AQA GCSE CHEMISTRY (HIGHER) · 8462

CHEMISTRY



EXAM QUESTION PACK

4.6.2 REVERSIBLE REACTIONS AND DYNAMIC EQUILIBRIUM (PACK 1)

SCORE	PERCENTAGE
/302	%

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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)

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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?

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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.

_____

_____

_____

_____

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(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.

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_____

(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)

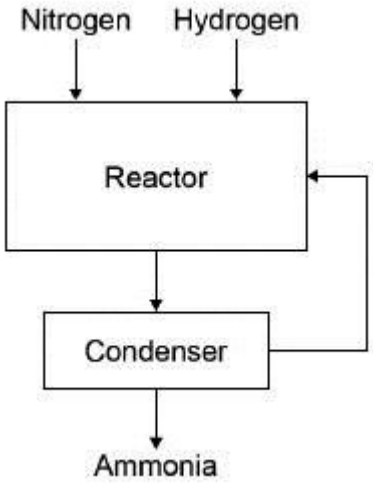
(c) Draw **one** line from each gas to the source of that gas.

Gas	Source
	Air
Hydrogen	Alcohol
	Ammonia
Nitrogen	Iron
	Natural gas

(2)

The diagram shows the Haber process.

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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.

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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 ☐

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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)

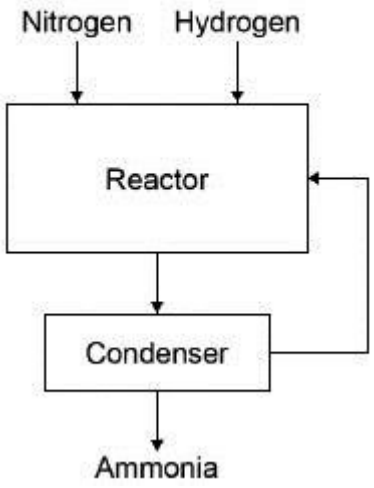
(Total 12 marks)

Q4.

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

Figure 1 shows the Haber process.

Figure 1



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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.

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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 _____

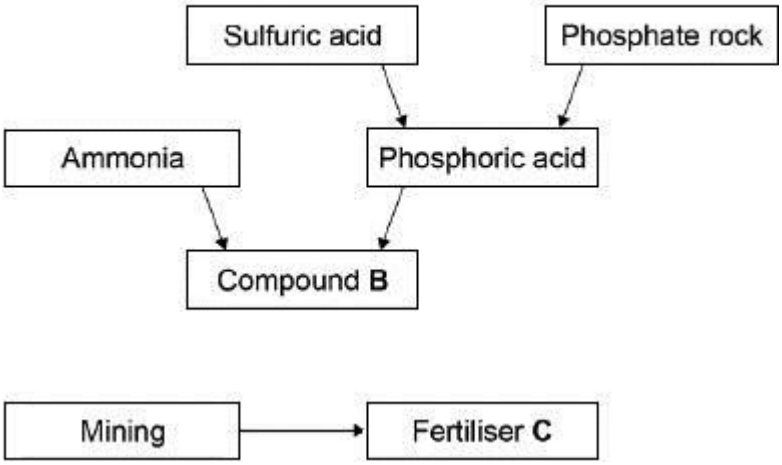
_____

(2)

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

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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.

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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)

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(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.

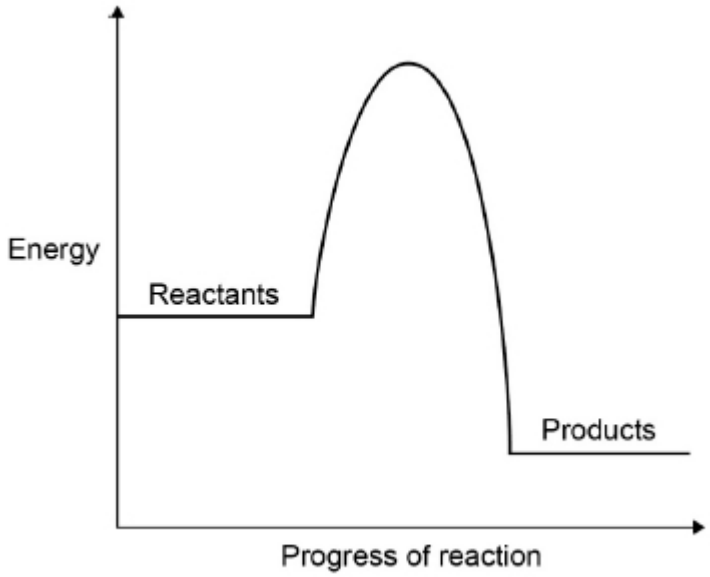
What is the formula of an alkane containing 18 hydrogen atoms?

_____

(1)

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

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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

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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)

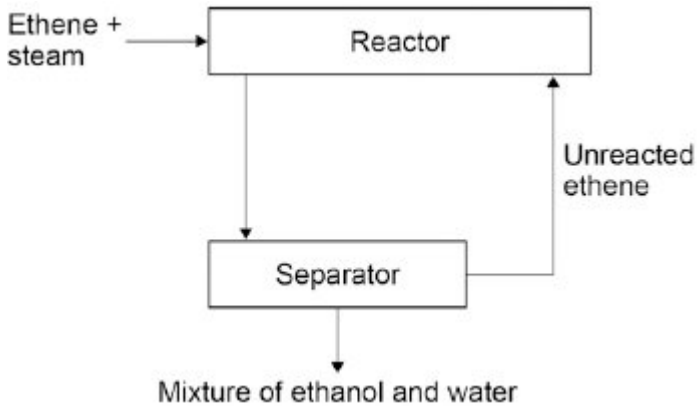
Q7.

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.

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_____

_____

_____

_____

(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)

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(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.**

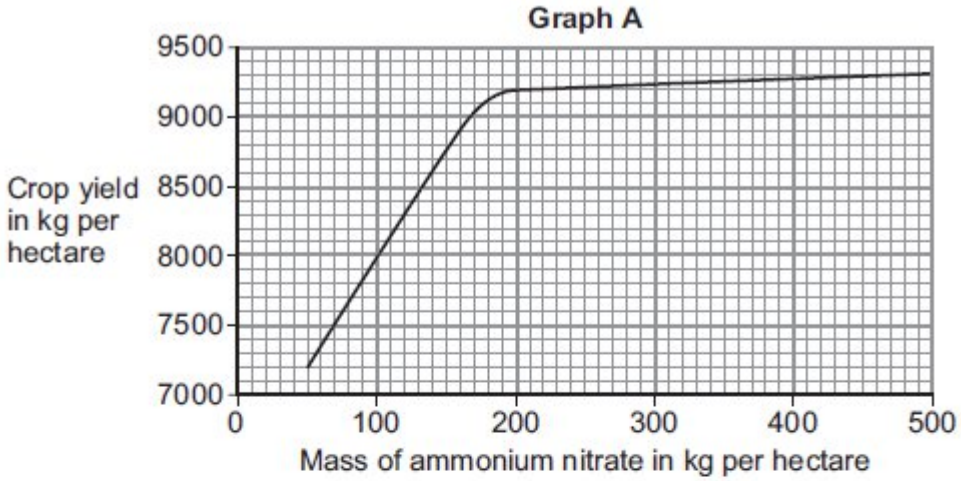
Farmers use ammonium nitrate as a fertiliser for crops.

