Chapter - 4
Gas Laws and Mole Concept

The postulates of kinetic molecular theory

- ✓ Gases are made up of minute particles (atoms/molecules).
- ✓ The attractive force between gaseous molecules is very low.
- ✓ As the molecules are so far apart, the volume of gaseous molecules is negligible in comparison with the total volume of the gas.
- ✓ The volume can be reduced by reducing the distance between the gaseous molecules.
- ✓ Gaseous molecules are in constant motion in all directions. As a result, the molecules collide with one another and with the walls of the container. The force produced due to the collision of molecules with the walls of the container results in gaseous pressure.
- ✓ Collisions of gaseous molecules are elastic in nature. That means, the kinetic energy of the molecules before and after the collision will be same.
- ✓ The average kinetic energy of the gaseous molecules is directly proportional to its temperature.

General Properties of Gases

Volume

- ✓ The space occupied by a substance is taken as its volume.
- ✓ The volume of a gas is the volume of the container in which it is occupied.
- ✓ $cm^3, m^3, cc, litre$ etc are the units of volume

$$1cm^3 = 1cc = 1\ mL$$

$$1000\ cm^3 = 1000\ mL = 1\ L$$

$$1\ m^3 = 1000\ L$$

Question : If a gas which is kept in a cylinder having a volume of 1 liter, is completely transferred to another 5 liter cylinder then what will be the volume of the gas?

Answer : 5 litre

Pressure

- ✓ Force exerted per unit Area is called pressure.
- ✓ Pressure of the gas is the force experienced per unit area on the inner surface of the container as a result of the collision of the gas molecules on the surface.

$$Pressure = \frac{Force}{Area}$$

- ✓ Generally, pressure is expressed in terms of atmospheric pressure (atm).
- ✓ The SI unit of pressure is Pascal (Pa) or N/m^2

$$1\ atm = 1.01325 \times 10^5\ Pa$$

Temperature

- ✓ Temperature is the average kinetic energy of molecules in a substance.
- ✓ The SI unit of temperature is Kelvin(K).

$$t℃ = (t + 273)\ K$$

Gas Laws

- ✓ law which describe the properties of gases with respect to temperature, volume, pressure, of gas are known as gas laws. The three important gas laws are,
  1. Boyle's law
  2. Charle's law
  3. Avagdro's law

1. Boyle's law (Pressure – Volume relationship)

Boyle's law state that, at constant temperature, volume of definite mass of gas is inversely proportional to its pressure.

$$\boldsymbol{V \propto \frac{1}{P}}$$

$$\boldsymbol{PV = Constant}$$

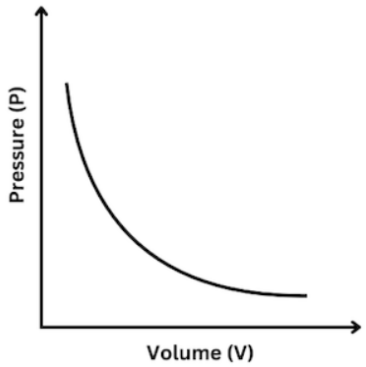
$$\boldsymbol{P_1V_1 = P_2V_2}$$

Where $V = Volume,\ P = Pressure$

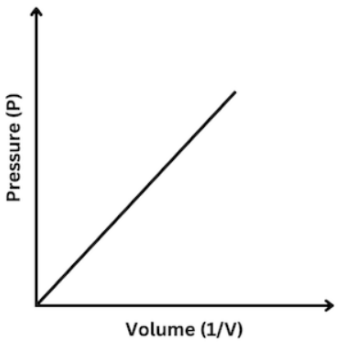
Question : The size of the air bubbles rising from the bottom of an aquarium increases. Why?

Answer : As the bubbles move upward, the pressure on them decreases. This causes increase in volume. So as the bubbles move upward, their size increases.

