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<u>Problem 55.47 (RHK)</u>

Coal burns according to

$$C + O_2 \rightarrow CO_2.$$

The heat of combustion is 3.3×10^7 J kg^{-1} *of atomic carbon consumed*. (a) *We have to express this in terms of energy per carbon atom*. (b) *We have to express it in terms of energy per kilogram of the initial reactants, carbon and oxygen.* (c) *Suppose that the Sun* $\left(\text{mass} = 2.0 \times 10^{30}\ \text{kg}\right)$ *were made of carbon and oxygen in combustible proportions and that it continued to radiate energy at its present rate of* 3.9×10^{26} W. *We have to find how long it would last*.

<u>Solution:</u>

(a)

Coal burns according to

$$C + O_2 \rightarrow CO_2.$$

The heat of combustion is 3.3×10^7 J kg^{-1} of atomic carbon consumed. Mass of one carbon atom is 12.000 u.

Therefore, the number of C atoms in 1.0 kg of carbon will be

$$N_{\text{carbon}} = \frac{1.0\ \text{kg}}{12.0 \times 1.6605 \times 10^{-27}\ \text{kg}} = 5.02 \times 10^{25}.$$

The heat of combustion of carbon is $3.3 \times 10^{7}\ \text{J kg}^{-1}$ of atomic carbon consumed. Therefore, energy per carbon atom will be

$$E_{\text{carbon atom}} = \frac{3.3 \times 10^{7}\ \text{J kg}^{-1}}{5.02 \times 10^{25}\ \text{carbon atoms per kg}}$$

$$= 6.573 \times 10^{-19}\ \text{J per carbon atom}$$

$$= \frac{6.573 \times 10^{-19}}{1.6 \times 10^{-19}}\ \text{eV per carbon atom}$$

$$= 4.11\ \text{eV per carbon atom.}$$

(b)

The mass of one carbon atom and one O_2 molecule will be 44 u. Therefore, combustion energy per kilogram of carbon and oxygen will be

$$E_{\text{combustion}} = 3.3 \times 10^{7} \times \frac{12}{44}\ \text{J kg}^{-1}$$

$$= 9.0 \times 10^{6}\ \text{J kg}^{-1}.$$

(c)

In this model of the Sun, the total energy from combustion of carbon and oxygen that in principle can be obtained will be

$$U = 9.0\times10^{6}\times2\times10^{30}\ \text{J}$$
$$= 1.8\times10^{37}\ \text{J}.$$

We assume that the Sun is radiating energy at its present rate of $3.9\times10^{26}\ \text{W}$. The life of the Sun in this model will therefore be

$$t = \frac{1.8\times10^{37}\ \text{J}}{3.9\times10^{26}\ \text{W}} = 4.62\times10^{10}\ \text{s}$$
$$= \frac{4.62\times10^{10}}{3.156\times10^{7}}\ \text{y}$$
$$= 1462\ \text{y}.$$