O Level Pure Chemistry Structured

Ammonia Test 1.0

Q1

(a) Ammonia is manufactured by the Haber Process.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 \qquad \Delta H = -92.4 \text{ kJ/mol}$$

The table below shows how the percentage yield of ammonia at equilibrium varies with both temperature and pressure.

pressure / atm	percentage yield of ammonia at equilibrium			
	200 °C	300 °C	400 °C	500 °C
40	72	34	13	5
100	81	51	25	10
200	86	63	36	18
300	88	69	40	24

(i) Describe how the percentage yield of ammonia at equilibrium changes with temperature.

....

....[1]

(ii) Describe how the percentage yield of ammonia at equilibrium changes with pressure.

....

....[1]

(iii) Explain how using a catalyst in the Haber Process has an economic advantage.

....

....

....[2]

(b) Ammonia is used to manufacture nitric acid by a two-stage process.

Stage 1 Ammonia is converted to nitrogen monoxide.

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$$

Stage 2 Nitrogen monoxide is converted to nitric acid.

$$4NO(g) + 2H_2O(g) + 3O_2(g) \rightarrow 4HNO_3(aq)$$

(i) It is possible to find out whether the reaction in **Stage 1** has completed by following the pH changes during the reaction.
Samples of gas are taken from the reaction vessel at regular time intervals and bubbled through water to form a solution. The pH of each solution is measured.
Explain why the measured pH changes during the reaction.

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....[3]

(ii) Use the equations in the two stages to construct an overall equation for the conversion of ammonia to nitric acid.

....[1]

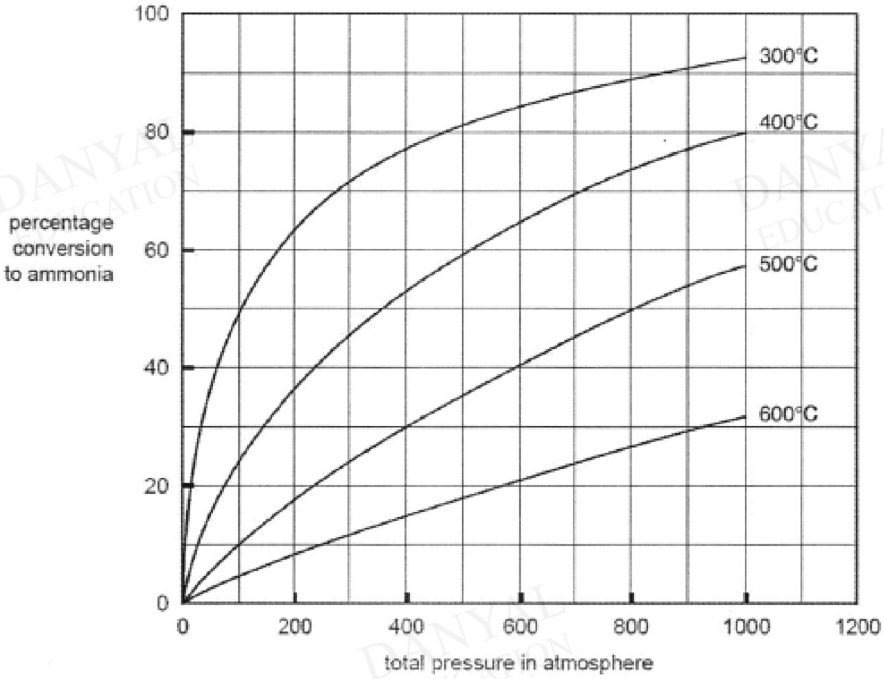
[Total: 8]

Q2

Ammonia is prepared industrially from hydrogen and nitrogen in the presence of a suitable catalyst according to the equation below.

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

The graph below shows the variation of the equilibrium yield of ammonia with pressure at different temperatures.



(a) A particular industrial plant uses a pressure of 400 atm and a temperature of 500°C. From the graph, determine the percentage yield of ammonia under these conditions.

.... [1]

(b) Deduce from the graph whether the production of ammonia from hydrogen and nitrogen is an exothermic or an endothermic reaction. Explain your reasoning.

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....

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.... [2]

(c) Temperatures less than 400°C are not used for this industrial reaction even though such temperatures give a greater equilibrium yield of ammonia. Give a possible reason why this is so.

