Science (Chemistry) - Class IX
Chap 3 - Atoms and Molecules

Introduction:

Around 500 BC, Indian philosopher Maharishi Kanad, postulated the theory if we go on dividing matter, we will obtain smallest particle beyond which further division can't be done which is known as 'parmanu'.

Laws of Chemical Composition

The chemical reaction between two or more substances give rise to products which is governed by certain laws called laws of chemical combination.

Laws of chemical Combination →
- Laws of conservation of Mass
- laws of constant proportion
- laws of multiple proportion
- laws of reciprocal proportion
- Gay lussac's law of combining volume.

Laws of Conservation of Mass

During a chemical reaction, the total mass of reactants will be equal to the total mass of the products. Mass can neither be created nor destroyed in a chemical reaction.

Example : $A \text{ (reactant)} + B \text{ (reactant)} \longrightarrow AB \text{ (product)}$

$$\text{Mass of } A + \text{Mass of } B \longrightarrow \text{Mass of } AB.$$

$$\text{Mass of reactants} = \text{Mass of products.}$$

Laws of Constant Proportions

In a chemical reaction, compounds always contain the same elements present in definite proportion by mass irrespective of their source.

It was given by Lavoisier.

" in a chemical substance the elements are always present in definite proportion by mass".

For example,

(i) 18 gm of H_2O = 2 gm of H_2 + 16 gm of O_2

$$\Rightarrow \frac{\text{Mass of Hydrogen}}{\text{Mass of oxygen}} = \frac{2}{16} = \frac{1}{8}$$

(ii) 36 g of H_2O = 4 g of H_2 + 32 g of O_2

$$\frac{\text{Mass of } H_2}{\text{Mass of } O_2} = \frac{4}{32} = \frac{1}{8}$$

(iii) 9 g of H_2O = 1 g of H_2 + 8 g of O_2

$$\frac{\text{Mass of } H_2}{\text{Mass of } O_2} = \frac{1}{8}$$

This verifies the mass of constant proportion as the ratio of hydrogen to oxygen is always same.

Dalton's Atomic Theory

Laws of chemical combination lacked explanation. Hence, John Dalton gave his theory about matter. He said that the smallest particle of matter is called 'atom'.

Six Postulates of Dalton's atomic theory:

1) All matter is made of very tiny particles called atoms.

2) Atoms are indivisible particles, which cannot be created or destroyed in a chemical reaction.

3) Atoms of a given elements are identical in mass and chemical properties.

4) Atoms of different elements have different masses and chemical properties.

5) Atoms combine in the ratio of small whole numbers to form compounds.

6) The relative number and kinds of atoms are constant in a given compound.

Atoms

Matter is made up of small particles called atoms. Atom is the smallest building block of matter. Atoms are very small, they are smaller than anything we can imagine or compare with.

According to modern atomic theory, an atom is the smallest particle of an element which takes part in chemical reaction.

Atoms are very small and which can't be seen even through very ~~small~~ powerful microscope.

Atomic radius is measured in nanometers
Nanometer $= 10^{-9}$ m.

For example, atomic radii of hydrogen atom is 1×10^{-10} m.

Atomic Mass

Mass of an atom is called atomic mass. It is the number which tells how many times an atom of an element is heavier than 1/12 mass of one carbon atom.

Mass of one atom of an element

$$= n \times \frac{1}{12} \text{ of the mass of one Atom C-12.}$$

n - atomic mass

$$\therefore \text{Atomic mass} = \frac{\text{Mass of one atom of an element}}{\frac{1}{12} \text{ mass of one carbon atom.}}$$

Atom existence

Atoms of most of the elements are very reactive and does not exist in free state.

Only the atoms of noble gases (He, Ne, Ar, Kr, Xe and Rn) are chemically unreactive and can exist in the free state as single atom.

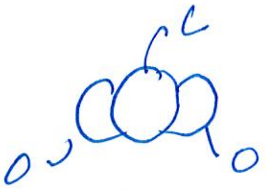
Atoms of all other elements combine together to form moleculars or ions.

