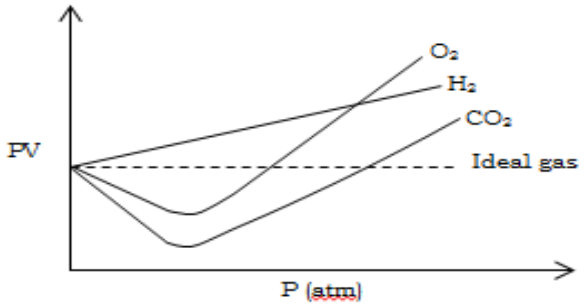
ADVANCED LEVEL PHYSICAL CHEMISTRY PROBLEMS

CHAPTER 1: MATTER

1. 1.86g of a compound X contains carbon, hydrogen, and nitrogen only. On combustion, X liberated 5.28g of carbon dioxide gas and 224cm^3 of nitrogen at s.t.p.
   (a) Determine the empirical formula of X
   (b) When vaporized, 0.2g of X occupied 81cm^3 at 184.1°C and 101325Pa. determine the molecular formula of X

2. A certain volume of a gaseous hydride of silicon of formula Si_nH_{2n+2} diffused through a narrow hole in 17.08s. The same volume of carbon dioxide diffused through the hole under identical conditions in 20.0s.
   (a) Determine the relative formula mass of the hydride
   (b) Determine the molecular formula of the hydride. ($Si = 28, O = 16$)

3. (a) State what is meant by the term ideal gas
   (b) Explain how liquefaction of a gas can be affected by
   (i) Pressure
   (ii) Temperature
   (c) The curves below show deviations of some gases from the ideal behaviour



   (i) State why hydrogen shows a small deviation from the ideal behaviour compared to other gases
   (ii) Compare the deviations of oxygen and carbon dioxide from the ideal behaviour
   (d) A gas Q contains 30.43% nitrogen and the rest being oxygen. 0.23g of Q occupied 154.11cm^3 at 150°C and 840mmHg. Determine the
   (i) Empirical formula of Q
   (ii) Molecular formula of Q
   (*1 mole of a gas occupies 24dm^3 at 25°C and 760mmHg*)

4. When 0.45g of compound Q made if carbon, oxygen and hydrogen atoms only was burnt, 0.44g of carbon dioxide and 0.09g of water was formed. The relative molecular mass of Q is 90. Determine the
   (i) Empirical formula of Q
   (ii) Molecular formula of Q

5. A sample of concentrated ammonia solution was placed at one end 'A' of a 0.8m glass tube held horizontally. At the other end 'B' was placed a sample of concentrated hydrochloric acid and both ends of the tube sealed. When the tube was left for some time, a whit ring was formed inside the tube.
   (a) Write equation for the formation of the white ring
   (b) Calculate the distance between B and the white ring

6. (a) A compound W, on combustion gave 0.629g of carbon dioxide and 0.257g of water. Determine the empirical formula of W
   (b) When 0.10g W was vaporized, it occupied a volume of 53.3cm^3 at s.t.p. Determine the
   (i) Molecular mass of W
   (ii) Molecular formula of W
   (c) 0.1g of Y occupied 22.1cm^3 when vaporized at 20°C and 766mmHg. Determine the molecular mass of Y

7. A compound Q contains 62.1% carbon and 10.3% hydrogen and the rest being oxygen. The vapour density of A is 2.59×10^{-3}gcm^{-3} at s.t.p.
   (a) Determine the
   (i) Empirical formula of Q
   (ii) Molecular formula of Q
   (b) Write down the structural formulae of all the possible isomers of Q

8. Compound R contains cobalt 24.8%, chlorine 29.8% and water 45.4%. Determine the
   (a) Empirical formula of R
   (b) Molecular formula of R
   ($Co = 58.9, Cl = 35.5, RFM\ of\ R\ is\ 237.9$)

