AQA GCSE CHEMISTRY (HIGHER) · 8462

CHEMISTRY



EXAM QUESTION PACK

4.10.4 THE HABER PROCESS AND THE USE OF NPK FERTILISERS (PACK 2)

SCORE	PERCENTAGE
/136	%

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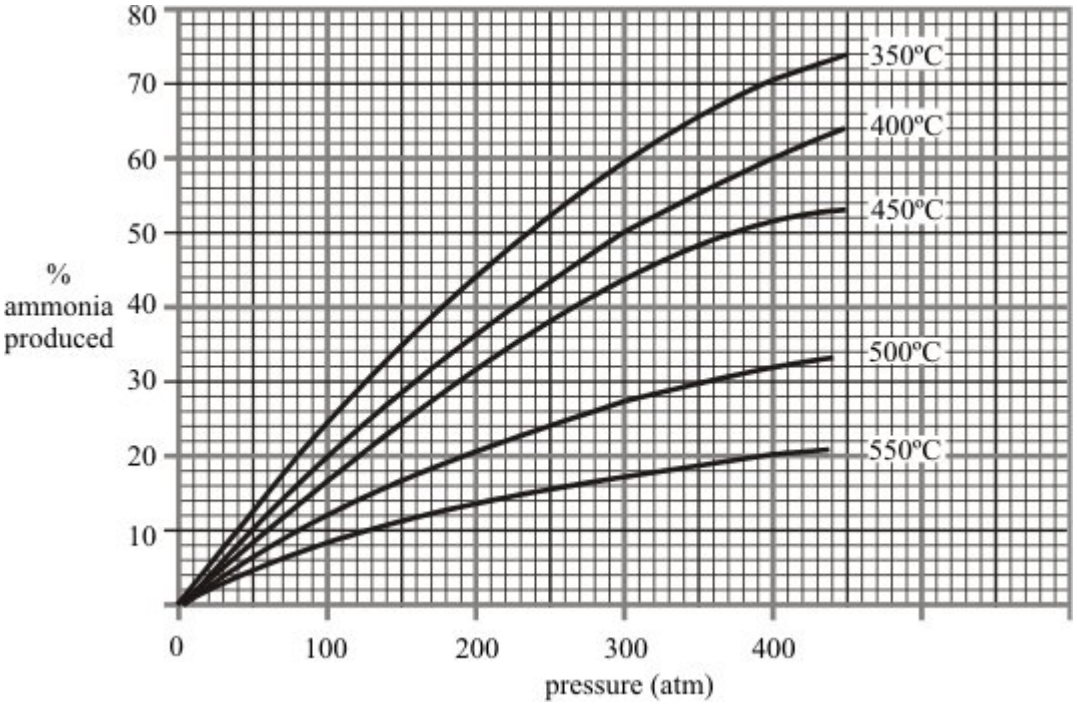
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Q1.

Ammonia is produced by the Haber process. In the process nitrogen and hydrogen are mixed. The pressure is increased to about 200 atmospheres. The gases are passed over an iron catalyst at about 450°C. The equation for the reaction is:

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

The reaction between nitrogen and hydrogen is reversible. This affects the amount of ammonia that it is possible to obtain from the process. The graph below shows how the pressure and temperature affect the percentage of ammonia that can be produced.



Use this information, together with your knowledge of the process, to explain why many industrial ammonia plants operate at 200 atmospheres and 450°C.

_____

_____

_____

_____

_____

_____

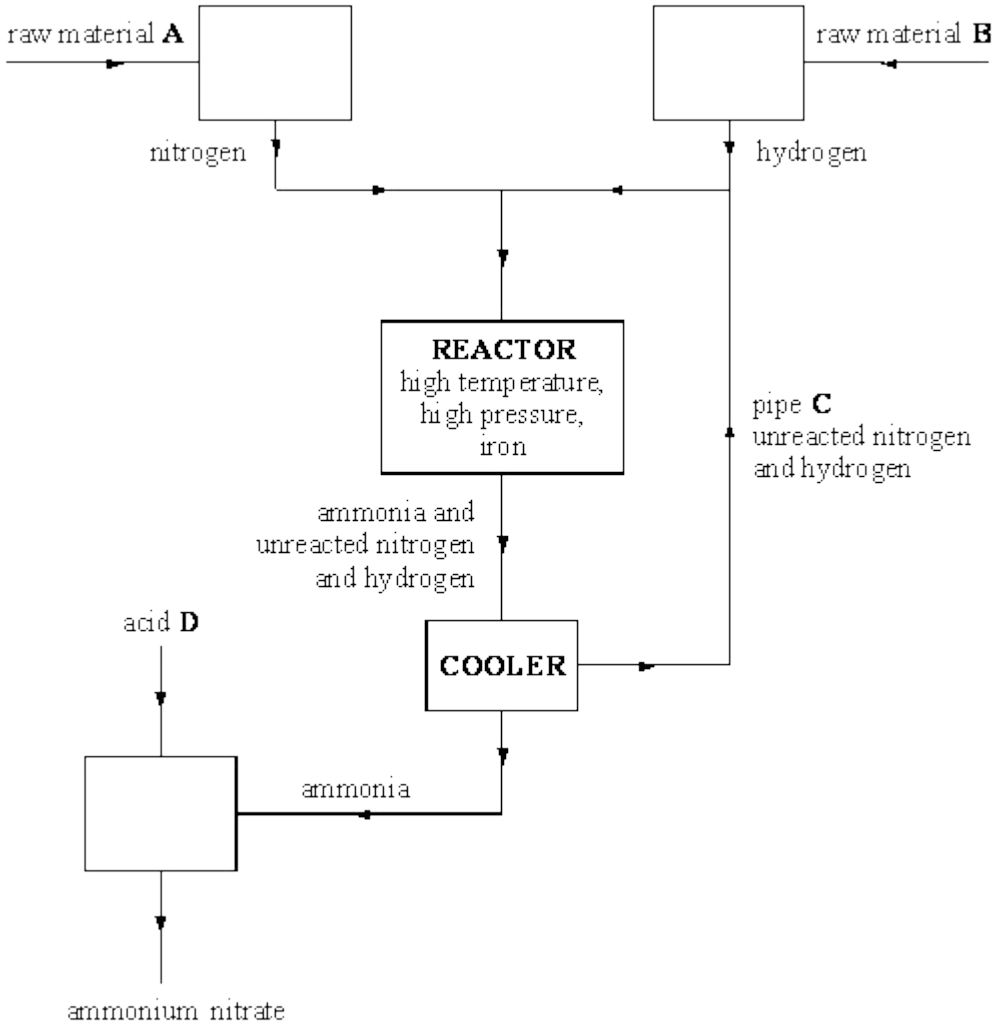
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(Total 5 marks)

