Chapter 5. Mole Concept And Stoichiometry

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Solution 1:

1. **Gay-Lussac's law:** It states that 'when gases react, they do so in volumes which bear a simple ratio to one another, and also to the volume of the gaseous product, provided all the volumes are measured at the same temperature and pressure'.
2. **Avogadro's law :** It states that 'Under the same conditions of temperature and pressure, equal volumes of all gases contain the same number of molecules'.

Solution 2:

(a) Atomicity of a gas: The number of atoms in a molecule of a gas is called its atomicity.

For example: Monoatomic means a gas molecule containing one atom. Similarly diatomic corresponds to two atoms and triatomic corresponds to three atoms in a molecule of a gas.

(b)

2H	H_2
2H corresponds to two atoms of Hydrogen element.	H_2 corresponds to a hydrogen molecule which contains two atoms of hydrogen.

Solution 3:
When stating the volume of a gas, the pressure and temperature should also be given because the volume of a gas is highly susceptible to slight change in pressure and temperature of the gas.

Solution 4:

a. The relative atomic mass of Cl atom is 35.5 a.m.u. because chlorine cossists of a mixture of two isotopes of masses 35 and 37 in the ratio of 3:1.

The average of the isotopic masses is 35 x 3 + 37 x 4 = 35.5

b.The value of Avogadro's number is 6.023×10^{23}.

c. The value of molar volume of a gas at STP is 22.4 dm^3 (litre) or 22400 cm^3 (ml).

Concept Insight: a. Isotopes are atoms of same having same atomic number but different mass number.
c. One mole of any gaseous molecules occupy 22.4dm^3 at standard temperature and pressure (STP). This volume is known as molar volume.

Solution 5:

(a) Vapour density It is Density of a gas, expressed as the mass of a given volume of the gas divided by the mass of an equal volume of a reference gas (such as hydrogen or air) at the same temperature and pressure.

(b) Molar volume: One mole of any gaseous molecules occupy 22.4dm^3 at standard temperature and pressure (STP). This volume is known as molar volume.

"The molar volume of a gas can be defined as the volume occupied by one mole of a gas at standard temperature and pressure."

(c) Relative atomic mass: " The relative atomic mass or atomic weight of an element is the number of times one atom of the element is heavier than 1/12 times of the mass of an atom of carbon – 12".

Relative atomic mass = Mass of 1 atom of the element/1/12 of the mass of one C^{12} atom.

(d) Avogadro's number: Avogadro's number is defined as the number of atoms present in 12g of C^{12} isotope i.e. 6.023 x $x10^{23}$ atoms.

- It is number of elementary units i.e. atoms, ions or molecules present in one mole of a substance.
- It is denoted by N_A.

(e) Relative molecular mass: "The relative atomic mass (or molecular weight) of an element or a compound is the number that represents how many times one molecule of the substance is heavier than 1/12 of the mass of an atom of carbon – 12.

Solution 6:

(a) The main applications of Avogadro's law are:

- Explanation of Gay-Lussac's Law
- Determination of atomicity of gases
- Determination of the molecular formula of a gaseous compound.
- Establishes relationship between the relative vapour density of a gas and its relative molecular mass.
- Establishes the relationship between gram molecular weight and volume of a gas at STP

(b) Explanation of Gay-Lussac's Law: Gay-Lussac had experimentally determined that one volume of hydrogen and one volume of chlorine react to produce two volumes of hydrogen chloride gas.
According to Avogadro's law, if:

1 volume of hydrogen contains n molecules of the gas then 1 volume of chlorine also contains n molecules of the gas. Therefore 2 volume of hydrogen chloride contain 2n molecules of the gas.

$H_2 + Cl_2 \rightarrow 2HCl$

1vol 1 vol 2 vol (by Gay-Lussac)
n n 2n (By Avogadro)

but hydrogen and chlorine are diatomic.
So, 2 atoms + 2 atoms → 2 molecules

1 atom + 1 atom → 1 molecule

i.e. 1 molecule of hydrogen chloride is formed when 1 atom of hydrogen combines with 1 atom of chlorine. Thus Avogadro's law explains Gay-Lussac's law of combining volumes.

Solution 7:

1. **Gram atom:** "The quantity of the element which weighs equal to its gram atomic mass is called one gram atom of that element".
   For example: The gram atomic mass of hydrogen is 1g. So, 1g of hydrogen is 1 gram atom of hydrogen.
2. **Gram mole:** "A sample of substance with its mass equal to its gram molecular mass is called one gram molecule of this substance or one gram mole".
   For example: Gram molecular mass of oxygen is 32 g. So One gram mole of oxygen is 32g.

Solution 8:

(a) The relative molecular mass of Potassium chlorate ($KClO_3$) is:

[atomic mass of 1 K atom + Atomic mass of 1 Cl atom + atomic mass of 3 O atoms]

$39 + 35.5 + 16 \times 3 = 122.5$

(b) The relative molecular mass of Sodium acetate (CH_3COONa) is:

[atomic mass of 2 C atom + Atomic mass of 3 H atom + atomic mass of 2 O atoms + atomic mass of 1 Na atom]

$12 \times 2 + 3 \times 1 + 16 \times 2 + 23 = 82$

(c) The relative molecular mass of Chloroform (CH_3Cl) is:

[atomic mass of 1 C atom + Atomic mass of 3 H atom + atomic mass of 1 Cl]

$12 + 3 \times 1 + 35.5 = 50.5$

(d) The relative molecular mass of Ammonium sulphate $(NH_4)_2SO_4$ is:

[atomic mass of 2 N atom + Atomic mass of 8 H atom + atomic mass of 1 S + atomic mass of 4 O atom]

$14 \times 2 + 8 \times 1 + 32 + 16 \times 4 = 132$

Solution 9:

Empirical formula:"Empirical formula of a compound is the formula which gives the number of atoms of different elements present in one molecule of the compound, in the simplest numerical ratio".

Molecular formula: "Molecular formula of a compound denotes the actual number of atoms of different elements present in one molecule of the compound".

