Density

Density is defined as the mass of a substance per unit volume, or:

$$\text{density} = \frac{\text{mass}}{\text{volume}} \qquad \left[D = \frac{m}{V} \right]$$

COMMON UNITS

For solids and liquids: g/cm^3 or g/mL (Note: 1 cm³ = 1 mL)

For gases: g/L

For all three states: kg/m^3 (useful because it uses base units)

NOTES

[1]   Density is expressed as mass over volume, so if the density has units of g/mL, then the mass must be expressed in grams and the volume in millilitres.

[2]   Normally the volume of a substance changes when it is heated or cooled. Such a change would alter the density, so density values are usually reported at a certain temperature.

[3]   If the quantity of a substance was increased, the mass and volume would both increase proportionally, so density remains constant.

Example 1:   49.2 mL of CCℓ₄ has a mass of 78.6 g. Determine its density.

Solution: $D = \dfrac{m}{V} = \dfrac{78.6\ g}{49.2\ mL} = 1.60\ g/mL$

EXERCISES

A. Given any pure substance:
1) What effect would doubling the volume have on the mass?
2) What effect would tripling the mass have on the volume?
3) How would its density be affected by these changes?

B. Water has a density of 1 g/mL. This means that 1 mL of water has a mass of 1 g.
1) If you had 20 mL of water, what would its mass be?
2) What is the density of 20 mL of water?

C. A block of magnesium has a mass of 42.9 g and a volume of 25.38 cm³. What is the density of magnesium?

D. Determine the density of:
1) a piece of metal having a volume of 65.0 mL and a mass of 565 g.
2) a substance occupying a volume of 75.5 mL and having a mass of 335 g.

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E. From the basic definition of density, solve algebraically for
   1) the mass   2) the volume

F. Lead has a density of 11.37 g/mL. Find:
   1) the mass of 16.0 mL of lead   2) the volume occupied by 175 g of lead

G. Chloroform, $CHC\ell_3$, has a density of 1.492 g/mL. Find:
   1) the volume of 25.00 g of chloroform   2) the mass of 25.00 mL of chloroform

H. The density of glycerin is 1.26 g/mL. What is the mass of 200 mL of pure glycerin?

I. Determine the mass in grams of each of the following:
   1) a 655-mL volume of acetic acid (D = 1.05 g/mL)
   2) a 125-mL volume of benzene (D = 0.880 g/mL)

J. Determine the volume occupied by each of the following:
   1) a 345-g sample of turpentine (D = 0.870 g/mL)
   2) a 495-g sample of carbon tetrachloride (D = 1.60 g/mL)

K. The density of diamond is 3.52 g/mL. What is the volume of 1 kg of diamond?

L. The density of cesium is 1.87 g/mL. What is the mass of 1 L of cesium?

M. Water displacement can be used to determine the volume of irregularly-shaped objects. A graduated cylinder was filled to the 125.0 mL mark with water. An irregularly-shaped crown with a mass of 324 g was submerged in the cylinder and the water level rose to 141.8 mL.
   1) What is the volume of the object?
   2) What is the density of the object?
   3) Use Wikipedia or your textbook: could the crown be made of gold?

N. [*Optional*] Concentrated hydrochloric acid solution (D = 1.19 g/mL) is 38% pure $HC\ell$ by weight. How much pure $HC\ell$ is there in 30.0 mL of $HC\ell$ solution?

SOLUTIONS
A. (1) Mass would double. (2) Volume would triple. (3) Density would remain the same.
B. (1) 20 g (2) 1 g/mL   C. 1.69 g/mL   D. (1) 8.69 g/mL   (2) 4.44 g/mL
E. (1) m = D×V   (2) V = m/D
F. (1) 182 g (2) 15.4 mL   G. (1) 16.76 mL   (2) 37.30 g
H. 252 g
I. (1) 688 g (2) 110 g   J. (1) 397 mL   (2) 309 mL   K. 284 mL   L. 1870 g
M. (1) 16.8 mL   (2) 19.3 g/mL   (3) Not telling. Go find out.
N. mass of solution: 35.7 g; mass of $HC\ell$ is 13.6 g