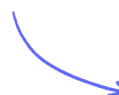


Reversibility & Equilibrium

Reversible Reactions / Energy Changes & Reversible Reactions / Equilibrium / The Effect of Changing Conditions on Equilibrium / The Effect of Changing Concentration / The Effect of Temperature Changes on Equilibrium / The Effect of Pressure Changes on Equilibrium

Easy (5 questions)	/35
Medium (10 questions)	/43
Hard (5 questions)	/42
Total Marks	/120

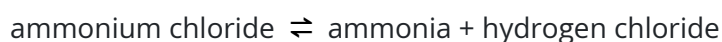
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Easy Questions

- 1 (a) When solid ammonium chloride is heated, ammonia gas and hydrogen chloride gas are produced.

The equation for this reaction is:



What does the symbol $\rightleftharpoons$ mean?

..... (1 mark)

- (b) What type of reaction is the reaction in part (a)?

Tick (✓) **one** box.

Neutralisation	
Combustion	
Thermal decomposition	
Reduction	

..... (1 mark)

- (c) Circle **one** phrase from the box to complete the sentence.

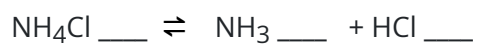
The reaction can be reversed by

heating it. cooling it. adding water.

(1 mark)

(d) The balanced symbol equation is shown below.

Complete the equation by adding the correct state symbols.



(2 marks)

- 2 (a)** Hydrated copper sulfate is a blue salt that contains water molecules within its lattice structure.

When heated, the water is removed from the structure, forming white anhydrous copper sulfate.

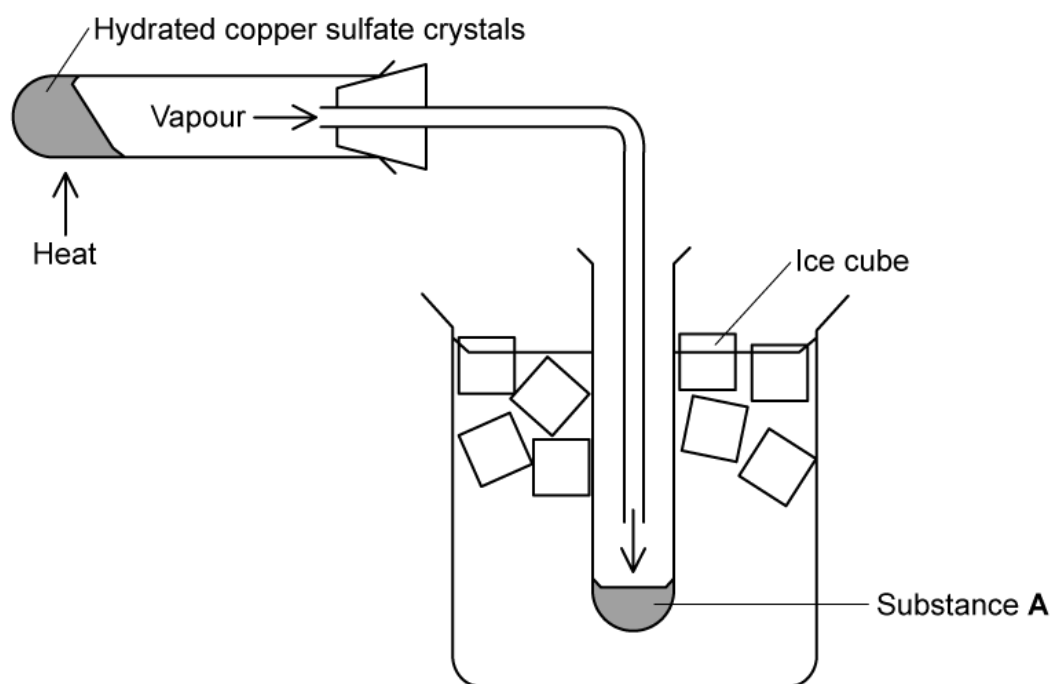
Complete the word equation for the reaction.

hydrated copper sulfate $\rightleftharpoons$ _____ + _____

(2 marks)

- (b)** A student heated hydrated copper sulfate using the equipment in **Figure 1**.

