10. Atoms and Molecules

Part-A

1. Question

From the given examples, form the pair of isotopes and the pair of isobars:

$_{18}Ar^{40}$, $_{17}Cl^{35}$, $_{20}Ca^{40}$, $_{17}Cl^{37}$

Answer

● Isotopes are the atoms of same chemical element having different

atomic mass. This means they differ in neutron number. For ex- $_{17}Cl^{35}$ and $_{17}Cl^{37}$. Here both atoms are chlorine atoms and have atomic number 17. So, each atom has 17 electrons and 17 protons. But the former one has atomic mass 35 and the latter one has atomic mass 37. This implies that former one has 18 neutrons (35-17) and latter one has 20 neutrons (37-17). Hence, they are isotopes.

● Isobars are the atoms of different elements having same atomic mass.

This implies that the sum of protons and neutrons in each atom is same. For ex- $_{18}Ar^{40}$ and $_{20}Ca^{40}$. Here, the former one is argon atom and latter one is calcium. Their atomic numbers are different. But their atomic mass is same i.e. 40. This implies that the number of nucleons in both atoms is same, even though the proton, electron and neutron numbers are different.

2. Question

Molecular mass of Nitrogen is 28. Its atomic mass is 14. Find the atomicity of Nitrogen.

Answer

Atomicity is the number of atoms in the molecule of an element. Molecular mass is calculated by adding up the masses of respective atoms present in the molecule. Nitrogen molecule contains only nitrogen atoms. Given -

Mass of molecule of nitrogen = 28

Mass of atom of nitrogen = 14

Let number of atoms in the molecule = x

So,

$$14 \times x = 28$$

$$x = \frac{28}{14} = 2$$

Hence, the atomicity of nitrogen is 2. 2 atoms of nitrogen make one

molecule of nitrogen.

3. Question

Gram molecular mass of Oxygen is 32 g. Density of Oxygen is 1.429 g/litre. Find the gram molar volume of Oxygen.

Answer

Given - Gram molecular mass of Oxygen = 32 g

Density of Oxygen = 1.429 g/litre

Gram molar volume of Oxygen = ?

Formula used is -

$$\text{Gram molar volume of Oxygen} = \frac{\text{Gram molecular mass of Oxygen}}{\text{Density of Oxygen}}$$

$$= \frac{32\ \text{g}}{1.429 \frac{\text{g}}{\text{litre}}}$$

$$= 22.4\ \text{litre}$$

4. Question

'Cl' represents Chlorine atom, 'Cl_2' represents Chlorine molecule.

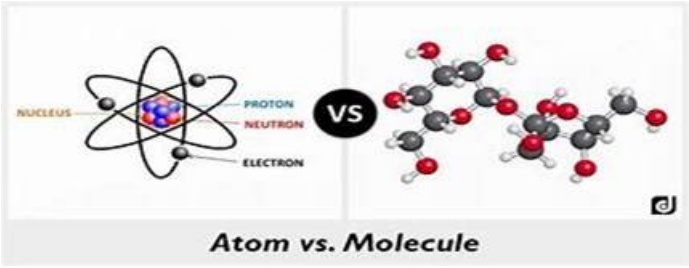
List out any two differences between atoms and molecules.

Answer

	Atom	Molecule
1.	The smallest particle of an element that can take part in a chemical reaction.	The smallest particle of an element or a compound that can exist freely.
2.	An atom is a non-bonded entity. It may or may not exist freely.	A molecule is a bonded entity. A molecule can exist freely.

Note –

Atoms combine to form molecules.



Atom vs. Molecule

5. Question

Calculate the gram molecular mass of water from the values of gram atomic mass of Hydrogen and of Oxygen.

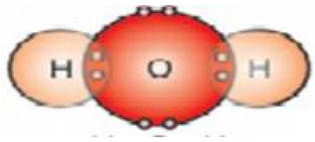
Gram atomic mass of Hydrogen = 1 g

Gram atomic mass of Oxygen = 16 g

Answer

If the molecular mass of a given substance is expressed in grams, it is known as gram molecular mass of that substance. Molecular mass is the sum of the atomic masses of all the atoms present in one molecule of the substance.

