Reversible Reactions + Dynamic Equilibrium 1

These practice questions can be used by students and teachers and is suitable for GCSE AQA Chemistry topic Questions 8462

Level: GCSE AQA Chemistry 8462

Subject: Chemistry

Exam board: GCSE AQA

Topic: Reversible Reactions + Dynamic Equilibrium 1

Q1.

This question is about copper sulfate.

Blue copper sulfate turns white when it is heated.

The word equation for the reaction is:

hydrated copper sulfate ⇌ anhydrous copper sulfate + water

blue white

(a) What name is given to hydrated copper sulfate in this reaction?

Tick **one** box.

- Catalyst ☐
- Element ☐
- Product ☐
- Reactant ☐

(1)

(b) What does the symbol ⇌ mean?

Tick **one** box.

- Endothermic ☐
- Exothermic ☐
- Reversible ☐
- Polymerisation ☐

(1)

(c) Complete the sentence.

The colour change when the water is added to anhydrous copper sulfate

is white to _____ .

(1)

A student heats 2.5 g of hydrate copper sulfate in a test tube.

0.9 g of water is given off.

The remaining solid is anhydrous copper sulfate.

(d) Calculate the mass of anhydrous copper sulfate produced.

_____

_____

_____

_____

Mass of anhydrous copper sulfate = _____ g

(2)

(e) Calculate the percentage of water contained in 2.5 g of hydrated copper sulfate.

_____

_____

_____

_____

_____

_____

Percentage of water = _____ %

(2)

(f) Draw **one** line from each compound to the formula for the compound.

Compound	Formula for the compound
	CuO
Copper sulfate	CuS
	$CuSO_4$
Water	H_2O
	H_2SO_4

(2)

(Total 8 marks)

Q2.

This question is about methanol.

(a) Methanol is broken down in the body during digestion.

What type of substance acts as a catalyst in this process?

Tick **one** box.

- Amino acid ☐
- Enzyme ☐
- Ester ☐
- Nucleotide ☐

(1)

In industry, methanol is produced by reacting carbon monoxide with hydrogen.

The equation for the reaction is:

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

(b) How many moles of carbon monoxide react completely with 4.0×10^3 moles of hydrogen?

Tick **one** box.

1.0×10^3 moles ☐

2.0×10^3 moles ☐

4.0×10^3 moles ☐

8.0×10^3 moles ☐

(1)

(c) The reaction is carried out at a temperature of 250 °C and a pressure of 100 atmospheres.

The forward reaction is exothermic.

Explain what happens to the yield of methanol if a temperature higher than 250 °C is used.

_____

_____

_____

_____

(2)

(d) A pressure of 100 atmospheres is used instead of atmospheric pressure.

The higher pressure gives a greater yield of methanol and an increased rate of reaction.

Explain why.

_____

(4)

A catalyst is used in the reaction to produce methanol from carbon monoxide and hydrogen.

(e) Explain how a catalyst increases the rate of a reaction.

(2)

(f) Suggest why a catalyst is used in this industrial process.

Do **not** give answers in terms of increasing the rate of reaction.

_____

_____

_____

_____

(1)

(g) Suggest the effect of using the catalyst on the equilibrium yield of methanol.

_____

_____

_____

_____

(1)

(Total 12 marks)

Q3.

The Haber Process is used to produce ammonia from nitrogen and hydrogen.

The equation for the reaction is:

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

(a) An ammonia molecule has the formula NH_3

How many atoms are there in one molecule of ammonia?

Tick (✓) **one** box.

2 ☐ 3 ☐ 4 ☐ 6 ☐

(1)

(b) What does the symbol ⇌ mean?

_____

_____

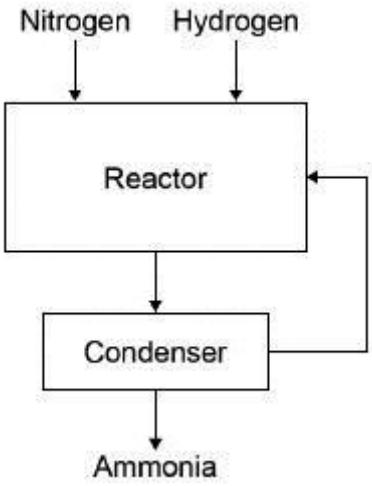
(1)

(c) Draw **one** line from each gas to the source of that gas.

Gas	Source
	Air
Hydrogen	Alcohol
	Ammonia
Nitrogen	Iron
	Natural gas

(2)

The diagram shows the Haber process.



A mixture of ammonia, hydrogen and nitrogen gases leave the reactor.

Table 1 shows the boiling points of the gases.

Table 1

Gas	Boiling point in °C
Ammonia	– 33
Nitrogen	– 196

Hydrogen	– 253

(d) The mixture is cooled to a temperature at which **only** the ammonia condenses to a liquid.

Which temperature could be used?

Tick (✓) **one** box.

− 20 °C ☐

− 40 °C ☐

− 200 °C ☐

− 260 °C ☐

(1)

(e) What happens to the unreacted nitrogen?

Tick (✓) **one** box.

Collected and sold ☐

Recycled to the reactor ☐

Released into the air ☐

Used as a catalyst ☐

(1)

Ammonia from the Haber process can be used to produce fertilisers.

Table 2 gives information about two compounds used in fertilisers.

Table 2

Fertiliser	Compound	Cost in £ / kg

A	Potassium chloride	0.24
B	Diammonium phosphate	0.35

(f) What type of bonding is present in potassium chloride?

Tick (✓) **one** box.

Covalent ☐

Ionic ☐

Metallic ☐

(1)

(g) Diammonium phosphate has the chemical formula $(NH_4)_2HPO_4$

Which **two** elements in $(NH_4)_2HPO_4$ improve agricultural productivity?

Tick (✓) **two** boxes.

Chlorine ☐

Hydrogen ☐

Nitrogen ☐

Oxygen ☐

Phosphorus ☐

A farmer uses fertilisers **A** and **B** on a field with an area of 0.05 km^2

(2)

(h) 50 kg of fertiliser A will cover an area of 0.01 km^2

Calculate the cost of fertilising a field with an area of 0.05 km^2 with fertiliser **A**.

Use **Table 2**.

_____

_____

_____

_____

Cost = £ _____

(2)

(i) Fertiliser **B** is more expensive than fertiliser **A**.

Suggest why the farmer uses **both** fertilisers.

_____

_____

_____

_____

(1)

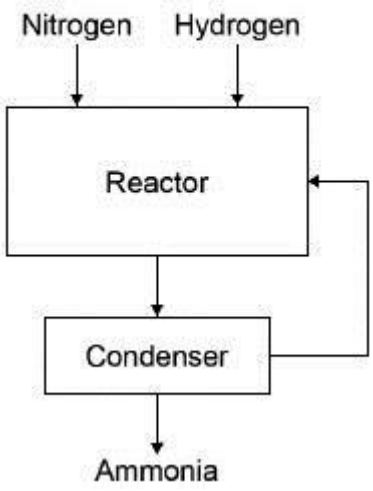
(Total 12 marks)

Q4.

Nitrogen and hydrogen react to produce ammonia in the Haber process.

Figure 1 shows the Haber process.

Figure 1



A gaseous mixture of ammonia, hydrogen and nitrogen leaves the reactor.

Table 1 shows the boiling points of the gases.

Table 1

Gas	Boiling point in °C
Ammonia	−33
Nitrogen	−196
Hydrogen	−253

(a) Suggest how ammonia is separated from the other gases.

(2)

(b) What happens to the unreacted hydrogen and nitrogen?

(1)

The equation for the reaction is:

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

The forward reaction is exothermic.

(c) Calculate the volume of ammonia produced from the complete reaction of 825 dm^3 of hydrogen.

Volume of ammonia = _____ dm^3

(2)

(d) The Haber process uses a temperature of 450 °C and a pressure of 200 atmospheres.

Why are these conditions used?

Tick **two** boxes.

A higher pressure is maintained using less energy	☐
A higher temperature would increase the equilibrium yield	☐
A lower pressure would decrease the equilibrium yield	☐
A lower temperature would make the reaction too slow	☐
There are more product molecules than reactant molecules	☐

(2)

Most of the ammonia produced is used to make fertilisers.

Table 2 shows information about compounds used as fertilisers.

Table 2

Compound	Formula	Cost in £ / tonne
A	NH_4NO_3	220
B	$(NH_4)_2HPO_4$	350
C	KCl	235

(e) Which element in compound A improves agricultural productivity?

_____

_____

(1)

(f) Which **two** compounds can be mixed to make a fertiliser containing three elements that improve agricultural productivity?

Give a reason why you have chosen these compounds.

Compounds _____ and _____

Reason

_____

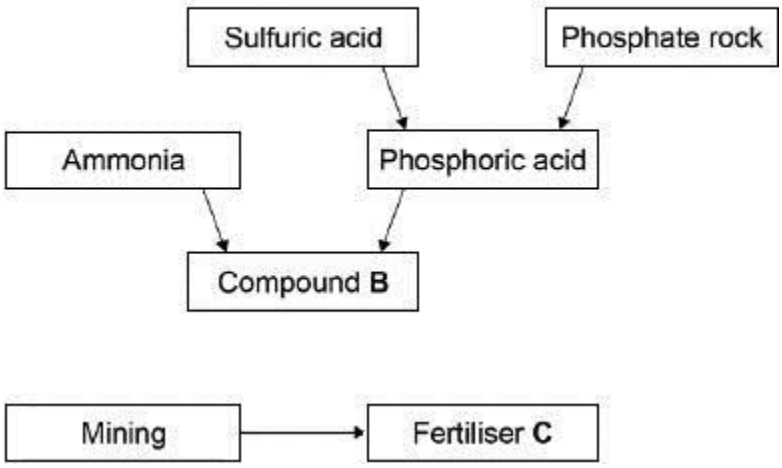
_____

_____

(2)

(g) **Figure 2** shows a flow chart for the production of compounds B and C.

Figure 2



Suggest **two** possible reasons for the difference in cost between compounds **B** and **C**.

1.

_____

___

_____

_____

2.

_____

___

_____

(2)

(Total 12 marks)

Q5.

Cobalt forms coloured compounds.

A pink cobalt compound reacts with hydrochloric acid.

The reaction can be represented as:

pink cobalt compound + hydrochloric acid ⇌ blue cobalt compound + water

The forward reaction is endothermic.

When both cobalt compounds are present in a solution at equilibrium, the equilibrium mixture is purple.

(a) What is meant by equilibrium?

(2)

(b) The equilibrium mixture is cooled.

Explain what happens to the concentration of the pink cobalt compound.

(3)

(c) More hydrochloric acid is added.

Explain what happens to the colour of the equilibrium mixture

(3)

(d) Why does cobalt form different coloured compounds?

(1)

(e) An oxide of cobalt has the formula Co_2O_3

Which cobalt ion is present in this oxide?

Tick (✓) **one** box.

Co^+ ☐

Co^{2+} ☐

Co^{3+} ☐

Co^{4+} ☐

(1)

(f) Cobalt compounds can act as catalysts.

Which two statements about cobalt compounds are correct?

Tick (✓) **two** boxes.

- They allow reactions to reach equilibrium more quickly. ☐
- They are reactants in reactions catalysed by cobalt compounds. ☐
- They are used up when acting as catalysts. ☐
- They increase the equilibrium yield of reactions. ☐
- They provide a different reaction pathway. ☐

(2)

(g) The reaction of hydrogen with carbon monoxide is catalysed by cobalt metal.

Balance the equation for the reaction.

$$H_2 \quad + \quad CO \quad \longrightarrow \quad C_6H_{14} \quad + \quad H_2O$$

(1)

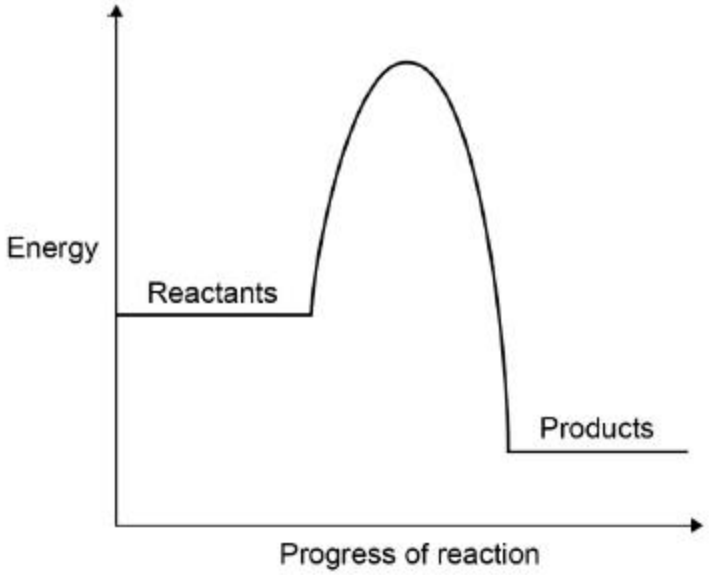
(h) C_6H_{14} is an alkane.

What is the formula of an alkane containing 18 hydrogen atoms?

_____

(1)

(i) The graph shows a reaction profile diagram for a reaction **without** a catalyst.



On the graph:

- draw the reaction profile diagram for a catalysed reaction
- draw and label an arrow to show the activation energy for the reaction **without** a catalyst.

(2)

(Total 16 marks)

Q6.

The word equation shows the reaction between anhydrous cobalt chloride and water.

anhydrous cobalt chloride (blue) + water ⇌ hydrated cobalt chloride (pink)

(a) Name the type of reaction shown by the sign ⇌

_____

_____

(1)

(b) When the student added water to anhydrous cobalt chloride what happened?

_____

_____

(1)

(c) A student measured the temperature rise when anhydrous cobalt chloride was added to water.

The student's results are shown in the table below.

	Trial 1	**Trial 2**	**Trial 3**
Temperature rise in °C	8.5	8.2	8.2

Calculate the mean temperature rise.

_____

_____

Temperature = _____ °C

(1)

(d) When water was added to anhydrous cobalt chloride an exothermic reaction took place.

Name the type of reaction when hydrated cobalt chloride reacts to form anhydrous cobalt chloride and water.

_____

_____

_____

_____

(1)

(Total 4 marks)

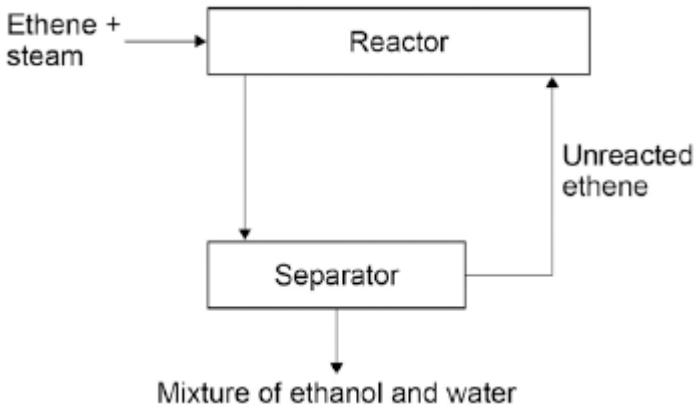
Q7.

In industry ethanol is produced by the reaction of ethene and steam at 300°C and 60 atmospheres pressure using a catalyst.

The equation for the reaction is:

$$C_2H_4\ (g) + H_2O\ (g) \rightleftharpoons C_2H_5OH\ (g)$$

The figure below shows a flow diagram of the process.



(a) Why does the mixture from the separator contain ethanol and water?

_____

_____

_____

_____

(1)

(b) The forward reaction is exothermic.

Use Le Chatelier's Principle to predict the effect of increasing temperature on the amount of ethanol produced at equilibrium.

Give a reason for your prediction.

_____

_____

_____

_____

_____

_____

_____

_____

(2)

(c) Explain how increasing the pressure of the reactants will affect the amount of ethanol produced at equilibrium.

_____

_____

_____

_____

_____

_____

_____

_____

(2)

(Total 5 marks)

Q8.

This question is about ammonia and fertilisers.

(a) Ammonia is produced by a reversible reaction.

The equation for the reaction is:

$$N_2 + 3H_2 \rightleftharpoons 2NH_3$$

Complete the sentence.

The forward reaction is exothermic, so the reverse reaction

is _____

(1)

(b) Calculate the percentage by mass of nitrogen in ammonia (NH_3).
Relative atomic masses (A_r): H = 1; N = 14
You **must** show how you work out your answer.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Percentage by mass of nitrogen = _____ %

(3)

(c) A neutral solution can be produced when ammonia reacts with an acid.

(i) Give the pH of a neutral solution.

pH _____

(1)

(ii) Which of these ionic equations shows a neutralisation reaction?

Tick (✓) **one** box.

$H^+ + OH^- \longrightarrow H_2O$ ☐

$NH_4^+ + OH^- \longrightarrow NH_4OH$ ☐

$H^+ + Cl^- \longrightarrow HCl$ ☐

$H^+ + H_2O \longrightarrow H_3O^+$ ☐

(1)

(iii) Name the salt produced when ammonia reacts with hydrochloric acid.

_____

(1)

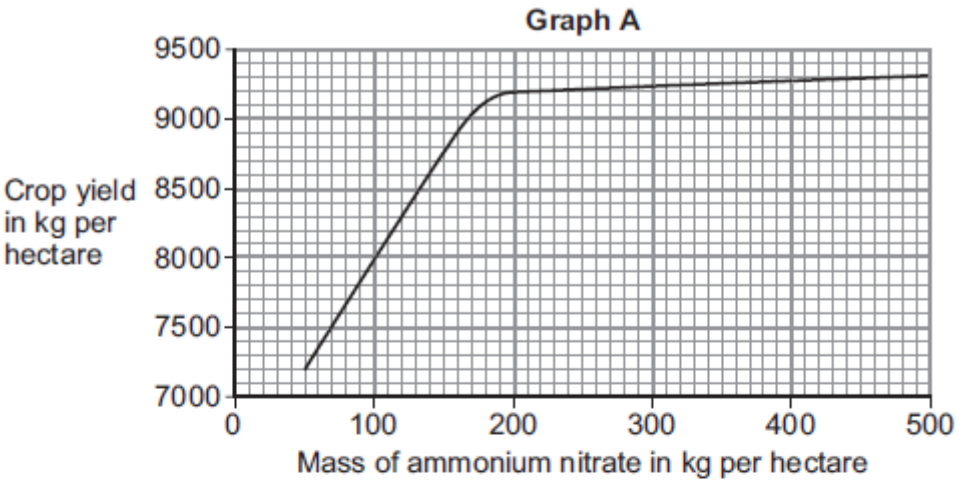
(d) **In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.**

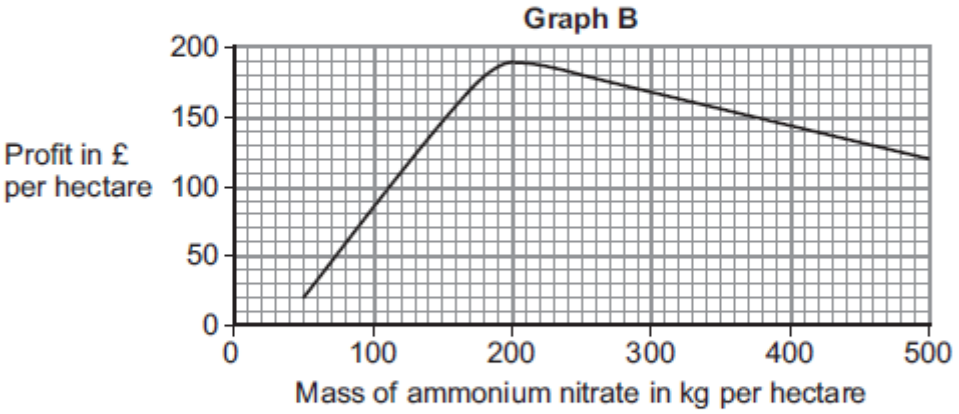
Farmers use ammonium nitrate as a fertiliser for crops.

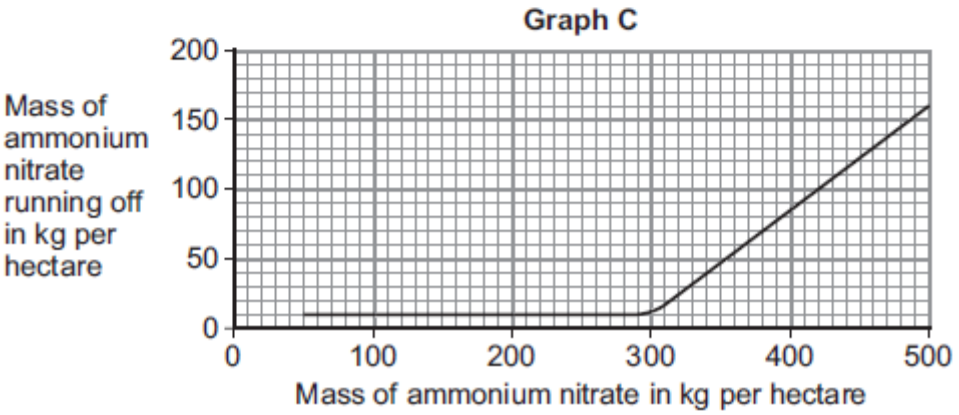
Rainwater dissolves ammonium nitrate in the soil.

Some of the dissolved ammonium nitrate runs off into rivers and lakes.

The graphs **A**, **B** and **C** below show information about the use of ammonium nitrate as a fertiliser. A hectare is a measurement of an area of land.







Suggest how much ammonium nitrate farmers should use per hectare.

Give reasons for your answer.

Use information from graphs **A**, **B** and **C**.

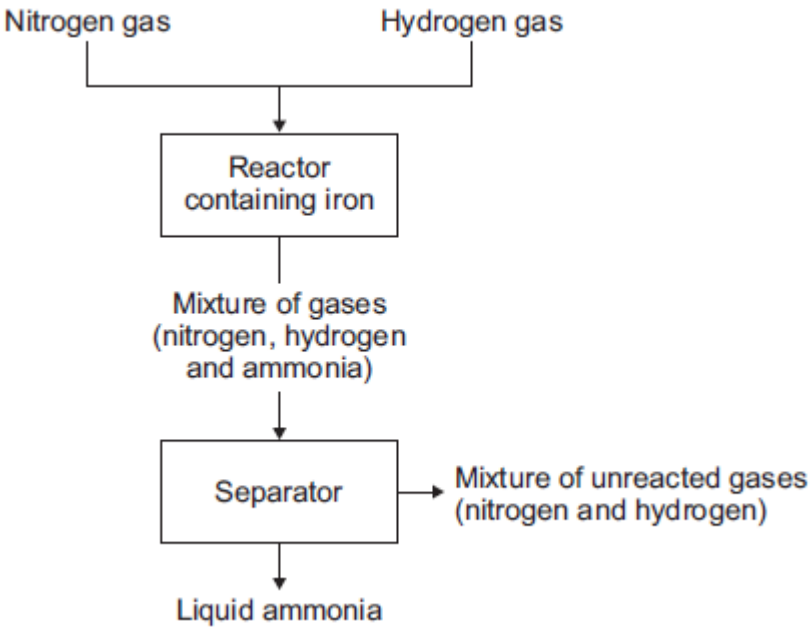
(6)

(Total 13 marks)

Q9.

This question is about the Haber process.

The diagram below shows a flow diagram for the Haber process.



(a) (i) Nitrogen gas and hydrogen gas are obtained from different sources.
Draw **one** line from each gas to its source.

Gas	Source
	Air
Nitrogen	Iron ore
Hydrogen	Limestone
	Natural gas

(2)

(ii) Explain why iron is used in the reactor for the Haber process.

_____

_____

_____

(2)

(iii) Describe how the ammonia is separated from the other gases.

_____

_____

_____

(2)

(iv) What happens to the mixture of unreacted gases (nitrogen and hydrogen)?

_____

_____

_____

(1)

(b) The reaction to produce ammonia is reversible.

Complete the word equation for this reaction.

nitrogen + _____

(2)

(Total 9 marks)

Q10.

This question is about ethanol.

(a) Ethanol can be made by fermentation of sugars from plants.

(i) What is a suitable temperature for fermentation?

Draw a ring around the correct answer.

0 °C **25 °C** **450 °C**

(1)

(ii) Fermentation produces a dilute solution of ethanol in water.

Name the process used to obtain ethanol from this dilute solution.

_____

(1)

(b) Ethanol made by fermentation can be used as a biofuel.

(i) Explain why increasing the use of biofuels may cause food shortages.

_____

_____

_____

_____

(2)

(ii) Explain why burning biofuels contributes less to climate change than burning fossil fuels.

_____

_____

_____

_____

_____

(2)

(c) **In this question you will be assessed on using good English, organising**

information clearly and using specialist terms where appropriate.

Ethanol can also be made by reacting ethene with steam in the presence of a catalyst.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g)$$

Figure 1 shows how the percentage yield of ethanol changes as the pressure is changed at three different temperatures.