Pressure – Volume (P – V) graph



P versus 1/V graph



Situation related to Boyle's law:

- ✓ The size of air bubble rising up from the bottom of an aquarium increases as they rise above the sea level.
- ✓ The size of weather balloons goes on increasing as they rise above the sea level.
- ✓ When an inflated balloon is immersed in a water, its size increases

Question : The volume of a definite mass of gas at 1 atm pressure is 1200 L. How much pressure is to be applied to change its volume to 30 L? (Temperature constant)

Answer :

$P_1 = 1\ atm,\ V_1 = 1200\ L,\ P_2 = \_\_\_,\ V_2 = 30\ L$

$P_1V_1 = P_2V_2$

$$P_2 = \frac{P_1V_1}{V_2} = \frac{1 \times 1200}{30} = 4\ atm$$

Charle's law (Temperature – Volume relationship)

At constant pressure, the volume of a definite mass of a gas is directly proportional to the temperature in Kelvin scale.

$$\boldsymbol{V \propto T}$$

$$\boldsymbol{\frac{V}{T} = Constant}$$

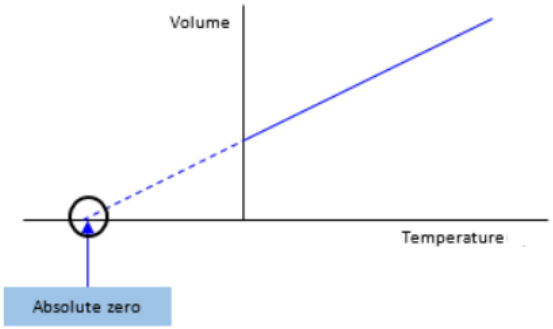
$$\boldsymbol{\frac{V_1}{T_1} = \frac{V_2}{T_2}}$$

Where V=Volume, T=Temperature in kelvin scale

Question : If an inflated ballon is kept in sunlight, it will burst. What may be the reason for this?

Answer : When the ballon placed in sun light, temperature increases. so volume of air inside the ballon increases. Thus ballon expands and finally bursts.

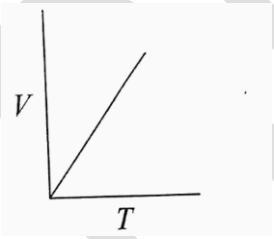
Temperature (in ℃) – Volume (T – V) graph



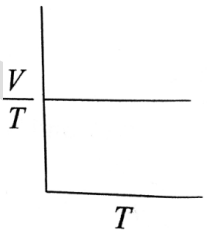
- ✓ At −273.15°C, the volume of a gas becomes zero.
- ✓ the
- ✓ lowest temperature that can be attained by a gas is $-273.15°C$ and named it **Absolute zero**.

$$Absolute\ zero = 0\ K = -273.15\ ℃$$

Temperature ($in\ K$) – Volume (T – V) graph



Temperature ($in\ K$) – Volume (T – V) graph



Situation related to Charles law:

- ✓ When an inflated balloon is kept in sunlight, it will burst.
- ✓ When an inflated balloon kept in cold water, its size decreased.
- ✓ During summer, vehicle tyres are filled with air at lower pressure.
- ✓ The containers of liquid ammonia are submerged in cold water for some time, before opening.

Question : The volume of a definite mass of hydrogen gas at 300 K temperature is 60 mL. At what temperature the volume of this gas becomes 20 mL?

Answer :

$T_1 = 300\ atm,\ V_1 = 60\ mL,\ T_2 = \_\_\_,\ V_2 = 30\ L$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$T_2 = \frac{V_2 \times T_1}{V_1} = \frac{30 \times 300}{60} = 150\ K$$

Avagadro's law (Number of molecules – Volume relationship)

At constant temperature and pressure, the volume of a gas is directly proportional to the number of molecules.

$$\boldsymbol{V \propto N}$$

$$\boldsymbol{\frac{V}{N} = Constant}$$

$$\boldsymbol{\frac{V_1}{N_1} = \frac{V_2}{N_2}}$$

Where V=Volume, N=Number of molecules

Situation related to Avogadro's law:

- ✓ Inflating balloons.
- ✓ Filling air in footballs.

Combined Gas Equation

- ✓ Consider both Boyle's law and Charles's laws together, we can write

$$V \propto \frac{T}{P}$$

$$\frac{PV}{T} = Constant$$

- ✓ If the pressure, volume and temperature of a definite mass of a gas are changed from P_1, V_1 and T_1 to P_2, V_2 and T_2 respectively, then

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

This is combined gas equation.

Question : The volume of a gas at 27℃ and 1 atm pressure is 100 mL. What will be its volume at 273 K temperature and 2 atm pressure?