One molecule of water is H_2O, which contains 2 hydrogen and one oxygen atoms. So, molecular mass is sum of atomic masses of hydrogen and oxygen atoms.



$$\text{Molecular mass of } H_2O = \text{atomic mass of oxygen} + 2 \times (\text{atomic mass of hydrogen})$$

$$= 16 + (2 \times 1)$$

$$= 16 + 2 = 18$$

Gram molecular mass of water is 18g.

6. Question

One mole of any substance contains 6.023 x 10^{23}particles.

If 3.0115 x 10^{23} particles are present in CO_2, find the number of moles.

Answer

Number of particles in one mole of any substance is 6.023 x 10^{23}

$$\text{number of moles} = \frac{\text{number of particles}}{6.023 \times 10^{23}}$$

$$= \frac{3.0115 \times 10^{23}}{6.023 \times 10^{23}}$$

$$= 0.5$$

Note:

1. If a compound or molecular substance is taken, like CO_2, N_2 etc, then 1

mole of the substance contains Avogadro number of molecules. 1 mole contains the mass equal to molecular weight of substance.

2. If a element is taken like C, S, Fe, then 1 mole contains Avogadro

number of atoms. 1 mole contains the mass equal to atomic weight of substance.

7. Question

_____ have equal number of neutrons.

i) Isobars ii) Isotones

iii) Isotopes iv) Mass Numbers

Answer

isotones

These are the atoms of different elements with same number of neutrons. Example : $_6C^{13}$ and $_7N^{14}$

Number of neutrons is obtained by subtracting atomic number from atomic mass number.

Number of neutrons in $_6C^{13}$ is (13-6) 7.

Number of neutrons in $_7N^{14}$ is (14-7) 7.

● Isobars are the atoms of different elements having same mass number but different atomic numbers.

● Isotopes are the atoms of same element with same atomic number but

different mass number.

● Mass numbers is the sum of protons and neutrons.

8. Question

Classify the following based on atomicity:

i) Chlorine ii) Neon

iii) Phosphorous iv) Ozone

Answer

● chlorine is diatomic because its molecule contains 2 atoms of chlorine. Cl_2

● neon is monoatomic because its molecule contains 1 atom of neon. Ne

● Phosphorous is polyatomic because its molecule contains 4 atoms of

phosphorous. If a molecule contains more than 3 atoms in its molecule its polyatomic. P_4

● ozone is triatomic because its molecule contains 3 atoms of oxygen. O_3

9. Question

Identify and correct the mistake in each of the following:

i) The molar volume of gas at STP is 22.4 cm^3.

ii) 2 x R.M.M. = V.D.

iii) An atom cannot exist independently.

iv) The ratio of atoms in a molecule may be integral or simple or may not be fixed.

v) H_2O is a homo atomic molecule.

Answer

(i) The molar volume of gas at STP is 22.4 litres (not cm^3.)

(ii) 2 x V.D = R.M.M

(iii) An atom may or may not exist independently. Atoms like Fe, Na

can exist independently.

(iv) The ratio of atoms in a molecule may be fixed and integral but

may not be simple.

(v) H_2O is a hetero atomic molecule. It contains more than one type

of atoms i.e hydrogen and oxygen. So, it's a hetero atomic molecule , not homo atomic molecule.

10. Question

Give a single term substitute for each of the following:

i) 6.023×10^{23} molecules ii) 22.4 litres of gas at STP

iii) 1/12th part of the mass of one atom of carbon

iv) The half of relative molecular mass

v) Molecular mass / atomic mass

Answer

(i) 1 mole of a compound or molecular substance / Avogadro number of molecules.

(ii) Molar volume

(iii) One atomic mass unit

(iv) Vapour density

(v) atomicity

Part-B

1. Question

Modern atomic theory takes up the wave concept, principle of uncertainty and other latest discoveries to give a clear-cut picture about an atom. State the findings of modern atomic theory.