9. A compound P contains 52.2% carbon and 13.0% hydrogen and the rest being oxygen.
   (a) Determine the empirical formula of P
   (b) When vaporized, 0.1g of P occupied 78.8cm^3 at 157 °C and 740mmHg. Determine the
   (i) Formula mass of P
   (ii) Molecular formula of P
   (c) Write the structural formulae of all the possible isomers of P

10. A chloride of beryllium Z, contains 11.25% beryllium and 88.75% chlorine. Determine the
   (a) Empirical formula of Z
   (b) Molecular formula of Z

11. (a) State Graham's law of diffusion.
   (b) A certain volume of oxygen diffused through a porous membrane in 120s. Under the same conditions, the same volume of a gas X diffused in 112s. calculate the formula mass of X

12. When 4.90g of an organic compound X, containing carbon and hydrogen only was burnt in oxygen, 15.78g of carbon dioxide and 5.38g of water were formed. Calculate the empirical formula of X.

13. When 8.8g of a hydrocarbon Z was burnt in excess air, 14.4g of water and 13.44dm^3 of carbon dioxide were produced at s.t.p. determine the
    (a) Empirical formula of Z
    (b) Molecular formula of Z
    (c) Write the structural formula for all the possible isomers of Z
    (Vapour density of Z is 22)

14. (a) An organic compound W contains carbon, hydrogen and oxygen only. On combustion. 0.463g of W gave 1.1g of carbon dioxide and 0.563g of water. Determine the empirical formula of W
    (b) When vaporized, 0.1g of W occupied 54.5cm^3 at 208°C and 98.3kPa. determine the molecular formula of W

15. A compound X, vapour density 58, contains carbon 62.07% and hydrogen 10.34% and rest being oxygen. Determine the
    (i) Empirical formula of X
    (ii) Molecular formula of X

16. (a) A gaseous hydrocarbon Y contains 44.4% carbon, 51.9% nitrogen and the rest being hydrogen. Determine the empirical formula of Y.
    (b) 50ml of Y diffused through a porous plug in 25s. under similar conditions, the same volume of hydrogen gas diffused in 6.8s. determine the molecular mass and hence formula of Y

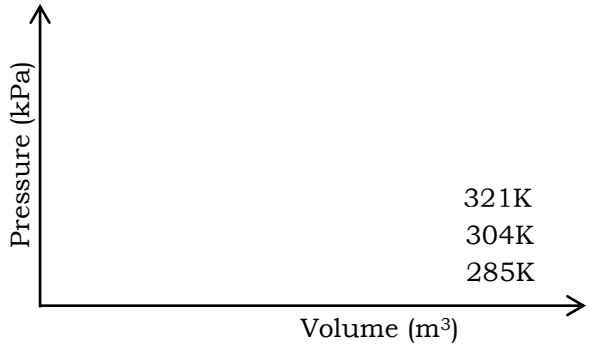
17. When 142cm^3 of a hydrocarbon Q of molecular mass 58 was exploded with excess oxygen and cooled to room temperature, the residual gas was 649cm^3. After addition of concentrated potassium hydroxide, the volume decreased to 126cm^3. Determine the molecular formula of Q

18. When 0.155g of an organic compound T was burnt in in excess oxygen, 0.220g of carbon dioxide and 0.153g of water were formed.
    (a) Determine the empirical formula of T
    (b) When vaporized, 0.225g of T occupied 119.11cm^3 at 127°C and 760mmHg. Determine the
    (i) Molecular mass of T
    (ii) Molecular formula of T
    (Molar gas volume at s.t.p is 22.4dm^3)

19. A gaseous hydrocarbon P contains 92.3% carbon.
    (a) Calculate the empirical formula of P
    (b) 0.13g of P occupies 112cm^3 at s.t.p. Calculate
    (i) The formula mass of P
    (ii) Molecular formula of P