Solution 10:

1. The empirical formula of C_6H_6 is: CH
2. The empirical formula of $C_6H_{12}O_6$ is: CH_2O.
3. The empirical formula of C_2H_2 is: CH
4. The empirical formula of CH_3COOH is: CH_2O.

Solution 11:

Three pieces of information conveyed by the formula H_2O is that:

1. It shows that there are 2 hydrogen atoms and 1oxygen atoms present in H_2O.
2. The hydrogen and oxygen atoms are present in simplest whole number ratio of 2:1.
3. It represents one molecule of compound water.

Solution 12:

"A mole is defined as the amount (mass) of a substance containing elementary particles like atoms, molecules or ions equal to Avogadro's number i.e. 6.023×10^{23}.

Or a collection of 6.023×10^{23} particles is called mole.

Number of elementary units present in one mole of a substance is 6.023×10^{23}.

Solution 13:

(a) Vapour density.

(b) One mole of gas.

(c) quantity of element which weighs equal to its gram atomic mass

(d) one

(e) 6.023×10^{23}

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Solution 14:

(a) Since one Oxygen molecule contains 2 atoms of oxygen, so it is a diatomic molecule.

$O + O \rightarrow O_2$

(b) The molecular mass of the given compound is determined experimentally by vapour density method also, in which the vapour density of the compound is determined. Vapour density is related to molecular mass as:

Molecular mass = 2 x vapour density.

(c) Since by definition of a mole it is defined as the amount (mass) of a substance containing elementary particles like atoms, molecules or ions equal to Avogadro's number i.e. 6.023×10^{23} so one mole of any gas contains the same number of molecules.

Solution 15:

1. $Na_2SO_4.10H_2O$.
2. $C_6H_{12}O_6$.

Solution 16:

Given reaction is:

$N_2 + O_2 \rightarrow 2NO$

According to Gay-Lussac's law in the above reaction 1 volume of nitrogen combines with 1 volume of oxygen to produce 2 volumes of nitric oxide.

i.e. $N_2 + O_2 \rightarrow 2NO$

1 vol. 1 vol. 2 vol.

The volume of nitric oxide produced is = 1400cm^3.

Let the volumes of nitrogen and oxygen gases be = x

Then, $N_2 + O_2 \rightarrow 2NO$
x x 1400cm^3

So, x + x = 1400

2x = 1400

x= 1400/2 = 700cm^3

Hence the volumes of reacting gases i.e. nitrogen and oxygen is 700 cm^3 each.

Solution 17:

Number of molecules in 12.8 g of sulphur dioxide gas.

Molecular mass of SO_2 = 64 a.m.u.

So, 64 g = 1 mole

12.8g = 12.8/64 = 0.2 mole

Now 1 mole of SO_2 contains = 6 x 10^{23} molecules

0.2 mole of SO_2 contains = 0.2 x 6 x 10^{23}

= 1.2 x 10^{23} molecules.

Solution 18:

Weight of 6 x 10^{23} molecules of oxygen = 32g

Weight of 1 molecule of oxygen = 32/6 x 10^{23} = 5.33 x 10^{23}g

Solution 19:

Pb + $(N)_2$ + $(O)_6$

207 + 2 x14+ 6 x 16 = 331.

So, the molecular mass of $Pb(NO_3)_2$ = 331.

331 by weight of $Pb(NO_3)_2$ contain 96 parts by weight of oxygen.

100 parts will contain = 96 x 100 /331 = 29%

So, the percentage composition of oxygen in lead nitrate is 29%.

Solution 20:

(a) Percentage of nitrogen in Ammonium nitrate [NH_4NO_3]

$(N)_2$ + $(H)_4$ + $(O)_3$

14 x 2 + 1 x 4+ 3 x 16 = 80.

So, the molecular mass of NH_4NO_3 = 80.

80 by weight of NH_4NO_3 contain 28 parts by weight of nitrogen.

100 parts will contain = 28 x 100 /80 = 35%

So, the percentage composition of nitrogen in Ammonium nitrate is 35%.

(b) Percentage of nitrogen in Ammonium phosphate [$(NH_4)_3PO_4$]

$(N)_3$ + $(H)_{12}$ +P + $(O)_4$

14 x 3 + 1 x 12+ 31 + 16 x 4 = 149.

So, the molecular mass of NH_4NO_3 =149.

149 by weight of $(NH_4)_3PO_4$ contain 42 parts by weight of nitrogen.

100 parts will contain = 42 x 100 /149 =28.18 %

So, the percentage of nitrogen in ammonium phosphate is 28.18 %.

Since the percentage of nitrogen is more in Ammonium nitrate so it is a better fertilizer.

Solution 21:

Empirical formula of a compound:

Element	Atomic mass	Percentage	Relative number of moles	Simplest mole ratio	Whole number ratio
Pb	207	90.66	90.66/207 = 0.44	0.44/0.44= 1	1 x3 =3
O	16	9.34	9.34 /16 =0.58	0.58 / 0.44 =1.32	1.32 x 3 =3.96 = 4

Since the mole ratio for oxygen is fractional so we multiply the whole ratio by 3 to make it a whole number.

So, the empirical formula of the compound is Pb_3O_4.

Solution 22:

Empirical formula of the compound is CH_2O.

Empirical formula mass = Atomic mass of C + Atomic mass of H + Atomic mass of O

= 12 + 2 x 1 + 16 = 30.

Now as empirical formula is equal to the vapour density then;

Molecular mass = 2 x vapour density

= 2 x 30 = 60

n = Molecular mass / Empirical formula mass

= 60 / 30 = 2

Molecular formula = n x empirical formula

= 2 x (CH_2O)

= $C_2H_4O_2$

The molecular formula of the compound is $C_2H_4O_2$.