Answer

● An atom is the smallest particle which takes part in chemical reaction.

● An atom is considered to be a divisible particle.

● The atoms of the same element may not be similar in all respects.

ex: Isotopes ($_{17}Cl^{35}$, $_{17}Cl^{37}$)

● The atoms of different elements may be similar in some respects.

ex. Isobars ($_{18}Ar^{40}$, $_{20}Ca^{40}$)

● The ratio of atoms in a molecule may be fixed and integral but may not be simple. Ex.$C_{12}H_{22}O_{11}$ is not a simple ratio. (Sucrose)

● The atoms of one element can be changed into the atoms of another element by transmutation.

● The mass of an atom can be converted into energy. This is in accordance with Einstein's equation $E = mc^2$ where E = energy, m = mass and c = velocity of light

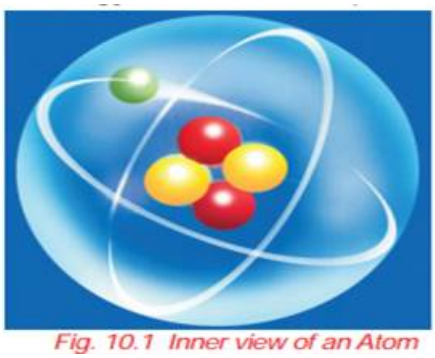


Fig. 10.1 Inner view of an Atom

2. Question

How will you establish the relation between vapour density and molecular mass of a gas by applying Avogadro's law?

Answer

Relative Molecular Mass: It is defined as the ratio of the mass of 1 molecule of the gas or vapour to the mass of 1 atom of hydrogen.

$$\text{Relative molecular mass of a gas} = \frac{\text{Mass of 1 molecule of the gas or vapour}}{\text{Mass of 1 atom of hydrogen}}$$

Vapour Density (V.D): It is defined as the ratio of the mass of a certain volume of the gas or vapour to the mass of the same volume of hydrogen at the same temperature and pressure.

$$\text{V.D} = \frac{\text{Mass of 1 volume of gas or vapour}}{\text{Mass of 1 volume of hydrogen}}$$

Applying Avogadro's Law,

$$\text{V.D} = \frac{\text{Mass of 1 molecule of gas or vapour}}{\text{Mass of 1 molecule of hydrogen}}$$

Since hydrogen is diatomic,

$$\text{V.D} = \frac{\text{Mass of 1 molecule of gas or vapour}}{2 \times \text{Mass of 1 atom of hydrogen}}$$

$$\text{V.D} \times 2 = \frac{\text{Mass of 1 molecule of gas or vapour}}{\text{Mass of 1 atom of hydrogen}}$$

2 x V.D = relative molecular mass of a gas or vapour

2 x Vapour density = Relative molecular mass

3. Question

Calculate the number of moles in:

i) 12.046×10^{23} atoms of Copper

ii) 27.95g of Iron

iii) 1.51 x 10^{23}molecules of CO_2

Answer

we know that to find the number of moles, the following formulae are used:

$$1.\ \text{Number of moles} = \frac{\text{mass}}{\text{atomic mass}}$$

$$2.\ \text{Number of moles} = \frac{\text{mass}}{\text{molecular mass}}$$

$$3.\ \text{Number of moles} = \frac{\text{no. of atoms}}{6.023 \times 10^{23}}$$

$$4.\ \text{Number of moles} = \frac{\text{no. of molecules}}{6.023 \times 10^{23}}$$

(i) Using formula 3,

$$\text{number of moles} = \frac{\text{no. of atoms}}{6.023 \times 10^{23}} = \frac{12.046 \times 10^{23}}{6.023 \times 10^{23}} = 2$$

So, 2 moles of copper contain 12.046 x 10^{23} atoms of copper.

(ii) Using formula 1,

$$\text{Number of moles} = \frac{\text{mass}}{\text{atomic mass}} = \frac{27.95 \text{ grams}}{56 \text{ grams}} \cong 0.5$$

So, 0.5 moles consist of 27.95 grams of iron.

