All questions are for both separate science and combined science students

Q1.

This question is about reactions between gases.

When hydrogen gas is heated with iodine gas, hydrogen iodide gas is produced.

The equation for this reversible reaction is:

$$\text{hydrogen} + \text{iodine} \rightleftharpoons \text{hydrogen iodide}$$

This reversible reaction reaches equilibrium in a sealed container.

(a) How does the equation show that the reaction is reversible?

_____

(1)

(b) Which two statements are correct when the reaction reaches equilibrium?

Tick (✓) two boxes.

The forward reaction and reverse reaction are both exothermic.	☐
The gases have escaped from the container.	☐
The hydrogen no longer reacts with iodine.	☐
The mass of each substance does not change.	☐
The rates of the forward reaction and reverse reaction are equal.	☐

(2)

(c) The initial mixture of hydrogen and iodine in the sealed container is purple.

Hydrogen iodide is colourless.

How will the colour of the mixture in the sealed container have changed when equilibrium is reached?
Tick (✓) one box.

The mixture will have become a deeper purple.	☐

The mixture will have become a paler purple. ☐

The mixture will have become colourless. ☐

(1)

(d) The rate of reaction between gases is affected by changing the pressure.

Complete the sentences.

When the pressure of the reacting gases is increased,

the rate of reaction _____.

This is because at higher pressures the distance

between the particles _____.

This means that the frequency of collisions _____.

(3)

(e) Give one other way of changing the rate of reaction between gases.

You should not refer to pressure in your answer.

_____

_____

(1)

(Total 8 marks)

Q2.

This question is about ammonia and fertilisers.

Ammonia is produced from nitrogen and hydrogen.

A catalyst is used to speed up the reaction.

The word equation for the reaction is:

nitrogen + hydrogen ⇌ ammonia

(a) What does the symbol ⇌ show about the reaction?

_____

_____

(1)

(b) Which catalyst is used when ammonia is produced from nitrogen and hydrogen?

Tick (√) one box.

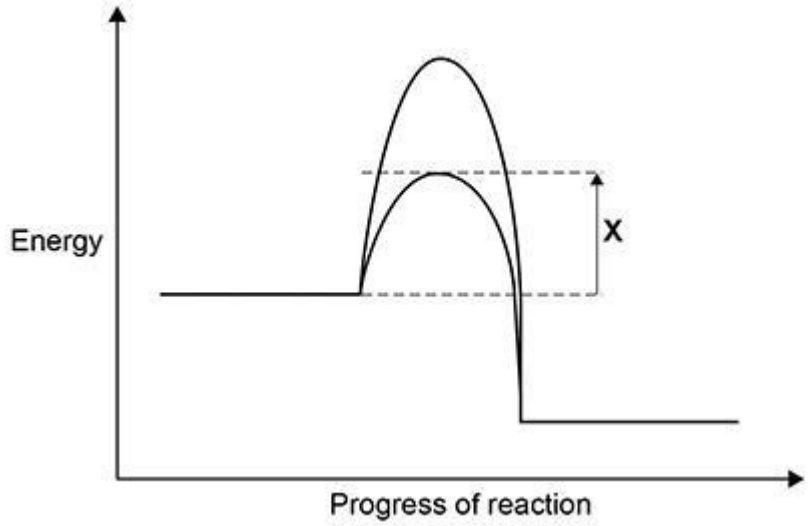
Chlorine ☐

Iron ☐

Oxygen ☐

(1)

(c) The diagram below shows the reaction profile for the production of ammonia both with a catalyst and without a catalyst.



What is represented by label X?

Tick (✓) one box.

