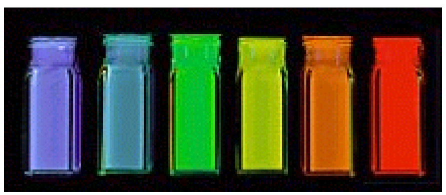
There is a need to define particle size, shape, polydispersity, and concentration.

The size of the particles of a monodisperse aerosol is completely defined by a single parameter, the particle diameter. However, most aerosols are polydisperse and may have particle sizes that range over two or more orders of magnitude. Because of this wide size range and the fact that the physical properties of aerosols are strongly dependent on particle size, distribution, and shape, it is necessary to characterize these size distributions by statistical means and also it is needed to find a reasonable way to define particle shape.

Quantum Dot

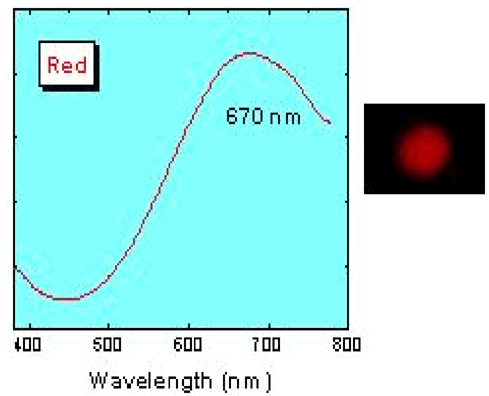
- 나노입자의 크기에 따라 다른 파장의 빛 발생

GaAs-Quantum Dots

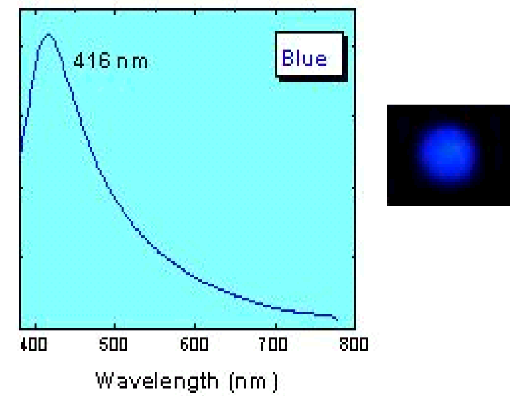


Si-Quantum Dots

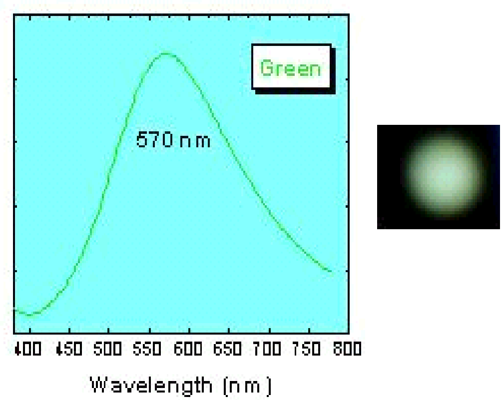
d (nm) = 2.9

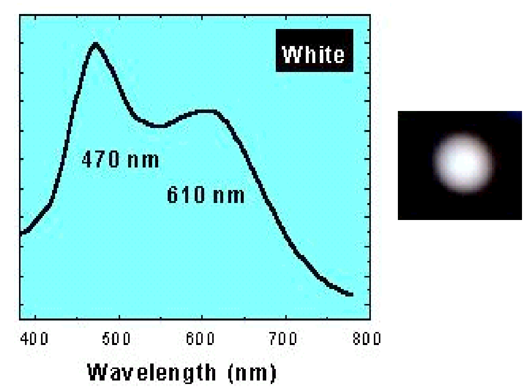


d (nm) = 1.3

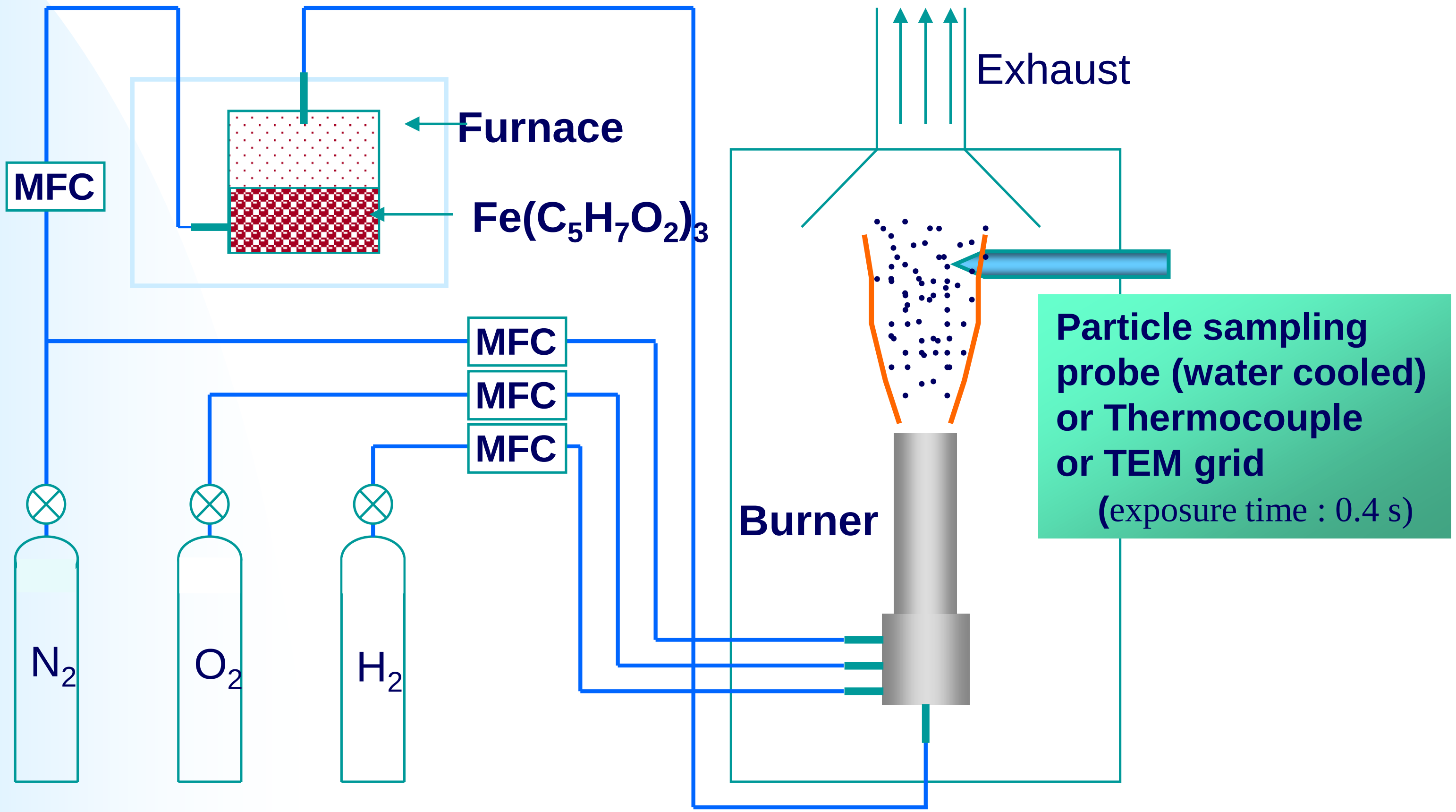


d (nm) = 2.0

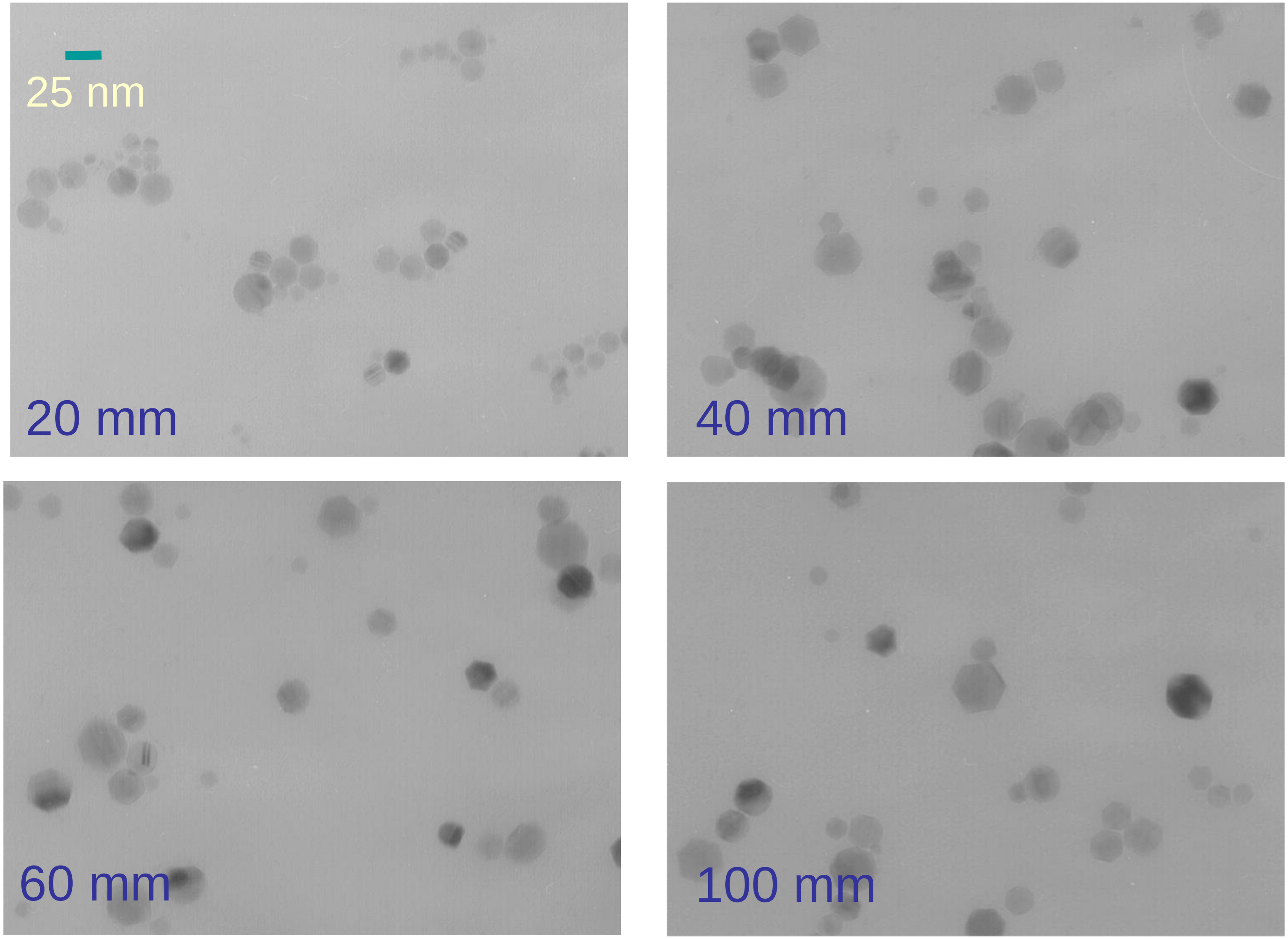




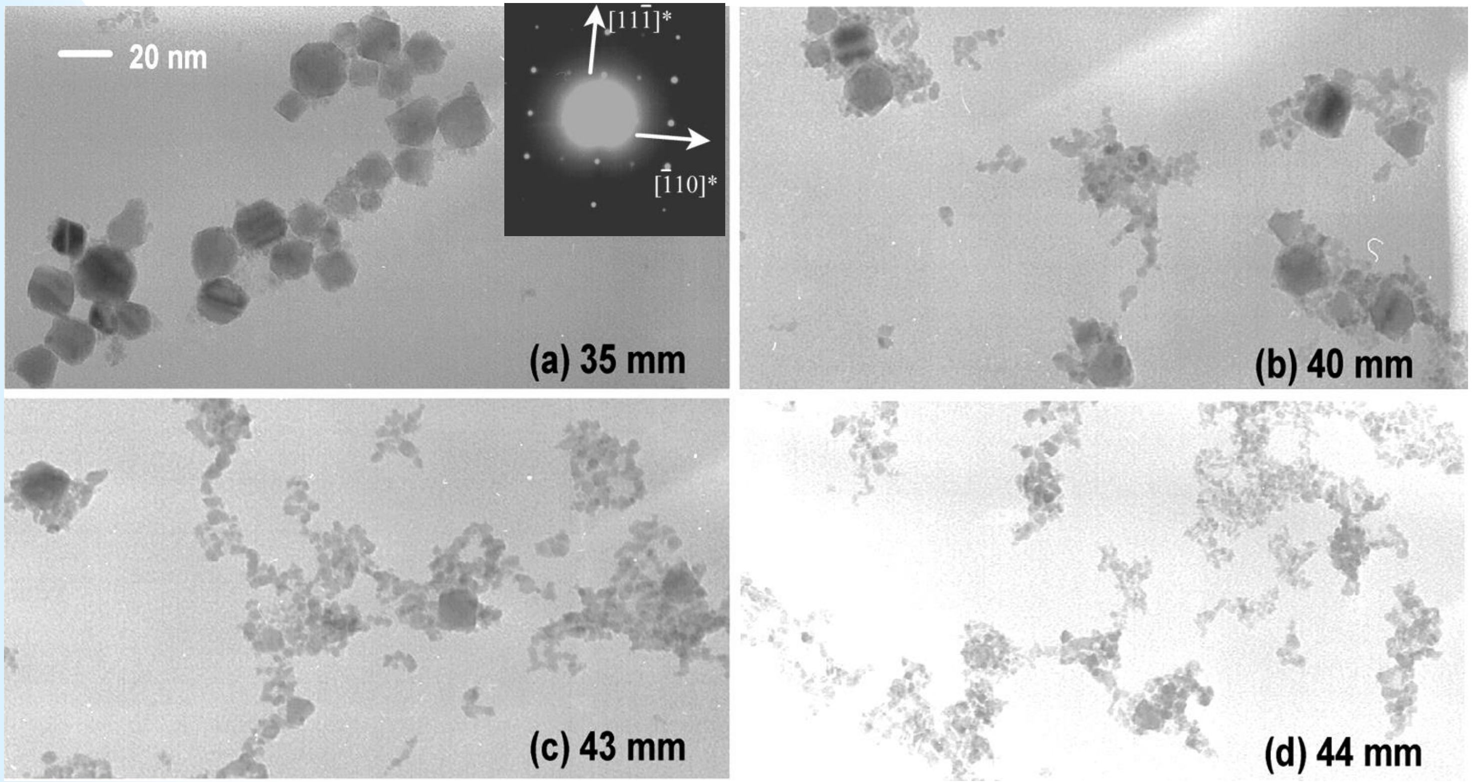
Synthesis of Fe_2O_3 Nanoparticles in a Flame



