| A brief History of the US (one-cent coin) Penny Composition | |
|---|-----------------------------|
| Year | Composition |
| 1793 to 1837 | 100% Cu |
| 1837 to 1857 | Bronze (95% Cu, 5% Sn & Zn) |
| 1857 to 1864 | 88% Cu & 12% Ni |
| 1864 to 1942 | Bronze (95% Cu, 5% Sn & Zn) |
| 1943 | Zinc-coated steel |
| 1944 to 1946 | Brass (95% Cu & 5% Zn) |
| 1946 to 1962 | Bronze (95% Cu, 5% Sn & Zn) |
| 1962 to 1982 | Brass (95% Cu & 5% Zn) |
| 1983 to | 97.6% Zn & 2.4 % Cu |



Percent Composition of Zinc and Copper in US Pennies:

- The current US penny is made of metallic copper (Cu) plated onto a zinc (Zn) core.
- In an object composed of multiple materials (like a penny), the density (d) is a weighted average of the densities of the pure substances that make up the object. Also assume that there is no change in volume when the pure metals are mixed.
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$$d_{penny} = (\%Cu \ by \ mass)d_{Cu} + (\%Zn \ by \ mass)d_{Zn}$$

$$d_{penny} = (p)d_{Cu} + (q)d_{Zn}$$

Where:

$$\%p + \%q = 100$$

$$q = 1.00 - p$$

$$d_{penny} = (p)d_{Cu} + (1.00 - p)d_{Zn}$$

$$d_{penny} = (p)d_{Cu} - (p)d_{Zn} + 1.00d_{Zn}$$

$$d_{penny} = (p)[d_{Cu} - d_{Zn}] + 1.00d_{Zn}$$

$$p = \frac{d_{penny} - 1.00d_{Zn}}{d_{Cu} - d_{Zn}} = \%Cu \ by \ mass$$

Density

- If we know the density of the penny (composite), we can use this equation to obtain the % copper (p) in the sample.
- The following measurements are needed to find the Percent Composition of Zinc and Copper in US Pennies:
 - a) Density of a penny
 - b) Density of pure copper.
 - c) Density of pure zinc

A Numerical Example (I):

A piece of gold jewelry weighing 9.35 g. Its volume is measured 0.654 g/cm³. Assume that the metal is an alloy of gold and silver, which have densities of 19.32 g/cm³ and 10.49 g/cm³, respectively. Calculate the percentage of gold (by mass) in the jewelry.

Solution:
$$d_{\text{Jewely}} = (p)d_{\text{Au}} + (q)d_{\text{Ag}}$$

$$d_{Jewelry=\frac{mass of Jewelry}{Volume of Jewelry}=\frac{9.35_g}{0.654_{cm^3}}=14.3^g/_{cm^3}}$$

$$p = \frac{d_{Jewelry} - 1.00d_{Ag}}{d_{Au} - d_{Ag}} = \% \text{ Gold by mass}$$

$$p = \frac{14.3 - 10.49}{19.32 - 10.49} = 0.431 = \% \text{ Gold by mass}$$

Where p is the percent, p= 0.431. So 100 X 0.431 gives you 43.1, which is 43 percent gold.

A Numerical Example (II):

Using the values below, determine the composition (mass % Cu and mass % Zn) of a 1982 pennies. Density of copper= 8.96g/mL Density of zinc= 7.14g/mL Density of pre-1982 pennies= 8.10g/mL

Solution:

$$d_{\text{penny}} = (p)d_{\text{Cu}} + (q)d_{\text{Zn}}$$

$$p = \frac{d_{penny} - 1.00d_{Zn}}{d_{Cu} - d_{Zn}} = \%Cu \text{ by mass}$$
$$p = \frac{8.10 \ g/_{mL} - 7.14 \ g/_{mL}}{8.96 \ g/_{mL} - 7.14 \ g/_{mL_{Zn}}} = 0.527 \ \%Cu \text{ by mass}$$

Where p is the percent, p= 0.527. So 100 X 0.527 gives you 52.7, which is 52.7 percent

copper.

Also, 100 - 52.7 = 47.3 gives the percent of zinc.