Questions are for both separate science and combined science students unless indicated in the question

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:

hydrogen + iodine ⇌ hydrogen iodide

This reversible reaction reaches equilibrium in a sealed container.

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

Equation contains the symbol ⇌

(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. ✗ Closed system	☐
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 increases.

This is because at higher pressures the distance

between the particles decreases.

This means that the frequency of collisions increases.

(3)

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

You should **not** refer to pressure in your answer.

Change the Temperature or add a catalyst.

(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?

The reaction is reversible

(1)

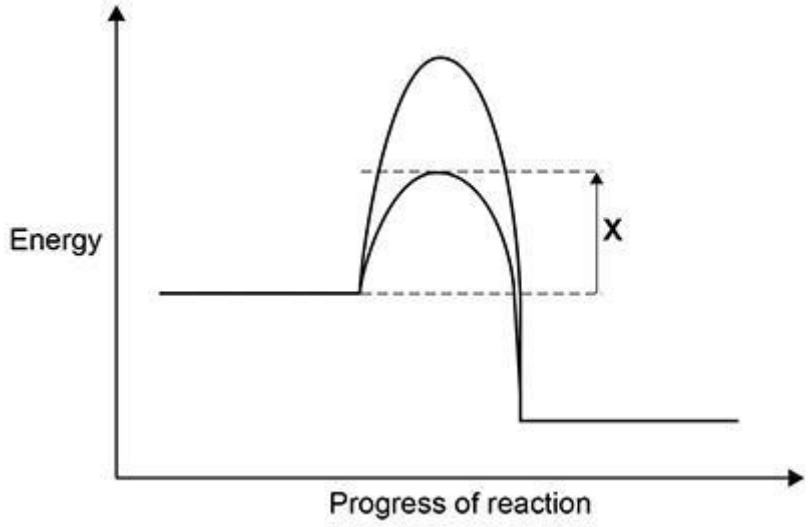
(b) Which catalyst is used when ammonia is produced from nitrogen and hydrogen?

Tick (✓) **one** box. **(separate only)**

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)

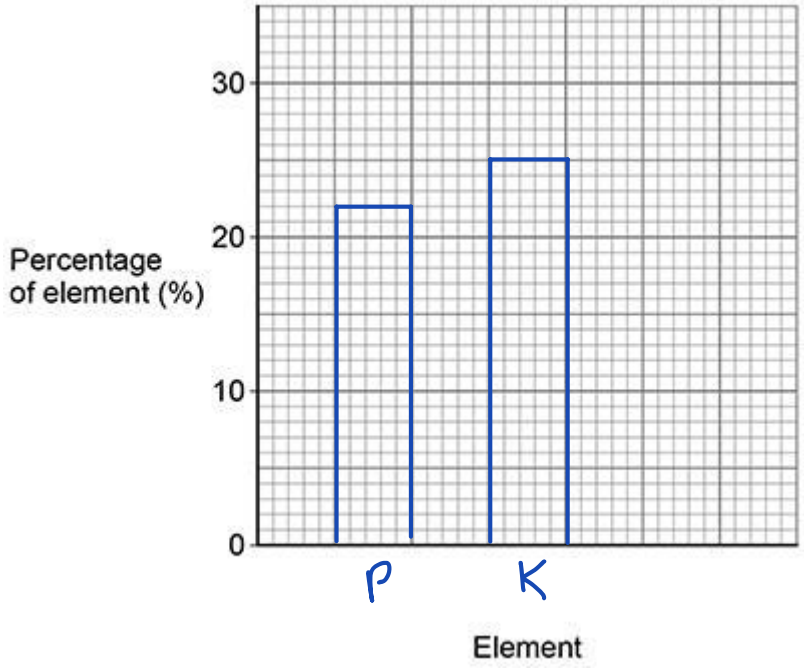
Ammonia is used to produce fertilisers.

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. **(separate only)**



(2)

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

There are other elements in the fertiliser besides P and K, e.g. N.

(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

53
64
44
21

(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?

P K

Use the table above.