Molecules

Molecules are formed by the combination of two or more atoms. For example, two atoms of Hydrogen (H_2) and one atom of Oxygen (O_2) react with each other and form one molecule of water.

H_2O

a water molecule



CO_2

A carbon dioxide molecule

NH_3

an ammonia molecule.

NO_2

a Nitrogen dioxide molecule

O_2

an oxygen molecule.

Molecules of Elements

The molecules of an element are constituted by the same type of atoms.

Atomicity : It is defined as the number of atoms present in a molecule.

On the basis of number of atoms, molecules can be categorize in four types :

a) Monoatomic : Molecules containing only atom are said to be monoatomic. Noble gases like helium, neon, argon etc exist in atomic form i.e, they are mono atomic. He, Ne, Ar. etc.

b) Diatomic : Molecules containing two atoms are said to be diatomic. For example, H_2, O_2, N_2, Br_2, Cl_2, Carbon monoxide (CO), hydrogen chloride (HCl) and Sodium chloride (NaCl).

c) Triatomic : Molecules containing three atoms are said to be triatomic. For example O_3 - ozone, CO_2, NO_2, H_2S - Hydrogen Sulphide.

d) Tetra atomic : Molecules containing four atoms. Example - $P4$, SO_3 etc.

(e) Polyatomic : Any molecule containing more than four atoms is called a polyatomic molecule. Example, Sulpher (S_8), methene - CH_4, Nitric Acid - HNO_3, ethanol - C_2H_5OH

Molecules of Compounds

Atoms of different elements join together in definite proportions to form molecules of compounds.

Example - Water (H_2O) - Hydrogen : Oxygen (1:8)

Ammonia - Nitrogen, Hydrogen (14:3)

Carbon Dioxide - Carbon, Oxygen (3:8)

Molecular Mass

It is defined as the sum of atomic masses of all atoms present in a molecule.

For example -

Molecular mass of CO_2 = 1× atomic mass of carbon + 2× atomic mass of oxygen

$$= 1 \times 12 + 2 \times 16$$
$$= 44$$

Ions

Ions are the atoms or group of atoms which have a net charge on them. For example - Na^+, Cl^- etc.

An ion is a charged particle and can be negatively or positively charged. A negatively charged ion is called an 'anion' and the positively charged ion, a 'cation'. Example NaCl, Na^+, Cl^-

Cation - Na^+, K^+, Mg^{2+} etc

Anion - Br^-, F^-, O^{2-} etc.

(10)

Monoatomic ion:

Ions containing only one atom. Na^+, K^+, Br^-, F^- etc.

Polyatomic ion:

Ion containing more than one atom.
CO_3^{2-}, NO_3^-, HCO_3^- etc.

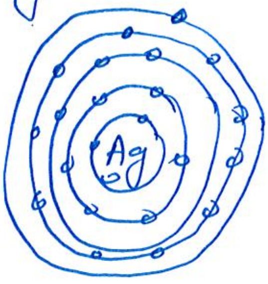
Valency

It is defined as the combining capacity of an element.

The outermost shell of any element is also called valence shell and the number of electrons present in that shell determines the valency.

Ag - Silver has 1 electron in its outermost shell.

Silver donates one electron, so valency of silver is +1.



Silver Atom Ag.

- In general metals are said to be electropositive elements because they have the tendency to donate electrons. For example, Sodium has valency +1, Calcium has valency of +2 etc.

- Non-metals are said to be electronegative elements because they have the tendency to accept electrons. For example, Chlorine has valency of −1, Oxygen has valency of −2 etc.

- There are certain elements which posses more than one valency. Example - Iron shows two types of valancies Fe^{+2} Ferrous and Fe^{+3} Ferric. Copper +1 - cuprous, +2 cupric

(11)

Classification of Ions on the basis of their valency

Monovalent ions : Ions having the valency of 1 are said to be monvalent. For example; OH^-, NO_3^-, HCO_3^-, HSO_4^- etc.

