Module-6: Mass Number and Molar Mass

MASS OF SUBATOMIC PARTICLES IN AMU

- Neutrons are *slightly* larger than protons. Both are **much larger** than electrons.
- Atomic masses are often expressed in the unit, '*atomic mass unit*' or simply *amu*.

  1 *amu* = 1 / 12th the mass of a carbon atom.

Mass of a proton = **1.00727 *amu***

Mass of a neutron = **1.00866 *amu***

Mass of an electron = **0.00055 *amu***

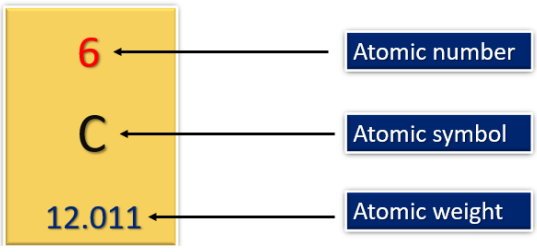
THE IMPORTANCE OF PROTONS

- The atomic number of an element is always equal to the total number of protons in the nucleus. The atomic number for an element is given by the letter Z.
- It is the number of protons that determines the identity of an element. In a neutral atom the number of protons and number electrons are equal in number.

Element	Atomic Number	Number of Protons	Number of Electrons
Carbon	6	6	6
Nickel	28	28	28
Uranium	92	92	92

INFORMATION ABOUT ELEMENTS IN THE PERIODIC TABLE

- Atomic number, atomic weight, and the atomic symbol for an element are all found in its box on the periodic table.



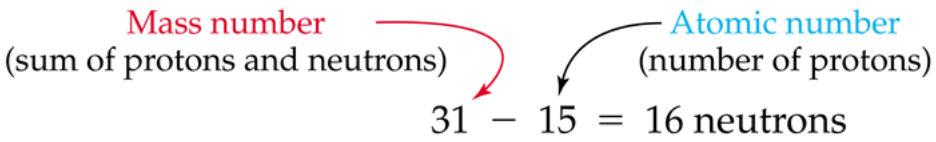
- The atomic number is found above the elemental symbol in that element's box on the periodic table. The atomic number is always a whole number.
- The atomic weight is written underneath the symbol and will be a measured value with a variable number of digits.

THE ISOTOPES

- Atoms which have same number of protons but different number of neutrons are called isotopes.
- While the number of protons in the nucleus defines an element's identity, variations in the number of neutrons in the nucleus give rise to different isotopes of the same element.

MASS NUMBER AND ATOMIC NUMBER

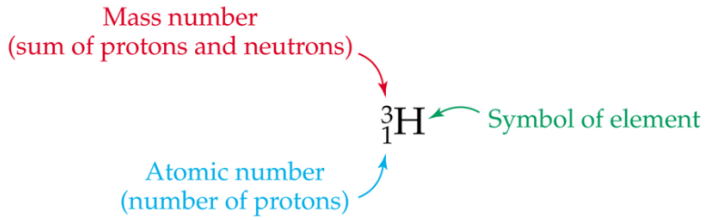
- Mass number and atomic number are not the same. Mass number is represented by the letter A. Mass number (A) = number of protons + number of neutrons
- From the difference between the mass number (A) and the atomic number (Z), the number of neutrons in a given isotope can be calculated.



- For a hypothetical isotope X, the atomic symbol is written first and then the mass number (left superscript) and the atomic number (left subscript) are written as show below.

$${}^{A}_{Z}X$$

- The isotope of hydrogen with a mass number of three is represented as,



THE MOLES

- The unit mole is applied to count only tiny atoms and molecules. This unit practically has no applications outside the realm of chemistry or chemical sciences.
- The number, 6.022×10^{23}, that we use to describe a mole is called as the Avogadro's number.
- The atomic mass for an element that is given on the periodic table is for one mole of that element.
- For example,

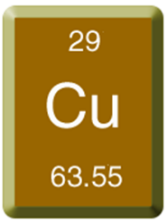
  1 mole of Na (sodium) = 22.9898 g of Na

  1 mole of Na = 6.022×10^{23} atoms of Na

  22.9898 g of Na = 6.022×10^{23} atoms of Na

Example: 1

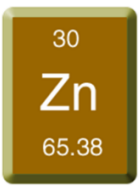
Here are 0.50 moles of copper. How many grams of copper do we have?



$$= \frac{63.55 g}{1 mol\ Cu} \times 0.5 mol\ Cu = 31.77\ g\ of\ Copper$$

Example: 2

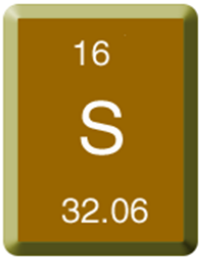
Here is a pile of the element zinc which weighs 65.38 grams. How many moles of zinc do we have?



