Today, we will:

- Finish Powerpoint slide show on particles
- Discuss particle terminology & definitions
- Define and discuss **number concentration** and how to define mean particle size
- Discuss **particle motion** – how particles move through the air; equations of motion

Summary – Remember these!

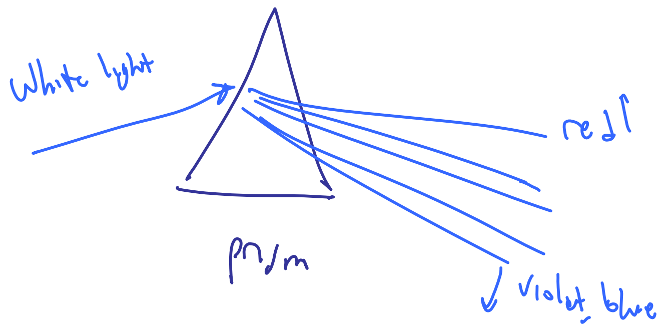
- $D_p > 1\ \mu m$ – Supermicron particles – due primarily to pulverizing, crushing, grinding – mechanical processes
- $D_p < 1\ \mu m$ Sub micron " – due primarily to combustion
  (get really deep into lungs → into alveoli)
- $D_p < 2.5\ \mu m$ "fine particles" "fines" = Respirable particles
  Go deep into lungs but not into alveoli
  $PM_{2.5}$ = one of the CAPs
- $D_p < 10\ \mu m$ = "coarse particles" "inhalable particles" → get into bronchial tubes
  [$D_p > 10\ \mu m$ get trapped by nose hairs or throat]
  PM_{10} = one of the CAPs
- $D_p > 10\ \mu m$ → non-inhalable, visible to naked eye if it is glowing or scattering sunlight significantly
- $D_p \gtrsim 70\ \mu m$ → visible to naked eye in general (not glowing)
- $D_p < 0.1\ \mu m$ → ultrafine particles
  → (100 nm) ← (nanometer = 10^{-9} m)
- $D_p < 0.05\ \mu m$ → nano particles
  (50 nm)

} Can pass through the alveoli membranes & go directly into bloodstream

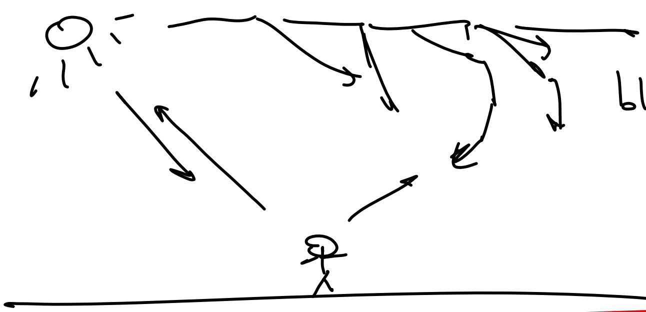
$0.4 \lesssim D_p \lesssim 0.7\ \mu m$ → visible light wavelengths

← ultraviolet → infrared

(what our eyes see)



→ explain why sky is blue during the day



reds don't refract as much

blue refracts most

Number Concentration

- For gases, we express the concentration of a gas species j as

$C_j \left(\frac{mass}{vol}\right)$ or $C_{molar,j} \left(\frac{mols}{vol}\right)$ or y_j (ppm)

mass concentration, molar concentration, mol fraction

For particles we don't use C_{molar} or ppm

→ use $\boxed{C_j \left(\frac{mass}{vol}\right)}$;

$C_{number,j}$ = number concentration

$$\boxed{C_{number,j} = \frac{\#\ particles}{m^3}}$$

typically in $\boxed{\frac{\text{millions of particles}}{m^3}}$

[e.g. $C_{number,j} = 34.8 \times 10^7$ particles/m^3 → $C_{number,j} = 348 \frac{\text{million part}}{m^3}$]

Conversion:

$$C_{number,j} = \frac{C_j}{M_{p,mean}}$$

← mean particle mass

$$M_{p,mean} = \rho_p \cdot \frac{\pi \left[D_{p,am}(mass)\right]^3}{6}$$

ρ_p: particle density

$\left[D_{p,am}(mass)\right]$: mean particle diameter based on <u>mass</u>

$$D_{p,am}(diameter) \neq D_{p,am}(mass) \quad ☆$$

$D_{p,am}(diameter)$: arithmetic mean particle dia. based on diameter

$D_{p,am}(mass)$: arithmetic mean particle dia. based on mass

Example: Comparison of arithmetic mean diameter based on diameter vs. mass

Given: Three particles occupy a cubic meter, as shown in the table. The density of the particles is 1000 kg/m^3. [Some people call this *unit density*, which is the density of water.]

To do: Calculate and compare $D_{p,\text{am}}$ (diameter) and $D_{p,\text{am}}$ (mass).

Solution:

Particle ID	D_p (micron)	$m_p = (\rho_p \pi D_p^3)/6$ (μg)
1	1	5.23599×10^{-7}
2	2	4.1887×10^{-6}
3	3	1.41372×10^{-5}

Sample calc → $m_{p,1} = \left(1000 \frac{\text{kg}}{\text{m}^3}\right) \pi \frac{(1.0 \times 10^{-6}\ \text{m})^3}{6} \left(\frac{10^6\ \mu\text{g}}{\text{g}}\right)\left(\frac{1000\ \text{g}}{\text{kg}}\right) = 5.236 \times 10^{-7}\ \mu\text{g}$

$D_{p,\text{am}}(\text{diameter}) = \sum (D_p) / n_{\text{particles}} = (1+2+3)/3 = 2.0\ \mu\text{m} = D_{p,\text{am}}(\text{dia})$

$m_{p,\text{mean}} = \sum m_p / n_{\text{particles}} = \frac{(\text{add these 3})}{3} = 6.2831 \times 10^{-6}\ \mu\text{g}$

$D_{p,\text{am}}(\text{mass}) = \left(\frac{6\ m_{p,\text{mean}}}{\pi \rho_p}\right)^{1/3} \rightarrow = 2.29\ \mu\text{m} = D_{p,\text{am}}(\text{mass})$ ☆

$\neq$

Example: Calculation of number concentration from mass concentration

Given: The PM$_{2.5}$ mass concentration of a sample of city air is right at the NAAQS limit for 24-hour exposure, namely 35 μg/m^3. The density of the particles is 1250 kg/m^3. The mean particle diameter based on mass is measured to be $D_{p,\text{am}}$ (mass) = 1.5 microns.

To do: Calculate the number concentration of particles, $c_{\text{number},j}$ in units of millions of particles per cubic meter. [Be careful with the units – answer should be between 10 and 50.]

Solution:

$c_{\text{number},j} = \frac{c_j}{m_{p,\text{mean}}} = \frac{6\ c_j}{\rho_p \pi [D_{p,\text{am}}(\text{mass})]^3}$

Units of $m_{p,\text{mean}}$ = mass [or mass per particle here]

$= \frac{6\ (35\ \mu\text{g}/\text{m}^3)}{(1250\ \text{kg}/\text{m}^3)\ \pi\ (1.50 \times 10^{-6}\ \text{m})^3 / \text{particle}} \left(\frac{1\ \text{kg}}{1000\ \text{g}}\right)\left(\frac{1\ \text{g}}{10^6\ \mu\text{g}}\right)$

$= 1.584 \times 10^7$ particles/m^3

$c_{\text{number},j} = 15.8$ million particles/m^3