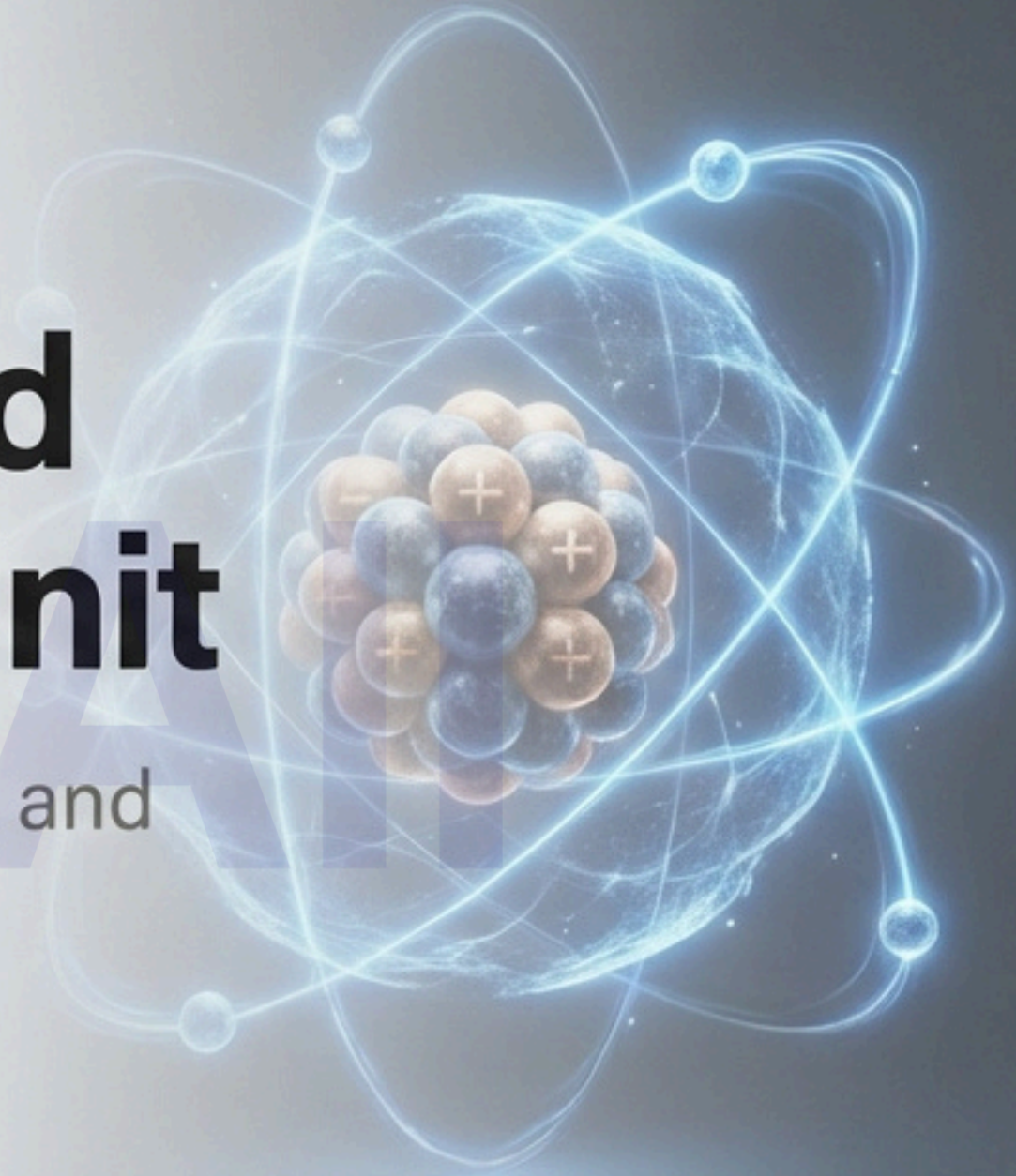


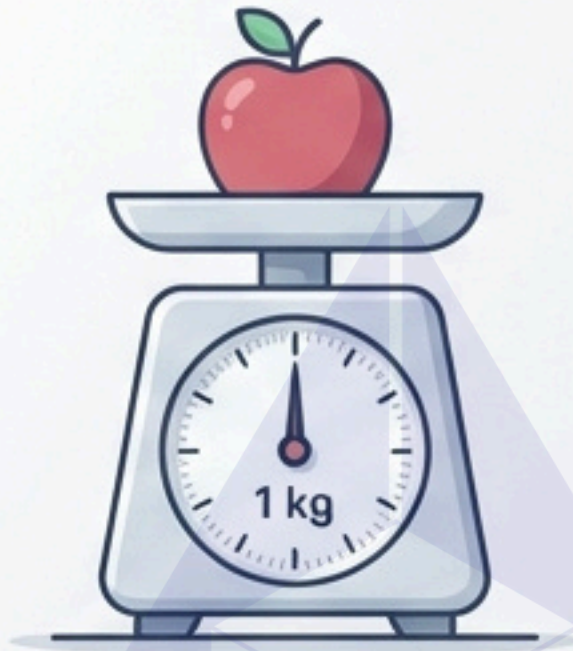


Why Atoms Need Their Own Mass Unit

The physics of atomic masses, isotopes, and the math behind the periodic table.



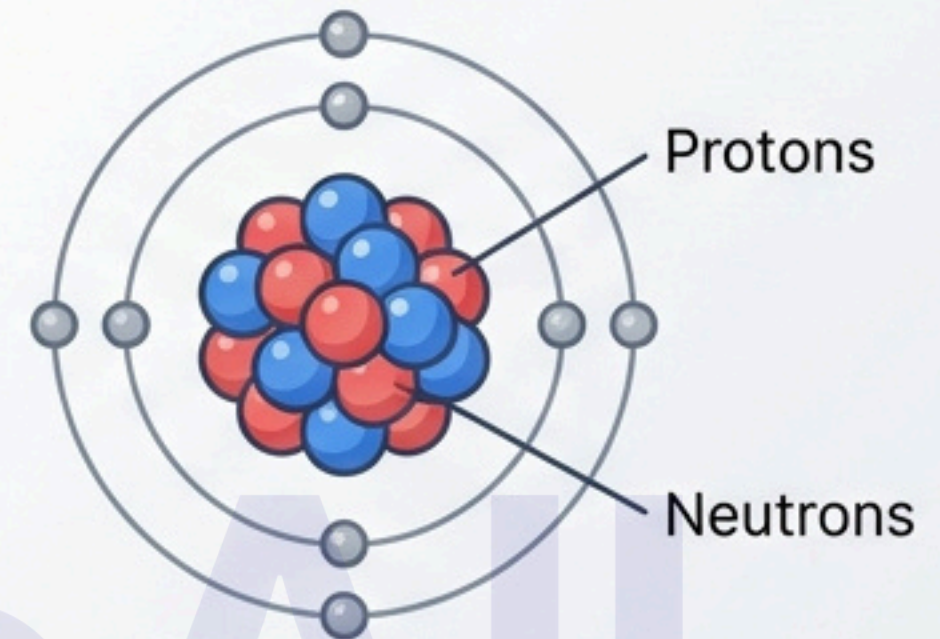
Teacher's Note: Welcome class. Today we're looking at Section 13.2 of your physics text. We're going to answer a simple question: how do we weigh something as tiny as an atom, and what do we do when mass spectrometers show us that atoms of the exact same element don't actually weigh the same amount?



The Standard Kilogram

Perfect for macro-world measurements
(books, people, apples).

