(-09) | 1.67(-08) | 2.95(-08) | 5.01(-08) | 7.59(-08) |
| $^{77}$Se | 5.56(-09) | 6.54(-09) | 1.06(-08) | 1.51(-08) | 2.56(-08) | 3.69(-08) |
| $^{78}$Se | 1.77(-08) | 2.08(-08) | 3.21(-08) | 4.59(-08) | 7.50(-08) | 1.04(-07) |
| $^{80}$Se | 3.54(-08) | 4.05(-08) | 5.19(-08) | 6.24(-08) | 7.39(-08) | 8.49(-08) |
| $^{82}$Se | 6.75(-09) | 7.77(-09) | 1.03(-08) | 1.23(-08) | 1.47(-08) | 1.68(-08) |
| $^{79}$Br | 6.80(-09) | 7.91(-09) | 1.15(-08) | 1.60(-08) | 2.33(-08) | 3.16(-08) |
| $^{81}$Br | 7.07(-09) | 8.23(-09) | 1.15(-08) | 1.52(-08) | 2.19(-08) | 2.90(-08) |
| $^{78}$Kr | 1.75(-10) | 2.12(-10) | 2.69(-10) | 4.96(-10) | 4.60(-10) | 7.56(-10) |
| $^{80}$Kr | 2.02(-09) | 2.60(-09) | 5.09(-09) | 8.82(-09) | 1.68(-08) | 2.54(-08) |
| $^{82}$Kr | 8.07(-09) | 9.30(-09) | 1.80(-08) | 2.87(-08) | 5.15(-08) | 7.59(-08) |
| $^{83}$Kr | 6.39(-09) | 7.56(-09) | 1.20(-08) | 1.67(-08) | 2.68(-08) | 3.72(-08) |
| Mass | 13  | 15  | 20   | 25   | 30   | 35   |
|------|-----|-----|------|------|------|------|
| \(^{84}\text{Kr}\) | 3.28(-08) | 3.89(-08) | 5.99(-08) | 8.11(-08) | 1.20(-07) | 1.60(-07) |
| \(^{86}\text{Kr}\) | 1.01(-08) | 1.17(-08) | 1.59(-08) | 1.95(-08) | 2.42(-08) | 2.83(-08) |
| \(^{85}\text{Rb}\) | 6.71(-09) | 7.90(-09) | 1.18(-08) | 1.53(-08) | 2.21(-08) | 2.87(-08) |
| \(^{87}\text{Rb}\) | 2.84(-09) | 3.43(-09) | 4.62(-09) | 6.02(-09) | 7.10(-09) | 8.41(-09) |
| \(^{84}\text{Sr}\) | 1.84(-10) | 2.51(-10) | 3.07(-10) | 5.46(-10) | 5.31(-10) | 6.59(-10) |
| \(^{86}\text{Sr}\) | 4.19(-09) | 5.42(-09) | 1.19(-08) | 1.91(-08) | 3.42(-08) | 4.91(-08) |
| \(^{88}\text{Sr}\) | 2.69(-08) | 3.23(-08) | 5.39(-08) | 8.01(-08) | 1.30(-07) | 1.76(-07) |
| \(^{87}\text{Y}\) | 6.38(-09) | 7.60(-09) | 1.19(-08) | 1.78(-08) | 2.74(-08) | 3.71(-08) |
| \(^{90}\text{Zr}\) | 8.21(-09) | 9.82(-09) | 1.37(-08) | 1.91(-08) | 2.54(-08) | 3.21(-08) |
| \(^{91}\text{Zr}\) | 1.74(-09) | 2.03(-09) | 2.98(-09) | 3.86(-09) | 5.49(-09) | 7.03(-09) |
| \(^{92}\text{Zr}\) | 2.70(-09) | 3.16(-09) | 4.56(-09) | 5.88(-09) | 8.07(-09) | 1.01(-08) |
| \(^{94}\text{Zr}\) | 2.72(-09) | 3.15(-09) | 4.50(-09) | 5.71(-09) | 7.65(-09) | 9.41(-09) |
| \(^{96}\text{Zr}\) | 3.75(-10) | 4.28(-10) | 5.50(-10) | 6.68(-10) | 7.73(-10) | 8.91(-10) |
| \(^{93}\text{Nb}\) | 9.52(-10) | 1.11(-09) | 1.62(-09) | 2.04(-09) | 2.78(-09) | 3.43(-09) |
| \(^{92}\text{Mo}\) | 6.18(-10) | 7.88(-10) | 9.88(-10) | 1.49(-09) | 1.50(-09) | 1.88(-09) |
| \(^{94}\text{Mo}\) | 4.90(-10) | 6.57(-10) | 9.02(-10) | 1.33(-09) | 1.40(-09) | 1.39(-09) |
| \(^{95}\text{Mo}\) | 5.59(-10) | 6.45(-10) | 8.86(-10) | 1.10(-09) | 1.38(-09) | 1.65(-09) |
| \(^{96}\text{Mo}\) | 8.64(-10) | 1.11(-09) | 1.50(-09) | 2.39(-09) | 2.83(-09) | 3.30(-09) |
| \(^{97}\text{Mo}\) | 5.11(-10) | 6.52(-10) | 1.17(-09) | 2.19(-09) | 3.97(-09) | 5.94(-09) |
| \(^{98}\text{Mo}\) | 7.74(-08) | 8.96(-08) | 1.24(-07) | 1.52(-07) | 1.91(-07) | 2.24(-07) |

Radioactive isotopes at \(t = 10^7\) s

\(^{3}\text{H}\) | 1.13(-59) | 1.32(-59) | 1.81(-59) | 2.25(-59) | 2.77(-59) | 3.24(-59) |
\(^{14}\text{C}\) | 2.36(-08) | 5.46(-08) | 8.86(-08) | 1.25(-07) | 8.87(-08) | 9.22(-08) |
\(^{22}\text{Na}\) | 2.50(-07) | 2.56(-07) | 1.69(-06) | 9.23(-06) | 2.52(-06) | 1.36(-05) |
\(^{26}\text{Al}\) | 1.09(-06) | 2.07(-06) | 2.19(-06) | 3.59(-06) | 2.93(-06) | 3.29(-06) |
\(^{32}\text{Si}\) | 5.78(-11) | 8.47(-11) | 2.01(-10) | 3.48(-11) | 5.90(-11) | 3.89(-11) |
\(^{36}\text{Cl}\) | 1.07(-07) | 1.84(-07) | 1.75(-07) | 2.25(-07) | 2.91(-07) | 3.04(-07) |
\(^{39}\text{Ar}\) | 1.23(-08) | 1.74(-08) | 2.98(-08) | 3.64(-08) | 5.10(-08) | 5.98(-08) |
\(^{41}\text{Ca}\) | 1.12(-06) | 1.86(-06) | 1.66(-06) | 4.52(-06) | 4.15(-06) | 5.42(-06) |
\(^{45}\text{Ca}\) | 4.86(-10) | 1.24(-09) | 2.54(-09) | 9.51(-09) | 4.13(-09) | 1.44(-08) |
\(^{44}\text{Ti}\) | 7.76(-05) | 5.66(-05) | 4.49(-05) | 1.04(-05) | 4.25(-05) | 1.12(-05) |
\(^{49}\text{V}\) | 2.72(-06) | 5.37(-06) | 5.30(-06) | 9.99(-06) | 5.86(-06) | 9.39(-06) |
Table 1—Continued