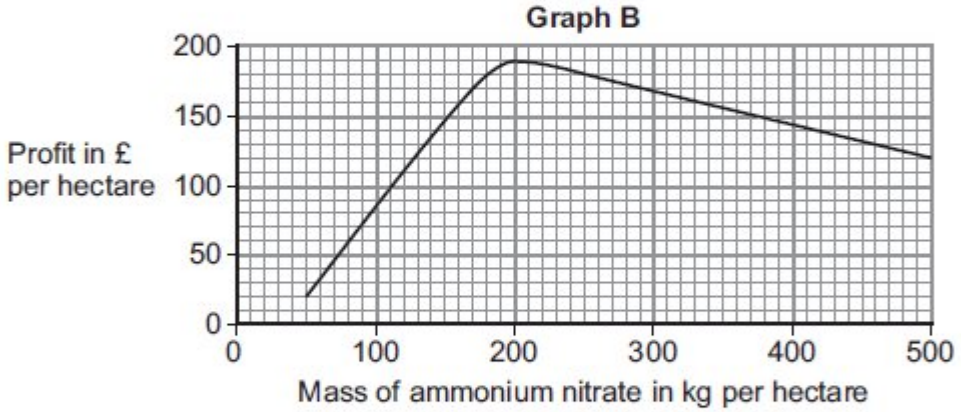
Rainwater dissolves ammonium nitrate in the soil.

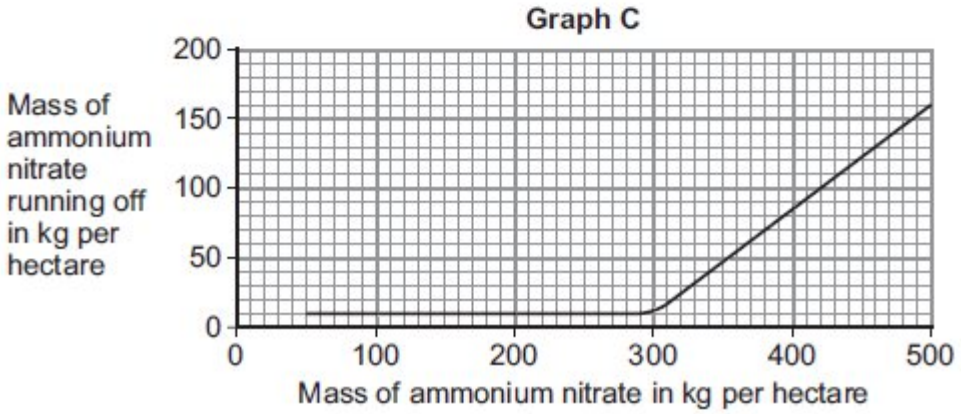
Some of the dissolved ammonium nitrate runs off into rivers and lakes.

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.

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Suggest how much ammonium nitrate farmers should use per hectare.

Give reasons for your answer.

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

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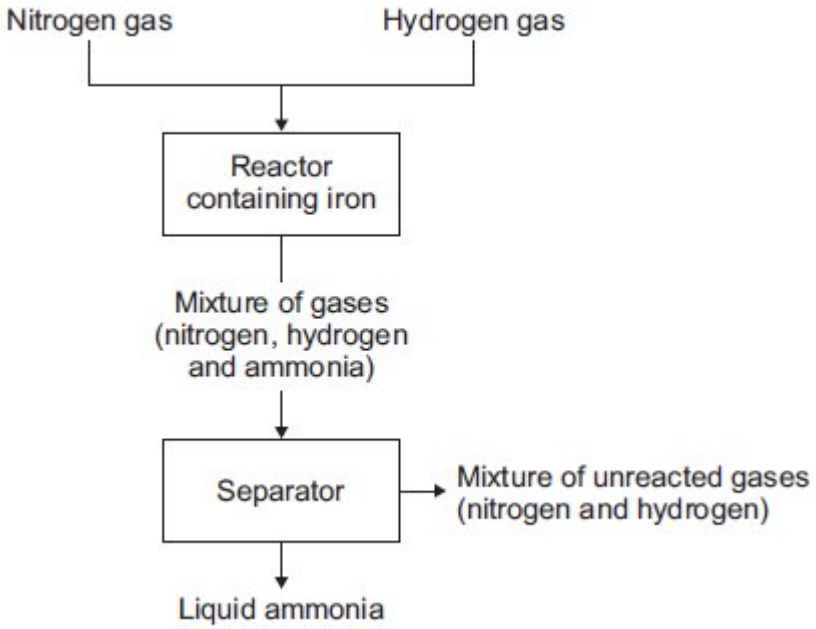
(6)

(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.

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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.

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(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.

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Figure 1

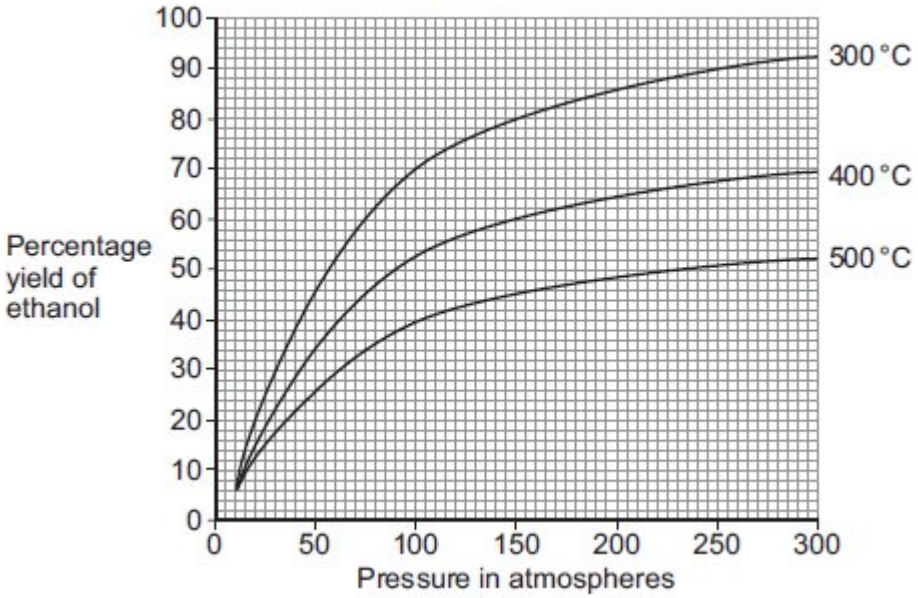
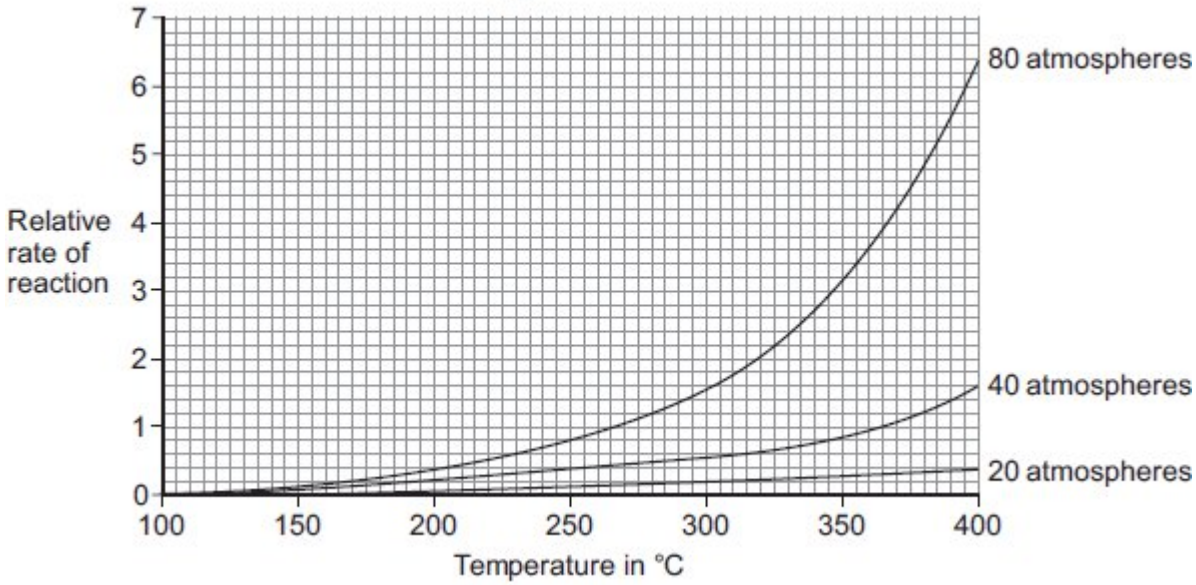


