an Al XRCD reference standard for a LEGO watt balance

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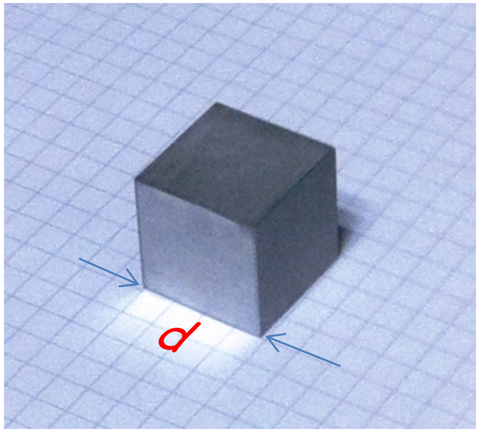
Instead of single-crystal, isotopically-enriched silicon-28 We use polycrystalline, mono-isotopic aluminium

"3. The calibrated mass, here *m* = 20.2 g, is added to the pan above Coil A."
--from description of NIST LEGO watt balance



Aluminium cube
made by Fabrice Boyer,
BIPM workshop

cube characteristics:

stated chemical purity, 99.999%
(polycrystalline, but maybe that will not matter to an accuracy of ≈1% ??)

edge length, d = 19.50 mm

calibrated mass, m = 20.04 g

Cost: comparable to the LEGO wb

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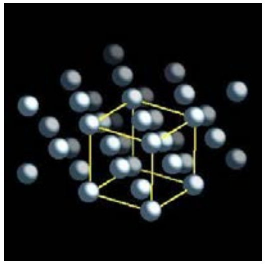
What we know about Aluminium

- Only one natural isotope: aluminium-27
- Crystal structure is FCC (4 atoms per unit cell)



- Unit cell has edge length, a_0, value known from x-ray crystallography to be **404.96 pm @ 23 °C**
- Relative atomic mass, $A_r(\mathrm{Al}) = m_a(\mathrm{Al})/m_u$ is known to be **26.9815**... (relative atomic masses are dimensionless)

Reminder: $m_u = m_a(^{12}\mathrm{C})/12$, known as the atomic mass constant

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Our cube hypothesis

- Volume of our aluminium cube = d^3
- Volume of a unit cell in an aluminium crystal = $a_0^{\,3}$
- Number of atoms in our aluminium cube, $N = 4(d/a_0)^3$, *if a single-crystal model works for a polycrystalline sample*.

Mass, m, of cube: $m = N \cdot m_a(\mathrm{Al})$, or

$$m = 4(d/a_0)^3 A_r(\mathrm{Al}) \boldsymbol{m}_\mathbf{u}$$

We can calculate the atomic mass constant, $\boldsymbol{m}_\mathbf{u}$, in kilograms.

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Avogadro's constant, N_A, comes next

$$\boldsymbol{N_A = M_u/m_u} = M(\mathrm{X})/m_a(\mathrm{X})$$

where M_u is the "molar mass constant" = **0.001 kg/mol (exactly)** in present SI; X is any "elementary entity"

The quantity $\boldsymbol{N_A h/M_u}$ (= h/m_u ; unit: m^2/s) is already known with uncertainty less than 1 part in 10^9 (CODATA 2010)

Having measured N_A (or m_u) we can determine the Planck constant, h !

Our result turned out to have an error of < 0.2 % wrt CODATA.

(same error as our results for $m_a(\mathrm{Al})$, m_u and N_A)

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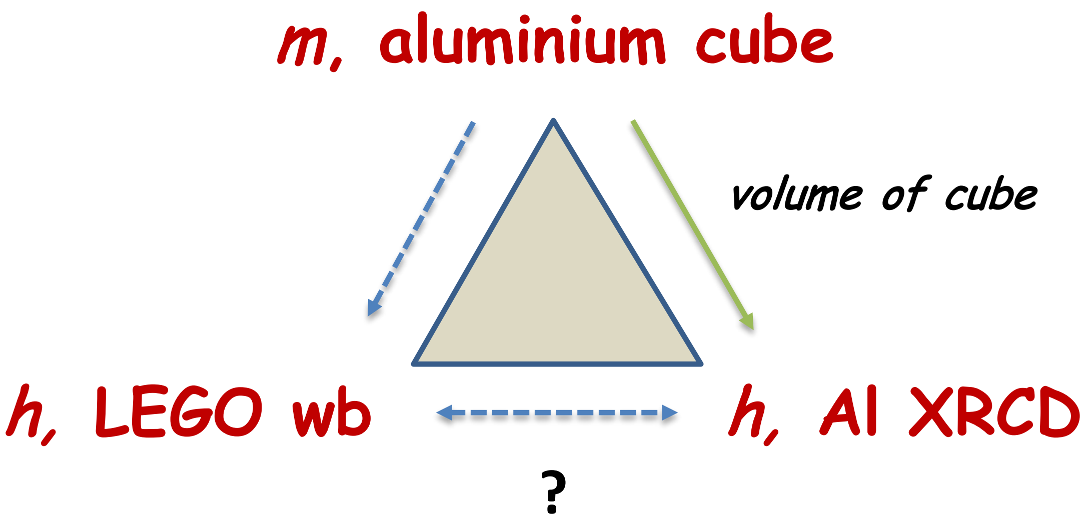
The next challenge: Confirm the metrological triangle



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