Question 1a:

NH_3 can be used to produce:

1. Fertilisers (Lucarelli, 2015).
2. Cleaning agents (Lucarelli, 2015).
3. Polymers (Lucarelli, 2015).
4. Explosives (Lucarelli, 2015).
5. Textiles (n.a., n.d.).

Question 1b:

NH_3 undergoes hydrolysis with water to produce OH^- ions.

$NH_{3\,(aq)} + H_2O_{(l)} \rightleftharpoons NH_4^+{}_{(aq)} + OH^-{}_{(aq)}$

This increases $[OH^-]$, meaning $[H_3O^+]>[OH^-]$ and hence pH is greater than 7, meaning the solution is alkaline.

Question 2:

$CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$

$n(CH_4) = \frac{1}{M(CH_4)} = 0.0623\text{mol}$

$n(H_2) = n(CH_4) \text{ x } \frac{4}{1} = 0.0623 \text{ x } 4 = 0.249\text{mol}$

70% efficiency: $n(H_2) = 0.7 \text{ x } 0.249 = 0.175\text{mol}$

$N_2 + 3H_2 \rightarrow 2NH_3$

$n(NH_3) = n(H_2) \text{ x } \frac{2}{3} = 0.175 \text{ x } \frac{2}{3} = 0.116\text{mol}$

95% efficiency: $n(NH_3) = 0.95 \text{ x } 0.116 = 0.111\text{mol}$

$m(NH_3) = 0.111 \text{ x } M(NH_3) = 1.88\text{g} = 1.9\text{g}$

Question 3:

m(N) = 1 x 0.15 = 0.15g

m(N) in NH_4HCO_3 = 0.306 x 0.15 = 0.0459g

n(N) = $\frac{0.0459}{14.01}$ = 0.00328mol

n(NH_4HCO_3) = n(N) = 0.00328mol

$NH_4HCO_3 \rightarrow NH_3 + H_2O + CO_2$

n(NH_3) = n(NH_4HCO_3) = 0.00328mol

90% efficiency: n(NH_3) = 0.9 x 0.00328 = 0.00295mol

m(NH_3) = 0.00295 x M(NH_3) = 0.0502g = 5.02 x 10^{-2}g

Question 4:

$$\frac{\text{m(NH}_3\text{) from Haber process}}{\text{m(NH}_3\text{) from chicken feather process}} = \frac{1.88}{0.0502} = 37.5$$

The Haber process produces 37.5 times more NH_3 than the chicken feather process on a gram-to-gram basis.

Question 5:

m(N) = 0.15 x 350000 = 52500g

m(N) in NH_4HCO_3 = 0.306 x 52500 = 16065g

n(N) = $\frac{16065}{14.01}$ = 1147mol

n(NH_4HCO_3) = n(N) = 1147mol

$NH_4HCO_3 \rightarrow NH_3 + H_2O + CO_2$

n(NH_3) = n(NH_4HCO_3) = 1147mol

90% efficiency: n(NH_3) = 0.9 x 1147 = 1032mol

$m(NH_3) = 1032 \text{ x } M(NH_3) = 17579g$

$\% \text{ yield} = \frac{5230}{17579} \text{ x } 100 = 29.75\% = 29.8\%$

Question 6:

Steam reforming process: $CH_4 + H_2O \rightleftharpoons CO + 3H_2$ $\Delta H = +ve$

Low pressure would favour the forward reaction, increasing yield, but low pressure would decrease reaction rate, hence a moderate pressure is used as a compromise (~80 atm).

High temperature would favour the forward reaction, increasing yield, and high temperature would increase reaction rate, hence a high temperature is used ($\sim 800^oC$).

Shift reaction: $CO + H_2O \rightleftharpoons H_2 + CO_2$ $\Delta H = -ve$

High pressure increases reaction rate without any compromise in equilibrium and so high pressure is used (~200 atm).

Low temperature favours the forward reaction, increasing yield, but low temperature would decrease reaction rate, hence a moderate temperature is used as a compromise.