| Mass  | 13   | 15   | 20   | 25   | 30   | 35   |
|-------|------|------|------|------|------|------|
| $^{53}\text{Mn}$ | 5.81(-05) | 1.25(-04) | 1.14(-04) | 2.27(-04) | 1.32(-04) | 2.16(-04) |
| $^{54}\text{Mn}$ | 5.67(-09) | 9.77(-09) | 1.26(-08) | 1.95(-08) | 2.04(-08) | 2.31(-08) |
| $^{55}\text{Fe}$ | 4.26(-05) | 9.75(-05) | 8.18(-05) | 1.49(-04) | 8.37(-05) | 1.34(-04) |
| $^{60}\text{Fe}$ | 1.12(-08) | 2.12(-08) | 1.40(-08) | 3.24(-08) | 1.75(-08) | 3.01(-08) |
| $^{57}\text{Co}$ | 1.84(-04) | 1.42(-04) | 1.38(-04) | 5.68(-05) | 9.91(-05) | 5.54(-05) |
| $^{60}\text{Co}$ | 1.84(-08) | 4.86(-08) | 6.46(-08) | 1.86(-07) | 1.06(-07) | 1.96(-07) |
| $^{56}\text{Ni}$ | 1.00(-01) | 1.00(-01) | 1.00(-01) | 1.00(-01) | 1.00(-01) | 1.00(-01) |
| $^{57}\text{Ni}$ | 3.48(-03) | 2.69(-03) | 2.60(-03) | 1.02(-03) | 1.82(-03) | 9.85(-04) |
| $^{59}\text{Ni}$ | 2.49(-04) | 1.46(-04) | 1.04(-04) | 1.65(-05) | 2.52(-05) | 1.41(-05) |
| $^{63}\text{Ni}$ | 6.74(-08) | 9.16(-08) | 2.24(-07) | 3.60(-07) | 7.04(-07) | 9.70(-07) |
| $^{65}\text{Zn}$ | 2.41(-06) | 1.23(-06) | 9.16(-07) | 1.85(-07) | 9.39(-07) | 3.83(-07) |
| $^{68}\text{Ge}$ | 1.44(-08) | 5.08(-09) | 2.73(-09) | 2.39(-09) | 2.93(-09) | 3.64(-09) |
| $^{79}\text{Se}$ | 2.71(-10) | 4.26(-10) | 1.41(-09) | 3.59(-09) | 4.55(-09) | 1.02(-08) |
| $^{81}\text{Kr}$ | 3.16(-10) | 4.20(-10) | 1.34(-09) | 2.25(-09) | 4.99(-09) | 7.80(-09) |
| $^{85}\text{Kr}$ | 2.87(-10) | 4.40(-10) | 1.23(-09) | 1.74(-09) | 3.03(-09) | 4.04(-09) |
| $^{90}\text{Sr}$ | 2.50(-12) | 5.02(-12) | 6.09(-12) | 1.43(-11) | 1.18(-11) | 2.09(-11) |
| $^{93}\text{Zr}$ | 7.06(-11) | 1.06(-10) | 3.48(-10) | 5.19(-10) | 1.03(-09) | 1.45(-09) |

Metallicity $Z = 6 \cdot 10^{-3}$

| $M_{\text{ejected}}$ | 11.56 | 13.54 | 18.42 | 23.18 | 28.28 | 32.87 |
|----------------------|------|------|------|------|------|------|
| $M_{\text{remnant}}$ | 1.44 | 1.46 | 1.58 | 1.82 | 1.72 | 2.13 |
| $^{56}\text{Ni}$ | 0.1000 | 0.1000 | 0.1000 | 0.1000 | 0.1000 | 0.1000 |
| $^1\text{H}$ | 6.57(+00) | 7.38(+00) | 9.18(+00) | 1.08(+01) | 1.22(+01) | 1.38(+01) |
| $^2\text{H}$ | 1.65(-16) | 1.77(-16) | 2.06(-16) | 2.34(-16) | 2.60(-16) | 2.88(-16) |
| $^3\text{He}$ | 2.11(-04) | 2.20(-04) | 2.50(-04) | 2.80(-04) | 3.12(-04) | 3.44(-04) |
| $^4\text{He}$ | 4.10(+00) | 4.73(+00) | 6.20(+00) | 7.60(+00) | 9.00(+00) | 1.02(+01) |
| $^6\text{Li}$ | 2.68(-10) | 2.85(-10) | 3.01(-10) | 3.28(-10) | 3.51(-10) | 3.56(-10) |
| $^7\text{Li}$ | 1.33(-11) | 1.08(-11) | 4.94(-12) | 2.61(-12) | 2.58(-12) | 3.29(-12) |
| $^9\text{Be}$ | 6.86(-11) | 7.47(-11) | 8.06(-11) | 8.60(-11) | 9.07(-11) | 9.61(-11) |
| $^{10}\text{B}$ | 4.80(-10) | 5.05(-10) | 5.65(-10) | 6.15(-10) | 6.59(-10) | 7.05(-10) |
| $^{11}\text{B}$ | 3.52(-09) | 3.90(-09) | 4.80(-09) | 5.63(-09) | 6.42(-09) | 7.19(-09) |
| $^{12}\text{C}$ | 9.89(-02) | 1.67(-01) | 3.47(-01) | 6.28(-01) | 5.94(-01) | 9.38(-01) |
Table 1—Continued

