ATOC 3500/CHEM 3151
Air Pollution Chemistry
Lecture 4

<u>Lecture 4: Particulate Matter</u>

<u>Text: Pages 5-6, 32, 208, 210-213</u>

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http://acmg.seas.harvard.edu/publications/jacobbook/bookchap8.pdf

Important Aspects of Aerosols (particulates)

An aerosol is defined as a suspension of particles in a gas. Aerosols are also called "particulates", and the term "PM" (particulate matter) is used to quantify the amount of liquid or solid material in the gas. For example, there is typically about ~20 micrograms (20×10^{-6} grams) of particulates in a cubic meter of air in Boulder, Colorado. So we say the PM in Boulder is "20 $\mu g\ m^{-3}$."

Aerosols (or "PM") are important for a variety of reasons, including affecting air quality, visibility, and health. Therefore, a lot of time and energy (and money!) is invested in understanding the processes that affect aerosols (their formation, loss, and impacts on atmospheric chemistry).

Important Aspects of Aerosols (particulates)

One of the differences between aerosols and a pure gas is that one can readily see aerosols because sunlight scatters off the small particles, so that they appear as a grey or brown "haze" in an otherwise clear atmosphere. For example, in the figure from space at right the aerosols are readily distinguished from the more "white" clouds.

One of the key differences between pure gases and aerosols, in terms of the impacts of aerosols or particulate matter on the environment and health, is that gases are in one state, whereas particles exist in many forms, and individual particles in aerosols can have different sizes and shapes. These differences can have different impacts. For example, large particles (such as dust) tend to fall out of the atmosphere over time. Therefore, they have short lifetimes in the air. Smaller particles, however, can remain suspended in the atmosphere for days, weeks, and even months, allowing them to be transported very long distances. It is not uncommon, for example, for smoke from forest fires and sulfuric acid droplets from volcanic eruptions to be found in ice cores from Antarctica – far from their original emission sources.

So when we talk about particulate matter, we need to deal with the chemical composition of the particles, as well as the sizes and shapes of all the all the individual particles. This makes for a very complicated description of an “aerosol” as more than just the total mass of condensed matter suspended in air.

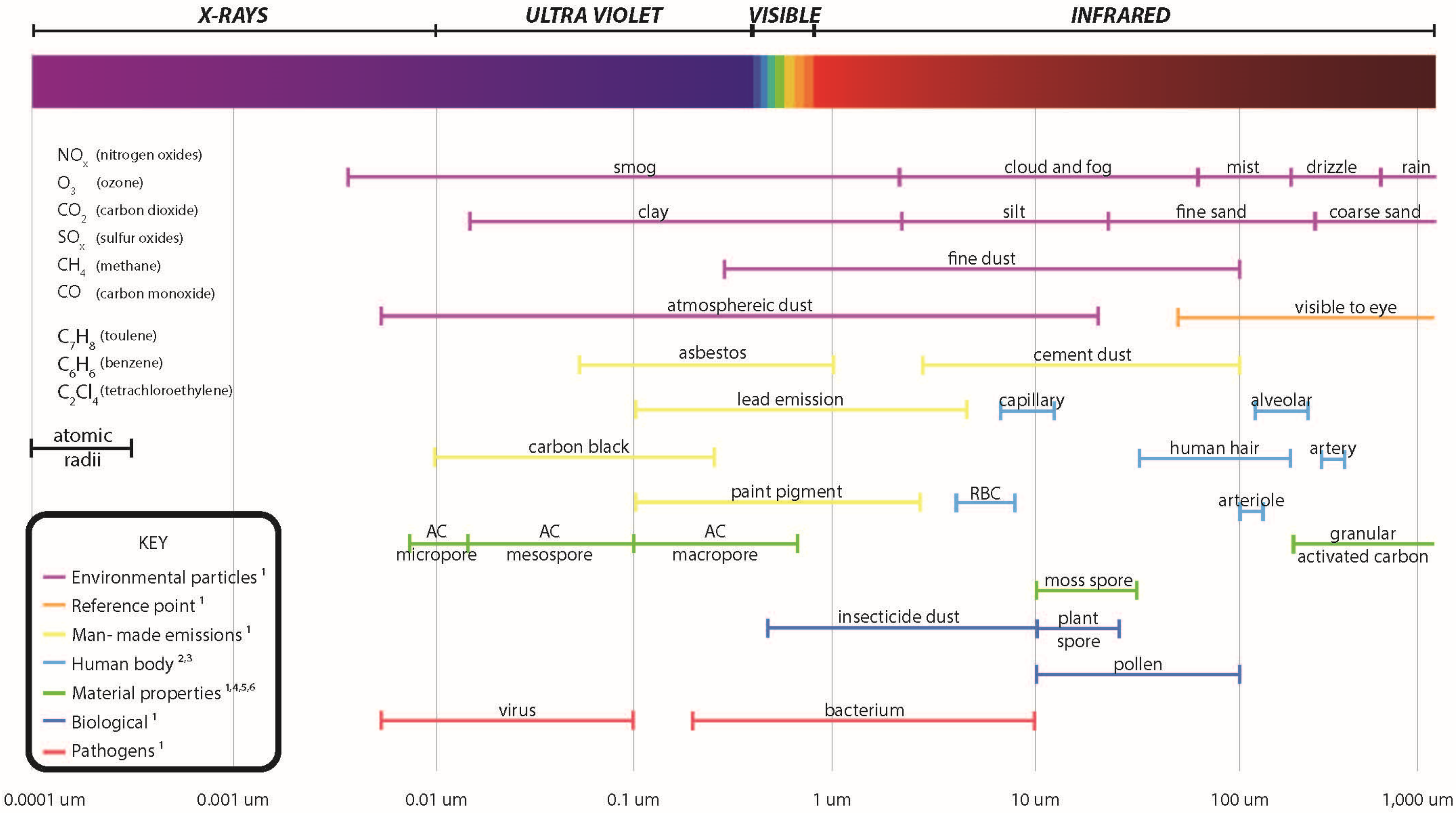
Here is a good overview of atmospheric aerosols:

https://iitbuildingscience.wordpress.com/2013/08/26/particulate-matter-and-health-implications/

The figure on the next slide provides a good illustration of the wide range of particles that are important in the atmosphere and different ways to classify them.

The spectrum at the top is related to the type of light that is scattered off different sizes of particles. Note that smaller particles scatter the shortest wavelengths of light, whereas the larger particles scatter longer wavelengths. This provides a way to remotely detect particles using "spectroscopy" (i.e., measuring particles from space).

In this class we will mostly deal with particles that range from about 10 nanometers (or 0.01 micrometers) in diameter up to about 10 micrometers (also called "microns" for short). These are the particles that are most influential in atmospheric chemistry.



1. http://www.h2odistributors.com/chart-particle-sizes.asp
2. http://www.coheadquarters.com/PennLibr/MyPhysiology/lect0p/lect0.03.htm
3. http://www.circulatory-system.com/blood-vascular-system/
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6. http://www.pottiaceae.com/imagenes/pdf/P6.pdf
7. http://www.gulflink.osd.mil/appendix_d.pdf
8. http://www.tsi.com/uploadedFiles/Product_Information/Literature/Application_Notes/ITI-050.pdf

Aerosols

(suspension of particles in air)

For now, note that there are three main 'modes' of particles suspended in air

- *Course* mode – particles larger than about 1 micrometer (μm) in diameter. Usually suspended by mechanical processes (e.g. windblown dust)

- *Fine* mode – particles between ~0.05-1 μm. Also called accumulation mode. Usually produced by condensation of water and other volatile materials on smaller particles (something like condensation, but better called *deliquescence* when water and sticking and dissolution on when talking about other species. This mode is responsible for *haze* (e.g. poor visibility).

Aerosols

(suspension of particles in air)

Ultrafine mode – smaller than 0.05 μm, formed exclusively from condensation (e.g. new particle growth). *Condensation nuclei* (CN) are particles that are particularly good at aiding in the formation of larger particles, and *cloud condensation nuclei* (CCN) are particles that eventually form water droplets. Usually small particles (~ few nm) form by homogeneous nucleation ("out of gas phase into liquid phase") of low-volatility gases like sulfuric acid, ammonia, and nitric acid. This typically requires neutralization (that is, positive charges, other than water, equal negative charges).

But particles are pretty complex, and there really isn't a simply way to classify them (doesn't mean we can't try!)

Photochemical Smog

Tends to be a mixture of reactive gases (like ozone) and particles

Particles and clouds also impact atmospheric composition

This is a picture of polar stratospheric clouds from Kiruna, Sweden. These clouds in the stratosphere made of ice and responsible for altering the normal chlorine chemistry in the ozone layer, thereby leading to ozone holes that are seen over Antarctica and the Arctic.

Where do clouds form?

In cold regions at high altitudes:

Noctilucent clouds (can see at night because they are high altitude)

High altitude "cirrus" clouds

And throughout the troposphere where it is relatively humid (formed when air cools)