Q2.

The flow chart below shows the main stages in the production of ammonium nitrate.

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(i) Name the **two** raw materials shown in the flow chart as **A** and **B** by choosing words from the list.

air **coke** **limestone** **natural gas**

Raw material **A** _____

Raw material **B** _____

(2)

(ii) Complete the word equation for the reaction which makes ammonia.

_____ + _____ → ammonia

(1)

(iii) What is the purpose of the iron in the reactor?

_____

_____

(1)

(iv) What is the purpose of pipe **C**?

_____

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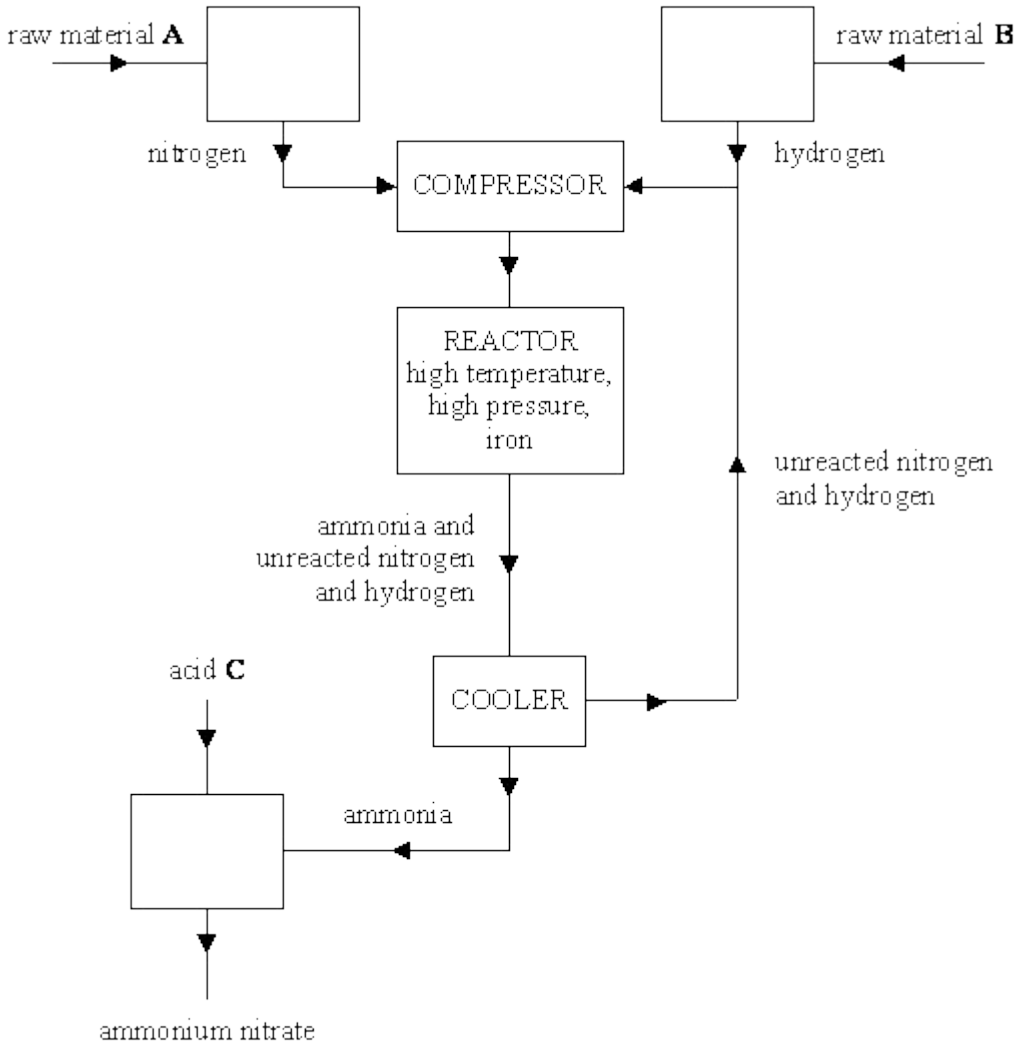
_____

(1)

(Total 5 marks)

Q3.

The flow chart below shows the main stages in the production of ammonium nitrate.



(a) (i) Name the two raw materials shown in the flow chart as **A** and **B**.

Raw material **A** _____

Raw material **B** _____

(2)

(ii) What is the purpose of the iron in the reactor?

_____

_____

(1)

(b) (i) Balance the equation which represents the reaction which produces ammonia in the Haber process.

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N_2 + _____ H_2 ⇌ _____ NH_3 and heat

(1)

(ii) The table shows how temperature and pressure affect the amount of ammonia produced in this reaction.