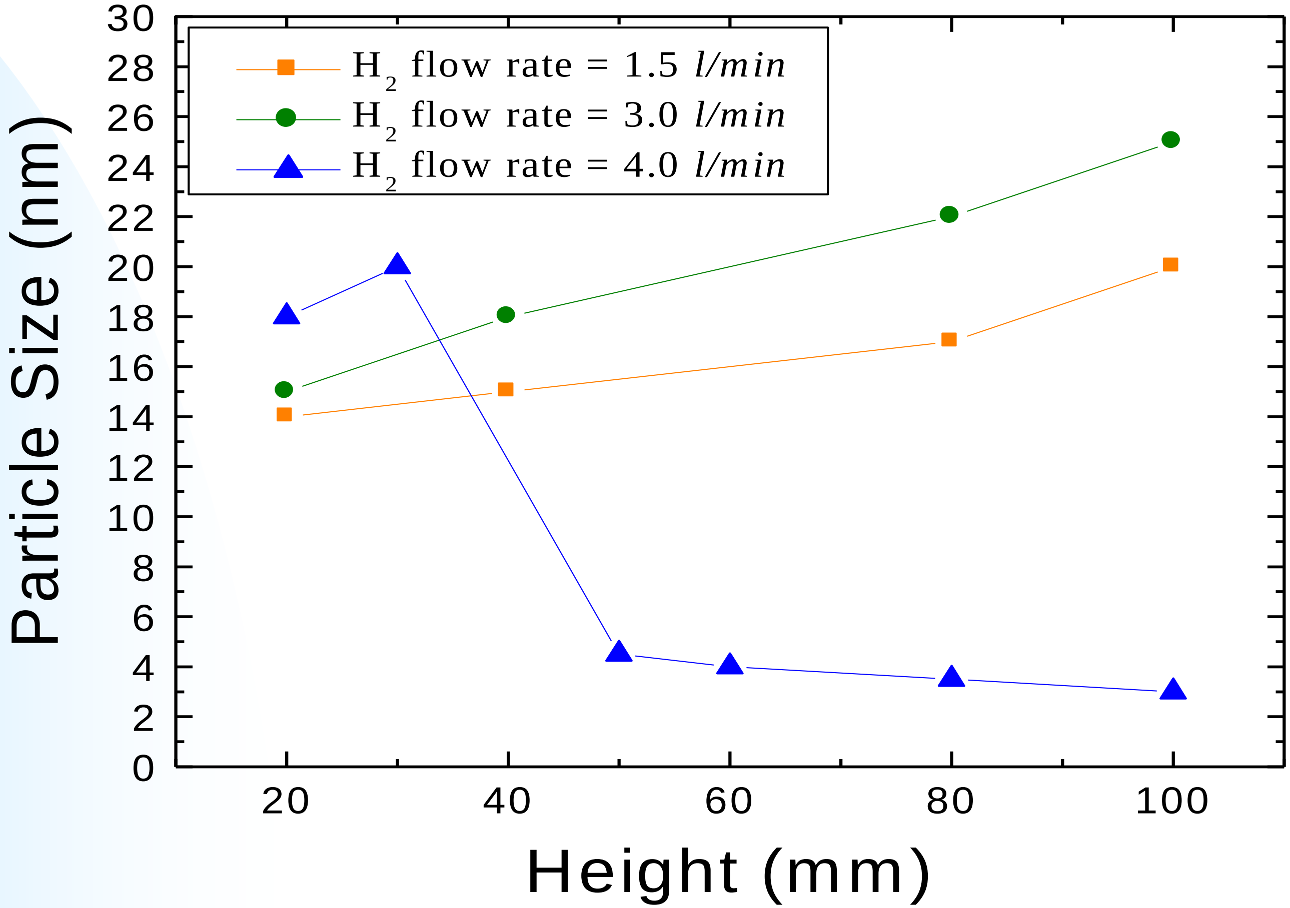
TEM micrographs of Fe_2O_3 nanoparticles with different collection heights (H_2 flow rate = 3.0 *l/min*)



TEM Images of Fe_2O_3 Nanoparticles
(H_2 flow rate = 4.0 l/min)

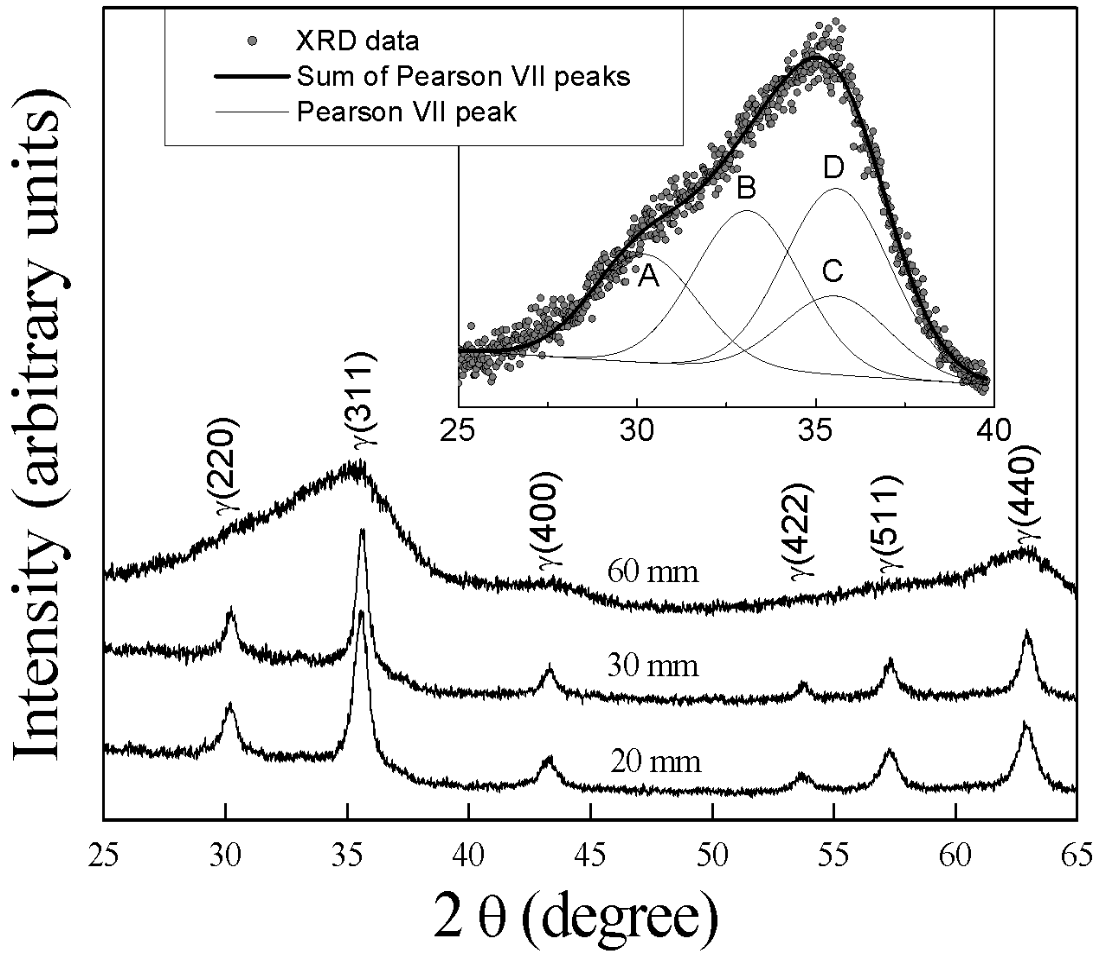


Particle Sizes vs H_2 Flow Rate



XRD Patterns of Fe_2O_3 Nanoparticles with Different Height

(H_2 flow rate = 4.0 l/min)