Answer :

$$P_1 = 1\ atm, V_1 = 100\ mL, T_1 = 273 + 27 = 300\ K$$

$$P_2 = 2\ atm, V_2 = \_\_\_\_, T_2 = 273\ K$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$V_2 = \frac{P_1V_1T_2}{P_2\,T_1} = \frac{1 \times 100 \times 273}{2 \times 300} = 45.5\ mL$$

Ideal Gas Equation

- ✓ Ideal gas equation is formed by combining Boyle's law, charles's law and Avogadro's law into a single expression.
- ✓ The equation $PV = nRT$ is called ideal gas equation, where

P = Pressure, V = Volume

n = number of moles, T = Temperature

$\boldsymbol{R}$ = **Universal gas constant**

- ✓ The gases which **obey ideal gas equation** at all temperature and pressure are known as **ideal gases**.

Mole Concept

- ✓ A mole is the quantity of a substance containing 6.022×10^{23} particles (atoms /molecules/ ions).
- ✓ The number 6.022×10^{23} is known as Avogadro number (N_A).
- ✓ Mole is the SI unit of quantity of matter.

Relative Atomic Mass

- ✓ Relative atomic mass indicates how many times one atom is heavier as compared to another.
- ✓ The atomic mass of an element is expressed as, how many times is the mass of the atom, when compared to the $1/12^{th}$ mass of a carbon – 12 atom, which is considered as a single unit. This mass is known as unified mass.

Atomic Mass of carbon – 12 atom = 12

Gram Atomic Mass

- ✓ The mass of an element in grams equal to its relative atomic mass is called gram atomic mass of the element.

Eg : 1. Atomic mass of Hydrogen = 1

Gram atomic mass of Hydrogen = 1g

Eg : 2. Atomic mass of Oxygen = 16

Gram atomic mass of oxygen = 16 g

- ✓ One gram atomic mass of any element contains one mole (6.022×10^{23}) atoms.

Atom	Relative Atomic Mass	Mass taken in g	Number of atoms
Carbon	12	12 g	6.022×10^{23}
Oxygen	16	32 g	$2 \times 6.022 \times 10^{23}$
Nitrogen	14	70 g	$5 \times 6.022 \times 10^{23}$
Chlorine	35.5	142 g	$4 \times 6.022 \times 10^{23}$

Molecuar Mass

- ✓ The total mass of atoms in a molecule is known as molecular mass.

Element / Compound	Chemcal formula	Molecular mass
Hydrogen	H_2	$2 \times 1 = 2$
Ammonia	NH_3	$14 + 3 \times 1 = 17$
Water	H_2O	$2 \times 1 + 16 = 18$
Chlorine	Cl_2	$2 \times 35.5 = 71$

(Atomic mass : $H = 1, N = 14, O = 16, Cl = 35.5$)

Gram Molecuar Mass (GMM)

- ✓ The mass in grams equal to the molecular mass of the substance is called Gram molecular mass of that substance.
- ✓ One gram molecular mass of a substance contains one mole (6.022×10^{23}) molecules.
- ✓ The mass of **one mole** a substance is called **molar mass** of that substance.

Eg : 1. Molecular Mass of ammonia = 17

Gram molecular mass of ammonia = 17g

Molarmass of ammonia = 17 g

2. Molecular Mass of water = 18

Gram molecular mass of water = 18g

Molar mass of water = 18 g

Substance	Molar mass	Given mass	Number of moles	Number of molecules
NH_3	17 g	85	5	$5 \times 6.022 \times 10^{23}$
CO_2	44 g	220	5	$5 \times 6.022 \times 10^{23}$
H_2O	18 g	180 g	10	$10 \times 6.022 \times 10^{23}$
NO_2	46 g	92 g	2	$2 \times 6.022 \times 10^{23}$
$C_6H_{12}O_6$	180 g	360 g	2	$2 \times 6.022 \times 10^{23}$
$NaCl$	58.5g	234 g	4	$4 \times 6.022 \times 10^{23}$

Volume of gases and mole

- ✓ If temperature and pressure are fixed at **273 K** and **1 atm** respectively, it is known as **STP** (**Standard Temperature and Pressure**).
- ✓ At **STP**, one mole of any gas occupies a volume of **22.4 L**. This is known as molar volume at STP.