(iii) Using formula 4,

$$\text{Number of moles} = \frac{\text{no. of molecules}}{6.023 \times 10^{23}} = \frac{1.51 \times 10^{23}}{6.023 \times 10^{23}} \cong 0.25$$

So, 0.25 moles of CO_2 consists of 1.51 x 10^{23} molecules.

Note:

1. If a compound or molecular substance is taken, like CO_2, N_2 etc, then 1

a mole of the substance contains Avogadro number of molecules. 1 mole contains the mass equal to the molecular weight of the substance.

2. If an element is taken like C, S, Fe, then 1 mole contains Avogadro

number of atoms. 1 mole contains the mass equal to the atomic weight of the substance.

4. Question

Find the gram molecular mass of the following from the data given:

i) H_2O ii) CO_2 iii) NaOH iv) NO_2 v) H_2SO_4

ELEMENT	SYMBOL	ATOMIC No.	ATOMIC MASS
Hydrogen	H	1	1
Carbon	C	6	12
Oxygen	O	8	16
Nitrogen	N	7	14
Sodium	Na	11	23
Sulphur	S	16	32

Answer

Molecular mass is the sum of the atomic masses of all the atoms present in one molecule of the substance.

1. H_2O = (1gX2) + 16g = 18g

2. CO_2 = 12g + (2 x16g) = 12 + 32 = 44g

3. NaOH = 23g + 16g + 1g = 40g

4. NO_2 = 14 + (2 x 16) = 46g

5. H_2SO_4 = (1gx2) + 32g + (4x16g) = 98g

5. Question

Complete the table given below:

ELEMENT	ATOMIC MASS	MOLECULAR MASS	ATOMICITY
Chlorine	35.5	71	
Ozone		48	3
Sulphur	32		8

Answer

Formula used is

$$\text{atomicity} = \frac{\text{molecular mass}}{\text{atomic mass}}$$

So, the complete table is

ELEMENT	ATOMIC MASS	MOLECULAR MASS	ATOMICITY
Chlorine	35.5	71	71/35.5 = 2
Ozone	48/3 =16	48	3
Sulphur	32	32 x 8 = 256	8

6. Question

Calculate the number of water molecules present in one drop of water which weighs 0.18 g.

Answer

According to mole concept we know that gram molecular weight of any compound consists of Avogadro number of molecules.

This implies that 18 grams of water consists 6.023 x 10^{23} molecules of water.

18 grams $\rightarrow$ 6.023 x 10^{23} molecules

0.18 grams $\rightarrow$?

$$= \frac{0.18 \text{ grams} \times 6.023 \times 10^{23} \text{ molecules}}{18 \text{ grams}} = 6.023 \times 10^{21} \text{ molecules}$$

7. Question

Fill in the blanks using the given data:

The formula of Calcium oxide is CaO. The atomic mass of Ca is 40, Oxygen is 16 and Carbon is 12.

i) 1 mole of Ca (____g) and 1 mole of Oxygen atom (___g) combine to form _____mole of CaO (____g).

ii) 1 mole of Ca (___g) and 1 mole of C (___g) and 3 moles of Oxygen atom (___g) combine to form 1 mole of $CaCO_3$ (___g)

Answer

i) 1 mole of Ca (40 g) and 1 mole of an Oxygen atom (16 g) combine to form 1 mole of CaO (56 g).

ii) 1 mole of Ca (40 g) and 1 mole of C (12 g) and 3 moles of an Oxygen atom (3x16 = 48 g) combine to form 1 mole of $CaCO_3$ (100 g)

Note:

1. If a compound or molecular substance is taken, like CO_2, N_2 etc, then 1

a mole of the substance contains Avogadro number of molecules. 1 mole contains the mass equal to the molecular weight of the substance.

2. If an element is taken like C, S, Fe, then 1 mole contains Avogadro

number of atoms. 1 mole contains the mass equal to the atomic weight of the substance.