| Mass  | 13     | 15     | 20     | 25     | 30     | 35     |
|-------|--------|--------|--------|--------|--------|--------|
| 13C   | 3.29(-04) | 3.77(-04) | 4.84(-04) | 5.83(-04) | 6.85(-04) | 7.86(-04) |
| 14N   | 1.47(-02) | 1.68(-02) | 2.02(-02) | 2.43(-02) | 2.90(-02) | 3.42(-02) |
| 15N   | 5.46(-06) | 6.07(-06) | 7.74(-06) | 9.15(-06) | 9.82(-06) | 1.14(-05) |
| 16O   | 2.68(-01) | 5.02(-01) | 1.38(+00) | 2.44(+00) | 3.90(+00) | 5.20(+00) |
| 17O   | 3.61(-05) | 3.60(-05) | 3.76(-05) | 4.31(-05) | 3.80(-05) | 4.71(-05) |
| 18O   | 6.08(-04) | 9.29(-04) | 7.12(-04) | 2.49(-04) | 1.39(-04) | 1.07(-04) |
| 19F   | 1.14(-06) | 1.29(-06) | 2.74(-06) | 4.98(-06) | 6.12(-06) | 8.96(-06) |
| 20Ne  | 8.19(-02) | 1.68(-01) | 4.79(-01) | 6.78(-01) | 1.36(+00) | 1.34(+00) |
| 21Ne  | 3.92(-05) | 7.41(-05) | 2.04(-04) | 3.60(-04) | 4.22(-04) | 5.21(-04) |
| 22Ne  | 2.92(-03) | 4.37(-03) | 1.17(-02) | 1.68(-02) | 2.04(-02) | 2.28(-02) |
| 23Na  | 1.24(-03) | 2.47(-03) | 7.65(-03) | 1.24(-02) | 1.71(-02) | 2.27(-02) |
| 24Mg  | 3.89(-02) | 6.58(-02) | 1.39(-01) | 1.24(-01) | 2.74(-01) | 2.18(-01) |
| 25Mg  | 1.19(-03) | 2.42(-03) | 5.02(-03) | 6.02(-03) | 9.14(-03) | 9.37(-03) |
| 26Mg  | 1.44(-03) | 2.57(-03) | 5.50(-03) | 8.33(-03) | 1.63(-02) | 1.84(-02) |
| 27Al  | 1.79(-03) | 3.57(-03) | 8.75(-03) | 1.36(-02) | 2.75(-02) | 3.05(-02) |
| 28Si  | 5.26(-02) | 1.05(-01) | 1.62(-01) | 2.24(-01) | 1.51(-01) | 2.56(-01) |
| 29Si  | 8.92(-04) | 1.38(-03) | 2.42(-03) | 2.26(-03) | 3.55(-03) | 3.51(-03) |
| 30Si  | 1.00(-03) | 1.45(-03) | 2.64(-03) | 2.08(-03) | 3.62(-03) | 3.42(-03) |
| 31P   | 2.89(-04) | 4.44(-04) | 7.65(-04) | 7.69(-04) | 1.03(-03) | 1.15(-03) |
| 32S   | 2.15(-02) | 5.13(-02) | 6.63(-02) | 1.22(-01) | 6.12(-02) | 1.21(-01) |
| 33S   | 1.06(-04) | 1.83(-04) | 2.98(-04) | 4.34(-04) | 3.17(-04) | 5.04(-04) |
| 34S   | 9.70(-04) | 1.39(-03) | 2.38(-03) | 2.29(-03) | 1.98(-03) | 3.14(-03) |
| 36S   | 5.62(-07) | 7.82(-07) | 1.32(-06) | 1.70(-06) | 2.33(-06) | 2.28(-06) |
| 35Cl  | 5.91(-05) | 1.06(-04) | 1.39(-04) | 2.63(-04) | 1.45(-04) | 2.56(-04) |
| 37Cl  | 1.07(-05) | 2.66(-05) | 3.94(-05) | 9.79(-05) | 7.66(-05) | 1.09(-04) |
| 36Ar  | 3.79(-03) | 9.62(-03) | 1.11(-02) | 2.31(-02) | 1.12(-02) | 2.23(-02) |
| 38Ar  | 2.38(-04) | 6.03(-04) | 6.66(-04) | 1.71(-03) | 5.31(-04) | 9.80(-04) |
| 40Ar  | 1.41(-07) | 1.83(-07) | 2.88(-07) | 4.54(-07) | 6.09(-07) | 7.20(-07) |
| 39K   | 4.83(-05) | 8.47(-05) | 6.82(-05) | 2.17(-04) | 7.48(-05) | 1.08(-04) |
| 40K   | 1.48(-07) | 2.69(-07) | 7.21(-07) | 1.25(-06) | 2.16(-06) | 2.91(-06) |
| 41K   | 2.95(-06) | 7.42(-06) | 8.45(-06) | 2.38(-05) | 1.45(-05) | 2.08(-05) |
| 40Ca  | 3.38(-03) | 8.15(-03) | 9.27(-03) | 1.90(-02) | 1.00(-02) | 1.90(-02) |
| 42Ca  | 6.18(-06) | 2.10(-05) | 2.05(-05) | 7.30(-05) | 3.47(-05) | 5.09(-05) |
| Mass | 13    | 15    | 20    | 25    | 30    | 35    |
|------|-------|-------|-------|-------|-------|-------|
| $^{43}$Ca | 1.18(-06) | 1.16(-06) | 2.94(-06) | 5.53(-06) | 9.31(-06) | 1.12(-05) |
| $^{44}$Ca | 9.26(-05) | 4.23(-05) | 3.76(-05) | 3.73(-05) | 7.76(-05) | 5.38(-05) |
| $^{46}$Ca | 1.82(-08) | 3.11(-08) | 3.38(-08) | 1.23(-07) | 7.81(-08) | 1.17(-07) |
| $^{48}$Ca | 4.81(-07) | 5.57(-07) | 7.47(-07) | 9.30(-07) | 1.13(-06) | 1.30(-06) |
| $^{45}$Sc | 3.29(-07) | 6.34(-07) | 1.33(-06) | 3.39(-06) | 7.06(-06) | 7.06(-06) |
| $^{46}$Ti | 3.94(-06) | 1.59(-05) | 9.30(-06) | 4.01(-05) | 1.29(-05) | 2.07(-05) |
| $^{47}$Ti | 2.28(-06) | 1.62(-06) | 2.17(-06) | 3.12(-06) | 4.77(-06) | 5.76(-06) |
| $^{48}$Ti | 2.33(-04) | 1.51(-04) | 1.53(-04) | 1.81(-04) | 2.25(-04) | 2.22(-04) |
| $^{49}$Ti | 3.44(-06) | 8.20(-06) | 9.86(-06) | 1.31(-05) | 1.19(-05) | 1.80(-05) |
| $^{50}$Ti | 7.34(-07) | 9.99(-07) | 2.11(-06) | 3.82(-06) | 6.68(-06) | 9.02(-06) |
| $^{50}$V | 1.14(-08) | 2.07(-08) | 5.64(-08) | 9.61(-08) | 1.08(-07) | 1.85(-07) |
| $^{51}$V | 7.40(-06) | 2.18(-05) | 2.46(-05) | 2.89(-05) | 1.92(-05) | 3.10(-05) |
| $^{50}$Cr | 2.10(-05) | 1.02(-04) | 8.58(-05) | 1.13(-04) | 4.88(-05) | 7.65(-05) |
| $^{52}$Cr | 8.80(-04) | 1.62(-03) | 1.95(-03) | 2.84(-03) | 2.31(-03) | 3.79(-03) |
| $^{53}$Cr | 6.11(-05) | 1.73(-04) | 1.99(-04) | 2.45(-04) | 1.87(-04) | 2.94(-04) |
| $^{54}$Cr | 2.24(-06) | 3.16(-06) | 6.53(-06) | 1.05(-05) | 1.62(-05) | 1.98(-05) |
| $^{55}$Mn | 2.93(-04) | 9.53(-04) | 1.10(-03) | 1.25(-03) | 8.31(-04) | 1.42(-03) |
| $^{54}$Fe | 1.72(-03) | 7.07(-03) | 7.23(-03) | 7.41(-03) | 4.37(-03) | 6.96(-03) |
| $^{56}$Fe | 1.04(-01) | 1.04(-01) | 1.06(-01) | 1.07(-01) | 1.08(-01) | 1.09(-01) |
| $^{57}$Fe | 3.93(-03) | 3.20(-03) | 2.78(-03) | 2.09(-03) | 2.89(-03) | 1.66(-03) |
| $^{58}$Fe | 5.07(-05) | 9.26(-05) | 2.60(-04) | 4.42(-04) | 7.13(-04) | 8.58(-04) |
| $^{59}$Co | 2.94(-04) | 2.15(-04) | 2.27(-04) | 2.67(-04) | 3.90(-04) | 3.74(-04) |
| $^{58}$Ni | 3.64(-03) | 3.51(-03) | 2.93(-03) | 1.57(-03) | 1.41(-03) | 1.28(-03) |
| $^{60}$Ni | 3.60(-03) | 2.05(-03) | 1.66(-03) | 1.06(-03) | 2.22(-03) | 6.36(-04) |
| $^{61}$Ni | 2.10(-04) | 1.04(-04) | 1.02(-04) | 9.27(-05) | 1.95(-04) | 1.43(-04) |
| $^{62}$Ni | 1.24(-03) | 6.51(-04) | 5.13(-04) | 3.51(-04) | 6.90(-04) | 5.62(-04) |
| $^{64}$Ni | 4.32(-06) | 5.93(-06) | 1.56(-05) | 3.67(-05) | 7.37(-05) | 1.03(-04) |
| $^{63}$Cu | 7.43(-06) | 6.65(-06) | 1.41(-05) | 3.97(-05) | 6.16(-05) | 7.95(-05) |
| $^{65}$Cu | 4.47(-06) | 3.41(-06) | 1.02(-05) | 2.37(-05) | 5.55(-05) | 8.18(-05) |
| $^{64}$Zn | 4.44(-05) | 1.88(-05) | 1.91(-05) | 2.28(-05) | 5.79(-05) | 5.36(-05) |
| $^{66}$Zn | 4.22(-05) | 1.75(-05) | 1.95(-05) | 3.02(-05) | 6.12(-05) | 8.31(-05) |
| $^{67}$Zn | 5.40(-07) | 6.16(-07) | 1.93(-06) | 6.33(-06) | 1.35(-05) | 1.96(-05) |
| $^{68}$Zn | 1.91(-06) | 2.55(-06) | 7.01(-06) | 2.05(-05) | 4.34(-05) | 6.70(-05) |
Table 1—Continued