TEMPERATURE (°C)	PRESSURE (ATM)	PERCENTAGE OF NITROGEN AND HYDROGEN CONVERTED TO AMMONIA (%)
250	200	75
250	1000	96
1000	1	0.01
1000	1000	1

Explain, as fully as you can, why a temperature of about 450°C and a pressure of about 200 atmospheres are normally used in the industrial process.

_____

_____

_____

_____

_____

_____

_____

_____

_____

(6)

(Total 10 marks)

Q4.

Ammonia is a very important chemical.

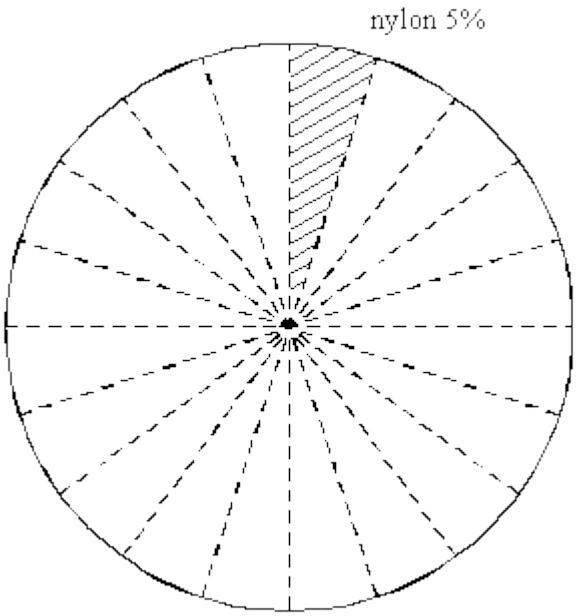
(a) The table shows the percentage of ammonia used to make different substances.

SUBSTANCES MADE FROM AMMONIA	PERCENTAGE (%) OF AMMONIA USED
fertilisers	75
nitric acid	10

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nylon	5
others	10

Shade on the pie chart the percentage of ammonia used to make nitric acid.



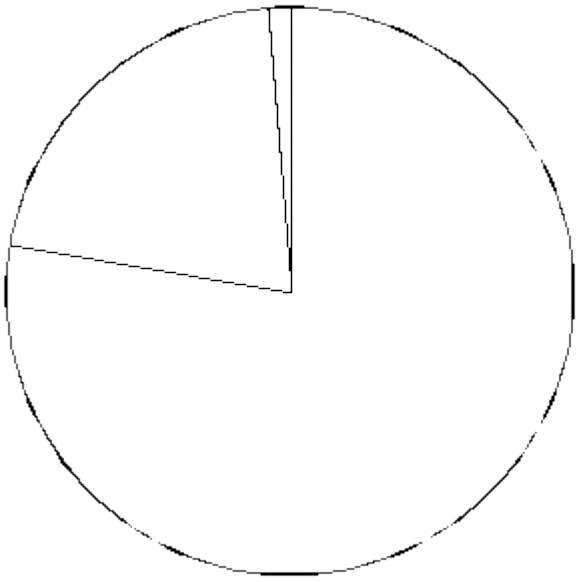
(1)

(b) Ammonia gas is made by the reaction between nitrogen gas and hydrogen gas.
Write a word equation to represent this reaction.

_____ + _____ ⇌ _____

(1)

(c) Nitrogen is one of the raw materials used to make ammonia.
Nitrogen is obtained from air.
This pie chart shows the proportion of nitrogen, oxygen and other gases in air.
Label the area which represents the proportion of nitrogen in air.



(1)

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(d) An artificial fertiliser contains compounds with the formulae:

NH_4NO_3 and **KCl**

(i) Use the Data Sheet to help you answer this question.
Name the elements in the compound NH_4NO_3.

1. _____

2. _____

3. _____

(2)

(ii) Use the Data Sheet to help you answer this question.
Name the compound KCl.

_____

(1)

(e) (i) Ammonium nitrate is one type of artificial fertiliser.
Calculate the relative formula mass of ammonium nitrate NH_4NO_3.
(Relative atomic masses: H = 1, N = 14, O = 16.)

_____

_____

(1)

(ii) Use your answer to part (f)(i) to help you calculate the percentage by mass of nitrogen present in ammonium nitrate NH_4NO_3.

_____

_____

_____

(2)

(Total 9 marks)

Q5.

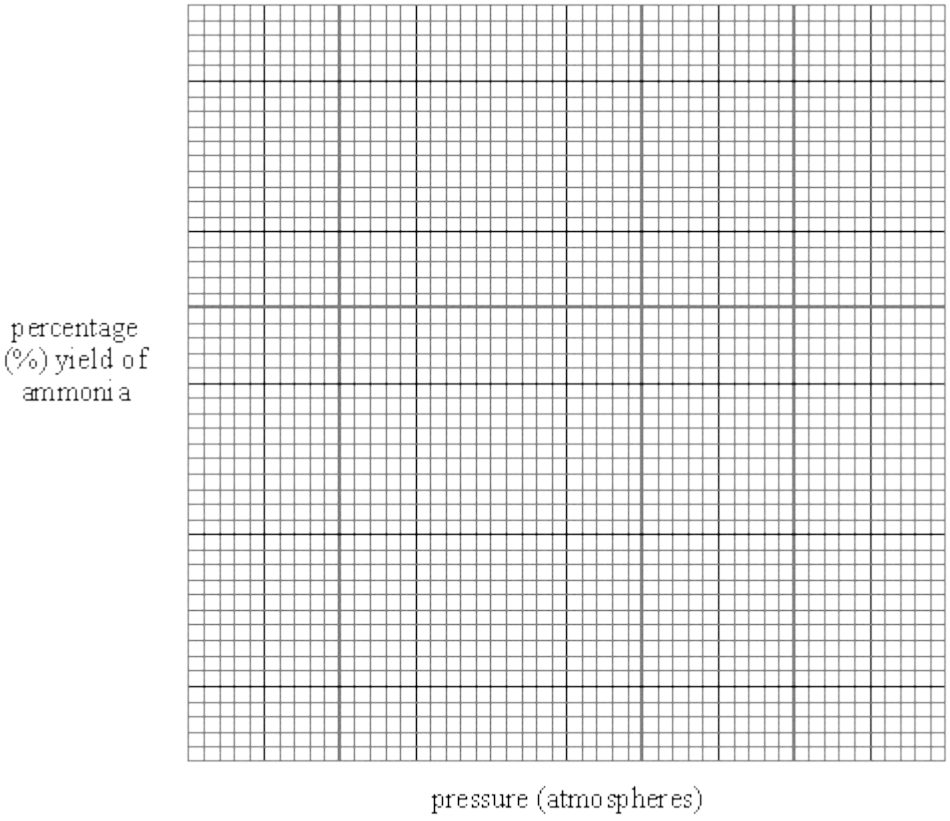
The Haber process is used to make ammonia NH_3.
The table shows the percentage yield of ammonia at different temperatures and pressures.