Figure 1



What **two** observations would be made when hydrated copper sulfate was heated? Tick (✓) **two** boxes.

Hydrated copper sulfate turns white	
Hydrated copper sulfate turns blue	
Substance A is a colourless liquid	
Substance A is a white solid	
Substance A is a blue solution	

(2 marks)

(c) When hydrated copper sulfate is heated, an endothermic reaction occurs.

What type of reaction occurs when water is added to anhydrous copper sulfate?

(1 mark)

(d) The word equation between anhydrous cobalt chloride and water is shown below.

anhydrous cobalt chloride + water $\rightleftharpoons$ hydrated cobalt chloride

(blue)

(pink)

What colour change would be seen when hydrated cobalt chloride is heated?

(2 marks)

(e) 5.2 g of hydrated cobalt chloride was heated in a test tube.

3.0 g of anhydrous cobalt chloride remained after heating.

Calculate the mass of water that was given off in grams.

.....
..... (2 marks)

(f) Calculate the percentage of water contained in 5.2 g of hydrated cobalt chloride.

Give your answer to 2 significant figures.

.....
.....
..... (3 marks)

3 (a) When a reversible reaction occurs in a closed system, it will reach equilibrium.

What is meant by a closed system?

Tick (✓) **one** box.

Only gases are allowed to escape	
Energy is unable to escape	
The reactants and products are unable to escape	

..... (1 mark)

(b) Which of the following statements is true about equilibrium?

Tick (✓) **one** box.

When equilibrium is reached, the reaction stops	
At equilibrium, the amount of reactants is the same as the amount of products	
At equilibrium, the rate of the forward reaction is equal to the rate of the reverse reaction	
When equilibrium is reached, all of the reactants have been used up	

(1 mark)

(c) Aqueous copper(II) ions can react with chloride ions to form copper chloride. The reaction is a reversible reaction. Aqueous copper(II) ions are blue and copper chloride solution is yellow.



blue

yellow

When left for a few minutes, the reaction reaches equilibrium. Complete the sentences using words from the box.

green	blue	yellow
copper(II) ions	chloride ions	copper chloride

At equilibrium, the reaction mixture is _____ because the reaction mixture contains _____ and _____.

(3 marks)

(d) The concentration of copper(II) ions was increased in the reaction in part (c).

Circle **one** word/phrase in each box to complete the sentences.

The system will respond to

counteract
maximise
increase

 the change.

The amount of products will

increase
decrease
remain the same

 until equilibrium is reached again.

The reaction mixture will turn

green.
yellow.
blue.

(3 marks)

- 4 (a)** The reaction between nitrogen and hydrogen to form ammonia is a reversible reaction. The forward reaction is exothermic.

Complete the word equation for the reaction, including the correct symbol that shows the reaction is reversible.

nitrogen + _____ ammonia

(2 marks)

- (b)** Predict what would happen to the amount of ammonia produced when the following change of conditions occur.

Choose a word from the box below to complete the table.

increase	decrease	remain the same
----------	----------	-----------------

Change of condition	Amount of ammonia produced would:
Increasing concentration of nitrogen	
Increasing the temperature	
Using a catalyst	

(3 marks)

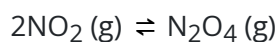
- (c)** In the reaction in part (a), nitrogen, hydrogen and ammonia are all gases.

In addition to the condition in part (b), what other condition could be changed that may alter the position of equilibrium?

..... (1 mark)

- 5 (a)** Nitrogen dioxide, NO_2 , which is a dark brown gas, exists in equilibrium with colourless, gaseous dinitrogen tetroxide, N_2O_4 .

The balanced symbol equation for this reaction is shown below.



dark brown colourless

How many atoms of oxygen are there in a molecule of dinitrogen tetroxide?

..... **(1 mark)**

- (b)** When the pressure increases, what happens to the amount of dinitrogen, N_2O_4 , in the reaction mixture?