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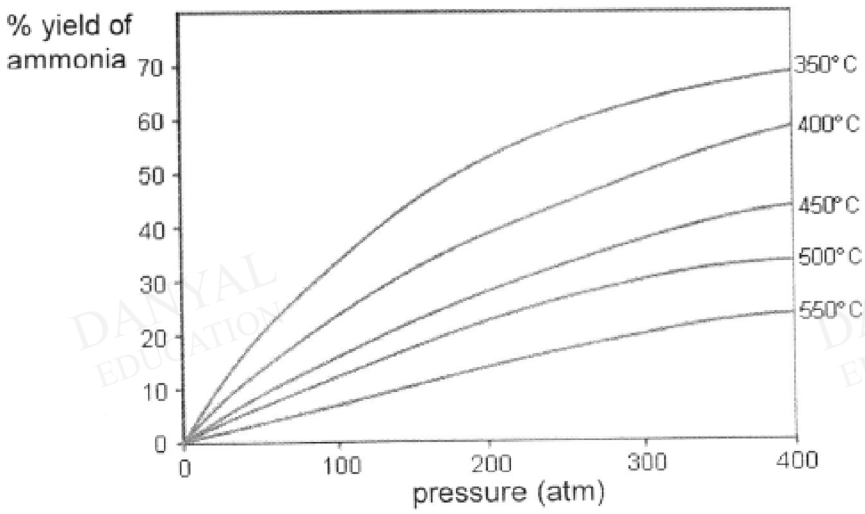
.... [1]

[Total: 4]

Q3

Ammonia is manufactured from nitrogen and hydrogen via the Haber process, using iron as catalyst. The graph below shows how the amount of ammonia produced (percentage yield) varies with both temperature and pressure.



(a) **(i)** From the graph, suggest whether a higher or lower temperature would result in more ammonia being formed from the Haber Process.

.... [1]

(ii) Suggest why this temperature is not used in the Haber Process?

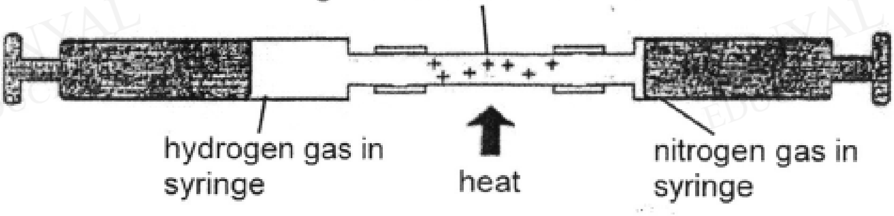
.... [1]

(b) Explain how using a catalyst in the Haber process has an economic advantage.

....

.... [1]

(c) The Haber Process can be demonstrated in the laboratory by the method shown below.



The mixture of nitrogen and hydrogen is passed back and forth over the hot iron wool until there is no further reaction.

Suggest why it is important to ensure that no air is present in the apparatus shown above.

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.... [1]

Q4

Ammonia can be manufactured using the Haber process. The percentage yield of ammonia using different temperatures and pressures are shown in the Table 10.1.

Table 10.1

pressure/ atm	ammonia yield/ %				
	100 °C	200 °C	300 °C	400 °C	500 °C
10	88.2	50.7	14.7	3.9	1.2
25	91.7	63.6	27.4	8.7	2.9
50	94.5	74.0	39.5	15.3	5.6
100	96.7	81.7	52.5	25.2	10.6
200	98.4	89.0	66.7	38.8	18.3
400	99.4	94.6	79.7	55.4	31.9
1000	99.9	98.3	92.6	79.8	57.5

(a) Describe how the percentage yield of ammonia is affected by

(i) increasing temperature,

....

....[1]

(ii) decreasing pressure.

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....[1]

(b) **(i)** With reference to the information provided, state the optimum conditions for the Haber process.

....[1]

(ii) Explain why the conditions stated in **(b)(i)** are not used commercially.

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....[2]

(c) The ammonia manufactured in Haber Process can be used to prepare nitric acid in another reaction called the Ostwald Process. This process converts ammonia into nitric acid in a three-step reaction.