Figure 2 shows how the rate of reaction changes as the temperature changes at three different pressures.

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.

_____

_____

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_____

_____

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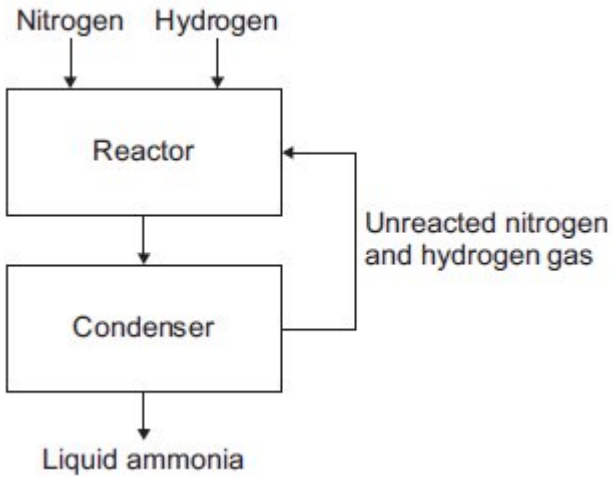
(6)

(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

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(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?

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_____

_____

(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)

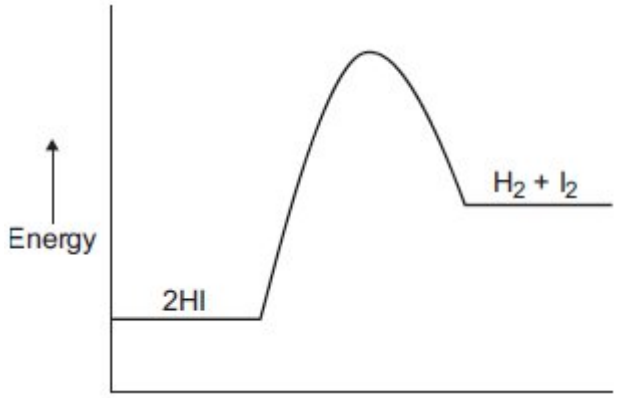
(c) The decomposition of hydrogen iodide into hydrogen and iodine is reversible.

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

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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.

_____

_____

_____

_____

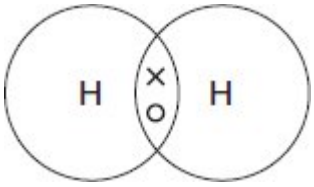
(2)

(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.

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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.

_____

_____

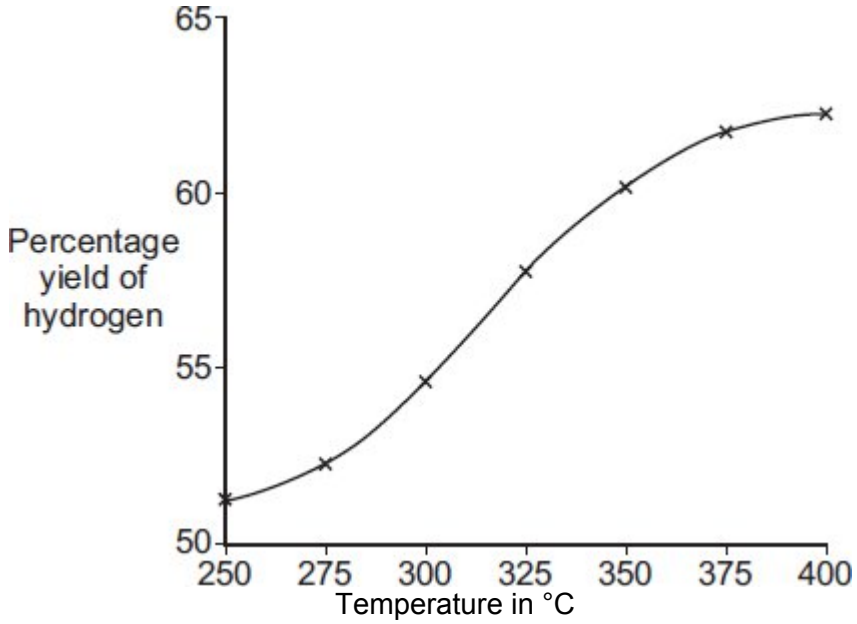
_____

_____

(2)

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

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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	Fractional distillation of crude oil.

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	of water.	

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.

_____

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_____

_____

_____

_____

_____

(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)

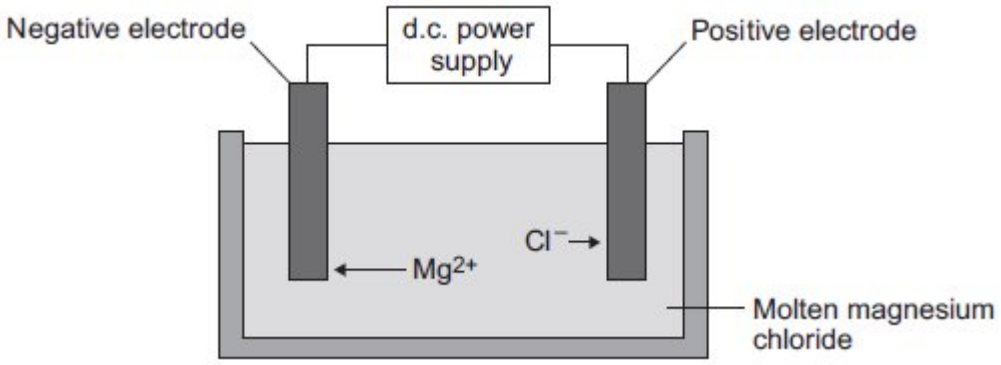
(Total 9 marks)

Q15.

