

The production of ammonia

1. (a) rate of reaction is increased 4  
 iron/powder  
 acts as catalyst  
 at higher temperatures  
 at higher pressures  
*any 4 answers for 1 mark each*
- (b) yield of ammonia is increased at higher pressure 7  
 since equilibrium is moved to the right (idea)  
 but there is high cost in manufacturing the plant to withstand very high pressures  
 so optimum\* pressure of about 250 atmospheres is used  
 (\* - just quoting the figures not enough)  
 very high pressure increases safety risk  
 yield of ammonia is increased at lower temperatures  
 since equilibrium is moved to the right  
 but the rate of reaction is reduced at lower temperatures  
 so process becomes uneconomic  
 optimum temperature of about 450°C is used  
 yield of ammonia is increased if the ammonia is removed from the reaction mixture  
 since equilibrium is moved to the right (idea)  
 so ammonia is removed as a liquid after cooling and condensing  
 unreacted nitrogen and hydrogen recycled  
 (credit nitrogen and ammonia because of misprint on the diagram)  
 NB Answers in (b) must clearly relate to yield not to rate  
 (except for the qualification w.r.t. temperature)  
*any 7 points for 1 mark each*
- [11]
2. (a) fewer product molecules than reactant molecules (owtte) 1  
*accept forward reaction produces fewer molecules*  
*accept left hand side for reactants and right hand side for products*
- or** 3 reactant molecules and 1 product
- or** 3 volumes of gas becomes 1 volume of gas  
*accept high pressure favours the side with fewer molecules*  
*ignore references to reaction rate*
- (b) any **three** from: 3
- low temperature gives best yield  
*accept add heat as increased temperature **or** 'less' as poor yield*  
**or** high temperature gives poor yield
  - because the reaction is exothermic  
*accept reverse argument if clearly expressed*
  - reaction too slow at low temperature **or** reaction faster at high temperature  
*accept add heat and reaction goes faster*
  - temperature used gives a reasonable yield at a fast rate / compromise explained  
*allow get less product but it takes less time for 2 marks*
- [4]

3. (i) high temperature 1  
*accept temperature given if  $\geq 400^{\circ}\text{C}$   
ignore value if "high" stated, unless silly value*  
endothermic or reaction takes in energy  
or  $\Delta H$  is +ve 1  
*independent marks*
- (ii) low pressure 1  
*or up to and including 10 atmospheres*  
(low pressure) favours a reaction in which more molecules are formed 1  
*2 moles  $\rightarrow$  4 moles  
(2 molecules  $\rightarrow$  4 molecules)  
independent marks*
- (iii) nickel **and** it is a transition / transitional element / metal (owtte) **or** nickel 1  
**and** variable oxidation state / number or it is similar to other named transition  
elements e.g. iron