2.2. ATOMIC WEIGHT

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- Introduction
- Definition
- Atomic weight of an element
- Atomic mass unit
- Gram atomic mass unit
- Concept of fractional atomic mass unit (ref giving example of chlorine)
- Dulong and Petit's method and its limitations
- Steps involved for the determination of atomic *[4 Hrs.]*

Why do we need atomic mass?
Atoms are extremely small, so their actual masses are extremely small.
For example, the mass of one atom is far too small to measure easily in a laboratory.
Therefore, chemists use a relative scale to compare the masses of atoms

Relative Atomic Mass (atomic wt., atomic mass)

Hence, the lightest element, hydrogen, was taken as the standard(reference) to express the masses of other elements.

Therefore, the atomic mass of an element may be defined as,

$$\text{Atomic mass of an element} = \frac{\text{mass of 1 atom of the element}}{\text{mass of 1 atom of hydrogen}}$$

Problems: the **isotope** of hydrogen is not specified; pure hydrogen is **expensive** and **difficult** to handle.

Later, the C-12 isotope was taken as a standard by IUPAC. In this C-12 scale,
"The atomic mass of an element is a number which indicates how many times one atom of the element is heavier than one-twelfth of an atom of ^{12}C isotope."
Mathematically,

$$\textbf{Atomic mass of an element} = \frac{\textbf{mass of 1 atom of the element}}{\textbf{mass of } \frac{1}{12\text{th}} \textbf{ of C}-12 \textbf{ isotope}}$$

In simple words:
It tells us **how heavy an atom is compared with the carbon-12 standard.**

This atomic mass is not the actual mass but the relative atomic mass, sometimes called atomic weight. Since atomic mass is the ratio of two masses, it has no unit, but the **atomic mass unit** (amu) is used for convenience.

⚠ Common Error to Avoid
Don't confuse atomic mass with mass number!
• Mass number = total protons + neutrons in one specific atom (always a whole number)
• Relative atomic mass = average mass compared to C-12 (often a decimal, due to isotopes)

Assignment
Make a personal study card listing the first 30 elements with their name, symbol, atomic number, and atomic mass. Review it daily until you know them from memory — this knowledge is used throughout all of chemistry!

Atomic number	Name of the element	Symbol	Atomic weight (atomic mass)	Valency
1	Hydrogen	H	1	1
2	Helium	He	4	0
3	Lithium	Li	7	1
4	Beryllium	Be	9	2
5	Boron	B	11	3
6	Carbon	C	12	4
7	Nitrogen	N	14	3
8	Oxygen	O	16	2
9	Fluorine	F	19	1
10	Neon	Ne	20	0
11	Sodium	Na	23	1
12	Magnesium	Mg	24	
13	Aluminium	Al	27	3
14	Silicon	Si	28	
15	Phosphorus	P	31	
16	Sulphur	S	32	2
17	Chlorine	Cl	35.5	
18	Argon	Ar	40	0
19	Potassium	K	39	1
20	Calcium	Ca	40	2
21	Scandium	Sc	45	3
22	Titanium	Ti	48	2,3
23	Vanadium	V	51	2,3
24	Chromium	Cr	52	3,4
25	Manganese	Mn	55	3
26	Iron	Fe	56	**2 and 3**
27	Cobalt	Co	59	2, 3
28	Nickel	Ni	59	2, 3
29	Copper	Cu	63.5	**1 and 2**
30	Zinc	Zn	65.5	**2**

Determination of Atomic Weight by Dulong and Petit's Method

In 1819, Dulong and Petit studied the **specific heat of solid elements**.

They found that atomic **weight × Specific heat ≈ 6.4**

Dulong and Petit's law states that **"the product of atomic weight and specific heat of any solid element is approximately equal to 6.4"**.

Atomic weight × Sp. Heat = 6.4 (approx.)