| Mass | 13       | 15       | 20       | 25       | 30       | 35       |
|------|----------|----------|----------|----------|----------|----------|
| 70Zn | 4.87(-08)| 5.81(-08)| 9.13(-08)| 1.73(-07)| 1.67(-07)| 2.70(-07)|
| 69Ga | 2.08(-07)| 2.94(-07)| 8.77(-07)| 2.83(-06)| 5.63(-06)| 9.00(-06)|
| 71Ga | 1.49(-07)| 2.08(-07)| 6.97(-07)| 2.04(-06)| 4.70(-06)| 7.47(-06)|
| 70Ge | 2.36(-07)| 3.33(-07)| 1.02(-06)| 3.50(-06)| 6.92(-06)| 1.16(-05)|
| 72Ge | 2.83(-07)| 3.83(-07)| 1.01(-06)| 2.96(-06)| 6.15(-06)| 1.04(-05)|
| 73Ge | 7.77(-08)| 1.04(-07)| 2.72(-07)| 9.18(-07)| 2.07(-06)| 3.34(-06)|
| 74Ge | 3.42(-07)| 4.32(-07)| 9.20(-07)| 2.46(-06)| 5.21(-06)| 8.73(-06)|
| 76Ge | 6.07(-08)| 6.98(-08)| 9.19(-08)| 1.29(-07)| 1.41(-07)| 1.85(-07)|
| 75As | 5.09(-08)| 6.63(-08)| 1.51(-07)| 4.39(-07)| 7.65(-07)| 1.30(-06)|
| 74Se | 4.67(-09)| 6.61(-09)| 1.69(-08)| 5.60(-08)| 3.44(-08)| 1.42(-07)|
| 76Se | 5.80(-08)| 7.72(-08)| 1.90(-07)| 5.70(-07)| 1.19(-06)| 2.20(-06)|
| 77Se | 3.93(-08)| 5.15(-08)| 1.18(-07)| 3.58(-07)| 7.51(-07)| 1.27(-06)|
| 78Se | 1.20(-07)| 1.49(-07)| 3.04(-07)| 7.69(-07)| 1.75(-06)| 2.92(-06)|
| 80Se | 2.32(-07)| 2.78(-07)| 4.03(-07)| 8.78(-07)| 1.10(-06)| 1.61(-06)|
| 82Se | 4.10(-08)| 4.75(-08)| 6.32(-08)| 8.43(-08)| 9.04(-08)| 1.14(-07)|
| 79Br | 4.60(-08)| 5.83(-08)| 1.08(-07)| 3.27(-07)| 6.16(-07)| 1.08(-06)|
| 81Br | 4.52(-08)| 5.32(-08)| 8.86(-08)| 1.82(-07)| 3.50(-07)| 5.18(-07)|
| 78Kr | 1.07(-09)| 1.26(-09)| 1.87(-09)| 3.80(-09)| 3.12(-09)| 7.02(-09)|
| 80Kr | 1.31(-08)| 1.59(-08)| 4.93(-08)| 8.94(-08)| 3.18(-07)| 4.80(-07)|
| 82Kr | 5.23(-08)| 6.48(-08)| 1.51(-07)| 3.45(-07)| 1.02(-06)| 1.80(-06)|
| 83Kr | 4.13(-08)| 5.06(-08)| 1.02(-07)| 2.25(-07)| 5.62(-07)| 9.71(-07)|
| 84Kr | 2.09(-07)| 2.55(-07)| 4.67(-07)| 9.40(-07)| 2.13(-06)| 3.52(-06)|
| 86Kr | 6.83(-08)| 8.24(-08)| 1.27(-07)| 2.19(-07)| 2.86(-07)| 3.84(-07)|
| 85Rb | 4.46(-08)| 5.53(-08)| 9.93(-08)| 2.26(-07)| 4.50(-07)| 7.02(-07)|
| 87Rb | 2.07(-08)| 2.83(-08)| 5.12(-08)| 1.17(-07)| 1.30(-07)| 2.77(-07)|
| 84Sr | 1.17(-09)| 1.43(-09)| 2.38(-09)| 6.75(-09)| 4.33(-09)| 9.36(-09)|
| 86Sr | 2.58(-08)| 3.47(-08)| 9.07(-08)| 1.90(-07)| 5.57(-07)| 1.01(-06)|
| 87Sr | 1.53(-08)| 2.10(-08)| 5.59(-08)| 1.27(-07)| 3.60(-07)| 6.28(-07)|
| 88Sr | 1.75(-07)| 2.24(-07)| 4.56(-07)| 9.15(-07)| 1.84(-06)| 2.98(-06)|
| 89Y  | 4.08(-08)| 5.06(-08)| 9.62(-08)| 1.92(-07)| 3.56(-07)| 5.52(-07)|
| 90Zr | 5.05(-08)| 6.13(-08)| 9.72(-08)| 1.82(-07)| 2.49(-07)| 3.62(-07)|
| 91Zr | 1.08(-08)| 1.31(-08)| 2.15(-08)| 4.04(-08)| 6.63(-08)| 9.51(-08)|
| 92Zr | 1.68(-08)| 2.01(-08)| 3.14(-08)| 5.14(-08)| 8.23(-08)| 1.15(-07)|
Table 1—Continued

| Mass | 13   | 15   | 20   | 25   | 30   | 35   |
|------|------|------|------|------|------|------|
| 94Zr | 1.67(-08) | 1.97(-08) | 2.87(-08) | 4.26(-08) | 6.42(-08) | 8.65(-08) |
| 96Zr | 2.37(-09) | 2.80(-09) | 3.50(-09) | 6.17(-09) | 5.68(-09) | 7.58(-09) |
| 93Nb | 5.93(-09) | 7.12(-09) | 1.11(-08) | 1.87(-08) | 3.01(-08) | 4.07(-08) |
| 92Mo | 3.69(-09) | 4.45(-09) | 6.79(-09) | 8.00(-09) | 9.22(-09) | 1.14(-08) |
| 94Mo | 2.88(-09) | 3.72(-09) | 5.80(-09) | 7.16(-09) | 8.49(-09) | 9.36(-09) |
| 95Mo | 3.43(-09) | 4.10(-09) | 5.66(-09) | 8.92(-09) | 9.15(-09) | 1.61(-08) |
| 96Mo | 5.07(-09) | 6.60(-09) | 1.06(-08) | 1.40(-08) | 2.00(-08) | 2.49(-08) |
| 97Mo | 3.31(-09) | 4.15(-09) | 7.67(-09) | 1.29(-08) | 2.68(-08) | 4.31(-08) |
| 98Mo | 4.68(-07) | 5.46(-07) | 7.48(-07) | 9.58(-07) | 1.20(-06) | 1.40(-06) |

