

Sample maths part-2
Environmental chemistry
Air composition-based calculation

Air composition (apprx) = 80% N₂ and 20% O₂ (mol basis only)

Average molecular weight of Air = $(0.8 \times 28 + 0.2 \times 32) = 29 \text{ g/mol}$ (apprx)

Math Sample:

2kg pure charcoal (¹²C) is to be burnt completely with air. Find the air, CO₂ and N₂ amount in kg's.

Solution:

$\text{C} + \text{O}_2 = \text{CO}_2$ (you must use a balanced equation)

Therefore from the mole ratio of the reaction we write,

$\text{C} : \text{O}_2 : \text{CO}_2 = 1:1:1$

and from air composition we got

$\text{O}_2 : \text{N}_2 : \text{Air} = 1:4:5$

Given, 2 kg C = $2000 \text{ g} / (12 \text{ g/mol}) = 166.67 \text{ mole C}$

Therefore, similar mole of O₂ required. So equivalent Air supposed to be 5 times than the mole amount of O₂ and released N₂ will be 4 times than the required O₂.

Therefore, Air amount = $5 \times 166.67 \text{ moles}$

$= 833.34 \text{ moles}$

$= (833.33 \times 29 / 1000) \text{ kg}$

$= 24.17 \text{ kg air}$

Similarly N₂ released amount will be $= (166.67 \times 4 \times 28 / 1000) \text{ kg} = 18.67 \text{ kg}$

Find CO₂ amount by yourself! (Isn't it 7.34 kg?)

Mole Fraction = mole of particular species / Σ total moles of the mixture.

1. A gas mixture contains 20% O₂, 30% CO₂, 25% H₂ and Rest N₂ (mole basis). Find the average molecular weight of this gas mixture.

Handwritten solution for the average molecular weight of a gas mixture:

①

O₂ = 20%
 CO₂ = 30%
 ✓ H₂ = 25%

75%

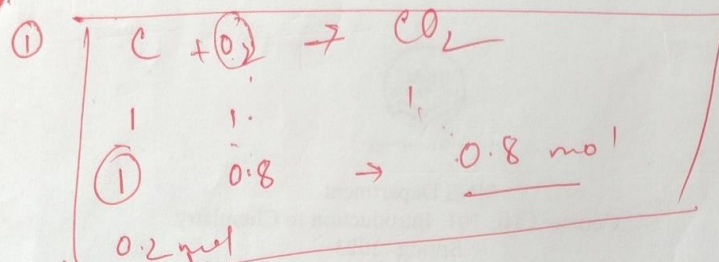
✓ N₂ = 25%

A. M. W. = $0.2 \times 32 + 0.3 \times 44 + 0.25 \times 2$
 $+ 0.25 \times 28 = 27.1$

✓

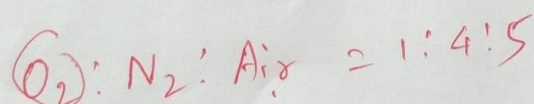
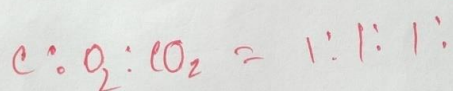
2. 2 kg charcoal (¹²C) was allowed to burn in the presence of 16 kg air to produce CO₂. If we consider no CO was produced and carbon has no reaction with N₂ then find the following-
 1. What is the limiting reactant here? Oxygen
 2. How much of the excess reactant will be left in the reactor?
C=675.9g
 3. How much N₂ gas will be found in the outlet stream? 12.36 kg
 4. How much O₂ will be found in the outlet stream?
 5. If the entire N₂ gas is separated from the outlet stream and allowed to react with supplied H₂ gas to produce ammonia gas by Haber-Bosch principle, then determine how much H₂ gas will be required and how much ammonia gas will be produced in (kg). H₂ = 2.65 kg and NH₃ = 15.006 kg

math



requiring amount

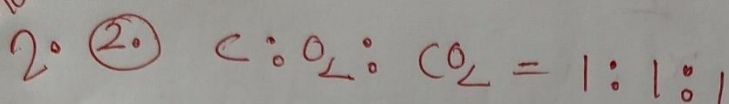
$$\text{C} = 24 \text{ kg} = 20000 \text{ g} = 20000 \div 12 \text{ (a.w.)} \\ = 166.67 \text{ mol}$$



$$\begin{array}{l} \text{Air} = 16 \times 1000 \\ = 16000 \text{ g} \div 29 \\ = 551.72 \text{ mol} \end{array}$$

$$\frac{\text{O}_2}{\text{Air}} = \frac{1}{5} \quad \therefore \text{O}_2 = \frac{551.72}{5} \\ = 110.35 \text{ mol}$$

math



$$110.35 \text{ mol O}_2 \approx 110.35 \text{ mol C}$$

$$\text{Excess} \rightarrow 166.67 - 110.35 = 56.32 \times 12 \text{ g} \\ = 675.84 \text{ g}$$