PRESSURE (ATMOSPHERES)	PERCENTAGE (%) YIELD OF AMMONIA AT 350°C	PERCENTAGE (%) YIELD OF AMMONIA AT 500°C
50	25	5
100	37	9
200	52	15
300	63	20

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400	70	23
500	74	25

(a) (i) Use the data in the table to draw two graphs on the grid below. Draw one graph for a temperature of 350°C and the second graph for a temperature of 500°C.
Label each graph with its temperature.



(4)

(ii) Use your graphs to find the conditions needed to give a yield of 30% ammonia.

_____ °C and _____ atmospheres

(1)

(iii) On the grid sketch the graph you would expect for a temperature of 450°C.

(1)

(b) (i) This equation represents the reaction in which ammonia is formed.

$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)} + \text{heat}$

What does the symbol $\rightleftharpoons$ in this equation tell you about the reaction?

_____

(1)

(ii) Use your graphs and your knowledge of the Haber process to explain why a temperature of 450°C and a pressure of 200 atmospheres are used in industry.

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_____

_____

_____

_____

_____

_____

(5)

(c) (i) Ammonium nitrate is one type of artificial fertiliser.
Calculate the relative formula mass of ammonium nitrate NH_4NO_3.
(Relative atomic masses: H = 1, N = 14, O = 16.)

_____

_____

(1)

(ii) Use your answer to part (c)(i) to help you calculate the percentage by mass of nitrogen present in ammonium nitrate NH_4NO_3.

_____

_____

(2)

(Total 15 marks)

Q6.

Nitrates, such as ammonium nitrate, are added to soil to help plant growth.



(a) When rain falls nitrates dissolve and can end up in drinking water.
Nitrates in drinking water can stop respiration in babies. This only happens if there is a lot of nitrate in the drinking water.

Plants use nitrates for growth. Humans need plants. Should large amounts of nitrates be added to soil?
Give **two** reasons for your answer.

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Answer _____

Reason 1 _____

_____

Reason 2 _____

_____

(2)

(b) The amount of nitrogen in a nitrate compound is important.

(i) How many nitrogen atoms are there in the formula of ammonium nitrate, NH_4NO_3

_____

(1)

(ii) Calculate the percentage of nitrogen in ammonium nitrate, NH_4NO_3.

(Relative atomic masses: H = 1; N = 14; O = 16)

_____

_____

_____

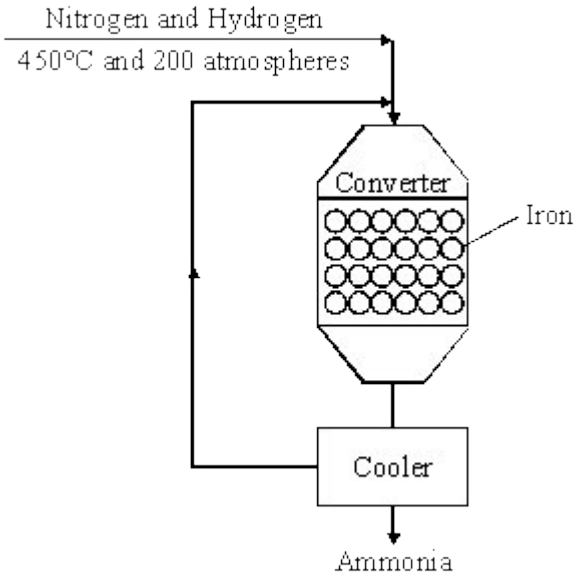
Percentage of nitrogen in ammonium nitrate = _____ %

(3)

(Total 6 marks)

Q7.

The diagram shows the final stages in the manufacture of ammonia.



(a) Why is iron used in the converter?

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_____

_____

(1)

(b) Write the word equation for the reaction in the converter.

_____ + _____ ⇌ _____

(1)

(c) The yield of ammonia is only about 15%.

(i) Why can the yield **not** be 100%?

_____

_____

(1)

(ii) Describe what happens to the mixture of gases after it leaves the converter.

_____

_____

_____

(2)

(Total 5 marks)

Q8.

In the Haber process, nitrogen and hydrogen react to make ammonia.

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

nitrogen + hydrogen ⇌ ammonia

Pressure in atmospheres	% ammonia present at equilibrium				
	Temperature in ºC				
	100	**200**	**300**	**400**	**500**
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

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1000	99.9	98.3	92.6	79.8	57.5

The actual conditions used in the Haber process are usually 450 °C and 200 atmospheres.

(a) What effect does increasing the pressure have on the percentage of ammonia made? Use the balanced symbol equation to explain why.

_____

_____

_____

_____

_____

_____

(2)

(b) A lower temperature of 100 °C gives high percentages of ammonia at most pressures. Why is this temperature **not** used in the Haber process?