Tick (✓) **one** box. **(separate only)**

A ☐ B ☑ C ☐ D ☐

(1)

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

Use the table above.

Tick (✓) **one** box. **(separate only)**

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:

	$Fe^{3+}(aq)$	+	$SCN^-(aq)$	⇌	$FeSCN^{2+}(aq)$
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.

(aq) - Water

(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.

Becomes more red, eqm moves to right

because the concentration of $FeSCN^{2+}$ increases so that the concentration of SCN^- ions reduces

(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.

Position of the equilibrium moves to the left so that the increase in temperature is reduced Therefore the forward reaction is Exothermic

(3)

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

There is no change in equilibrium position because no gases are present.

(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+}	✓	Transition metal ion.
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?

Equation contains the symbol ⇌

(1)

(b) The forward reaction is endothermic.

Name the type of energy change in the reverse reaction.

Exothermic

(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	✓

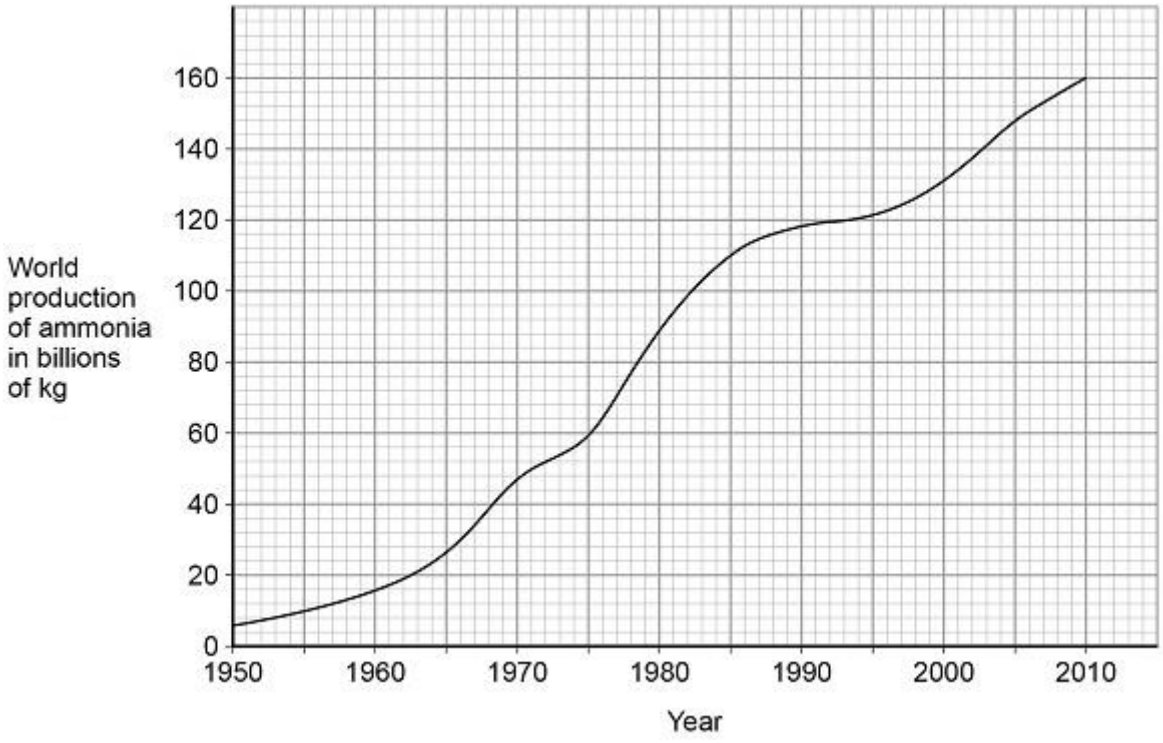
To use less energy ☑

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.

World production of ammonia increased.
The increase was not linear

(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. **(separate only)**

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. **(separate only)**

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. **(separate only)**

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.