20. (a) An organic compound H contains carbon 80%, hydrogen 6.7% and the rest being oxygen. Calculate the empirical formula of H
    (b) 0.5g of H when vaporized at 150°C and 760mmHg occupied 144.6cm^3. determine the molecular formula of H

21. (a) The diagram below shows the isothermals of a gas.
    (i) What is the critical temperature of the gas
    (ii) Which isothermal almost represents an ideal gas
    (iii) What does the region ABC represent
    (b) State two conditions for liquefying a gas



22. 1.18g of a compound P on vaporization occupied 300cm^3 at s.t.p.
    (a) Calculate the formula mass of P
    (b) The empirical formula of P is C_2H_4O. Determine the molecular formula of P

23. A certain organic liquid K contains 54.5% carbon, 36.4% oxygen and 9.1% hydrogen. If the formula mass of K is 44, determine the
    (a) Empirical formula of K
    (b) Molecular formula of K

24. An organic compound R contains 40% carbon, 6.77% hydrogen and the rest being oxygen. If the molecular mass of the compound is 180. Calculate the
    (a) Empirical formula of R
    (b) Molecular formula of R

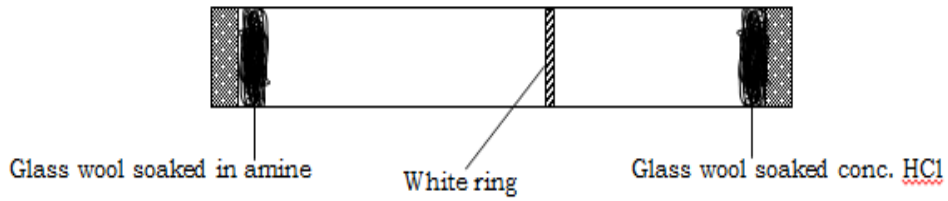
25. 1.5g of a compound, A, containing carbon, hydrogen and oxygen gave 2.2g of carbon dioxide and 1.8g of water on complete combustion in excess pure oxygen. Calculate the empirical formula of A.

26. 2.5g of an organic, Z, which contains carbon, hydrogen and oxygen only, gave on combustion 2.0g of carbon dioxide and 1.3g of water. Calculate the empirical formula of Z.

27. The combustion of a hydrocarbon X gave 8.8g of carbon dioxide and 4.5g of water, if the molecular mass of X is 58. Determine the
    (a) Empirical formula of X
    (b) Molecular formula of X

28. Under the same conditions of temperature and pressure, nitrogen diffuses 1.42 times as fast as a gaseous hydrocarbon Q, which contains 85.7% carbon. Calculate the
    (a) Molecular mass of Q
    (b) Molecular formula of Q

29. Two pieces of glass wool, one soaked in an amine ($C_nH_{2n+1}NH_2$) and the other in conc. Hydrochloric acid were placed at the opposite ends of a 1.0m glass tube as shown below.



    After some time, a white ring was seen 0.52m from the end at which the amine was place. Calculate the
    (a) Molecular mass of the amine.
    (b) Molecular formula of the amine

30. (a) Oxygen diffuse through a small hole in 0.935 times faster than gas X. calculate the formula mass of X
    (b) Gas X contains 57% oxygen and the rest being carbon
    (i) Determine the molecular formula of X
    (ii) Write an equation for the reaction between X and copper(II) oxide.

31. 0.60g of hydrogen and 9.0g of nitrogen and 10.2g of oxygen were put in 2dm^3 container at 25°C. Calculate the total pressure in the container. ($R = 8.314 Jmol^{-1}K^{-1}$)

32. A vessel contains 10.0g of oxygen at 25°C and a pressure of 4.8atm. Calculate the
    (a) __ Volume of the vessel ($R = 0.082 latm\ mol^{-1}K^{-1}$)
    (b) The final pressure when 0.8mol of hydrogen was added to into the vessel at 25°C without changing the volume.
    (c) The pressure of the gas in the vessel, if the mixture was exploded an allowed to cool to 25°C.

