Units and Best Practice

Units prove to be a confusing aspect of this course. The units which are *commonly in use* in the field are the "standard" for this course. Unfortunately, the units are "mixed" (that is, a mixture of cgs and mks). Some useful conversion factors are listed below. Some best practices you should follow are:

1. ALWAYS perform a units analysis and perform a "sanity" check to determine that your answer is reasonable. In most cases, "unreasonable" answers are a result of unit problems. For example, if your answer is that the argon ion density in a plasma etching reactor is 10^{50} ions/cm^3, your answer is unreasonable and you probably have a units problem. You know your answer is unreasonable since if the density is really 10^{50} argon ions/cm^3, the mass of 10 cm^3 of the plasma would be equal to twice the mass of the earth.

2. **Never, ever be confused by expressing temperature in Energy Units (or vice-versa). Temperature in Energy Units ALWAYS Means**

$$T\ (eV) \equiv kT\ (eV)$$

3. Unless specified otherwise, you final answers in homework problems should be expressed in the following units.

Electron energies or temperatures	eV
Atomic or molecular energies or temperatures	K or eV
Lengths	cm
Electron, atomic or molecular masses	AMU or g
Electron, atomic or molecular speeds	cm/s
Cross sections	cm^2 or A^2
Mobilities	cm^2/V-s
Diffusion coefficients	cm^2/s
Rates coefficients (1st, 2nd, 3rd order)	s^{-1}, cm^3/s, cm^6/s
Electric fields	V-cm^{-1}
Normalized Electric Fields	V-cm^{-2} or Td (10^{-17} V-cm^2)
Densities	cm^{-3}
Power	W
Power deposition (specific)	W-cm^{-3}
Current density	Amps-cm^{-2}

Useful Conversion Factors

$k = 1.38 \times 10^{-16}$ erg/K = 1.38×10^{-23} J/K

1 eV = 1.6×10^{-12} ergs = 1.6×10^{-19} J ≡ 11,594.2 K

q = e = 1.6×10^{-19} C (coulomb) = 4.8×10^{-10} esu

1 V = 1 J/C = 10^7 erg/C

$\varepsilon_o = 8.85 \times 10^{-12}$ [F/m or C^2/m-J] = 8.85×10^{-14} [F/cm or C^2/cm-J]

m_e (electron mass) = 0.911×10^{-27} g = 0.911×10^{-30} kg

E/N: 1 Td (Townsend) = 10^{-17} V-cm^2 = 10^{-21} V-m^2 = 0.354 V/cm-Torr at (T = 273 K)

1 Å^2 = 10^{-16} cm^2 = 10^{-20} m^2

1 atm = 760 Torr = 1.013 bar

Gas Density: $N = \frac{P}{kT} = 9.654 \times 10^{18} \frac{P(\text{Torr})}{T(\text{K})}$ cm^{-3}

1 m^3 = 10^6 cm^3

Useful Relationships

Electron speed for energy ε : $v = \left(\frac{2\varepsilon}{m_e}\right)^{1/2}$ = 5.93 x 10^7 $(\varepsilon(eV))^{1/2}$ cm/s

Average electron thermal speed for temperature T_e: $v = \left(\frac{8kT_e}{\pi m_e}\right)^{1/2}$ = 6.69 x 10^7 $(T_e(eV))^{1/2}$ cm/s

Debye Length: $\lambda_D = \left(\frac{\varepsilon_o kT_e}{n_e q^2}\right)^{1/2} = \left(\frac{kT_e}{4\pi n_e q^2}\right)^{1/2} = 743\left[\frac{T_e(eV)}{n_e\left(cm^{-3}\right)}\right]^{1/2} cm$

mks cgs

Plasma Frequency:

ω_p (radian/s) $= \left(\frac{n_e q^2}{m_e \varepsilon_o}\right)^{1/2} = \left(\frac{4\pi n_e q^2}{m_e}\right)^{1/2} = 5.64\times10^4\left[n_e\left(cm^{-3}\right)\right]^{1/2}\frac{radians}{s}$

mks cgs

Rate coefficient: $k\left(\frac{cm^3}{s}\right) = \langle \sigma \bullet v \rangle$ (e.g. (e.g. $\frac{\partial N}{\partial t} = n_e kN$))

σ = cross section cm^2 v = velocity cm/s

Conductivity: $\sigma = \frac{n_e q^2}{m_e \nu_m} = 2.81\times10^{-4}\frac{n_e\left(cm^{-3}\right)}{\nu_m\left(s^{-1}\right)}\frac{1}{\Omega - cm}$

ν_m = electron momentum transfer collision frequency

Electron Mobility: $\mu_e = \frac{q}{m_e \nu_m} = \frac{1.756\times10^{15}}{\nu_m\left(s^{-1}\right)}\frac{cm^2}{V - s}$