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Unit 3 Activity 5

1\. **Given**

$n = 2.5 \text{ mol C}$

$N_A = \frac{6.022\times10^{23} \text{ atoms C}}{\text{mol C}}$

Required

$N_C = ?$

Solution

$N = n \times N_A$

$N_C = 2.5 \text{ mol C} \times \frac{6.022\times10^{23} \text{ atoms C}}{\text{mol C}}$

$= 1.5055 \times 10^{24}$

$= 1.5 \times 10^{24} \text{ atoms C}$

$\therefore$ There are 1.5×10^{24} atoms of carbon

2\. **Given**

$N_A = \frac{6.022\times10^{23} \text{ atoms rust}}{\text{mol rust}}$

$N_{Rust} = 1.88\times10^{22} \text{ atoms rust}$

Required

$n = ?$

Solution

$N = n \times N_A$

$n = \frac{N}{N_A}$

$= \frac{1.88\times10^{22} \text{ atoms rust}}{\frac{6.022\times10^{23} \text{ atoms rust}}{\text{mol rust}}}$

$= 0.0312188642$

$= 0.0312 \text{ mol rust}$

$\therefore$ There are 0.0312 moles of rust

3\. **Given**

$m = 5 g$, $M_{Fe} = 55.845 \text{ g/mol}$, $M_O = 15.999 \text{ g/mol}$, $N_A = \frac{6.022\times10^{23} \text{ formula units}}{\text{mol}}$

$M_{Fe_2O_3} = M_{Fe_2} + M_{O_3} = 2(55.845) + 3(15.999) \text{ g/mol} = 159.687 \text{ g/mol}$

Required

$n = ?$

$N = ?$

Solution

$n = \frac{m}{M_{Fe_2O_3}} = \frac{5 g}{159.687 \text{ g/mol}} = 0.0313112526\text{4} = 0.031 \text{ mol}$

$N = n \times N_A$

$= 0.031 \text{ mol} \times \frac{6.022\times10^{23} fu}{\text{mol}}$

$= 1.86682\times10^{22} = 1.9\times10^{22} fu\ Fe_2O_3$

$\therefore$ There are 1.9×10^{22} formula units Fe_2O_3

4. Given

Atomic mass of Si = 28.086 u
Atomic mass of O = 15.999 u
Atomic mass of H = 1.008 u

Required

Molecular Mass of $Si(OH)_4$

Solution

Molecular mass = Atomic mass Si + 4(Atomic mass O) + 4(Atomic mass H)

$= 28.086\,u + 4(15.999\,u) + 4(1.008\,u)$

$= 96.114\,u$

$\doteq 96.11\,u$

∴ The molecular mass of $Si(OH)_4$ is 96.11 u

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5. Given n # of C = 9

M of carbon = 12.011 g/mol, M of hydrogen = 1.008 g/mol, M of Oxygen = 15.999 g/mol

M of aspirin = $M_{C_9} + M_{H_8} + M_{O_4} = 9(12.011) + 8(1.008) + 4(15.999)$ g/mol

$= 180.159$ g/mol

Required

% C = ?

Solution

$$\%\,element = \frac{n \times M_{element}}{M_{compound}} \times 100\%$$

$$\%\,C = \frac{9 \times 12.011\,g/mol}{180.159\,g/mol} \times 100\%$$

$= 60.00199823$

$= 60.00\%$ C

∴ Carbon mass composition is 60.00% in $C_9H_8O_4$ (aspirin)

6. Assume 100g sample

Given

$m_C = 12.1\,g\ C$

$m_O = 16.2\,g\ O$

$m_{Cl} = 71.7\,g\ Cl$

$M_C = 12.011\ g/mol$

$M_O = 15.999\ g/mol$

$M_{Cl} = 35.453\ g/mol$

Required

Empirical Formula COCl=?

$n_C = ?$

$n_O = ?$

$n_{Cl} = ?$

Solution

$$n_C = \frac{m_C}{M_C} = \frac{12.1\,g}{12.011\,g/mol} = 1.007409874\ mol \doteq 1.01\ mol\ C$$

$$n_O = \frac{m_O}{M_O} = \frac{16.2\,g}{15.999\,g/mol} = 1.012563285\ mol \doteq 1.01\ mol\ O$$

$$n_{Cl} = \frac{m_{Cl}}{M_{Cl}} = \frac{71.7\,g}{35.453\,g/mol} = 2.022395848\ mol \doteq 2.02\ mol\ Cl$$

C	O	Cl
1.01	1.01	2.02
1	1	2

Divide by lowest mole, 1.01

∴ The empirical formula is $COCl_2$ for phosgene

7. Assume a 100g sample

Given

$m_C = 40.9g$ C

$m_H = 4.6g$ H

$m_O = 54.5g$ O

$M_C = 12.01$ g/mol

$M_H = 1.01$ g/mol

$M_O = 16$ g/mol

$M_{compound} = 176.14$ g/mol

Required

Molecular formula CHO = ? Empirical Molar Mass?