So, 1 mole of Ca is 40 grams, 1 mole of O atom is 16 grams and 1 mole of C is 12 grams of C. 1 mole of CaO is 56 grams (40+16) of CaO and 1 mole of $CaCO_3$ is 100 grams (40+12+48).

8. Question

How many grams are there in:

i) 5 moles of water

ii) 2 moles of Ammonia

iii) 2 moles of Glucose

Answer

we know that in the case of compounds –

$$\text{Number of moles} = \frac{\text{mass}}{\text{molecular mass}};$$

$$\text{mass} = \text{number of moles} \times \text{molecular mass}$$

Molecular mass of water (H_2O) = (2 + 16) = 18 grams

Molecular mass of ammonia (NH_3) = (14+3) = 17 grams

Molecular mass of glucose ($C_6H_{12}O_6$) = (72 + 12+ 96) = 180 grams

Applying the above formula to all 3 cases-

(i) Mass = 5 x 18 = 90 grams

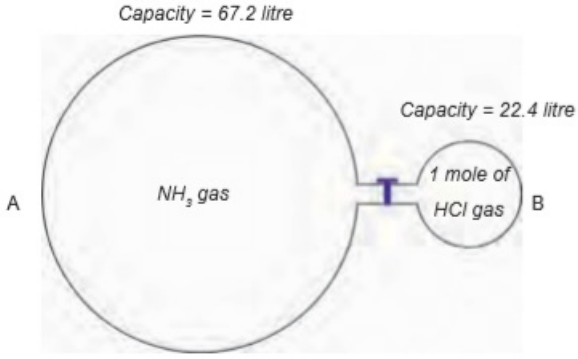
(ii) Mass = 2 x 17 = 34 grams

(iii) Mass = 2 x 180 = 360 grams

Part-C

1. Question

When ammonia reacts with hydrogen chloride gas, it produces white fumes of ammonium chloride. The volume occupied by NH_3 in glass bulb A is three times more than the volume occupied by HCl in glass bulb B at STP.



i) How many moles of ammonia are present in glass bulb A?

ii) How many grams of NH_4Cl will be formed when the stopper is opened?

(Atomic mass of N = 14, H = 1, Cl = 35.5)

iii) Which gas will remain after completion of the reaction?

iv) Write the chemical reaction involved in this process.

Answer

(i) 3 moles

(ii) 53.5 grams (14 + 4 + 35.5)

(iii) Ammonia (2 moles will be remaining)

(iv) $NH_3 + HCl \rightarrow NH_4Cl$

Explanation -1 mole of any gas at STP occupies 22.4 litres of volume. So, 1 mole of ammonia occupies 22.4 litres of volume. 67.2 litres (22.4 x 3) of volume is 3 moles of ammonia. 22.4 litres of HCl is 1 mole of HCl. According to reaction ,1 mole of ammonia reacts with 1 mole of HCl to form 1 mole of NH_4Cl, which comes out as white fumes.

$NH_3 + HCl \rightarrow NH_4Cl$

Even though 3 moles of ammonia is present in bulb, only one 1 mole undergoes reaction with 1 mole of HCl. The other 2 moles of ammonia remain unreacted.

2. Question

Nitro glycerine is used as an explosive. The equation for the explosive reaction is

$4C_3H_5((NO_3))_3 \rightarrow 12CO_2 + 10H_2O + 6N_2 + O_2$

(l) (g) (l) (g) (g)

(Atomic mass of C = 12, H = 1, N = 14, O=16)

1. How many moles does the equation show for i) Nitroglycerine ii) gas molecules produced?

2. How many moles of gas molecules are obtained from 1 mole of nitroglycerine?

3. What is the mass of 1 mole of nitroglycerine?

Answer

1. 4 moles of nitroglycerine ; CO_2 (12) + N_2(6) + O_2(1) = 19 moles of

gas molecules are formed.

2. 4 moles of nitroglycerine gives 19 moles of gas molecules. So, 1 mole

of nitroglycerine gives (19/4) 4.75 moles of gas molecules.