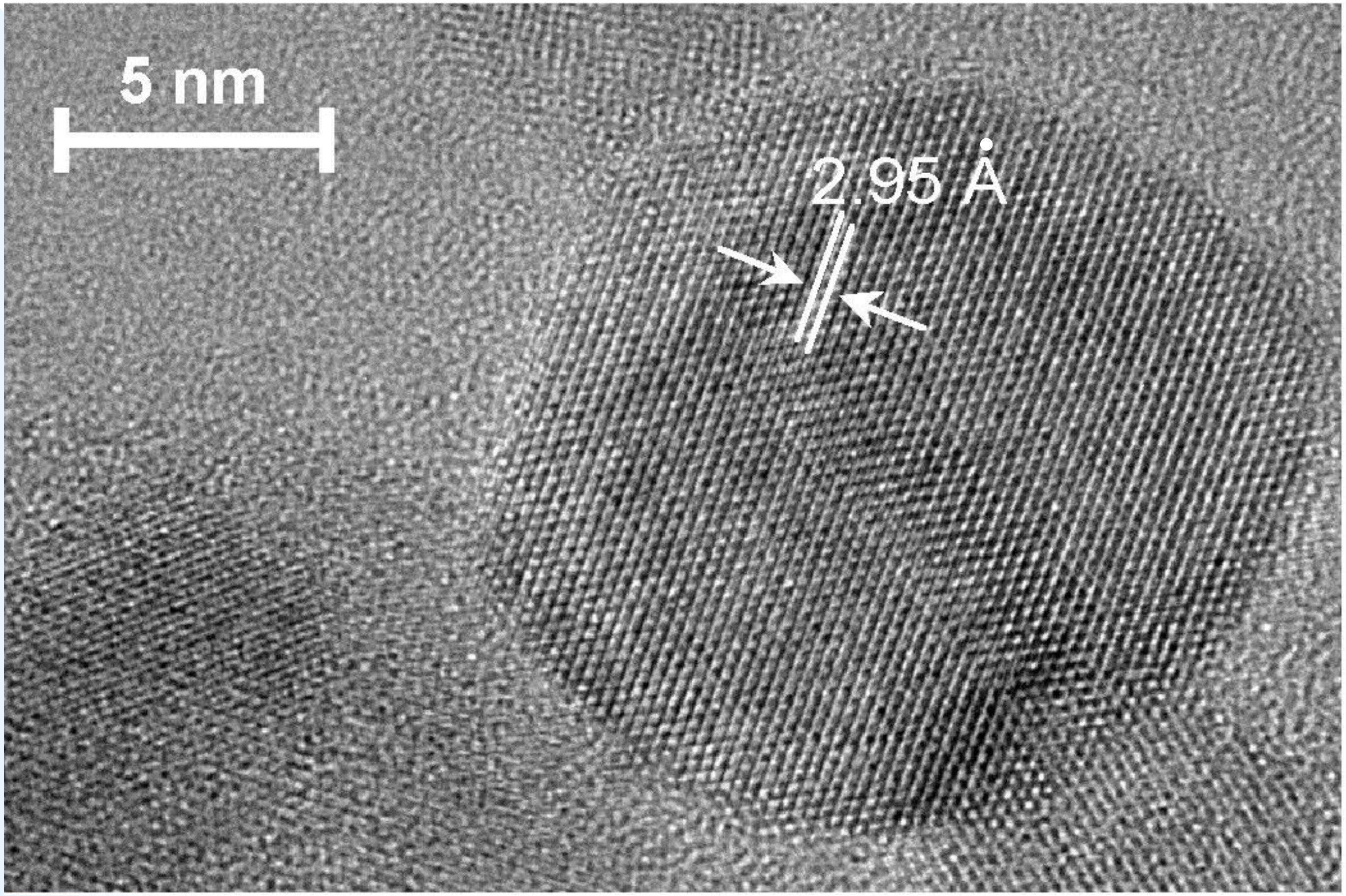


Particle sizes
Estimated by
Scherrer formula

- 20 mm ≅ 15 nm (γ)
- 30 mm ≅ 18 nm (γ)

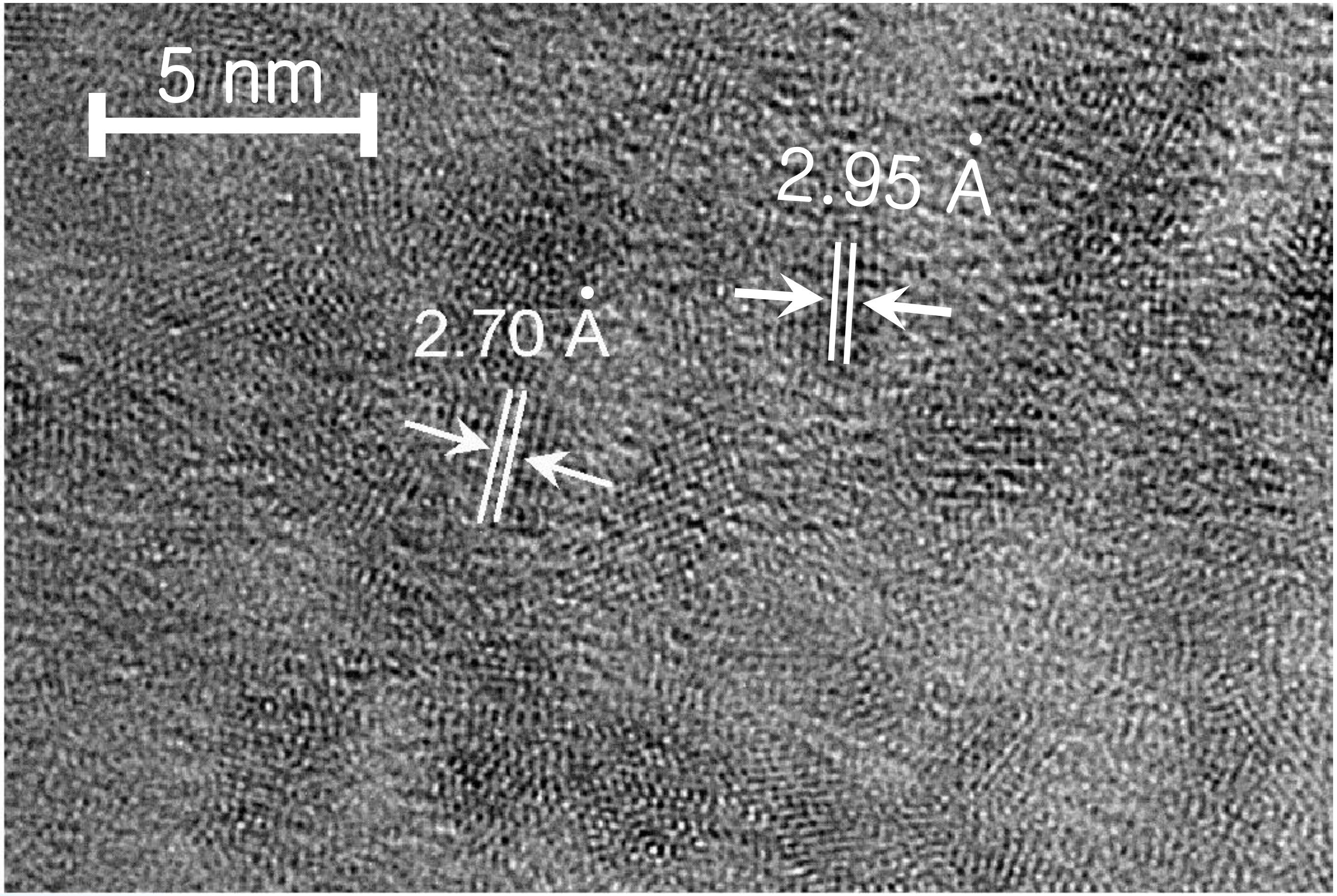
High Resolution TEM Images of Fe_2O_3 Nanoparticles Collected at 20 mm