Gas	Molar mass	Given mass	Number of moles	Volume at STP(L)
O_2	32 g	32 g	1	$1 \times 22.4 = 22.4$
NH_3	17 g	170 g	10	$10 \times 22.4 = 224$
CO_2	44 g	132 g	3	$3 \times 22.4 = 67.2$
NO_2	46 g	92 g	2	$2 \times 22.4 = 44.8$

Important Formulas

n denotes number of moles

$$n = \frac{given\ mass}{molar\ mass}$$

$$n = \frac{given\ Volume\ at\ STP\ in\ L}{22.4}$$

$$n = \frac{given\ number\ of\ molecules}{6.022 \times 10^{23}}$$

$$mass = n \times molar\ mass$$

$$volume\ at\ STP = n \times 22.4\ L$$

$$number\ of\ molecules = n \times 6.022 \times 10^{23}$$

$$number\ of\ atoms = atomicity \times n \times 6.022 \times 10^{23}$$

Question : 224 L O_2 (oxygen) gas is taken at STP.

a. How many moles of oxygen are there in it?

b. How many molecules are there in it?

c. Calculate the mass of this oxygen sample. (Hint: atomic mass O = 16)

Answer :

Given volume at STP $= 224$ L

a. Number of moles $= \frac{224}{22.4} = 10$

b. Number of molecules $= 10 \times 6.022 \times 10^{23}$

c. Molar mass of $O_2 = 2 \times 16 = 32$ g

Mass $= 10 \times 32 = 320$ g

Question : Find the samples with equal volumes from the ones given below at STP.

a. 64 g O_2 b. 44 g CO_2

c. $2 \times 6.022 \times 10^{23}$ NH_3 molecules

Answer :

a. Molar mass of $O_2 = 2 \times 16 = 32$ g

Number of moles $= \frac{64}{32} = 2$

Volume at STP $= 2 \times 22.4 = 44.8$ L

b. Molar mass of $CO_2 = 12 + 2 \times 16 = 44$ g

Number of moles $= \frac{44}{44} = 1$

Volume at STP $= 1 \times 22.4 = 22.4$ L

c. Number of moles $= 2$

Volume at STP $= 2 \times 22.4 = 44.8$ L

(a) and (c) has same volume at STP

Mole concept and chemical equations

- Example 1

$2\ H_2 + O_2 \rightarrow 2\ H_2O$

2 mol $H_2 + 1$ mol $O_2 \rightarrow 2$ mol H_2O

4 g $H_2 + 32$ g $O_2 \rightarrow 36$ g H_2O

- Example 2

$N_2 + 3\ H_2 \rightarrow 2\ NH_3$

1 mol $N_2 + 3$ mol $H_2 \rightarrow 2$ mol NH_3

28 g $N_2 + 6$ g $H_2 \rightarrow 34$ g NH_3

- Example 1

$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$

1 mol $CH_4 + 2$ mol $O_2 \rightarrow 1$ mol $CO_2 + 2$ mol H_2O

$16\text{ g } CH_4 + 64\text{ g } O_2 \rightarrow 44\text{ g } CO_2 + 36\text{ g } H_2O$

Question : Calculate the amount of lime in kg required to neutralise 980 kg of sulphuric acid.

Answer :

$$H_2SO_4 + Ca(OH)_2 \rightarrow CaSO_4 + 2H_2O$$

Molar mass of $H_2SO_4 = 2 \times 1 + 32 + 4 \times 16 = 98$ g

Molar mass of $Ca(OH)_2 = 40 + (16 + 1) \times 2 = 74$ g

Number of moles of 980 kg $H_2SO_4 = \frac{980 \times 1000}{98}$

$$= 10000$$

$$1mol\ H_2SO_4 + 1\ mol\ Ca(OH)_2 \rightarrow 1\ mol\ CaSO_4 + 2\ mol\ H_2O$$

1 mol H_2SO_4 requires 1 mol $Ca(OH)_2$

Hence

10000 mol H_2SO_4 requires 10000 mol $Ca(OH)_2$

Mass of 10000 mol of $Ca(OH)_2 = 10000 \times 74$

$$= 740000\ g = 740\ kg$$

740 kg of lime is required to neutralise 980 kg of sulphuric acid

Let us assess

Convert the units of the given temperatures.

