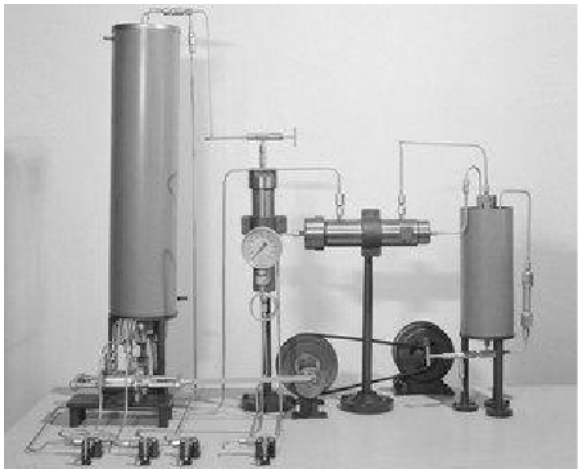
1. 100 years ago, Fritz Haber was the first scientist to successfully react nitrogen gas from the air to make a compound.

He used laboratory apparatus similar to this.



Haber reacted small amounts of nitrogen and hydrogen in a closed system to make ammonia.
The reaction is exothermic.

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

He investigated how changing the conditions affected the yield.

What effect does increasing the pressure, temperature and using a catalyst have on the yield?

---

[3]

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2(a). This is an equation for a reaction that occurs in a lightning flash.

$N_2 + O_2 \rightleftharpoons 2NO$

Very high temperatures are needed.

(i) Explain how you can tell that this equation refers to an equilibrium.

---

[1]

(ii) Use ideas about rates to explain what is happening when the reaction reaches dynamic equilibrium.

---

[2]

(b). Scientists can use this reaction to make nitrogen compounds from gases in the air.

(i) Suggest a use for these compounds.

---

[1]

(ii) The scientists discuss increasing the pressure on the reaction.

Describe and explain the effect on the equilibrium position.

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[2]

END OF QUESTION PAPER

Question			Answer/Indicative content	Marks	Guidance
1			increasing the pressure increases the yield ✓ increasing the temperature decreases the yield ✓ using a catalyst has no effect on yield ✓	3	
			Total	3	
2	a	i	Equilibrium sign / ⇋ / arrows point both ways ✓	1 (AO 1.1)	ALLOW answers referring to the sign/arrow IGNORE it is reversible
		ii	forward and back(ward) reactions / both directions / reactants(N_2 and O_2) forming products (NO) and products forming reactants✓ rates are equal ✓	2 (AO 2 × 1.1)	ALLOW equations for the correct reactions Examiner's Comments Most expressed some idea of stability at equilibrium. More able candidates stated that the reaction is reversing or going both ways. Some went on to explain that the rates of the forward and backward reactions are equal. In some answers, the explanations were unclear, for example stating 'both reactions are at the same rate' without clearly stating that 'both reactions' means that one is going in each direction.
	b	i	Fertilisers / explosives	1 (AO 1.1)	ALLOW for growth of/nitrates for plants but IGNORE plants alone/ammonia/Haber process

Question			Answer/Indicative content	Marks	Guidance
		ii	No change ✓ Equal moles/molecules/particles on each side (of the equation) ✓	2 (AO 2 × 1.1)	Mark separately <u>Examiner's Comments</u> Candidates often expressed some understanding that an increase in pressure favours the side with fewer moles. Application of this principle to this particular equation is very challenging. Only the higher ability candidates recognised that the number of moles of gas on each side were equal so that there is not overall effect. Some candidates introduced the idea of rates into the answer, rather than focussing on equilibria.
			Total	6	