Solution 23:

(i) From the equation:

Molecular weight of KNO_3 = (Atomic mass of K + Atomic mass of N + Atomic mass of O) = (39 + 14 + 16 x 3) = 101

Molecular mass of of KNO_2 = (39 +14 +16 x 2) = 85

From the reaction:

2 moles of KNO_3 gives = 2 moles of KNO_2

So, 202 g of KNO_3 gives = 170 g of KNO_2

(ii) Given equation is: $2KNO_3 \rightarrow 2KNO_2 + O_2$

Molecular mass of KNO_3 is: (Atomic mass of K + Atomic mass of N + Atomic mass of O) = (39 + 14 + 16 x 3) = 101

Molecular mass of of KNO_2 = (39 +14 +16 x 2) = 85

Now, decomposition of 101 g of KNO_3 yield = 16 g of O_2

So, decomposition of 5.05 g of KNO_3 will yield = 16 x 5.05 /101 = 0.8 g

Hence, when 5.05 g of potassium nitrate decomposes completely 0.8 g of oxygen is formed.

Solution 24:

(a) (i) Volume occupied by 48 g of oxygen.

As 32g of oxygen at STP occupies volume of = 22.4 L
48 g of oxygen at STP occupies volume of = 22.4 x 48 /32 = 33.6 L
Hence, 48 g of sulphur dioxide will occupy a volume of 33.6 L

(ii) Volume occupied by 16 g of sulphur dioxide.

64 g of sulphur dioxide at STP occupies volume of = 22.4 L

16 g of sulphur dioxide at STP occupies volume of = 22.4 x 16 /64 = 5.6 L

Hence, 16 g of sulphur dioxide will occupy a volume of 5.6 L

(b) 4 L of a gas at STP has mass = 5 g

22.4 L of a gas at STP will has molecular mass = 5 x 22.4 /4 = 28

So, the molecular mass of a gas will be 28.

Solution 25:

Molecular formula of $MgCO_3$ is = 84

Molecular formula of H_2SO_4 = 98

Now if, 84 g of $MgCO_3$ requires = 98 g of H_2SO_4

3 g of $MgCO_3$ will require = 98 x 3/84 = 3.5 g

So, 3.5 g of sulphuric acid will be required to dissolve 3 g of magnesium carbonate.

Solution 26:

Ferrous sulphate is $FeSO_4 .7H_2O$
Molecular mass of Ferrous sulphate is $FeSO_4 .7H_2O$ is:
Atomic mass of Fe + Atomic mass of S + Atomic mass of H + Atomic mass of O
56 + 32 + 1 x 14 + 16 x 11 = 278
278 parts by weight of crystals contain 126 parts of water
100 parts will contain = 126 x 100 /278 = 45.32%
So, the percentage of water in ferrous sulphate crystals is 45.32%

Solution 27:

Element	Atomic mass	Percentage	Relative number of moles	Simplest mole ratio	Whole number ratio
C	12	12.76	12.76/12 = 1.06	1.06/1.06 = 1	1
H	1	2.13	2.13/1 = 2.13	2.13 /1.06 =2	2
Br	80	85.11	85.11/80 = 1.06	1.06 /1.06 =1	1

So the Empirical formula of the compound will be CH_2Br.

Now the Empirical formula mass will be = Atomic mass of C + Atomic mass of H + Atomic mass of Br

= 12 + 1 x 2 + 80 = 94

Now as Molecular mass = 2 x vapour density

= 2 x 94 =188.

So n = Molecular mass / empirical formula mass

= 188/94 = 2

Molecular formula of the compound is = n x empirical formula

= 2 x (CH_2Br)

= $C_2H_4Br_2$

Solution 28:

Calculation of molar mass of M from first oxide:

Let us assume the atomic mass of M as x.

Atomic mass of Oxygen = 16

Element	Percentage	Relative number of moles	Simplest mole ratio
M	100-20.12 = 79.88	79.88/x	79.88/1.25x
O	20.12	20.12/16 = 1.25	1.25/1.25 = 1

So, molar mass of M, x = 63.5

Calculation Of formula of second oxide:

Element	Atomic mass	Percentage	Relative number of moles	Simplest mole ratio	Whole number ratio
M	63.5	88.81	88.81/63.5 =1.4	1.4/0.69 = 2	2
O	16	11.19	11.19/16 = 0.69	0.69/0.69 = 1	1

So formula of second oxide is M_2O.

Solution 29:

Conversion of sulphur dioxide to sulphur trioxide follows the following balanced equation:

$4SO_2 + 2O_2 \rightarrow 4SO_3$

According to Gay-Lussac's law:

4 vol. 2 vol. 4 vol.

Volume of SO_2 = 4 vol. =300 mL

Volume of O_2 = 2 vol. =300 x 2 /4 = 150 mL

Volume of oxygen required = 21% = 150 mL

Volume of air required at STP = 100% = 100 x 150 /21 =714.28 mL

So, the volume of air at STP, required to convert 300 mL of sulphur dioxide to sulphur trioxide is 714.28 mL

Solution 30:

Given reaction is:

$AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$

Molecular mass of $AgNO_3$ is 170

Molecular mass of AgCl is 143.5

170 g of $AgNO_3$ produces =143.5 g of AgCl

17 g of $AgNO_3$ will produce = 143.5 x 17 /170 = 14.35 g

So, the weight of silver chloride precipitated is 14.35 g

Solution 31:

12 g of carbon contains = 6.023×10^{23} number of carbon atoms

10^{-12} g of carbon will contain = $6.023 \times 10^{23} \times 10^{-12} / 12$

$= 0.5019 \times 10^{11}$

$= 5.019 \times 10^{10}$

So, the number of carbon atoms in the signature is 5.019×10^{10}.