℃	K
0	273
100	373
30	……
……	300
40	……

2. Complete the table. (Atomic Mass - H = 1, C = 12, O = 16, N = 14)

Substance	Molecular mass	Given mass	Number of moles	Volume at STP
H_2	……	10 g	……	112 L
CO_2	……	440 g	……	……
NH_3	……	340 g	……	……

3. A balanced equation of the reaction to produce ammonia is given.

$$N_2 + 3\ H_2 \rightarrow 2\ NH_3$$

a. How many moles of hydrogen is required for 10 moles of nitrogen to react completely?

b. How much ammonia will be produced if 10 moles of nitrogen react completely?

4. 448 L of gas is stored in a cylinder at 0°C and 1 atm pressure.

a. How many moles of molecules does this gas contain?

b. What is the number of molecules in this sample?

5. 400 L of gas is stored in a cylinder at 27 °C and constant pressure.

a. What will be the temperature if the volume of this gas is reduced to 200 L at the same pressure?

b. Which gas law is relevant to this context?

c. The boiling point of a substance is 3°C. Above what temperature in Kelvin does this substance obey the gas laws?

6. a. What is the number of Cl_2 molecules in 710 g chlorine gas?

b. What is the total number of atoms in this sample?

7. How many grams of hydrogen is required to react with 700 g nitrogen in the production of ammonia?

8. Calculate the following.

a. How many moles of $CaCO_3$ are present in its 1 kg?

b. Mass of the same number of NH_3 molecules as contained in 88 g of CO_2.

c. Mass of 22.4 L CO_2 kept at STP.

(Hint: Atomic mass - H = 1, C = 12, O = 16, N = 14, Ca = 40)

9. The volume of a cylinder containing NH_3 at STP is 4480 mL.

a. Find the number of moles of NH_3 in the cylinder.

b. Find the mass of this NH_3 gas.

c. How many molecules of NH_3 are there in this gas cylinder??

10. Consider the chemical reaction

$$2H_2 + O_2 \rightarrow 2H_2O$$

a. How many moles of oxygen (O_2) should react to obtain 10 mole H_2O?

b. Find the mass of Oxygen gas (O_2) required to obtain 10 mole H_2O?

(Atomic mass - H = 1, O = 16)

Answers

1.

℃	K
0	273
100	373
30	303
27	300
40	313

2.

Substance	Molecular mass	Given mass	Number of moles	Volume at STP
H_2	2	10 g	5	112 L
CO_2	44	440 g	10	224 L
NH_3	17	340 g	20	448 L

3. $N_2 + 3\,H_2 \rightarrow 2\,NH_3$

$1\,mol\,N_2 + 3\,mol\,H_2 \rightarrow 2\,mol\,NH_3$

a.

$10\ mol\ N_2 + 30\ mol\ H_2 \rightarrow 20\ mol\ NH_3$

30 moles of hydrogen is required for 10 moles of nitrogen to react completely.

b. $10\ mol\ N_2 + 30\ mol\ H_2 \rightarrow 20\ mol\ NH_3$

20 **moles of ammonia will be produced if 10 moles of nitrogen react completely.**

4. 0°C and 1 atm pressure $= STP$

a. number of moles $= \frac{448}{22.4} = 20$

b. number of molecules $= 20 \times 6.022 \times 10^{23}$

5. a. $T_1 = 27 + 273 = 300\ K$, $V_1 = 400$ L

$T_2 =$ ____ , $V_2 = 200$ L

$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$T_2 = \frac{V_2 \times T_1}{V_1} = \frac{200 \times 300}{400} = 150\ K$