Radioactive isotopes at $t = 10^7$ s

| Element | Mass   | 13   | 15   | 20   | 25   | 30   | 35   |
|---------|--------|------|------|------|------|------|------|
| 3H      | 1.14(-59) | 1.34(-59) | 1.82(-59) | 2.29(-59) | 2.79(-59) | 3.25(-59) |
| 14C     | 6.62(-08) | 2.27(-07) | 8.57(-07) | 1.71(-06) | 4.73(-07) | 1.01(-06) |
| 22Na    | 2.12(-07) | 1.21(-06) | 9.39(-07) | 4.50(-06) | 1.50(-05) |
| 26Al    | 2.61(-06) | 4.42(-06) | 8.30(-06) | 9.76(-06) | 7.40(-06) |
| 32Si    | 1.26(-09) | 2.34(-09) | 3.17(-09) | 4.57(-09) | 8.68(-09) | 4.76(-09) |
| 36Cl    | 4.52(-07) | 7.41(-07) | 1.33(-06) | 1.58(-06) | 2.30(-06) | 2.86(-06) |
| 39Ar    | 1.47(-07) | 2.58(-07) | 5.53(-07) | 1.05(-06) | 1.12(-06) | 1.22(-06) |
| 41Ca    | 1.93(-06) | 6.13(-06) | 6.26(-06) | 2.05(-05) | 9.70(-06) | 1.48(-05) |
| 45Ca    | 8.86(-09) | 5.76(-08) | 5.81(-08) | 4.36(-07) | 3.00(-07) | 6.97(-07) |
| 44Ti    | 8.72(-05) | 3.58(-05) | 2.58(-05) | 1.64(-05) | 4.35(-05) | 1.02(-05) |
| 49V     | 2.73(-06) | 6.60(-06) | 8.32(-06) | 1.07(-05) | 7.99(-06) | 1.25(-05) |
| 53Mn    | 5.52(-05) | 1.67(-04) | 1.90(-04) | 2.35(-04) | 1.75(-04) | 2.80(-04) |
| 54Mn    | 3.39(-08) | 6.51(-08) | 9.48(-08) | 1.13(-07) | 1.09(-07) | 1.54(-07) |
| 55Fe    | 4.57(-05) | 9.44(-05) | 1.87(-04) | 2.26(-04) | 1.37(-04) | 2.42(-04) |
| 60Fe    | 3.20(-07) | 8.30(-07) | 5.82(-07) | 3.26(-06) | 1.11(-06) | 2.02(-06) |
| 57Co    | 1.92(-04) | 6.54(-05) | 1.31(-04) | 9.56(-05) | 1.30(-04) | 6.53(-05) |
| 60Co    | 3.83(-07) | 1.10(-06) | 1.75(-06) | 4.20(-06) | 2.65(-06) | 5.55(-06) |
| 56Ni    | 1.00(-01) | 1.00(-01) | 1.00(-01) | 1.00(-01) | 1.00(-01) |
| 57Ni    | 3.62(-03) | 2.99(-03) | 2.41(-03) | 1.68(-03) | 2.37(-03) | 1.14(-03) |
| 59Ni    | 2.68(-04) | 1.71(-04) | 1.13(-04) | 6.50(-05) | 9.16(-05) | 2.62(-05) |
| 63Ni    | 1.42(-06) | 2.58(-06) | 6.20(-06) | 2.70(-05) | 3.15(-05) | 3.95(-05) |
| 65Zn    | 2.86(-06) | 1.04(-06) | 1.14(-06) | 2.63(-06) | 4.35(-06) | 7.94(-06) |
| 68Ge    | 2.12(-08) | 7.11(-09) | 4.07(-09) | 5.31(-09) | 4.42(-09) | 7.60(-09) |
| Mass | 13   | 15   | 20   | 25   | 30   | 35   |
|------|------|------|------|------|------|------|
| Se   | 5.06E-09 | 1.28E-08 | 3.80E-08 | 2.38E-07 | 3.98E-07 | 8.67E-07 |
| Kr   | 2.00E-09 | 2.29E-09 | 1.30E-08 | 2.58E-08 | 1.38E-07 | 1.98E-07 |
| Kr   | 5.06E-09 | 9.25E-09 | 2.96E-08 | 1.17E-07 | 2.30E-07 | 3.55E-07 |
| Sr   | 1.11E-10 | 3.16E-10 | 4.29E-10 | 4.04E-09 | 2.09E-09 | 5.21E-09 |
| Zr   | 5.39E-10 | 1.00E-09 | 3.38E-09 | 9.63E-09 | 1.96E-08 | 2.88E-08 |

