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

Air composition (apprx) = 80% N_2 and 20% O_2 (mol basis only)

Average molecular weight of Air = (0.8 x 28 + 0.2 x 32) = 29 g/mol (apprx)

Math Sample:

2kg pure charcoal (^{12}C) is to be burnt completely with air. Find the air, CO_2 and N_2 amount in kg's.

Solution:

$C + O_2 = CO_2$ (you must use a balanced equation)

Therefore from the mole ratio of the reaction we write,

$C : O_2 : CO_2 = 1:1:1$

and from air composition we got

$O_2 : N_2 : Air = 1:4:5$

Given, 2 kg C = 2000 g/ (12 g/mol) = 166.67 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 x 166.67 moles

= 833.34 moles

= (833.33x29/1000) kg

= 24.17 kg air

Similarly N2 released amount will be = (166.67 x 4 x 28/1000) kg = 18.67 kg

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

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

1. A gas mixture contains 20% O_2, 30% CO_2, 25% H_2 and Rest N_2 (mole basis). Find the average molecular weight of this gas mixture.

Math

P

1

$O_2 = 20\%$

$CO_2 = 30\%$

$H_2 = 25\%$

75%

$N_2 = 25\%$

29 %: $N_2 : O_2$

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

2. 2 kg charcoal (^{12}C) was allowed to burn in the presence of 16 kg air to produce CO_2. 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 N_2 gas will be found in the outlet stream?12.36 kg
   4. How much O_2 will be found in the outlet stream?
   5. If the entire N_2 gas is separated from the outlet stream and allowed to react with supplied H_2 gas to produce ammonia gas by Haber-Bosch principle, then determine how much H_2 gas will be required and how much ammonia gas will be produced in (kg). H_2 = 2.65 kg and NH_3= 15.006 kg

math

2 ① $C + O_2 \rightarrow CO_2$

1 : 1 : 1

1 : 0.8 → 0.8 mol

0.2 mol

required amount

$C = 2 \text{ kg} = 2000\text{g} = 2000 \div 12 \text{ (a.w)}$

$= 166.67 \text{ mol}$

$C : O_2 : CO_2 = 1 : 1 : 1$

$\text{Air} = 16 \times 1000$

$= 16000\text{g} \div 29$

$= 551.72 \text{ mol}$

$O_2 : N_2 : \text{Air} = 1 : 4 : 5$

$\frac{O_2}{\text{Air}} = \frac{1}{5}$; $\therefore O_2 = \frac{551.72}{5}$

$= 110.35 \text{ mol}$

math

2. ② $C : O_2 : CO_2 = 1 : 1 : 1$

$110.35 \text{ mol } O_2 : 110.35 \text{ mol } C$

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

$= 675.84\text{g}$

math

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

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

$\therefore N_2 = 4 \times O_2$

$= 4 \times 110.35$ mol.

$= 441.4$ mol $\times 28$ (g)

$= 12359.2$ g $\div 1000$

$= 12.359$ kg.

math

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

Math-2

(5.) $N_2 + 3H_2 \longrightarrow 2NH_3$

1 : 3 : 2

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

$H_2 = 3 \times 441.4$ mol $= 1324.2$ mol $\times 2$

$= 2684.4$ g $= 2.684$ kg

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

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

$= 15007.6$ g $= \underline{15.007 \text{ kg}}$ 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

$$\frac{x\ 882.8\ M}{x\ 1000L}$$

$1000L \longrightarrow 882.8$

$1L \longrightarrow x = \frac{882.8 \times 1}{1000}$

$0.9\ M \qquad = 0.8828\ mol\ L^{-1}$

$= 0.9\ M.$

for.

NH_3

$[OH^-] = 0.9.$

$pOH = -\log(0.9) = 0.0457.$

$\therefore pH = 14 - pOH = 14 - 0.046$

$= 13.954.$

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) $C + O_2 \rightarrow CO_2$

$x \quad x \quad x$.

Normal condition: $x\ O_2$, $4x.\ N_2$ → Air $5x$ → $x\ CO_2$

[For, $O_2 : N_2 :$ Air $= 1 : 4 : 5$

$2x\ O_2$, $8x\ N_2$ → Air $10x$ → $x\ CO_2$, $x\ O_2$, $8x\ N_2$

[$O_2 : N_2 :$ Air $= 1 : 4 : 5$
When double $= 2 : 8 : 10$].

So, $\frac{x}{10x} CO_2 + \frac{x}{10x} O_2 + \frac{8x}{10x} N_2$

$= \frac{x}{10x} 44 + \frac{x}{10x} 32 + \frac{8x}{10x} 28$.

$= \frac{44x}{10x} + \frac{32x}{10x} + \frac{224x}{10x}$

$= \frac{44x + 32x + 224x}{10x}$

$= \frac{300\cancel{x}}{10\cancel{x}}$

$= 30.\ g/mol$.

Ans:-