Choose words from the box to complete the sentence.

increases	fewer
larger	decreases
remains the same	

The amount of dinitrogen tetroxide _____ because the equilibrium position will shift towards the side with _____ number of molecules.

(2 marks)

- (c)** What would you expect to happen to the colour of the reaction mixture if the pressure was increased?

Circle the correct answer.

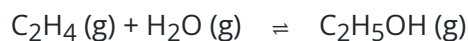
Become paler	Become darker	Remain the same colour
--------------	---------------	------------------------

(1 mark)

Medium Questions

- 1 (a) A company manufactures ethanol ($\text{C}_2\text{H}_5\text{OH}$) for sale to other chemical companies as a raw ingredient for many products.

The reaction for the process is as follows:



The forward reaction is **exothermic**.

The temperature and pressure of the reaction can be adjusted to increase the yield of ethanol when the reaction is at equilibrium.

Explain what is meant by the term **equilibrium**.

.....

.....

.....

..... (4 marks)

- (b) Explain what effect increasing the temperature would have on the **yield** of ethanol at equilibrium.

.....

.....

.....

..... (4 marks)

- (c) Explain what effect increasing the pressure would have on the **yield** of ethanol at equilibrium.

.....

..... (2 marks)

(d) How can the direction of a reversible reaction be changed?

..... (2 marks)

(e) **Figure 1** shows the effect of changing pressure on the percentage yield of ethanol at three different temperatures.