Activation energy with a catalyst ☐

Activation energy without a catalyst ☐

Overall energy change with a catalyst ☐

Overall energy change without a catalyst ☐

(1)

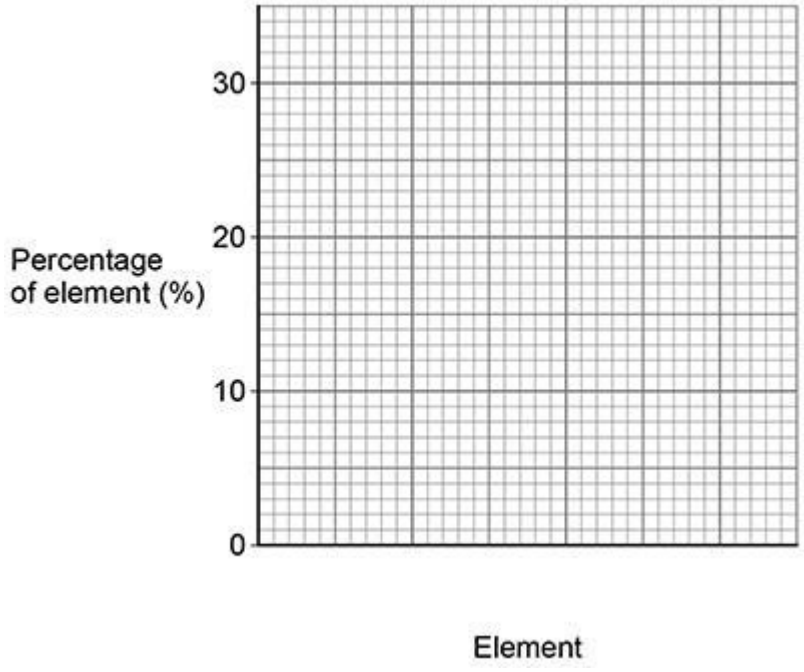
Ammonia is used to produce fertilisers.

NPK fertilisers contain the elements nitrogen, phosphorus and potassium.

A fertiliser contains:

- 22% phosphorus
- 25% potassium.

(d) Draw a bar chart on the graph below to show the percentages of phosphorus and of potassium in this fertiliser.



(2)

(e) Why do the percentages of phosphorus and of potassium in this fertiliser not add up to 100%?

_____

_____

(1)

Fertilisers help plants grow by adding essential elements to soil.

The table below shows the percentages of nitrogen, phosphorus and potassium in four fertilisers, A, B, C and D.

Fertiliser	Percentage (%) of essential element		
	Nitrogen (N)	Phosphorus (P)	Potassium (K)
A	14	0	39
B	25	16	23
C	21	23	0
D	21	0	0

(f) Plants lacking essential elements do not grow well because:

- too little phosphorus can cause slow plant growth
- too little potassium can cause leaves to have brown edges.

Which fertiliser helps prevent slow plant growth and brown leaf edges?

Use the table above.

Tick (✓) one box.

A ☐ B ☐ C ☐ D ☐

(1)

(g) Which fertiliser has the greatest total percentage of essential elements?

Use the table above.

Tick (✓) one box.

A ☐ B ☐ C ☐ D ☐

(1)
(Total 8 marks)

Q3.

This question is about a reversible reaction.

The reaction between solutions of iron(III) ions (Fe^{3+}) and thiocyanate ions (SCN^-) is reversible.
The ionic equation for the reaction is:

	$Fe^{3+}(aq)$	+	$SCN^-(aq)$	$\rightleftharpoons$	$FeSCN^{2+}(aq)$
Colour of solution:	yellow		colourless		red

The colour of the equilibrium mixture is orange at room temperature.

(a) Give the name of the solvent used to dissolve the ions in this reaction.

_____

(1)

(b) A few drops of a colourless solution containing a high concentration of thiocyanate ions (SCN^-) are added to the orange equilibrium mixture.

Explain the colour change observed.

_____

_____

_____

_____

_____

_____

(3)

(c) A water bath is set up at a temperature above room temperature.

When a test tube containing the orange equilibrium mixture is placed in the water bath, the mixture becomes more yellow.

Explain what this shows about the energy change for the forward reaction.

_____

_____

_____

_____

_____

_____

(3)

(d) Explain why a change in pressure does not affect the colour of the equilibrium mixture.

_____

_____

_____

_____

(2)

(e) Other metal ions form coloured equilibrium mixtures with thiocyanate ions.

