STOICHIOMETRY : LIMITING REACTANT

METHODS OF DETERMINING LIMITING REACTANT : 4 METHODS

METHOD 4 : Example

One step in the industrial production of nitric acid is the reaction of ammonia with molecular oxygen to form nitrogen oxide.

$$4NH_3(g) + 5O_2(g) \longrightarrow 4NO(g) + 6H_2O(g)$$

In a study of this reaction, a chemist mixed 132 g of ammonia with 273 g oxygen and allowed them to react to completion. What is the limiting reactant.

Solution

We need the molar masses :

$M_r(NH_3) = 17.03\ g\,mol^{-1}$

$M_r(O_2) = 32.00\ g\,mol^{-1}$

$M_r(NO) = 30.01\ g\,mol^{-1}$

$M_r(H_2O) = 18.02\ g\,mol^{-1}$

Limiting Reactant

Convert masses to moles. $n\,(moles) = \dfrac{m\,(grams)}{M_r\,(molar\ mass,\ g\,mol^{-1})}$

$$n_{NH_3} = \frac{m_{NH_3}}{M_r(NH_3)} = \frac{132\,g}{17.03\,g\,mol^{-1}} = 7.75\ mols.$$

$$n_{O_2} = \frac{m_{O_2}}{M_r(O_2)} = \frac{273\,g}{32.00\,g\,mol^{-1}} = 8.53\ mols.$$

METHOD 4

- By comparing moles of the reactant required for the reaction with the available moles of the same reactant.
- If the required reactant is more than the available reactant, then this reactant will the limiting reagent. If the required reactant is less than the available reactant, then this reactant is in excess.

$4NH_3 \equiv 5O_2$ (from the balanced equation)
(7.75 mols) (8.53 mols)

Consider 2 possibilities :

a) If O_2 is the limiting reactant.

$$\frac{n_{NH_3}}{n_{O_2}} = \frac{4}{5} \rightarrow n_{NH_3} = \frac{4}{5} \times n_{O_2}$$
$$= \left(\frac{4}{5} \times 8.53\right) \text{ mols}$$

we have excess of $(7.75 - 6.82) = 0.93$ mols of NH_3.

$n_{NH_3} = 6.82$ mols (required)
(but n_{NH_3} available = 7.75 mols)

Since the available NH_3 is more than enough, thus our assumption that O_2 is the limiting reactant is correct.

b) If NH_3 = limiting reactant

$$n_{O_2} = \frac{5}{4} \times n_{NH_3}$$
$$= \left(\frac{5}{4} \times 7.75\right) = 9.69 \text{ mols (required)}$$

(but n_{O_2} available is not enough – ie 8.53 mols only

So NH_3 cannot be the limiting reactant.

Reaction :	$4NH_3$	+ $5O_2$	⟶ $4NO$	+ $6H_2O$
Starting amount (mol)	7.75	8.53	0	0
change in amount (mol)	−6.82	−8.53	+6.82	+10.24
Final amount (mol)	0.93	0	6.82	10.24

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