b. Charles law

c. $273 + 3 = 276\ K$

6. a. Molar mass of $Cl_2 = 2 \times 35.5 = 71$ g

number of moles of $Cl_2 = \frac{710}{71} = 10$

number of Cl_2 molecules $= 10 \times 6.022 \times 10^{23}$

b. atomicity $= 2$

number of atoms $= 2 \times 10 \times 6.022 \times 10^{23}$

$= 20 \times 6.022 \times 10^{23}$

7. Molar mass of nitrogen $= 2 \times 14 = 28$ g

Molar mass of hydrogen $= 2$ g

Number of moles of nitrogen $= \frac{70}{28} = 25$

$1\ mol\ N_2 + 3\ mol\ H_2 \rightarrow 2\ mol\ NH_3$

$25\ mol\ N_2 + 75\ mol\ H_2 \rightarrow 50\ mol\ NH_3$

75 mol of H_2 is required to react with 25 mol N_2

Mass of hydrogen $= 75 \times 2 = 150$ g

150 g of H_2 is required to react with 710 g of N_2

8. $1\ kg = 1000$ g

a. Molar mass of $CaCO_3 = 40 + 12 + 3 \times 16 = 100$ g

Number of moles $= \frac{1000}{100} = 10$

b. Molar mass of $CO_2 = 44$ g

Molar mass of $NH_3 = 17$

Number of moles of $CO_2 = \frac{88}{44} = 2$

Number of moles of $NH_3 = 2$

Mass of $NH_3 = 2 \times 17 = 34$ g

c. Number of moles of $CO_2 = 1$

Mass of $CO_2 = 1 \times 44 = 44$ g

9. Volume of $NH_3 = 4480\ mL = 4.48$ L

a. Number of moles of $NH_3 = \frac{4.48}{22.4} = 0.2$

b. Mass of $NH_3 = 0.2 \times 17 = 3.4$ g

c. Number of molecules $= 0.2 \times 6.022 \times 10^{23}$

10.

$2\ mol\ H_2 + 1\ mol\ O_2 \rightarrow 2\ mol\ H_2O$

a.

$10\ mol\ H_2 + 5\ mol\ O_2 \rightarrow 10\ mol\ H_2O$

5 moles of oxygen should react to obtain 10 mole H_2O

b. Number of moles of $O_2 = 5$

Mass of $O_2 = 5 \times 32 = 160$ g

Question Bank with Answers

1. Find the relation and fill in the blanks. The relationship between the number of molecules of a gas and its volume at constant temperature and pressure is given.

No. of molecules	Volume (L)
x	20
……	5

a. $2x$ b. $\frac{x}{4}$ c. $\frac{x}{2}$ d. x

2. The combustion equation for methane is given.

$CH_4 + 2\ O_2 \rightarrow CO_2 + 2\ H_2O$

(Atomic mass : C – 12, H – 1, O – 16)

a. Find the mass of oxygen required to react with 160 g of methane.

b. Find the volume of CO_2 at STP produced by the complete combustion of 80 g of methane.

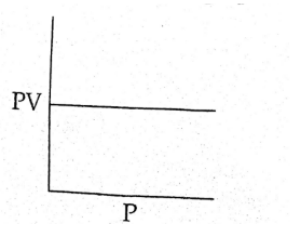
3. The volume of a sample of NH_3 gas at STP is 89.6 L.

(Atomic mass : N – 14, H – 1)

a. Calculate the mass of NH_3 sample.

b. How many molecules are present in the sample?

4. Analyse the given graph drawn at constant temperature and answer the questions.



a. State the gas law associated with this graph?

b. The volume of a given mass of gas at a pressure 2 atm is 450 L. What will be the new volume if the pressure of this gas is increased 3 times? (Temperature is constant)

5. The relationship between the volume and pressure of a fixed mass of gas at constant temperature is given randomly in the table. Match the following.

Pressure (P)	Volume (V)
(X) 8 atm	(p) 2 L
(Y) 2 atm	(q) 6 L
(Z) 4 atm	(r) 3 L
	(s) 12 L

Choose the **correct** answer from the options given below.

	(X)	(Y)	(Z)
(a)	(p)	(q)	(s)
(b)	(p)	(r)	(q)
(c)	(s)	(p)	(r)
(d)	(r)	(s)	(q)

6. At 1 atm pressure and 273 K temperature, 320 g of SO_2 has a volume of 112 L.

a. What is the volume of 10 g of H_2 under the same pressure and temperature ?

b. State the gas law related to this situation.

(Hint : molar mass $SO_2 = 64, \quad H_2 = 2$)

7. Analyse the chemical equation given below and answer the questions

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

a. How many moles of SO_3 will be formed when 2 mol sulphur dioxide completely reacts with 1 mol oxygen ?

b. How many molecules of oxygen are to be reacted with sulphur dioxide to obtain 20 mol of sulphur trioxide ?

c. What is the volume of sulphur dioxide gas required to obtain 224 L of SO_3 gas at STP ?

(Hint : molar mass $SO_2 = 64, \quad SO_3 = 80$)

8. Quicklime is produced by heating limestone strongly.

$CaCO_3 + Heat \rightarrow CaO + CO_2$

a. How many grams of limestone are to be heated to obtain 224 g of quicklime without remaining any unreacted reactant ?

b. What is the mass of carbon dioxide liberated when this amount of quicklime if formed?