Divalent Ions : Ions having the valency of 2 are said to be divalent. For oxample; SO_4^{2-}, SO_3^{2-}, CO_3^{2-} etc.

Trivalent Ions :- Ions having the valency of 3 are said to be trivalent. For example PO_4^{3-}, N^{3-} etc.

Writing Chemical formulae of Compounds.

Rule 1 - Cross multiply the valancies of elements to form a compound.

$$A^{+2} \times B^{-3} \longrightarrow A_3 B_2$$

Rule 2 - If compound consist of metal and non-metal then metal is written first.
For example, in Calcium Chloride ($CaCl_2$) and Zinc Sulphide (ZnS), Calcium and zinc are metals, so they are written first.

Rule 3 : If compound is formed with polyatomic ions then polyatomic ions are written in brackets. For example, in aluminium sulphate [$Al_2(SO_4)_3$], the polyatomic sulphate SO_4^{2-} is enclosed in a bracket before writting the subscript 3. Three sulphate groups are joined to two aluminium atoms.

Note: compounds made up of metals and non-metals are called salts.

Formulae of Simple Compounds:

1. Hydrogen Chloride

$$\begin{tikzcd} \text{Symbol} & H \arrow[r, phantom, "+"] & Cl \arrow[r] & HCl \\ \text{Valency} & 1 \arrow[ur] & 1 \arrow[ul] & \end{tikzcd}$$

2. Hydrogen Sulphide

$$\begin{tikzcd} H \arrow[r, phantom, "+"] & O \arrow[r] & H_2O \\ 1 \arrow[ur] & 2 \arrow[ul] & \end{tikzcd}$$

$$\begin{tikzcd} H \arrow[r, phantom, "+"] & S \arrow[r] & H_2S \\ 1 \arrow[ur] & 2 \arrow[ul] & \end{tikzcd}$$

3. Carbon Tetrachloride:

$$\begin{tikzcd} C \arrow[r, phantom, "+"] & Cl \arrow[r] & CCl_4 \\ 4 \arrow[ur] & 1 \arrow[ul] & \end{tikzcd}$$

The formula of ionic compounds are simply the whole number ratio of the positive to negative ion in the structure.

4. Magnesium chloride: We write the symbol of cation (Mg^{2+}) first followed by symbol of anion (Cl^-) then their charges are cris. crossed.

$$Mg + Cl \longrightarrow MgCl_2$$

$$2+ \qquad 1-$$

5) Aluminium Oxide :

$Al + O \rightarrow Al_2O_3$

3+ 2-

(6) Calcium Oxide :

$Ca + O \rightarrow Ca_2O_2$ (or CaO)

2+ 2-

7) Sodium Nitrate :

$Na + NO_3 \rightarrow NaNo_3$

1+ 1-

8) Calcium Hydroxide :

$Ca + OH \rightarrow Ca(OH)_2$

2+ 1-

We use brackets when we have two or more of the same ion in the formula. Bracket around OH indicates that there are 2 hydroxyl (OH) groups joined to form one calcium atom.

9) Sodium Carbonate :

$Na + CO_3 \rightarrow Na_2CO_3$

1+ 2-

Bracket not needed if there is only one ion.

10) Ammonium Sulphate : $NH_4 + SO_4 \rightarrow (NH_4)_2SO_4$

1+ 2-

Molecular Mass and Mole Concept

Mole : The quantity of a substance is expressed in term of mole. One mole is defined as the amount of substance which contains 6.023×10^{23} units of particle.

$$1 \text{ mole} = 6.023 \times 10^{23} \text{ units (Avogadro's Number } N_A)$$

For example, one mole of oxygen atom represents 6.023×10^{23} atoms of oxygen and 5 moles of oxygen atoms contain $5 \times 6.023 \times 10^{23}$ atoms of oxygen.

Molar Mass (Molecular Mass)

The mass of 1 mole of substance is called Molar Mass. Atomic mass or molecular mass in gram is equal to molar mass. The molecular mass of a substance is the sum of the atomic masses of all the atoms in a molecule.

