Estimate air mass density at IUPAC'S standard temperature and pressure, STP: temperature 273.15 K and absolute pressure 100 kPa.

GUESSTIMATION

Assume air is a dry, ideal gas composed only of nitrogen. A mol of ideal gas at STP occupies 22.0 L, but, since nitrogen is in a gaseous form, N_2, then two moles of nitrogen occupy 22.0 L at STP. The molar mass of nitrogen is 14 kg/mol. Then,

$$\rho_m \sim \frac{14\,\mathrm{g}}{1\,\mathrm{mol}} \frac{1\,\mathrm{kg}}{10^3\,\mathrm{g}} \frac{2\,\mathrm{mol}}{22.0\,\mathrm{L}} \frac{10^3\,\mathrm{L}}{1\,\mathrm{m}^3} \sim 1.227\,678\,571\,428\,54\,\mathrm{kg/m^3}\,,$$

which gives our estimate of dry air mass density of 1.23 kg/m³.

COMPLEX ESTIMATION

Assume air is a dry, ideal gas:

$$p = \rho_n k_{\mathrm{bo}} \theta\,,$$

where p represents pressure, ρ_n particle number density, k_{bo} Boltzmann's constant and θ thermodynamic temperature.

Isolate ρ_n to find:

$$\rho_n = \frac{p}{k_{\mathrm{bo}}\theta}\,,$$

Replace the numeric values for the STP to have $\rho_n \sim 2.652 \cdot 10^{25}\,\mathrm{m}^{-3}$.

Assume air is only nitrogen with molar mass of 0.028 013 4 kg/mol:

$$\rho_m \sim \frac{2.652 \cdot 10^{25}}{\mathrm{m}^3} \frac{0.028\,013\,4\mathrm{kg}}{\mathrm{mol}} \frac{1\mathrm{mol}}{6.022\,141 \cdot 10^{23}} \sim 1.233\,\mathrm{kg\,m}^{-3}\,,$$

where ρ_m represents mass density and $6.022\,141 \cdot 10^{23}$ is Avogadro's number, k_{av}.

Thus, the final estimate for air mass density is 1.233 kg/m³.

A search in the web, [2], results in 1.2922 kg/m³.

IRON MASS DENSITY

Reference iron mass density value: $7.874\,\mathrm{g\,cm^{-3}}$, [3].

GUESSTIMATION Iron is heavier than water and lighter than mercury, so estimate its mass density ρ value as

$$\rho = \sqrt{1\,\mathrm{g/cm^3} \cdot 14\,\mathrm{g/cm^3}} \sim 3.741\,657\,386\,773\,941\,\mathrm{g/cm^3}\,,$$

which yields our first estimate for the value of iron mass density as $3\ \mathrm{g/cm^3}$.

MAHAJAN EQUATION According to [1, p. 57], mass density of elements can be estimated via their atomic masses, A:

$$\rho/\mathrm{g\,cm^{-3}} = \frac{A}{18}\,.$$

With this model, estimate the mass density of iron as $55/18 \sim 3\ \mathrm{g\,cm^{-3}}$.

ATOMIC RADIUS The atomic radius of iron is $126\,\mathrm{pm}$, [3]. Round this value to 10^{-8} cm.

Consider atoms to be cubes with sides equal to two times their atomic radius (one atomic diameter). Then, the volume of an iron atom will be $(2\cdot 10^{-8}\ \mathrm{cm})^3 \sim 10^{-23}\ \mathrm{cm^3}$.

An iron atom has 56 nucleons (neutrons and protons), so its mass is 56 times the proton mass: $56\cdot 2\cdot 10^{-24}\ \mathrm{g} \sim 10^{-22}\ \mathrm{g}$.

Thus, our iron mass density estimate becomes $10^{-22}\ \mathrm{g}/10^{-23}\ \mathrm{cm^3} \sim 10\,\mathrm{g/cm^3}$.

Finally, by using the same model (cubic atom), by using all the exact values for the properties and by carrying all the decimals in the calculations, one finds an estimate of iron mass density of $6.14\,\mathrm{g/cm^3}$.

[1] Sanjoy Mahajan. *The Art of Approximation in Science and Engineering*. MIT OpenCourseWare, Spring 2008.

[2] the free encyclopedia Wikipedia. Density of air, July 2014. URL `http://en.wikipedia.org/wiki/Density_of_air`.

[3] the free encyclopedia Wikipedia. Iron, July 2014. URL `http://en.wikipedia.org/wiki/Iron`.