$[H_2]/[O_2] = 0.8$

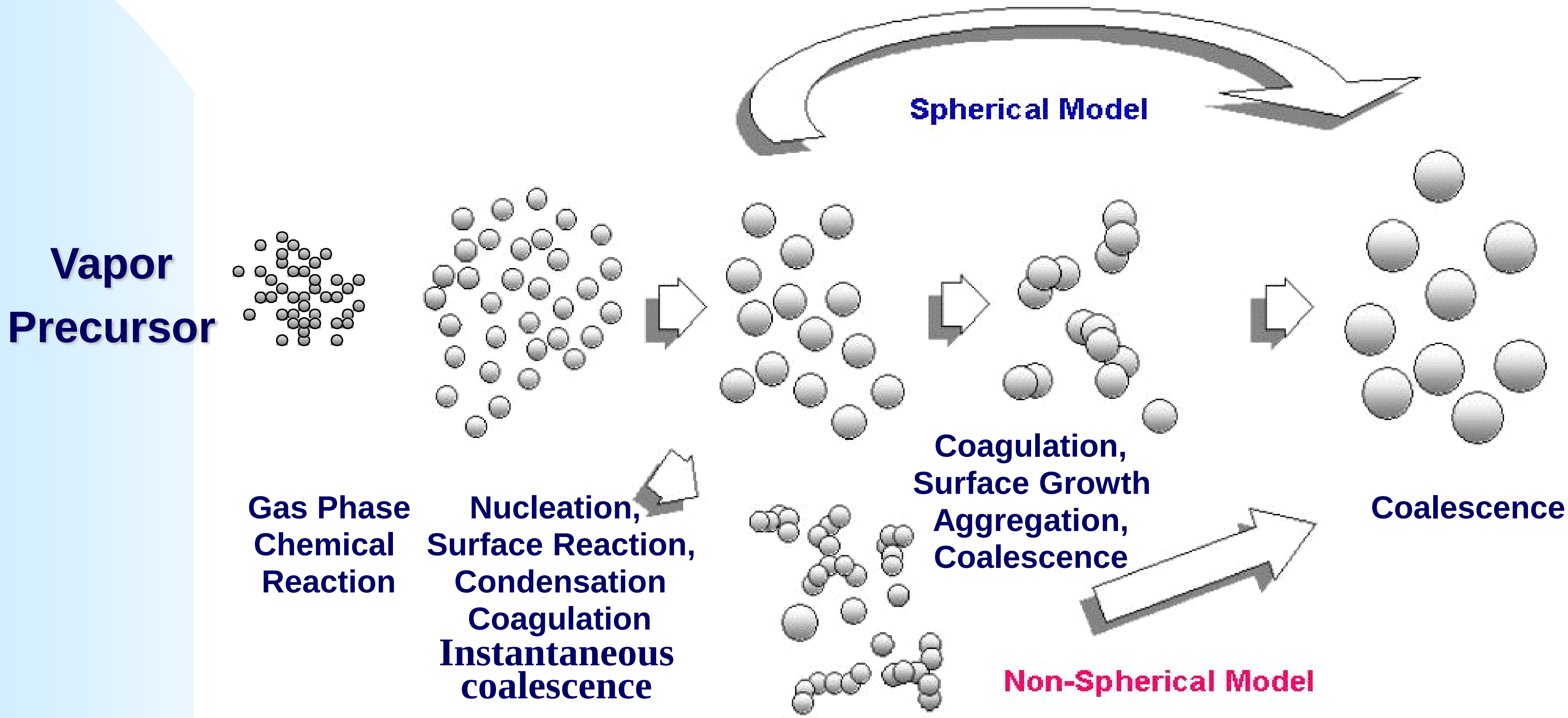


High Resolution TEM Images of Fe_2O_3 Nanoparticles Collected at 60 mm

Yang et al., 2003, Fragmentation of Fe2O3 nanoparticles driven by a phase transition --, APL, 83, 4842



Nanoparticle Growth during Gas Phase Synthesis

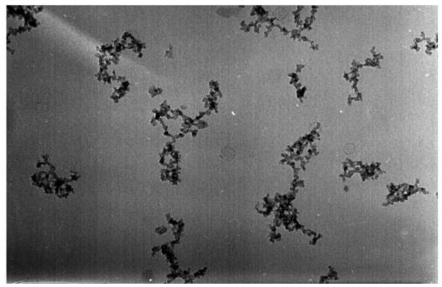


+Transport Processes

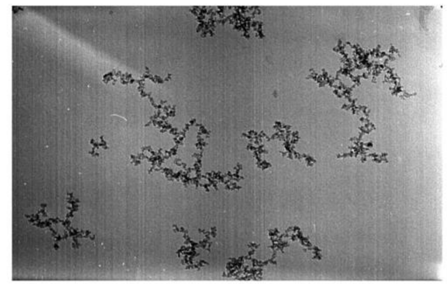
(convection, diffusion, thermophoresis, deposition, etc)

Growth of Aggregates

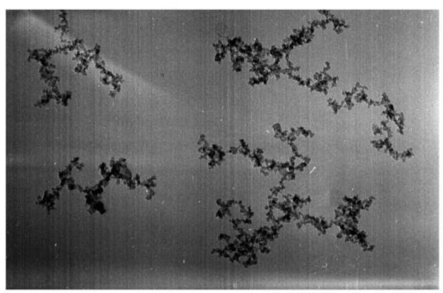
200 nm



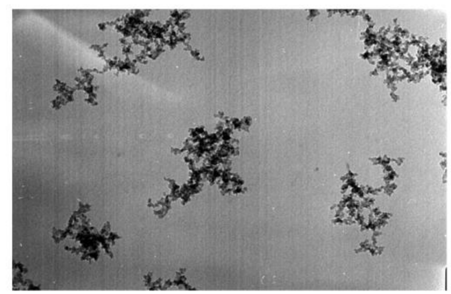
z=7.5 mm



z=10 mm



z=15 mm



z=25 mm

*** Particle concentration**

- **number concentration N: #/cm^3**
- **particle surface (area) concentration S: μm^2/ cm^3**