Figure 1

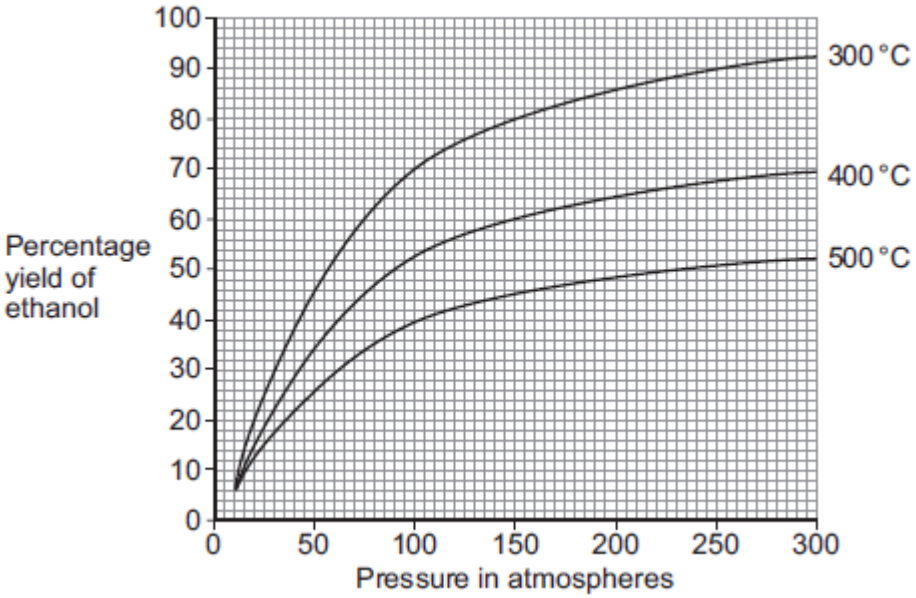
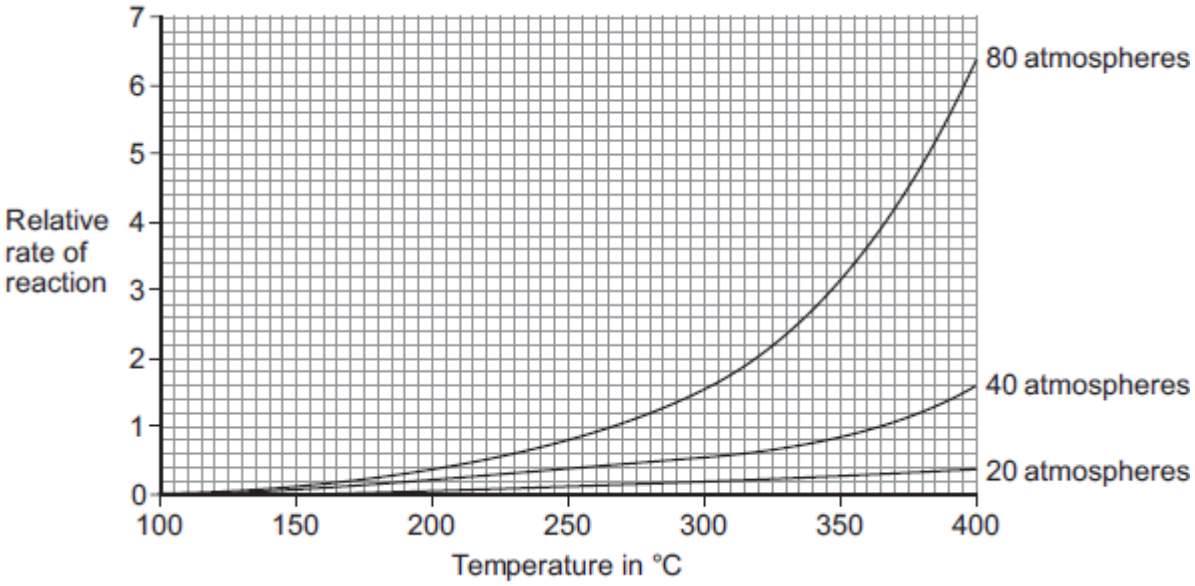


Figure 2 shows how the rate of reaction changes as the temperature changes at three different pressures.

Figure 2



In one process for the reaction of ethene with steam the conditions are:

- 300 °C
- 65 atmospheres
- a catalyst.

Use the information in **Figure 1** and **Figure 2**, and your own knowledge, to justify this choice of conditions.

_____

_____

_____

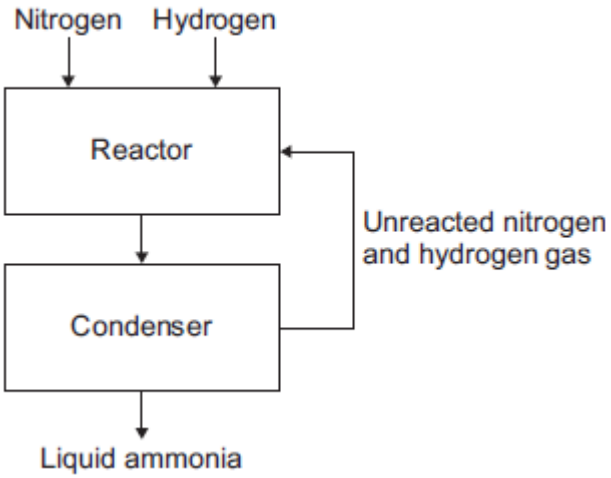
(6)

(Total 12 marks)

Q11.

A flow diagram of the Haber process is shown below.

The Haber process produces ammonia from nitrogen and hydrogen.



(a) Use the correct answer from the box to complete the sentence.

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

Hydrogen is obtained from _____ .

(1)

(b) In the reactor, nitrogen and hydrogen at a high pressure are heated and passed over a catalyst.

(i) Use the correct answer from the box to complete the sentence.

25	**100**	**450**

The temperature in the reactor is _____ °C

(1)

(ii) Use the correct answer from the box to complete the sentence.

copper	**iron**	**nickel**

The catalyst used in the reactor is _____ .

(1)

(iii) How does a catalyst speed up a reaction?

Tick (✓) **one** box.

The catalyst lowers the activation energy. ☐

The catalyst gives the reactants extra energy. ☐

The catalyst increases the pressure in the reactor. ☐

(1)

(c) A mixture of gases leaves the reactor.

The mixture contains ammonia, nitrogen and hydrogen.

Describe what happens to this mixture of gases in the condenser.

Use the flow diagram to help you.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(Total 7 marks)

Q12.

This question is about reversible reactions and chemical equilibrium.

(a) Reversible reactions can reach equilibrium in a closed system.

(i) What is meant by a closed system?

_____

_____

_____

_____

(1)

(ii) Explain why, when a reversible reaction reaches equilibrium, the reaction appears to have stopped.

_____

_____

_____

_____

_____

_____

_____

_____

(2)

(b) In the Haber process, the reaction of nitrogen with hydrogen to produce ammonia is reversible.

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

(i) Name a natural resource from which hydrogen is produced.

_____

_____

(1)

(ii) The Haber process uses a catalyst to speed up the reaction.

Explain how a catalyst speeds up a reaction.

_____

_____

(2)

(iii) What happens to the amount of ammonia produced at equilibrium if the pressure is increased?

Give a reason for your answer.

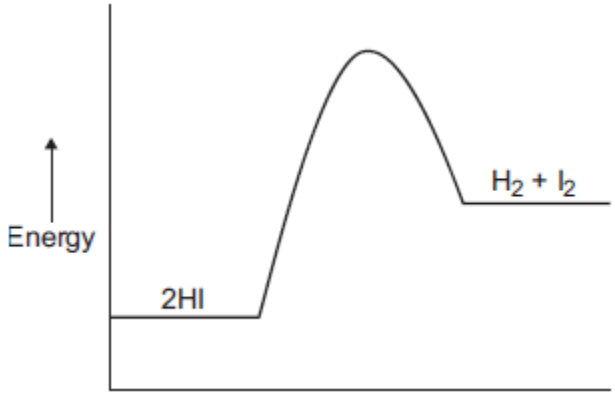
(2)

(c) The decomposition of hydrogen iodide into hydrogen and iodine is reversible.

$$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$$

The forward reaction is endothermic.

The energy level diagram shown below is for the forward reaction.



(i) Draw an arrow to show the activation energy on the diagram.

(1)

(ii) How does the diagram show that the reaction is endothermic?

_____

_____

_____

(1)

(iii) Suggest what effect, if any, increasing the temperature will have on the amount of hydrogen iodide at equilibrium.

Give a reason for your answer.

_____

_____

_____

_____

_____

_____

_____

_____

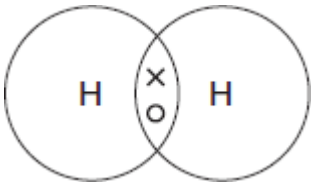
(2)

(Total 12 marks)

Q13.

Hydrogen gas is produced by the reaction of methane and steam.

(a) The diagram represents a molecule of hydrogen.



(i) What type of bond joins the atoms of hydrogen?

Tick (✓) **one** box.

Covalent ☐

Metallic ☐

Ionic ☐

(1)

(ii) A catalyst is used in the reaction.

Draw a ring around the correct answer to complete the sentence.

A catalyst

increases the rate of reaction.
increases the temperature.
increases the yield of a reaction.

(1)

(b) The equation for the reaction of methane and steam is:

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$$

(i) What is meant by the symbol $\rightleftharpoons$?

_____

(1)

(ii) Lowering the pressure reduces the rate of reaction.

Explain why, in terms of particles.

_____

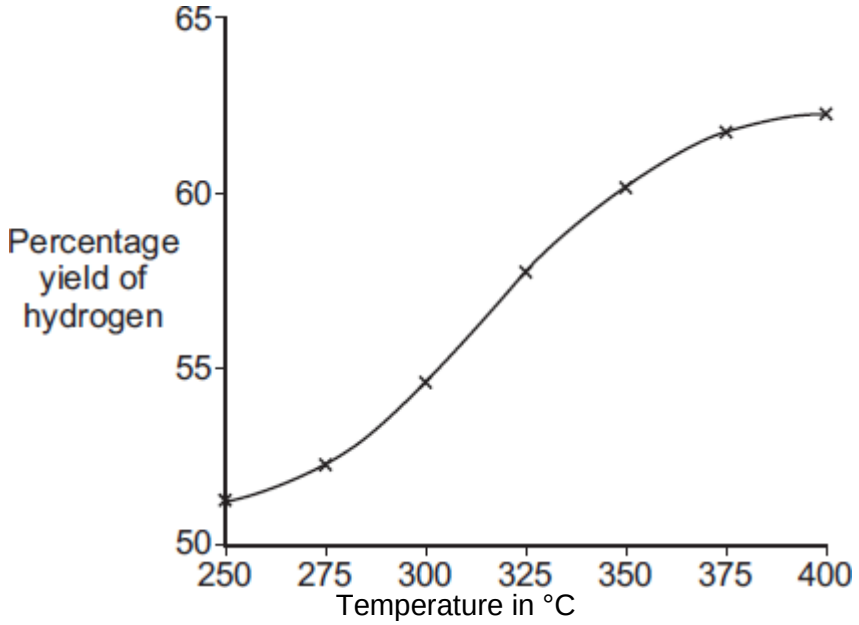
_____

_____

_____

(2)

(iii) The graph shows the yield of hydrogen at different temperatures.



The forward reaction is endothermic.

How does the graph show that the forward reaction is endothermic?

_____

_____

_____

(1)

(iv) Why is a higher yield produced if the reaction is repeated at a lower pressure?

_____

_____

_____

_____

(1)

(c) *In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.*

Car engines are being developed that use hydrogen gas as a fuel instead of petrol.

The table compares the two fuels.

Hydrogen	Petrol

Energy	5700 kJ per litre	34 000 kJ per litre
State	Gas	Liquid
Equation for combustion	$2H_2 + O_2 \rightarrow 2H_2O$	$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$
How the fuel is obtained	Most hydrogen is produced from coal, oil or natural gas. Hydrogen can be produced by the electrolysis of water or the solar decomposition of water.	Fractional distillation of crude oil.

Use the information in the table and your knowledge of fuels to evaluate the use of hydrogen instead of petrol as a fuel.

You should describe the advantages and disadvantages of using hydrogen instead of petrol.

Extra space

(6)

(Total 13 marks)

Q14.

A company manufactures ethanol (C_2H_5OH).

The reaction for the process is:

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \qquad \Delta H = -45 \text{ kJ per mole}$$

The temperature and pressure can be changed to increase the yield of ethanol at equilibrium.

(a) Explain what is meant by equilibrium.

(3)

(b) (i) How would increasing the temperature change the **yield** of ethanol at equilibrium?

Give a reason for your answer.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(2)

(ii) How would increasing the pressure change the **yield** of ethanol at equilibrium?

Give a reason for your answer.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(2)

(c) A catalyst is added to increase the rate of the reaction.

Explain how adding a catalyst increases the rate of a chemical reaction.

_____

_____

_____

_____

_____

_____

_____

_____

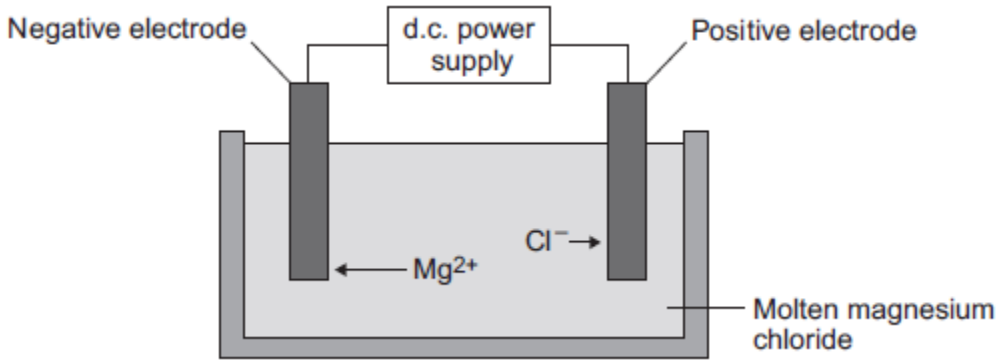
(2)

(Total 9 marks)

Q15.

Some students investigated reactions to produce magnesium.

(a) The students used electrolysis to produce magnesium from magnesium chloride, as shown in the figure below.



(i) Magnesium chloride contains magnesium ions and chloride ions.

Why does solid magnesium chloride **not** conduct electricity?

_____

_____

_____

_____

(1)

(ii) One of the products of the electrolysis of molten magnesium chloride is magnesium.

Name the other product.

_____

_____

(1)

(iii) Why do magnesium ions (Mg^{2+}) move to the negative electrode?

_____

_____

_____

_____

(1)

(iv) At the negative electrode, the magnesium ions (Mg^{2+}) gain electrons to become magnesium atoms.

How many electrons does each magnesium ion gain?

_____

(1)

(b) The students did the experiment four times and weighed the magnesium produced.

The table below shows their results.

Experiment	Mass of magnesium produced in grams
1	1.13
2	0.63
3	1.11
4	1.09

(i) There is an anomalous result.

Suggest **one** possible reason for the anomalous result.

_____

_____

_____

_____

(1)

(ii) Calculate the mean mass of magnesium produced, taking account of the anomalous result.

_____

_____

_____

_____

_____

Mean mass = _____ g

(2)

(c) The formula of magnesium chloride is $MgCl_2$

The relative formula mass of magnesium chloride is 95.

The relative atomic mass of magnesium is 24.

(i) Use the equation to calculate the percentage mass of magnesium in magnesium chloride.

$$\text{Percentage mass of magnesium} = \frac{\text{mass of magnesium}}{\text{mass of magnesium chloride}} \times 100\%$$

_____

_____

_____

Percentage mass of magnesium in magnesium chloride = _____ %

(2)

(ii) Draw a ring around the relative mass of chlorine in $MgCl_2$

71 **95** **119**

(1)

(d) Magnesium is also produced from the reaction of magnesium oxide with silicon.

(i) The equation for the reaction is:

$$2\,MgO(s) + Si(s) \rightleftharpoons SiO_2(s) + 2\,Mg(s)$$

What is the meaning of this symbol $\rightleftharpoons$?

Draw a ring around the correct answer.

neutralisation reaction **precipitation reaction** **reversible reaction**

(1)

(ii) The forward reaction is endothermic.

Draw a ring around the correct answer to complete the sentence.

In an endothermic reaction the temperature of the surroundings

decreases.
increases.
stays the same.

(1)

(Total 12 marks)

Q16.

In 1909 Fritz Haber invented a process to produce ammonia from nitrogen and hydrogen.

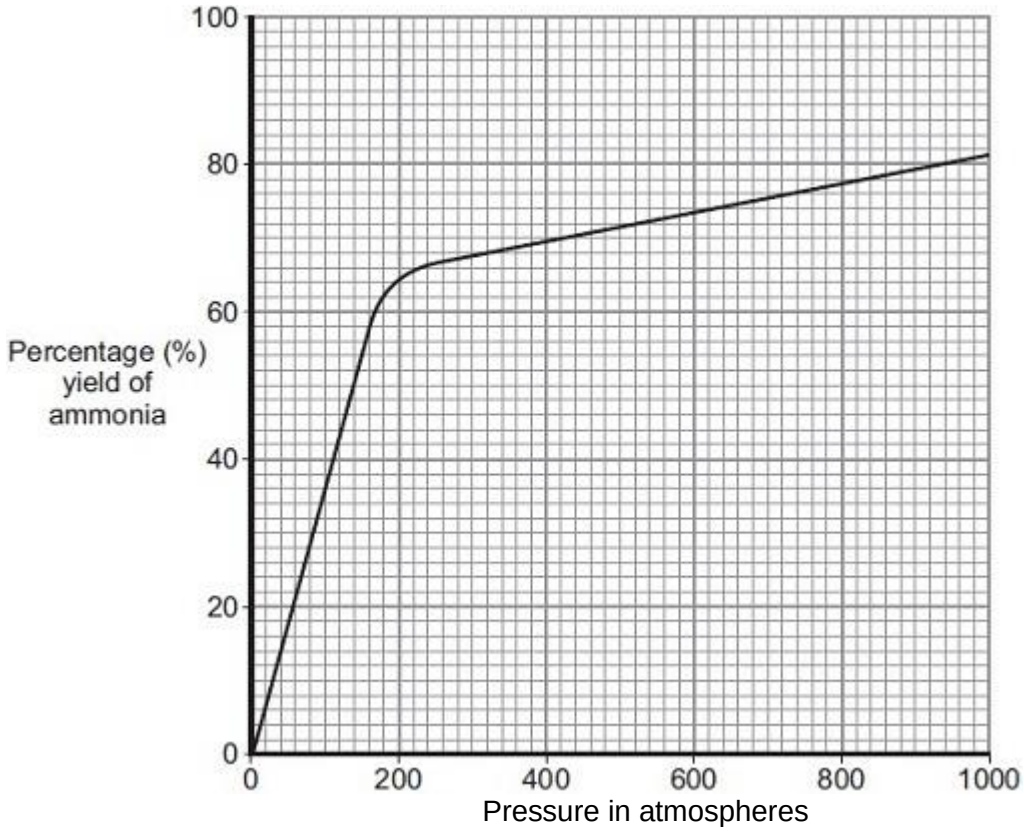
(a) Complete the word equation, showing that the reaction is reversible.

nitrogen + hydrogen _____ _____

(2)

(b) **Figure 1** shows how the yield of ammonia at 300 °C changes with pressure.

Figure 1

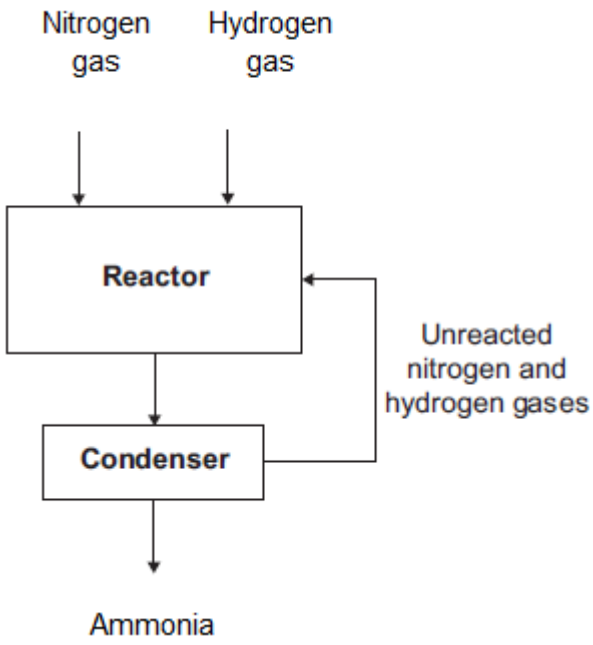


Describe how the yield of ammonia changes as the pressure increases.

(3)

(c) **Figure 2** represents the Haber process.

Figure 2



How does the Haber process avoid wasting nitrogen and hydrogen?

_____

_____

(1)

(d) Before the Haber process, nitrates had been mined in South America. Nitrates are used for making fertilisers.

The Haber process allowed nitrates to be produced on a large scale, anywhere in the world.

(i) Suggest what effect the Haber process had on the miners in South America.

_____

_____

(1)

(ii) Suggest **one** advantage of producing nitrates on a large scale.

_____

_____

(1)

(Total 8 marks)

Q17.

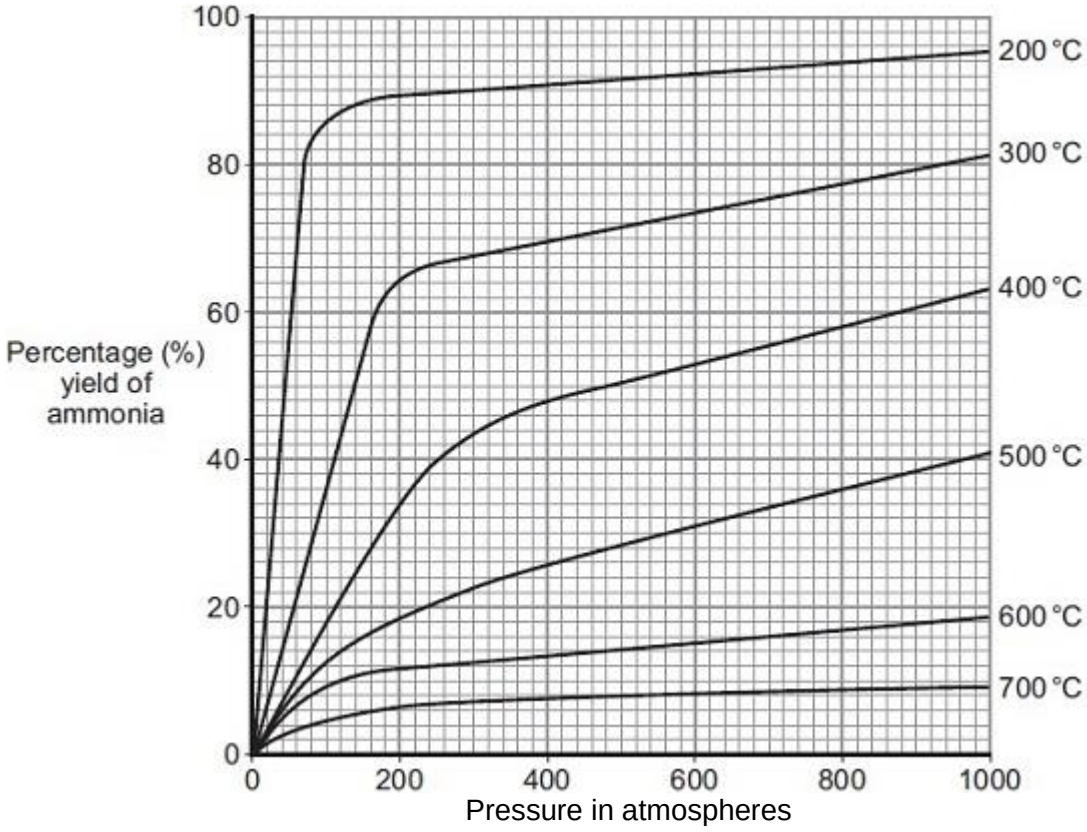
In 1909 Fritz Haber invented a process to produce ammonia from nitrogen and hydrogen.

(a) Complete and balance the chemical equation for the production of ammonia from nitrogen and hydrogen.

$N_2 \quad + \quad 3\ H_2 \quad \rightleftharpoons \quad$ _____

(2)

(b) The figure below shows how the equilibrium yield of ammonia changes with pressure at different temperatures.



(i) Use the information in given in the figure to complete the sentence.

The temperature on the graph that gives the highest yield of ammonia is

_____ °C.

(1)

(ii) The temperature used in the Haber process for the production of ammonia is 450 °C.

Why is a temperature much lower than 450 °C **not** used for the Haber process?

_____

_____

(1)

(iii) Use the information in the figure to answer this question.

Draw a ring around the pressure that gives the highest yield of ammonia.

100 **200** **300** **400**

(1)

(iv) The pressure used in the Haber process for the production of ammonia is 200 atmospheres.

Why is a pressure lower than 200 atmospheres **not** used for the Haber process?

_____

_____

(1)

(c) Explain how ammonia is separated from unreacted nitrogen and hydrogen in the Haber process.

_____

_____

_____

_____

(2)

(Total 8 marks)

Q18.

Ammonium salts, such as ammonium sulfate, are used to help farmers grow crops.

(a) Use the correct word from the box to complete the sentence.

fertilisers	**insecticides**	**pesticides**

Ammonium salts contain nitrogen and are used by farmers as

_____to replace the nitrogen lost from the soil.

(1)

(b) Ammonia is made by reacting nitrogen with hydrogen.

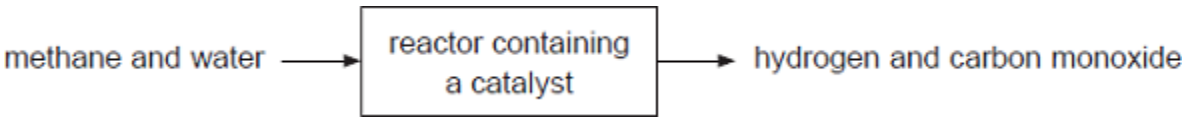
Which raw material provides nitrogen?