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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

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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)

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(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.

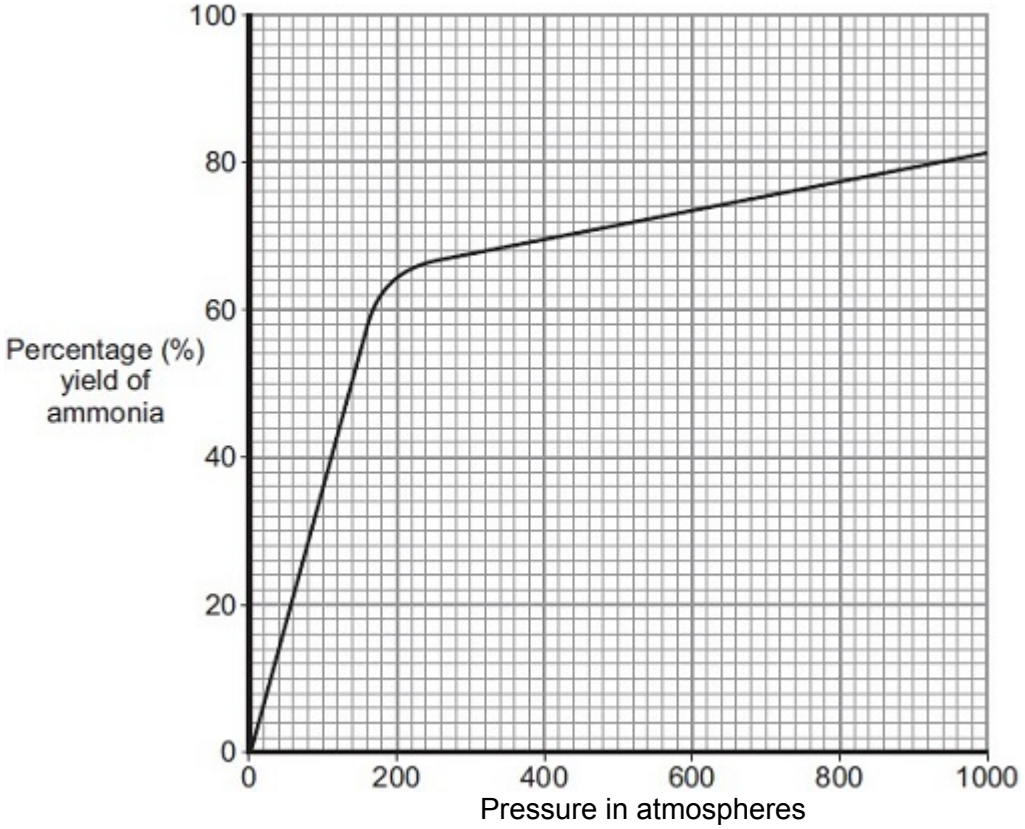
nitrogen + hydrogen _____ _____

(2)

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

Figure 1

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

_____

_____

_____

_____

_____

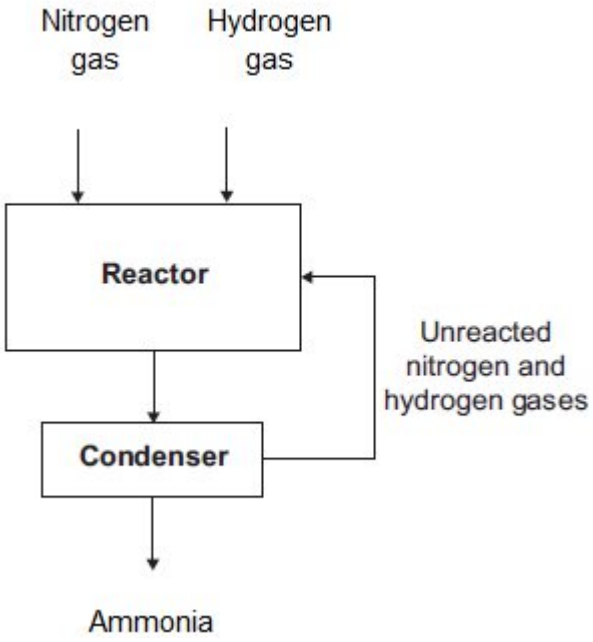
_____

(3)

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

Figure 2

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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.

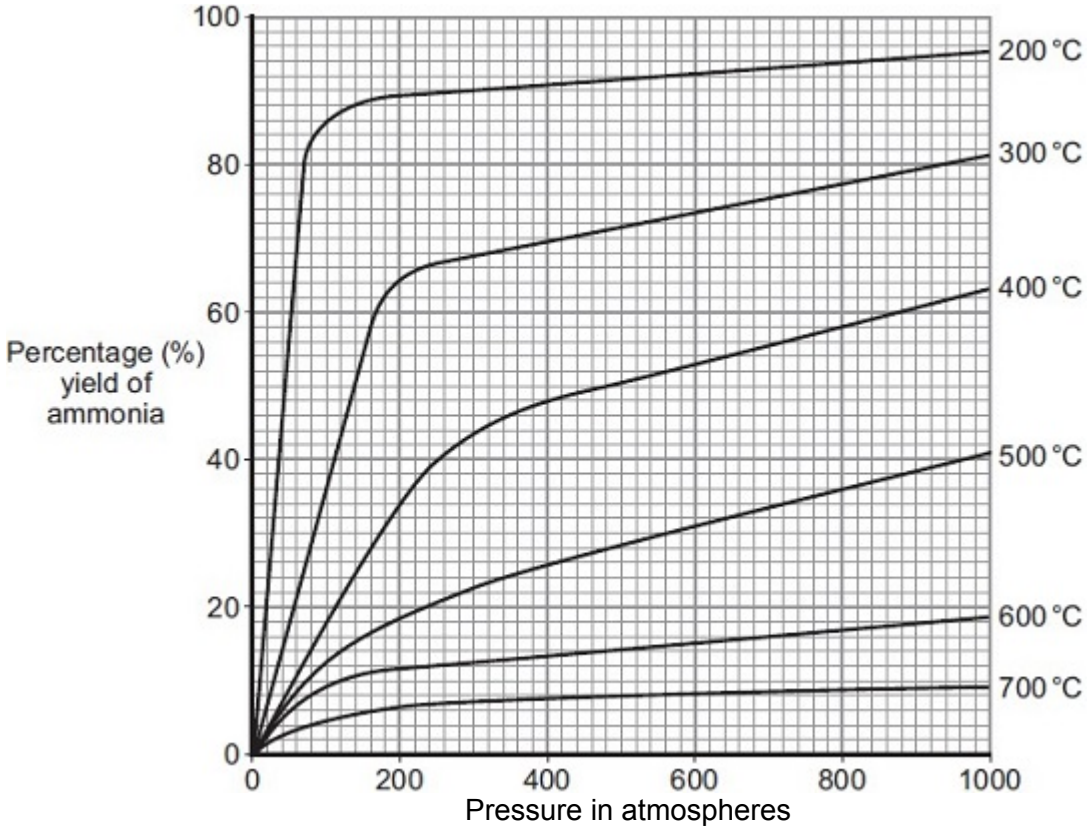
(a) Complete and balance the chemical equation for the production of ammonia from nitrogen and hydrogen.