Illustration

Specific heat of a solid element can be easily determined in the laboratory. Specific heat is the amount of heat required to raise the temperature of 1 gram of substance by 1 ^{0}C. The product of atomic weight and specific heat is termed **atomic heat**. Therefore, according to Dulong and Petit's law, the atomic heat of all solid elements is nearly equal to 6.4. This can be illustrated by the following table:

Solid element	Atomic weight	Specific heat	Atomic heat = Atomic weight × Sp. heat
Sodium (Na)	22.98	0.29	6.6
Magnesium (Mg)	24.30	0.25	6.0
Iron (Fe)	55.84	0.12	6.7
Zinc (Zn)	65.40	0.093	6.0
Tin (Sn)	118.71	0.054	6.4
Silver (Ag)	107.86	0.056	6.0
Gold (Au)	196.96	0.032	6.3

Steps in Dulong and Petit's method:

1. Find **the equivalent weight** of the solid element (by any suitable method).
2. Find the **Specific heat** of the element (in the lab). Then, calculate the approximate atomic weight of the element by Dulong and Petit's law.

$$\textbf{Approx. atomic weight} = \frac{6.4}{\textbf{specific heat}}$$

> Specific heat is the amount of heat needed to raise the temperature of 1 gram of a substance by 1°C. It can be easily measured in the laboratory.

3. Divide the approximate atomic weight by the equivalent weight to get approximate valency.

$$\textbf{Approx. Valency} = \frac{\textbf{Approx. atomic weight}}{\textbf{Equivalent weight}}$$

4. **Round** the Approximate valency to the **nearest whole number** (as the valency is always a whole number). Use this as the **valency** for that element.
5. Now find the correct atomic weight using the relation:

Correct atomic weight = Equivalent weight × Valency

Limitations of Dulong and Petit's Law

1. Dulong and Petit's law holds especially for solid elements, including metals.
2. The atomic weight of non-metals like beryllium, boron, carbon, silicon, sulphur, etc. cannot be determined by this method. This is because the specific heat of these elements varies with temperature.
3. This law is only applicable to heavier elements; however, it cannot be applied to lighter elements having high melting points.

Worked Example

1. The specific heat of a metal is 0.259, and its equivalent weight is 12 g. What is the exact atomic weight of that metal?

   Solution:
   Given: specific heat = 0.259
   Equivalent weight = 12
   Now, we know, approx. atomic weight = $\frac{\mathbf{6.4}}{\mathbf{specific\ heat}} = \frac{6.4}{0.259} = 24.710$

   Again, Approx. Valency = $\frac{\text{Approx. atomic weight}}{\text{Exact equivalent weight}} = \frac{24.710}{12} = 2.059$

   Changing the approximate valency 2.059 to a whole number, 2.

   Finally, Correct atomic weight = Equivalent weight × Valency = 12 x 2 = 24

   Therefore, the atomic weight of the metal is 24 amu.

2. State Dulong and Petit's law. 1
3. Define atomic weight and state Dulong and Petit's law. 4
   Define atomic weight. State Dulong and Petit's law and its methods to determine atomic weight. [4]
   State Dulong and Petit's law. How can you determine the atomic weight by this method? [5]
   State Dulong's and Petit's law in detail. [5]

4. 0.5204 grams of metal yields 0.7012 grams of its chloride. The specific heat of the metal is 0.049. Now find the exact atomic weight of the metal. [4]
5. State Dulong and Petit's law. 0.444 grams of metal, when dissolved in dilute HCl, gave 177 mL of dry hydrogen at 10°C and 750 mm Hg pressure; the specific heat of the metal is 0.107. Calculate the exact atomic wt. of the metal. [1+4]
6. 0.44 grams of a metal, when dissolved in dilute HCl acid, gave 177 mL of dry hydrogen gas at 10°C and 745 mm of pressure. The specific heat of the metal is 0.107. Calculate the exact atomic weight of the metal.
7. 0.45 gm of metal, when dissolved in dil. HCl gave 760 cc of H_2 at 27°C and 640 mm Hg pressure. The specific heat of the metal is 0.23. Calculate the exact atomic wt. of the metal. [3]
8. 0.5302 grams of metal yields 0.7052 grams of its chloride. The specific heat of the element is 0.059. Calculate the exact atomic weight of the metal. [4]
9. The valency of the metal is 3, and its oxide contains 31.6% oxygen. Calculate the atomic weight of the metal. 5

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