_____

_____

_____

(1)

(c) Describe and explain the effect of an increase in the temperature on the reaction between nitrogen and hydrogen in the Haber process.

_____

_____

_____

_____

_____

_____

_____

_____

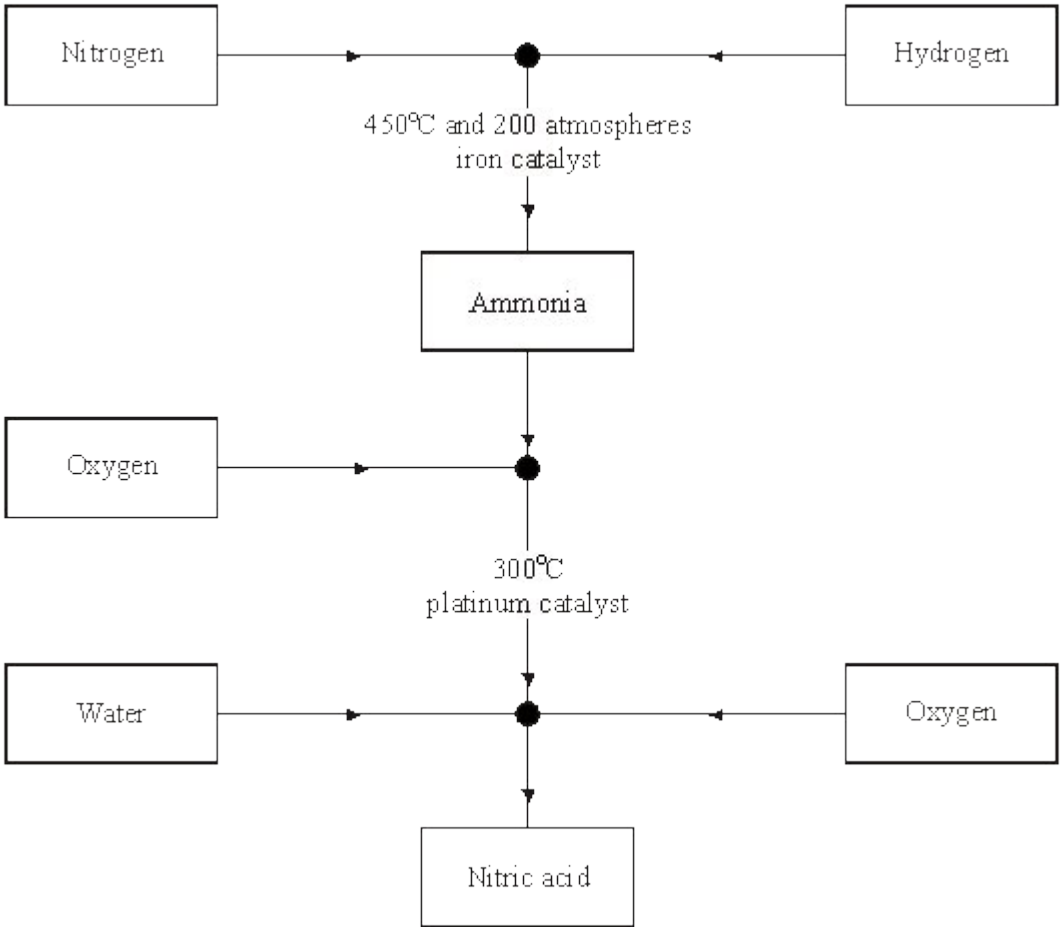
(3)

(Total 6 marks)

Q9.

The flow diagram shows how to make ammonia and nitric acid from the nitrogen in the air.

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(a) A fertiliser is made by neutralising ammonia with nitric acid. What is the name of this fertiliser?

_____

(1)

(b) In the flow diagram, why are two different catalysts used?

_____

_____

(1)

(c) What happens to catalysts at the end of a reaction?

_____

_____

(1)

(d) Explain why catalysts are used in many industrial chemical reactions.

_____

_____

_____

(2)

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(e) Explain, in terms of collisions between molecules, why a high pressure is used in the reaction between nitrogen and hydrogen.

_____

_____

_____

_____

(2)

(Total 7 marks)

Q10.

(a) In industry ammonia is produced from nitrogen and hydrogen. The equation for the reaction is:

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

(i) What does the symbol (g) represent?

_____

(1)

(ii) What does the symbol $\rightleftharpoons$ represent?

_____

(1)

(iii) Nitrogen is used for the industrial production of ammonia. From what raw material does this nitrogen come?

_____

(1)

(iv) Hydrogen is used for the industrial production of ammonia. It is obtained from the reaction between methane and steam. The equation for this reaction is:

$CH_4 + H_2O \rightarrow 3H_2 + CO$

Explain how you can tell that this equation is balanced.

_____

_____

_____

_____

(2)

(b) Ammonia is used to make ammonium salts which can be used as fertilisers.

(i) Complete the names in the following sentence.

One example is ammonium _____ which is made by reacting

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ammonia with _____ acid.

(2)

(ii) All ammonium salts are soluble in water. Why is this a useful property of a fertiliser?

_____

_____

(1)

(c) Ammonia is a covalent, chemical compound.

(i) Complete the following sentence to describe a chemical compound.

In a chemical compound, two or more _____

_____

_____

(1)

(ii) What is a covalent bond?

_____

_____

(1)

(Total 10 marks)

Q11.

(a) Ammonia is manufactured from nitrogen and hydrogen. The equation for the reaction between them is:

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

(i) What is the source of the nitrogen?

_____

(1)

(ii) Why does increasing the pressure increase the chance of molecules of hydrogen reacting with molecules of nitrogen?

_____

_____

(1)

(iii) The percentage yield of ammonia is the percentage, by mass, of the nitrogen and hydrogen which has been converted to ammonia. Calculate the mass, in tonnes, of ammonia which can be produced from 90 tonnes of hydrogen when the percentage yield is 50%. The relative atomic masses are: H 1; N 14.