Solution 1996-1:

(lation of number of molecules in each gas sample:

(i) _ _ of carbon dioxide:

22.4 L of carbon dioxide has = 6.023×10^{23} molecules

2 L of carbon dioxide will have = $6.023 \times 10^{23} \times 2 / 22.4 = 0.5377 \times 10^{23}$ molecules

(ii) 3L of chlorine

22.4 L of chlorine has = 6.023×10^{23} molecules

3 L of chlorine will have = $6.023 \times 10^{23} \times 3/22.4 = 0.8066 \times 10^{23}$ molecules

(iii) 5 L of hydrogen

22.4 L of hydrogen has = 6.023×10^{23} molecules

5 L of hydrogen will have = $6.023 \times 10^{23} \times 5/22.4 = 1.34 \times 10^{23}$ molecules

(iv) 4 L of nitrogen

22.4 L of nitrogen has = 6.023×10^{23} molecules

4 L of nitrogen will have = $6.023 \times 10^{23} \times 4/22.4 = 1.07 \times 10^{23}$ molecules

(v) 1 L of sulphur dioxide

22.4 L of sulphur dioxide has = 6.023×10^{23} molecules

1 L of sulphur dioxide will have = $6.023 \times 10^{23} \times 1/22.4 = 0.27 \times 10^{23}$ molecules

From the above calculation of number of molecules in different gases we can conclude that the:

(a) The greatest number of molecules are present in 5 L of hydrogen gas sample.

(b) The least number of molecules is in 1 L of sulphur dioxide gas sample.

Solution 1996-2:

(a) 64 g of SO_2 will be produced at STP from = 22.4L of H_2S

12.8 g of SO_2 will be produced at STP from = $22.4 \times 12.8 / 64$ = 4.48 L

So, 4.48 L of hydrogen sulphide at STP will burn in oxygen to yield 12.8 g sulphur dioxide.

(b) From the equation we know that 2 moles of H_2S burn in presence of 3 moles of Oxygen so:

44.8 L of H_2S requires = 67.2 L of oxygen

4.48 L of H_2S will require = $67.2 / 44.8 \times 4.48 = 6.72$ L

So, 6.72 L of oxygen would be required for complete combustion.

Solution 1996-3:

Molecular mass of Mg $(NO_3)_2.6H_2O$ is = 256

Now, 256 parts by weight of crystal contains 192 parts by weight of oxygen.

So 100 parts by weight will contain = 192 x 100 /256 = 75%

Hence, total percentage of oxygen in magnesium nitrate crystal $Mg(NO_3)_2.6H_2O$ is 75%.

Solution 1996-4:

Empirical formula of the compound is as:

Element	Atomic mass	Percentage	Relative number of moles	Simplest mole ratio	Whole number ratio
N	14	87.5	87.5/14 =6.25	6.25 /6.25 = 1	1
H	1	12.5	12.5 /1 = 12.5	12.5 /6.25 =2	2

So, the empirical formula of the compound is NH_2.

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Solution 1997-1:

(a) No. it is not possible to change the temperature and pressure of a fixed mass of a gas without changing its volume because all the three variables are interrelated to each other by the gas equation as:

PV/T = K (constant) -- 1)

Hence if we change any one or two of the variables in the above equation then automatically third variable also has to change to make equation 1 equal to a constant.

(b) "The molar volume of a gas can be defined as the volume occupied by one mole of a gas at standard temperature and pressure". It has been noticed that one mole of any gaseous molecules occupy 22.4 L of volume at standard temperature and pressure.

Solution 1997-2:

Molecular mass of urea is =60

60 kg of urea has = 28 Kg of nitrogen

1000 Kg of urea will have = 28 x 1000 /60 = 466.66 or 467 Kg.

Solution 1997-3:

(a)

Element	Atomic mass	Percentage	Relative number of moles	Simplest mole ratio	Whole number ratio
Na	23	37.6	37.6/23 =1.63	1.63/0.83 = 1.9	2
Si	28	23.1	23.1/28 = 0.83	0.83/0.83 = 1	1
O	16	39.3	39.3/16 = 2.45	2.45/0.83 = 2.9	3

So the empirical formula of the compound is Na_2SiO_3.

(b) Given the empirical formula of the compound is C_2H_5.

Vapour density is = 29.

Empirical formula mass of the compound = 29

As, molecular mass = 2 x vapour density

= 2 x 29 = 58

So, molecular mass of the compound =58
Molecular formula = n x Empirical formula

Now, n = Molecular mass/ Empirical formula mass

= 58/29 =2

Molecular formula = 2 x (C_2H_5)

= C_4H_{10}

So, molecular formula of compound is = C_4H_{10}.

Solution 1997-4:

Molecular mass of ammonium dichromate = 252

Now, 252 g of ammonium dichromate evolves = 22.4 L of nitrogen at STP

63 g of ammonium dichromate will evolve = 22.4 x 63 /252 = 5.6 L

So, 63 g of ammonium dichromate will evolve 5.6 L of oxygen.

Solution 1998-1:

(a) Molecular mass of borax $Na_2B_4O_7.10H_2O$ = 382

382 parts by weight of borax contain 44 parts by weight of boron

So 100 parts will contain = 44 x 100 /382 = 11.5%

Percentage of boron (B) in borax ($Na_2B_4O_7.10H_2O$) = 11.5%.

(b) (i)

Element	Atomic mass	Percentage	Relative number of moles	Simplest mole ratio	Whole number ratio
C	12	26.7	26.7/12 = 2.2	2.2/2.2 = 1	1
O	16	71.1	71.1/16 =4.44	4.44/2.2 =2	2
H	1	2.2	2.2/1 = 2.2	2.2/2.2 = 1	1

So the empirical formula of the compound is CO_2H.

(ii) The relative molecular mass of A is 90

Empirical Formula mass of compound is = 45

Then, n= Molecular mass/Empirical Formula Mass

= 90/45 = 2

Molecular formula of compound = n x Empirical formula

= 2 x (CO_2H)

= $C_2O_4H_2$.

Solution 1998-2:

(i) Given equation is: $2H_2O$ (l) → $2H_2$ (g) + O_2 (g)

According to Gay-Lussac's law;

2 volume of water produces 2 volume of hydrogen and 1 volume of oxygen

i.e 2 volume of water produces = 2 volume of hydrogen = 2500 cm^3

2 volume of water will produce = 1 volume of Oxygen = 2500/2 = 1250 cm^3

i.e. = 1250 cm^3

(ii) Given equation is: $2NH_3$ (g) +2 $^{1/2}$ O_2 (g) → 2NO (g) + $3H_2O$ (l)

Molecular mass of NO = 30

Molecular mass of H_2O = 18

From the equation:

2 moles of NO = 3 moles of H_2O

60 g of NO = 54 g of H_2O

1.5g of NO = 54 x 1.5 /60 = 1.35 g of H_2O.