33. A compound was analysed and found to have 66.7% carbon, 11.1% hydrogen and the rest being oxygen. Determine the
    (a) Empirical formula of X
    (b) Molecular formula of X

34. A compound Z contains carbon, hydrogen and oxygen. Element analysis shows that 54.5% is carbon and 9.09% is hydrogen.
    (a) Calculate the empirical formula of X
    (b) 0.524g of Z occupies 148cm^3 at 20°C and 740mmHg. Determine the molecular formula of Z.

35. (a) Complete combustion of 7.05g of organic compound Z containing carbon hydrogen and oxygen gave 17.8g carbon dioxide and 9.27g of water. Calculate the empirical formula of Y
    (b) When vaporized, at 760mmHg and 400K, 0.225g of Y occupied 100cm^3. Calculate the molecular formula of Y.

36. 0.236g of an organic compound Y on combustion gave 0.528g of carbon dioxide and 0.324g of water. If 0.295g of Y at s.t.p gave 56cm^3 of nitrogen gas and the molecular weight of Y is 59, determine the molecular formula of Y

37. 15cm^3 of a gaseous hydrocarbon P were exploded with 105cm^3 of oxygen. After cooling, the residual gas occupied 75cm^3. On addition of potassium hydroxide solution, there was a contraction in volume to 30cm^3. Determine the molecular formula of P

38. 50.0cm^3 of gas W effused through a tiny aperture in 146s. the same volume of carbon dioxide under the same conditions effuses in 11.5s. calculate the molecular mass of W

39. It takes 2½ minutes for 25.0cm^3 of hydrogen to effuse through a pin hole. Find the time taken for the same volume of oxygen gas under the same conditions to effuse through the same pinhole

40. A gaseous alkane diffused through a porous partition at a rate of 2.56cms^{-1}. Helium diffuses through the same partition under the same conditions at a rate of 8.49cm^{3}s^{-1}. Determine the molecular formula of the alkane.

41. 20cm^3 of a gaseous hydrocarbon X were exploded with 120cm^3 of oxygen. After explosion and cooling to room temperature, the volume of gas remaining was 90cm^3 and this volume decreased to 50cm^3 on treatment with aqueous potassium hydroxide. Determine the molecular formula of X

42. 10cm^3 of a gaseous hydrocarbon P was mixed with 33cm^3 of oxygen. The mixture was exploded and after cooling to room temperature, the resultant volume of the gas was 28cm^3. On addition of concentrated potassium hydroxide, the volume decreased to 8cm^3. Determine the formula of P

43. A mixture of 10cm^3 of a gaseous hydrocarbon and 100cm^3 of excess oxygen was exploded. After explosion and cooling to room temperature, the volume of the residual gas was 75cm^3, which decreased to 35cm^3 on treatment with potassium hydroxide. Calculate the molecular formula of Q

44. When 10cm^3 of a hydrocarbon, C_xH_y, were exploded with excess oxygen and cooled to room temperature, there was a contraction in volume of 30cm^3. When the gaseous product was bubbled through potassium hydroxide solution, there was a further contraction in volume of 30cm^3. Determine the formula of the hydrocarbon

45. 10cm^3 of a hydrocarbon, C_aH_b was exploded with excess oxygen. When the mixture of the gaseous product was cooled to room temperature, 50cm^3 of steam condensed. When

the gaseous product was treated with potassium hydroxide solution, there was a contraction of 40cm^3. Determine the formula of the hydrocarbon.