Show clearly how you get to your answer.

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_____

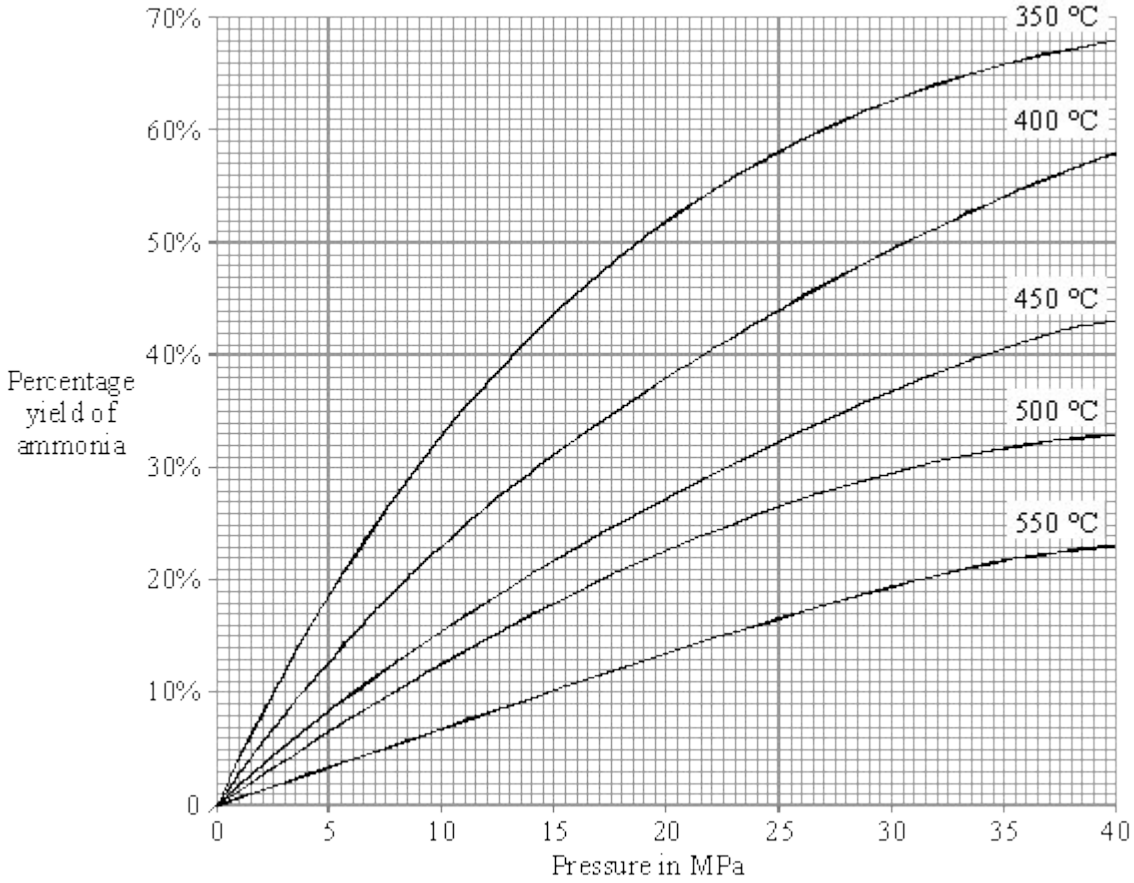
_____

_____

Mass = _____ tonnes

(2)

(b) The percentage yield of ammonia depends on the temperature and pressure inside the reaction vessel. The set of graphs show this.



(i) MPa is the symbol for which unit?

_____

(1)

(ii) What is the percentage yield of ammonia produced at a temperature of 450 °C and a pressure of 20 MPa?

_____

(1)

(iii) Suggest what changes the chemical engineers should make to both the temperature and the pressure to **increase** the percentage yield of ammonia.

Temperature _____

Pressure _____

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(1)

(iv) How can the rate of ammonia production be increased without changing the temperature or pressure or the mass of hydrogen and nitrogen?