Step 1: $4NH_3\ (g) + 5O_2\ (g) \rightleftharpoons 4NO\ (g) + 6H_2O\ (g)$

Step 2: $2NO\ (g) + O_2\ (g) \rightleftharpoons 2NO_2\ (g)$

Step 3: $3NO_2\ (g) + H_2O\ (l) \rightarrow 2HNO_3\ (aq) + NO\ (g)$

(i) Explain why the products of the Ostwald Process are not wasted.

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....[1]

(ii) It is possible to monitor the progress of the Ostwald Process by measuring pH changes during the process.

State and explain the changes in pH before the start of step 1 and at the end of step 2.

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....[2]

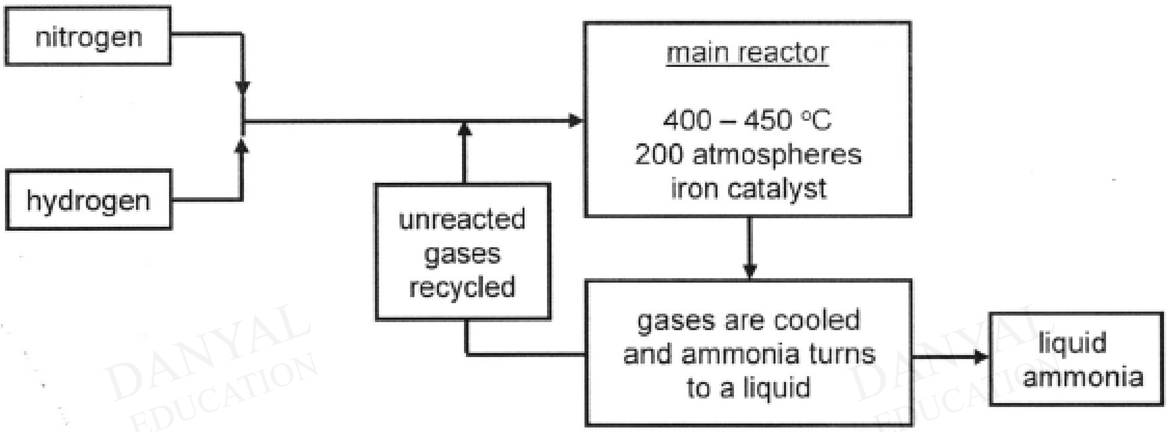
(iii) Calculate the maximum mass of nitric acid which can be made from 840 dm^3 of ammonia at room temperature and pressure.

[2]

[Total: 10]

Q5

B8 The Haber process for making ammonia can be represented by the flow diagram below.



(a) State how nitrogen and hydrogen can be obtained for the making of ammonia.

nitrogen .... hydrogen ....

[2]

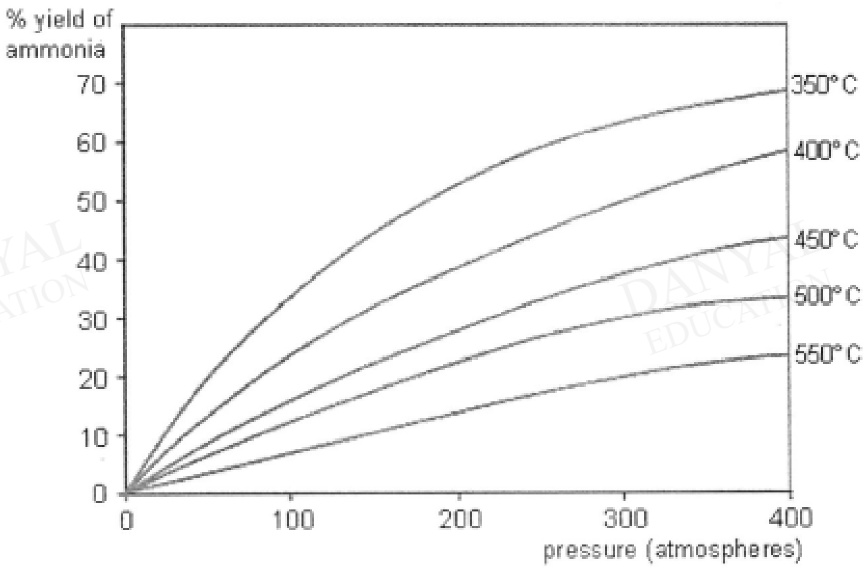
(b) Which element is reduced in the reaction?