(Hint : Molar mass $CaCO_3$ = 100, CaO = 56)

9. Match the following

A	B
a) 17 g NH_3	i) 6.022×10^{23} atoms
b) 88 g CO_2 at STP	ii) 22.4 L
c) 14 g N	iii) 44.8 L
	iv) 6.022×10^{23} molecules

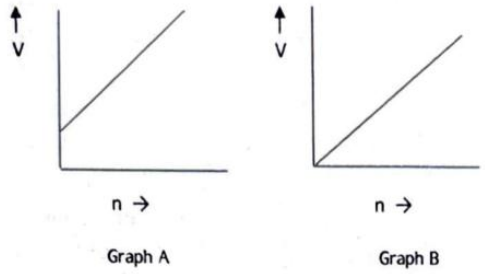
Choose the correct answer from the options given below.

	(a)	(b)	(c)
A.	(ii)	(i)	(iii)
B.	(i)	(iv)	(iii)
C.	(iv)	(iii)	(i)
D.	(ii)	(iii)	(iv)

10. a. When a fixed mass of a gas kept at a pressure of 2 atm is heated to a temperature of 77°C, its volume became 10 L. What will be its volume when it is cooled to a temperature of 7°C at the same pressure?

b. State the law related to this situation.

11. Two graphs regarding the volume of a gas kept at constant pressure and temperature are given.



a. Which of these graphs illustrate Avogadro's Law?

b. State Avogadro law.

c. If the volume of 20 mole of a gas kept at a fixed temperature and pressure is 640 L. What is the volume of 5 moles of gas kept at the same temperature?

12. The atomic mass of carbon is 12 and that of oxygen is 16

a. Find the molar mass of CO_2.

b. What is the volume of 880 g of CO_2 gas kept at STP?

c. How many molecules are there in 440 g of CO_2?

d. How many grams of carbon should be burnt to get 88 g of CO_2?

13. N_2 reacts with H_2 to form NH_3.

a. Write the balanced chemical equation of this reaction.

b. What is the mass of nitrogen required to get 68 g of NH_3 ?

(atomic mass N = 14, H = 1)

c. How,many moles of N_2 will be remained if 60 g of H_2 reacts completely with 560 g of N_2 ?

Answers

1. $V_1 = 20, \quad N_1 = x, \quad V_2 = 5, \quad N_2 = \_\_\_\_$

$$\frac{V_1}{N_1} = \frac{V_2}{N_2}$$

$$N_2 = \frac{V_2 N_1}{V_1} = \frac{5\,x}{20} = \frac{x}{4}$$

Option (b) $x/4$ is the right answer.

2. a. Methane $= CH_4$

Molar mass of methane $= 12 + 4 \times 1 = 16$ g

Molar mass of $CO_2 = 12 + 2 \times 16 = 44$ g

Molar mass of $H_2O = 2 \times 1 + 16 = 18$ g

$$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$$

$$16\,g\,CH_4 + 64g\;\;O_2 \rightarrow 44g\;\;CO_2 + 36g\;\;H_2O$$

$\times 10$ $\times 10$ $\times 10$ $\times 10$

$$160\,g\,CH_4 + 640\,g\;\;O_2 \rightarrow 440g\;\;CO_2 + 360g\;\;H_2O$$

640 g of oxygen is required to react with 160 g of methane

b. $CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$

$$16\,g\,CH_4 + 64g\;\;O_2 \rightarrow 44g\;\;CO_2 + 36g\;\;H_2O$$

$\times 5$ $\times 5$ $\times 5$ $\times 5$

$$80\,g\,CH_4 + 320\,g\;\;O_2 \rightarrow 220\,g\;\;CO_2 + 180\,g\;\;H_2O$$

Number of moles of $220\,g$ of $CO_2 = \frac{220}{44} = 5$

Volume of $220\,g$ of $CO_2 = 5 \times 22.4 = 112$ L

3. a. Number of moles of $NH_3 = \frac{89.6}{22.4} = 4$

Molar mass of $NH_3 = 17$ g

Mass of $NH_3 = 4 \times 17 = 68$ g

b. Number of molecules $= 4 \times 6.022 \times 10^{23}$

4. a. Boyle's law (Pressure – Volume relationship)

b. $P_1 = 2$ atm, $\qquad V_1 = 450$ L

$P_2 = 3 \times 2 = 6$ atm, $\qquad V_2 = \_\_\_\_$

$$P_1V_1 = P_2V_2$$

$$V_2 = \frac{P_1V_1}{P_2} = \frac{2 \times 450}{6} = 150\,L$$

5. $8 \times 3 = 2 \times 12 = 4 \times 6 = 24\ (constant)$

Option (d) is the right answe.