Draw a ring around your answer.

air **crude oil** **water**

(1)

(c) Methane and water react together to form hydrogen.



How does the catalyst help this reaction?

_____

(1)

(d) The reaction between nitrogen and hydrogen to make ammonia can be represented by this equation.

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

What is the meaning of this symbol $\rightleftharpoons$?

Draw a ring around your answer.

endothermic reaction **precipitation reaction** **reversible reaction**

(1)

(e) A solution of ammonia in water is alkaline.

(i) Which **one** of these values could be the pH of a solution of ammonia?

Draw a ring around your answer.

4 **7** **10**

(1)

(ii) Ammonium sulfate can be made by reacting ammonia solution with sulfuric acid.

Use the correct answer from the box to complete the sentence.

ammonium sulfate	**hydrogen**	**sulfuric**	**water**

During the reaction the hydrogen ions (H^+) from the acid react with hydroxide ions

(OH^-) from the alkali to make

_____ .

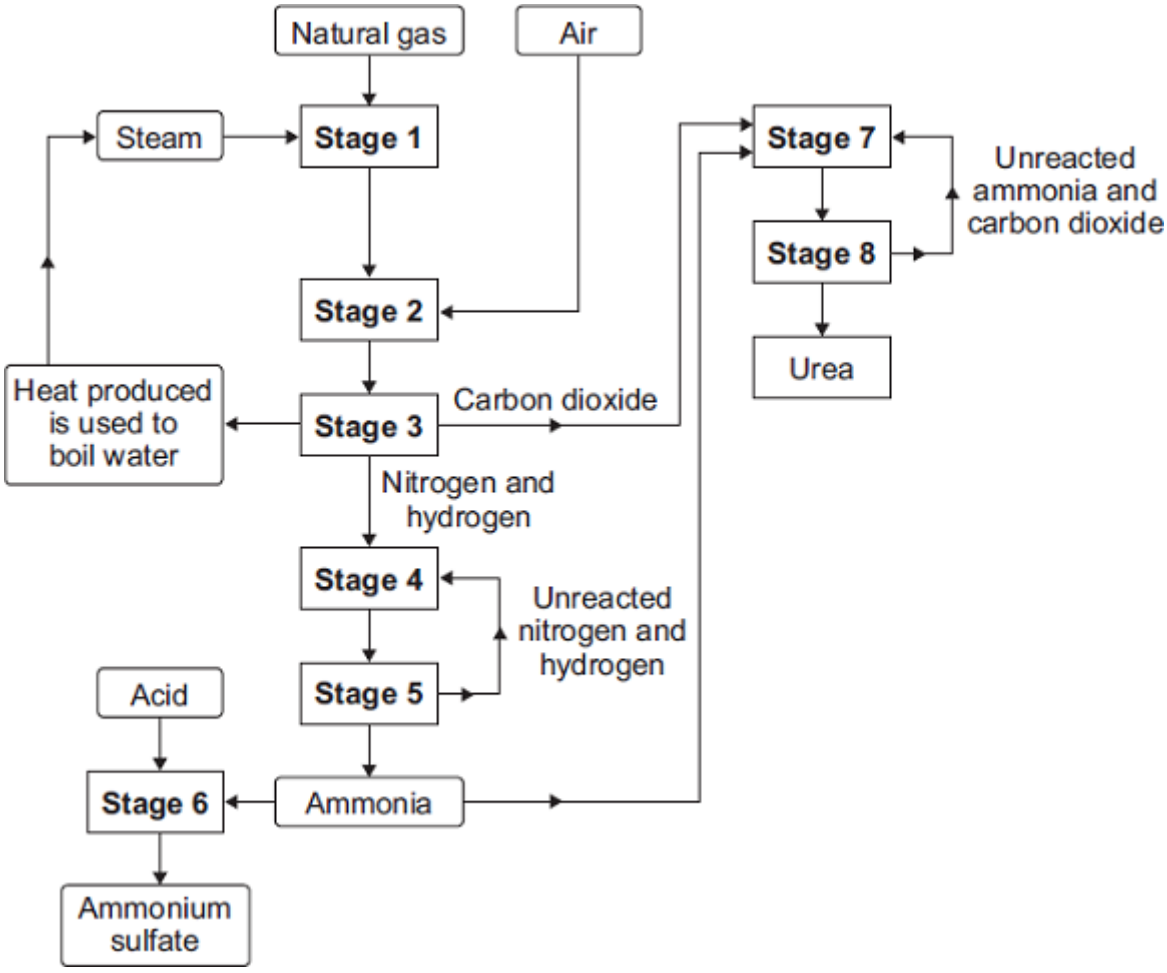
(1)

(Total 6 marks)

Q19.

Ammonium sulfate and urea are made from ammonia. These compounds are used by farmers.

The flow diagram shows the stages to make ammonium sulfate and urea.



(a) Give **two** examples from the flow diagram of the efficient use of energy and raw materials.

_____

_____

_____

_____

_____

_____

(2)

(b) The equation for the reaction in Stage **4** is shown below.

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

The forward reaction is exothermic.

State **and** explain:

(i) how a **decrease** in temperature would affect the yield of ammonia at equilibrium

(2)

(ii) how an **increase** in pressure would affect the yield of ammonia at equilibrium.

(2)

(c) The equation for the reaction in Stage **7** is shown below.

$$\underset{\text{ammonia}}{2\ NH_3} + CO_2 \rightleftharpoons \underset{\text{urea}}{NH_2CONH_2} + H_2O$$

The table gives the relative formula masses (M_r) of the reactants and the products for this reaction.

Formula of reactant or product	Relative formula masses (M_r)
NH_3	17
CO_2	44
NH_2CONH_2	60
H_2O	18

Percentage atom economy can be calculated using:

$$\text{Percentage atom economy} = \frac{M_r \text{ of useful product}}{\text{total } M_r \text{ of all reactants added together}} \times 100\%$$

Calculate the percentage atom economy for the reaction in Stage **7**.

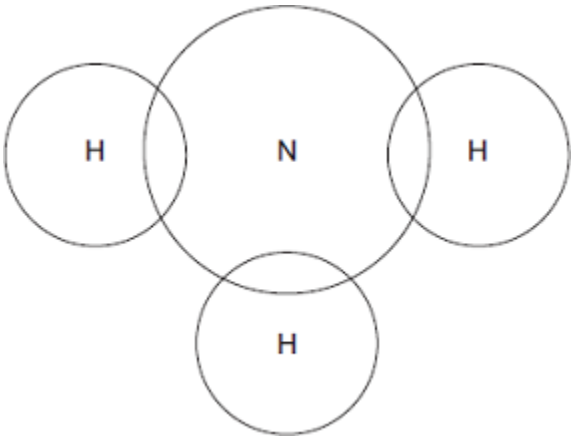
Percentage atom economy = _____ %

(2)
(Total 8 marks)

Q20.

(a) Complete the dot and cross diagram to show the electrons in the outer energy levels of ammonia (NH_3).

You may use the periodic table to help you.



(2)

(b) Ammonia can be used to make ammonium nitrate (NH_4NO_3).

(i) Draw a ring around the correct answer to complete the sentence.

Ammonium nitrate can be made by reacting ammonia with | ethanoic / hydrochloric / nitric | acid.

(1)

(ii) State **one** use of ammonium nitrate.

_____

(1)

(iii) Calculate the relative formula mass (M_r) of ammonium nitrate (NH_4NO_3).

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

_____

_____

Relative formula mass (M_r) = _____

(2)

(iv) Calculate the percentage by mass of nitrogen in ammonium nitrate.

_____

_____

_____

_____

Percentage by mass of nitrogen = _____ %

(2)

(c) *In this question you will be assessed on using good English, organising information clearly and using specialist terms where appropriate.*

Ammonia is manufactured from nitrogen and hydrogen by the Haber process:

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

The forward reaction is exothermic.

The conditions used in the Haber process are:

- 200 atmospheres pressure
- 450 °C
- iron catalyst.

Use the equation and your knowledge of reversible reactions to explain why these conditions are used in the Haber process.

To get full marks you must consider **both** yield **and** rate of reaction in your answer.

_____

_____

_____

_____

_____

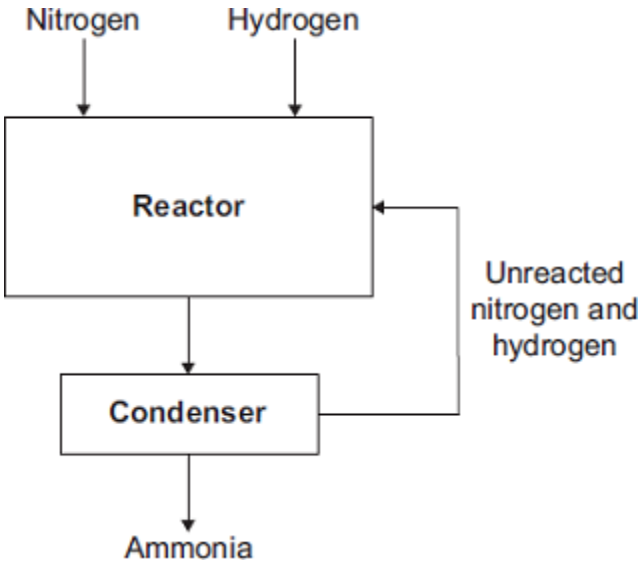
_____

(6)

(Total 14 marks)

Q21.

The flow diagram shows the Haber process. In the Haber process ammonia is produced from nitrogen and hydrogen.



(a) The word equation for the production of ammonia is:

nitrogen + hydrogen $\rightleftharpoons$ ammonia

Draw a ring around the correct answer to complete the sentence.

The symbol $\rightleftharpoons$ in the word equation shows the reaction is

exothermic.
reversible.
slow.

(1)

(b) The reactor contains iron.

Complete the sentence.

The iron speeds up the reaction because it is a _____

(1)

(c) What happens to the unreacted nitrogen and hydrogen?

_____

_____

_____

_____

(1)

(d) The sentences describe how ammonia is produced in the Haber process.

The sentences are in the wrong order.

P Ammonia is separated as a liquid.

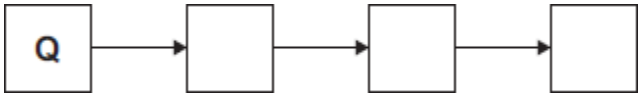
Q Nitrogen and hydrogen are mixed together.

R A mixture of gases enters the condenser.

S Nitrogen and hydrogen react to produce ammonia.

Complete the boxes below to show the correct order of the sentences.

The first box has been done for you.

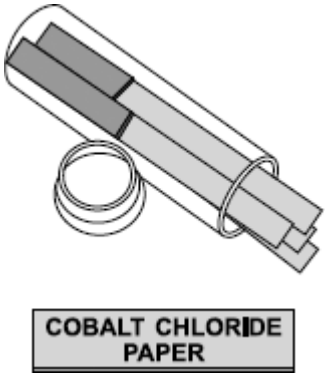


(2)

(Total 5 marks)

Q22.

Read the information and then answer the questions.



Cobalt chloride paper can be used to test for water.

The paper contains anhydrous cobalt chloride.

The jar containing the papers must be kept closed when not being used.

The equation shows the reaction between anhydrous cobalt chloride and water.

$$CoCl_2 + 6\ H_2O \rightleftharpoons CoCl_2.6H_2O$$

anhydrous cobalt chloride — hydrated cobalt chloride

(blue) (pink)

(a) Choose **one** word from the box to complete the sentence.

endothermic	**exothermic**	**reversible**

The symbol ⇌ means that the reaction is _____

(1)

(b) Describe the colour change when water is added to the cobalt chloride paper.

_____

_____

_____

_____

(1)

(c) Suggest why the jar containing the unused cobalt chloride papers must be kept closed.

_____

_____

_____

_____

(1)

(Total 3 marks)

Q23.

(a) Ammonia solution is used in cleaning products to remove grease from kitchen surfaces.

Ammonia solution is alkaline.

(i) Draw a ring around the number most likely to be the pH of ammonia solution.

1 **3** **7** **10**

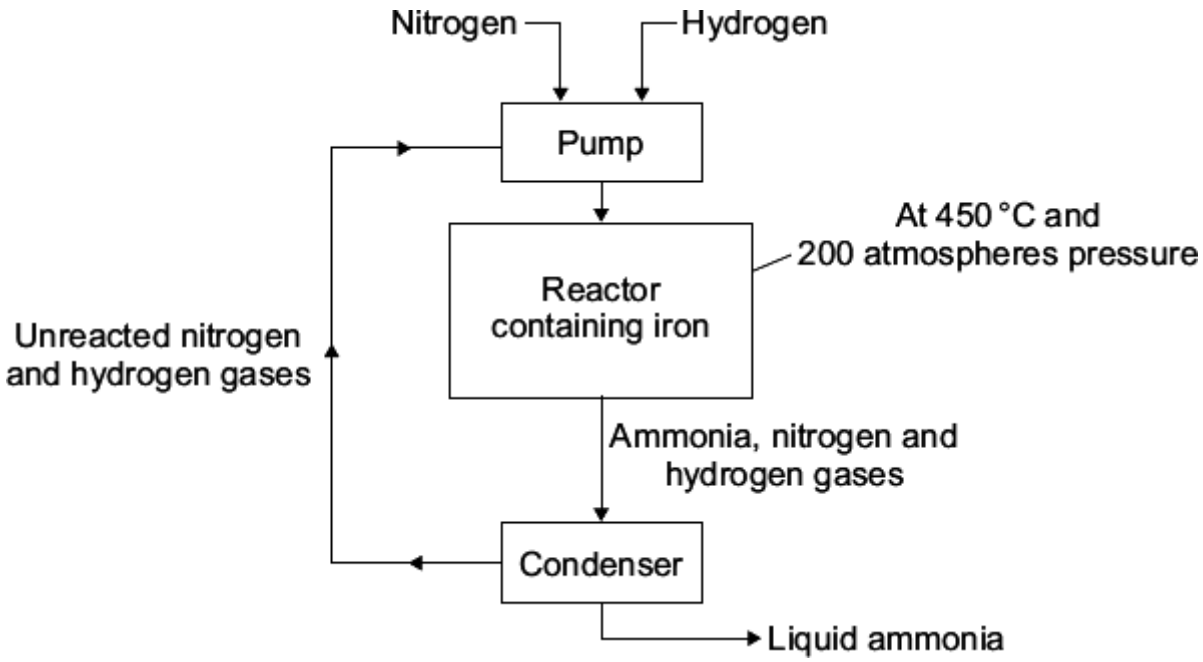
(1)

(ii) Draw a ring around the ion in ammonia solution which makes it alkaline.

Cl^- **H^+** **Na^+** **OH^-**

(1)

(b) Ammonia is made using the Haber process.



(i) Where does the nitrogen used in the Haber process come from?

Draw a ring around your answer.

air **natural gas** **water**

(1)

(ii) A high temperature of 450 °C is used in the reactor.

Tick (✓) **two** reasons in the table which explain why high temperatures make reactions faster.

Reasons	**Tick (✓)**
Particles move faster	
Particles are closer together	
Particles collide more often	
Particles have less energy	

(2)

(iii) The iron in the reactor speeds up the reaction but is not used up.

What is the name given to substances that speed up the chemical reaction but which are not used up during the reaction?

_____

(1)

(c) Complete the sentence.

The condenser separates the ammonia from the unreacted nitrogen and hydrogen

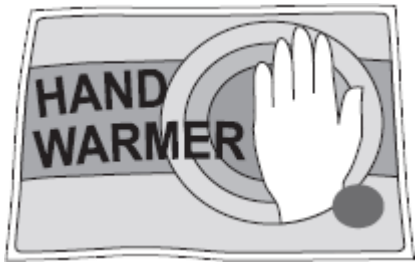
by turning the ammonia into a _____

(1)

(Total 7 marks)

Q24.

Hand warmers use chemical reactions.



(a) The table shows temperature changes for chemical reactions **A**, **B** and **C**.

Reaction	Starting temperature in °C	Final temperature in °C	Change in temperature in °C
A	18	25	+ 7
B	17	_____	+ 5
C	18	27	+ 9

What is the final temperature for reaction **B**? Write your answer in the table.

(1)

(b) (i) What name is given to reactions that heat the surroundings?

_____

(1)

(ii) Which reaction, **A**, **B** or **C**, would be best to use in a hand warmer?

Reaction ☐

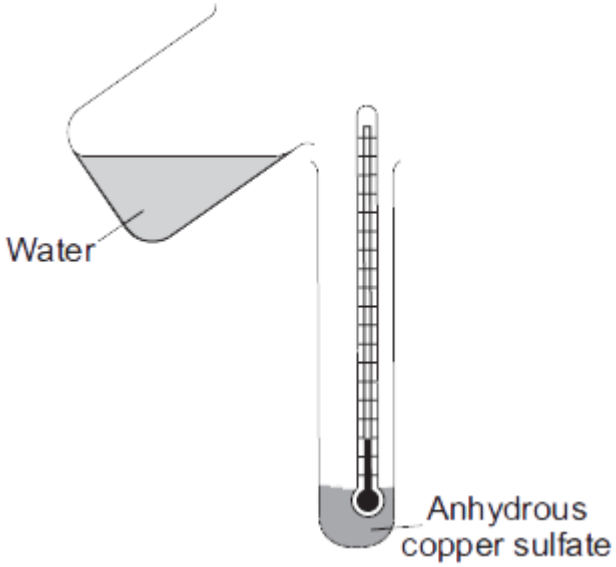
Give a reason why you chose this reaction.

_____

_____

(2)

(c) A student added water to some anhydrous copper sulfate.



The equation for the reaction is shown.

anhydrous copper sulfate + water ⇌ hydrated copper sulfate

$CuSO_4$ + 5 H_2O ⇌ $CuSO_4.5H_2O$

The student measured the temperature before and after the reaction.

(i) The measurements showed that this reaction can be used for a hand warmer.

Draw a ring around the correct answer to complete the sentence.

When water is added to anhydrous copper sulfate the temperature

of the mixture | increases. / decreases.

stays the same.

(1)

(ii) Anhydrous copper sulfate is white.

What colour is seen after water is added to the anhydrous copper sulfate?

_____

(1)

(iii) What does the symbol ⇌ mean?

_____

(1)

(iv) The student heated a tube containing hydrated copper sulfate.

Name the solid substance produced.

_____

(1)

(Total 8 marks)

Q25.

Stage smoke is used for special effects at pop concerts.

By Sam Cockman [CC BY 2.0], via Flickr

Ammonium chloride can be used to make stage smoke.
Ammonium chloride is a white solid.
When heated, ammonium chloride produces white smoke which can be blown onto the stage.

The equation shows what happens when ammonium chloride is heated and cooled.

$$NH_4Cl(s) \underset{\text{cooled}}{\overset{\text{heated}}{\rightleftharpoons}} NH_3(g) + HCl(g)$$

ammonium chloride (white)	ammonia (colourless)	hydrogen chloride (colourless)

(a) The sentences explain how the smoke is made.

Draw a ring around the correct answer in each box to complete each sentence.

Use the information and the equation to help you.

When heated, ammonium chloride makes two colourless [solids. / liquids. / gases.]

These are blown into the air where they cool and make a [colourless / black / white] [solid / liquid / gas]

which is [ammonia. / ammonium chloride. / hydrogen chloride.]

(4)

(b) Complete the sentence.

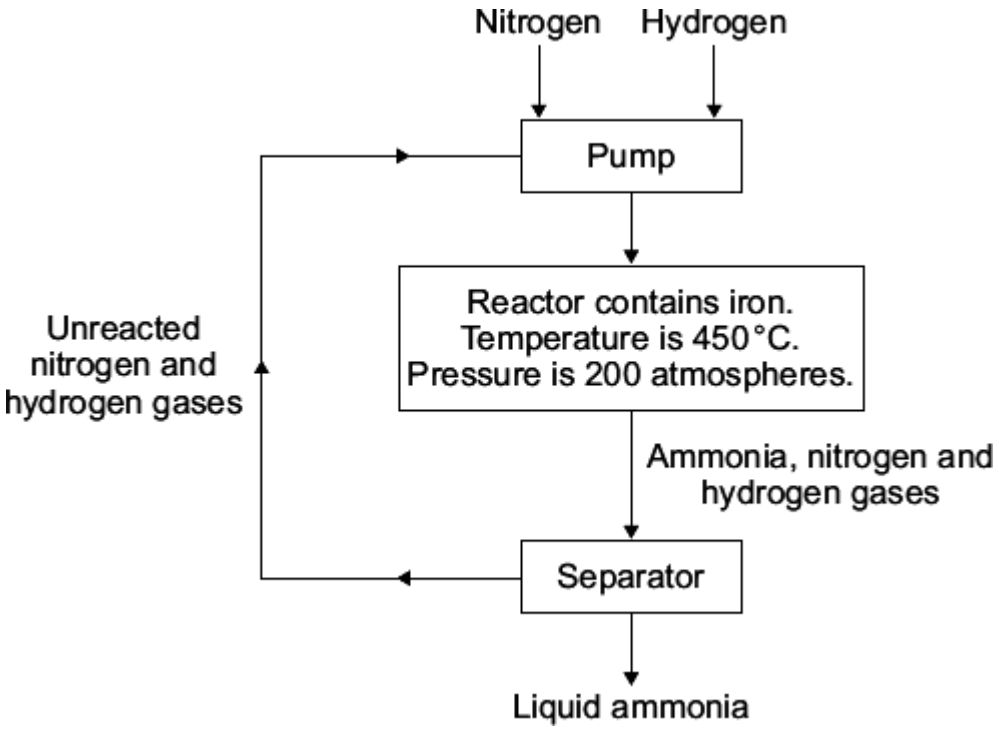
The symbol $\rightleftharpoons$ means that the reaction is _____

(1)

(Total 5 marks)

Q26.

Ammonia is made using the Haber process.



(a) How is ammonia separated from unreacted nitrogen and hydrogen in the separator?

_____

_____

_____

_____

_____

_____

_____

_____

(2)

(b) The equation shows the reaction which takes place in the reactor:

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

(i) Why does the yield of ammonia at equilibrium increase as the temperature is decreased?

_____

_____

_____

_____

(1)

(ii) A temperature of 450 °C is used in the reactor to make the reaction take place quickly.

Explain, in terms of particles, why increasing the temperature makes a reaction go faster.

_____

_____

_____

_____

_____

_____

_____

_____

(2)

(iii) Why does the yield of ammonia at equilibrium increase as the pressure is increased?

_____

_____

_____

_____

(1)

(iv) The pressure used in the reactor is 200 atmospheres.
Suggest why a much higher pressure is **not** used.

_____

_____

_____

_____

(1)

(c) Use the equation for the reaction in the reactor to help you to answer these questions.

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

(i) It is important to mix the correct amounts of hydrogen and nitrogen in the reactor.

20 m^3 of nitrogen is reacted with hydrogen.

What volume of hydrogen (measured at the same temperature and pressure as the nitrogen) is needed to have the correct number of molecules to react with the nitrogen?

Volume of hydrogen needed = _____ m^3

(1)

(ii) Calculate the maximum mass of ammonia that can be made from 2 g of nitrogen.

Relative atomic masses: H = 1; N = 14.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Maximum mass of ammonia = _____ g

(3)

(d) The expected maximum mass of ammonia produced by the Haber process can be calculated.

(i) In one process, the maximum mass of ammonia should be 80 kg.

The actual mass of ammonia obtained was 12 kg.

Calculate the percentage yield of ammonia in this process.

_____

_____

_____

_____

Percentage yield of ammonia = _____ %

(1)

(ii) Give **two** reasons why it does **not** matter that the percentage yield of ammonia is low.
Use the flow diagram at the start of this question to help you.

_____

_____

_____

_____

_____

_____

_____

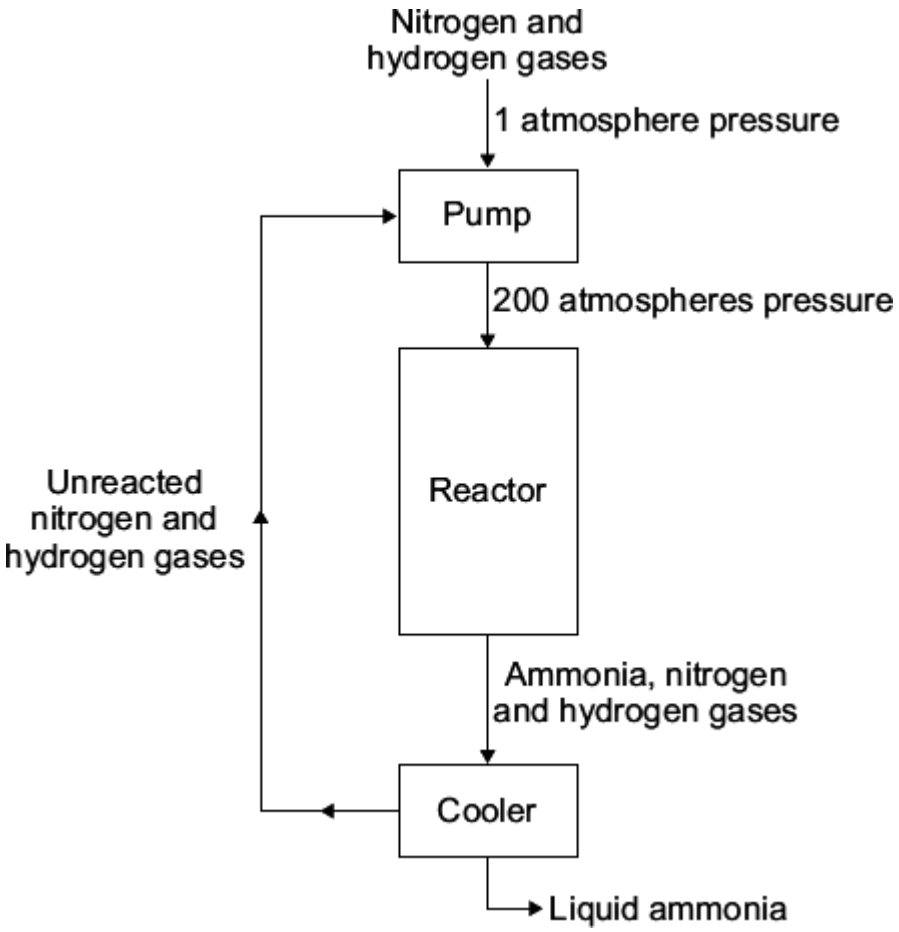
_____

(2)

(Total 14 marks)

Q27.