46. 10cm^3 of a hydrocarbon X were exploded with excess oxygen and the mixture cooled to room temperature. On treatment with conc. potassium hydroxide solution, the volume decreased by 40cm^3. If the RFM of the hydrocarbon is 58, determine the molecular formula of X

47. When 10cm^3 of a hydrocarbon, Q, were exploded with excess oxygen and cooled to room temperature, the volume of the residual gases was 150cm^3. On treatment with potassium hydroxide solution, the volume decreased to 110cm^3. If the RFM of Q is 54, determine the formula of Q

48. 20cm^3 of a gaseous hydrocarbon M was exploded with excess oxygen and cooled to room temperature. When bubbled through conc. potassium hydroxide solution, a contraction in volume of 60cm^3 occurred. If the RMM of M is 42, determine the formula of M

49. (a) State Graham's law of diffusion
    (b) The table below shows the times (t) taken for gases of different molecular mass (M_r) to diffuse through a narrow opening under similar conditions.

t(s)	25.00	34.23	41.67	47.62
M_r	16	30	44	58

Plot a graph of rate of diffusion, $(\frac{1}{t})$ against $\sqrt{\frac{1}{M_r}}$

    (c) Using your graph in (b) above, find the molecular mass of a gas
    (i) Whose rate of diffusion is 0.02ss^{-1}
    (ii) That takes 38.42 seconds to diffuse

50. (a) For each of the information provided below, determine the molecular mass of an organic compound Z containing carbon, oxygen and hydrogen
    (i) Oxygen diffuses 1.199 times faster than Z
    (ii) 0.1g of Z when vaporized at 80°C and 890mmHg, it occupied a volume of 53.77cm^3
    (iii) 25cm^3 of Z effuses through a small pore in 12.2 seconds. Under similar conditions, the same volume of oxygen takes 10.5 seconds
    (b) 10cm^3 of the vapour of Z was mixed with 130cm^3 of oxygen, and the mixture exploded. On cooling to room temperature, the volume of the residual mixture was 125cm^3 which dropped to 105cm^3 on passing the mixture through conc. potassium hydroxide solution. Determine the molecular formula of Z.

51. (a) For each of the information provide, determine the molecular mas of K which contains only carbon, hydrogen and hydrogen.
    (i) When 0.05g of K were vaporized, it occupied a volume of 39.5cm^3 at 27°C and 740mmHg
    (ii) 17cm^3 of nitrogen diffuses through a porous plug in 8.2 seconds while under the same conditions, K takes 8.8 seconds

(iii) K diffuses 0.935 times faster than nitrogen

(b) $20cm^3$ of K were exploded with $100cm^3$ of oxygen and the mixture cooled to room temperature. The resultant gaseous volume was $102cm^3$. This decreased by $20cm^3$ after absorption with potassium hydroxide. Determine the molecular formula of K

52. (a) For each of the information provided, determine the molecular mass of M which contains only carbon, hydrogen and oxygen

(i) When 0.20g of M was vaporized, it occupied a volume of $107.54cm^3$ at 115°C and 750mmHg.

(ii) A certain volume of carbon dioxide diffuses through a small opening in 13.8 seconds. The same volume of M diffuses through the same opening in 18.8 seconds under the same conditions.

(iii) Carbon dioxide diffuses 1.363 times faster than M

(b) $15cm^3$ of the organic compound M were exploded with $155cm^3$ of oxygen. And the mixture cooled to room temperature. The resultant gaseous volume was $140cm^3$. On passing the mixture through potassium hydroxide solution, the volume of the mixture reduced to $95cm^3$. Determine the formula of the organic compound.

53. (a) For each of the information provided, determine the molecular mass of compound A, that contains carbon, oxygen and hydrogen.

(i) $10.4cm^3$ of hydrogen diffuses through a small plug in 23.2 seconds. Under the same conditions, the same volume of A takes 89.89 seconds.

(ii) When 0.05g of A was vaporized, it occupied $37.33cm^3$ at s.t.p.

(iii) A diffuses 3.875 times slower than hydrogen under the same conditions.