Answer: one mole

Example: 3

This pile of sulfur contains 6.02×10^{23} atoms of sulfur. What is the mass, in grams, of this sample of sulfur?



Answer: 32.06 g

THE MOLAR MASS

- Molar mass of a substance is the sum of the molar masses of the constituent elements,

Example: 4 Molar mass of sucrose, $C_{12}H_{22}O_{11}$.

To calculate the molar mass of sucrose, let us list the elements present in sucrose, and look up the atomic mass of each element in the periodic table. Then, multiply the atomic mass of each element by the number of times that element appears in the chemical formula, and total the results.

Element	Atomic mass/mol	Total (g)
Carbon	12.01 g/mol	$12 \times 12.01 = 144.12$
Hydrogen	1.008 g/mol	$22 \times 1.008 = 22.176$
Oxygen	16.00 g/mol	$11 \times 16.00 = 176.00$
Molar mass of $C_{12}H_{22}O_{11}$.		**342.30 g/mol**

Example: 5 Molar mass of sodium chloride, NaCl.

Element	Atomic mass/mole	Total (g)
Sodium	23.00 g/mol	$1 \times 23.00 = 23.00$
Chlorine	35.45 g/mol	$1 \times 35.45 = 35.45$
Molar mass of NaCl		**58.45 g/mol**

Example: 6 Molar mass of acetaminophen, $C_8H_9NO_2$

Element	Atomic mass/mol	Total (g)
Carbon	12.01 g/mol	8 × 12.01 = 96.08
Hydrogen	1.008 g/mol	9 × 1.008 = 9.072
Nitrogen	14.01 g/mol	1 × 14.01 = 14.01
Oxygen	16.00 g/mol	2 × 16.00 = 32.00
Molar mass of $C_8H_9NO_2$.		**151.16 g/mol**

- From the molar mass and mass of a substance we can calculate the moles of that substance.

Example: 7

How moles of KBr are there in 51.20 g of KBr. The molar mass of KBr is 119.0 g.

$$51.20 gKBr \times \frac{1 molKBr}{119.0 gKBr} = 0.4303 molKBr$$

Example: 8

How grams of carbon are there in 13.70 moles of carbon? The molar mass of carbon 12.01 g/mol.

$$13.70\ mol\ C \times \frac{12.01\ g\ C}{1\ mol\ C} = 165.0\ g\ C$$

Practice Problems

1. How many protons, electrons and neutrons are present in neutral atoms of the following isotopes

i. $^{65}_{29}Cu$ ii. $^{124}_{50}Sn$ iii. $^{197}_{79}Au$ iv $^{93}_{40}Zr$

2. How many neutrons are there in 25.0 g of Ni-58 isotope?

3. Write the correct symbols for the atoms that contain:

i. 25 protons, 25 electrons and 27 neutrons

ii. 10 protons, 10 electrons and 12 neutrons

iii. 47 protons, 47 electrons and 60 neutrons

iv. 94 protons, 94 electrons and 145 neutrons

4. Calculate the molar masses for the following compounds.

(i) Na_2CrO_4, (ii) Na_2SO_4, (iii) $Ca_3(PO_4)_2$,

(iv) NH_4Cl, (v) K_2CO_3, (vi) $KMnO_4$.

5. A gold coin contains 2.70×10^{22} atoms of gold, what is the mass of this gold coin?

6. An old copper penny weights 3.11 g, how many copper atoms are there in the penny?

7. Which one of the following has the highest number of atoms?

(A) 5.0 g of iron (B) 5.0 g of nickel (C) 5.0 g of cobalt

8. How many sodium ions are there in 10.0 g of NaCl?

9. How many sodium ions are there in 10.0 g of Na_2O?

10. A sample of $CaCl_2$ contains 0.50 mole of chloride ions, what is the mass of the $CaCl_2$ sample?