

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

1 Nitrogen dioxide (NO₂) is a brown gas.

Dinitrogen tetraoxide (N₂O₄) is a colourless gas.

The two gases can exist together in dynamic equilibrium according to the equation



A mixture of nitrogen dioxide gas and dinitrogen tetraoxide gas is allowed to reach equilibrium in a sealed container at 20°C. This equilibrium mixture is brown in colour.

(a) The sealed container is immersed in hot water at 60°C.

As the temperature of the gas mixture increases, the pressure of the gas mixture also increases.

(i) Predict the effect of the increase in temperature on the position of equilibrium. **(separate only)**

(1)

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(ii) Predict the effect of the increase in pressure on the position of equilibrium. **(separate only)**

(1)

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(iii) Suggest why it is difficult to predict which way the equilibrium will shift. **(separate only)**

(1)

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(b) Suggest why the equilibrium mixture is a darker shade of brown at 60°C than the equilibrium mixture at 20°C. **(separate only)**

(2)

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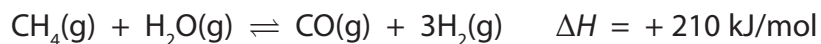
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(Total for Question 1 = 5 marks)

- 2 The hydrogen needed for the manufacture of ammonia is made by a process called steam reforming.

In this process, a mixture of methane and steam is passed over a nickel catalyst.

The equation for the reaction is



- (a) In this part of the question, assume that the reaction reaches a position of equilibrium.

- (i) Predict whether a high or low temperature would produce the highest yield of hydrogen.

Give a reason for your choice. **(separate only)**

(1)

prediction

reason

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- (ii) Predict whether a high or low pressure would produce the highest yield of hydrogen.

Give a reason for your choice. **(separate only)**

(1)

prediction

reason

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

(2)

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(c) Some of the carbon monoxide produced is removed in another reaction.

In this reaction, carbon monoxide is mixed with steam and passed over a heated catalyst.

The reaction is reversible and the carbon monoxide is oxidised to carbon dioxide.

(i) Write a chemical equation for this reaction.

(2)

(ii) Explain why the carbon in carbon monoxide is oxidised in this reaction.

(1)

(iii) The carbon dioxide produced can be removed by passing the gas through a solution of potassium carbonate, K_2CO_3

The potassium carbonate reacts with carbon dioxide and water to form potassium hydrogencarbonate, $KHCO_3$

Write a chemical equation for this reaction.

(2)

(Total for Question 2 = 9 marks)