(if particles are spheres and monodisperse, $\pi d^2 \times N = S$)

- **particle volume concentration: μm^3/ cm^3**
- **particle mass concentration: μg/ cm^3**

* Characterization of particle sizes

Interval, μm	n_i (#/cm^3)	midpoint	n_i / μm
1 – 2	30	1.5	30
2 – 3	90	2.5	90
3 – 5	50	4.0	25
5 – 10	20	7.5	4
10 – 20	10	15	1

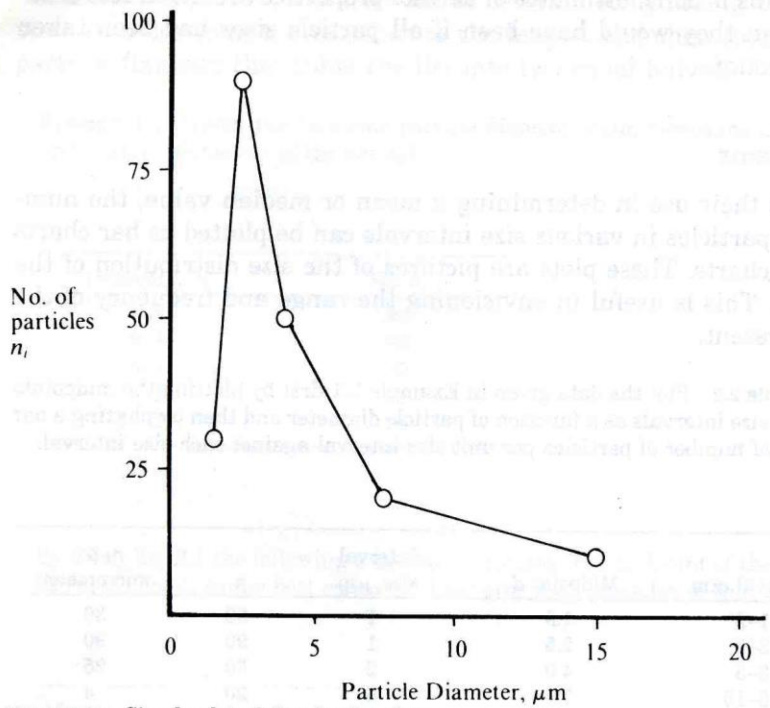
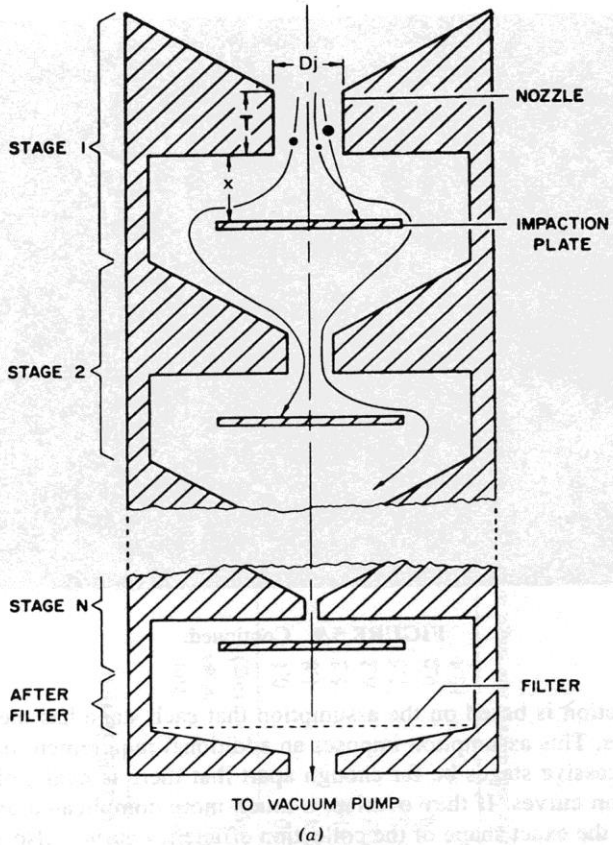


Figure 2.1a Simple plot of distribution data.

Histogram :

simple description for particle size distribution, but, the profile can be strongly distorted by changing the width of particle size.



(a)

IGURE 5.9 Cascade impactor (*a*) Schematic diagram. Reprinted with permission from *erosol Measurement,* by Dale Lundgren et al. Copyright 1979 by the Board of Regents of ie State of Florida. (*b*) Eight stage Anderson ambient cascade impactor with nozzle plate nd impaction plate shown at left.

The sequential separation divides the entire distribution of particles into a series f contiguous groups according to their aerodynamic diameters. From the gravimet-

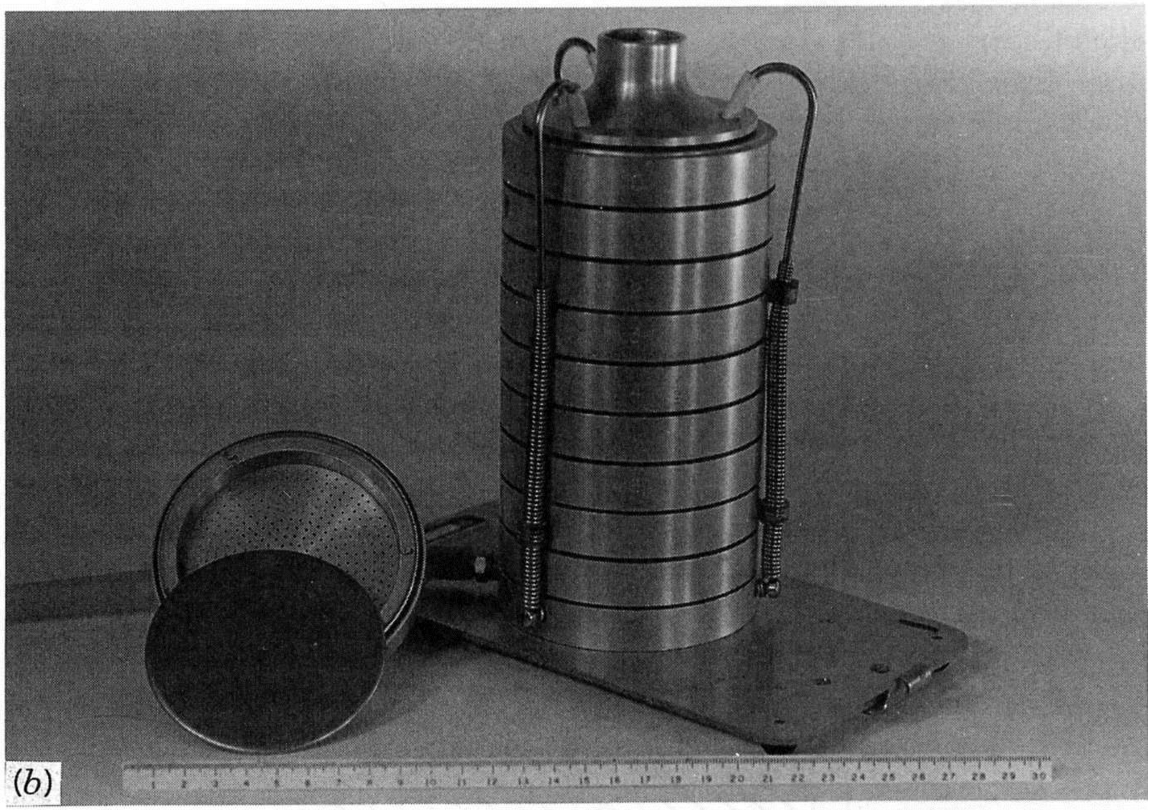
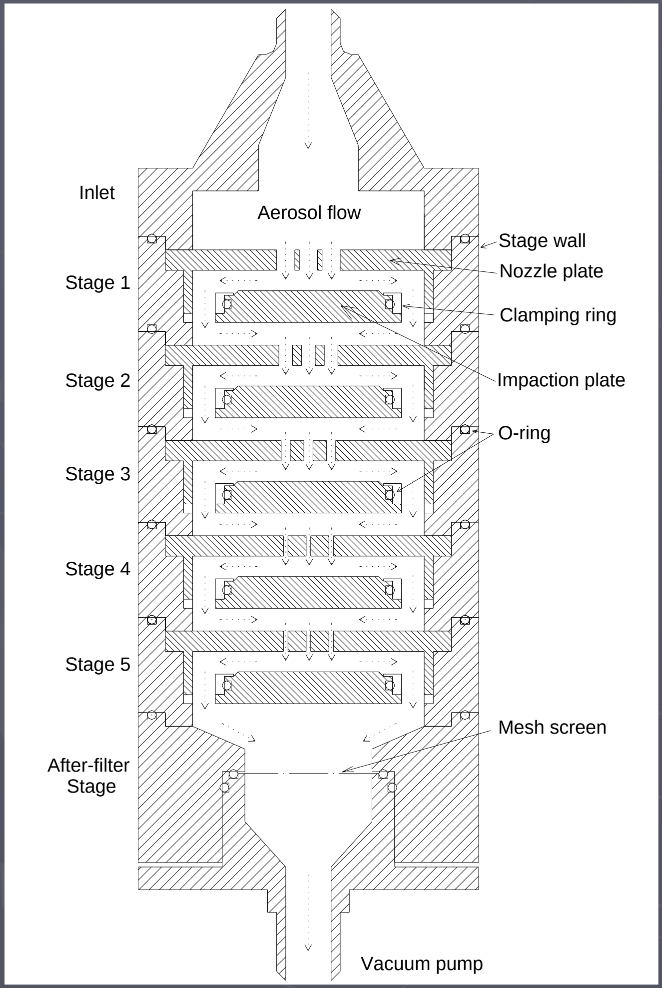