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

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(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)

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(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.



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(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.

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(1)

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

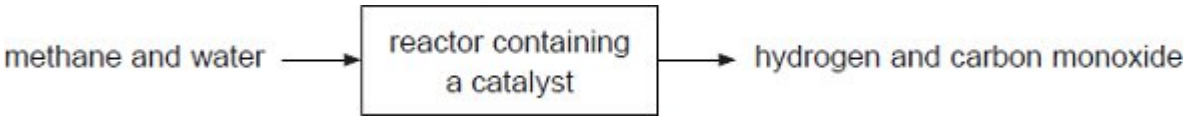
Which raw material provides nitrogen?

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**

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

(OH^-) from the alkali to make

_____ .

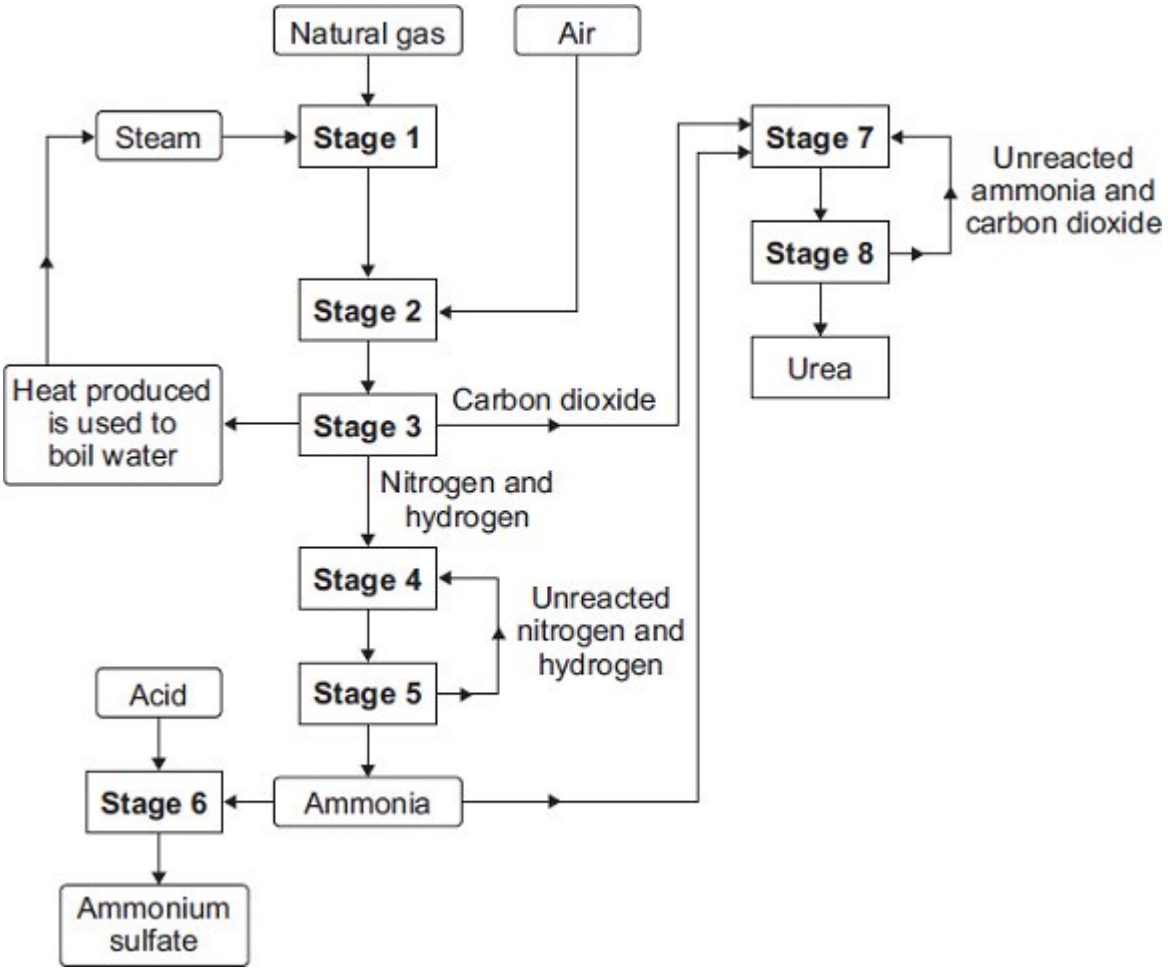
(1)

(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.

_____

_____

_____

_____

_____

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_____

(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

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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 = _____ %

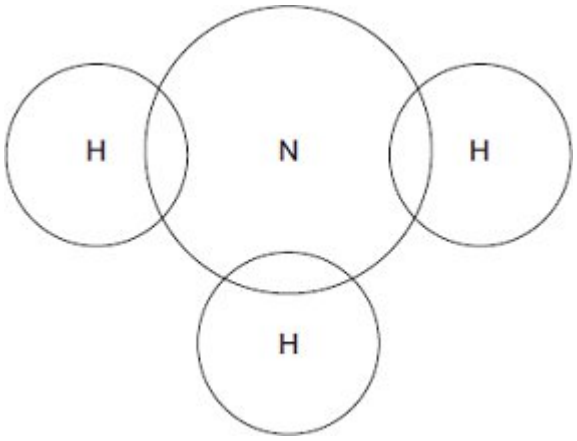
(2)

(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.

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(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.

_____

_____

_____

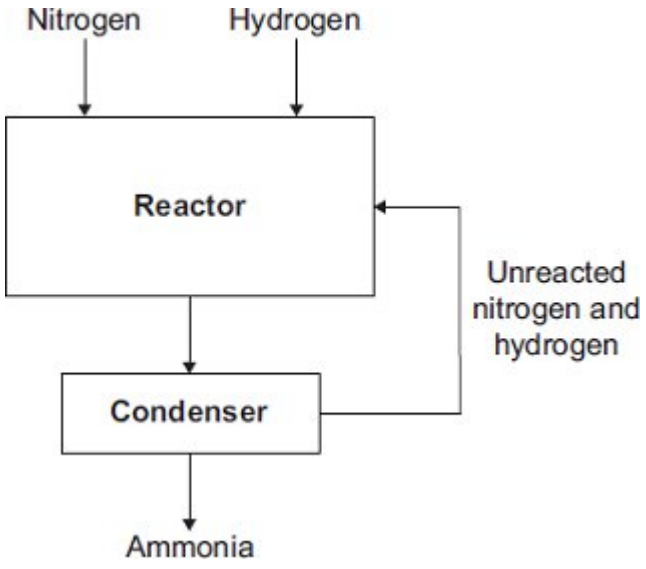
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(6)

(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.