3. Gram molecular mass of nitroglycerine is 1 mole of nitroglycerine.

So, mass of 1 mole of nitroglycerine is 227 grams.

[(3x12)C + (5x1)H + (3x14)N + (9x16)O]

3. Question

Sodium bi carbonate breaks down on heating:

$2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$

(Atomic mass of Na = 23, C = 12, H = 1, O=16)

i) How many moles of sodium bi carbonate are there in the equation?

ii) What is the mass of sodium bicarbonate used in this equation?

iii) How many moles of carbon dioxide are there in this equation?

Answer

(i) Two (coefficient of sodium bi carbonate)

(ii) 1 mole of sodium bi carbonate contains 84 grams. Two moles of

sodium bi carbonate contains 168 grams. So, 168 grams of sodium bi carbonate is used in the equation.

(iii) 1 mole (coefficient of CO_2)

4. Question

40 g of calcium was extracted from 56 g of calcium oxide

(Atomic mass of Ca= 40, O=16)

i) What mass of oxygen is there in 56 g of calcium oxide?

ii) How many moles of oxygen atoms are there in this?

iii) How many moles of calcium atoms are there in 40 g of calcium?

iv) What mass of calcium will be obtained from 1000 g of calcium oxide?

Answer

(i) 16 grams of O

(ii) 1 mole of oxygen atoms

(iii) 1 mole

(iv) 714.38 grams.

56 grams of CaO gives 40 grams of Ca. 1000 grams of CaO gives (1000x40)/56 = 714.28 grams of calcium

Explanation –

$CaO \rightarrow Ca + O$

56 40 16

1 mole of any compound (or gas in molecular form) contains the mass equal to its gram molecular mass. 1 mole of any element contains the mass equal to its gram atomic mass. So,

1 mole of CaO = 40 + 16 = 56 grams

1 mole of Ca = 40 grams

1 mole of oxygen atoms = 16 grams

1 mole of calcium oxide dissociates to form 1 mole of Ca and 1 mole of O atoms.

5. Question

How many grams are there in the following?

i) 1 mole of chlorine molecule, Cl_2

ii) 2 moles of sulphur molecules, S_8

iii) 4 moles of ozone molecules, O_3

iv) 2 moles of nitrogen molecules, N_2

Answer

we know that when gases are present in the molecular form, 1 mole of any gas is equal to 6.023×10^{23} molecules of that gas, which is equal to the gram molecular weight of gas in the combined state.

(i) 1 mole of chlorine molecules contains 71 grams of Cl_2. (2×35.5)

(ii) 2 moles of sulphur molecules contain 512 grams of S_8. (2×32×8)

(iii) 4 moles of ozone molecules contain 192 grams of O_3. (4× 16× 3)

(iv) 2 moles of nitrogen molecules contain 56 grams of N_2. (2× 14× 2)

6. Question

Find how many moles of atoms are there in:

i) 2 g of nitrogen.

ii) 23 g of sodium

iii) 40 g of calcium.

iv) 1.4 g of lithium

v) 32 g of sulphur.

Answer

We know the formula that

$$\text{Number of moles} = \frac{\text{mass}}{\text{atomic mass}}$$

Applying the above formula for all cases.

(i) $\text{Number of moles} = \frac{\text{mass}}{\text{atomic mass of nitrogen}} = \frac{2\,\text{g}}{14\,\text{g}} = 0.1428$

(ii) $\text{Number of moles} = \frac{\text{mass}}{\text{atomic mass of sodium}} = \frac{23\,\text{g}}{23\,\text{g}} = 1$

(iii) $\text{Number of moles} = \frac{\text{mass}}{\text{atomic mass of calcium}} = \frac{40\,\text{g}}{40\,\text{g}} = 1$

(iv) $\text{Number of moles} = \frac{\text{mass}}{\text{atomic mass of lithium}} = \frac{1.4\,\text{g}}{7\,\text{g}} = 0.2$

(v) $\text{Number of moles} = \frac{\text{mass}}{\text{atomic mass of sulphur}} = \frac{32\,\text{g}}{32\,\text{g}} = 1$