Solution 1999-1:

(a) Given equation is:

$P + 5HNO_3 \rightarrow H_3PO_4 + H_2O + 5NO_2$

(i) Molecular mass of phosphorous = 31

Molecular mass of phosphoric acid = 98

31 g of phosphorous produces = 98 g of phosphoric acid

6.2 g of phosphorous will produce = 98 x 6.2 /31 = 19.6 g

Hence, 19.6 g of phosphoric acid can be prepared from 6.2 g of phosphorous.

(ii) Molecular mass of nitric acid = 63

31 g of phosphorous will consume= 63 g of nitric acid.

(iii) Moles of steam formed from 31g phosphorus = 1 mol
moles of steam from 6.2g phosphorus = 1mol× 6.2g /31g = 0.2 mol.
volume of steam produced at S.T.P = (0.2 mol) × (22.4 L/mol)
= 4.48 litre.
Since the pressure (760 mm) remains constant, but the temperature (273 + 273) = 546 is doubled,
the volume of the steam also gets doubled
∴ volume of steam produced at 760 mm Hg and 273°C = 4.48 × 2 = 8.96 litres.

(b) $4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O$
4 vol. 5 vol. 4 vol.

Volume of reactants = 4 vol. of ammonia + 5 vol. of oxygen = 9 vol.

9 vol. of reactants produces 4 vol. of Nitric oxide
Therefore, 27 vol. of reactants will produce 4×27 lit /9. = 12 litres of Nitric oxide

Solution 1999-2:

Molecular weight of $Ca(NO_3)_2$ = 164

164 parts by weight of calcium nitrate contains 28 parts by weight of nitrogen.

28 Kg of nitrogen will be replaced by = 164 Kg of $Ca(NO_3)_2$

20 Kg of nitrogen will be replaced by = 164 x 20 /28 = 117.14 kg

For, 1 hectare of field 20 Kg of nitrogen will be replaced by =117.14 Kg of $Ca(NO_3)_2$

For, 10 hectare of field 20 Kg of nitrogen will be replaced by = 117.14 x 10 = 1171.4 Kg

Hence, 1171.4 Kg of the fertilizer calcium nitrate, $Ca(NO_3)_2$ would be required to replace nitrogen in 10 hectare field.

Solution 1999-3:

(a) As we know from **Avogadro's law** that under same conditions of temperature and pressure, equal volumes of all gases contain the same number of molecules so if a vessel contains N molecules of oxygen at a certain temperature and pressure and since the vessel remains same so same volume of sulphur dioxide will be present in the vessel and hence N molecules of sulphur dioxide can be accommodated in the vessel at the same temperature and pressure.

(b) (i) Flask having oxygen gas:

16 g of oxygen gas has = 6.023×10^{23} molecules

2g of oxygen gas will have = $6.023 \times 10^{23}/16 \times 2 = 0.75 \times 10^{23}$

Flask having hydrogen:

1 g of hydrogen has= 6.023×10^{23} molecules

2g of hydrogen gas will have = $6.023 \times 10^{23} \times 2/1 = 12.05 \times 10^{23}$

So, hydrogen gas has greater number of molecules.

(ii) Amount of hydrogen and oxygen gases is same = 2 g

So, for oxygen 32 g of gas has =N molecules

Then, 2g of gas has = N/32 x 2 = 16

No of molecules of oxygen = N/16.

Solution 2000-2:

Element	Atomic mass	Percentage	Relative number of moles	Simplest mole ratio	Whole number ratio
N	14	42	42/14 =3	3/3 = 1	1
O	16	48	48/16 =3	3/3 = 1	1
H	1	9	9/1 =9	9/3 =3	3

So the empirical formula of the compound is NH_2OH.

Solution 2000-1:

(a) At STP, 22400 cm^3 of each H_2S and Cl_2 will give 32 g of sulphur i.e.

44800 cm^3 of $H_2S + Cl_2$ gives = 32 g of S

(112 +120) = 232 cm^3 of $H_2S + Cl_2$ will give = 32 x 232 /44800 = 0.16 g of S

(b) $Na_2CO_3.10H_2O \xrightarrow{\Delta} Na_2CO_3 + 10\ H_2O$

molecular weight of washing soda is 286.14 g

molecular weight of sodium carbonate is 106 g

286.14 g of $Na_2CO_3.10H_2O$ forms 106 g of sodium carbonate on heating

57.2 g of $Na_2CO_3.10H_2O$ forms = 106 X 57.2 / 286.14 = 21.2 g

(c) $Na_2SO_4 + Pb(NO_3)_2 \rightarrow PbSO_4 + 2NaNO_3$

molecular weight of Na_2SO_4 is 142 g

molecular weight of $PbSO_4$ is 303 g

303 g of $PbSO_4$ is formed by 142 g of Na_2SO_4

15.1 g of $PbSO_4$ is formed by = 142 X 15.1 / 303 = 7.1 g of Na_2SO_4

Solution 2000-1:
Gay – Lussac proposed this law.

Solution 2001-2:
Molecular mass of ethane = 30
According to Gay-Lussac's law:
2 vol. of C2H6 requires= 7 vol. of oxygen
Vol. of C2H6 = 2 vol. = 100 L
Vol. of oxygen required = 7 vol. =350 L

Solution 2001-3:

(a) If 20 L of nitrogen has = X number of molecules

Then, 10 L of chlorine will have = X x 10 /20 = X/2.

(b) If 20 L of nitrogen has = X number of molecules

Then, 20 L of ammonia will have = X x 20 /20 = X.

