INTRODUCTION TO NUCLEAR ENGINEERING — Homework 1.4

Problem: In a medical test for a certain molecule, the concentration in the blood is reported as 123 mcg/dL. What is the concentration in proper SI notation?

Solution: Convert both units in the numerator and the denominator to single-prefixed units and rewrite the constant using scientific notation with one place to the left of the decimal as follows:

$concentration := 123$ milicentigram/deciliter, Concentration as given in problem

$$conc_{SI} := \frac{concentration \cdot 10^{-3} \times 10^{-2}}{10^{-1} \cdot 10^{-3}}$$ grams/milliliter, Concentration in proper SI units

$conc_{SI} = 12.3$ g/ml, Concentration in blood

This concludes the problem solution for **Homework Problem 1.4**!

[HW_1_4.xmcd]

Problem: Estimate the number of atoms in a 3000 lbf automobile. State any assumptions you make.

Solution: First, we will assume that the atom density is approximately **10^{22} atoms per cm^3** in accordance with the estimate given in section 1.2.5 of the text. Next we will assume that the total volume of a 3000 lb_f automobile may be approximated by those exterior dimensions given below times 2/3 to account for the shortened height measurement at the hood and trunk areas. The number of atoms can then be approximated as follows:

2006 Optima EX Sedan Curb Weight - Automatic (lb.) 3179.1
Wheelbase (in.) 107.1
Length (in.) 186.4
Width (in.) 71.1
Height (in.) 58.3
Track Front (in.) 61.5
Track Rear (in.) 61.1

$$Vol_{Optima} := \frac{2}{3}\cdot(186.4\cdot 71.1\cdot 58.3)\cdot 2.54^3$$ cm^3, Approximate volume of car

$$Nad := 10^{22}$$ atoms/cm^3, Atomic density (assumed)

$$Num_{atoms} := Vol_{Optima}\cdot Nad$$ Estimated number of atoms in car

$$Num_{atoms} = 8.441\times 10^{28}$$

This concludes the problem solution for **Homework Problem 1.11**!

[HW_1_11.xmcd]

Problem: A reactor is fueled with 4 kg uranium enriched to 20 atom-percent in ^{235}**U**. The remainder of the fuel is ^{238}**U**. The fuel has a mass density of 19.2 g/cm^3.

(a) What is the mass of ^{235}**U** in the reactor?

(b) What are the atom densities of ^{235}**U** and ^{238}**U** in the fuel?

Solution: The atom density may be found utilizing Eq. (1.5) as follows:

$\rho_{fuel} := 19.2$ g/cm^3, Mass density of fuel

$m_{fuel} := 4 \cdot 10^3$ g, mass of fuel

$\gamma_{U235} := 0.20$ atom percent of ^{235}**U** in fuel

$\gamma_{U238} := 0.80$ atom percent of ^{238}**U** in fuel

$N_a := 0.6022 \cdot 10^{24}$ atoms/mole, Avogadro's number

$A_{U235} := 235.0439231$ g/mole, Gram atomic weight of ^{235}**U**

$A_{U238} := 238.0507826$ g/mole, Gram atomic weight of ^{235}**U**

$A_{fuel} := \gamma_{U235} \cdot A_{U235} + \gamma_{U238} \cdot A_{U238}$ g/mole, Gram atomic weight of this mix of uranium fuel

$A_{fuel} = 237.4494$

$Matom_{U235} := \dfrac{A_{U235}}{N_a}$ g/atom, Mass of ^{235}**U** atom

$Matom_{U235} = 3.9030873978744607 \times 10^{-22}$

$$Natoms_{U235} := \frac{m_{fuel} \cdot N_a \cdot \gamma_{U235}}{A_{fuel}}$$ atoms of ^{235}**U** in fuel sample

$$Natoms_{U235} = 2.0289 \times 10^{24}$$

$$m_{U235} := Matom_{U235} \cdot Natoms_{U235}$$ g, Mass of ^{235}**U** in fuel sample

$$m_{U235} = 791.8956$$

$$w_{U235} := \frac{m_{U235}}{m_{fuel}}$$ mass fraction of ^{235}**U** $w_{U235} = 0.198$

$$w_{U238} := \frac{m_{fuel} - m_{U235}}{m_{fuel}}$$ mass fraction of ^{238}**U** $w_{U238} = 0.802$

$$N_{U235} := \frac{w_{U235} \cdot \rho_{fuel} \cdot N_a}{A_{U235}}$$ atoms/cm^3, Atom density of ^{235}**U** in fuel mix

$$N_{U235} = 9.7387 \times 10^{21}$$

$$N_{U238} := \frac{w_{U238} \cdot \rho_{fuel} \cdot N_a}{A_{U238}}$$ atoms/cm^3, Atom density of ^{238}**U** in fuel mix

$$N_{U238} = 3.8955 \times 10^{22}$$

This concludes the problem solution for **Homework Problem 1.13**!

[HW_1_13.xmcd]

Problem: A crystal of **NaI** has a density of 2.17 g/cm³. What is the atom density of sodium in the crystal?

Solution: The solution is as follows:

$\rho_{NaI} := 2.17$ g/cm³, Mass density of **NaI**

$N_a := 0.6022 \cdot 10^{24}$ atoms/mole, Avogadro's number

$A_{Na} := 22.989770$ g/mole, Gram atomic weight of **Na**

$A_I := 126.90447$ g/mole, Gram atomic weight of **I**

$A_{NaI} := A_{Na} + A_I$ g/mole, Gram molecular weight of **NaI**

$A_{NaI} = 149.8942$

Because the atom density of **Na** or **I** in **NaI** will be the same as the molecular density, we may use Eq. (1.4) to figure the molecular density of **NaI** as follows:

$N_{NaI} := \dfrac{\rho_{NaI} \cdot N_a}{A_{NaI}}$ molecules/cm³, Molecular density of **NaI**

$N_{Na} := N_{NaI}$ atoms/cm³, Atomic density of **Na**

$N_{Na} = 8.718 \times 10^{21}$

This concludes the problem solution for **Homework Problem 1.15**!

[HW_1_15.xmcd]

Problem: A concrete with a density of 2.35 g/cm^3 has a hydrogen content of 0.0085 weight fraction. What is the atom density of hydrogen in the concrete?

Solution: The solution using Eq. (1.5) is as follows:

$\rho := 2.35$ g/cm^3, Mass density of concrete

$w_H := 0.0085$ Weight fraction of hydrogen in concrete

$N_a := 0.6022 \cdot 10^{24}$ atoms/mole, Avogadro's number

$A_H := 1.00794$ g/mole, Gram atomic weight of **H**

$N_H := \dfrac{w_H \cdot \rho \cdot N_a}{A_H}$ atoms/cm^3, Atomic density of **H** in concrete

$N_H = 1.1934 \times 10^{22}$

This concludes the problem solution for **Homework Problem 1.16**!

[HW_1_16.xmcd]