$n_C = ?$

$n_H = ?$

$n_O = ?$

Solution

$$n_C = \frac{m_C}{M_C} = \frac{40.9g}{12.01 g/mol} = 3.40549542 \doteq 3.41 \text{ mol C}$$

$$n_H = \frac{m_H}{M_H} = \frac{4.6g}{1.01 g/mol} = 4.554455446 \doteq 4.55 \text{ mol H}$$

$$n_O = \frac{m_O}{M_H} = \frac{54.5g}{16 g/mol} = 3.40625 \doteq 3.41 \text{ mol O}$$

C	H	O
3.41	4.55	3.41
1	1.33	1
3	3.99	3
3	4.00	3

divide by lowest mole 3.41

$\therefore$ cannot have fractional atoms

$\because 0.33 = \frac{1}{3}$

mutiply by 3

Empirical Formula is $C_3H_4O_3$

~~###~~ 7. cont.

Empirial Molar Mass

$\hookrightarrow M_{C_3H_4O_3} = M_{C_3} + M_{H_4} + M_{O_4}$

$= 3(12.01) + 4(1.01) + 3(16)$

$= 88.07$ g/mol

Ratio $M_{compound}$ to $M_{C_3H_4O_3}$

$\hookrightarrow \frac{\text{Molecular Molar Mass}}{\text{Empirical molar mass}} = \frac{176.14}{88.07} = 2$

Ratio = 2:1

$\hookrightarrow 2 \times C_3H_4O_3$ = Molecular Formula

Molecular Formula = $C_6H_8O_6$

∴ the Molecular Formula for vitamin C is $C_6H_8O_6$

8. Water = H_2O

↳ Law of definite proportions

↳ ~~Dalton~~ Atoms chemically combined in simple definite numbers.

↳ A given compound always has the same proportion of it's constituent elements by mass.

Water → Hydrogen + Oxygen

36g → 4g + 32g

Mass Ratio = $\frac{32}{4} \frac{O}{H} = \frac{8}{1} \rightarrow \underset{O:H}{8:1}$

↳ Contains all element in a fixed constant ratio.

9.

Given

$m_{C_3H_8} = 50\,g$, $M_{CO_2} = M_C + M_O = 12.011 + 2(15.999) = 44.009\,g/mol$

$M_{C_3H_8} = M_{C_3} + M_{H_8} = 3(12.011) + 8(1.008)\,g/mol = 44.097\,g/mol$

Required

$n_{C_3H_8} = ?$

$m_{CO_2} = ?$

Solution

$n = \frac{m}{M}$

$= \frac{50\,g}{44.097\,g/mol}$

$= 1.133863982$

$\doteq 1.13\,mol\ C_3H_8$

Let x represent the amount of CO_2 gas produced

$C_3H_8 : CO_2$

coefficients → $1 : 3$

$n \rightarrow 1.13 : x$

$\frac{1}{1.13} = \frac{3}{x}$

$x = 3(1.13)$

$= 3.39\,mol\ CO_2$

$m_{CO_2} = n_{CO_2} \times M_{CO_2}$

$= 1.13\,mol\ CO_2 \times \frac{44.009\,g}{mol}$

$= 49.73\,g \doteq 49.7\,g$

∴ There 49.73 g of CO_2 ~~produced~~ mass.

10.

Given

$m_{NH_3} = 100.0 g$

$m_{O_2} = 250 g$

$M_{NH_3} = M_N + M_{H_3}$ ~~= 3(1.008)~~

$= 14.007 + 3(1.008)$ g/mol

$= 17.031$ g/mol

$M_{O_2} = 2(15.999) = 31.998$ g/mol

$M_{NO} = M_N + M_O = 14.007 + 15.999$ g/mol $= 30.006$ g/mol

Actual Yield = 175 g NO

Required

$n_{NH_3} = ?$

$n_{O_2} = ?$

$m_{NO} = ?$

Solution

$n = m/M$

$n_{NH_3} = \frac{m_{NH_3}}{M_{NH_3}}$

$= \frac{100 g}{17.031 g/mol}$

$= 5.871645822$

$\doteq 5.87$ mol NH_3

$n_{O_2} = \frac{m_{O_2}}{M_{O_2}}$

$= \frac{250 g}{31.998 g/mol}$

$= 7.812988312$

$= 7.81$ mol O_2

mol to coefficient ratio of $NH_3 = 5.87/4 = 1.4675$

mol to coefficient ratio of $O_2 = 7.81/5 = 1.562$

∴ Lowest ratio is of NH_3 and thus it is the limiting reagent

10. cont.d

Let x represent the theoretical amount of NO produced.

	NH_3	:	NO
coefficients	4	:	4
n	5.87	:	x

$$\rightarrow \frac{4}{5.87} = \frac{4}{x}$$

$$4x = 4(5.87)$$

$$x = \frac{\cancel{4}(5.87)}{\cancel{4}}$$

$$x = 5.87 \text{ mol NO}$$

$$m_{NO} = n_{NO} \times M_{NO}$$

$$= 5.87\text{ mol} \times 30.006 \text{ g/mol}$$

$$= 176.13522 \text{ g NO}$$

$$\doteq 176.14 \text{ g NO}$$

∴ The theoretical yield of NO is 176.14g

$$\text{Percentage yield} = \frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100\%$$

$$\%\text{ yield} = \frac{175\text{ g}}{176.14\text{ g}}$$

$$= 99.3527875 6\%$$

$$\therefore \%\text{ yield} \doteq 99.4\%$$

∴ The percentage yield of NO for this reaction is 99.4%