(b) $10cm^3$ of A were mixed with $120cm^3$ of excess oxygen, exploded and cooled to room temperature. The gaseous residual volume was $125cm^3$. When bubbled through potassium hydroxide solution, the volume decreased to $10cm^3$. Determine the formula of A

54. (a) An organic compound R containing carbon, hydrogen and nitrogen only. 38.71% of the compound is carbon. On combustion, 0.51g of R gave $184.26cm^3$ of nitrogen gas at s.t.p. Determine the empirical formula of R.

(b) When vaporized, 0.48g of R occupied a volume of $346.84cm^3$ at s.t.p. determine the molecular formula of R

55. (a) An organic compound T contains carbon, hydrogen and nitrogen only. When 0.42g of the compound was burnt in excess oxygen, 0.596g of carbon dioxide was produced. When 0.51g of T were burnt, $184.26cm^3$ of nitrogen gas were formed at s.t.p. determine the empirical formula of T.

(b) When vaporized, 0.48g of T occupied a volume of $4422.63cm^3$ at 80°C and 770mmHg. Determine the molecular formula of T

56. (a) When 0.45g of an organic compound, L, containing carbon, hydrogen and nitrogen only was burnt completely, $199.5cm^3$ of nitrogen were collected at 62°C and 760mmHg. When 0.25g of the organic compound was burnt in excess oxygen, 0.355g of carbon dioxide gas was produced. Determine the empirical formula of L

(b) 13.5cm^3 of hydrogen effuse through a narrow pore in 7.5 seconds. Under the same conditions, the same volume of L takes 66.4 seconds. Determine the molecular formula of L

57. (a) An amine P contains 53.33% carbon. When 0.12g of P was burnt in excess oxygen, 29.87cm^3 of nitrogen were produced at s.t.p. determine the empirical formula of P
(b) When vaporized, 0.1g of P occupied a volume of 67.93cm^3 at 102°C and 765mmHg. Determine the molecular formula of P

58. (a) When 0.41g of an amine Z was burnt in excess oxygen, 0.802g of carbon dioxide was formed, 102.04cm^3 of nitrogen at s.t.p. determine the empirical formula of Z
(b) When 0.1g of Z was vaporized, it occupied a volume of 49.78cm^3 at s.t.p. determine the formula of Z

59. (a) 0.215g of an amine K was burnt in excess oxygen, 0.42 g of carbon dioxide was produced. When 0.205g of K was completely burnt in oxygen, 62.72cm^3 of nitrogen were collected. At 67°C and 770mmHg. Determine the empirical formula of K
(b) Methane diffuses 1.6764 times faster the K under the same conditions and volume. Determine the formula of K

60. (a) When 0.40g of an amine X was burnt in excess oxygen, 1.135g of carbon dioxide and 48.17cm^3 of nitrogen were produced at s.t.p. determine the empirical formula of X
(b) When vaporized, 0.53g of X occupied a volume of 190.29 cm^3 at 150°C and 760mmHg. Determine the molecular formula of X.

61. (a) An amine W contains 77.42% carbon. When 0.22g of W was burnt in excess oxygen, 26.50cm^3 of nitrogen gas were collected at s.t.p. determine the empirical formula of W
(b) When vaporized, 0.22g of W occupied 52.99cm^3 at s.t.p. determine the molecular formula of W

62. (a) When 0.11g of an organic compound Y containing carbon, hydrogen and nitrogen was burnt in excess oxygen. 0.312g of carbon dioxide was produced 0.25g of the compound on combustion yielded 43.04cm^3 of nitrogen at 107°C and 740mmHg. Determine the empirical formula of Y
(b) 15cm^3 of carbon dioxide diffused through a porous plug in 42.8 seconds. The same volume of Y under the same conditions took 62.2 seconds to diffuse through the same hole. Determine the molecular formula of Y

63. (a) When 0.325g of an amine Z was burnt in excess oxygen, 469.68cm^3 of carbon dioxide and 39.14cm^3 of nitrogen were produced at s.t.p. determine the empirical formula of Z
(b) Carbon dioxide diffuses 1.4538 times faster than the vapour of Z under the same conditions. Determine the molecular formula of Z

64. (a) When 0.225g of an amine N was burnt in excess oxygen, 364.43cm^3 of carbon dioxide and 30.37cm^3 of nitrogen at 37°C and 770mmHg. Determine the empirical formula of N.