Haber process: $N_2 + 3H_2 \rightarrow 2NH_3$ $\Delta H = -ve$

High pressure favours the forward reaction, increasing yield, and high pressure increases reaction rate, hence a high pressure is used (~200 atm).

Low temperature favours the forward reaction, increasing yield, but low temperature decreases reaction rate, hence a moderate temperature is used as a compromise ($\sim 400^oC$).

Question 7:

$n = n(N_2) + n(H_2) + n(NH_3) = 8.93 \text{ x } 10^7\text{mol}$

$$P = \frac{nRT}{V} = \frac{8.93 \text{ x } 10^7 \text{ x } 8.314 \text{ x } 476}{9.25 \text{ x } 10^6} = 3.82 \text{ x } 10^4\text{kPa}$$

Question 8:

The temperature for the chicken feather process is 600^{o}C and so it's higher than for the Haber process (~400^{o}C) but lower than for the steam reforming process (~800^{o}C).

Pressure for the chicken feather process is 73atm, less than that of the Haber process and steam reforming process (~200atm).

Question 9:

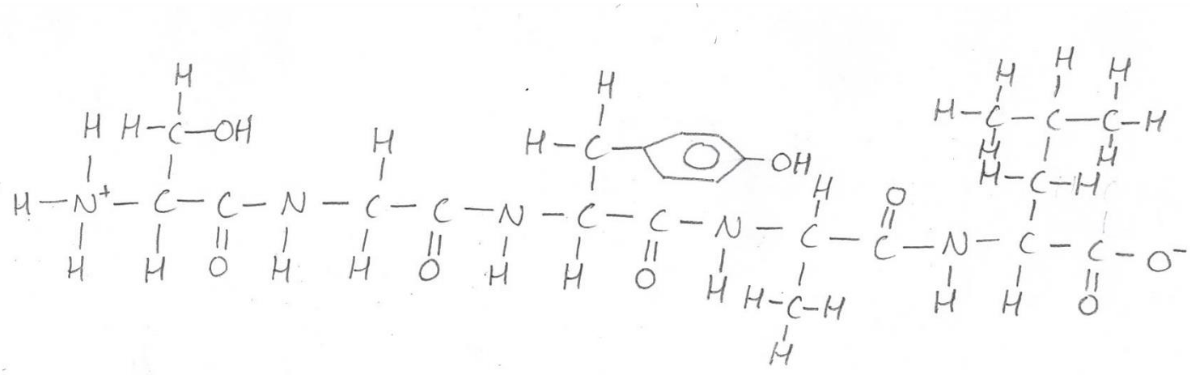
High pressures in the Haber process and steam reforming need to be maintained, costing a lot of energy. Lower pressures are used in the chicken feather process, reducing energy demand.

High temperatures in steam reforming and the Haber process uses up a lot of energy. The decomposition of NH_4HCO_3 in chicken feathers occurs at a low temperature, reducing energy demands.

Feathers are a renewable resource and are being recycled. CO_2 generated in the chicken feather process may be recycled and used again.

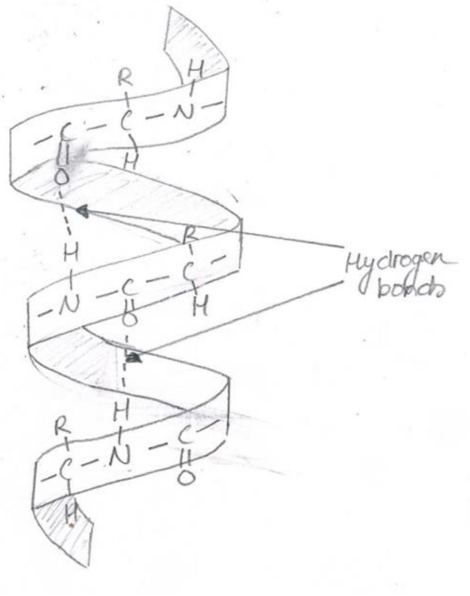
Other nitrogen containing compounds that'd otherwise go to landfill may also be used in the process developed for chicken feathers.