Which metal ion could form a coloured equilibrium mixture with thiocyanate ions?

Tick (✓) one box.

Al^{3+} ☐

Co^{2+} ☐

Mg^{2+} ☐

$Na+$ ☐

(1)
(Total 10 marks)

Q4.

Hydrogen is a raw material in the Haber process. Hydrogen is produced from methane. The word equation for the reaction is:

methane + steam ⇌ carbon monoxide + hydrogen

(a) How can you tell that the reaction is reversible?

_____

_____

(1)

(b) The forward reaction is endothermic.

Name the type of energy change in the reverse reaction.

_____

_____

(1)

(c) A nickel catalyst is used in this reaction.

Why is a catalyst used in this reaction?

Tick (✓) two boxes.

To increase the temperature ☐

To produce less carbon monoxide ☐

To reduce costs ☐

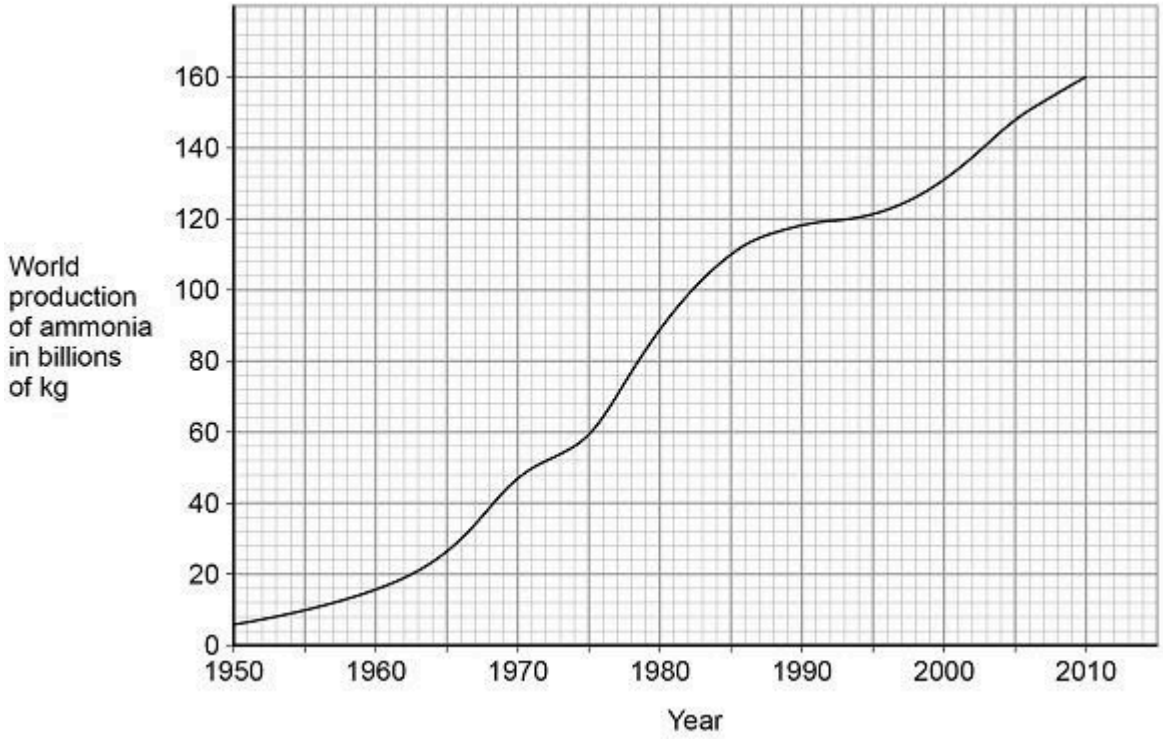
To use less energy ☐

To use less methane ☐

(2)

(d) The Haber process also uses nitrogen to produce ammonia.

The graph below shows how the world production of ammonia changed between 1950 and 2010.



Describe how the world production of ammonia changed between 1950 and 2010.

_____

_____

_____

_____

(2)

Most of the ammonia produced is used to make fertilisers.