FIGURE 5.9 Continued.

- Cascade impactor (Kwon *et al.*, 2003)



Cutoff diameter

- Definition of cutoff diameter: aerodynamic diameter where 50% collection efficiency acquired
- Example of efficiency curves for Cascade impactor

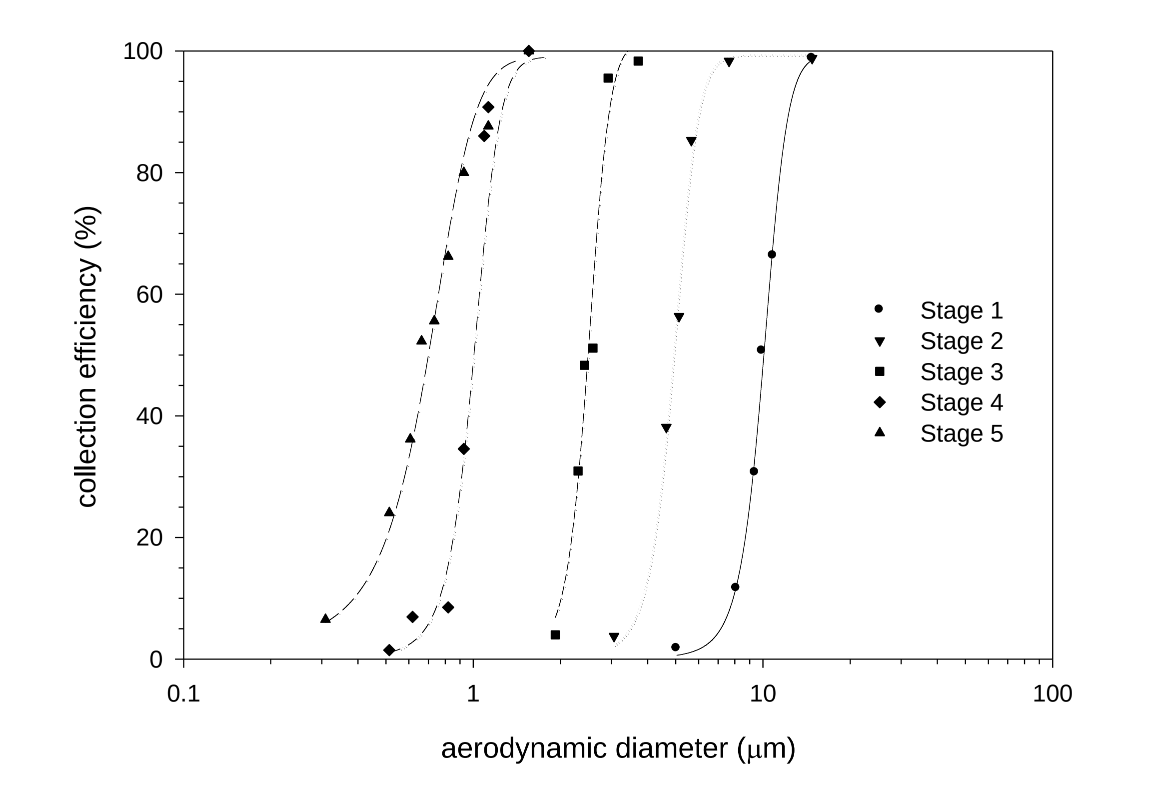


TABLE 5.5 Example of Cascade Impactor Data Reduction

Stage Number	Initial Mass (mg)	Final Mass (mg)	Net Mass (mg)	Mass Fraction (%)	d_{50} (μm)	Size Range of Collected Particles (μm)	Cumulative Mass Fraction[a] (%)
1	850.5	850.6	0.1	0.6	9.0	>9.0	100.0
2	842.3	844.1	1.8	11.0	4.0	4.0–9.0	99.4
3	855.8	861.0	5.2	31.7	2.2	2.2–4.0	88.4
4	847.4	853.6	6.2	37.8	1.2	1.2–2.2	56.7
5	852.6	855.1	2.5	15.2	0.70	0.70–1.2	18.9
Downstream filter	78.7	79.3	0.6	3.7	0	0–0.70	3.7
			16.4	100.0			

[a]Cumulative mass fraction is plotted against the upper limit of each size range, to construct a cumulative mass distribution curve.

To prevent this distortion, the histogram can be normalized for interval width by dividing the number of particles in each interval by the width of that interval.