Figure 1

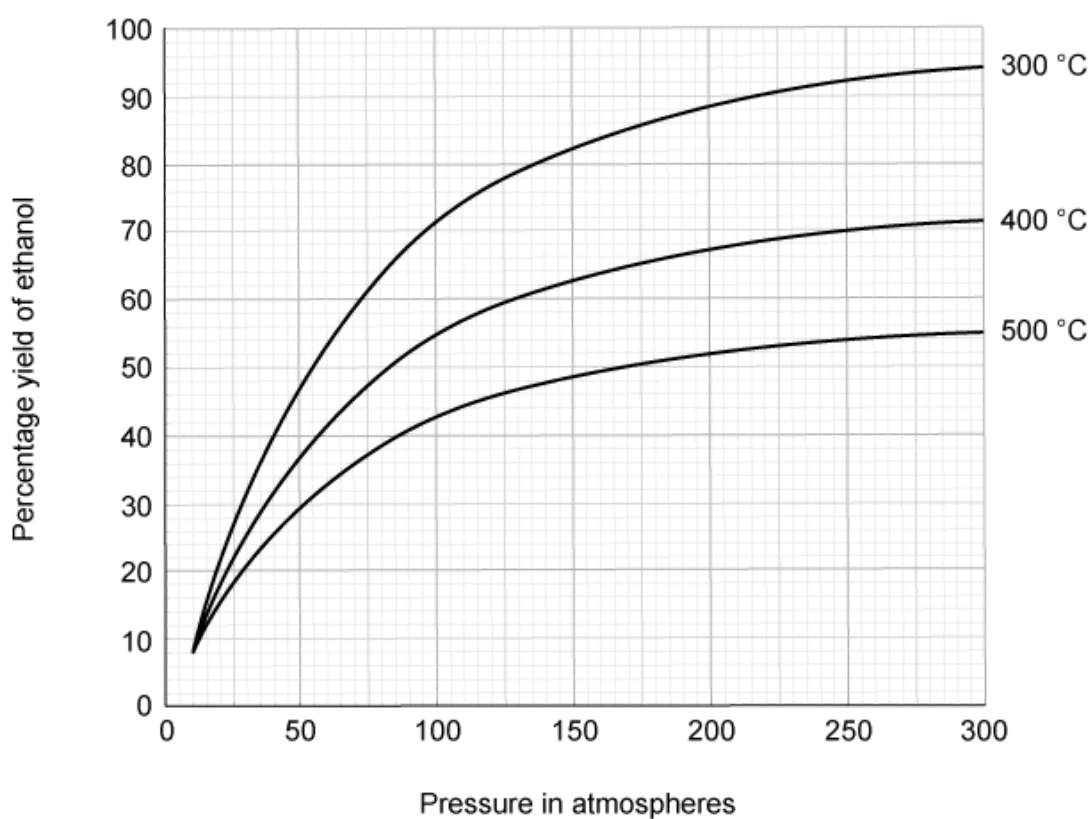
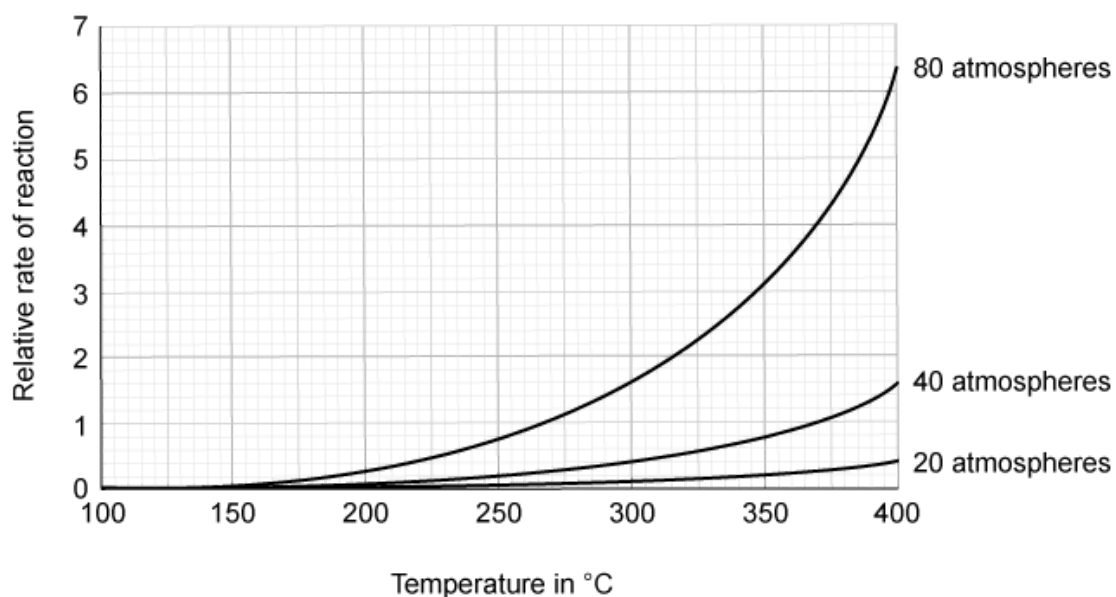


Figure 2 shows the effect of changing temperature on the rate of reaction at three different pressures.

Figure 2



The conditions for the reaction of ethene with steam in one of the processes are:

- 65 atm
- 300 °C
- a catalyst.

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

- 2 The Haber process is an example of a reversible reaction where the forward reaction is exothermic:



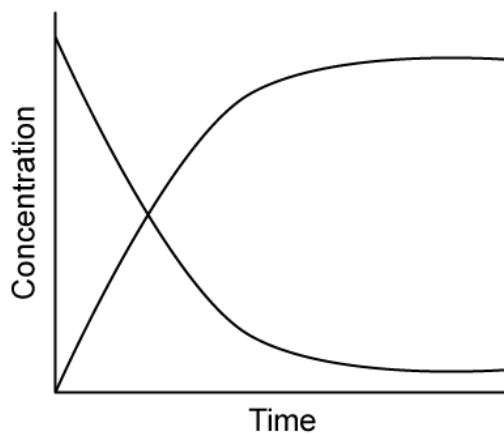
What is **not** true about this system when it is at equilibrium?