_____

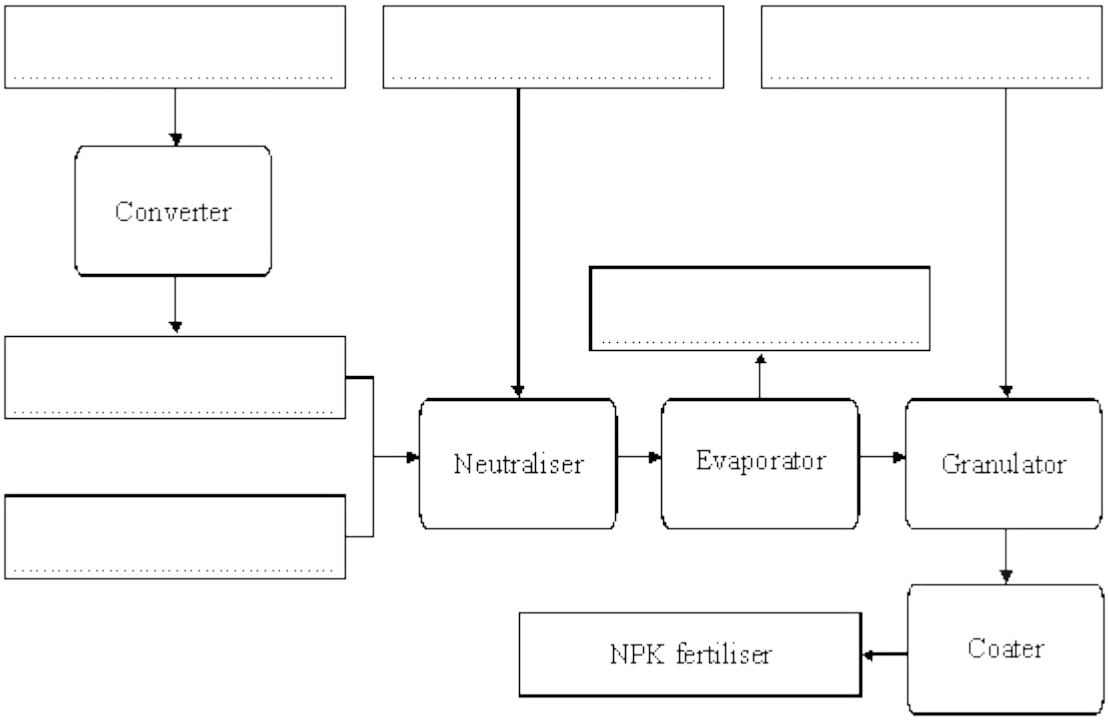
_____

(1)

(c) About four-fifths of ammonia production is used to produce fertilisers. One of them is known as NPK. It is made in the following way.

- Some ammonia is converted to nitric acid which is then mixed with phosphoric acid.
- The mixture is neutralised with more ammonia and the solution is partly evaporated.
- Potassium chloride is added to form granules.
- The granules are coated to make the fertiliser free-flowing.

Complete the flow-chart for the production of NPK by writing in the names of the correct chemicals in the **six** boxes.



(2)

(Total 10 marks)

Q12.

(a) Ammonium sulphate is made by the reaction:

$$2NH_3(aq) + H_2SO_4(aq) \rightarrow (NH_4)_2SO_4(aq)$$

(i) Complete the **three** answers in the table.

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Question	Answer
How many hydrogens are there in the formula of ammonium sulphate?	_____
What is the name of the substance with the formula NH_3?	_____
What is the name of the substance with the formula H_2SO_4?	_____

(3)

(ii) What is the main use for ammonium sulphate?

_____

(1)

(iii) A similar reaction is used to make ammonium nitrate. What is the name of the acid which must be used?

_____

(1)

(b) NH_3 is made by the reversible reaction:

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

(i) Explain what the term *reversible reaction* means.

_____

_____

_____

(2)

(ii) What is the name of the raw material which is the source of nitrogen (N_2)?

_____

(1)

(iii) Nitrogen is an element. Explain what the term *element* means.

_____

_____

_____

(2)

(Total 10 marks)

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Q13.

(a) Iron powder is used in the manufacture of ammonia. Why is it used?

_____

_____

(1)

(b) Ammonia is manufactured from nitrogen and hydrogen. The equation for the reaction between them is:

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

(i) Which **two** raw materials are used to make the hydrogen?

_____ and _____

(1)

(ii) Why does increasing the pressure increase the chance of molecules of nitrogen reacting with molecules of hydrogen?

_____

_____

(1)

(iii) Calculate the mass, in tonnes, of ammonia which could be produced from 560 tonnes of nitrogen.

The relative atomic masses are: H 1; N 14.

Show clearly how you get to your answer.

_____

_____

_____

Mass of ammonia = _____ tonnes

(3)

(Total 6 marks)

Q14.

Ammonia is manufactured in the Haber Process, from nitrogen and hydrogen.

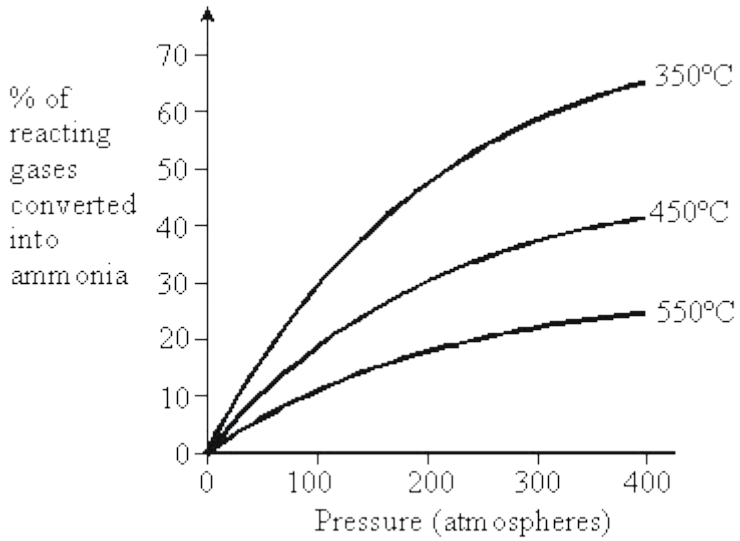
(a) Balance this symbol equation for the process.

$N_2 + \quad H_2 \rightleftharpoons \quad NH_3$

(2)

(b) The graph below shows the percentage of reacting gases converted into ammonia, at different temperatures and pressures.

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(i) What does the graph suggest about the temperature and pressure needed to convert the maximum percentage of reacting gases into ammonia?

_____

_____

_____

(2)

(ii) Suggest reasons why the manufacture of ammonia in the Haber Process is usually carried out at about 400°C and 200 atmospheres pressure.