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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.

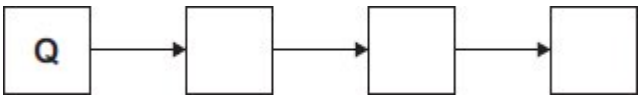
Q Nitrogen and hydrogen are mixed together.

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.



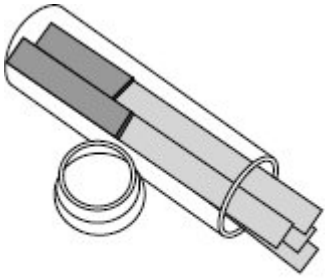
(2)

(Total 5 marks)

Q22.

Read the information and then answer the questions.

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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 (blue) — hydrated cobalt chloride (pink)

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

endothermic	**exothermic**	**reversible**

The symbol $\rightleftharpoons$ 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.

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(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**

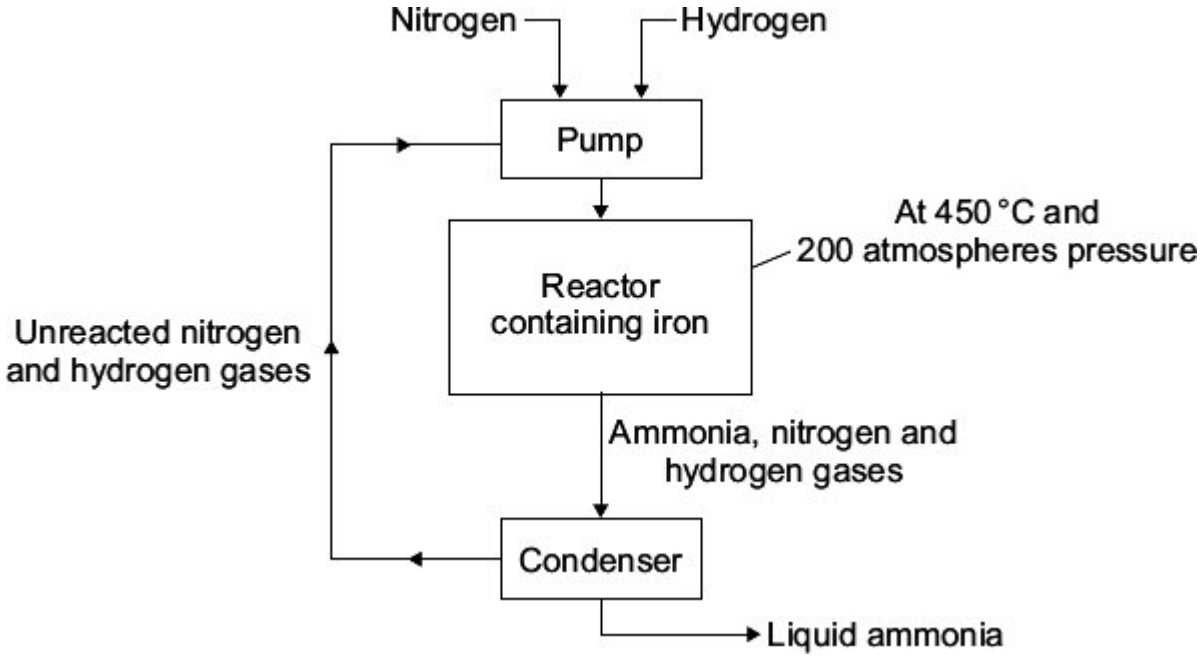
(1)

(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?

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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

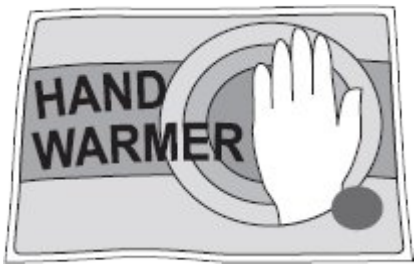
by turning the ammonia into a _____

(1)

(Total 7 marks)

Q24.

Hand warmers use chemical reactions.



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

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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 ☐

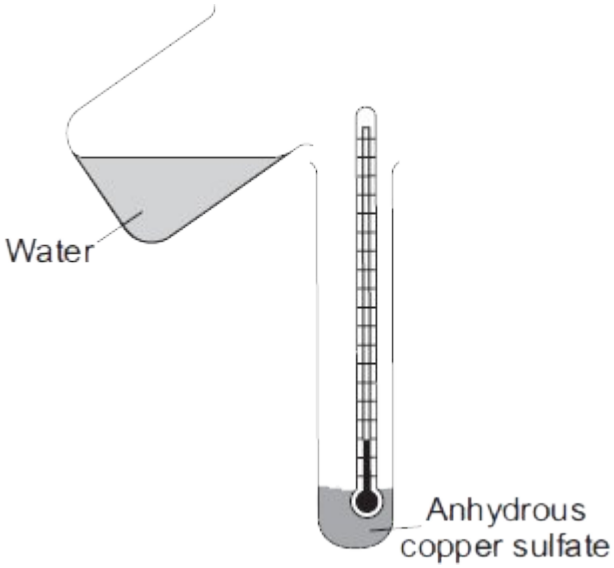
Give a reason why you chose this reaction.

_____

_____

(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 ⇌ $CuSO_4.5H_2O$

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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.

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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	solid
black	liquid
white	gas

which is

ammonia.
ammonium chloride.
hydrogen chloride.

(4)

(b) Complete the sentence.

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

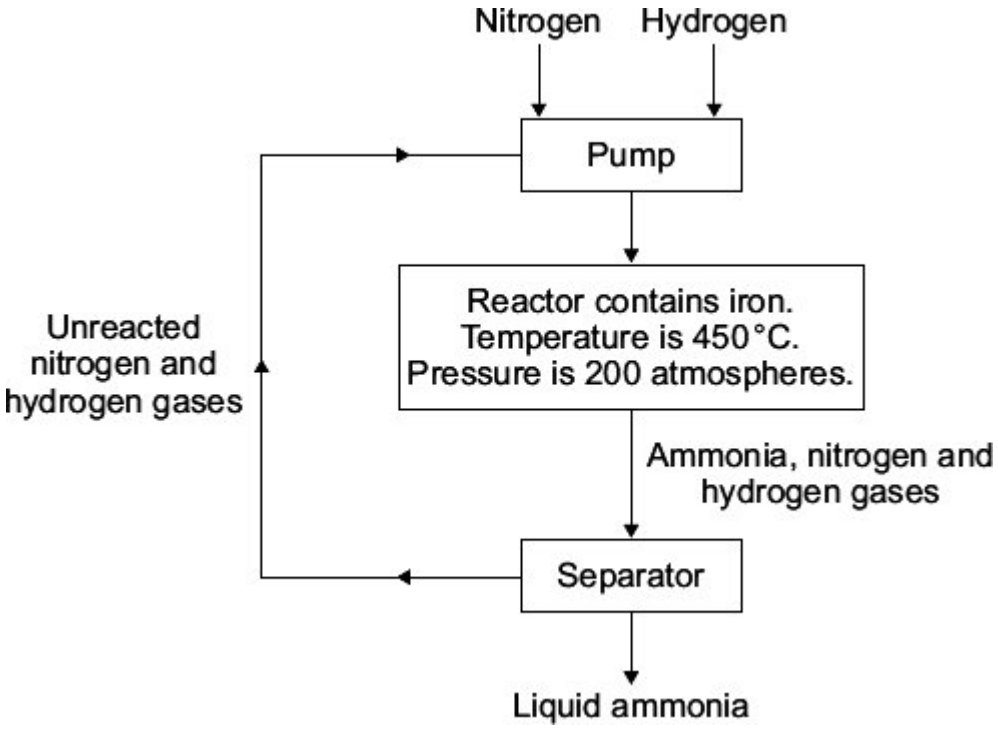
(1)

(Total 5 marks)

Q26.

