[2017 HSC] Analyse the conditions required to optimise the production of ammonia using the Haber process. (7 marks)

The Haber process is a method to synthesise ammonia from hydrogen and nitrogen gas, forming the equilibrium system:

$$N_{2(g)} + H_{2(g)} \leftrightharpoons 2NH_{3(g)}\ \Delta < 0$$

Le Chatelier's Principle states that if a system at equilibrium is disturbed then the equilibrium will shift in order to counteract the change. Lower temperatures cause the equilibrium to minimise the change and increase the temperature by shifting to the right to favour the exothermic reaction. Higher pressures cause equilibrium to favour the reaction producing fewer moles of gas, shifting equilibrium right. Higher reactant concentrations cause a shift to the right. The liquefication of ammonia by a condenser also removes it out of the equilibrium, thus decreasing the concentration of products resulting in a shift to the right.

With higher temperatures a greater proportion of reactant molecules have sufficient KE to overcome EA, and so can undergo a successful collision, increasing reaction rate. Decreasing temperature increases yield (favours forward exothermic reaction). Hence a compromise between reaction rate and yield, with temperatures of 400-500◦C is used to give moderate yields relatively quickly. Excessively high temperatures can also damage the catalyst and be dangerous as well as expensive.

With higher pressures, a lower volume (higher pressure) increases the concentration of particles, so there are more successful collisions between molecules, increasing reaction rate. Increasing pressure shifts equilibrium right to partially reduce the pressure, increasing yield. However, high pressures are expensive to maintain, and there are risks of explosions/pressure build-up, so a compromise of pressures of 200-250 atm are used

A powdered magnetite catalyst (Fe_3O_4) provides an alternative reaction pathway with a lower EA, hence increasing number of particles with KE > EA, increasing the number of successful collisions and hence reaction rate. Thus, it allows for a higher reaction rate despite lower temperatures and pressures, reducing production costs. Production costs are further decreased by recycling unreacted gases back into the reaction chamber.

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