(c) If 20 L of nitrogen has = X number of molecules

Then, 5 L of sulphur dioxide will have = X x 5 /20 = X/4.

Gas	Volume (litres)	Number of molecules
Chlorine	10	X/2
Nitrogen	20	X
Ammonia	20	X
Sulphur dioxide	5	X/4

Solution 2001-4:

The term is vapour density.

Solution 2001-5:

According to Gay-Lussac's law: In the equation

$4\ N_2O + CH_4 \rightarrow CO_2 + 2H_2O + 4N_2$

Vol. of H_2O produced is = 2 vol. = 150cm^3

Vol. of N_2O required is = 4 vol. = 150 x 4 /2 = 300 cm^3

300 cm^3 of dinitrogen oxide (N_2O) is required to give 150 cm^3 of steam.

Solution 2001-6:

Molecular mass of fertilizer superphosphate, $Ca(H_2PO_4)_2$ = 234

234 parts by weight of fertilizer contains 62 parts by weight of phosphorous

So, 100 parts will contain = 62 x 100 /234 = 26.5%

Solution 2001-7:

Given, density of chloride relative to hydrogen = 162.5

Percentage of chlorine = 65.5%

Percentage of Metal M = 100-65.5 = 34.5%

Element	Atomic mass	Percentage	Relative number of moles	Simplest mole ratio	Whole number ratio
M	56	34.5	34.5/56 =0.62	0.62/0.62 = 1	1
Cl	35.5	65.5	65.5/35.5 =1.85	1.85/0.62 = 2.98	3

Empirical formula = MCl_3

Empirical formula mass = 56 + 3 x 35.5 = 162.5

Molecular mass = 2 x Vapour density = 2 x 162.5 = 325

n = Molecular mass / Empirical formula mass

= 325 /162.5 = 2

Molecular formula = n x empirical formula

= 2 x MCl_3

= M_2Cl_6

Solution 2002-1:

(a) X molecules of N_2 occupies V litres.

3X molecules of CO occupies 3V litres.

(b) X molecules of O_2 = 8/32 = 1/4 mole of O_2

So, X molecules of CO_2 = 1/4 molecule of CO_2

So, Mass of CO_2 present in the sample = ¼ x gram molecular mass of CO_2

= 1/4 x 44 = 11g

(c) Avogadro's law.

Solution 2002-2:

Molecular formula of ammonium chloroplatinate $(NH_4)_2PtCl_6$:

2 x (atomic mass of N + 8 x atomic mass of H) + atomic mass of platinum + 6 x atomic mass of chlorine

2 x (14 + 8) + 195 + 6 x 35.3= 444

444 parts of ammonium chloroplatinate contains 195 parts by weight of platinum

So, 100 parts will contain = 195 x 100 /444 = 43.9% = 44%

Solution 2002-3:

Element	Atomic mass	Percentage	Relative ratio of moles	Simplest mole ratio	Whole number ratio
Na	23	42.1	42.1/23 = 1.8	1.8/0.6 = 3	3
P	31	18.9	18.9/31 = 0.6	0.6/0.6 = 1	1
O	16	39	39/16 =2.4	2.4/ 0.6 = 4	4

Empirical formula = Na_3PO_4.

Solution 2003-1:

(a) $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

1 vol. 2 vol. 1 vol. 2 vol.

One volume of methane requires oxygen = 2 vol.

So, Vol. of oxygen used = 2 x 22.4 = 44.8 dm^3

$2H_2 + O_2 \rightarrow 2H_2O$

2 vol. 1vol. 2 vol.

2 volume of hydrogen needs one volume of oxygen

So, Volume of oxygen used =22.4 /2 = 11.2 dm^3

Total volume of oxygen used = 44.8 + 11.2 = 56.0 dm^3

(b) Calculation of number of molecules in each gas sample:

(i) 8 g of hydrogen:

1 g of hydrogen = 6.023 x 10^{23} molecules

8 g of hydrogen will have = 6.023 x 10^{23}x 8 = 48.184 x 10^{23} molecules

(ii) 8 g of oxygen:

32 g of oxygen has = 6.023 x 10^{23} molecules

8 g of oxygen will have = 6.023 x 10^{23}/32 x 8 = 1.50 x10^{23} molecules

(iii) 8 g of carbon dioxide:

44 g of carbon dioxide has = 6.023 x 10^{23} molecules

8 g of carbon dioxide will have = 6.023 x 10^{23}/44 x 8 = 1.0 x10^{23} molecules

(iv) 8 g of sulphur dioxide:

64 of sulphur dioxide has = 6.023 x 10^{23} molecules

8 g of sulphur dioxide will have = 6.023 x 10^{23}/64 x 8 = 0.75 x10^{23} molecules

(v) 8 g of chlorine:

35.5 g of chlorine has = 6.023 x 10^{23} molecules

8 g of chlorine will have = 6.023 x 10^{23}/71 x 8 = 0.68 x10^{23} molecules

Hence, chlorine gas will have least number of molecules. Hydrogen gas will have the most number of molecules.

Solution 2004-1:

(a) (i) Moles = Weight of substance in grams/ molecular weight

So, Moles of SO_2 = 3.2 /64 = 0.05

(ii)Number of molecules = Moles x 6.023×10^{23}
So, number of molecules of SO_2 = $0.05 \times 6.023 \times 10^{23}$
= 0.30115×10^{23} = 0.302×10^{23}

(iii) 64 g of SO_2 occupy a volume = 22.4 L
So, 3.2 g of SO_2 will occupy a volume = 22.4 x 3.2 /64 = 1.12 L

(b) Molecular weight of $KMnO_4$ = 39 + 55 + 16 x 4 = 158
Molecular weight of K_2SO_4 = 2 x 39 + 32 + 16 x 4 = 174
Molecular weight of $FeSO_4$ = 56 + 32 + 64 = 152
2 x 158 g of $KMnO_4$ yields = 174 g of K_2SO_4
So, 15.8 g of $KMnO_4$ will yield = 174 x 15.8 / 2 x 158 = 8.7 g of K_2SO_4
174 g of K_2SO_4 yields 152 g of $FeSO_4$
So, 8.7 g of K_2SO_4 will yield = 152 x 8.7/174 = 7.6 g of $FeSO_4$
Hence, 7.6 g of iron (II) sulphate is used in the above reaction.