The flow diagram shows how ammonia is made.



(a) What effect, if any, does the **pump** have on the pressure of the nitrogen and hydrogen?

Draw a ring around the correct answer to complete the sentence.

The pump [decreases / has no effect on / increases] the pressure.

(1)

(b) The word equation for making ammonia is:

nitrogen + hydrogen $\rightleftharpoons$ ammonia

In the **reactor** only a small amount of the nitrogen and hydrogen is changed into ammonia.

Tick (✓) the reason why.

Reason why	Tick (✓)
Ammonia is formed from two elements.	
Nitrogen and hydrogen are gases.	
The reaction is reversible.	

(1)

(c) In the **cooler** the mixture of gases is cooled.

Draw a ring around the correct answer to complete the sentence.

The cooler turns the ammonia into

a liquid.

a solid.

an element.

(1)

(d) What happens to the unreacted nitrogen and hydrogen from the **reactor**?

_____

_____

_____

_____

(1)

(Total 4 marks)

Q28.

Humberstone was a town in the desert of Northern Chile in South America. It was built for the people who worked in the nearby sodium nitrate mines.

The sodium nitrate was used as a fertiliser.

The sodium nitrate was exported by ship to countries all around the world.

Today the mines have closed and nobody lives in Humberstone.

One of the reasons for the mines closing was the invention of the Haber process.

By Sznegra (Own work) [CC-BY-SA-3.0], via Wikimedia Commons

(a) The Haber process is used to make ammonia (NH_3).

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

The forward reaction is exothermic.

(i) Name the raw materials that are used to supply the nitrogen and hydrogen.

Nitrogen _____

Hydrogen _____

(2)

(ii) The Haber process uses a temperature of 450 °C.

Explain, as fully as you can, why a temperature of 450 °C is used rather than a much higher temperature or a much lower temperature.

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(iii) Ammonia can be converted to ammonium nitrate by adding an acid.

Name this acid.

(1)

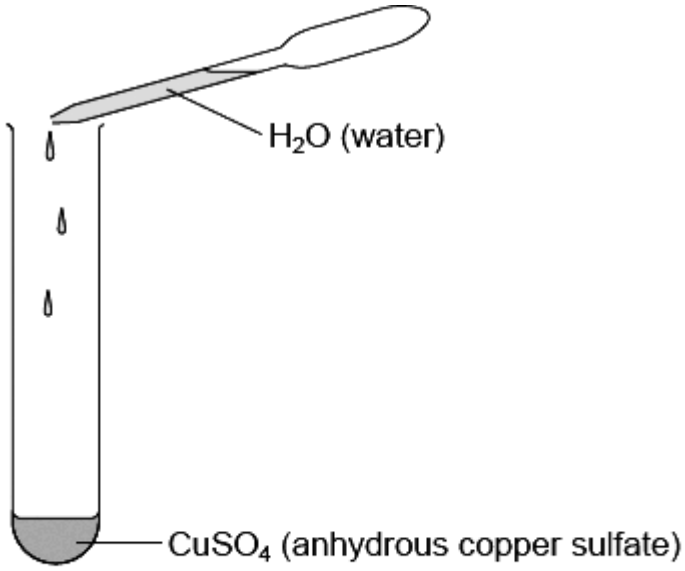
(b) Suggest and explain why the invention of the Haber process caused the closure of the Humberstone mines in Chile.

(2)

(Total 8 marks)

Q29.

The diagram shows how anhydrous copper sulfate can be used to test for water.



$$\underset{\text{white}}{CuSO_4} + \underset{\text{colourless}}{5H_2O} \rightleftharpoons \underset{\text{blue}}{CuSO_4.5H_2O}$$

(a) What colour change will you see when water is added to the $CuSO_4$?

Colour changes from _____ to _____

(1)

(b) Draw a ring around the meaning of the symbol $\rightleftharpoons$

endothermic **exothermic** **reversible**

(1)

(Total 2 marks)

Q30.

The equation for a reaction to produce hydrogen is:

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

(a) Explain why changing the pressure does **not** affect the yield of hydrogen at equilibrium.

_____

_____

(1)

(b) Suggest why the best yield of hydrogen at equilibrium is obtained at **low** temperatures.

(1)

(c) The temperature used in industry needs to be high enough for the reaction to take place quickly. Explain, in terms of particles, why the rate of reaction increases when the temperature is increased.

(3)

(d) Scientists have developed catalysts which allow the reaction to take place quickly at lower temperatures. How could this be good for the manufacturer and for the environment?

_____

(2)

(Total 7 marks)

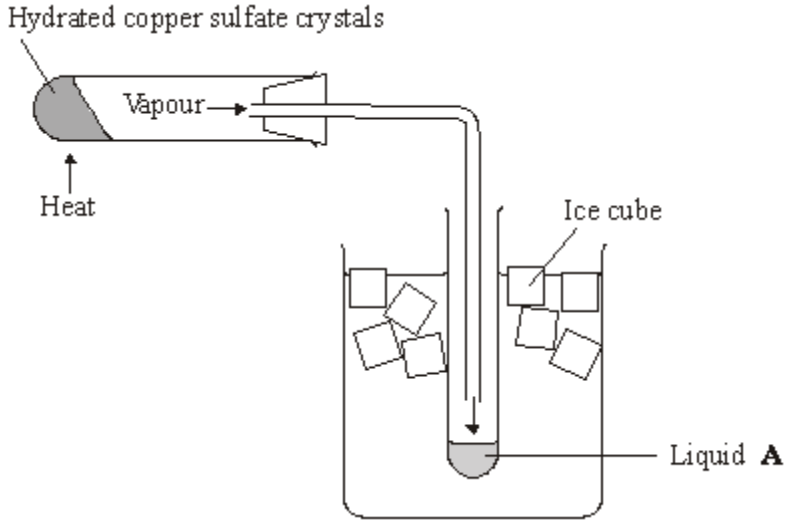
Q31.

A student heated some hydrated copper sulfate crystals.
The equation for this reaction is shown below.

$CuSO_4.5H_2O(s) \rightleftharpoons CuSO_4(s) + 5H_2O(l)$

hydrated copper sulfate crystals anhydrous copper sulfate water

The diagram shows the apparatus used.



(a) Name liquid **A** _____

(1)

(b) What helped the vapour to condense into liquid **A**?

_____

_____

_____

_____

(1)

(c) Put a tick (✓) next to the correct meaning of the symbol $\rightleftharpoons$

Meaning	(✓)

equal amounts of reactants and products	
exothermic reaction	
reversible reaction	

(1)

(d) The student weighed the copper sulfate before and after it was heated. The experiment was repeated and the two sets of results are shown in the table.

Mass of copper sulfate before heating in grams	Mass of copper sulfate after heating in grams	Mass lost in grams
2.50	1.65	0.85
2.50	1.61	0.89

(i) Draw a ring around the **average** mass lost for these two sets of results.

0.85 g **0.87 g** **0.89 g**

(1)

(ii) The student used the same mass of copper sulfate each time but the mass lost was different.

Put a tick (✓) next to the **two** reasons which could explain why the mass lost is different.

Reason	(✓)
The student used different test tubes for the two experiments.	
The student made errors in weighing during the experiments.	
The student used more ice in one of the experiments.	
The student did not heat the copper sulfate for long enough in one of the experiments.	

(2)

(e) Anhydrous copper sulfate is used to test for water.

Use words from the box to complete the sentence.

blue	**green**	**red**	**white**

Water changes the colour of anhydrous copper sulfate from

_____ to _____ .

(2)

(Total 8 marks)

Q32.

Methanol is a fuel that is used in some racing cars instead of petrol.

Methanol can be made from carbon monoxide and hydrogen. The equation for this reaction is shown below.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

The forward reaction is exothermic.

(a) A high pressure (between 50 and 100 atmospheres) is used in this process.

Explain why the highest equilibrium yield of methanol is obtained at high pressure.

_____

_____

_____

_____

(1)

(b) The temperature used in this process is about 250 °C.

It has been stated that, 'the use of this temperature is a compromise between the equilibrium yield of product and the rate of reaction'.

Explain this statement.

_____

_____

_____

_____

_____

_____

_____

_____

_____

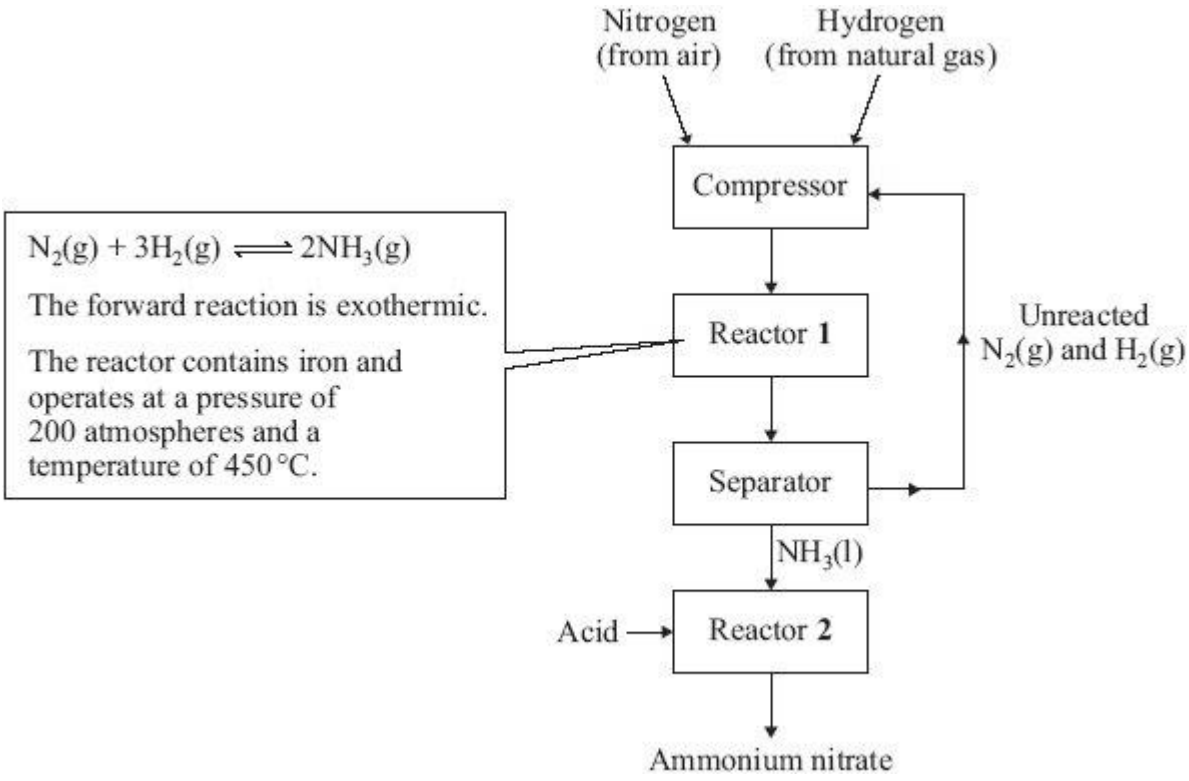
_____

(3)
(Total 4 marks)

Q33.

Ammonium nitrate is an important chemical. The diagram shows the main stages in the manufacture of ammonium nitrate.

Study the diagram and then answer the question.



(a) What is the purpose of the iron in reactor **1**?

(1)

(b) Explain why the best yield of ammonia at equilibrium is obtained:

(i) at low temperature

_____

_____

_____

(1)

(ii) at high pressure.

_____

_____

_____

_____

(1)

(c) The temperature used in reactor **1** is 450 °C.

Explain why a much lower temperature is **not** used.

_____

_____

_____

_____

(1)

(d) A mixture of ammonia, nitrogen and hydrogen leaves reactor **1**.

In the separator, what is done to the mixture to separate the ammonia from the other gases?

_____

_____

_____

_____

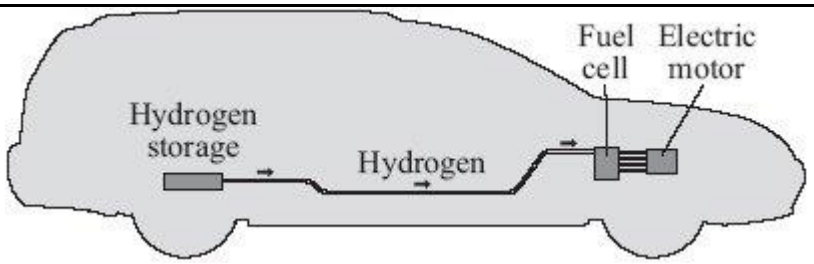
(1)

(Total 5 marks)

Q34.

Read the article and then answer the questions that follow.

Hydrogen fuel for cars?



Hydrogen is an excellent fuel. It can be made by the electrolysis of potassium hydroxide solution.

Hydrogen gas can be stored under pressure in a cylinder but a leak of the gas could cause an explosion.

It has been found that lithium nitride can absorb and then release large volumes of hydrogen. A chemical reaction takes place between the hydrogen and the lithium nitride. The hydrogen is held in the resulting compounds by chemical bonds.

The problem is that the rate at which hydrogen is absorbed and then released from normal sized particles of lithium nitride is slow.

Recently scientists have made 'nanosized' particles of lithium nitride. These particles absorb hydrogen in the same way as normal sized lithium nitride particles. The 'nanosized' particles have the advantage that they absorb and release the hydrogen much faster when needed in the fuel cell.

It is hoped that 'nanosized' particles of lithium nitride may provide a safe method of storing hydrogen in the future.

(a) Hydrogen is produced at the negative electrode during the electrolysis of potassium hydroxide solution.

(i) Why are hydrogen ions attracted to the negative electrode?

_____

_____

_____

_____

_____

(1)

(ii) Potassium ions are also attracted to the negative electrode.

Explain why hydrogen gas is formed but not potassium.

_____

(1)

(b) Lithium nitride is made by reacting lithium with nitrogen.

Balance the equation for this reaction.

$$\_\_\_\_\_\ Li + N_2 \rightarrow \_\_\_\_\_\ Li_3N$$

(1)

(c) (i) The equation for the reaction of lithium nitride with hydrogen is:

$$Li_3N + 2H_2 \rightleftharpoons LiNH_2 + 2LiH$$

What feature of this reaction allows the hydrogen to be released?

(1)

(ii) Hydrogen stored in a fuel tank filled with lithium nitride would be safer in an accident than a cylinder full of hydrogen.

Suggest and explain why.

(2)

(d) Lithium nitride is an ionic compound which contains lithium ions (Li^+) and

nitride ions (N^{3-}).

(i) The formation of a lithium ion from a lithium atom is an oxidation reaction.

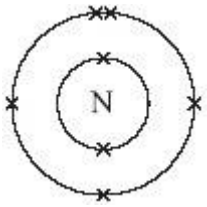
Explain why.

_____

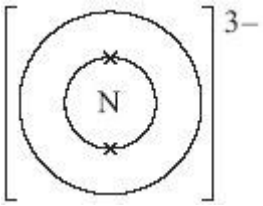
_____

(1)

(ii) The diagram shows the electronic structure of a nitrogen atom.



Complete the diagram below to show the electronic structure of a nitride ion (N^{3-}).

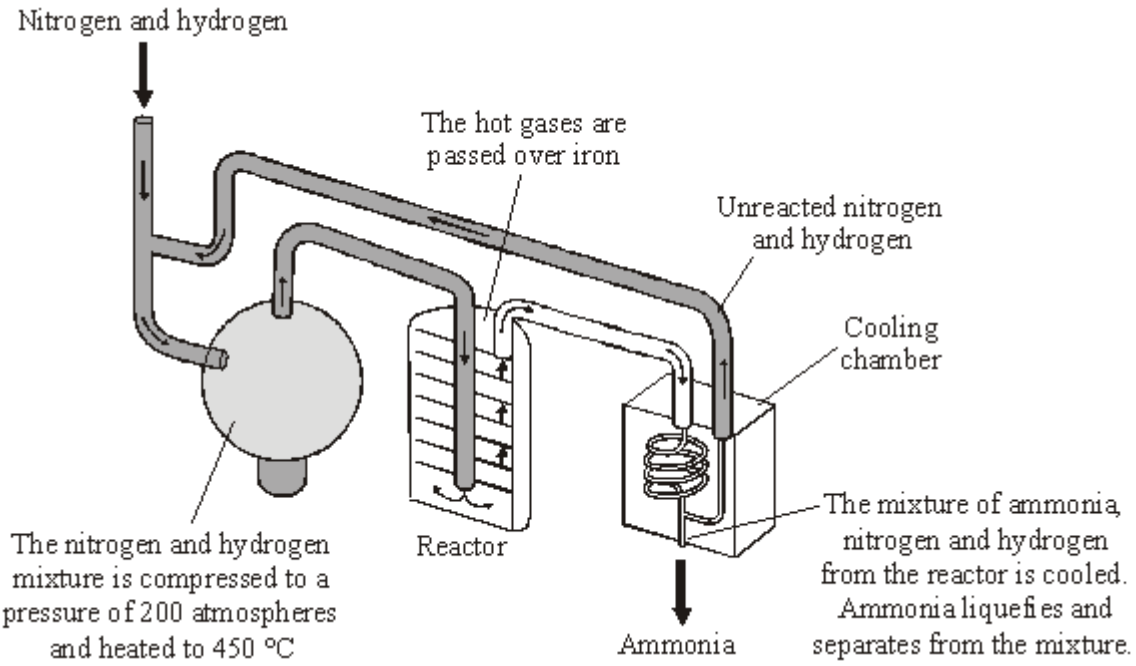


(1)

(Total 8 marks)

Q35.

The Haber process is named after the German chemist, Fritz Haber.
The diagram shows the main stages in the Haber process.



(a) Use the diagram to help you to answer these questions.

(i) Complete the word equation for the reaction that takes place in the reactor.

nitrogen + _____ ⇌ _____

(1)

(ii) What does the symbol ⇌ mean?

_____

(1)

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

_____

(1)

(iv) Ammonia is separated from unreacted nitrogen and hydrogen.

Draw a ring around the physical property that allows this separation to take place.

_____

_____

(1)

(v) What is done with the unreacted nitrogen and hydrogen?

_____
_____

(1)

(b) Some of the products that can be made from ammonia are:

- fertilisers
- dyes
- explosives
- medicines
- plastics

(i) The Haber process was invented a few years before the start of the First World War. It is thought that the First World War would have finished earlier if the Germans had **not** invented the Haber process.

Suggest why.

_____
_____

_____
_____

(1)

(ii) The Haber process has helped to increase food production.

Explain why.

_____
_____

_____
_____

(1)

(c) Factories that make ammonia are very large and operate night and day.

(i) Ammonia factories are often near towns.

Suggest why.

_____
_____

(1)

(ii) Suggest and explain **one** reason why local people might not want an ammonia factory near their town.

_____

_____

_____

_____

_____

_____

_____

_____

(2)

(Total 10 marks)

Mark schemes

Q1.

(a) reactant

1

(b) reversible

1

(c) blue

allow shades of blue, e.g. pale blue

1

(d) 1.6 (g)

1

(e) $\frac{0.9}{2.5} \times 100$

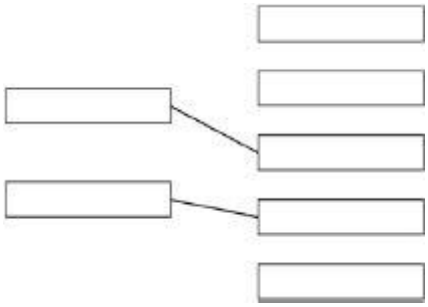
1

= 36 (%)

1

*an answer of 36 (%) scores **2** marks*

(f)



copper sulfate − $CuSO_4$

1

water − H_2O

1

[8]

Q2.

(a) enzyme

1

(b) 2.0×10^3 moles

1

(c) smaller yield

allow less methanol is produced

1

(because) favours endothermic reaction

allow (because) favours reverse reaction

allow equilibrium / reaction shifts to the left
allow equilibrium / reaction shifts to reduce the temperature
ignore reference to forward reaction is exothermic
ignore references to rate

1

(d) (yield)
equilibrium position moves to the product side
allow equilibrium / reaction moves to the right
allow equilibrium / reaction shifts to reduce the pressure

1

(because) fewer molecules / moles / particles on product side
allow (because) fewer molecules / moles / particles on the right
allow (because) smaller volume on product side

1

(rate)
more collisions per unit time
allow increases collision frequency / rate
ignore more collisions alone
ignore faster collisions
*do **not** accept any indication of more energetic / forceful collisions*

1

(because) more molecules / particles per unit volume
allow (gas) molecules / particles closer together
ignore more molecules / particles alone

1

allow converse arguments

(e) provides different reaction pathway
allow provides a different mechanism / route

1

(which has a) lower activation energy

1

ignore references to collisions

(f) less energy is needed
allow reduces the temperature required
allow reduces costs
ignore references to pressure
ignore references to rate or time

1

(g) no effect / change

1

[12]

Q3.

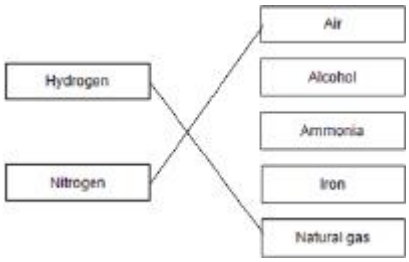
(a) 4

1

(b) reversible (reaction)

1

(c)



1
1

(d) −40 °C

1

(e) recycled to the reactor

1

(f) ionic

1

(g) nitrogen

1

phosphorus

1

(h) 0.24 × 50 × 5

allow £87.50

1

= £60

1

*an answer of £60 scores **2** marks*

(i) may need to use nitrogen, phosphorus and potassium

allow neither fertiliser has all the elements / nutrients needed.

[12]

Q4.

(a) cool

1

to −34 °C

allow temperatures below −34 °C but above −196 °C

1

(b) recycled (to the reactor)

1

(c) $825 \times \frac{2}{3}$

1

= 550 (dm^3)

1

*an answer of 550 (dm^3) scores **2** marks*

(d) a lower pressure would decrease the equilibrium yield

1

a lower temperature would make the reaction too slow

1

(e) nitrogen / N

1

(f) **B** and **C**

1

contain nitrogen, phosphorus and potassium

1

(g) (**B**)

any **two** from:
- more stages
- uses more energy
- uses more raw materials
- takes longer

*allow converse for **C***

2

[12]

Q5.

(a) in a closed system

1

the rate of the forward and backward reactions are equal

1

(b) concentration increases

1

(because) reaction / equilibrium moves to the left / reactant side

1

(since the) reverse reaction is exothermic

allow (so that) temperature increases

1

(c) becomes blue

1

(because) reaction / equilibrium moves to the right / product side

1

(so) concentration of blue cobalt compound increases

allow (so that) concentration of hydrochloric acid decreases

1

(d) (cobalt has) ions with different charges

allow (cobalt is a) transition metal

1

(e) Co^{3+}

1

(f) they allow reactions to reach equilibrium more quickly

1

they provide a different reaction pathway

1

(g) **13**H_2 + **6**CO → C_6H_{14} + **6**H_2O

allow multiples

1

(h) C_8H_{18}

1

(i) curve below printed curve

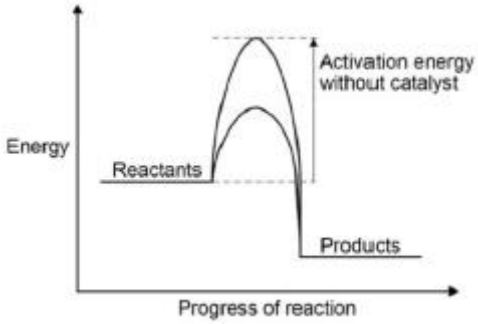
*do **not** accept different reactant or product levels*

1

vertical arrow from reactant level to peak of **printed** curve

1

an answer of:



scores **2** marks

[16]

Q6.

(a) reversible

allow equilibrium

1

(b) The colour changed from blue to pink

1

(c) 8.3 (°C)

1

(d) endothermic

allow dehydration

ignore reversible

1

[4]

Q7.

(a) both water <u>vapour</u> and ethanol will condense

allow steam for water vapour

allow they both become liquids

allow ethane condenses at a lower temperature

allow some of the steam hasn't reacted

allow it is a reversible reaction / equilibrium

1

(b) amount will decrease

1

because the equilibrium will move to the left

1

(c) more ethanol will be produced

1

because system moves to least / fewer molecules

1

[5]

Q8.