Atomic Mass of Fe is 56 amu (mass/g mol^{-1})

Molar mass of Fe = 56 gram

$$\text{Molecular mass of } H_2O = 2 \times 1 + 1 \times 16$$
$$= 18 \text{ amu}$$

$$\text{Molar mass of } H_2O = 18 \text{ gram}$$

$$\text{No. of moles} = \frac{\text{Given Mass}}{\text{Molar Mass}}$$

For example, number of moles in 112 gm of iron will be

$$\frac{\text{Given mass}}{\text{Molar mass}} = \frac{112}{56} = 2 \text{ moles or } 2 \times 6.023 \times 10^{23} \text{ atoms.}$$

Calculating number of atoms of each type and total number of atoms for given mass or moles:

Given Mass of molecule (Say A_pB_q)

↓ $\frac{\text{Given Mass}}{\text{Molar Mass}}$

No. of Moles

↓ No. of moles × N_A (Avogadro's Number)

No. of molecules

↓ No. of atom in A = p× No. of moles
No. of atoms in B = q × No. of molecule.

No. of atoms.

Percentage of an element in a compound.

A compound is composed of different elements and it tells that how much percentage of different elements is present in a compound.

$$\% \text{ of element} = \frac{\text{mass of element}}{\text{total mass of compound}} \times 100$$

1 dozen = 12 Nos

1 Gross = 144 Nos.

Laws of chemical Combination

Compounds are formed by chemical combination of reactants (atoms or molecules) in fixed proportion by weight or by volume. This is acheived by following certain laws known as laws of chemical combination.

1. Law of Conservation of Mass:

The law of conservation of mass states:- " Mass can neither be created nor destroyed in a chemical reaction".

Total mass of reactants = Total mass of products..

Example,

$$2H_2 + O_2 \longrightarrow 2H_2O$$

(2× mass of H_2) + mass of O_2 2× mass of molecule

$2 \times 2 + + 2 \times 16 = 36$ $2 \times 18 = 36$

As there is no loss of mass of substance, i.e. mass is conserved, that's why law o'ser called this the law of conservation of mass.

2. Law of Constant Proportion:

This law states that-," a chemical compound always contain exactly the same proportion of elements by mass".
This law is also known as law of definite proportions.

Example,

$$2H_2 + O_2 \longrightarrow 2H_2O$$

4 : 32 2 : 16

1 : 8 1 : 8

① a. Calculate the relative molecular mass of water (H_2O)
b. Calculate the molecular mass of HNO_3.

2) Calculate the formula unit of $CaCl_2$.

3) Calculate the molecular masses of H_2O, O_2, Cl_2, CO_2, CH_4, C_2H_6, C_2H_4, NH_3, CH_3OH.

4) Calculate the formula unit mass of ZnO, Na_2O, K_2CO_3.

(5) Calculate the number of moles for the following:

(i) 52 g of He

(ii) 12.044×10^{23} number of He atoms.

(6) Calculate the mass of the following:

(i) 0.5 mole of N_2 gas

(ii) 0.5 mole of N atoms

(iii) 3.011×10^{23} no. of N atom

(iv) 6.022×10^{23} no. of N_2 molecules.

(7) Calculate the number of particles in each of the following:

(i) 46 g of Na atoms

(ii) 8 g O_2 molecules

(iii) 0.1 mole of carbon atom.

8) If one mole of carbon atoms weighs 12 gram, what is the mass (in gram) of 1 atom of carbon?

9) Which has more number of atoms 100 gram of sodium or 100 gram of iron.

(10) Calculate the molar mass of the following substances.
(a) Ethyne, C_2H_2 (b) Sulphur molecule, S_8
(c) Phosphorus molecule, P_4 (d) Hydrochloric acid HCl.

(e) Nitric acid, HNO_3

(11) What is mass of : (a) 1 mole of nitrogen atom
(b) 4 moles of aluminium atoms (c) 10 moles of sodium sulphite (Na_2SO_3).

