* For 1 mole of gas, both have same vol. of 24dm^3 but mass of N_2 (28g) > H_2 (2g)
∴ Mass of molar vol. of N_2 is greater than that of H_2.

	N_2	H_2
% vol.	25	75
% mass	82	18

diff % by mass, % by vol.

No: AMMONIA - Chapter 10

Q. N_2 & H_2 mixed in ratio 1:3

$N_2 + 3H_2 \rightleftharpoons 2NH_3$, 1 mole of N_2 reacts with 3 moles of H_2 to form NH_3. Since molar vol. of gases are constant at r.t.p., the volume ratio corresponds to mole ratio.

* $N_2:H_2$ 3:1 corresponds to reacting mole ratio of nitrogen to hydrogen in $N_2 + 3H_2 \rightleftharpoons 2NH_3$

Manufacturing Ammonia

Ammonia (weak alkali; pH: 8–10; UI: blue) — manufactured by → Haber Process

(#1) describe manufacture of NH_3 from N_2, H_2.

1. N_2, H_2 (g) mixed in 1:3
2. Gas mixture compressed to 250 atm
3. Compressed gases flow over iron catalyst + heated to 450°C — only ~15% conversion of N_2, H_2
4. NH_3, N_2, H_2 mixture cooled
5. NH_3 (g) condenses ↳ Stored under pressure in tanks (* NH_3 b.p. ↑ than N_2, H_2 b.p.)
6. Unreacted nitrogen & H_2 transferred back to converter to be recycled. (unreacted gases are not wasted)
   - ↑ overall yield of NH_3
   - $ to obtained N_2, H_2 is ↑, not economically viable to discard unreacted
   - save $
   - save energy → raw mat. processed

Haber Process → through a reversible reaction (can go forward & backward at the same time)

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

⇒ forward: $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$ (reactants → product)
backward: $2NH_3(g) \rightarrow N_2(g) + 3H_2(g)$ (decomp.)

Nitrogen — obtained from fractional distillation of liquid air → 70% N_2.

Hydrogen — obtained from cracking (breaking down) of crude oil fractions

↑ temp, ↓ % yield of NH_3 (see ROR. ↑ temp = NH_3 decomposes faster; ↑ temp, more NH_3 particles have energy ≥ to E_a)

reduce decomp. of NH_3: ↓ temp, ↑ yield of NH_3

Lower temp → slower rxn ↳ compromise 450°C
(↓ temp, KE of NH_3 particles ↓, particles move slower, ↓ freq. of effective collisions, decomp. ↓)

higher pressure, lower temp. (↑ pressure too low, rxn may take place too slowly)

max. yield at min. cost → **Optimal conditions**
- pressure of 250 atm
- temp of 450°C
- finely-divided iron catalyst

(#2) interpret data relating to conditions used involving reversible reactions

↑ pressure, ↑ yield of NH_3, faster rxn (↑ pressure, reactant particles closer together, ↑ no. of particles per unit vol., ↑ freq. of effective collisions) → maintain high pressure → incur large $ (operate, maintain)
- expensive equipment
- large amt. of electricity
- + dangerous

↳ compromise 250 atm

see ROR! catalyst speeds up rxn — rxn is slow despite relatively high temp & high pressure
- lowers E_a of rxn by providing an alt. pathway with lower E_a for rxn.
- ↓ more reactant particles have enough/greater energy ≥ E_a required for successful rxn
- ↑ freq. of effective collisions

see ROR. ↑ total exposed SA per unit mass ↓ ↑ freq. of effective collisions of catalyst + reactants (may not happen.)

NPK fertilisers — can make NPK as long as compounds contain these elements
- Nitrogen
- Phosphorus
- Potassium

Soil Fertilisers 101

Ch 8.1: acid + base → salt + water

$Ca(OH)_2$: (slaked lime) calcium hydroxide (strong base) → neutralise excess acidity in soil

$(NH_4)_2SO_4$: ammonium sulfate → provide plants w nitrogen — essential for plant growth.

Qn. With ionic equation, why cannot add ammonium compounds to soils w calcium hydroxide (slaked lime)?

see (heated) ammonium salt + alkali → NH_3 (g) + salt (aq) + H_2O (l) ↓ NH_3!

$$NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(g) + H_2O(l)$$

↳ Ammonium compounds will react with $Ca(OH)_2$ to produce NH_3 gas which will escape into atmosphere. Loss in NH_3(g) will reduce nitrogen content in soil which is essential for plant growth.

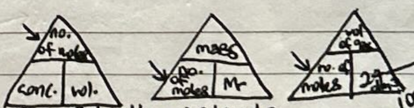
Qn. Finding mass of nitrogen in bag of fertiliser (1kg) containing $(NH_4)_2SO_4$.

$$\text{Mass of } N_2 = \frac{2(14)}{2(14) + 8(1) + 32 + 4(16)} \times 1\text{kg}$$

⇒ Mr × No. of particles / sum of Mr × No. of particles for each element. ↓ find mass. If find % mass = ×100%.

Mass = No. of moles × Mr

$= 0.212\text{kg}$ (3s.f.) #



$1\text{dm}^3 = 1000\text{cm}^3$

$\text{m}^3 = 1000\,000\text{ cm}^3$

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

↳ Find L.R. (moles)
1. No. of moles of both reactants.
2. Mole Ratio → find no. of moles.
3. L.R. → less moles

↳ Find Theoretical mass of product. ⇒ no. of moles × Mr.

↳ % yield.

No: _____

Laboratory Preparation of Ammonia

NH_3 → obtained from ammonium salts

Ch8.1

alkali + ammonium salt → salt + H_2O + $NH_3(g)$

- Heat any ammonium salt (~~ammonia!!!~~) with an alkali.
  (E.g. ammonium chloride NH_4Cl (s) or (aq) and sodium hydroxide $NaOH$ (aq) ⇒ produces $NaCl$ (aq), H_2O (l), NH_3 (g))

Reactions w Ammonia gases

neutralisation: $2NH_3(g) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq)$

- $NH_3(g)$ cannot be dried by
  - conc. sulfuric acid → react, get neutralised (H_2SO_4 is acid) to form ammonium sulfate.
  - fused calcium chloride → react, form calcium chloride complexes
- $NH_3(g)$ can be dried by → calcium oxide / quicklime → will not react, CaO is a base, NH_3 is a base.
  - ↳ calcium hydroxide (slaked lime)

- nitric acid + aqueous ammonia → NH_4NO_3 (salt)
  (acid, base)

→ $HNO_3(aq) + NH_3(aq) \rightarrow NH_4NO_3(aq)$ ⇒ no water

get H_2 other than cracking of crude oil

steam reforming

$CH_4 + 2H_2O(g) \rightarrow CO_2 + 4H_2$

$CH_4 + 2H_2O(g) \rightarrow CO_2 + 4H_2$