Table 1—Continued

Metallicity $Z = 2 \cdot 10^{-2}$

| $M_{ejected}$ | 11.58 | 13.37 | 18.39 | 23.20 | 28.27 | 32.90 |
|---------------|-------|-------|-------|-------|-------|-------|
| $M_{remnant}$ | 1.42  | 1.63  | 1.61  | 1.80  | 1.73  | 2.10  |
| $^{56}\text{Ni}$ | 0.1000 | 0.1000 | 0.1000 | 0.1000 | 0.1000 | 0.1000 |
| $^1\text{H}$    | 6.22E+00 | 7.02E+00 | 8.73E+00 | 1.02E+01 | 1.18E+01 | 1.32E+01 |
| $^2\text{H}$    | 1.55E-16 | 1.63E-16 | 1.89E-16 | 2.17E-16 | 2.42E-16 | 2.64E-16 |
| $^3\text{He}$   | 4.83E-04 | 5.63E-04 | 6.90E-04 | 8.08E-04 | 9.26E-04 | 1.04E-03 |
| $^4\text{He}$   | 4.37E+00 | 4.92E+00 | 6.47E+00 | 7.87E+00 | 9.22E+00 | 1.05E+01 |
| $^6\text{Li}$   | 7.29E-10 | 1.07E-09 | 1.18E-09 | 1.30E-09 | 1.37E-09 | 1.41E-09 |
| $^7\text{Li}$   | 5.52E-11 | 1.33E-10 | 1.03E-10 | 7.12E-11 | 4.84E-11 | 3.25E-11 |
| $^9\text{Be}$   | 1.94E-10 | 2.75E-10 | 3.06E-10 | 3.35E-10 | 3.52E-10 | 3.79E-10 |
| $^{10}\text{B}$ | 1.32E-09 | 1.85E-09 | 2.11E-09 | 2.31E-09 | 2.51E-09 | 2.70E-09 |
| $^{11}\text{B}$ | 1.16E-08 | 1.46E-08 | 1.82E-08 | 2.14E-08 | 2.46E-08 | 2.76E-08 |
| $^{12}\text{C}$ | 1.06E-01 | 2.05E-01 | 3.15E-01 | 6.07E-01 | 6.45E-01 | 9.37E-01 |
| $^{13}\text{C}$ | 1.16E-03 | 1.31E-03 | 1.69E-03 | 2.03E-03 | 2.39E-03 | 2.71E-03 |
| $^{14}\text{N}$ | 4.62E-02 | 5.07E-02 | 6.22E-02 | 7.19E-02 | 8.57E-02 | 1.02E-01 |
| $^{15}\text{N}$ | 1.82E-05 | 2.19E-05 | 3.00E-05 | 3.44E-05 | 3.65E-05 | 4.18E-05 |
| $^{16}\text{O}$ | 3.05E-01 | 5.16E-01 | 1.38E+00 | 2.44E+00 | 3.89E+00 | 5.22E+00 |
| $^{17}\text{O}$ | 1.66E-04 | 1.55E-04 | 1.38E-04 | 1.47E-04 | 1.52E-04 | 1.72E-04 |
| $^{18}\text{O}$ | 3.40E-03 | 4.19E-03 | 5.72E-03 | 3.71E-03 | 9.94E-04 | 5.07E-04 |
| $^{19}\text{F}$ | 3.54E-06 | 4.19E-06 | 7.62E-06 | 1.49E-05 | 2.19E-05 | 2.69E-05 |
| $^{20}\text{Ne}$ | 5.59E-02 | 3.60E-02 | 5.35E-01 | 7.17E-01 | 1.30E+00 | 1.29E+00 |
| $^{21}\text{Ne}$ | 6.25E-05 | 8.70E-05 | 4.32E-04 | 7.81E-04 | 9.40E-04 | 1.08E-03 |
| $^{22}\text{Ne}$ | 8.59E-03 | 1.30E-02 | 3.01E-02 | 5.12E-02 | 6.59E-02 | 7.09E-02 |
| $^{23}\text{Na}$ | 1.25E-03 | 1.38E-03 | 1.30E-02 | 2.42E-02 | 3.98E-02 | 4.54E-02 |
| $^{24}\text{Mg}$ | 3.66E-02 | 3.39E-02 | 1.33E-01 | 1.29E-01 | 2.21E-01 | 1.95E-01 |
| Mass | 13   | 15   | 20   | 25   | 30   | 35   |
|------|------|------|------|------|------|------|
| $^{25}\text{Mg}$ | 2.65(-03) | 2.06(-03) | 1.76(-02) | 2.35(-02) | 3.20(-02) | 3.49(-02) |
| $^{26}\text{Mg}$ | 3.45(-03) | 4.11(-03) | 1.83(-02) | 3.07(-02) | 5.23(-02) | 7.12(-02) |
| $^{27}\text{Al}$ | 2.28(-03) | 1.73(-03) | 1.88(-02) | 3.09(-02) | 5.79(-02) | 6.90(-02) |
| $^{28}\text{Si}$ | 6.78(-02) | 1.31(-01) | 1.56(-01) | 2.45(-01) | 1.90(-01) | 2.77(-01) |
| $^{29}\text{Si}$ | 2.46(-03) | 3.45(-03) | 5.66(-03) | 6.79(-03) | 9.11(-03) | 1.09(-02) |
| $^{30}\text{Si}$ | 2.96(-03) | 4.07(-03) | 6.07(-03) | 6.55(-03) | 9.93(-03) | 1.09(-02) |
| $^{31}\text{P}$ | 6.17(-04) | 1.01(-03) | 1.41(-03) | 1.78(-03) | 2.39(-03) | 2.86(-03) |
| $^{32}\text{S}$ | 2.79(-02) | 6.06(-02) | 6.62(-02) | 1.24(-01) | 7.80(-02) | 1.26(-01) |
| $^{33}\text{S}$ | 1.98(-04) | 3.95(-04) | 4.49(-04) | 7.67(-04) | 7.38(-04) | 1.00(-03) |
| $^{34}\text{S}$ | 2.26(-03) | 4.73(-03) | 4.64(-03) | 6.16(-03) | 6.74(-03) | 9.27(-03) |
| $^{36}\text{S}$ | 3.40(-06) | 6.03(-06) | 9.13(-06) | 1.22(-05) | 1.74(-05) | 1.93(-05) |
| $^{35}\text{Cl}$ | 9.20(-05) | 1.88(-04) | 2.12(-04) | 4.45(-04) | 3.47(-04) | 4.93(-04) |
| $^{37}\text{Cl}$ | 2.95(-05) | 4.78(-05) | 1.15(-04) | 2.46(-04) | 2.94(-04) | 3.84(-04) |
| $^{36}\text{Ar}$ | 4.65(-03) | 9.99(-03) | 1.08(-02) | 2.13(-02) | 1.27(-02) | 2.08(-02) |
| $^{38}\text{Ar}$ | 7.01(-04) | 1.59(-03) | 1.39(-03) | 3.92(-03) | 2.14(-03) | 3.09(-03) |
| $^{40}\text{Ar}$ | 5.79(-07) | 1.12(-06) | 1.99(-06) | 2.95(-06) | 3.59(-06) | 4.40(-06) |
| $^{39}\text{K}$ | 9.43(-05) | 1.10(-04) | 1.45(-04) | 3.67(-04) | 2.01(-04) | 2.61(-04) |
| $^{40}\text{K}$ | 4.20(-07) | 6.46(-07) | 2.00(-06) | 3.63(-06) | 6.26(-06) | 8.27(-06) |
| $^{41}\text{K}$ | 7.23(-06) | 1.06(-05) | 1.99(-05) | 4.39(-05) | 4.00(-05) | 5.21(-05) |
| $^{40}\text{Ca}$ | 3.99(-03) | 8.23(-03) | 8.56(-03) | 1.64(-02) | 1.06(-02) | 1.66(-02) |
| $^{42}\text{Ca}$ | 1.86(-05) | 3.79(-05) | 5.27(-05) | 1.70(-04) | 1.15(-04) | 1.61(-04) |
| $^{43}\text{Ca}$ | 2.96(-06) | 2.78(-06) | 9.86(-06) | 1.78(-05) | 2.91(-05) | 3.68(-05) |
| $^{44}\text{Ca}$ | 1.09(-04) | 6.37(-05) | 8.53(-05) | 1.00(-04) | 1.54(-04) | 1.68(-04) |
| $^{46}\text{Ca}$ | 1.00(-07) | 7.67(-07) | 5.41(-07) | 2.10(-06) | 1.22(-06) | 2.37(-06) |
| $^{48}\text{Ca}$ | 1.60(-06) | 1.89(-06) | 2.49(-06) | 3.11(-06) | 3.78(-06) | 4.35(-06) |
| $^{45}\text{Sc}$ | 1.03(-06) | 1.87(-06) | 5.42(-06) | 1.26(-05) | 1.79(-05) | 2.55(-05) |
| $^{46}\text{Ti}$ | 9.72(-06) | 1.69(-05) | 2.48(-05) | 8.26(-05) | 4.59(-05) | 6.49(-05) |
| $^{47}\text{Ti}$ | 5.10(-06) | 5.11(-06) | 7.49(-06) | 1.18(-05) | 1.78(-05) | 2.28(-05) |
| $^{48}\text{Ti}$ | 2.52(-04) | 2.06(-04) | 1.81(-04) | 2.04(-04) | 2.30(-04) | 2.45(-04) |
| $^{49}\text{Ti}$ | 6.66(-06) | 1.26(-05) | 1.52(-05) | 2.31(-05) | 2.68(-05) | 3.86(-05) |
| $^{50}\text{Ti}$ | 2.58(-06) | 3.36(-06) | 8.66(-06) | 1.59(-05) | 2.75(-05) | 3.84(-05) |
| $^{50}\text{V}$ | 3.88(-08) | 1.31(-07) | 2.01(-07) | 4.02(-07) | 4.52(-07) | 6.90(-07) |
| $^{51}\text{V}$ | 1.75(-05) | 3.35(-05) | 3.60(-05) | 5.15(-05) | 4.11(-05) | 6.30(-05) |
Table 1—Continued