(b) The vapour of N under the same conditions diffuses 0.6879 times faster than carbon dioxide. Determine the molecular formula of N

65. (a) State

(i) Boyle's law

(ii) Graham's law of diffusion

(b) Explain the following

(i) Critical point

(ii) Compressibility factor

(b) (i) Show how the compressibility factor for a real gas varies with pressure at two different temperatures.

(ii) Explain the differences in behaviour of the gas at the two temperatures

(d) The time taken for equal volumes of two gases to diffuse under identical conditions was determined as below. Use it to determine the RFM of A

Gas	Oxygen	A
Time(s)	28.30	33.20

66. (a) When 0.368g of a compound Q, containing carbon and hydrogen was vaporized, it occupied 161.4cm^3 at 37°C and 760mmHg. Determine the RFM of Q

(b) When 142 cm^3 of Q were exploded with excess oxygen and cooled to room temperature, the volume of the residual gas was 694cm^3. After adding conc. potassium hydroxide, the volume decreased to 126cm^3. Determine the molecular formula of Q.

67. (a) When 0.1g of aluminium chloride was vaporised at 350°C and 1 atmosphere pressure, 19.2 cm^3 of vapour was formed.

(i). Calculate the relative molecular mass of aluminium chloride

(ii). Write the molecular formula of aluminium chloride in vapour state at 350°C.

68. (a) What is meant by the term critical temperature

(b) Explain why it is possible to liquefy a gas below its critical temperature.

(c) Use a P-V graph to describe how liquefaction occurs for a gas below its critical temperature

(d) Give two ways of liquefying a gas

(e) Explain why real gases deviate from the ideal behaviour

(c) (i) Name any two types of intermolecular forces

(ii) Give any two evidences for the existence of intermolecular forces.

69. (a) Distinguish between a real gas and an ideal gas

(b) The pressure and volume changes for a 0.02g of a vaporized substance Q at 25°C were as shown below.

Pressure (Nm^{-2})	2.2	5.4	6.3	8.5	10.10
Volume (m^3)	0.500	0.200	0.172	0.128	0.106

(i) Plot a graph of pressure against $\frac{1}{volume}$

(ii) Use your graph to determine the molecular mass of Q ($R = 8.314 JK^{-1}mol^{-1}$)

(c) On analysis, it was found that Q contains carbon, hydrogen and oxygen only in the proportions of 52.17% carbon and 13.04% hydrogen.

(i) Determine the molecular formula of Q

(ii) Write the structural formulae of all the possible isomers and their IUPAC names.

69. A hydrocarbon Y contains 85.7% carbon and has a density of $2.5 gl^{-1}$ at s.t.p.

(a) Calculate the empirical formula of Y

(b) Determine the molecular formula of Y

(c) Write the structural formulae of all the possible open chain isomers of Y

70. A compound M, relative molecular mass 93, burns with a sooty flame, and contains 77.42% carbon, 7.53% hydrogen and the rest being nitrogen. Determine the molecular formula of M

71. An alkane R, diffuses through a porous partition in 2 minutes. Under similar conditions, the same volume of oxygen diffuses in 1.75 minutes

(a). (i). Calculate the formula mass of R

(ii). Determine the molecular formula of R

(b). Write equations to show how R can be synthesized from propanone

72. $10cm^3$ of a hydrocarbon P was exploded in $90cm^3$ of oxygen. On cooling to room temperature, the residual gases occupied $70cm^3$. When the residual gases were passed through potassium hydroxide solution, the volume reduces to $40cm^3$. Determine the molecular formula of P