(e) Why did the world production of ammonia change between 1950 and 2010?

Tick (✓) two boxes.

The demand for food changed. ☐

The demand for fuels changed. ☐

The nitrogen percentage in air changed. ☐

The number of cars changed. ☐

The world population changed. ☐

(2)

The following table shows data about four fertilisers, A, B, C and D.

Fertiliser	Percentage by mass of nitrogen (%)	Percentage by mass of phosphorus (%)	Percentage by mass of potassium (%)
A	35.0	0.0	0.0
B	21.2	0.0	0.0
C	21.2	23.5	0.0
D	0.0	0.0	52.3

(f) Which combination of fertilisers A, B, C and D provides all of the elements needed for an NPK fertiliser?

Use the table.

Tick (✓) one boxes.

A and C ☐

A and D ☐

B and C ☐

C and D ☐

(1)

(g) Which fertiliser is not made using ammonia?

Use the table above.

Tick (✓) one boxes.

A ☐

B ☐

C ☐

D ☐

(1)

(Total 10 marks)

Q5.

This question is about reversible reactions and equilibrium.

Hydrogen is used to produce ammonia in the Haber process.

The hydrogen is made in two stages.

Stage 1 is the reaction of methane and steam to produce carbon monoxide and hydrogen.

The equation for the reaction is:

$$CH4(g) + H2O(g) \rightleftharpoons CO(g) + 3\ H2(g)$$

(a) Calculate the atom economy for the formation of hydrogen in stage 1.

Relative atomic masses (*A*r): H = 1 C = 12 O = 16

_____

_____

_____

_____

Atom economy = _____%

(2)

(b) Explain why a low pressure is used in stage 1.

Give your answer in terms of equilibrium.

_____

_____

_____

_____

(2)

(c) Stage 2 uses the carbon monoxide produced in stage 1.

The carbon monoxide is reacted with more steam to produce carbon dioxide and more hydrogen.
The equation for the reaction in stage 2 is:

$$CO(g) + H2O(g) \rightleftharpoons CO2(g) + H2(g)$$

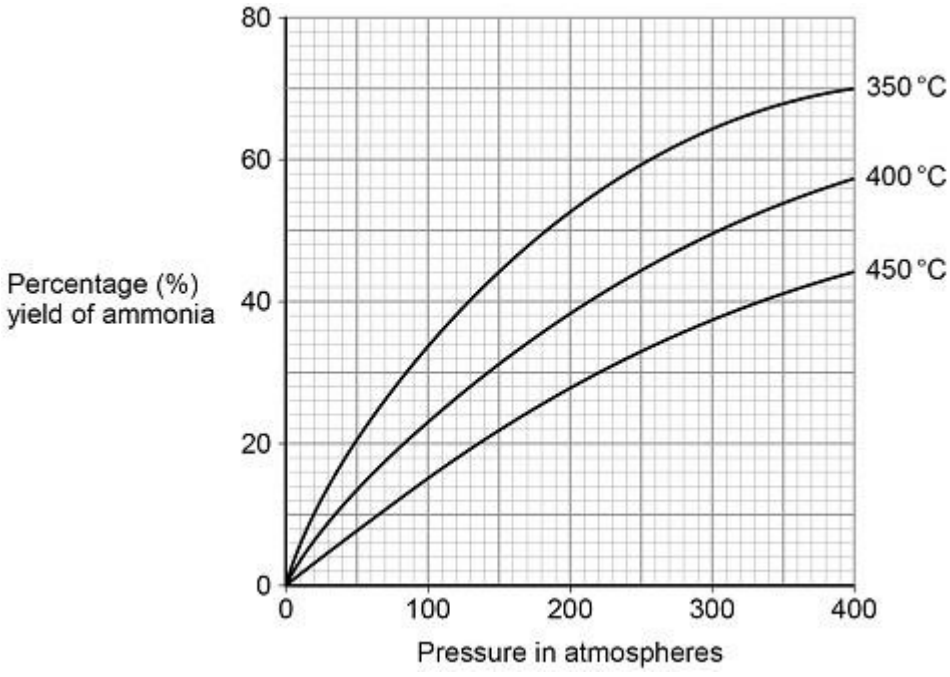
What is the effect of increasing the pressure on the equilibrium yield of hydrogen in stage 2?