6. a. 273 K temperature and 1 atm pressure $= STP$

Number of moles of 10 g of $H_2 = \frac{10}{2} = 5$

Volume of 10 g of $H_2 = 5 \times 22.4 = 112$ L

b. Avogadro's law

7.

$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

a. 2 moles of SO_3 will be formed.

$2\ mol\ SO_2(g) + 1\ mol\ O_2(g) \rightleftharpoons 2mol\ SO_3(g)$

b.

$20\ mol\ SO_2(g) + 10\ mol\ O_2(g) \rightleftharpoons 20\ mol\ SO_3(g)$

Number of moles o oxygen required $= 10$

Number of oxygen molecules $= 10 \times 6.022 \times 10^{23}$

c. Number of moles in 224 L of $SO_3 = \frac{224}{22.4} = 10$

$$10\ mol\ SO_2(g) + 5\ mol\ O_2(g) \rightleftharpoons 10\ mol\ SO_3(g)$$

10 moles of sulphur dioxide (SO_2) gas is required to botain 10 moles of SO_3 gas.

Volume of 10 moles of SO_2 gas at STP $= 10 \times 22.4 = 224\ L$

8. Molar mass of $CO_2 = 100 - 56 = 44\ g$

$$100\ g\ CaCO_3 \rightarrow 56\ g\ CaO + 44\ g\ CO_2$$

$\times 4$ $\times 4$ $\times 4$

$$400\ g\ CaCO_3 \rightarrow 224\ g\ CaO + 176\ g\ CO_2$$

a. Mass of limestone $(CaCO_3)$ required $= 400$ g

b. Mass of carbon dioxide liberated $= 176$ g

9. 17 g $NH_3 = 1$ mol $NH_3 = 6.022 \times 10^{23}$molecules

88 g CO_2 at STP $= 2$ mol of $CO_2 = 44.8$ L

14 g N $= 1$ mol N $= 6.022 \times 10^{23}$ N atoms

Option (C) is the right answer.

10. a. $T_1 = 273 + 77 = 350\ K$, $V_1 = 10$ L

$T_2 = 273 + 7 = 280\ K$, $V_2 = \_\_\_$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$V_2 = \frac{V_1 T_2}{T_1} = \frac{10 \times 280}{350} = 8\ L$$

b. Charles's law

11. a. Graph B

b. At constant temperature and pressure, the volume of a gas is directly proportional to the number of molecules.

c. $N_1 = 20$ moles, $V_1 = 640$ mL

$N_2 = 5$ moles, $V_2 = \_\_\_$

$$\frac{V_1}{N_1} = \frac{V_2}{N_2}$$

$$V_2 = \frac{V_1 N_2}{N_1} = \frac{640 \times 5}{20} = 160\ mL$$

12. a. Molar mass of $CO_2 = 12 + 216 = 44$ g

b. Number of moles in 880 g of $CO_2 = \frac{880}{44} = 20$

Volume at STP $= 20 \times 22.4 = 448$ L

c. Number of moles in 440 g of $CO_2 = \frac{440}{44} = 10$

Number of CO_2 molecules $= 10 \times 6.022 \times 10^{23}$

d. $C + O_2 \rightarrow CO_2$

12 g C + 32 g O_2 → 44 g CO_2

× 2 × 2 × 2

24 g C + 64 g O_2 → 88 g CO_2

Mass of carbon required = 24 g

13. a. $N_2 + 3\ H_2 \rightarrow 2\ NH_3$

b.

28 g N_2 + 6 g H_2 → 34 gNH_3

× 2 × 2 × 2

56 g N_2 + 12 g H_2 → 68 g NH_3

Mass of nitrogen required= 56 g

c. 28 g N_2 + 6 g H_2 → 34 gNH_3

× 10 × 10 × 10

280 g N_2 + 60 g H_2 → 340 g NH_3

Mass of N_2 required = 280 g

Mass of N_2 remaned $= 560 - 280 = 280$ g

Number of moles of N_2 remained $= \frac{280}{28} = 10$