(a) endothermic

1

(b) 82 (%)

*correct answer with working gains **3** marks*

*if 17 or 34 not shown in working **max 2** marks*

accept 82.4

accept 82.35 to full calculator display (82.35294...) correctly rounded to at least 2 sf

if no answer or incorrect answer, then

*(M_r =) 17 gains **1** mark **or***

*14/17 gains **2** marks*

OR

*(2M_r =) 34 gains **1** mark **or***

*28/34 gains **2** marks*

OR

*14/their M_r shown gains **1** mark **or***

*correct calculation of 14/their M_r gains **2** marks*

3

(c) (i) 7 / seven

1

(ii) $H^+ + OH^- \rightarrow H_2O$

1

(iii) ammonium chloride

allow NH_4Cl

1

ignore an incorrect formula

(d) Marks awarded for this answer will be determined by the Quality of Written Communication (QWC) as well as the standard of the scientific response. Examiners should also apply a 'best-fit' approach to the marking.

Level 3 (5 – 6 marks):
Suggestion with reasons from all three graphs, and linking of ideas which may explain a compromise.

Level 2 (3 – 4 marks):
Suggestion with reasons referring to more than one graph.

Level 1 (1 – 2 marks):
Suggestion with a reference to a graph.

0 marks:
No relevant content.

Examples of chemistry points made in response:
A reasonable suggested amount of fertiliser would be in the region of 200 kg (per ha).
Accept any suggestion from about 180 kg (per ha) to 500 kg (per ha).

Yield:
- Using fertiliser improves yield.
- Yield improved most up to about 200 kg (per ha) of fertiliser.
- Yield only increased slightly above about 200 kg (per ha).

Profit:
- About 200 kg of fertiliser gives the most profit.
- Above about 200 kg (per ha) of fertiliser profit declines.

Run off:
- Run off is at low levels until about 300 kg (per ha) of fertiliser.
- Above about 300 kg (per ha) of fertiliser, run off increases.

Examples of linking of ideas:
- Overall 200 kg gives high crop yield and most profit.
- In conclusion 200 kg gives high crop yield and low run off.
- 200 kg gives most profit and low run off.

Examples of compromise:
- Profits go down after about 200 kg (per ha) of fertiliser because cost of fertiliser is not covered by increased yield.
- 200 kg gives the highest profit although it is not the highest yield.
- 500 kg gives the best yield but has the most runoff.

6

[13]

Q9.

(a) (i) nitrogen: air

1

hydrogen: natural gas

1

(ii) as a catalyst

1

so the reaction speeds up

allow lowers activation energy or so a lower temperature can be used

1

(iii) cooled

1

ammonia condenses / liquefies

*allow nitrogen **and** hydrogen remain in the gaseous state*

1

(iv) recycled

allow reused or returned to the reactor

1

(b) reversible arrows

1

hydrogen **and** ammonia

1

[9]

Q10.

(a) (i) 25 °C

1

(ii) (fractional) distillation

1

(b) (i) (fertile) land is used to grow fuel crops **or** crops are grown for fuel **or** farmers get a better price for crops for fuel **or** crops for biofuels take up space

ignore biofuels are made from food or plants

1

less food grown **or** food prices rise **or** less (fertile) land to grow food

1

(ii) (crops / plants) take in carbon dioxide (while growing / during photosynthesis)

1

so the CO_2 given out was previously taken in

*do **not** accept burning biofuels does not release CO_2 or releases less CO_2 unqualified*

*if no other mark awarded, a statement of "carbon neutral" scores **1** mark*

1

(c) Marks awarded for this answer will be determined by the Quality of Communication (QC) as well as the standard of the scientific response. Examiners should also refer to the information in the Marking Guidance and apply a 'best–fit' approach to the marking.

0 marks
No relevant content

Level 1 (1−2 marks)
At least one statement about the effect of a condition on either rate **or** yield.

Level 2 (3−4 marks)
Correct statements about the effect of at least one condition on rate **and** yield.

Level 3 (5−6 marks)
Correct statements about the effect of at least one condition on rate and yield **and** at least one correct statement about compromise conditions.

Examples of the points made in the response

Temperature
- a higher temperature gives a lower yield
- a higher temperature gives a faster rate

Pressure
- a higher pressure gives a higher yield
- increase in yield gets less as pressure increases
- a higher pressure gives a faster rate
- increase in rate increases as pressure increases

Catalyst
- using a catalyst speeds up reaction
- catalysts allow a lower temperature to be used and so save energy / reduce energy costs

Compromise
- a higher pressure gives a greater yield but increases costs / (safety) risks
- a high pressure gives a faster rate but increases costs / risks
- a high temperature makes reaction faster but reduces yield
- a catalyst makes reaction faster so a lower temperature can be used which will increase the yield

6

[12]

Q11.

(a) natural gas

allow correct answer shown in box if answer line blank

1

(b) (i) 450

allow correct answer shown in box if answer line blank

1

(ii) iron

allow correct answer shown in box if answer line blank

1

(iii) The catalyst lowers the activation energy.

1

(c) (the gases are) cooled

1

ammonia condenses

allow ammonia liquefies

1

nitrogen and hydrogen are recycled

*if no other mark awarded allow ammonia is separated for **1** mark*

1

[7]

Q12.

(a) (i) nothing can enter **and** nothing can leave the reaction

allow sealed reaction vessel

1

(ii) forward and backward reactions have same rate

1

so there is no (overall) change in quantities of reactants and products

allow concentrations of reactants and products

1

(b) (i) natural gas

allow methane / CH_4

allow fossil fuels / hydrocarbons

allow water

1

(ii) provides an alternative reaction pathway

1

which has a lower activation energy

ignore references to collisions

1

(iii) the amount (of ammonia) increases

allow yield increases

1

the equilibrium moves to the side (of the equation) with fewer (gaseous) molecules / moles

allow it favours the forward reaction

1

(c) (i) vertical arrow from reactants to maximum

1

(ii) (energy of) products higher than (energy of) reactants

allow converse

1

(iii) amount of hydrogen iodide decreases

1

equilibrium moves in the direction of the endothermic reaction

allow it favours the forward reaction

1

[12]

Q13.

(a) (i) covalent

1

(ii) increases the rate of reaction

1

(b) (i) the reaction is reversible

1

(ii) at lower pressure the molecules will be further apart

1

so there will be fewer collisions <u>per unit time</u>

accept frequency of collisions lower

1

(iii) as the temperature increases, the yield of the reaction increases

1

(iv) 2 molecules / volumes become 4 **or** more molecules / volumes **of** product than reactant

1

(c) Marks awarded for this answer will be determined by the Quality of Communication (QoC) as well as the standard of the scientific response. Examiners should also refer to the information on page 5, and apply a 'best-fit' approach to the marking.

0 marks
No relevant content

Level 1 (1 – 2 marks)
Candidate has written about some basic points from the table but has not added any extra knowledge. Candidate may have included advantages **or** disadvantages.

Level 2 (3 – 4 marks)
Candidate has attempted an evaluation using points from the table and their own knowledge. Candidate has included advantages **and** disadvantages.

Level 3 (5 – 6 marks)
Candidate has given an evaluation that includes both advantages and disadvantages. Candidate has clearly linked points from the table with their own knowledge and uses appropriate scientific terminology.

examples of the points made in the response

Advantages of using hydrogen:

- its combustion only produces water
- combustion of hydrogen does not produce carbon dioxide **or** does not contribute to climate change
- petrol requires much more oxygen to burn so partial combustion is possible producing carbon monoxide
- combustion of hydrogen does not produce any particulates **or** does not contribute to global dimming
- petrol comes from a non-renewable source **or** there are renewable ways of producing hydrogen, eg electrolysis of water.

Disadvantages of using hydrogen:

- hydrogen has to be stored at high pressure **or** risk of explosion or larger volume needed for storage.
- much less energy produced from the combustion of hydrogen **or** need to refuel more often
- most methods of producing hydrogen need fossil fuels.

6

[13]

Q14.

(a) the forward and backward reactions occur

allow reversible

1

at (exactly) the same rate

1

in a closed system

allow therefore the concentrations / amounts of the reactants and products <u>remain</u> the same

1

(b) (i) increasing the temperature would <u>lower</u> the yield of ethanol **or** the (position of) equilibrium moves to the left

*if student has stated that increasing the temperature increases the yield then award **0** marks*

1

since the backwards reaction is endothermic **or** the forward reaction is exothermic

1

(ii) increasing the pressure would <u>increase</u> the yield of ethanol **or** the (position of) equilibrium moves to the right

if student has stated that increasing the pressure decreases

*the yield then award **0** marks*

1

because the position (of equilibrium) moves in the direction of the lower number of moles (of gas)

2 (moles / molecules / volumes / particles) on lhs / 1 (mole / molecule / volume / particle) on rhs

1

(c) (a catalyst) provides an alternative pathway

1

with lower activation energy

or

(a catalyst) lowers the activation energy (1)

so less energy is needed to react **or** more particles react (1)

1

[9]

Q15.

(a) (i) ions cannot move

allow only conducts as a liquid

1

(ii) chlorine

1

(iii) they are positively / oppositely charged

or

they are attracted

1

(iv) 2

1

(b) (i) any **one** from:

- not all the magnesium was collected

  allow some magnesium was lost
- *used less time **or** lower current **or** different battery / power pack **or** different balance **or** lower voltage*
- error in reading balance
- error in recording result

1

(ii) 1.11

*correct answer with or without working gains **2** marks.*

*if answer incorrect, allow **1** mark for 0.99*

***or** for 1.13 + 1.11 + 1.09*

2

(c) (i) *25 – 25.3*

*correct answer with or without working gains **2** marks.*
*If answer incorrect, allow **1** mark for 24 / 95*

2

(ii) 71

1

(d) (i) reversible reaction

1

(ii) decreases

1

[12]

Q16.

(a) ⇌

1

ammonia

allow NH_3

1

(b) increases

1

quickly at first *then slows*

ignore levels off
allow rate of increase slows for first two marking points

1

at any number in range from 160 – 220 (atmospheres)

allow any number in range 60 – 66 (%)

1

(c) (nitrogen and hydrogen) recycled

allow (nitrogen and hydrogen) reused

1

(d) (i) *jobs lost*

*accept mines closed **or** local economy damaged*

1

(ii) any **one** from:

- *nitrates* / fertilisers cost less
- more crops / food can be grown
- food costs less
- *nitrates / fertilisers more widely available*

1

[8]

Q17.

(a) $2NH_3$

*allow NH_3 with incorrect or missing balancing for **1** mark*

allow multiples

2

(b) (i) 200

1

(ii) rate of reaction (too) slow

allow converse

ignore references to yield / cost

1

(iii) 400

1

(iv) lower yield

allow converse

accept shifts equilibrium to left

allow favours the backward reaction

allow favours side with more (gaseous) molecules

allow lower rate

1

(c) (gases) cooled

it = ammonia

1

ammonia liquefied

accept ammonia condensed

*accept ammonia cooled below boiling point for **2** marks*

1

[8]

Q18.

(a) fertilisers

1

(b) air

1

(c) speeds up the reaction

accept lowers the activation energy

ignore makes the reaction work

1

(d) reversible reaction

1

(e) (i) 10

1

(ii) water

accept H_2O / hydrogen oxide

1

[6]

Q19.

(a) any **two** from:

- heat water / make steam / boil water **or** heat / steam used in stage 1 or from stage 3
- carbon dioxide from stage 3 used in stage 7 /to make urea
- nitrogen and / or hydrogen <u>recycled</u>
- ammonia and / or carbon dioxide <u>recycled</u>

allow unreacted material / gas recycled from stage 5 (to 4)

allow unreacted material / gas recycled from stage 8 (to 7)

*NB: if neither of the last two points are awarded unreacted material recycled = **1** mark*

2

(b) (i) increase yield

<u>because</u> (forward) reaction is exothermic

ignore references to rate

1

allow <u>because</u> (forward) reaction gives out heat

1

(ii) increase yield

ignore references to rate

1

<u>because</u> more (gaseous) reactant molecules than (gaseous) product molecules

accept <u>because</u> greater volume on the left than the right

1

(c) 76.9 - 77

correct answer gains 2 marks with or without working
*allow 77 **or** 76.923…*
*allow 76 **or** 0.77 **or** 0.76923 for **1** mark*
*if answer incorrect allow **1** mark for **either***

$$\frac{60}{\text{attempt at total } M_r \text{ of all reactants}} \times 100$$

or

$$\frac{\text{attempt at total } M_r \text{ of area}}{78} \times 100$$

2

[10]

Q20.

(a) three bonding pairs

*do **not** allow non-bonding electrons in hydrogen*
ignore any inner shells on nitrogen

1

two non-bonding electrons

allow either dots and crosses or combination of both

1

(b) (i) nitric

1

(ii) fertilisers / explosives

ignore other uses

1

(iii) 80

*correct answer with or without working gains **2** marks*

*if answer incorrect, allow 14 + (1 × 4) + 14 + (16 × 3) for **1** mark*

2

(iv) 35

*allow ecf from **(b)(iii)***

*allow ecf for **1** mark for correct working but incorrect answer.*

*if answer incorrect, allow 28 / 80 × 100 for **1** mark*

*if answer is 17.5 % allow **1** mark*

2

(c) Marks awarded for this answer will be determined by the Quality of Communication (QoC) as well as the standard of the scientific response. Examiners should also refer to the information on page 5, and apply a 'best−fit' approach to the marking.

0 marks
No relevant content

Level 1 (1 − 2 marks)
There are statements about the conditions used. There is no correct explanation of the link between rate or yield and the conditions.

Level 2 (3 − 4 marks)
There is a correct explanation of the conditions used that links the conditions to rate **or** yield

Level 3 (5 − 6 marks)
There is an explanation covering at least temperature and pressure, which shows understanding of the compromise between rate **and** yield

examples of chemistry points made in the response:

200 atmospheres pressure
- high pressure gives a high yield of ammonia
- too high a pressure causes risk of explosion
- high pressure costly to maintain
- a high pressure will cause the rate to be higher
- 4 moles of gas become 2 (or fewer moles of gas in products)

450 °C

- high temperature increases the rate of reaction
- optimum temperature
- (forward reaction is exothermic so) a high yield of ammonia requires a low temperature
- but too low a temperature causes the rate of reaction to be too slow

iron catalyst

- a catalyst speeds up the reaction
- an iron catalyst allows a lower temperature to be used (saving energy and causing a higher yield)
- iron catalyst increases the rate of reaction equally in both reactions

others

- compromise conditions
- unreacted nitrogen and hydrogen is recycled

6

[14]

Q21.

(a) reversible

1

(b) catalyst

1

(c) recycled

allow re-used

1

(d) (Q) S R P

*allow **1**mark if one letter in correct place.*

2

[5]

Q22.

(a) reversible

1

(b) (from blue) to pink

*do **not** accept*

incorrect initial colour

1

(c) sensible answers such as:

- stop water reaching papers

  accept stop entry of moisture / wet / dampness / condensation

- water (vapour) in air

  ignore references to toxicity of cobalt chloride

1

[3]

Q23.

(a) (i) 10

1

(ii) OH^-

1

(b) (i) air

1

(ii) particles move faster

1

particles collide more often

1

(iii) catalyst(s)

1

(c) liquid

1

[7]

Q24.

(a) 22

1

(b) (i) exothermic

1

(ii) C

1

gives out most heat energy

accept has largest temperature change / increase

*allow has highest (final) temperature **or** hottest*

1

(c) (i) increases

1

(ii) blue

ignore pale / dark etc

1

(iii) reversible (reaction)

*allow goes both ways **or** two / either way*

1

(iv) anhydrous copper sulfate

1

[8]

Q25.

(a) gases

1

white

1

solid

1

ammonium chloride

1

(b) reversible

allow phonetic spelling

allow goes both / two / either way(s)

1

[5]

Q26.

(a) mixture is cooled / cooling

1

so ammonia / it condenses

or

so ammonia <u>turns into</u> a liquid (but nitrogen and hydrogen remain as gases)

1

(b) (i) exothermic reaction

accept reverse reaction is endothermic

or

equilibrium / reaction moves in the direction which raises the temperature

ignore answers based on rate or collisions

1

(ii) they / particles / molecules move faster **or** have more (kinetic) energy

allow atoms instead of particles

ignore particles move more / vibrate

*do **not** accept electrons (max1)*

1

any **one** from:

- particles / molecules collide more often / more frequently / more likely to collide

  ignore collide faster

  ignore more collisions

- more of the collisions are successful **or** particles collide with more energy / harder **or** more of the particles have the activation energy

  accept more successful collisions

1

(iii) more molecules / particles / moles / volumes on LHS (of equation than RHS)

accept 4 molecules / particles / moles / volumes on LHS and 2 molecules / particles / moles / volumes on RHS

or

greater volume on LHS (than RHS)

or

equilibrium / reaction moves in the direction which reduces the pressure / volume

accept converse

1

(iv) cost

or

difficulty in containing such a high pressure

allow risk of explosion

ignore dangerous

1

(c) (i) 60

1

(ii) 2.4(2857….)

*correct answer gains **3** marks with or without working*

accept any answer that rounds to 2.4

ignore units

if answer is incorrect look for evidence of correct working to a

*maximum of **2** marks.*

moles of N_2 = 2/28 = (0.0714)

moles of ammonia = 2 × 0.0714 = (0.1428)

mass of ammonia = 0.1428 × 17 = (2.4276)

or

28 → 34

1g →34/28

2g →2.4… ….

3

(d) (i) 15

1

(ii) unreacted gases are recycled

allow unreacted gases are reused

1

rate (of production) is fast

accept production is continuous

ignore compromise between rate and yield

1

[14]

Q27.

(a) increases

1

(b) the reaction is reversible

1

(c) A liquid

1

(d) recycled / reused (owtte)

accept returned to pump / start

1

[4]

Q28.

(a) (i) nitrogen - air

accept atmosphere

1

hydrogen - north sea gas / natural gas / methane / CH_4

accept water / (crude) oil / coal / hydrocarbons / brine

1

(ii) *allow converse throughout*

- high temperature gives a low yield

1

- because reaction is exothermic

must be linked to first bullet point

1

- but at low temperatures the rate is (too) slow

if no other marks awarded accept 450°C is a compromise between yield and rate

or

*450°C gives a reasonable yield in a reasonable time for **1** mark*

1

(iii) nitric (acid)

accept HNO_3

1

(b) Ammonia / Haber process can be used to make fertiliser

1

with a specified economical reason

eg raw materials for Haber process readily available
eg transport costs are lower or no need to import
eg Haber process is a continuous process

ignore employment / labour costs

1

[8]

Q29.

(a) white to blue

accept colourless to blue

1

(b) reversible

1

[2]

Q30.

(a) same number of (gaseous) molecules / moles / volume on both sides of the equation

allow particles for molecules

*do **not** accept atoms*

ignore amount

1

(b) (forward) reaction is exothermic

accept reverse answer

1

(c) any **three** from:

- particles gain energy
- particles move faster

  allow particles collide faster / quicker

  ignore move more / vibrate more
- particles collide more **or** more collisions
- more of the collisions are successful **or**
  more of the particles have the activation energy **or**
  particles collide with more force / energy

3

(d) any **two** from:

- more product (obtained in shorter time)

  accept better yield (of product)
- less fuel needed

  accept less energy / heat / electricity needed

  or

lower fuel costs

ignore cheaper unqualified

- less pollution caused by burning fuels

or

less specified type of pollution caused by producing heat / burning fuels

*allow correct specified pollutants caused by burning fossil fuels eg CO_2 / greenhouse gases **or** correct effect of burning fossil fuels eg global warming*

accept thermal / heat pollution

- using less fuel conserves resources

accept sustainable

accept fossil fuels are non-renewable

2

[7]

Q31.

(a) water

*accept H_2O **or** $5H_2O$*

2 must be below halfway

1

(b) the cold water / ice / cubes (owtte)

*accept 'cooled down' **or** references to cold*

1

(c) reversible reaction

1

(d) (i) 0.87g

1

(ii) the student made errors in weighing during the experiments

1

the student did not heat the copper sulfate for long enough in one of the experiments

1

(e) white

1

blue

*allow **1** mark for blue to white*

1

[8]

Q32.

(a) fewer product molecules than reactant molecules (owtte) **or**

accept forward reaction produces fewer molecules

accept left hand side for reactants and right hand side for products

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

1

(b) any **three** from:

- 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*

3

[4]

Q33.

(a) to speed up the reaction **or** it is a catalyst

allow higher level answers such as to reduce the activation energy

ignore cost or yield

1

(b) (i) reaction is exothermic

*accept reverse reaction is endothermic **or** high temperature causes decomposition of ammonia*

ignore reference to rate

1

(ii) more (gaseous) reactant molecules than (gaseous) product molecules

accept 4 volumes / moles of reactant and 2 volumes / moles of product

*accept lower volume of products **or** volume lower on right hand side*

accept 'favours the reaction which produces fewer molecules'

ignore incorrect number of moles

ignore reference to 'amount' of product / reactant

ignore references to rate

1

(c) (rate is) too slow / slower owtte

allow catalyst would not work

accept at higher temperature the rate is quicker

accept at lower temperatures particles do not collide as often ***or*** *fewer particles have the activation energy* ***or*** *particles do not have the activation energy*

ignore reaction would not work

ignore optimum / compromise type answers

1

(d) cooled

allow ammonia / it is turned into a liquid ***or*** *is condensed*

ignore references to boiling point

1

[5]

Q34.

(a) (i) any **one** from:

- they are positive / cations
- they are H^+
- opposite charges attract

ignore atom

1

(ii) potassium is more reactive (or reverse)

assume 'it' refers to hydrogen

allow potassium reacts <u>with</u> water

allow potassium is very reactive ***or*** *most reactive metal / element*

allow hydrogen gains electrons more easily / is reduced more easily

accept potassium is higher up the reactivity series

1

(b) 6 **and** 2

accept correct multiples and fractions

1

(c) (i) the reaction / it is reversible **or** a description of a reversible reaction

allow 'it is an equilibrium'

allow reversible symbol drawn correctly

allow 'the reverse / back reaction'

1

(ii) **lithium nitride**

assume that 'it' or if they do not specify means lithium nitride

assume lithium / lithium nitrate refers to lithium nitride

- hydrogen is bonded / held / absorbed / has formed a compound / reacted with lithium nitride

1

plus **one** of:

- does not explode / cause a fire
- is not free / less hydrogen
- is not under pressure
- does not leak
- is only released slowly

1

- compound of hydrogen with lithium nitride / product is (more) stable / less reactive / less chance of a reaction

accept converse for hydrogen as below

assume that gas / hydrogen means gas in the cylinder

- *hydrogen (in cylinder) / gas is not bonded / held absorbed / in a compound / reacted with lithium nitride*

1

*plus **one** of:*

- *can explode / cause a fire*
- *is free*
- *is under pressure*
- *can leak*
- *releases quickly*

1

(d) (i) loss of an electron **or** loses electrons

do not accept any ref. to oxygen

1

(ii) full outer shell of 8 electrons on circle

need not be paired

can be ×, dot or e

*do **not** accept if extra electrons added to inner shell*

1

[10]

Q35.

(a) (i) nitrogen + hydrogen → ammonia

accept full correct balanced equation

1

(ii) reversible (reaction) (owtte)

*do **not** allow just 'backwards' (unqualified)*

1

(iii) catalyst / speed up reaction

accept to lower activation energy

1

(iv) boiling point

1

(v) recycled (owtte)

1

(b) (i) used to make explosives (owtte) used to make medicines (owtte)

1

(ii) used to make fertilisers (owtte)

1

(c) (i) sensible answers such as

provides workers (owtte)

good transport links

ignore reference to raw materials

1

(ii) sensible idea

1

linked reason

idea

linked reason

eg escape of chemicals /fumes /waste gases / pollution

harmful to health / environmental damage owtte

*do **not** allow harmful / damage / smell (unqualified)*

risk of explosion

because of high pressures / may endanger local people / dangerous

risk of fire

because of high temperatures / may endanger local people

noise

*any detrimental effect on quality of life **or** night and day*

lorries / traffic

danger / noise / pollution etc

unsightly

detrimental effect on quality of life / house prices / reduced tourism

uses a lot of land

loss of habitats

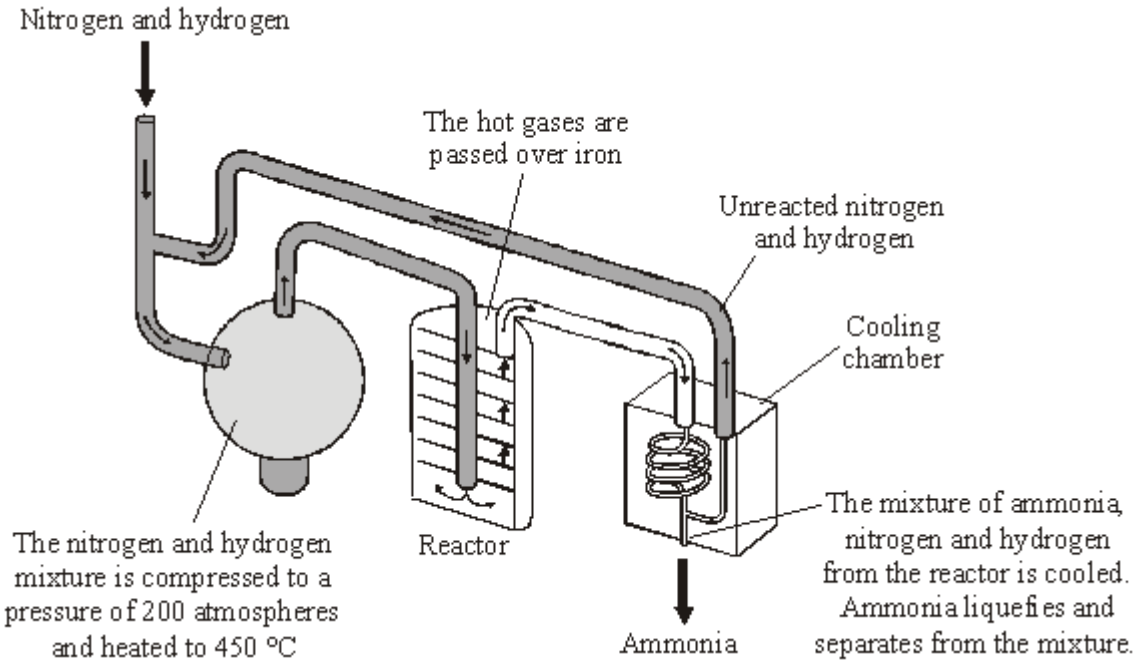
1

[10]

Q1.