| Mass | 13  | 15  | 20  | 25  | 30  | 35  |
|------|-----|-----|-----|-----|-----|-----|
| $^{50}$Cr | 6.54(-05) | 1.32(-04) | 1.77(-04) | 2.53(-04) | 1.36(-04) | 2.26(-04) |
| $^{52}$Cr | 1.10(-03) | 2.04(-03) | 1.78(-03) | 2.61(-03) | 2.49(-03) | 3.55(-03) |
| $^{53}$Cr | 1.13(-04) | 2.42(-04) | 2.37(-04) | 3.31(-04) | 2.82(-04) | 4.12(-04) |
| $^{54}$Cr | 7.55(-06) | 9.44(-06) | 2.28(-05) | 3.59(-05) | 5.32(-05) | 6.56(-05) |
| $^{55}$Mn | 6.56(-04) | 1.36(-03) | 1.34(-03) | 1.95(-03) | 1.64(-03) | 2.45(-03) |
| $^{54}$Fe | 5.03(-03) | 1.05(-02) | 1.22(-02) | 1.63(-02) | 1.13(-02) | 1.79(-02) |
| $^{56}$Fe | 1.13(-01) | 1.15(-01) | 1.20(-01) | 1.24(-01) | 1.28(-01) | 1.31(-01) |
| $^{57}$Fe | 4.69(-03) | 3.50(-03) | 4.09(-03) | 3.53(-03) | 3.86(-03) | 3.26(-03) |
| $^{58}$Fe | 1.76(-04) | 2.28(-04) | 8.75(-04) | 1.40(-03) | 2.16(-03) | 2.66(-03) |
| $^{59}$Co | 4.49(-04) | 2.98(-04) | 6.52(-04) | 9.04(-04) | 1.21(-03) | 1.33(-03) |
| $^{58}$Ni | 8.01(-03) | 5.02(-03) | 6.20(-03) | 4.75(-03) | 4.74(-03) | 3.95(-03) |
| $^{60}$Ni | 3.45(-03) | 2.29(-03) | 2.31(-03) | 1.94(-03) | 2.55(-03) | 1.74(-03) |
| $^{61}$Ni | 2.46(-04) | 1.80(-04) | 2.22(-04) | 2.85(-04) | 4.47(-04) | 4.94(-04) |
| $^{62}$Ni | 1.93(-03) | 9.10(-04) | 1.13(-03) | 1.30(-03) | 2.03(-03) | 2.13(-03) |
| $^{64}$Ni | 1.88(-05) | 3.08(-05) | 1.00(-04) | 2.16(-04) | 3.64(-04) | 4.93(-04) |
| $^{63}$Cu | 1.82(-05) | 1.92(-05) | 8.67(-05) | 2.22(-04) | 3.03(-04) | 4.06(-04) |
| $^{65}$Cu | 1.08(-05) | 2.06(-05) | 4.40(-05) | 9.20(-05) | 2.03(-04) | 2.92(-04) |
| $^{64}$Zn | 3.87(-05) | 2.74(-05) | 3.64(-05) | 5.16(-05) | 1.10(-04) | 1.40(-04) |
| $^{66}$Zn | 6.38(-05) | 3.46(-05) | 5.66(-05) | 1.05(-04) | 2.13(-04) | 3.10(-04) |
| $^{67}$Zn | 1.82(-06) | 1.75(-06) | 1.09(-05) | 2.67(-05) | 5.88(-05) | 9.12(-05) |
| $^{68}$Zn | 8.23(-06) | 1.03(-05) | 4.39(-05) | 1.14(-04) | 2.30(-04) | 3.50(-04) |
| $^{70}$Zn | 2.48(-07) | 9.13(-07) | 1.08(-06) | 3.30(-06) | 3.51(-06) | 7.33(-06) |
| $^{69}$Ga | 8.32(-07) | 1.08(-06) | 5.10(-06) | 1.46(-05) | 2.78(-05) | 4.34(-05) |
| $^{71}$Ga | 7.62(-07) | 1.29(-06) | 4.84(-06) | 1.27(-05) | 2.76(-05) | 3.89(-05) |
| $^{70}$Ge | 8.79(-07) | 1.13(-06) | 5.60(-06) | 1.67(-05) | 3.42(-05) | 5.21(-05) |
| $^{72}$Ge | 1.21(-06) | 1.52(-06) | 6.44(-06) | 1.78(-05) | 3.27(-05) | 5.25(-05) |
| $^{73}$Ge | 3.11(-07) | 2.96(-07) | 2.15(-06) | 6.28(-06) | 1.21(-05) | 1.95(-05) |
| $^{74}$Ge | 1.48(-06) | 1.73(-06) | 6.94(-06) | 1.87(-05) | 3.40(-05) | 5.42(-05) |
| $^{76}$Ge | 2.35(-07) | 3.72(-07) | 5.95(-07) | 1.60(-06) | 1.52(-06) | 3.11(-06) |
| $^{75}$As | 2.17(-07) | 2.85(-07) | 1.07(-06) | 3.29(-06) | 4.60(-06) | 8.11(-06) |
| $^{74}$Se | 1.97(-08) | 3.84(-08) | 7.34(-08) | 1.88(-07) | 1.57(-07) | 3.43(-07) |
| $^{76}$Se | 2.33(-07) | 2.90(-07) | 1.22(-06) | 3.38(-06) | 6.93(-06) | 1.08(-05) |
| $^{77}$Se | 1.92(-07) | 2.86(-07) | 1.11(-06) | 3.43(-06) | 4.98(-06) | 8.60(-06) |
### Table 1—Continued