_____

_____

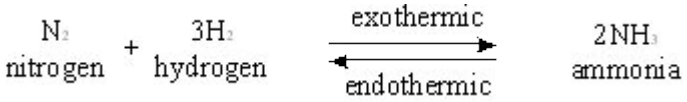
_____

(2)

(Total 6 marks)

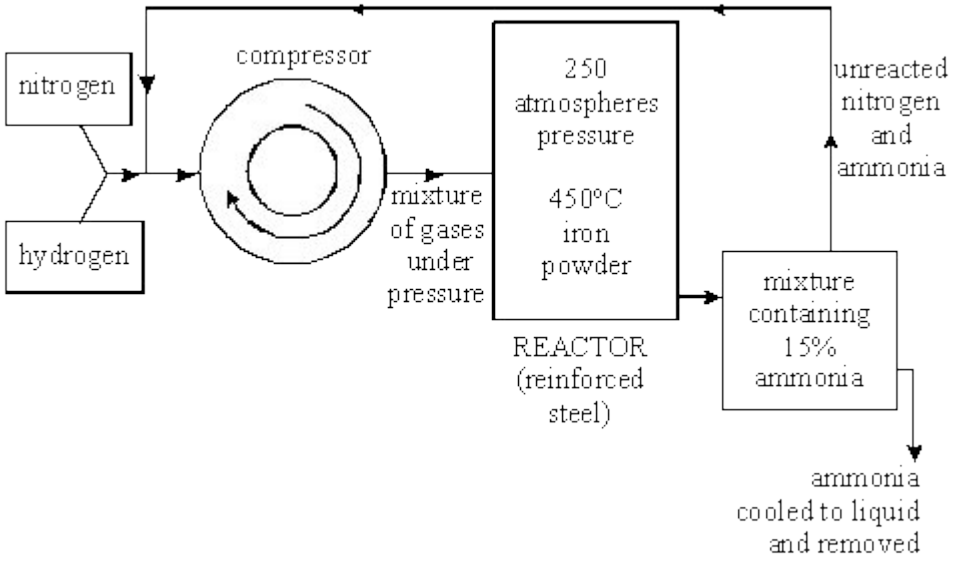
Q15.

Ammonia is manufactured from nitrogen and hydrogen. The reaction is shown in the equation below.

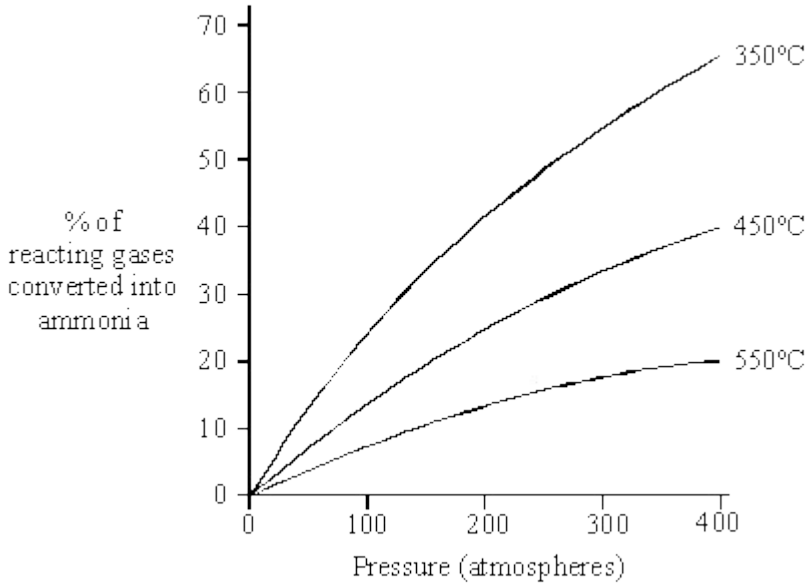


The diagram shows some details of the manufacturing process.

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The graph shows the percentage of reacting gases converted into ammonia at different temperatures and pressures.



At room temperature and pressure, the reaction is very slow and only a small percentage of the reacting gases is converted to ammonia.

Use the information on the diagram and graph to:

(a) describe the conditions used in the manufacture of ammonia **to increase the rate of reaction**.

_____

_____

_____

_____

_____

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_____

(4)

(b) describe and explain the conditions used in the manufacture of ammonia **to increase the yield.**

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(7)

(Total 11 marks)

Q16.

Ammonia is manufactured by the Haber Process, where nitrogen and hydrogen react together as follows:

$N_2 + 3H_2 \Leftrightarrow 2NH_3$

The reaction is reversible. A balance is eventually reached when ammonia is being formed at the same rate at which it is decomposing.

This point is called 'equilibrium'.

	PERCENTAGE OF AMMONIA AT EQUILIBRIUM		
PRESSURE (ATM)	100° C	300° C	500° C
25	91.7	27.4	2.9
100	96.7	52.5	10.6
400	99.4	79,7	31.9

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(a) (i) What is meant by a 'reversible reaction'?

_____

_____

(1)

(ii) Which substances are present in the mixture at equilibrium?

_____

(1)

(b) (i) Under what conditions shown in the table is the maximum yield of ammonia obtained?

_____

_____

(2)

(ii) The Haber Process is usually carried out at a higher temperature than that which would produce the maximum yield. Suggest why.

_____

_____

_____

_____

(2)

(c) Ammonia can be converted into nitric acid in three stages:

Stage 1 Ammonia reacts with oxygen from the air to form nitrogen monoxide and water

$$4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O$$

Stage 2 On cooling, nitrogen monoxide reacts with oxygen from the air to form nitrogen dioxide.

Stage 3 Nitrogen dioxide reacts with water to form nitric acid and nitrogen monoxide.

(i) Describe the conditions under which the reaction in Stage 1 takes place.

_____

_____

_____

_____

(3)

(ii) Balance the equation for the reaction at Stage 2.

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$NO + O_2 \longrightarrow NO_2$

(1)

(iii) Balance the equation for the reaction at Stage 3.

$NO_2 + H_2O \longrightarrow HNO_3 + NO$

(1)

(d) The chemical plant for manufacturing ammonia is often on the same site as plants manufacturing nitric acid and fertilisers.

(i) What advantages will this have for the manufacturing company?

_____

_____

_____

_____

(2)

(ii) Briefly describe **two** important ways in which it is possible to reduce the environmental impact of such plants on the surrounding area.

1. _____

_____

2. _____

_____

(2)

(Total 15 marks)

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