Solution 2004-2:

(a) Mass of one litre of oxygen gas liberated at room temperature = 1.32 g

Mass of one litre of hydrogen under the same conditions of temperature and pressure = 0.0825 g

Relative Molecular mass of oxygen = Weight of n molecule of O_2/Weight of 1/2 molecule of hydrogen

= 1.32X2/0.0825 = 32 a.m.u.

(b) 2 $KMnO_4$ → $K_2MnO_4 + MnO_2 + O_2$

Molecular mass of $KMnO_4$ = 158

Molar volume of O_2 at room temperature = 24 L

2 x158 g of $KMnO_4$ at room temperature yields = 24 L of O_2

15.8 g of $KMnO_4$ will yield = 24 x 15.8 /2 x 158 = 1.2 L of O_2.

Solution 2005-1:

(a) $2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$

Molecular mass of $NaHCO_3$ = 84

Molecular mass of Na_2CO_3 =106

From the above reaction:

1 Na_2CO_3 is obtained from = 2 $NaHCO_3$

106 g of Na_2CO_3 is obtained from = 168 g of $NaHCO_3$

So, 21.2 g of Na_2CO_3 will be obtained from = 168 x 21.2 /106 = 33.6 g of $NaHCO_3$

(b) $NaCl + NH_3 + CO_2 + H_2O \rightarrow NaHCO_3 + NH_4Cl$

From the equation, 1 mole of CO_2 i.e. 22.4 L of CO_2 is used to produce = 1 mole of $NaHCO_3$

Now as, 84 g of $NaHCO_3$ requires = 22.4 L of CO_2

33.6 g of $NaHCO_3$ will require = 22.4 x 33.6 /84 = 8.96 L of CO_2.

Solution 2006-1:

(a) (i) Gas D contains the maximum number of molecules.

(ii) If the temperature and the pressure of gas A are kept constant, then the volume of the gas will get doubled.

(iii) Gay –Lussac's law of combining volumes.

(iv) Gases A D

1 : 4

5.6 dm^3 4 x 5.6 dm^3 at STP

22.4 dm^3 (molar volume)
6 x 10^{23} molecules.

(v) 6 x 10^{23} molecules is Avogadro's number of molecules contained in one gram mole of the substance if gas D is N_2O then,

1 gram mole of N_2O = 2 x 14 + 16 = 44 g

(b) Molecular mass of aluminium nitride (AlN_3) = 27 + 14 x 3 = 69

Now, 69 parts by weight of aluminium nitride contains = 42 parts by weight of nitrogen
So, 100 parts will contain = 42 x 100 /69 = 60.86%

Hence, the percentage of nitrogen in aluminium nitride is 60.86%.

Solution 2006-2:

(a) Determination of empirical formula:

Element	Atomic mass	Percentage	Relative Number of moles	Simplest mole ratio	Whole number ratio
K	39	47.9	47.9/39 = 1.2	1.2/0.6 = 2	2
Be	9	5.5	5.5/9 = 0.6	0.6/0.6 =1	1
F	19	46.6	46.6/19 = 2.4	2.4/0.6 = 4	4

The empirical formula of compound = K_2BeF_4

(b) $3CuO + 2NH_3 \rightarrow 3Cu + 3H_2O + N_2$

Molecular mass of CuO = 80
Volume occupied by 1 mole of NH_3 = 22.4 L
From the equation:
3 moles of CuO is reduced by 2 moles of ammonia

For 240 g of CuO, volume of NH_3 consumed = 44.8 L

For 120 g of CuO, volume of NH_3 consumed = 44.8 x 120 /240 = 22.4 L

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Solution 2006-3:

(a) Molecular mass of ethylene (CH_2-CH_2) = 28 g

Number of moles = Given weight / Molecular weight

= 1.4 / 28 = 0.05 moles

Now, number of molecules in 1 mole = 6.023×10^{23}

So, number of molecules in 0.05 moles $= 6.023 \times 10^{23} \times 0.05 = 0.3 \times 10^{23}$

$= 3 \times 10^{22}$ molecules.

Volume occupied by 1 mole of ethylene = 22.4 L

So, volume occupied by 0.05 moles of ethylene = 22.4 x 0.05

= 1.12 L

(b) Vapour density = Molecular weight / 2 = 28 /2 = 14.

Solution 2006-4:

(a) Molecular weight of sodium aluminium fluoride (Na_3AlF_6) = 210

Now, 210 parts by weight of Na_3AlF_6 contains = 69 parts by weight of sodium

So, 100 parts will contain = 69 x 100 /210 = 32.8 or 33%

(b) $2CO + O_2 \rightarrow 2CO_2$

From the reaction:

2 volumes of CO consumes = 1 volume of O_2

So, 560 mL of CO consumes = ½ x 560 = 280 mL

Now, 2 volume of CO gives = 2 volume of CO_2

So, 560 mL of CO will give = 2 x 560 /2 = 560 mL

Solution 2007-1:

(i) $NH_4NO_3 \rightarrow N_2O + 2H_2O$

From the equation:

1 mole of NH_4NO_3 yields 2 mole of H_2O

So, 44.8 L of steam = 22.4 L of N_2O at STP

8.96 L of steam = 22.4 x 8.96 /44.8 = 4.48 L of N_2O at STP.

(ii) Molecular mass of NH_4NO_3 = 80

44.8 L of steam is liberated by = 80 g of NH_4NO_3

8.96 L of steam will be liberated by = 80 x 8.96 / 44.8 = 16 L

(iii) 80 parts by weight of NH_4NO_3 contains 48 parts by weight of oxygen

So 100 parts will contain = 48 x 100 /80 = 60 %

Solution 2007-2:

(i) Empirical formula of compound:

Element	Atomic mass	Percentage	Relative Number of moles	Simplest mole ratio	Whole number ratio
C	12	4.8	4.8/12 = 0.4	0.4/0.4 = 1	1
Br	80	95.2	95.2/80 = 1.19	1.19/0.4 = 3	3

Empirical formula of the compound is CBr_3.