- A. The energy change of the reverse reaction is endothermic
- B. The equilibrium occurs within a closed system
- C. The reaction has reached completion and stopped
- D. The rate of the forward reaction is equal to the rate of the reverse reaction

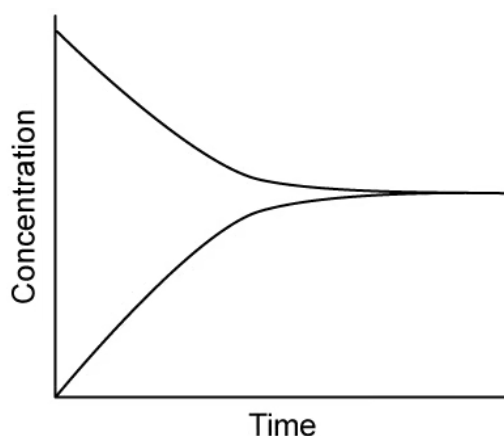
(1 mark)

- 3 Which graph shows the highest yield of products?

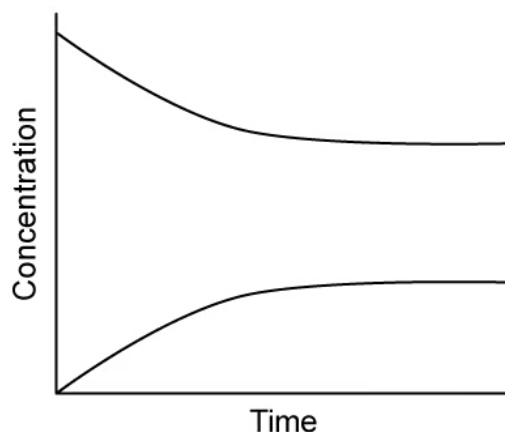
A.



B.



C.

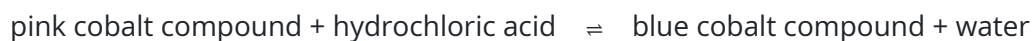


D. All of the above have the same yield of products

(1 mark)

4 (a) A pink coloured compound of cobalt reacts with hydrochloric acid.

The word equation for the reaction is:



The forward reaction is endothermic.

If carried out under correct conditions the reaction reaches equilibrium.

The mixture at equilibrium contains both cobalt compounds and the mixture is purple.

The equilibrium mixture is cooled.

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

.....

.....

.....

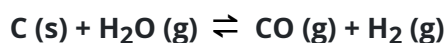
(3 marks)

(b) A chemist adds more hydrochloric acid to the reaction.

Explain what happens to the colour of the mixture.

.....

5 The gasification of carbon is a reversible endothermic reaction:



Which of the following conditions could be changed to **increase** the relative amount of H_2 gas produced?

- A. Increase the surface area to volume ratio of the carbon
- B. Increase the pressure
- C. Increase the temperature
- D. Add a catalyst

(1 mark)

6 Which statement is **not** true about Le Chatelier's Principle?

- A. If changes to the conditions of a system are made, the system responds to counteract the change
- B. If the concentration of the product is decreased, more reactants will react until an equilibrium position is reached again
- C. Increasing the pressure will shift the position of the equilibrium to the side with the smaller number of molecules of gas
- D. If temperature is decreased for an exothermic reaction, the relative amount of products made at the equilibrium point decreases

(1 mark)

7 Hydrogen gas and iodine vapour can react to form hydrogen iodide:



Which statement is **not** true?

- A. This reaction is reversible
- B. Equal amounts of reactants and product are eventually made at equilibrium
- C. This reaction can reach an equilibrium point in a closed system

D. There are equal total numbers of moles of reactant and product

(1 mark)

8 Which option shows **two** correct statements about reversible reactions and equilibrium?

	Statement 1	Statement 2
A	The sign for a reversible reaction is $\rightleftharpoons$	Reversible reactions are slower than non-reversible ones
B	At equilibrium the rate of the forward reaction and the rate of the reverse reaction are equal	An endothermic reaction is exothermic if reversed
C	Reversible reactions are not useful in industry as they do not go to completion	To reach an equilibrium the reaction must occur in a closed system
D	The rate of the reaction is zero at equilibrium	The concentration of the product is constant at equilibrium

(1 mark)

9 (a) This question is about chemical equilibrium and reversible reactions.