(12) Convert into mole : (a) 12 g of oxygen gas (b) 20 g of water
(c) 22 g of carbon dioxide.

13) What is the mass of (a) 0.2 mole of oxygen atoms?
(b) 0.5 mole of water molecules?

(14) Calculate the number of molecules of sulphur (S_8) present in 16 g of solid sulphur.

15) Calculate the number of aluminium ions present in 0.051 g of aluminium oxide.

Solution

① (a) Atomic mass of hydrogen = 1 u $H=1$ amu

" Oxygen = 16 u $O=16$ amu

So molecular mass of H_2O = $2\times1+1\times16$

= 18 u (g/mol)

(b) Molecular mass of HNO_3 = $1+14+3\times16$

$H=1$

= $1+14+48$

$N=14$

= 63 u (g/mol)

$O=16$

(2)

Formula unit mass of $CaCl_2$ = $1\times40+2\times35.5$ Ca - 40

= 40 + 71   Cl - 35.5

= 111 u (g/mol)

(3) Molecular mass of H_2 = 2×1 = 2 u $H=1$

Molecular mass of O_2 = 2×16 = 32 u $O=16$

Molecular mass of Cl_2 = 2×35.5 = 71 u $Cl=35.5$

Molecular mass of CO_2 = $12+2\times16$ $C=12$

= 44 u $O=16$

Molecular mass of CH_4 = $12+4\times1$ = 16 u

" C_2H_6 = $2\times12+6\times1$ = 30 u

C_2H_4 = 28 u

NH_3 = 17 $N=14$

CH_3OH = 32 u

(4) formula unit mass ZnO = 81 u   Zn = 65   C = 12

" Na_2O = 62 u   Na = 23   O = 16

" K_2CO_3 = 138 u   K = 39   g/mol

(5) (i) Atomic mass unit of He = 4 u
molar mass of He = 4 g/mol

∴ 1 mole = 4 g (or)
4 g = 1 mole

$1 g = \frac{1}{4}$ mole

$52 g = \frac{1}{4} \times 52 = \frac{52}{4}$ moles

52g of He = 13 moles.

(ii) We know 1 mole = 6.022×10^{23} atoms of He

(or)
6.022×10^{23} atoms of He = 1 mole

12.044×10^{23} atoms of He = $\frac{12.044 \times 10^{23}}{6.022 \times 10^{23}}$ moles

= 2 moles.

(6) (i) molar mass of N_2 = 2 × 14   N = 14 g/mol
= 28 g/mol or amu (u)

∴ 1 mole of N_2 = 28 g

0.5 mole = 28 × 0.5 g of N_2
= 14 g of N_2

(ii) Molar mass of N atom = 14 g/mol

1 mole = 14 g

∴ 0·5 mole = 14×0·5 = 7g

(iii) 1 mole of N atom = $6·022×10^{23}$ atom of N

or $6·022×10^{23}$ atoms of N = 1 mole of N

∴ $3·011×10^{23}$ atom of N = $\frac{3·011×\cancel{10^{23}}}{6·022×\cancel{10^{23}}}$ moles of N

= 0·5 moles of N

1 mole of N = 14 g

0·5 mole N = 14×0·5

= 7 g

(iv) 1 mole of N_2 mole = $6·022×10^{23}$ molecules of N_2

∴ $6·022×10^{23}$ molecules of N_2 = 1 mole = 2×14 = 28 g

∴ 1 mole of N_2 = $6·022×10^{3}$ N_2 molecules = 28 g.

(7) (i) Atomic mass of Na = 23 g/mol or amu

23 amu = 1 mole = $6·022×10^{23}$ particles.

∴ 46g = $\frac{46}{23}$ × $6·022×10^{23}$ particle.

= $12·044×10^{23}$ particles.

(ii) Atomic (Molar mass) of O = 16 g/mol

Molecular mass of O_2 = 2×16

= 32 g/mol

∴ 32 g = 1 mole = 6.022×10^{23} particle.