(ii)Vapour density = 252

Empirical formula mass = 12 + 3 x 80 = 252

Molecular mass = 2 x Vapour density

= 2 x 252 = 504

Now, n= Molecular mass / Empirical Formula Mass

= 504/252 = 2

Molecular formula = n x Empirical Formula

= 2 X (CBr_3)

= C_2Br_6.

(iii)This substance can be prepared by substitution method.

Solution 2008-1:

The gas laws which relates the volume of a gas to the number of molecules of the gas is **avogadro's law**

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Solution 2008-2:

(i) $2C_8H_{18} + 25\ O_2 \rightarrow 16CO_2 + 18H_2O$

From the equation:

2 moles of C_8H_{18} produces = 16 moles of CO_2

1 mole of C_8H_{18} will produce = 16/2 = 8 moles of CO_2

So, 8 moles of CO_2 is produced.

(ii) Now, 1 mole of CO_2 occupies = 22.4 L at STP

So, 8 moles of CO_2 will occupy = 22.4 x 8 = 179.2 L at STP

(iii) Since 2 moles of C_8H_{18} produces = 16 moles of CO_2

= 16 x 44 = 704

So by burning 2 moles of octane 704 g of CO_2 is produced.

(iv) Molecular formula of octane = C_8H_{18}

Its empirical formula will be = C_4H_9.

Solution 2008-3:

(a) (i)

Element	Atomic mass	Percentage	Relative Number of moles	Simplest mole ratio	Whole number ratio
C	12	14.4	14.4/12 = 1.2	1.2/1.2 = 1	1
H	1	1.2	1.2/1 = 1.2	1.2/1.2 = 1	1
Cl	35.5	84.5	84.5/35.5 = 2.4	2.4/1.2 = 2	2

Empirical formula of the compound is $CHCl_2$.

(ii) Now, empirical formula mass = 12 +1+ 35.5 x 2

= 12 +1+71 = 84

n = Relative molecular mass/Empirical Formula mass

= 168 / 84 = 2

So, molecular formula = n x (Empirical Formula)

= 2 x $CHCl_2$

= $C_2H_2Cl_4$.

(iii) Addition reaction with chlorine.

(b) (i) $C + 2H_2SO_4 \rightarrow CO_2 + 2H_2O + 2SO_2$

From the equation:

2 moles of sulphuric acid oxidizes 1 mole of carbon

i.e. 2 x 98 g of sulphuric acid oxidizes 12 g of carbon

So, 49 g of sulphuric acid will oxidize = 12 x 49 /196 = 3 g

3 g of carbon is oxidized by 49 g of sulphuric acid.

(ii) Again from the equation:

2 moles of sulphuric acid liberates 2 moles of sulphur dioxide.

i.e. 196 g of sulphuric acid liberates = 44.8 dm^3 of sulphur dioxide

49 g of sulphuric acid will liberate = 44.8 x 49 /196 = 11.2 dm^3

Hence, 11.2 dm^3 of sulphur dioxide is liberated at the same time.

Solution 2009-2:

(a) Applying Gay-Lussac's law on the equation:

$2C_2H_{2\ (g)} + 5O_{2\ (g)} \rightarrow 4CO_{2\ (g)} + 2H_2O_{\ (g)}$

2 vol.   5 vol.   4 vol.

As 2 volume of acetylene requires = 5 volume of oxygen

So, 200 cm^3 of acetylene will require = 5 x 200 /2 = 500 cm^3

Now further, 2 volume of acetylene produces = 4 volume of carbon dioxide

So, 200 cm^3 of acetylene will produce = 4 x 200 /2 = 400 cm^3

Hence, 500 cm^3 of oxygen and 400 cm^3 of carbon dioxide is formed.

(b) Calculation of empirical formula:

Percentage of hydrogen = 12.5%

Percentage of nitrogen =100 -12.5 = 87.5%

Element	Atomic mass	Percentage	Relative Number of moles	Simplest mole ratio	Whole number ratio
N	14	87.5	87.5/14= 6.25	6.25/6.25 = 1	1
H	1	12.5	12.5/1 = 12.5	12.5/6.25 = 2	2

Empirical formula = NH_2

Given molecular mass = 37
Empirical formula mass = 16
n = Molecular mass / Empirical Formula mass
 = 37 /16 = 2.3 or approximately 2
Molecular formula = n x Empirical formula
 = 2 x NH_2
 = N_2H_4

Solution 2009-3:
The correct statement is that equal volumes of all gases under identical conditions contain the same number of molecules.

Solution 2009-4:

(a) (i) Molecular weight of nitrogen = 28

As 6.023×10^{23} molecules of nitrogen weigh = 28

24×10^{23} molecules will weigh = $28 \times 24 \times 10^{23} / 6.023 \times 10^{23}$
= $28 \times 40 = 1120$ g

(ii) As 6.023×10^{23} molecules of nitrogen occupies = 22.4 dm^3 at STP

24×10^{23} molecules will occupy = $22.4 \times 24 \times 10^{23} / 6.023 \times 10^{23}$

= 896 dm^3

(b) $NaCl + AgNO_3 \rightarrow AgCl + NaNO_3$

As 143 g of AgCl is obtained from = 58 g of NaCl

So, 14.3 g of AgCl will be obtained from = $58 \times 14.3 / 143$ = 5.8 g of NaCl

Weight of commercial NaOH = 30 g

Percentage of NaCl in NaOH = $5.8 \times 100 / 30$ = 19.33%

(c) As at STP 100 cm^3 of gas weighs = 0.5 g
So, at STP 22400 cm^3 of gas will weigh = $0.5 \times 22400 / 100$ = 112 g

Solution 2009-1:
The relative molecular mass of the gas is 10.