**26 decimal places!
Too inconvenient
for calculations.**



The Carbon-12 Atom

1.992647×10^{-26} kg



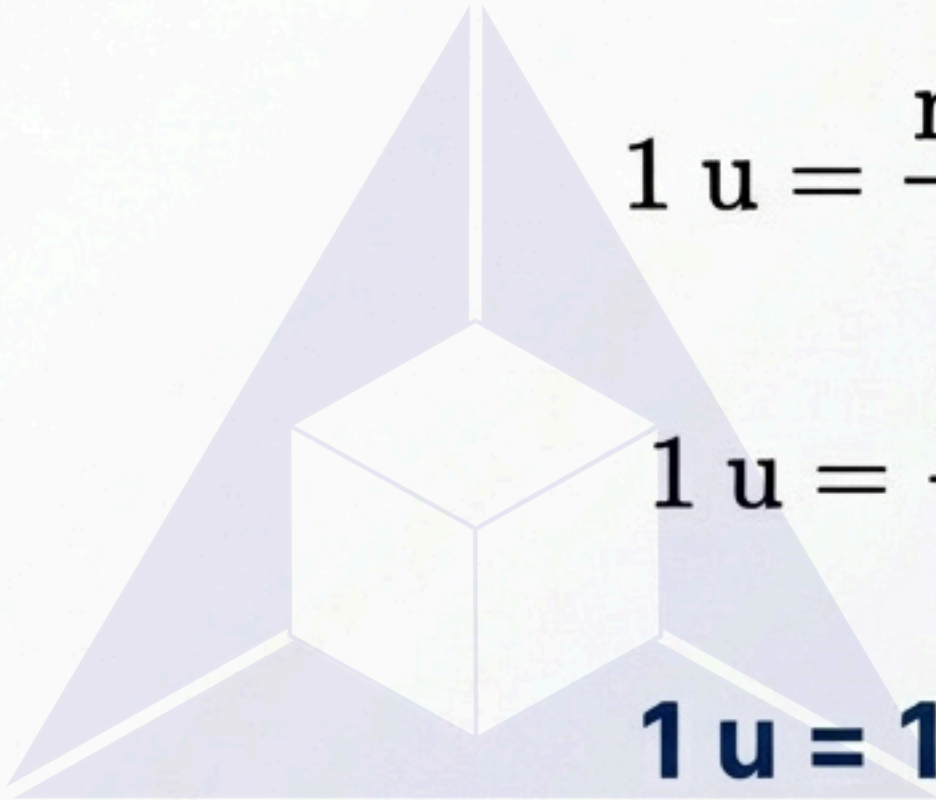
Teacher's Note: Imagine trying to weigh a single atom of Carbon-12 using kilograms. You get this incredibly tiny number with 26 decimal places. Writing this out every time we do a calculation is just asking for mistakes. The kilogram is built for human-sized objects, not atoms. We need a new, more convenient baseline unit.

Defining the Atomic Mass Unit (u)

The new baseline is defined as exactly 1/12th the mass of a carbon-12 atom.



Eq. (13.1)


$$1 \text{ u} = \frac{\text{mass of one } ^{12}\text{C atom}}{12}$$

$$1 \text{ u} = \frac{1.992647 \times 10^{-26} \text{ kg}}{12}$$

$$1 \text{ u} = 1.660539 \times 10^{-27} \text{ kg}$$



Teacher's Note: To fix this, scientists agreed to create the atomic mass unit, or 'u'. We define 1 'u' as exactly one-twelfth the mass of a single Carbon-12 atom. When you do the math, dividing the tiny kilogram mass of Carbon by 12, you get 1.660539 times 10 to the negative 27 kilograms. This is our new baseline standard for the whole periodic table.



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$$E=mc^2$$



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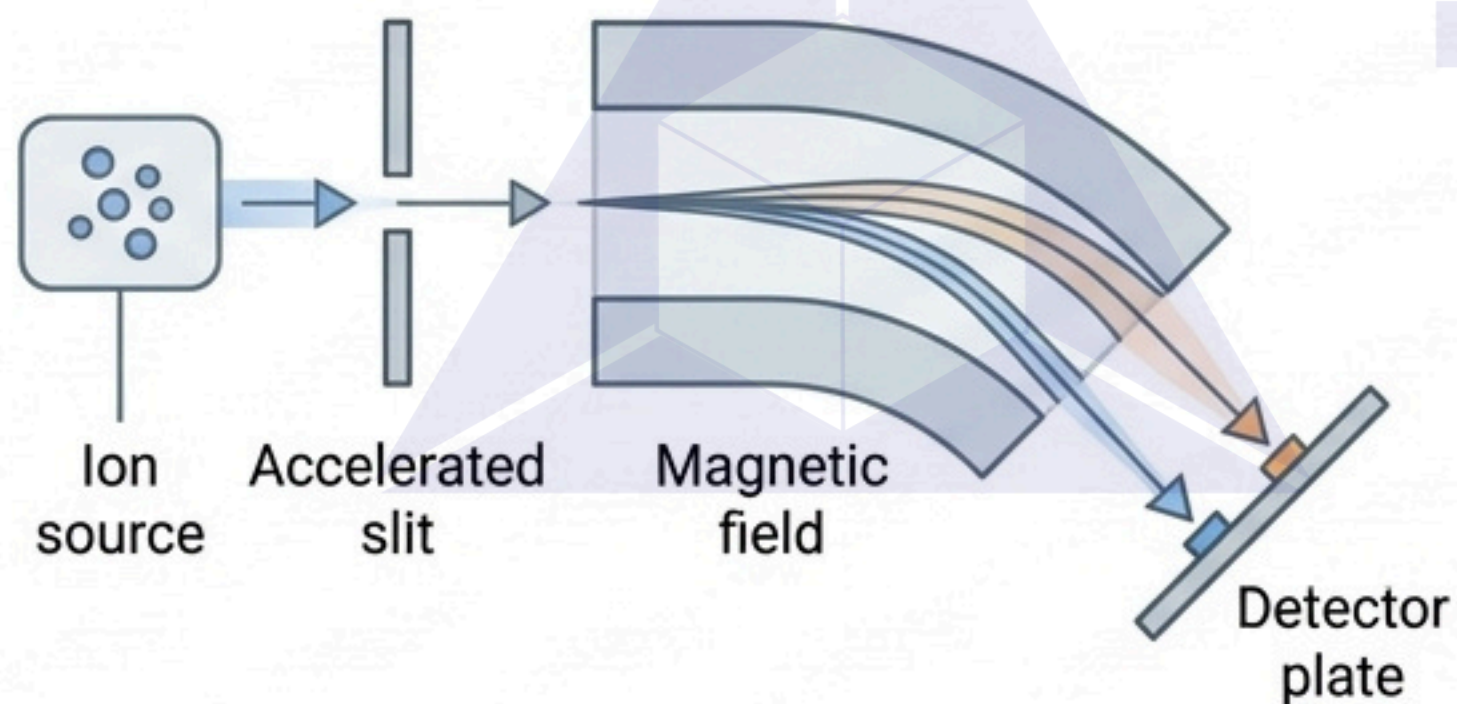
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Atoms of the same element can weigh differently.