Ammonia is made using the Haber process.

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(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.

_____

_____

_____

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_____

(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)

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(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.

_____

_____

_____

_____

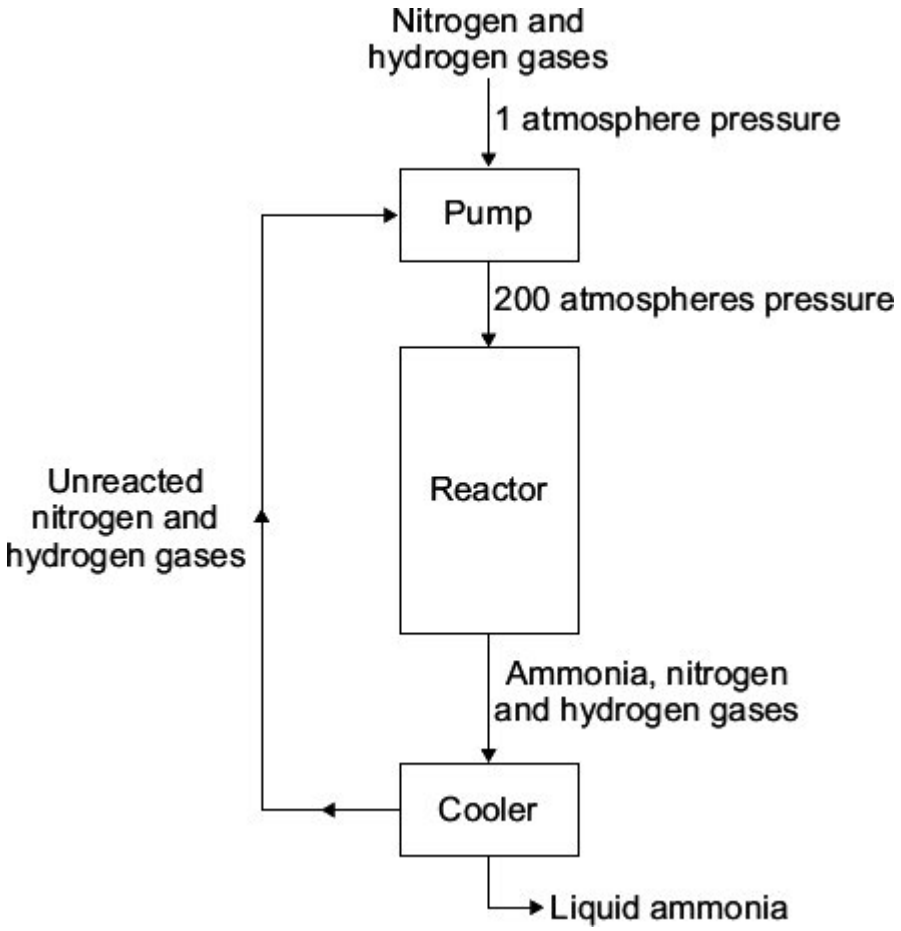
(2)

(Total 14 marks)

Q27.

The flow diagram shows how ammonia is made.

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(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:

$$\text{nitrogen} + \text{hydrogen} \rightleftharpoons \text{ammonia}$$

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.	

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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

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(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.

_____

_____

_____

_____

_____

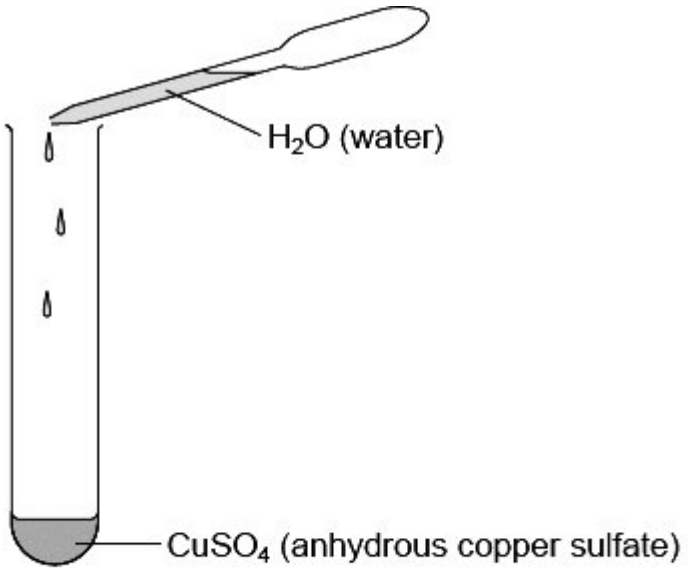
(2)

(Total 8 marks)

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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.

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_____

_____

(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.

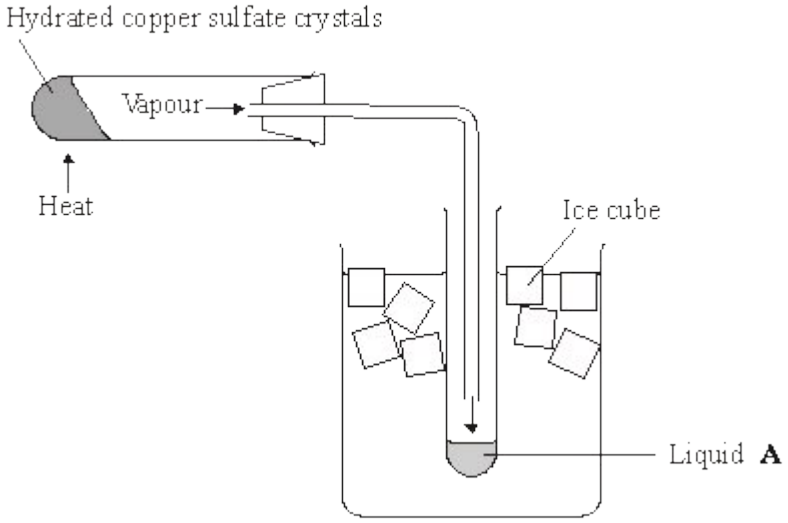
A student heated some hydrated copper sulfate crystals.
The equation for this reaction is shown below.