Atom economy = $\frac{\text{Mass of desired product}}{\text{Mass of all products}} \times 100\%$

The equation for the reaction is:

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

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

Relative atomic masses (A_r): H = 1 C = 12 O = 16 **(separate only)**

Atom economy $= \frac{3H_2}{CO + 3H_2} = \frac{3\times(1\times2)}{(12+16)+3\times(1\times2)} = \frac{6}{34} \times 100\%$

Atom economy = 17.65 %

(2)

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

Give your answer in terms of equilibrium.

To produce a higher yield of product. H_2

Because fewer moles of gas on left hand side
So equilibrium moves to the right hand side to
increase pressure.

(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:

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

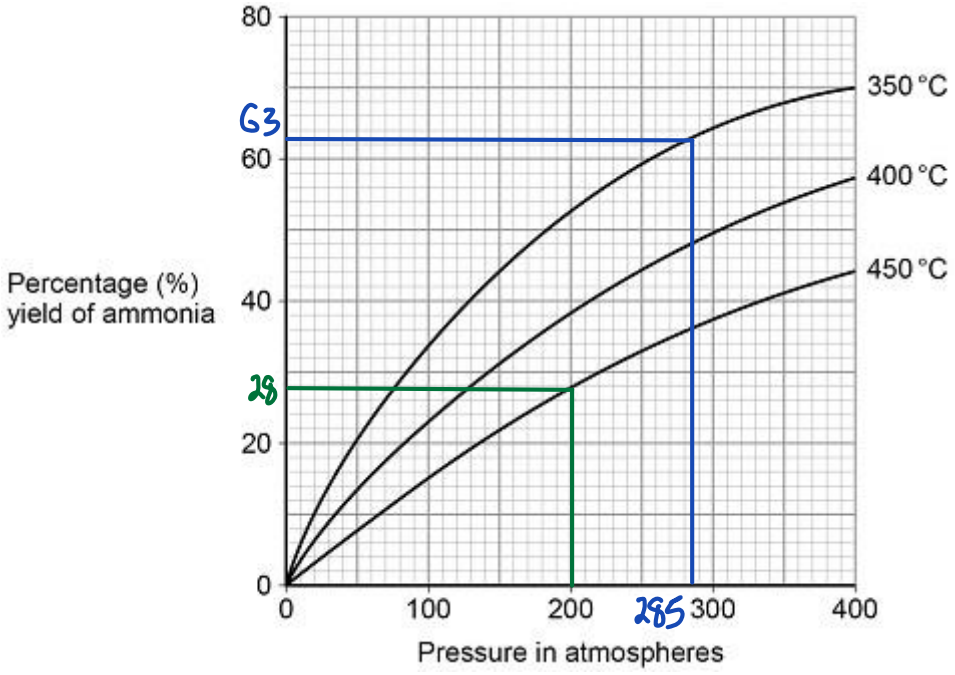
2 2

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

No effect on yield of hydrogen. Equilibrium unaffected
as equal number of moles on both sides

(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. **(separate only)**

450° 200 atm = 28 % yield

350° 285 atm = 63 % yield

x Greater = $\frac{63}{28}$ = 2.25

Percentage yield = 2.25 times greater

(3)

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

Give **one** reason why. **(separate only)**

Higher energy costs (stronger equipment)

(1)

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

Higher temperatures produce a lower % yield of ammonia

(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. **(separate only)**

Increased population requires more food so demand for fertilisers 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?

Within a closed system:
The rate of the forward and backward reactions are equal

(2)

(b) The equilibrium mixture is cooled.

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

Concentration of pink cobalt compound increases because equilibrium moves to the left (reactants) since the backward reaction is exothermic. and equilibrium moves to increase the temperature.

(3)

(c) More hydrochloric acid is added.

Explain what happens to the colour of the equilibrium mixture

Equilibrium mixture becomes purple because equilibrium moves to the right (product) side. so concentration of blue cobalt compound increases

(3)

(d) Why does cobalt form different coloured compounds?

