4.9.1 Density

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The density (ρ) of a material is the mass (M) of a unit volume (V) of the material:

$$\rho = \frac{M}{V}$$

(1) What units are used for density?

The density of materials is ultimately determined by the concentration of atoms in a given volume and the intrinsic mass of these atoms.

Gases have some of the lowest densities because there are few atoms or molecules in a given volume. Gases such as hydrogen and helium are especially low density because the atoms are intrinsically light (low mass).

Materials such as uranium metal have very high densities because they consist of tightly packed, high-mass atoms.

(2) Find density values for the following materials: hydrogen, uranium, lead, water.

(3) What volume would 1kg of water occupy?

(4) What volume would 1g of uranium occupy?

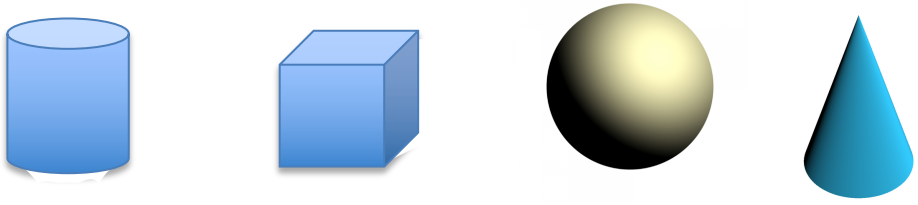
Students often have problems converting between units of volume. For example, converting mm^3 to m^3, or from cm^3 to m^3. Let us look at converting mm^3 to m^3.

$$1mm^3 = (1 \times 10^{-3})^3 m^3 = 1 \times 10^{-9} m^3$$

So $1mm^3$ is 1 billionth of $1m^3$!

(5) How does $1cm^3$ compare to $1m^3$?

(6) What are the formulae for working out the volumes of the following shapes?



(7) What mass would a 1m diameter sphere of lead have?

(8) How would you measure the density of an irregular shaped object?

Density of mixtures

Often materials (such as alloys) contain a mixture of more than one substance. We need to be able to work out the combined density of the mixture.

Consider a mixture of two substances, A and B. A has a volume V_A, mass M_A and density ρ_A. B has a volume V_B, mass M_B and density ρ_B. The combined density (ρ_{mix}) of the mixture is given by:

$$\rho_{mix} = \frac{total\ mass}{total\ volume} = \frac{M_A + M_B}{V_A + V_B} = \frac{\rho_A V_A + \rho_B V_B}{V_A + V_B}$$

If we know the percentage volume of A and B, and their densities we can use this formula to find the combined density.

(9) An alloy of copper and tin contains 88% copper and 12% tin, by volume. The densities of copper and tin are 8900kgm^{-3} and 7300kgm^{-3} respectively. Find the density of the alloy. (Hint: calculate using a total volume of 1m^3)

Sometimes the mixture is described in terms of the relative mass fraction of the two substances. In this case we can find the density of the mixture:

$$\rho_{mix} = \frac{total\ mass}{total\ volume} = \frac{M_A + M_B}{V_A + V_B} = \frac{M_A + M_B}{\left[\frac{M_A}{\rho_A} + \frac{M_B}{\rho_B}\right]}$$

(10) An alloy of copper and zinc contains 65% copper and 35% zinc, by mass. The densities of copper and tin are 8900kgm^{-3} and 7140kgm^{-3} respectively. Find the density of the alloy. (Hint: calculate using a total mass of 1000kg)