The Haber process is named after the German chemist, Fritz Haber.

The diagram shows the main stages in the Haber process.



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An exothermic reaction takes place when nitrogen reacts with hydrogen to make ammonia.

The reaction can be represented by this equation.

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

(a) Calculate the maximum mass of ammonia that could be made from 1000 g of nitrogen.

Relative atomic masses: H = 1; N = 14

Mass _____ g

(3)

(b) At a temperature of 450 °C and 200 atmospheres the actual mass of ammonia produced when 1000 g of nitrogen is passed through the reactor is 304 g.

Calculate the percentage yield of ammonia produced in the reactor.

(If you did not answer part (a), then assume that the maximum mass of ammonia that can be made from 1000 g of nitrogen is 1100 g. This is **not** the correct answer to part (a).)

Percentage yield of ammonia = _____ %

(2)

(c) State **and** explain:

(i) how a **decrease** in temperature would affect the yield of ammonia

(2)

(ii) how an **increase** in pressure would affect the yield of ammonia.

(2)

(d) Factories that make ammonia are often near to large towns.

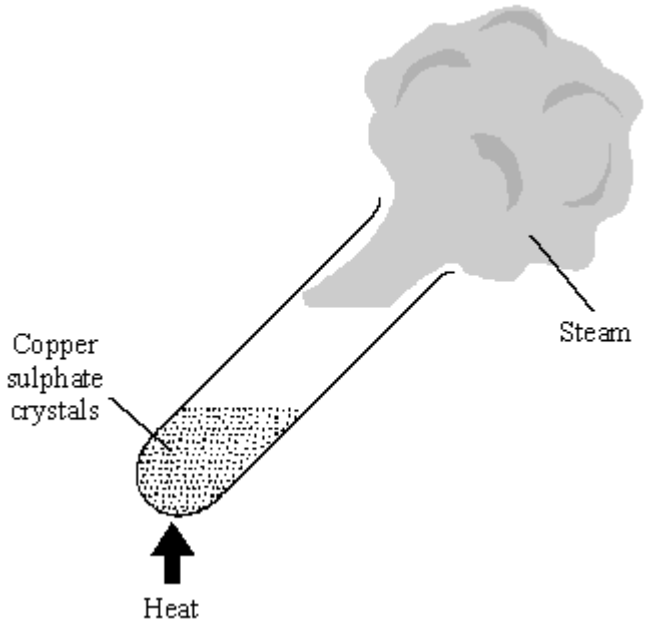
Discuss the economic, safety and environmental factors to be considered when there is an ammonia factory near a town.

(3)

(Total 12 marks)

Q2.

A student heated some blue copper sulphate crystals. The crystals turned into white copper sulphate.



(a) The blue copper sulphate had to be heated to change it into white copper sulphate.

State whether the reaction was exothermic or endothermic. _____

Explain your answer.

(1)

(b) The word equation for this reaction is shown below.

hydrated copper sulphate (blue) [+ heat energy] $\rightleftharpoons$ anhydrous copper sulphate (white) + water

(i) What does the symbol $\rightleftharpoons$ tell you about this reaction?

_____

(1)

(ii) How could the student turn the white powder back to blue?

_____

(1)

(Total 3 marks)

Q3.

The reaction of methane with steam is used in industry to make hydrogen.

(a) One of the reactions in this process is represented by this equation.

CH_4 (g) + H_2O $\rightleftharpoons$ CO (g) + $3H_2$ (g)

The forward reaction is endothermic.

State the conditions of temperature and pressure that would give the maximum yield of hydrogen.

Explain your answers.

(i) Temperature

_____

_____

_____

_____

(2)

(ii) Pressure

_____

_____

_____

_____

(2)

(iii) Which one of the following metals is most likely to be a catalyst for this process? Draw a ring around your answer.

aluminium **lead** **magnesium** **nickel** **sodium**

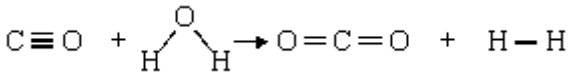
Give a reason for your choice.

_____

_____

(1)

(b) A second stage in this process is represented by this equation.



(i) Use the bond energies given in the table to help you to calculate the nett energy transfer (energy change) for this reaction.

Bond	Bond energy in kJ/mol
C ≡ O	1077
C = O	805
H – H	436
O – H	464

_____

_____

_____

_____

_____

_____

Nett energy transfer = _____ kJ/mol

(3)

(ii) State whether this reaction is exothermic or endothermic. _____

Explain, by reference to your calculation, how you know.

_____

_____

_____

_____

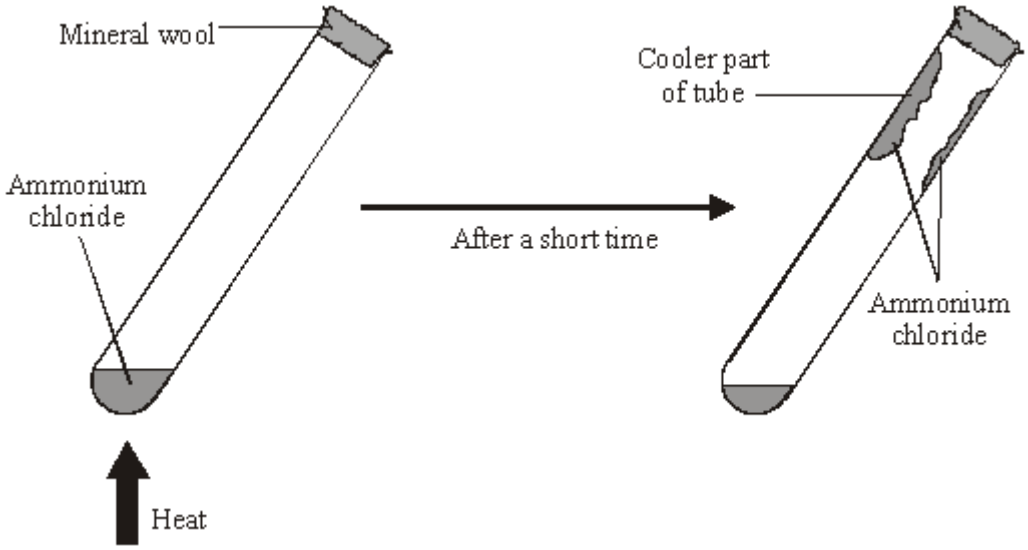
(2)

(Total 10 marks)

Q4.

A student did two experiments using ammonium chloride.

(a) In the first experiment the student heated a small amount of ammonium chloride in a test tube.



Two reactions take place in the test tube.

Reaction **1**	ammonium chloride → ammonia + hydrogen chloride (colourless gases)
Reaction **2**	ammonia + hydrogen chloride → ammonium chloride

(i) Complete the sentences by crossing out the **incorrect** word in each box.

Reaction **1** takes place at a [high / low] temperature.

Reaction **2** takes place at a [high / low] temperature.

(1)

(ii) Draw a ring around the word which best describes reactions **1** and **2**.

combustion **displacement** **oxidation** **reduction** **reversible**

(1)

(iii) Suggest a reason for the mineral wool at the top of the test tube.

_____

_____

(1)

(b) In the second experiment the student mixed a small amount of ammonium chloride with some water in a beaker.

The temperature of the water was measured before and after adding the ammonium chloride.

Temperature before adding the ammonium chloride	20°C
Temperature after adding the ammonium chloride	16°C

Draw a ring around the word which best describes the process which takes place.

combustion **displacement** **endothermic** **exothermic** **freezing**

(1)

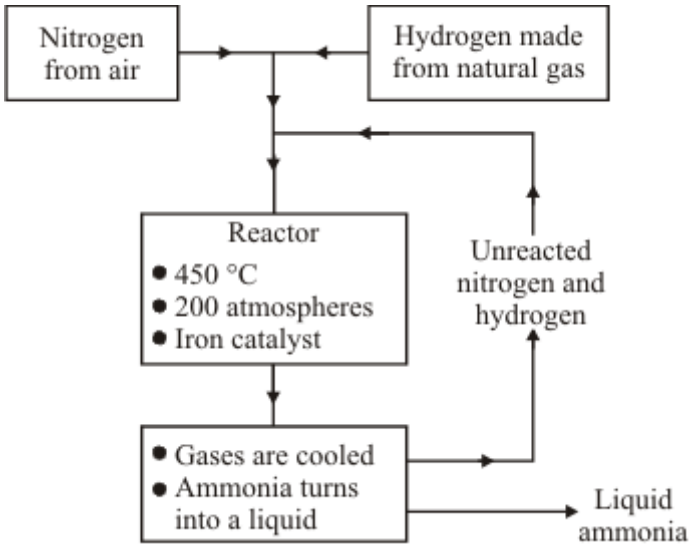
(Total 4 marks)

Q5.

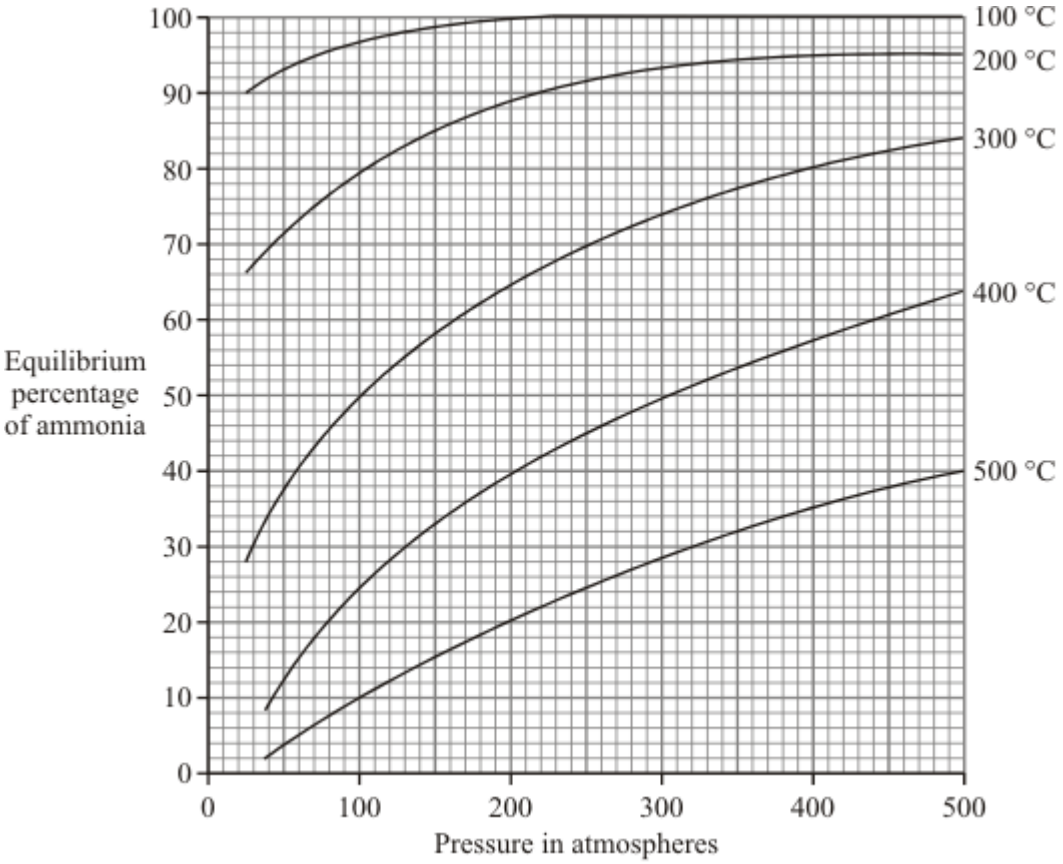
Ammonia is made from nitrogen and hydrogen in the Haber process.

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

Flow Chart for the Haber Process



Effect of temperature and pressure on the amount of ammonia at equilibrium



(a) Use the information given above and your knowledge of the Haber process and reversible reactions to help you to answer this question.

State which conditions of temperature and pressure would give the highest percentage of ammonia at equilibrium. Explain why.

(4)

(b) The Haber process uses a temperature of 450 °C and a pressure of 200 atmospheres.

Explain why these conditions are chosen.

_____

_____

_____

_____

_____

(3)

(Total 7 marks)

Q6.

The monomer chloroethene is made from ethene in a two-stage process,

(a) The first stage is to convert ethene to 1,2-dichloroethane.

$$2C_2H_4(g) + 4HC1(g) + O_2(g) \rightleftharpoons 2C_2H_4Cl_2(g) + 2H_2O(g)$$

ethene 1,2-dichloroethane

State and explain the effect of increasing the pressure on:

(i) the yield of 1,2-dichloroethane;

_____

_____

(2)

(ii) the rate of reaction.

_____

_____

(2)

(b) In the second stage 1,2-dichloroethane is converted into chloroethene.

$C_2H_4C1_2 \rightarrow C_2H_3C1 + HCl$

This reaction is a thermal decomposition.

Suggest what would need to be done to decompose 1,2-dichloroethane.

_____

_____

(1)

(Total 5 marks)

Q7.

Transition metals are useful as catalysts. Iron is used as a catalyst in the manufacture of ammonia.

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

(i) What is meant by $\rightleftharpoons$ in the chemical equation?

_____

_____

(1)

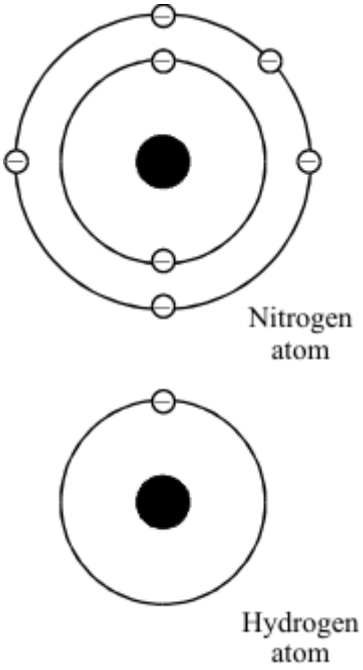
(ii) What would be the effect on the yield of ammonia if the pressure was increased?

_____

_____

(1)

(iii) Draw a diagram to show the arrangement of the electrons in a molecule of ammonia. The electron arrangement of each atom is shown.

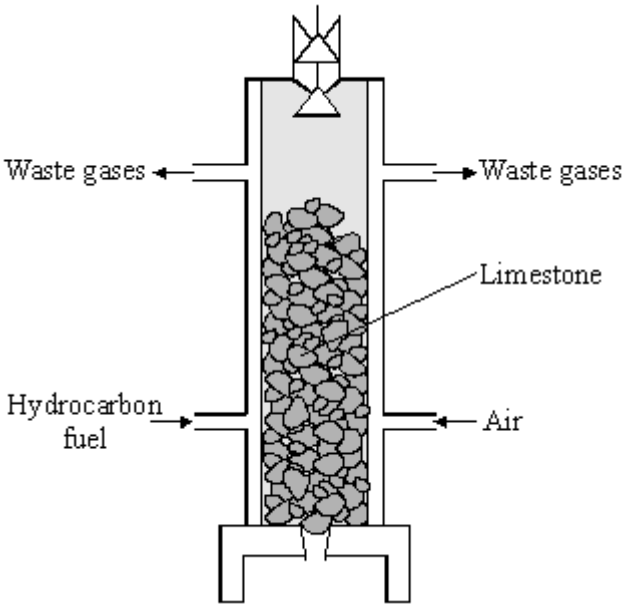


(1)

(Total 3 marks)

Q8.

Limestone is a useful mineral. Every day, large amounts of limestone are heated in limekilns to produce lime. Lime is used in the manufacture of iron, cement and glass and for neutralising acidic soils.



$CaCO_3 \rightleftharpoons CaO + CO_2$

(i) The decomposition of limestone is a *reversible* reaction. Explain what this means.

_____

_____

_____

_____

(2)

(ii) Calculate the mass of lime, CaO, that would be produced from 250 tonnes of limestone, $CaCO_3$.

Relative atomic masses: C 12; O 16; Ca 40.

_____

_____

_____

_____

_____

Mass of lime = _____ tonnes

(3)

(Total 5 marks)

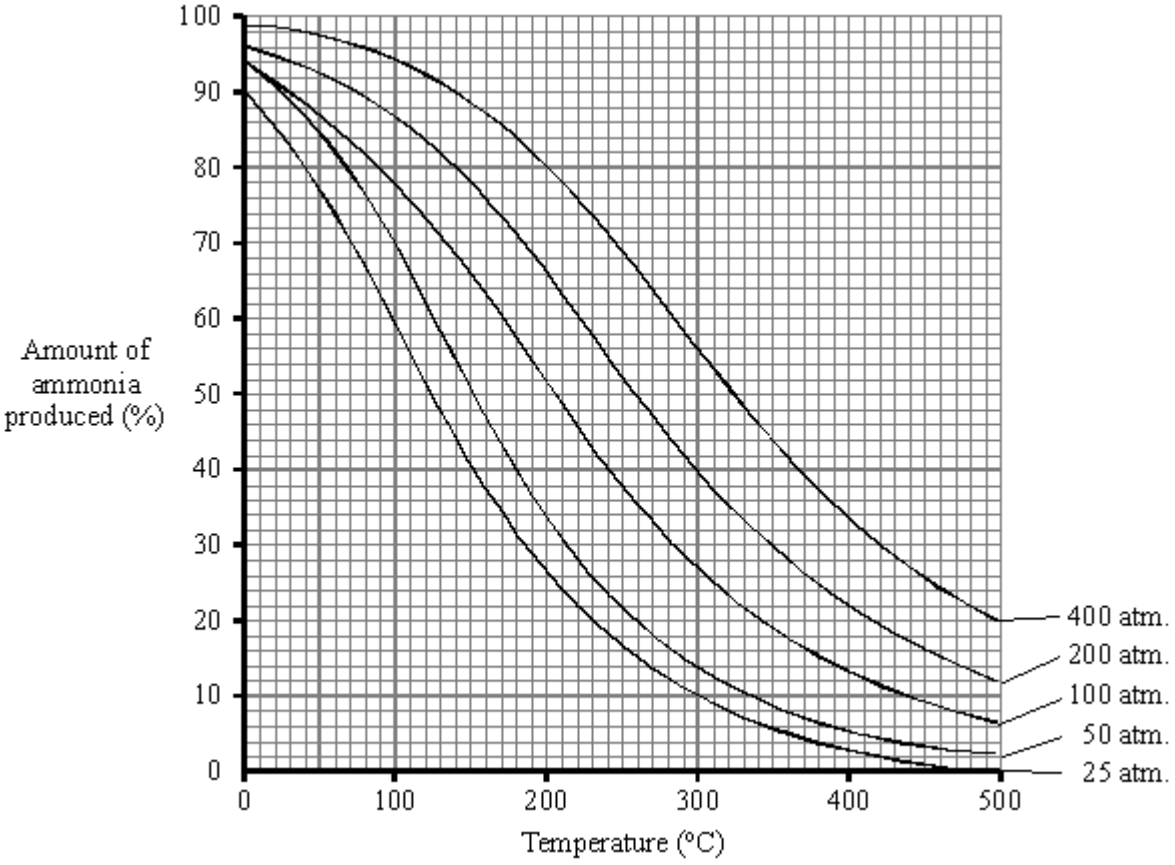
Q9.

The Haber process is used to make ammonia (NH_3) which is an important substance.

The equation below shows the reaction in which ammonia is formed.

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

The graph below shows how temperature and pressure affect how much ammonia is produced in the reaction.



In the industrial process a mixture of nitrogen and hydrogen is passed over iron at a temperature of about 450 °C and 200 atmospheres pressure.

(a) Use the graph to find the percentage of ammonia present when the temperature and pressure are 450 °C and 200 atmospheres.

_____ %

(2)

(b) Explain why the nitrogen and hydrogen mixture is passed over iron.

_____

_____

(2)

(c) Explain, as fully as you can, using the graph and your knowledge of the Haber process why 450 °C and 200 atmospheres were chosen as conditions for this process.

_____

_____

(8)

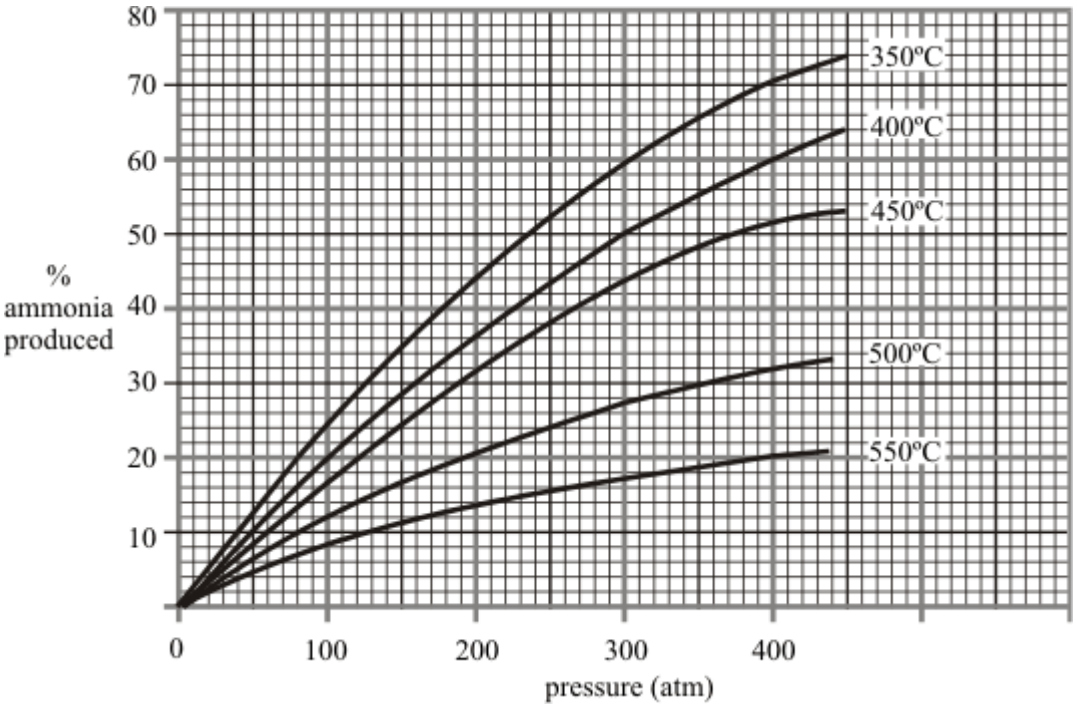
(Total 12 marks)

Q10.

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.

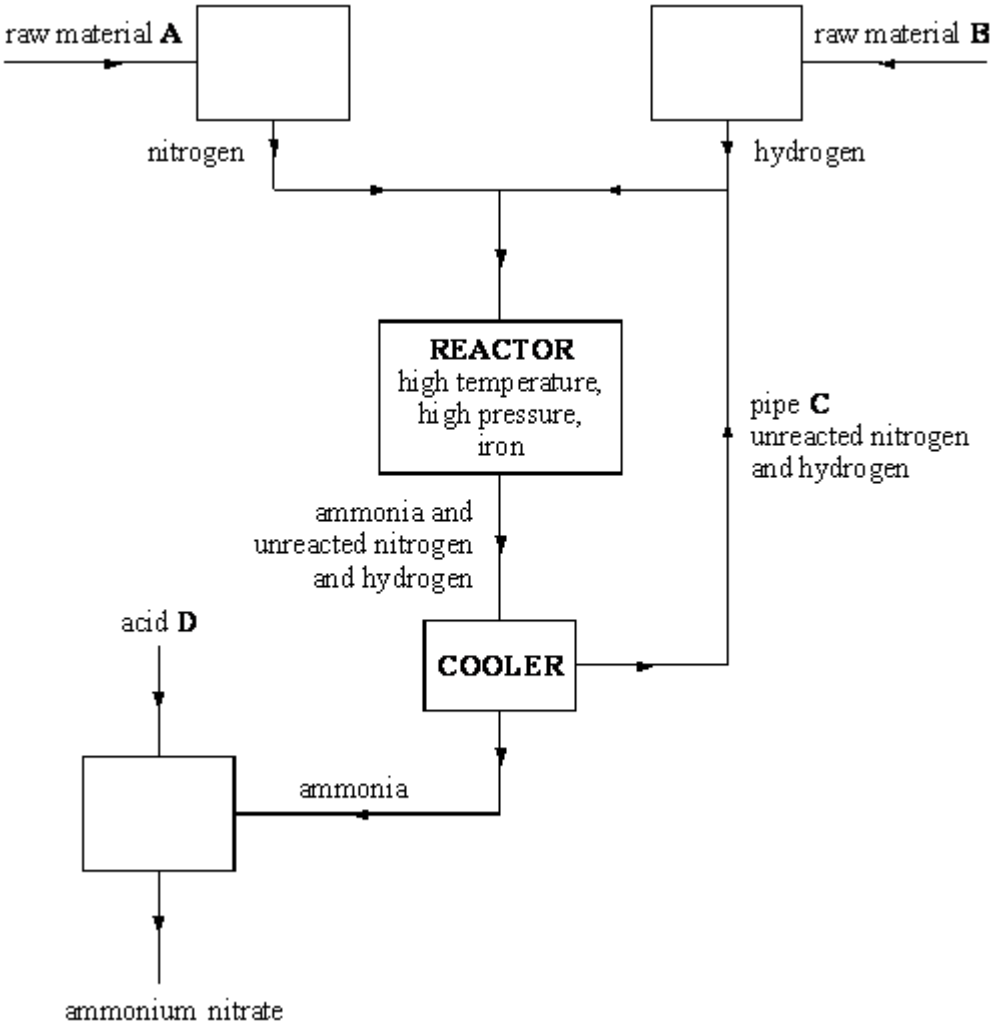


Use this information, together with your knowledge of the process, to explain why many industrial ammonia plants operate at 200 atmospheres and 450°C.