Use ideas about changes in oxidation state to explain your answer.

....

....[1]

(c) The graph shows the yield of ammonia that is made under different conditions.



(i) Explain, in terms of collisions between (reacting) particles, how a higher temperature affects the rate of reaction in the reactor.

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....[2]

(ii) Using the information in the graph, state the conditions that would produce the highest yield of ammonia.

....[1]

(iii) What effect does the iron catalyst have on the yield of ammonia obtained?

Explain your reasoning.

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....[2]

(iv) Explain why the unreacted gases obtained from the main reactor are recycled.

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....[1]

(v) In practice, it is not possible to obtain 100% yield of ammonia in the Haber process.

Explain why this is so.

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....[1]

Answers

Ammonia Test 1.0

Q1

A4a(i)	The percentage yield of ammonia decreases with increasing temperature.	1
(ii)	Percentage yield of ammonia increases with increasing pressure.	1
(iii)	Catalyst speeds up the reaction / lowers activation energy. Catalyst shortens the production time / lowers energy costs as less energy is used.	1 1
b(i)	Ammonia is an alkaline gas, while oxygen, nitrogen monoxide and water vapour are neutral gases. Ammonia gas is gradually used up, the pH decreases as the products are neutral. When pH value remains constant at 7, it indicates that ammonia gas is used up completely for reaction and left with the neutral gases.	1 1 1
(ii)	$NH_3 + 2O_2 \rightarrow HNO_3 + H_2O$	1

Q2

(a)	30%	[1]
(b)	**Exothermic reaction** The **percentage yield of ammonia increases with lower applied temperature**. The lower applied temperature favors the forward reaction of ammonia production.	[1] [1]
(c)	Slows down the rate of production of ammonia	[1]

Q3

(a)	**(i)**	Lower temperature	1
	(ii)	Lower temperature results in a slower rate of reaction.	1
(b)		speeds up the reaction / lowers the activation energy lowers energy costs / less energy used/only a small amount is needed (Reject: Catalyst can be re-used and hence save cost as this is not a significant contributing economic advantage)	1
(c)		This to prevent hydrogen from reacting with oxygen in the air.	1

Q4

(a)(i)	Percentage yield of ammonia drops as temperature increases;	[1]
(a)(ii)	Percentage yield of ammonia decreases as pressure decreases;	[1]
(b)(i)	100 °C, 1000 atm;	[1]
(b)(ii)	Extremely high pressure of 1000 atm is operationally dangerous/ may cause explosion of the reaction vessel/ incurs high maintenance cost; Speed of reaction is too slow at 100 °C; A: costly to maintain pressure at 1000 atm and 100 °C(1m)	[1] [1]
(c)(i)	Nitrogen monoxide produced in step 3 can be used for step 2; R: water produced in step 1 can be used for step 3 R: products from each step can be used for the next step R: products can be reused for other steps	[1]
(c)(ii)	pH is above 7 before the start of step 1 while pH is below 7 at the end of step 2; Ammonia gas present at the start is alkaline while nitrogen dioxide produced at the end is acidic;	[1] [1]
(c)(iii)	No. of moles of ammonia = 840/24 = 35 mol; No. of moles of nitric acid = 35 x (2/3) = 23.33 mol Mass of nitric acid = 23.33 x (1+14+16x3) = 1470 g;	[1] [1]

Q5

(a)	nitrogen – fractional distillation of liquid air [1] hydrogen – cracking of petroleum / crude oil [1]
(b)	Nitrogen as the oxidation state <u>decreases</u> from 0 in N_2 to –3 in NH_3. [1]
(c)	(i) Higher temperature ⇒ increase in kinetic energy & speed of particles [1] ⇒ increase in frequency of effective collisions [1] ⇒ increase in rate of reaction (ii) 350 °C and 400 atmospheres [1] (iii) no effect on yield of ammonia [1] increases the speed of both the forward and reverse reactions to the same extent [1] (iv) to increase yield of ammonia / reduce cost/ reduce waste / save materials or resources [1] (v) reversible reaction [1]