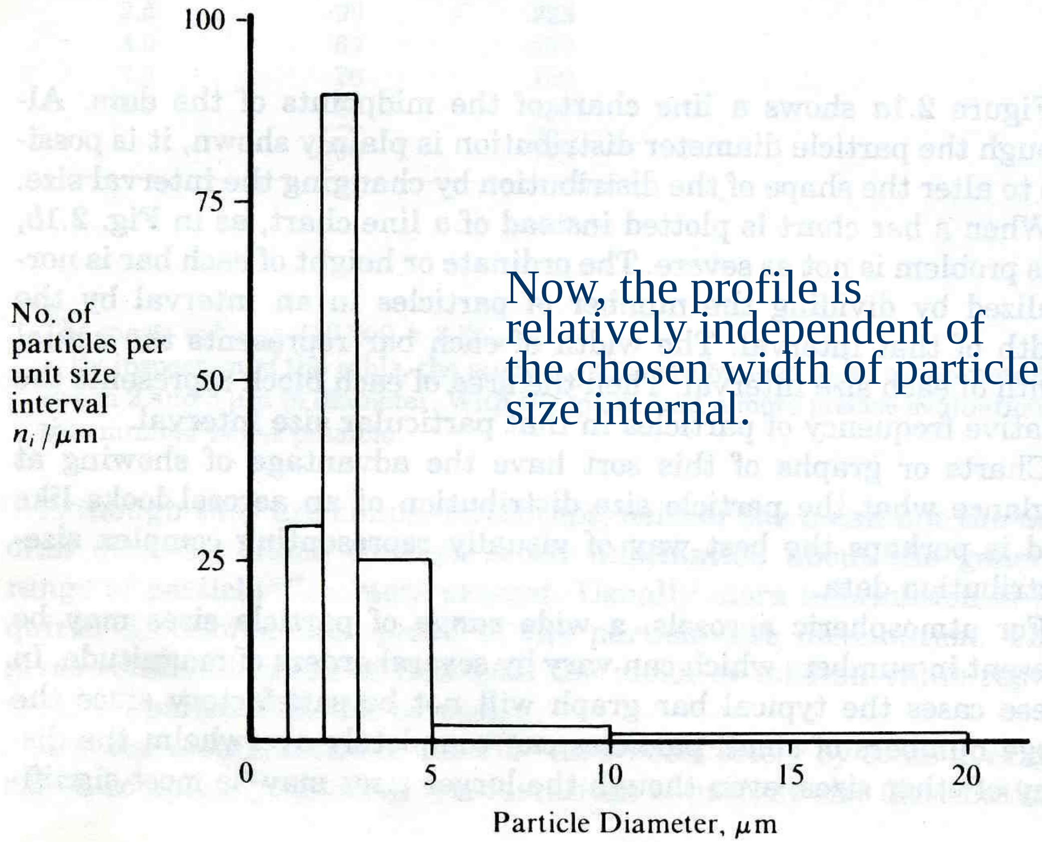


Figure 2.1b Bar graph of particle distribution data.

Now, the profile is relatively independent of the chosen width of particle size internal.

*** Particle size distribution function $n(d_p)$: number of particles per unit size interval**

Unit: #/cm^3·㎛

$n(d_p)dd_p$: numbers of particles per unit volume between d_p and $d_p + dd_p$

N (total number concentration) #/cm^3 $= \int_0^\infty n(d_p)dd_p$

$$f(d_p) = \frac{n(d_p)}{N}$$: **frequency function or probability density function**

$$df = \frac{n(d_p)dd_p}{N} = f(d_p)dd_p$$

$$\int_0^\infty f(d_p)dd_p = \frac{1}{N}\int_0^\infty n(d_p)dd_p = 1.0$$

For usual aerosols, a wide range of particle size may be present in numbers which can vary by several orders of magnitude. In this case, the typical bar graph will be over-crowded at small sizes and display almost zero at other sizes since the large numbers of small particles can completely overwhelm the display of other sizes.
Though, the larger sizes may be most significant in terms of mass or surface area.

→ One solution is to plot the logarithms of particle diameters on the X-axis instead of the diameters themselves. This spreads out the presentation of distribution data over a much broad range of particle size.

Example 2.3 Plot the data given in Example 2.1 in the form of $\Delta n/\Delta \log d$ versus $\log d$.

log d

Interval	Midpoint	No. Δn	$\Delta \log d$	$\Delta n/\Delta \log n$
1–2	1.5	30	0.30	100
2–3	2.5	90	0.18	511
3–5	4.0	50	0.22	225
5–10	7.5	20	0.30	66
10–20	15.0	10	0.30	33

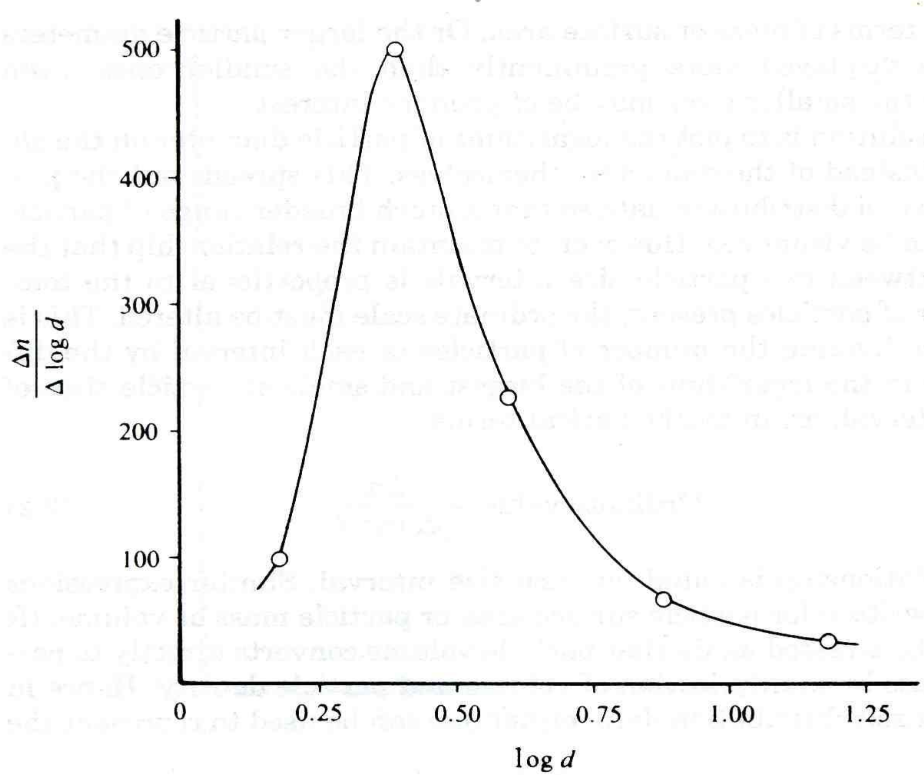


Figure 2.2 Plot of data from Example 2.3. A continuous distribution is assumed.

*** Particle size distribution function is a function of size, position and time** $n(dp,\vec{r},t)$

and

Total number concentration $N(\vec{r},t)$ is a function of position and time

*** Once we determine the size distributions of particles in space and time, we know everything about aerosols.**
(the evolution of particles, transport, deposition, collection …)

*** For non-spherical particles, we often use**
- equivalent diameter to define the size distribution function. However, if you need to know more details about the evolution of morphology as well as the size, you need to define different size distribution function.

Instead of $n(d_p,\vec{r},t)$ **, you need to know** $n(v,s,\vec{r},t)$

v: particle volume

s: particle surface area

For spheres, once you know the diameter, then you can determine others such as volume $(\frac{\pi d_p{}^3}{6})$, surface are $(\pi d_p{}^2)$. For non-spheres, particle volume and surface area are independent.