_____

_____

(1)

The graph below shows the percentage yield of ammonia produced at different temperatures and pressures in the Haber process.



A temperature of 450 °C and a pressure of 200 atmospheres are used in the Haber process.

(d) A student suggested that a temperature of 350 °C and a pressure of 285 atmospheres could be used instead of those used in the Haber process.
Determine how many times greater the percentage yield of ammonia

obtained would be. Use the graph.

_____

_____

_____

_____

Percentage yield = _____ times greater

(3)

(e) A pressure of 285 atmospheres is not used in the Haber process instead of 200 atmospheres.

Give one reason why.

_____

_____

(1)

(f) How does the graph above show that the forward reaction in the Haber process is exothermic?

_____

_____

(1)

(g) World production of ammonia is now about 30 times greater than it was in 1950.

Suggest why the demand for ammonia has increased.

_____

_____

_____

_____

(2)

(Total 12 marks)

Q6.

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.

$$H_2 + CO \rightarrow C_6H_{14} + H_2O$$

(1)

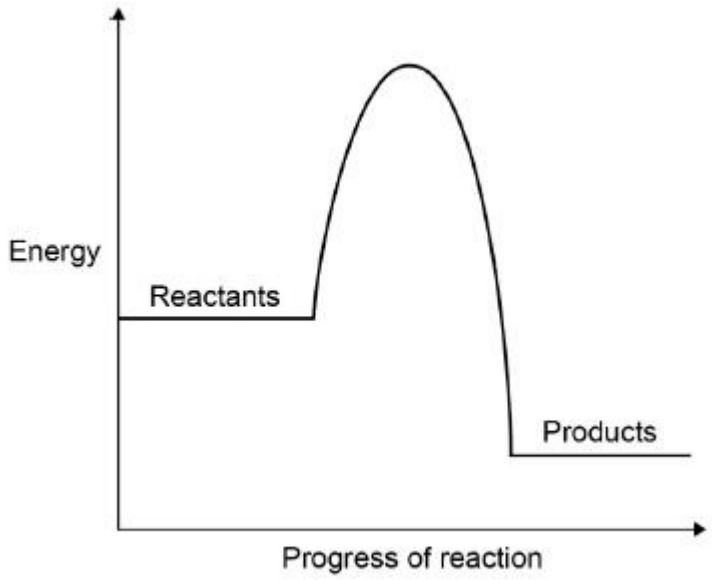
(h) C_6H_{14} is an alkane.

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)

Q7.

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)

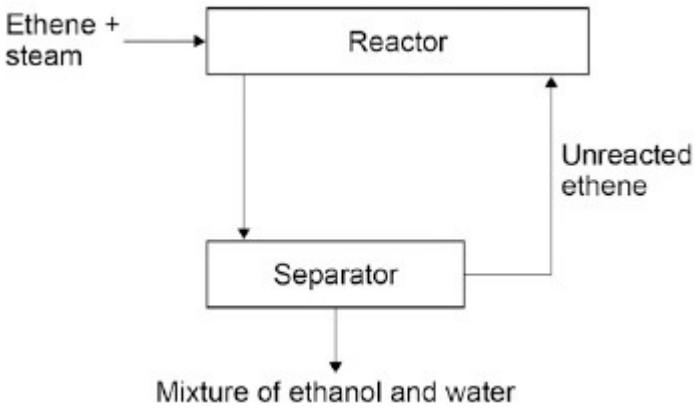
Q8.

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)

Q9.

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:

$$CO(g) + 2H2(g) \rightleftharpoons CH3OH(g)$$

(b) How many moles of carbon monoxide react completely with 4.0 × 103 moles of hydrogen?

Tick one box.

1.0 × 103 moles ☐

2.0 × 103 moles ☐

4.0 × 103 moles ☐

8.0 × 103 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)