12C

Carbon - 12 (Stable)

Half life: Infinite

Flip a coin until you get “heads.” Then absorb a proton (i.e. 1H) to become 13N and create a photon.

13C

Carbon - 13 (Stable)

Half life: Infinite

The long 13N half life means 13C is only produced after catalytic fusion has stopped. In the unlikely even you hot here, keep flipping a coin until you get “heads.” Then, absorb a proton (1H) to become 14N and produce a photon.

13N

Nitrogen - 13 (β+ decay to 13C)

Half life: 10 minutes

Set a timer for 10 minutes. Keep flipping a coin. If you get “heads,” absorb a proton (1H) to become 14O and emit a photon. Otherwise, decay to 13C, creating a positron and a neutrino. The positron annihilates with an electron to produce two photons.

14N

Nitrogen - 14 (Stable)

Half life: Infinite

Flip a coin until you get “heads.” Then absorb a proton (i.e. 1H) to become 15O and a photon.

15N

Nitrogen - 15 (Stable)

Half life: Infinite

Flip a coin. If you get “heads,” absorb a proton (i.e. 1H) to become 16O and emit a photon.

If you get “tails,” absorb a proton (1H) to become 12C and 4He. Congratulations! You have now catalyzed one cycle of hydrogen fusion, turning four 1H into one 4He. Continue from 12C.

14O

Oxygen - 14 (β+ decay to 14N)

Half life: 71 sec

Wait for 71 s. Then flip a coin. If you get “heads,” you β+ decay to 14N. If you get “tails,” wait 71 s and flip again.

15O

Oxygen - 15 (β+ decay to 15N)

Half life: 122 sec

Wait 122 s and flip a coin. If you get “heads,” β+ decay to 15N, producing a neutrino and a positron that annihilates with an electron to make two photons. If you get “tails,” wait another 122 s and flip again.

16O

Oxygen - 16 (Stable)

Half life: Infinite

Flip a coin until you get “heads.” Then absorb a proton (i.e. 1H) to become 17F and emit a photon.

17O

Oxygen - 17 (Stable)

Half life: Infinite

Flip a coin until you get “heads.” Then absorb a proton (i.e. 1H) to become 14N and emit a 4He nucleus.

Congratulations! You have now catalyzed one cycle of hydrogen fusion, turning four 1H into one 4He. Continue from 14N.

18O

Oxygen - 18 (Stable)

Half life: Infinite

Because of the long half life of 18F, 18O is only produced at the end of a star’s life after the catalytic reactions have stopped.

17F

Fluorine - 17 (β+ decay to 17O)

Half life: 65 sec

Set a timer for 65 s and keep flipping a coin. If you get “heads” before your half life is up, absorb a proton (1H) and become 18Ne and emit a photon. Otherwise, β+ decay to 17O and emit a positron (annihilates with an electron to become two photons) and a neutrino.

18F

Fluorine - 18 (β+ decay to 18O)

Half life: 110 minutes

Roll a single die. If you get one, absorb a 4He to become 20Ne. Otherwise, absorb a proton (1H) to become 15O and emit a 4He.

Congratulations! You have now catalyzed one cycle of hydrogen fusion, turning four 1H into one 4He. Continue from 15O.

19F

Fluorine - 19 (Stable)

Half life: Infinite

Congratulations! You have broken out of the CNO cycle! There are no reactions by which 19F can participate in the production of any further 4He. You may take a well earned rest!

18Ne

Neon - 18 (β+ decay to 18F)

Half life: 2 sec

Wait 2 s and flip a coin. If you get “heads,” you β+ decay to 18F, a positron and a neutrino. The positron annihilates with an electron to make two photons. If you get “tails,” wait 2 s and flip again.

19Ne

Neon - 19 (β+ decay to 19F)

Half life: 17 s

Wait for 17s and flip a coin. If you get “heads,” β+ decay to 19F, producing a neutrino and a positron (which annihilates with an electron to produce two photons. If you get “tails,” wait for 17 s and flip again.

20Ne

Neon - 20 (Stable)

Half life: Infinite

Congratulations! You have broken out of the CNO cycle! There are no reactions by which 19F can participate in the production of any further 4He. You may take a well earned rest!

21Na

Sodium - 21 (β+ decay to 21Ne)

Half life: Infinite

Congratulations! You have broken out of the CNO cycle! There are no reactions by which 21Na can participate in the production of any further 4He. You may take a well earned rest!

15O

Oxygen - 15 (β+ decay to 15N)

Half life: 122 sec

Wait 122 s and flip a coin twice during that time. If either time you get “tails,” absorb a 4He to make 19Ne and a photon. Go to 19Ne. Otherwise, at the end of 122s, flip a coin for the decay. If you get “heads,” β+ decay to 15N, producing a neutrino and a positron that annihilates with an electron to make two photons. If you get “tails,” wait another 122 s and flip again.

18Ne

Neon - 18 (β+ decay to 18F)

Half life: 2 sec

Flip a coin. If you get “tails,” absorb a 4He to create 21Na and a free proton (1H). You only get to do this once since the half life is so short. If you get “heads,” wait 2 s and flip a coin. If you get “heads,” you β+ decay to 18F, a positron and a neutrino. The positron annihilates with an electron to make two photons. If you get “tails,” wait 2 s and flip again for the decay. You do not get to flip for the absorption more than once.