If carried out in a closed system, reversible reactions can reach a state of equilibrium.

Explain what a closed system is.

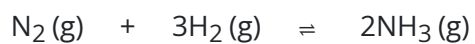
(1 mark)

(b) When a reversible reaction reaches equilibrium, it appears to have stopped.

Explain why.

..... (2 marks)

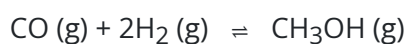
- (c) In the Haber process, the reaction of nitrogen with hydrogen to produce ammonia is reversible.



Explain, with reasons, what happens to the amount of ammonia produced at equilibrium if the pressure is increased.

..... (3 marks)

- 10 (a)** Methanol is produced by reacting carbon monoxide with hydrogen as shown in the equation:



The reaction is normally performed at a temperature of 250 °C and a pressure of 100 atm.

The forward reaction is exothermic.

Explain what would happen to the yield of methanol if a temperature higher were used.

.....

.....

.....

.....

(4 marks)

- (b)** Explain why the high pressure gives a greater yield of methanol and an increased rate of reaction.

.....

.....

.....

.....

(4 marks)

Hard Questions

1 (a) This question is about equilibrium.

An ionic equation for the reaction between iron (III), Fe^{3+} and thiocyanate ions, SCN^{2+} is shown below:

At room temperature, the mixture of the equilibrium solution is orange.

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

Which solvent would be used to dissolve the ions in this reaction?

..... (1 mark)

(b) Explain the effect, if any, of changing pressure on the colour of the equilibrium mixture.

.....
.....
..... (3 marks)

(c) A few drops of a colourless solution containing a high concentration of Fe^{3+} ions are added to the orange equilibrium mixture.

Explain the colour change observed.

.....
.....
..... (3 marks)

- (d) A water bath is set up at a temperature below room temperature.

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

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

.....

.....

..... (3 marks)

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

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

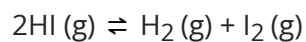
Tick (✓) **one** box.

Mg ²⁺	
Al ³⁺	
Li ⁺	
Cu ²⁺	

..... (1 mark)

2 (a) This question is about reversible reactions.

The decomposition of hydrogen iodide into hydrogen and iodine is reversible.



The forward reaction is endothermic.

Explain the effect of increasing temperature on the amount of hydrogen iodide, HI.

(2 marks)

(b) Explain what effect, if any, increasing the pressure will have on the amount of hydrogen iodide at equilibrium.

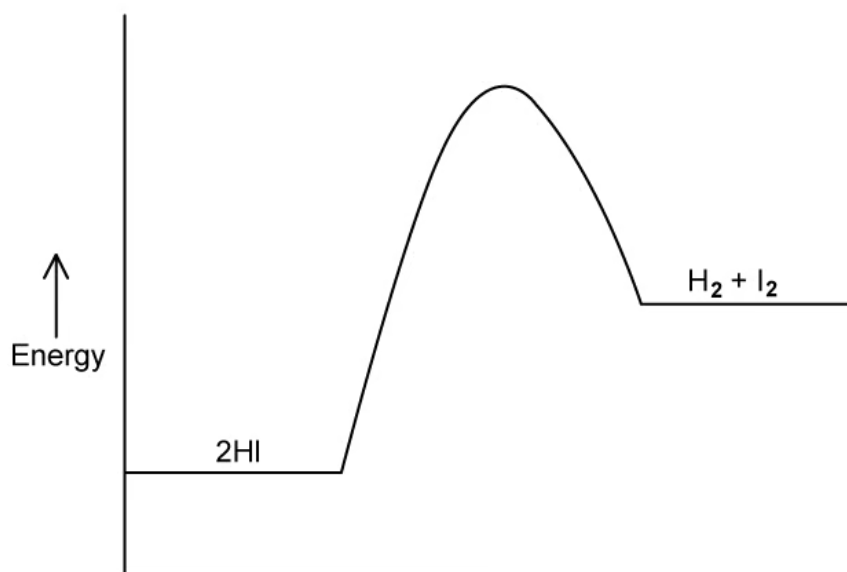
(2 marks)

(c) An endothermic reaction can be represented using the following reaction profile in **Figure 1**.