(Total 5 marks)

Q11.

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



(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**?

_____

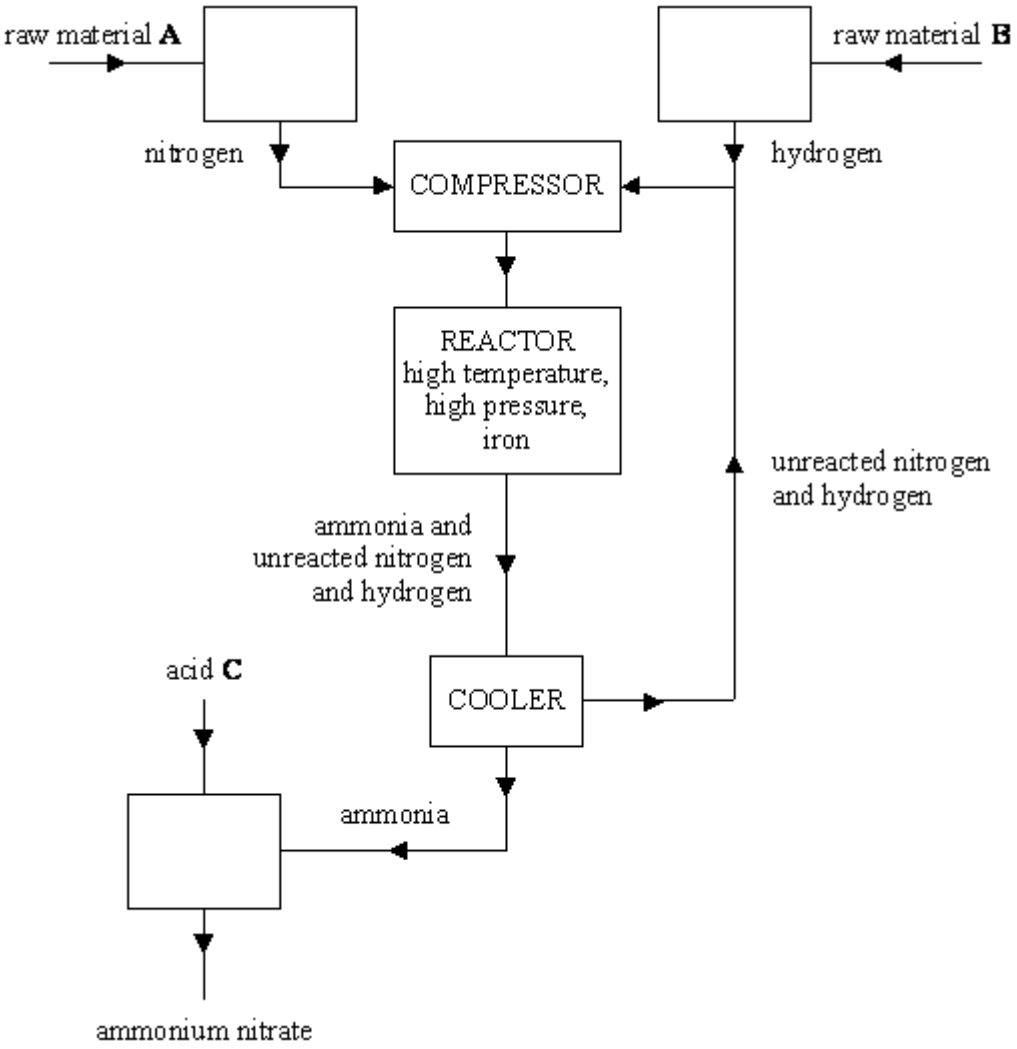
_____

(1)

(Total 5 marks)

Q12.

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.

N_2 + _____ H_2 $\rightleftharpoons$ _____ 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)

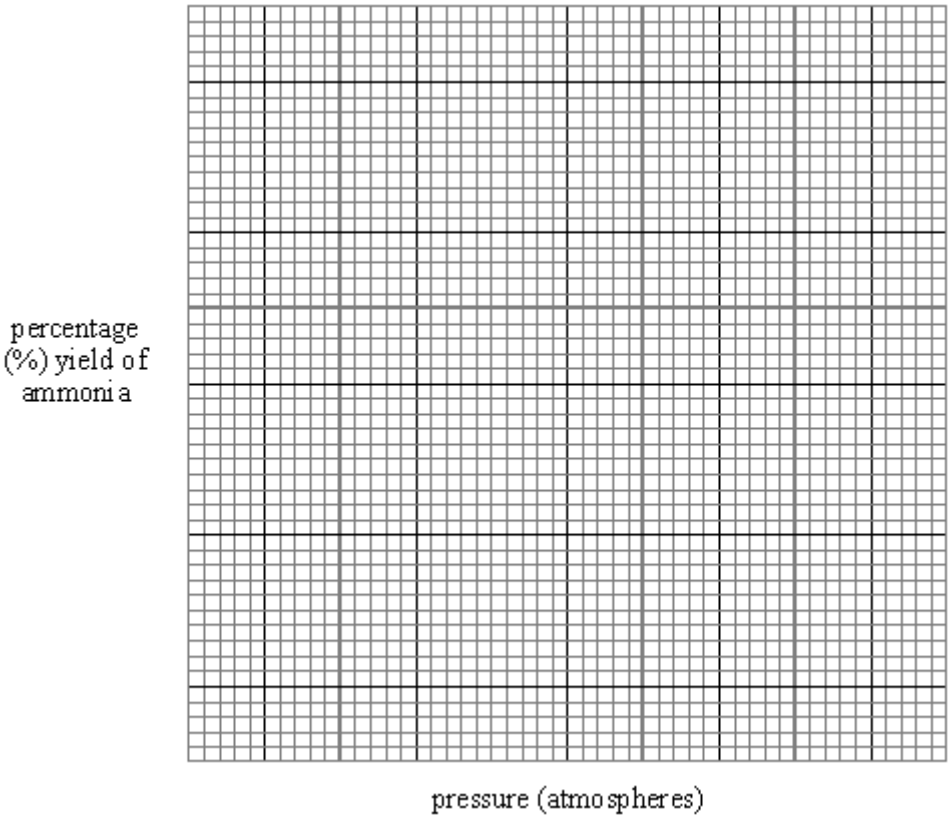
Q13.

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
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.

_____

_____

_____

_____

_____

_____

(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.

_____

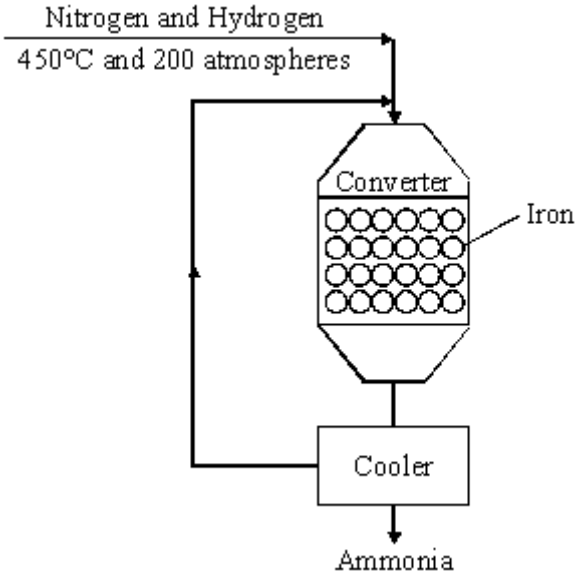
_____

(2)

(Total 15 marks)

Q14.

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



(a) Why is iron used in the converter?

_____

_____

(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)

Q15.

Hydrated copper sulphate is a blue solid. When it is heated, white solid anhydrous copper sulphate is made. This is a reversible reaction.

hydrated copper sulphate [+ heat energy] ⇌ anhydrous copper sulphate + water

(blue) (white)

(a) To make the forward reaction work, the hydrated copper sulphate must be heated all the time.

What type of reaction is this?

_____

_____

(1)

(b) Anhydrous copper sulphate can be used in a test for water. What **two** things will happen when water is added to anhydrous copper sulphate?

1. _____

_____

2. _____

_____

(2)

(Total 3 marks)

Q16.

(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 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?

_____

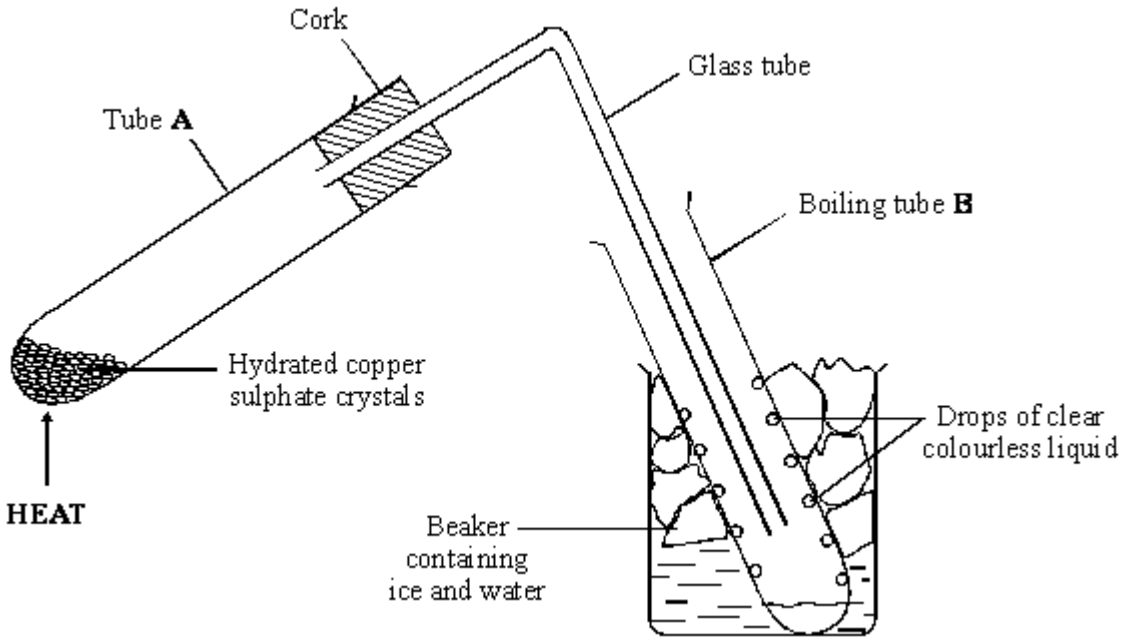
_____

(1)

(Total 10 marks)

Q17.

The diagram shows the apparatus for an experiment. Hydrated copper sulphate crystals were heated. They became anhydrous copper sulphate.



(a) Name a suitable piece of equipment to heat tube **A**.

_____

(1)

(b) Use words from the box to complete the **two** spaces in the table. You may use each word once or not at all.

black	blue	orange	red	purple	white

Name	**Colour**
Hydrated copper sulphate crystals	_____
Anhydrous copper sulphate	_____

(2)

(c) What is the purpose of the ice and water in the beaker?

_____

_____

(1)

(d) Drops of a clear, colourless liquid formed on the inside of tube **B**.

(i) Name the liquid.

_____

(1)

(ii) Explain how the liquid came to be inside tube **B**.

_____

_____

_____

(2)

(e) Anhydrous copper sulphate can be turned into hydrated copper sulphate. What would you need to add? Apart from the change in colour, what could you observe?

_____

_____

_____

(2)

(f) Copper sulphate can be made from black copper oxide by reacting it with an acid. Name the acid.

_____

(1)

(Total 10 marks)

Q18.

(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.

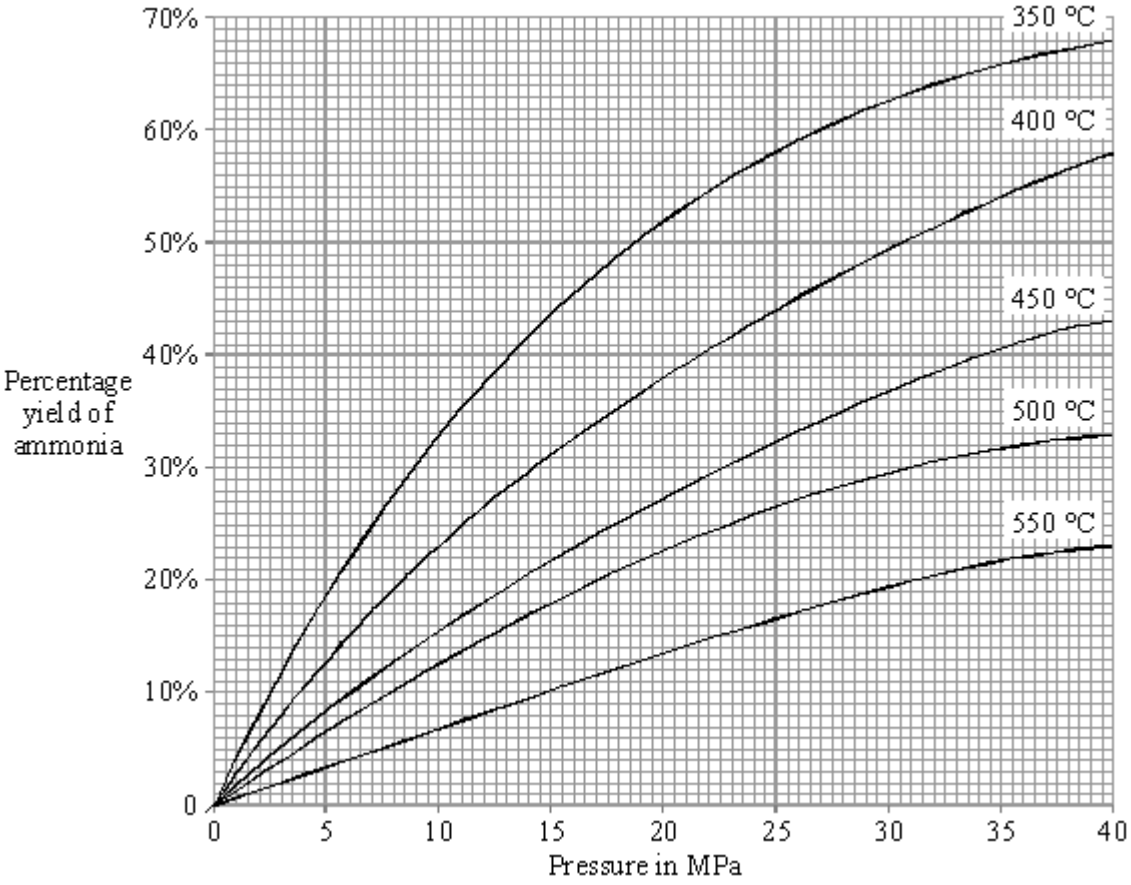
_____

_____

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 _____

(1)

(iv) How can the rate of ammonia production be increased without changing the

temperature or pressure or the mass of hydrogen and nitrogen?

_____

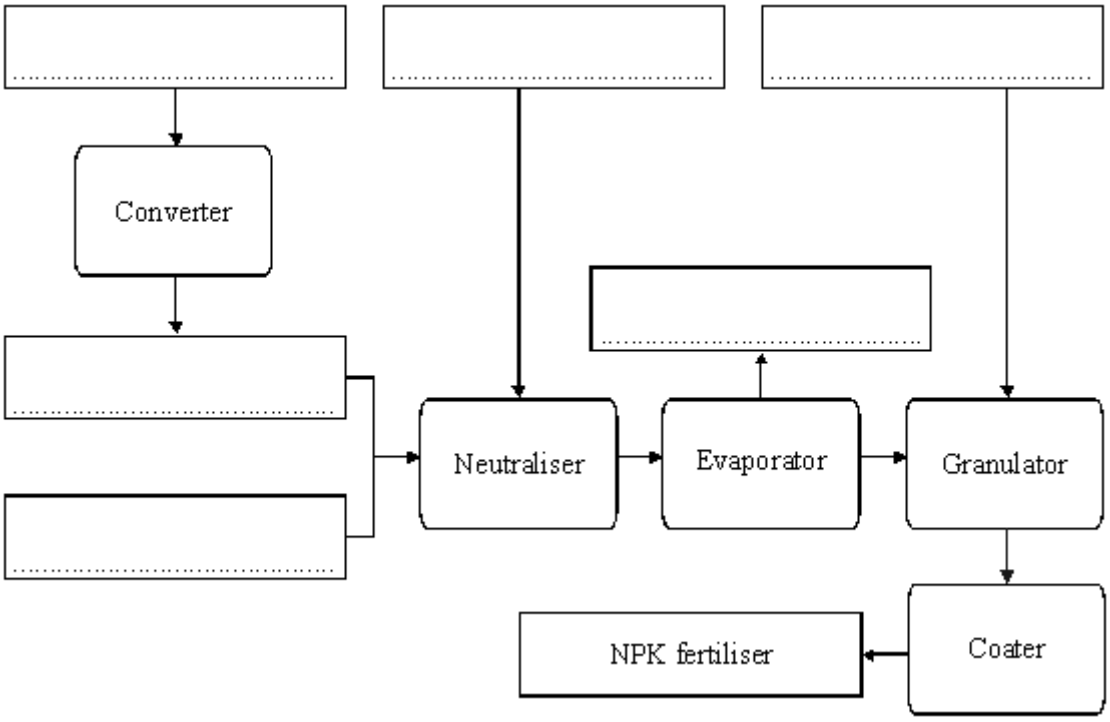
_____

(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)

Q19.

(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.

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)

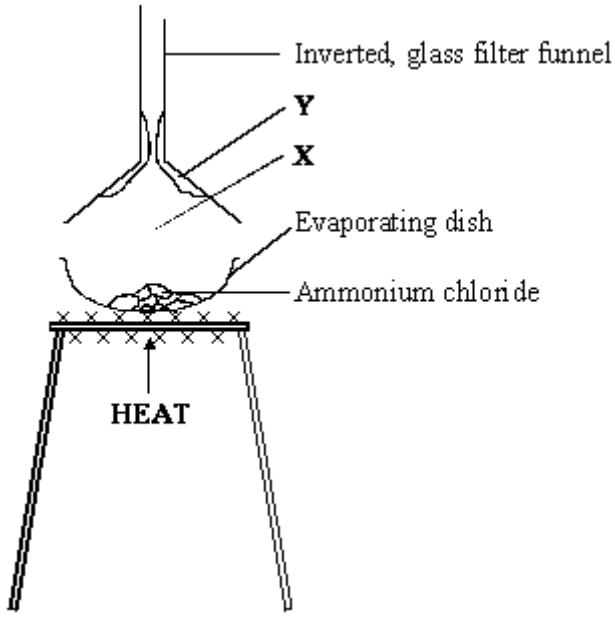
Q20.

(a) The equation for the reaction that takes place when ammonium chloride is heated is:

$NH_4Cl(s) \rightleftharpoons NH_3(g) + HCl(g)$

ammonium chloride — ammonia — hydrogen chloride

The diagram shows how a teacher demonstrated this reaction. The demonstration was carried out in a fume cupboard.



(i) Apart from the gases normally in the atmosphere, which two gases would be at **X**?

_____ and _____

(1)

(ii) Name the white solid that has formed at **Y**.

_____

(1)

(iii) Why was the demonstration carried out in a fume cupboard?

_____

_____

(1)

(iv) Complete the **four** spaces in the passage.

The chemical formula of ammonia is NH_3. This shows that there is one atom of _____ and three atoms of _____ in each _____ of ammonia. These atoms are joined by bonds that

are formed by sharing pairs of electrons. This type of bond is called

a _____ bond.

(4)

(b) Electrons, neutrons and protons are sub-atomic particles.

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

Name of sub-atomic particle	Relative mass	Relative charge
_____	1	+1
_____	1	0
_____	$\frac{1}{1840}$	–1

(2)

(ii) Which **two** sub-atomic particles are in the nucleus of an atom?

_____ and _____

(1)

(Total 10 marks)

Q21.

(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)

Q22.

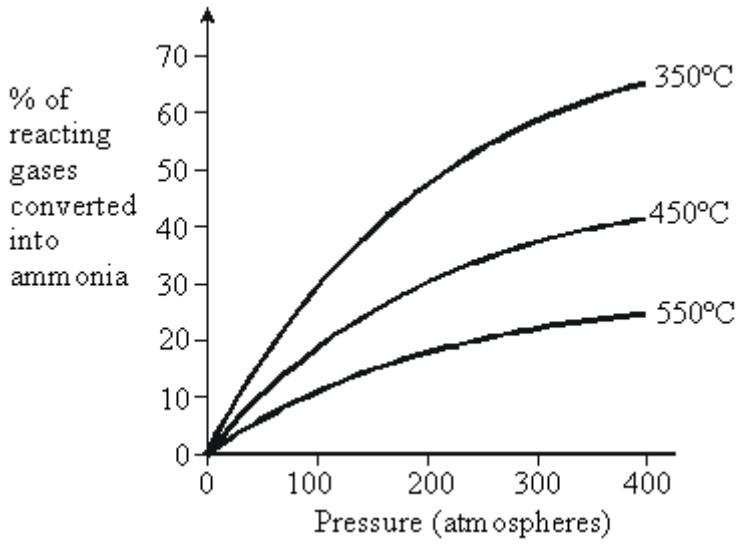
Ammonia is manufactured in the Haber Process, from nitrogen and hydrogen.

(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.



(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.

_____

_____

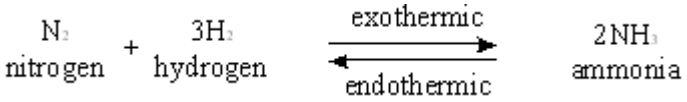
_____

(2)

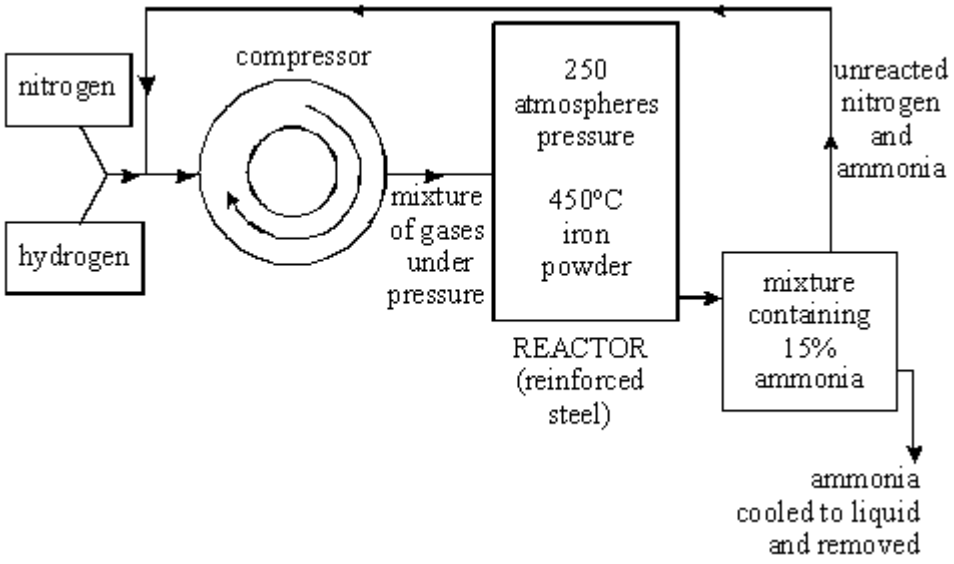
(Total 6 marks)

Q23.