Math

2. ③ $O_2 : N_2 = 1:4$. [$O_2 : N_2 : Air = 1:4:5$]

$$\therefore \frac{N_2}{O_2} = \frac{4}{1}$$

$$\therefore N_2 = 4 \times O_2$$

$$= 4 \times 110.35 \text{ mol}$$

$$= 441.4 \text{ mol} \times 28 \text{ (g)}$$

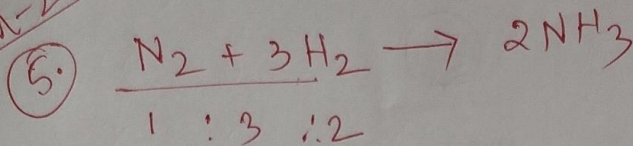
$$= 12359.2 \text{ g} \div 1000$$

$$= 12.359 \text{ kg}$$

Math

2. ④ As O_2 is limiting reactant so, No CO_2 is found in the outlet stream.

Math-2



$$\Rightarrow \frac{H_2}{N_2} = \frac{3}{1}$$

$$H_2 = 3 \times 441.4 \text{ mol} = 1324.2 \text{ mol} \times 2$$

$$= 2648.4 \text{ g} = 2.648 \text{ kg}$$

$$\frac{NH_3}{N_2} = \frac{2}{1}$$

$$\Rightarrow NH_3 = 2 \times 441.4 = 882.8 \times 17 \text{ g}$$

$$= 15007.6 \text{ g} = 15.007 \text{ kg} \text{ Ans.}$$

3. Consider the last part of question number 4. The produced ammonia gas was entirely dissolved in 1000 dm^3 of water. Find the pH of the solution.

ans: pH = 13.95

Math
③

$$\frac{882.8 \text{ M} \times 1000 \text{ L}}{1000 \text{ L}} \rightarrow 882.8$$
$$\frac{882.8 \times 1}{1000} = 0.8828 \text{ mol L}^{-1} = 0.9 \text{ M}$$

for. NH_3

$$[\text{OH}^-] = 0.9$$
$$\text{pOH} = -\log(0.9) = 0.0457$$
$$\therefore \text{pH} = 14 - \text{pOH} = 14 - 0.046 = 13.954$$

4. A certain mole of charcoal (^{12}C) has to be completely converted to CO_2 after reaction with the oxygen of air. If double amount of air (mole basis) was supplied in the reactor then find the average molecular weight of the outlet gas mixture stream. Note that, carbon has no reaction with nitrogen in this case.

Ans: 30 g/mol

④ $\text{C} + \text{O}_2 \rightarrow \text{CO}_2$
 $x \quad x \quad x$

Normal condition

$x \text{ O}_2$
 $4x \text{ N}_2$

Air $5x$

$x \text{ CO}_2$

[For, $\text{O}_2 : \text{N}_2 : \text{Air} = 1 : 4 : 5$]

$2x \text{ O}_2$
 $8x \text{ N}_2$

Air $10x$

$x \text{ CO}_2$
 $x \text{ O}_2$
 $8x \text{ N}_2$

[$\text{O}_2 : \text{N}_2 : \text{Air} = 1 : 4 : 5$]
 when double $= 2 : 8 : 10$

So, $\frac{x}{10x} \text{ CO}_2 + \frac{x}{10x} \text{ O}_2 + \frac{8x}{10x} \text{ N}_2$

$= \frac{x}{10x} 44 + \frac{x}{10x} 32 + \frac{8x}{10x} 28$
 $= \frac{44x}{10x} + \frac{32x}{10x} + \frac{224x}{10x}$
 $= \frac{44x + 32x + 224x}{10x} = \frac{300x}{10x} = 30 \text{ g/mol}$
 Ans: -