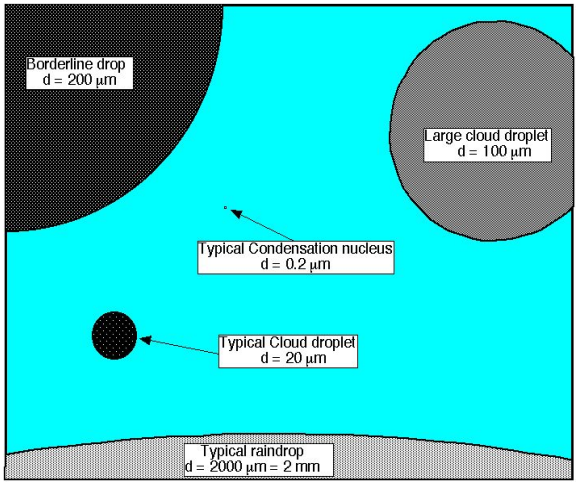

Without droplets of water, most clouds would be transparent! If you were to look inside a cloud you would see droplets of water of many different sizes because droplets constantly grow in size once they are formed.

The figure to the left shows some typical kinds of water droplets you might find in a cloud along with their diameters in micrometers (microns). Recall that one micrometer=1/1000000 or 10^{-6} meters.

The following exercises let you explore some of the properties of water droplets. In all cases, assume that the droplet is a perfect sphere!

Problem 1 – Water droplets are made out of water (of course!) and water has a density of 1000 kg/m^3. What is the mass, in grams, of each of the five types of droplets described in the figure?

Problem 2 – To the nearest 1000, about how many typical cloud droplets have to be combined to form one large cloud droplet?

Problem 3 – To the nearest 1000, about how many large cloud droplets have to combine to form one typical raindrop?

Problem 4 – Suppose that it takes about 2 minutes for a large cloud droplet to double in mass. How long does it take a large cloud droplet to grow into a raindrop and leave the cloud?

Common Core Math Standards:

CCSS.Math.Content 6.RP.3.d Use ratio reasoning to convert measurement units; manipulate and transform units appropriately when multiplying or dividing quantities.
CCSS.Math.Content.8.G.C.9 Know the formulas for the volumes of cones, cylinders, and spheres and use them to solve real-world and mathematical problems.
CCSS.Math.Content.8.EE.A.4 Perform operations with numbers expressed in scientific notation, including problems where both decimal and scientific notation are used. Use scientific notation and choose units of appropriate size for measurements of very large or very small quantities (e.g., use millimeters per year for seafloor spreading). Interpret scientific notation that has been generated by technology

Problem 1 – Water droplets are made out of water (of course!) and water has a density of 1000 kg/m^3. What is the mass, in grams, of each of the five types of droplets described in the figure?
Answer: Recall Volume = 4/3 π R^3 and Mass = Density x Volume.

Raindrop: d=2 mm, r=1 mm = 0.001 meters
V = 4/3 π $(0.001)^3$ = 4.2×10^{-9} m^3
Mass = 1000 kg/m^3 x 4.2×10^{-9} m^3 x (1000gm/1kg) = **0.004 grams**

Borderline Drop: d = 200 microns, r = 100 microns. = 0.0001 meters
V = 4/3 π $(0.0001)^3$ = 4.2×10^{-12} m^3
Mass = 1000 x 4.2×10^{-12} x (1000gm/1kg) = **4.2×10^{-6} grams** (= 4.2 micrograms)

Large Cloud Droplet: d = 100 microns, r = 50 microns = 0.00005 meters
V = 4/3 π $(0.00005)^3$ = 5.2×10^{-13} m^3
Mass = 1000 x 5.2×10^{-13} x (1000gm/1kg) = **5.2×10^{-7} grams** (0.5 micrograms)

Typical Cloud Droplet: d = 20 microns, r = 10 microns = 0.00001 meters
V = 4/3 π $(0.00001)^3$ = 4.2×10^{-15} m^3
Mass = 1000 x 4.2×10^{-15} x (1000gm/1kg) = **4.2×10^{-9} grams** (4.2 nanograms)

Typical Condensation Nucleus: d = 0.2 microns, r = 0.1 microns = 0.0000001 meters
V = 4/3 π $(0.0000001)^3$ = 4.2×10^{-21} m^3
Mass = 1000 x 4.2×10^{-21} x (1000gm/1kg) = **4.2×10^{-15}** grams

Problem 2 – To the nearest 1000, about how many typical cloud droplets have to be combined to form one large cloud droplet? Answer: N = Mass of large droplet / mass of typical cloud droplet = 5.2×10^{-7} gm/4.2×10^{-9} gm = 124 typical droplets.

Problem 3 – To the nearest 1000, about how many large cloud droplets have to combine to form one typical raindrop? Answer: N = Mass of raindrop/mass of large droplet = 0.004 grams/5.2×10^{-7} grams = 7692 or about **8000 large droplets**.

Problem 4 – Suppose that it takes about 2 minutes for a large cloud droplet to double in mass. How long does it take a large cloud droplet to grow into a raindrop and leave the cloud?

Answer: In Problem 3 we saw that about 8000 large cloud droplets equals a raindrop. Since 8000 is about 2^{13}, we need 13 doubling times to grow this large, which takes 13 x 2 minutes = **26 minutes**.

Note: Students may want to make a scaled model of droplet sizes using styrofoam balls or other round objects.