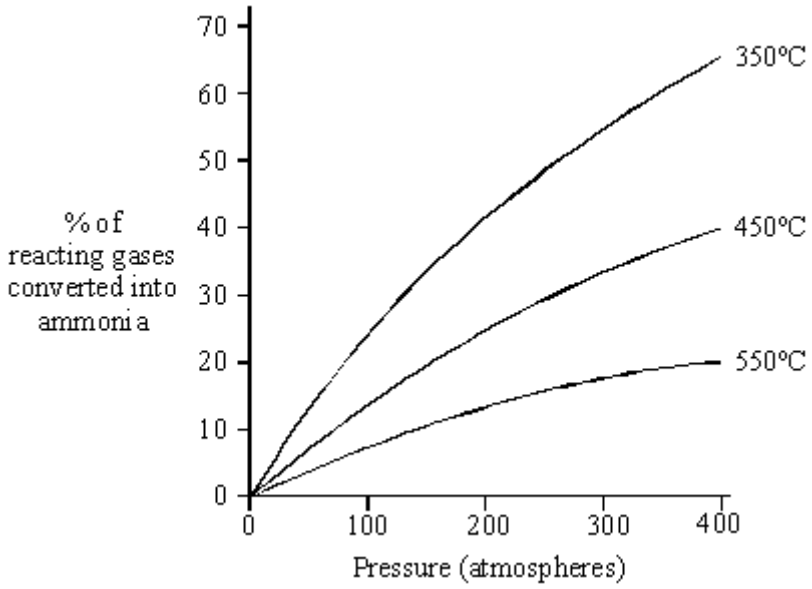
Ammonia is manufactured from nitrogen and hydrogen. The reaction is shown in the equation below.



The diagram shows some details of the manufacturing process.



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**.

(4)

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

(7)

(Total 11 marks)

Q24.

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

(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.

$NO + O_2 \longrightarrow NO_2$

(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. _____

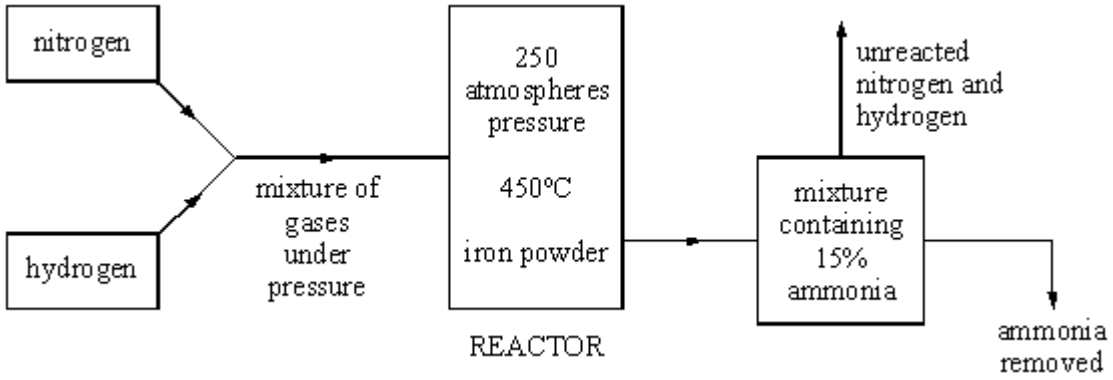
_____

(2)

(Total 15 marks)

Q25.

Ammonia is manufactured from nitrogen and hydrogen in the Haber Process. The diagram shows some details of the manufacturing process.



(a) Nitrogen is obtained from the air.
From where is the hydrogen obtained?

_____

(1)

(b) What happens to the unreacted nitrogen and hydrogen?

_____

_____

(1)

(c) Ammonium nitrate is made from ammonia.

Farmers spread nitrates on to soil to make crops grow better.

The nitrates may get into people's bodies even if they do not eat the crops.

Explain how this can happen.

(2)

(d) The equation for the Haber Process is this:

$N_2 + 3H_2 \underset{}{\overset{\text{exothermic}}{\rightleftharpoons}} 2NH_3$

At equilibrium, nitrogen, hydrogen and ammonia are present in the reactor.

(i) What is meant by 'equilibrium'?

(1)

(ii) Explain, as fully as you can, why:

- the yield of ammonia decreases with increase in temperature,
- despite this fact, a comparatively high temperature of 4500C is used for the industrial process,
- iron powder is added to the reactor.

(4)

(Total 9 marks)

Mark schemes

Q1.

(a) 1213.8 to 1214.3

*gains **3** marks without working*

correct answer not given then check working

1) moles of N_2 = $\frac{1000}{28}$ = 35.7 mol

***1** mark for each correct step*
*do **not** penalise rounding errors in this part*

2) moles of NH_3 = 2 × (answer from (1)) = 71.4 mol

3) mass of NH_3 = (answer from 2) × 17 = 71.4 × 17 = 1214 g

3

or

- 28g of N_2 → 34g of NH_3

  ***1** mark for each correct step*

- 1g of N_2 → $\frac{34}{28}$ = 1.214g NH_3

  *do **not** penalise rounding errors in this part*

- 1000 g of N_2 → 1000 × 1.214
  = 1214g

  allow error carried forward eg

or

- 1000 × $\frac{34}{28}$

*gains **2** marks if correct answer not given*

*1000 × $\frac{28}{34}$ gains **1** mark, **2** marks if correctly calculated*

*(823.5g) 1000 × $\frac{28}{17}$ gains **1** mark if calculated correctly (1647.05g)*

or

other correct methods

look for the key ideas in the methods above

(b) 25 **/** 25.035 **or** ecf from (a)

*gains **2** marks even when there is no working*

*incorrect answer then 304/(their answer from (a)) × 100 gains **1** mark*

or using figures from part (b)

27.6 / 28

*gains **2** marks even when there is no working*

*accept 27 for **1** mark*

*if answers incorrect then304/1100 × 100 gains **1** mark*

2

(c) (i) increase yield

1

reaction is exothermic

or

allow decreased yield because rate of reaction is slower / fewer collisions for **2** marks

***must** get both points for **2** marks*

1

(ii) increase yield

1

plus **one** from:

- more (gaseous) reactant molecules than (gaseous) product molecules (owtte)

  accept greater volume on the left than the right owtte

- increased rate of reaction / more collisions

1

(d) any **one** from:

economic

- large town provides workforce
- workers do not have to travel far to the factory. (owtte)
- transport infrastructure already in place for large town. (owtte)
- factory brings prosperity to town (owtte)
- factory provides employment

- reduced tourism
- reduction in local house prices
- any other sensible economic factor linked to town

1

any **one** from:

safety

- escape of dangerous / harmful chemicals / gases (owtte)
  *do **not** allow polluting gases unqualified*
- danger of increased traffic
- risk of explosion.(owtte) /danger of high pressure
- consequences of an accident could be severe if the town is close
- any other sensible safety idea

1

any **one** from:

environmental

- factory might be unsightly (owtte)
- screening of factory (owtte)
- loss of habitats (owtte)
- plant trees/ hedges etc on and around plant site
- pollution of water / air / soil could harm plants / animals **or** noise pollution
  must be explained
- CO_2 is produced by burning fuels / heating
- CO_2 causes global warming / any effect of global warming
- eye sore
- any other sensible environmental factor

1

[12]

Q2.

(a) endothermic **and** because it takes in heat / energy
__both__ for one mark

1

(b) (i) reversible reaction (or explanation)

1

(ii) add water

*do **not** accept cooling **or** reverse the reaction*

1

[3]

Q3.

(a) (i) high temperature

accept temperature given if ≥ 400 °C
ignore value if "high" stated, unless silly value

1

endothermic or reaction takes in energy
or Δ H is +ve

independent marks

1

(ii) low pressure

or up to and including 10 atmospheres

1

(low pressure) favours a reaction in which more molecules are formed

2 moles → 4 moles
(2 molecules → 4 molecules)

independent marks

1

(iii) nickel **and** it is a transition / transitional element / metal (owtte) **or** nickel **and** variable oxidation state / number or it is similar to other named transition elements e.g. iron

1

(b) (i) (bonds broken =) 2005 (kJ)

1

(bonds formed =) 2046 (kJ)

1

energy change = 2005 – 2046 = (–)41

for correct subtraction ignore sign

1

(ii) (exothermic)

if in part (b)(i) answer is not 41
answer is consequential on endothermic or exothermic shown

*accept correct reasoning for **incorrect** answer from (b)(i)*

energy given out forming new bonds

*do **not** accept energy needed to form new bonds*

1

greater than energy put in to break old bonds

*accept exothermic **and** more energy given out than taken in for 1 mark*
*accept negative value for energy change **or** energy in products less than energy in reactants for 1 mark*

1

[10]

Q4.

(a) (i) high **and** low

both needed for mark

1

(ii) reversible

1

(iii) to prevent ammonium chloride / solid / particles escaping

idea of a filter
*do **not** accept 'to prevent gases escaping'*

1

(b) endothermic

1

[4]

Q5.

(a) ***2** marks for comments related to temperature*

low / lower / lowest temperature (**or** 100 °C from graph)

ignore references to catalyst

1

any **one** from:

- (forward) reaction exothermic

  ***or** reverse reaction endothermic*

- if the temperature is increased the yield of product will decrease **or** reaction right to left

  *high temperature favours reverse reaction **or** reverse argument*

  *the lower the temperature the greater the yield = **2** marks*

  ***2** marks for comments related to pressure*

1

high / higher / highest pressure (or greater than 200 atm. from graph)

1

any **one** from:

- four reactant molecules but only two product molecules (owtte)

  reverse reaction goes from 2 molecules / moles / volumes to 4 molecules / moles / volumes

- increase in pressure favours the reaction which produces the least number of molecules

  decrease in pressure favours the back reaction because it produces the most molecules

1

(b) any **three** from:

- at low temperatures the reaction is too slow
- 450 °C gives a reasonable yield at a fast rate / compromise between yield and rate (*)
- 200 atm. gives a reasonable yield at a reasonable cost / safely / compromise between yield and cost / safety (*)

  *(*) or 450°C and 200 atm / these are compromise conditions for **1** mark*
- catalyst works better at higher temperature
- (very) high pressures could be dangerous (owtte)

  safety factor
- (very) high pressures are expensive (owtte)
- (yield is not too important because) unreacted gases can be recycled

3

[7]

Q6.

(a) (i) yield increases

two marks are linked

1

because more (gaseous) reactant molecules / particles than (gaseous) product molecules / particles

accept 7 → 4 moles or volumes
ignore more reactants
accept fewer particles on the right

1

(ii) increased (rate) / faster / speeds up etc

two marks are linked

1

more collisions **or** increased concentration **or** particles closer together

greater chance of more successful collisions

1

(b) heat / high temperatures

*do **not** accept burn it ignore cracking / catalyst*

1

[5]

Q7.

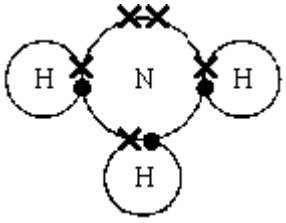
(i) reversible (reaction)

1

(ii) (yield of ammonia) increases

1

(iii)



1

[3]

Q8.

(i) a reaction in which the products can be changed back to reactants

*accept a reaction that can go forwards **or** backwards*

1

under certain conditions

1

(ii) M_r $CaCO_3$ = 100

1

M_r CaO = 56

1

mass of CaO = 140 (tonnes)

1

mark consequentially

[5]

Q9.

(a) 16%

for 2 marks

(attempt by drawing lines etc gains 1 mark)

2

(b) iron is a catalyst;
which speeds up the reaction

for 1 mark each

2

(c) (from the graph) the best **yield** is obtained at high pressure;
and low temperature;
it is a reversible reaction;
in which formation of ammonia is favoured at low temperature

(because) the reaction is exothermic;
and the formation of ammonia is favoured at high pressure because greater number of gaseous reactant molecules than gaseous product molecules/because greater vol of reactant than volume of product molecules;
pressure used is limited by cost/materials;
rate of reaction slow at low temperatures;
actual temperature and pressure used is a good compromise (between a good yield and reasonable rate);
removal of ammonia makes rate more important than yield;

any 8 for 1 mark each

8

[12]

Q10.

Effect of pressure

- high pressure increases yield

  for 1 mark

- either because less product molecules (Le Chatelier)
  or but high pressure increases cost/safety

  for 1 mark

Effect of temperature

- low temperature increases yield

  for 1 mark

- either because exothermic reaction (Le Chatelier)

  for 1 mark

- or but at low temperature rate is slow/catalyst does not work

Compromise

- optimum conditions to balance rate and % yield

  for 1 mark

- or rate is slow (at higher temperature) so need a catalyst
  or low percentage conversion so recycle untreated gases

[5]

Q11.

(i) A = air
B = natural gas

for 1 mark each

2

(ii) nitrogen

both for 1 mark

1

(iii) catalyst / speed up reaction

for 1 mark

1

(iv) recycle unreacted gases / save money

for 1 mark

1

[5]

Q12.

(a) (i) A = air
B = natural gas / methane / north sea gas / CH_4 / oil / naphtha/ steam water (H_2O)

Accept answers written in the box at the start of the question.

each for 1 mark

2

(ii) catalyst / speed up the reaction / lower the activation energy

for 1 mark

1

(b) (i) 3 2

for 1 mark

1

(ii) reversible reaction

so that amount of product depends on conditions used

(linked to first point)

best yield at low temperatures

because it is an exothermic reaction / gives out heat (linked)

reaction rate too slow at low temperatures

450 °C is a compromise between a reasonable yield of ammonia at a fast rate of reaction

catalyst works best when heated

best yield at high pressures

because there is a decrease in the number of gaseous molecules (linked)

increasing the pressure also increases the rate

the pressure used is limited by cost, safety etc

the fact that all the nitrogen and hydrogen are not converted to ammonia does not matter because unreacted gases can be recycled through process

any six for 1 mark each

6

[10]

Q13.

(a) (i) both scales (must be sensible) (use at least half the paper)
plots for 350°C (to accuracy of +/- 1/2 square)
plots for 500°C (to accuracy of +/- 1/2 square)
lines of best fit (sensible smooth curves) (ignore below 50 atm.)
(must not join the dots and each curve must be a single line)

for 1 mark each

4

(ii) read accurately from their graph (must be 350 °C and pressure read to +/– half square from their graph)

for one mark

1

(iii) smooth curve drawn between 350°C and 500 °C - must be of similar shape to the other curves - a dashed line would be accepted here but would not be accepted for part (i)

for one mark

1

(b) (i) reversible reaction (owtte) / equilibrium / equilibria /
reaction goes in both directions etc.

for one mark

1

(ii) maximum of 2 marks from each section up to a maximum total of 5

<u>effect of temperature (max. 2 marks)</u>
best yield at low temperature / poor yield at high temperature
reaction too slow at low temperature / fast at high temperature

<u>effect of pressure (max. 2 marks)</u>
high yield at high pressure (owtte) / low yield at low pressure
ideas to do with cost / safety factor of using higher pressures

<u>evaluation (max. 2 marks)</u>
formation of ammonia favoured at low temperature **because**
reaction is exothermic formation of ammonia favoured at high
pressure **because** more reactant molecules than product molecules
actual temperature and / or pressure used are a compromise
between good yield and reasonable rate ammonia removed
/ unreacted nitrogen and hydrogen recycled so rate more important
than yield catalyst used (not a wrongly named catalyst)

for 1 mark each

5

(c) (i) $NH_4NO_3 = 14 + (4 \times 1) + 14 + (3 \times 16) = 80$ (ignore units)

for one mark

1

(ii) ecf (error carried forward from part (i))
look for (28/80) for first mark

gains 1 mark

but 35% (% sign not needed)

special case of (14/80 × 100 = 17.5%) gains one mark

gains 2 marks

2

[15]

Q14.

(a) as a catalyst

accept to speed up the reaction (equilibrium)

1

(b) nitrogen + hydrogen ⇌ ammonia

$N_2 + H_2 \rightleftharpoons NH_3$

accept mixed formula / word equations
ignore balancing

1

(c) (i) the reaction is reversible / an equilibrium

accept that ammonia can break down again into nitrogen and hydrogen
accept reaction goes both ways
*do **not** accept some nitrogen and hydrogen do not react*

1

(ii) (the gases are cooled)

no marks as given in the diagram
accept correct formulae NH_3, N_2 H_2

1

ammonia removed as a liquid

*accept ammonia liquefies **or** condenses*

nitrogen and hydrogen are recycled

accept nitrogen and hydrogen are put back through the converter
accept 'other gases' only if ammonia identified for first mark

1

[5]

Q15.

(a) endothermic (reaction)

accept thermal decomposition

1

(b) gives out heat (energy)

accept exothermic (reaction)

1

turns blue

accept goes to hydrated copper sulphate

1

[3]

Q16.

(a) (i) gas

accept they are all gases

1

(ii) reversible (reaction)

accept can go either way
accept ammonia can be decomposed (to nitrogen and hydrogen)
accept could be (an) equilibrium
do not credit just 'equilibrium'

1

(iii) (liquid) air **or** atmosphere

1

(iv) same number **or** amount **or** weight (of atoms) on each side (of the equation)

accept "sums" for each side

accept same amounts of elements on each side
*do not credit molecules **or** compounds*
do not credit both sides are the same unless explained

1

of the same type

***or** gives a correct example 'e.g. six hydrogen atoms' (on each side)*

1

(b) (i) nitrate **or** sulphate **or** phosphate

if first left blank, second may be awarded

do not credit chloride

nitric **or** sulphuric **or** phosphoric

1

(only if correct above, exception is for ammonium chloride followed by hydrochloric acid (1 mark))

as appropriate if only the formula is given this should be credited only if it is correct in every detail i.e. NH_4NO_3 HNO_3 $(NH_4)_2SO_4$ H_2SO_4
accept correct name with an incorrect version of the formula
do not credit a correct formula with an incorrect version of the name e.g. 'nitrate/sulphite' etc

1

any **one** of

* (solution) can be sprayed (on the fields **or** crops)

accept more even distribution

* dissolves in soil water **or** rain (water)

accept soaks into soil (because soaks implies water)

* can be taken up by (plant) roots

do not credit can be added to water to "feed" the plants

1

(c) (i) elements **or** different atoms are bonded or joined **or** combined **or** reacted

do not credit just 'atoms'

*do not credit added **or** mixed*

1

(ii) (pairs of) electrons are shared

do not credit an electron is shared

1

[10]

Q17.

(a) Bunsen (burner)

accept spirit burner do not credit candle

1

(b) blue

1

white

credit (1) if both colours correct but answers are reversed

1

to cool the tube (B)

*accept answers which anticipate part (d) e.g. 'to condense the water vapour' or gases **or** vapours*

1

(d) (i) water

do not credit 'condensation'

1

(ii) (Water) vapour from the crystals (from tube A)

*accept steam **or** steam from tube A*

1

condenses **or** cools

accept turns to (liquid) water

1

(e) add water

gets hot **or** hotter **or** warm **or** warmer turns into solution dissolves

or the temperature rises or there is an exothermic reaction
*accept steams **or** hisses ignore any reference to colour(s)*

2

(f) sulphuric acid

accept H_2S0_4 only if correct in every detail

1

[10]

Q18.

(a) (i) atmosphere

or (fractional distillation of liquid) air

1

(ii) **either**

more (chance) of them colliding/

not just 'faster'

coming into contact

or

the volume of the product / the ammonia is less than /

only half the volume of the reactants / the nitrogen and hydrogen

1

(iii) 3 × (1 ×2) of hydrogen

→ 2 × (14 +1 ×3) of ammonia

*accept 6 parts of hydrogen →34 parts of ammonia **or** similar*

i.e. candidate uses the atomic masses and works correctly from the equation

1

= 225 (tonnes/t)

unit not required

1

(b) (i) megapascal(s)

accept million pascal(s)

1

(ii) 28 (%)

accept any answer in the range 28.0 to 28.5 inclusive

1

(iii) reduce the temperature and increase the pressure

both required

1

(iv) **either**

use a catalyst

accept use iron as a catalyst

accept use iron which has been more finely divided

accept use iron / catalyst with a bigger (surface) area

accept use a better catalyst

1

or

remove the ammonia (as it is produced)

*accept react the ammonia with **or** dissolve the ammonia in water (as it is produced)*

1

(c) ammonia
nitric acid
phosphoric acid

all three on the left correct

ammonia potassium chloride

all three on the right correct

water **or** water vapour

accept 'steam'

1

[10]

Q19.

(a) (i) 8

ammonia

do not credit ammonium

sulphuric acid

do not credit just sulphuric; credit sulfuric acid

do not credit hydrogen sulphate

3

(ii) (as a) fertiliser

1

(iii) nitric (acid)

accept HNO_3 if correct in every detail

1

(b) (i) chemical change (in which)

***or** under suitable conditions*

1

product(s) can be converted to reactant(s)

***or** direction of reaction can be reversed*

***or** equilibrium can be achieved*

do not credit reaction can be reversed

1

(ii) air

***or** (the) atmosphere*

1

(iii) made of atoms

1

which are all the same

credit the idea that the particles (in an element) are all the same even if the name of the particles (the first mark) is incorrect

or *which have the same number of protons*

or *which have the same atomic number / proton number*

it cannot be broken down into anything simpler (2) marks

1

[10]

Q20.

(a) (i) ammonia and hydrogen chloride

both required either order
accept formulae if correct in every detail

1

(ii) ammonium chloride / NH_4Cl

do not credit ammonia chloride

1

(iii) the fumes / gases / are poisonous / toxic

or *ammonia and hydrogen chloride are poisonous / toxic / lethal*
accept just ammonia is poisonous / toxic
accept just hydrogen chloride is poisonous / toxic
accept vapour is poisonous / toxic
do not credit just fumes are dangerous
or *harmful*

1

(iv) nitrogen

do not credit N/N_2

1

hydrogen

do not credit H/H_2

1

molecule

do not credit compound ***or*** *mole*

1

covalent

accept single / molecular

1

(b) (i) proton

neutron

electron

either *all three correct*

or *one or two correct*

however do not credit a response which is repeated

2

(ii) protons and neutrons

both required in either order

1

[10]

Q21.

(a) any **one** from

(as a) catalyst

or *to mix with promoters*

to speed up the reaction (process)

or *process is quicker do not credit just it is quicker*

to save energy
to reduce costs

or *process is cheaper*
do not credit just it is cheaper

larger surface area
(than lumps of iron)

or *larger surface area for the (catalysed) reaction (to take place)*

1

(b) (i) water **or** steam
and methane
or natural gas
or North Sea gas

both required either order

1

(ii) **EITHER**
more (chance) of them colliding / coming into contact

do not credit just faster

OR volume of the product / ammonia less than / only half the volume of the reactants / the nitrogen and hydrogen

1

(iii) **EITHER**
680 (tonnes)

OR 28 (of nitrogen) → 34 (of ammonia)

accept any correct 14 : 17 ratio

1

560 (of nitrogen) → 34 × 20 (of ammonia)

3

[6]

Q22.

(a) N_2 + **3** H_2 ↔ **2** NH_3

2

(b) (i) lower temperature gives higher % conversion
higher pressure gives higher % conversion
each for 1 mark

2

(for T = 350 °C and P = 400 At. award 2 marks)

the most economical combination
reaction too slow at lower temperatures
plant too expensive at higher pressures
any 2 for 1 mark each

2

[6]

Q23.

(a) rate of reaction is increased
iron/powder
acts as catalyst
at higher temperatures
at higher pressures
any 4 answers for 1 mark each

4

(b) yield of ammonia is increased at higher pressure
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

7

[11]

Q24.

(a) (i) *idea that it is*

a reaction in which the products can themselves react to reform the original substance or a reaction that can go in either direction

(allow explanation in terms of the specific reaction in the question)

for 1 mark

1

(ii) nitrogen, hydrogen and ammonia
(allow formulae)

for 1 mark

1

(b) (i) high pressure/400 atm
low temperature/100 °C

for 1 mark each

2

(ii) higher rate of <u>reaction</u>
good rate of <u>production</u>
or *idea* that more economic (ally viable)
(allow catalyst more effective at higher temperature)

for 1 mark each

2

(c) (i) *ideas that it involves*

use of catalyst

gains 1 mark

but use of platinum catalyst

gains 2 marks

2

high temperature/900 °C

for 1 mark

1

(ii) <u>2</u> $NO + O_2 \rightarrow$ <u>2</u>NO_2

for 1 mark each

1

(iii) <u>3</u> $NO_2 + H_2O \rightarrow$ <u>2H</u>NO_3+NO

for 1 mark each

1

(d) (i) references to

- transport reductions
- economic savings
- saves time

- guaranteed consumer/supplier

for 1 mark each

2

(ii)
- selection of site
- design of plant
- safe disposal of waste
- make gas emissions safe(r)
- monitoring/safety checks
- reduction of waste gas emissions
- research into more efficient processes
- research into energy savings/use of cooling water
- training of staff re: emergency procedures
- warning/evacuation procedures for the community

(or any two sensible suggestions)

any two for 1 mark each

2

[15]

Q25.

(a) from natural gas [*allow from water/ steam / brine / river / lake / sea*]

for 1 mark

1

(b) *idea that* they are recycled / re-used

for 1 mark

1

(c) *ideas that*

- nitrates may get into ground water / rivers
- so contaminate / get into our drinking water
- eating animals which have eaten crop/ or eating contaminated fish

[do not allow 'eutrophication']

any two for 1 mark each

2

(d) (i) *idea that*
when rate of forward = rate of reverse reaction
[<u>not</u> just 'reversible' or 'can be reversed']
[allow ammonia is breaking up into nitrogen and hydrogen as fast as nitrogen and hydrogen are forming ammonia
<u>or</u> amounts of products and reactants stay constant*]*

for 1 mark

1

(ii) *ideas that*

- at higher temperatures, equilibrium moves to **the** left **or** reverse / endothermic
- reaction / favoured **or** makes products → reactants
- but at lower temperatures the (rate of) reaction is (very) slow
- so a higher temperature is used for economic reasons/so ammonia is produced at higher rate
- iron powder is a catalyst / speeds up the reaction
  [not increases the yield]
- low yield not wasteful if reactants re-cycled

[credit iron powder has a greater surface area]

each for 1 mark

4

[9]