8 g of O_2 molecule = $\frac{8}{32} \times 6.022 \times 10^{23}$

= 1.5055×10^{23} particle.

(iii) atomic mass of C = 12 g/mol

12 g = 1 mol = 6.022×10^{23} atoms of C

∴ 6.022×10^{23} atoms of C = 12 g

Mass of 1 atom of C = $\frac{12}{6.022 \times 10^{23}}$ g

= 1.9926×10^{-23} g

(9) Given atomic mass of Na = 23 u Fe = 56 u.

23 g of Na = 6.022×10^{23} number of atom

∴ 100 g of Na = $\frac{6.022 \times 10^{23}}{23} \times 100$ Number of atom.

= 2.6182×10^{24} number of atom

56 g of Fe = 6.022×10^{23} number of atom

100 g of Fe = $\frac{6.022 \times 10^{23}}{56} \times 100$ number of atom.

= 1.0753×10^{24} number of atom.

∴ 100 g of Na contain more atom.

(10) (a) Molar mass of C_2H_2 = 28 g

(b) Sulphur molecule S_8 = 8×32 = 256 g

(c) Phosphorus molecule, P_4 = 4×31 = 124 g

(d) Hydrochloric acid HCl = 36.5 g

(e) Nitric acid, HNO_3 = 63 g.

(11) (a) atomic mass of nitrogen = 14 g/mol
1 mole of N = 14 g

(b) Atomic mass of aluminium = 27 g
1 mole of Al = 27 g
4 moles of Al = 4×27 g
= 108 g

(c) Molecular mass of Sodium Sulphite
(Na_2SO_3) = 2×23+32+3×16
= 126 g

Na = 23
S = 32
O = 16

1 mole of Na_2SO_3 = 126 g
10 moles of Na_2SO_3 = 10×126 = 1260 g

(12) (a) 32 g (O_2) = 1 mole

12 g of O_2 gas = $\frac{12}{32}$ mole = 0.375 mole

(b) Molecular mass of H_2O = 18 g
∴ 18 g of H_2O = 1 mole
20 g of H_2O = 20/18 = 1.11 mole (approx)

(iii) Molecular mass of CO_2 = 12+16 = 44 g

∴ 44 g of CO_2 = 1 mole

$22\text{ g of } CO_2 = \frac{22}{44}$ mole = 0.5 mole.

(13) (a) Molecular mass of O atom = 16 g

∴ 1 mole O atom = 16 g

0.2 mole of O atom = 16×0.2 = 3.2 g

(b) Molecular mass of H_2O molecule = 18 g

∴ 1 mole of H_2O = 18 g

0.5 mole of H_2O = 18×0.5

= 9 g

(14) Molecular mass of S_8 (Sulpher) = 8×32 g = 256 g

∴ 1 mole of S_8 = 256 g = 6.022×10^{23} molecule.

Then 16 g of S_8 contain = $\frac{6.022 \times 10^{23}}{256} \times 16$ molecule

= 3.76×10^{22} Molecule (approx.)

(15) Molecular mass of Aluminium Oxide (Al_2O_3) = 2×27 + 3×16 = 102 g

1 mole of Al_2O_3 = 102 g of Al_2O_3 = 6.022×10^{23} molecules of Al_2

0.051 g of Al_2O_3 contains = $\frac{6.022 \times 10^{23}}{102} \times 0.051$ molecule.

= 3.011×10^{20} molecules.

The number of aluminium ions (Al^{3+}) present in one molecule of Al_2O_3 is 2. ∴ 3.01×10^{20} molecule = $2 \times 3.011 \times 10^{22}$ = 6.022×10^{22} io