Cobalt is a transition metal and has ions with different charges (oxidation states)

(1)

(e) An oxide of cobalt has the formula $Co_2O_3^{2-}$

$3 \times 2- = 6-$

$2\,Co = 6+$

$Co = 3+$

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.

$$13\,H_2 + 6\,CO \rightarrow C_6H_{14} + 6\,H_2O$$

(1)

(h) C_6H_{14} is an alkane.

C_nH_{2n+2}

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

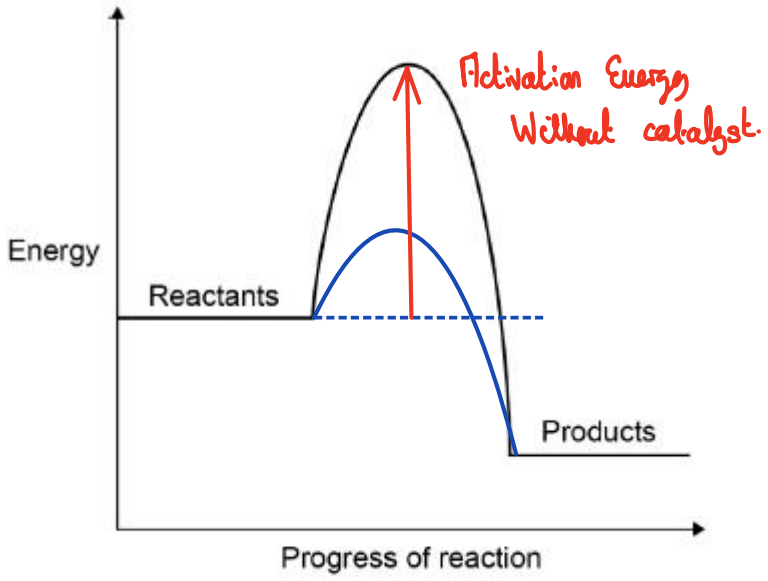
$2n+2 = 18$, C_8H_{18}

$2n = 18-2$

$n = \frac{16}{2} = 8$

(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 ⇌

Reversible reaction

(1)

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

The colour changed from blue to pink

(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. $\frac{8.5 + 8.2 + 8.2}{3} = 8.3$

Temperature = 8.3 °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.

Endothermic reaction

(1)

(Total 4 marks)

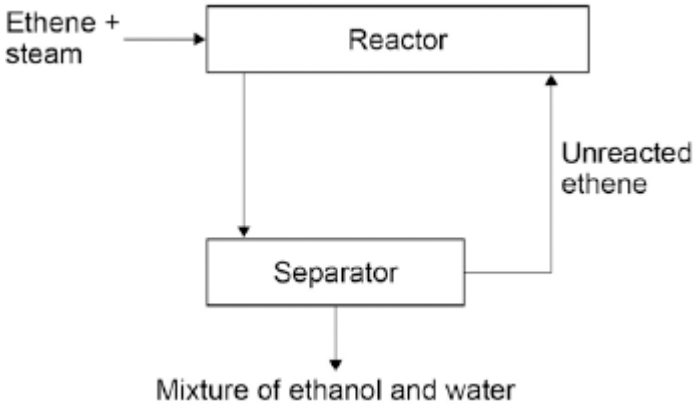
Q8.

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?

Because both water vapour and ethanol will condense.

(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.

Amount of ethanol will decrease because equilibrium will move to the left. (to counteract increasing temp, reverse endothermic reaction favoured)

(2)

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

More ethanol will be produced because equilibrium will move to the right as system moves to least / fewer molecules.

(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:

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

1 : 2

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

$\therefore \frac{4.0 \times 10^3}{2}$

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.

Methanol yield reduces because endothermic reaction is favoured and so

equilibrium will move to the left.

(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.

Greater Yield

Equilibrium position moves to the product side because there are fewer molecules on right side

Rate Increase

More collisions occur per unit time because there are more molecules per unit volume (gas molecules are closer together).

(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.

Catalyst provides a different reaction pathway which has a lower activation energy.

(2)

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

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

Less energy is required thus reduced costs.

(1)

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

No effect on equilibrium yield.
(Just gets there quicker).

(1)

(Total 12 marks)