Question 10:

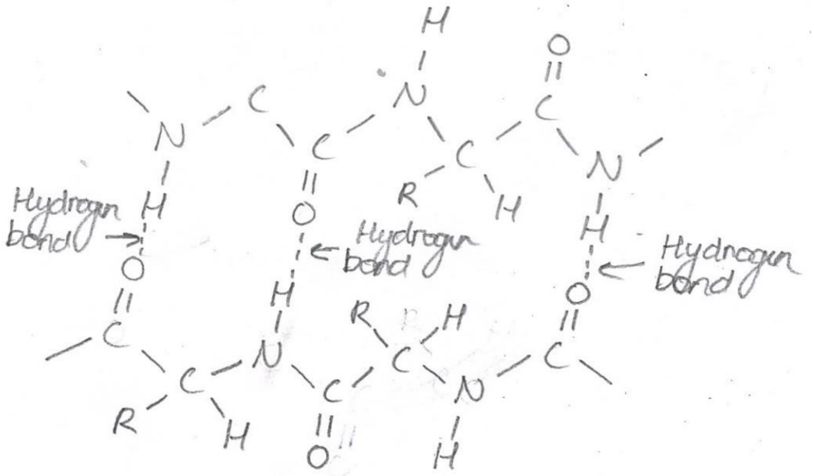


Question 11:

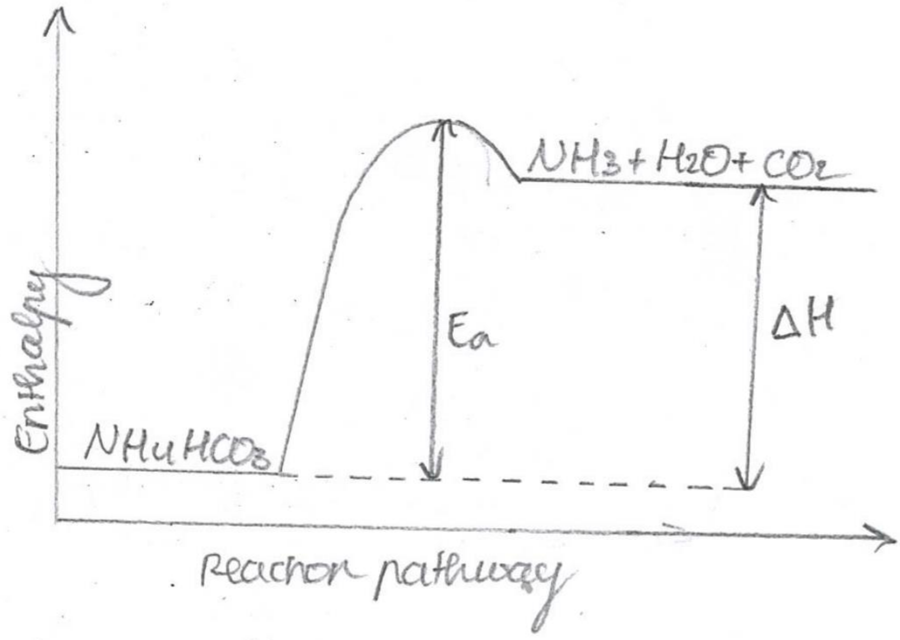
Alpha helix structures are due to interactions within the peptide chain (Cricelli, 2021). Hydrogen bonding occurs between the lone pair of electrons on the carboxyl group and the hydrogen on the amino group to produce a right-hand coiled helix (Cricelli, 2021).



Beta-pleated sheet structures are due to interactions between adjacent polypeptides (Cricelli, 2021). Polypeptides line up alongside one another (ether the same protein chain or a different protein chain) and hydrogen bonding occurs between a lone pair of electrons from the carbonyl group and the hydrogen atom on the amino group (Cricelli, 2021). This results in hydrogen bonds within the plane of the sheet structure (Cricelli, 2021). All the carbonyl and amino groups are involved in hydrogen bonding in beta-pleated sheets (Cricelli, 2021).



Question 12:



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