$CuSO_4.5H_2O(s)$		$CuSO_4(s)$	+	$5H_2O(1)$
hydrated copper sulfate crystals		anhydrous copper sulfate		water

The diagram shows the apparatus used.

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(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 ⇌

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.

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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.

_____

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_____

_____

_____

_____

_____

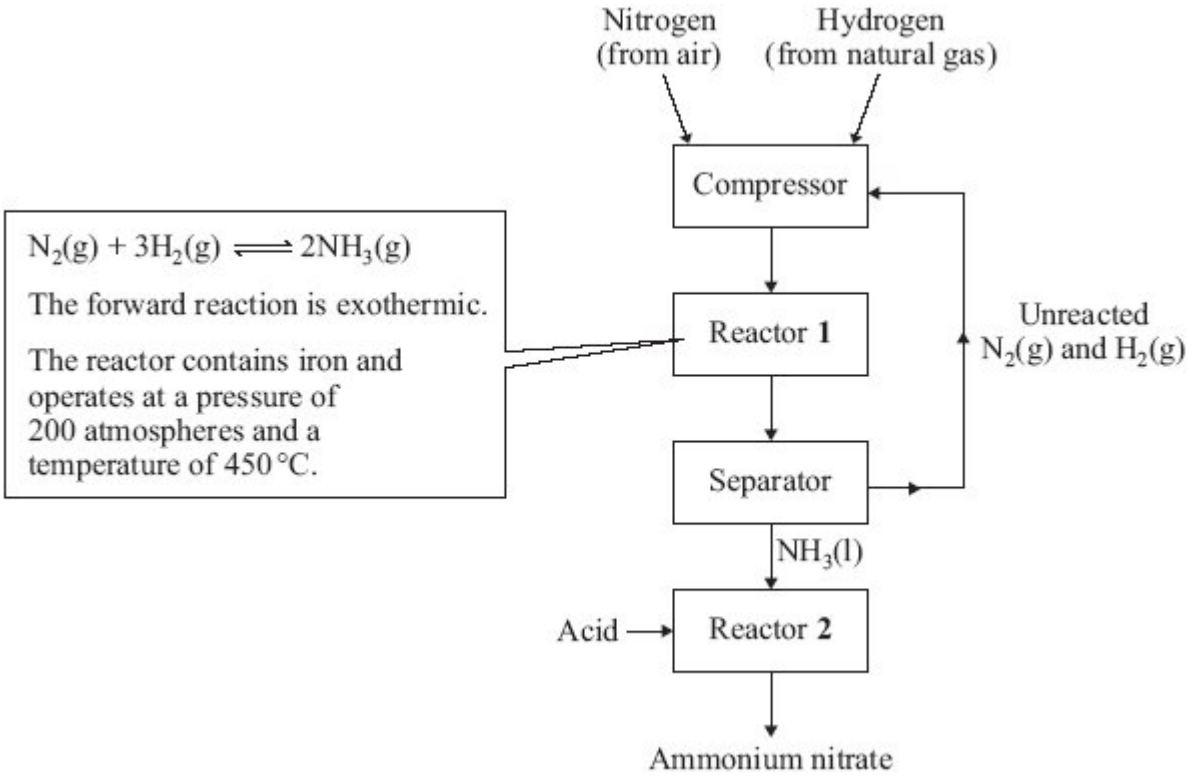
(3)

(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

_____

_____

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(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?

_____

_____

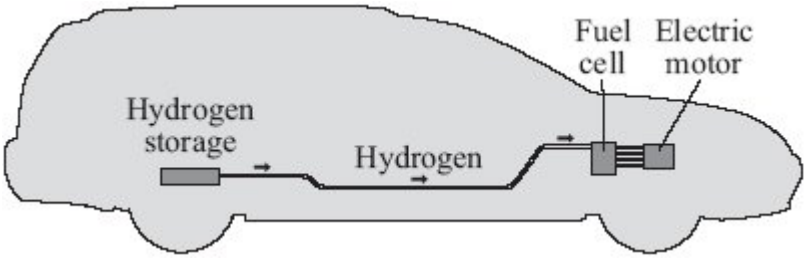
(1)

(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.

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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.

_____

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_____

_____

_____

_____

(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.

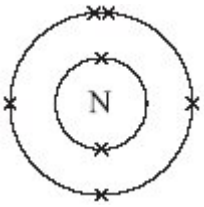
Explain why.

_____

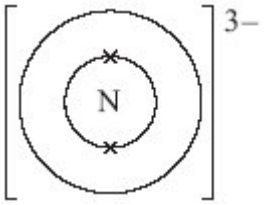
_____

(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-}).



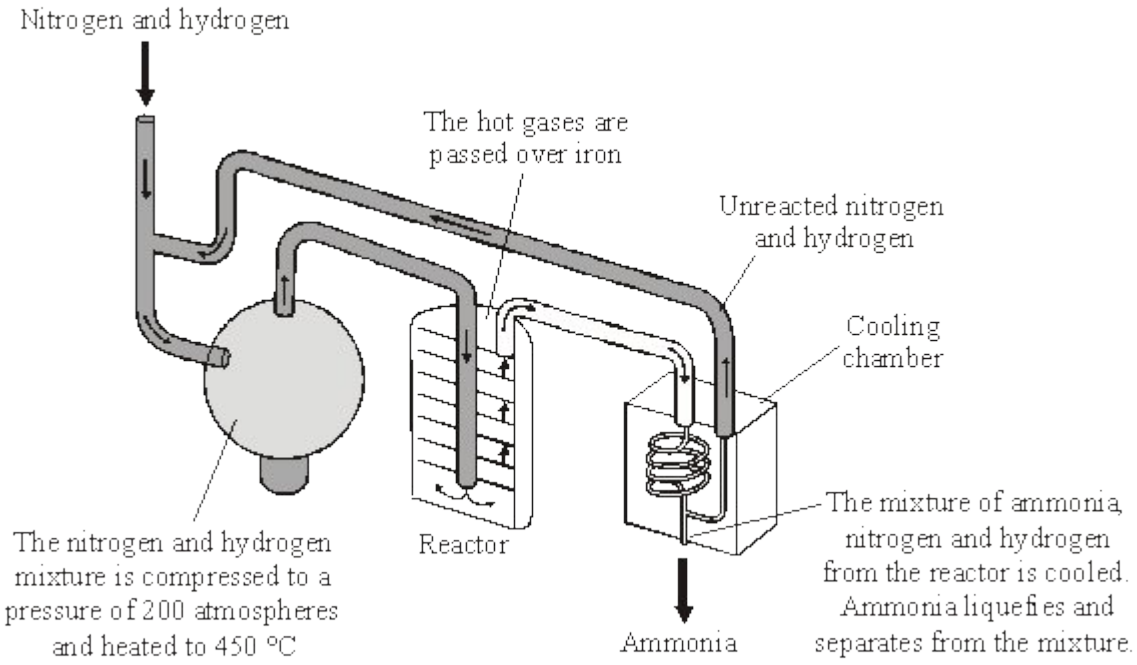
(1)

(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.

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(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

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- 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)

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