Energy Systems HW3 (3.1, 3.3, 3.7)

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3.1) Write down the chemical formulas for the combustion of alkanes in Table 3.2 with n = 2 to n = 8. Determine the mass of $CO_2$ produced per MJ of energy

| n | formula | name | mole mass | MJ/kg |
|---|---|---|---|---|
| n = 2 | $C_2H_6$ | ethane | 30 g/mol | 51.9 |
| n = 3 | $C_3H_8$ | propane | 44 g/mol | 50.3 |
| n = 4 | $C_4H_{10}$ | butane | 58 g/mol | 49.5 |
| n = 5 | $C_5H_{12}$ | pentane | 72 g/mol | 48.7 |
| n = 6 | $C_6H_{14}$ | hexane | 86 g/mol | 48.1 |
| n = 7 | $C_7H_{16}$ | heptane | 100 g/mol | 48.1 |
| n = 8 | $C_8H_{18}$ | octane | 114 g/mol | 46.8 |

Equations

$C_2H_6 + 3.5O_2 \longrightarrow 2CO_2 + 3H_2O$  n = 2

$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$  n = 3

$C_4H_{10} + 6.5O_2 \longrightarrow 4CO_2 + 5H_2O$  n = 4

$C_5H_{12} + 8O_2 \longrightarrow 5CO_2 + 6H_2O$  n = 5

$C_6H_{14} + 9.5O_2 \longrightarrow 6CO_2 + 7H_2O$  n = 6

$C_7H_{16} + 11O_2 \longrightarrow 7CO_2 + 8H_2O$  n = 7

$C_8H_{18} + 12.5O_2 \longrightarrow 8CO_2 + 9H_2O$  n = 8

Test Calculation (n = 2)

1 mol of $C_2H_6 \longrightarrow$ 2 mols of $CO_2$

molecular weight of ethane = 2(12) + 6(1) = 30 kg/kmol

molecular weight of $CO_2$ : 12(1) + 16(2) = 44 kg/kmol

energy/kg for ethane = 51.9 MJ/kg

$$\left(\frac{51.9\ MJ}{\cancel{kg\ C_2H_6}}\right)\left(\frac{30\cancel{kg\ C_2H_6}}{1\cancel{kmol\ C_2H_6}}\right)\left(\frac{1\cancel{kmol\ C_2H_6}}{2\ kmol\ CO_2}\right)\left(\frac{1\ kmol\ CO_2}{44\ kg\ CO_2}\right) = \frac{17.69\ MJ}{1\ kg\ CO_2}$$

(General Formula)

$$\left(\frac{MJ}{kg\ element}\right)\left(\frac{\text{mole weight element}}{\text{moles of element}}\right)\left(\text{mole ratio}\left(\frac{\text{element}}{CO_2}\right)\right)\left(\frac{\text{moles of } CO_2}{\text{mole weight } CO_2}\right)$$

- See MATLAB script

3.3) Current world price of oil : \$52.02 (USD / bbl)

Source https://www.bloomberg.com/energy Accessed 2/7/2017

CL1 : COM , WTI Crude Oil (Nymex)

Current world price of natural gas : \$3.86 (1000 m$^3$) as of November 2016.

Source https://www.eia.gov/dnav/ng/hist/n9505us3m.htm

Accessed 2/7/2017

Current world price of coal : \$50.05 (per short ton) as of 2/03/2017

Energy Content of fuels (Via Appendix V in the Energy Systems book)

Crude Oil : 1 bbl , $6.19 \times 10^9$ J

Bituminous Coal : 1 short ton , $2.81 \times 10^{10}$ J

Natural Gas (STP) : 1 cubic meter , $3.857 \times 10^7$ J

Goal: Cost of energy / GJ

efficiency - 100% no losses

General $\left(\frac{\text{Cost}}{\text{unit}}\right)\left(\frac{\text{unit}}{\text{energy}}\right)$

1) Oil (Crude)

$$\left(\frac{\$52.02}{1\cancel{bbl}}\right)\left(\frac{1\cancel{bbl}}{6.19\times10^9\cancel{J}}\right)\left(\frac{1\times10^9\cancel{J}}{1GJ}\right) = \frac{\$8.4038}{1GJ}$$

2) Natural Gas

$$\left(\frac{\$3.86}{1000\cancel{m^3}}\right)\left(\frac{1\cancel{m^3}}{3.857\times10^7\cancel{J}}\right)\left(\frac{1\times10^9\cancel{J}}{1GJ}\right) = \frac{\$0.10007}{1GJ}$$

3) Coal

$$\left(\frac{\$50.05}{1\cancel{ton}}\right)\left(\frac{1\cancel{ton}}{2.81\times10^{10}\cancel{J}}\right)\left(\frac{1\times10^9\cancel{J}}{1GJ}\right) = \frac{\$1.78113}{1GJ}$$

3.7) Total energy needs of a person in the United States is satisfied by burning coal. How much coal per person must be burned on average per day

- Assume 40% of US energy consumption is from coal

- US energy consumption (year)
  - $97.7 \times 10^{15}$ Btu (2015) source - www.eia.gov/energyexplained/?page=us_energy_home
    (97.7 quadrillion Btu)

- coal energy $= 40\%(97.7 \times 10^{15}\ \text{Btu}) = 3.908 \times 10^{16}\ \text{Btu}$

- convert to joules $\longrightarrow (3.908 \times 10^{16}\ \text{Btu})\left(\frac{1055.06\ \text{Joules}}{1\ \text{Btu}}\right) = 4.123175 \times 10^{19}\ \text{J}$

- Assume US population in 2015 : 320,000,000 - source https://www.census.gov/popclock

- linear useage of energy per day : $\frac{4.123175 \times 10^{19}\ \text{J}}{365\ \text{days}} = 1.129636986 \times 10^{17}\ \text{J/day}$

- Energy per day a person must produce : $\frac{1.129636986 \times 10^{17}\ \text{J}}{320,000,000} = 3.530115582 \times 10^{8}\ \text{J per person}$

- Bituminous coal energy - 1 short ton : $2.81 \times 10^{10}$ J (Appendix V)

- Coal per day required : $\left(\frac{1\ \text{short ton}}{2.81 \times 10^{10}\ \cancel{\text{J}}}\right)\left(3.530115582 \times 10^{8}\ \cancel{\text{J}}\ \text{per person}\right) =$

  $1.256268889 \times 10^{-2}$ short ton of coal person

  $\left(1.256268889 \times 10^{-2}\ \text{short ton}\right)\left(\frac{2000\ \text{lb}}{1\ \text{short ton}}\right) = \boxed{25.125\ \text{lbs of coal a person}}$