| Mass | 13   | 15   | 20   | 25   | 30   | 35   |
|------|------|------|------|------|------|------|
| 78Se | 4.62(-07) | 5.08(-07) | 1.92(-06) | 5.10(-06) | 1.01(-05) | 1.57(-05) |
| 80Se | 8.91(-07) | 9.61(-07) | 3.10(-06) | 8.04(-06) | 1.07(-05) | 1.66(-05) |
| 82Se | 1.57(-07) | 2.37(-07) | 4.19(-07) | 1.02(-06) | 1.02(-06) | 1.86(-06) |
| 79Br | 1.71(-07) | 1.73(-07) | 9.14(-07) | 2.59(-06) | 4.08(-06) | 7.44(-06) |
| 81Br | 1.70(-07) | 1.93(-07) | 5.64(-07) | 1.51(-06) | 2.42(-06) | 3.28(-06) |
| 78Kr | 4.02(-09) | 5.29(-09) | 7.67(-09) | 1.46(-08) | 1.38(-08) | 2.09(-08) |
| 80Kr | 6.16(-08) | 8.46(-08) | 1.89(-07) | 3.79(-07) | 1.66(-06) | 1.50(-06) |
| 82Kr | 1.93(-07) | 2.14(-07) | 8.12(-07) | 2.04(-06) | 5.37(-06) | 7.43(-06) |
| 83Kr | 1.60(-07) | 2.02(-07) | 6.29(-07) | 1.61(-06) | 3.07(-06) | 4.69(-06) |
| 84Kr | 7.42(-07) | 8.02(-07) | 2.51(-06) | 5.07(-06) | 1.10(-05) | 1.79(-05) |
| 86Kr | 2.90(-07) | 3.80(-07) | 1.13(-06) | 2.32(-06) | 3.35(-06) | 4.57(-06) |
| 85Rb | 1.64(-07) | 1.67(-07) | 7.24(-07) | 1.53(-06) | 3.03(-06) | 4.91(-06) |
| 87Rb | 1.09(-07) | 1.71(-07) | 4.97(-07) | 1.24(-06) | 1.55(-06) | 3.08(-06) |
| 84Sr | 4.37(-09) | 7.76(-09) | 9.60(-09) | 2.73(-08) | 1.99(-08) | 3.53(-08) |
| 86Sr | 9.43(-08) | 1.08(-07) | 3.90(-07) | 7.25(-07) | 2.35(-06) | 3.99(-06) |
| 87Sr | 5.26(-08) | 5.65(-08) | 2.35(-07) | 4.24(-07) | 1.49(-06) | 2.62(-06) |
| 88Sr | 6.45(-07) | 7.88(-07) | 1.98(-06) | 3.98(-06) | 8.79(-06) | 1.50(-05) |
| 89Y  | 1.44(-07) | 1.73(-07) | 4.06(-07) | 8.54(-07) | 1.68(-06) | 2.72(-06) |
| 90Zr | 1.75(-07) | 2.28(-07) | 3.64(-07) | 7.23(-07) | 1.05(-06) | 1.55(-06) |
| 91Zr | 3.80(-08) | 5.46(-08) | 9.65(-08) | 2.17(-07) | 3.29(-07) | 5.38(-07) |
| 92Zr | 5.76(-08) | 6.55(-08) | 1.24(-07) | 2.11(-07) | 3.76(-07) | 5.26(-07) |
| 94Zr | 5.69(-08) | 6.48(-08) | 1.10(-07) | 1.75(-07) | 2.73(-07) | 3.80(-07) |
| 96Zr | 8.26(-09) | 1.32(-08) | 1.83(-08) | 5.05(-08) | 3.70(-08) | 7.15(-08) |
| 93Nb | 2.02(-08) | 2.26(-08) | 4.77(-08) | 8.52(-08) | 1.47(-07) | 2.07(-07) |
| 92Mo | 1.26(-08) | 1.69(-08) | 2.07(-08) | 2.80(-08) | 3.38(-08) | 4.00(-08) |
| 94Mo | 9.88(-09) | 1.39(-08) | 1.84(-08) | 2.30(-08) | 2.70(-08) | 3.22(-08) |
| 95Mo | 1.15(-08) | 1.33(-08) | 2.41(-08) | 4.26(-08) | 5.00(-08) | 8.65(-08) |
| 96Mo | 1.69(-08) | 2.18(-08) | 3.31(-08) | 4.33(-08) | 8.01(-08) | 8.34(-08) |
| 97Mo | 1.10(-08) | 1.44(-08) | 2.29(-08) | 4.19(-08) | 8.48(-08) | 1.20(-07) |
| 98Mo | 1.55(-06) | 1.77(-06) | 2.52(-06) | 3.23(-06) | 4.08(-06) | 4.79(-06) |

Radioactive isotopes at $t = 10^7$ s

| 3H  | 1.14(-59) | 1.32(-59) | 1.82(-59) | 2.29(-59) | 2.79(-59) | 3.25(-59) |
| 14C | 8.50(-08) | 7.14(-07) | 4.13(-06) | 8.36(-06) | 3.93(-06) | 5.90(-06) |
| Mass | 13   | 15   | 20   | 25   | 30   | 35   |
|------|------|------|------|------|------|------|
| Na   | 7.64(-08) | 8.07(-08) | 2.37(-06) | 6.76(-06) | 2.74(-06) | 9.74(-06) |
| Al   | 1.07(-05) | 7.00(-06) | 1.53(-05) | 2.48(-05) | 2.22(-05) | 3.19(-05) |
| Si   | 4.52(-08) | 5.01(-07) | 9.16(-08) | 1.76(-07) | 1.22(-07) | 2.08(-07) |
| Cl   | 1.35(-06) | 2.57(-06) | 3.77(-06) | 5.65(-06) | 7.94(-06) | 1.02(-05) |
| Ar   | 6.18(-07) | 1.17(-06) | 4.39(-06) | 7.50(-06) | 8.27(-06) | 9.77(-06) |
| Ca   | 3.83(-06) | 6.36(-06) | 1.25(-05) | 3.30(-05) | 2.36(-05) | 3.14(-05) |
| Ca   | 9.76(-08) | 6.47(-07) | 1.28(-06) | 3.85(-06) | 1.50(-06) | 6.49(-06) |
| Ti   | 9.11(-05) | 4.20(-05) | 4.03(-05) | 2.19(-05) | 3.06(-05) | 9.33(-06) |
| V    | 4.31(-06) | 9.60(-06) | 9.40(-06) | 1.32(-05) | 1.05(-05) | 1.61(-05) |
| Mn   | 9.35(-05) | 2.20(-04) | 2.07(-04) | 2.94(-04) | 2.38(-04) | 3.61(-04) |
| Mn   | 9.39(-08) | 1.66(-07) | 2.03(-07) | 2.97(-07) | 2.84(-07) | 3.86(-07) |
| Fe   | 1.02(-04) | 2.30(-04) | 2.43(-04) | 3.79(-04) | 2.76(-04) | 4.37(-04) |
| Ti   | 2.25(-06) | 9.33(-05) | 1.13(-05) | 5.04(-05) | 1.67(-05) | 4.12(-05) |
| Co   | 2.18(-04) | 1.57(-04) | 1.74(-04) | 1.42(-04) | 1.39(-04) | 1.04(-04) |
| Co   | 2.27(-06) | 1.17(-05) | 1.13(-05) | 2.44(-05) | 1.22(-05) | 3.27(-05) |
| Ni   | 1.00(-01) | 1.00(-01) | 1.00(-01) | 1.00(-01) | 1.00(-01) | 1.00(-01) |
| Ni   | 4.09(-03) | 2.92(-03) | 3.16(-03) | 2.40(-03) | 2.48(-03) | 1.74(-03) |
| Ni   | 3.55(-04) | 1.69(-04) | 1.92(-04) | 1.33(-04) | 1.46(-04) | 6.24(-05) |
| Ni   | 6.61(-06) | 8.87(-06) | 6.76(-05) | 1.91(-04) | 2.14(-04) | 3.18(-04) |
| Zn   | 3.58(-06) | 1.58(-06) | 3.42(-06) | 6.53(-06) | 1.05(-05) | 2.60(-05) |
| Ge   | 4.07(-08) | 1.01(-08) | 9.32(-09) | 7.88(-09) | 8.15(-09) | 7.10(-09) |
| Se   | 3.45(-08) | 2.14(-08) | 6.95(-07) | 2.28(-06) | 2.84(-06) | 6.70(-06) |
| Kr   | 7.65(-09) | 7.10(-09) | 3.61(-08) | 8.31(-08) | 6.71(-07) | 5.51(-07) |
| Kr   | 2.90(-08) | 1.88(-08) | 4.36(-07) | 1.06(-06) | 2.03(-06) | 3.41(-06) |
| Sr   | 1.35(-09) | 1.85(-08) | 1.24(-08) | 7.26(-08) | 4.61(-08) | 1.47(-07) |
| Zr   | 2.10(-09) | 2.05(-09) | 2.19(-08) | 5.49(-08) | 1.12(-07) | 1.67(-07) |