APPENDIX I

Elements, their Atomic Number and Molar Mass

Element	Symbol	Atomic Number	Molar mass/ (g mol^{-1})
Actinium	Ac	89	227.03
Aluminium	Al	13	26.98
Americium	Am	95	(243)
Antimony	Sb	51	121.75
Argon	Ar	18	39.95
Arsenic	As	33	74.92
Astatine	At	85	210
Barium	Ba	56	137.34
Berkelium	Bk	97	(247)
Beryllium	Be	4	9.01
Bismuth	Bi	83	208.98
Bohrium	Bh	107	(264)
Boron	B	5	10.81
Bromine	Br	35	79.91
Cadmium	Cd	48	112.40
Caesium	Cs	55	132.91
Calcium	Ca	20	40.08
Californium	Cf	98	251.08
Carbon	C	6	12.01
Cerium	Ce	58	140.12
Chlorine	Cl	17	35.45
Chromium	Cr	24	52.00
Cobalt	Co	27	58.93
Copper	Cu	29	63.54
Curium	Cm	96	247.07
Dubnium	Db	105	(263)
Dysprosium	Dy	66	162.50
Einsteinium	Es	99	(252)
Erbium	Er	68	167.26
Europium	Eu	63	151.96
Fermium	Fm	100	(257.10)
Fluorine	F	9	19.00
Francium	Fr	87	(223)
Gadolinium	Gd	64	157.25
Gallium	Ga	31	69.72
Germanium	Ge	32	72.61
Gold	Au	79	196.97
Hafnium	Hf	72	178.49
Hassium	Hs	108	(269)
Helium	He	2	4.00
Holmium	Ho	67	164.93
Hydrogen	H	1	1.0079
Indium	In	49	114.82
Iodine	I	53	126.90
Iridium	Ir	77	192.2
Iron	Fe	26	55.85
Krypton	Kr	36	83.80
Lanthanum	La	57	138.91
Lawrencium	Lr	103	(262.1)
Lead	Pb	82	207.19
Lithium	Li	3	6.94
Lutetium	Lu	71	174.96
Magnesium	Mg	12	24.31
Manganese	Mn	25	54.94
Meitneium	Mt	109	(268)
Mendelevium	Md	101	258.10
Mercury	Hg	80	200.59
Molybdenum	Mo	42	95.94
Neodymium	Nd	60	144.24
Neon	Ne	10	20.18
Neptunium	Np	93	(237.05)
Nickel	Ni	28	58.71
Niobium	Nb	41	92.91
Nitrogen	N	7	14.0067
Nobelium	No	102	(259)
Osmium	Os	76	190.2
Oxygen	O	8	16.00
Palladium	Pd	46	106.4
Phosphorus	P	15	30.97
Platinum	Pt	78	195.09
Plutonium	Pu	94	(244)
Polonium	Po	84	210
Potassium	K	19	39.10
Praseodymium	Pr	59	140.91
Promethium	Pm	61	(145)
Protactinium	Pa	91	231.04
Radium	Ra	88	(226)
Radon	Rn	86	(222)
Rhenium	Re	75	186.2
Rhodium	Rh	45	102.91
Rubidium	Rb	37	85.47
Ruthenium	Ru	44	101.07
Rutherfordium	Rf	104	(261)
Samarium	Sm	62	150.35
Scandium	Sc	21	44.96
Seaborgium	Sg	106	(266)
Selenium	Se	34	78.96
Silicon	Si	14	28.08
Silver	Ag	47	107.87
Sodium	Na	11	22.99
Strontium	Sr	38	87.62
Sulphur	S	16	32.06
Tantalum	Ta	73	180.95
Technetium	Tc	43	(98.91)
Tellurium	Te	52	127.60
Terbium	Tb	65	158.92
Thallium	Tl	81	204.37
Thorium	Th	90	232.04
Thulium	Tm	69	168.93
Tin	Sn	50	118.69
Titanium	Ti	22	47.88
Tungsten	W	74	183.85
Ununbium	Uub	112	(277)
Ununnilium	Uun	110	(269)
Unununium	Uuu	111	(272)
Uranium	U	92	238.03
Vanadium	V	23	50.94
Xenon	Xe	54	131.30
Ytterbium	Yb	70	173.04
Yttrium	Y	39	88.91
Zinc	Zn	30	65.37
Zirconium	Zr	40	91.22

The value given in parenthesis is the molar mass of the isotope of largest known half-life.