Label

- Activation energy
- Overall energy change

Figure 1



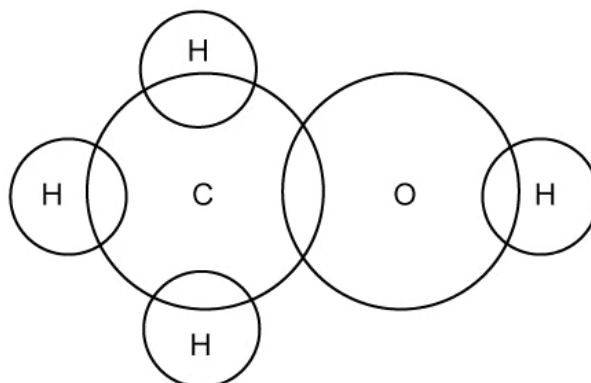
(2 marks)

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

(1 mark)

3 (a) Methanol, CH₃OH, is a fuel that can be produced from carbon monoxide and hydrogen.

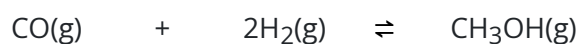
Complete the dot and cross diagram to show the bonding in methanol.



(2 marks)

(b) The reaction between carbon monoxide and hydrogen to produce methanol is shown below.

The forward reaction is exothermic.



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

(1 mark)

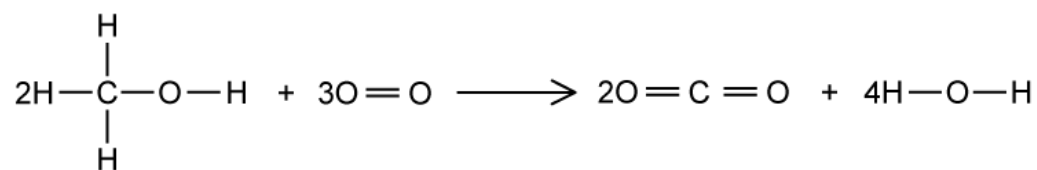
(c) The temperature used is 250 °C.

Explain why this temperature is a compromise between the rate of reaction and the equilibrium yield of product.

(3 marks)

(d) Methanol can undergo combustion to release energy.

The equation for this reaction is shown below:



Bond energies are shown in **Table 1**.

Table 1.

	C-H	C-O	O=O	C=O	O-H
Bond energy in kJ / mol	410	360	496	800	466

Calculate the overall energy change for the reaction using the diagram and table above.

.....

.....

..... (3 marks)

- (e) A catalyst is used in the reaction to produce methanol to increase the rate of the reaction.

Explain how it increases the rate of reaction.

.....

..... (2 marks)

- (f) State the effect, if any, of using a catalyst on the equilibrium yield of methanol.

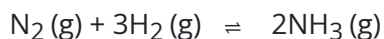
..... (1 mark)

(g) How many moles of carbon monoxide completely react with 6.0×10^3 mol of hydrogen?

Use the equation in part (b) to help you.

..... **(1 mark)**

4 (a) Ammonia is produced from the reaction of nitrogen with hydrogen in the Haber process:



The forward reaction is exothermic.

The conditions normally used in the Haber process are:

- 450 °C
- Pressure of 200 atm
- Iron catalyst

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

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

(6 marks)

(b) 425 dm^3 of ammonia is produced when nitrogen reacts with 825 dm^3 of hydrogen.

Calculate the volume of unreacted hydrogen.

Give your answer in cm^3

5 The decomposition of ammonium chloride is endothermic:



Which changes to the conditions would **both decrease** the amount of product in this reaction?

	Change 1	Change 2
A	Increase pressure	Decrease temperature
B	Decrease pressure	Decrease temperature
C	Increase pressure	Increase temperature
D	Decrease pressure	Increase temperature

(1 mark)