Accurate measurements using a mass spectrometer reveal that a single element can have varying types of atoms.



Same Chemical Properties

Different Masses

Isotopes (Greek for “same place”). They occupy the same place in the periodic table but differ in mass.



Teacher's Note: So we have our new unit. Simple, right? But then scientists started measuring atoms with a device called a mass spectrometer. They found a major complication: atoms of the exact same element can actually have different masses! We call these **“isotopes”**. The word comes from Greek meaning “same place”, because they sit in the exact same spot on the periodic table, but they weigh slightly different amounts.

The Weighted Average: Chlorine

The Isotopes

Chlorine-35 | Mass: 34.98 u | Abundance: 75.4%

Chlorine-37 | Mass: 36.98 u | Abundance: 24.6%

$$[(75.4 \times 34.98) + (24.6 \times 36.98)] / 100$$

$$= 35.47 \text{ u}$$

(Matches the atomic mass on the periodic table)



Teacher's Note: Let's look at Chlorine. In nature, a sample of Chlorine is a mix of two isotopes. About 75.4 percent has a mass of 34.98 u, and about 24.6 percent is heavier, at 36.98 u. To find the true average mass, we take a "weighted average" based on their abundance. This exact calculation gives us 35.47 u, which perfectly matches the atomic mass you see on your periodic table.

Hydrogen Isotopes & The Proton

Hydrogen
1.0078 u
99.985% abundance

Deuterium
2.0141 u

Tritium
3.0160 u

The nucleus of the lightest hydrogen atom is a single proton.

$$\text{Eq. (13.2): } m_p = 1.00727 \text{ u} = 1.67262 \times 10^{-27} \text{ kg}$$



Teacher's Note: Even hydrogen, the lightest element, has three isotopes: regular hydrogen, deuterium, and tritium. Because the regular hydrogen atom is 99.985% abundant, it is our baseline. Its nucleus is simply a single proton. Using our new unit, the mass of a proton is strictly defined as 1.00727 u. Notice how close it is to 1 u, but not exactly 1.

Key Takeaways

1. The Unit (u)

1 u is defined as exactly 1/12th the mass of a Carbon-12 atom (1.660539×10^{-27} kg).

2. Isotopes

Atoms of the same element (same chemical properties) with different masses. Detected via mass spectrometer.

3. Weighted Averages

An element's atomic mass is the weighted average of its natural isotopes based on relative abundance (e.g., Chlorine = 35.47 u).

4. Proton Mass

The nucleus of the lightest hydrogen atom. Defined precisely as $m_p = 1.00727$ u.



Teacher's Note: Let's review exactly what you need to know for your exam. First, memorize the definition of 1 'u'. Second, know that isotopes are atoms of the same element with different masses. Third, understand that because of these isotopes, we must use a weighted average for an element's atomic mass. And finally, know the mass of a single proton in our new unit. Keep these definitions clear, and you'll do great.



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