

# Equilibria

## Question Paper 2

<b>Level</b>	International A Level
<b>Subject</b>	Chemistry
<b>Exam Board</b>	CIE
<b>Topic</b>	Equilibria
<b>Sub-Topic</b>	
<b>Paper Type</b>	Theory
<b>Booklet</b>	Question Paper 2

**Time Allowed:** 65 minutes

**Score:** /54

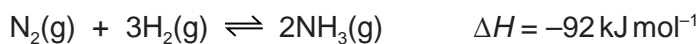
**Percentage:** /100

**Grade Boundaries:**

A*	A	B	C	D	E	U
>85%	77.5%	70%	62.5%	57.5%	45%	<45%

- 1 The Haber process for the manufacture of ammonia,  $\text{NH}_3$ , was originally devised at the start of the 20th century and was developed into a full-scale industrial process by Carl Bosch in 1913.

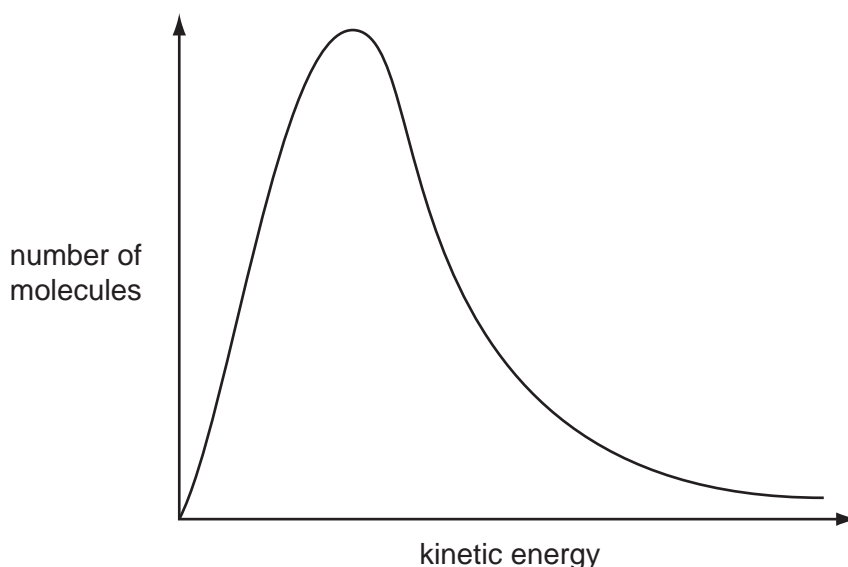
The key step in the process is the reversible reaction of nitrogen and hydrogen in the presence of an iron catalyst.



- (a) The hydrogen for this reaction can be formed by reacting methane with steam, during which carbon monoxide is also produced. Write an equation for this reaction.

..... [1]

- (b) Use the Boltzmann distribution shown to explain why a catalyst increases the rate of this reaction.



.....  
 .....  
 .....  
 ..... [4]

- (c) Draw a three-dimensional diagram to show the shape of an ammonia molecule. Name this shape and state the bond angle.

shape ..... bond angle ..... [3]

(d) The Haber process is typically carried out at a temperature of 400 °C.

(i) With reference to Le Chatelier’s Principle and reaction kinetics, state and explain one advantage and one disadvantage of using a higher temperature.

.....

.....

.....

.....

.....

.....

..... [4]

(ii) State the expression for the equilibrium constant,  $K_p$ , for the formation of ammonia from nitrogen and hydrogen in the Haber process.

$K_p =$

[1]

(iii) 2.00 moles of nitrogen and 3.00 moles of hydrogen were put in a vessel and left to reach equilibrium.

At equilibrium, the pressure was  $2.00 \times 10^7$  Pa and the mixture contained 1.60 moles of ammonia.

Calculate  $K_p$ . Include the units.

$K_p =$  .....

units = .....

[5]

[Total: 18]

2 Ammonium sulfate is a fertiliser which is manufactured by the reaction between ammonia and sulfuric acid.

(a) Ammonia is described as a weak base and sulfuric acid as a strong acid.

By using an equation, explain clearly what is meant by the term *weak base*.

.....  
.....  
.....  
.....  
..... [3]

(b) Ammonia and sulfuric acid are both manufactured by processes which involve chemical equilibria.

(i) Sulfuric acid is produced from sulfur trioxide which is made by the Contact process.

State **three** important operating conditions for the Contact process for the manufacture of sulfur trioxide.

For **each** of your conditions, you should avoid the use of vague phrases such as 'high temperature'.

condition 1 .....

.....

condition 2 .....

.....

condition 3 .....

.....

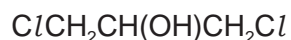
(ii) How is the sulfur trioxide produced converted into sulfuric acid?

.....

.....

[4]

- (c) Chloropropanols such as 1,3-dichloropropan-2-ol (1,3-DCP) are present in some foods.



1,3-DCP

- (i) What will be produced when 1,3-DCP is reacted separately with the following reagents under suitable conditions?  
In each case give the **structural** formula.

concentrated sulfuric acid

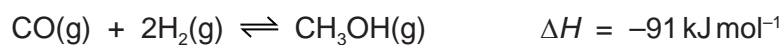
an excess of ammonia

- (ii) Describe as fully as you can what type of reaction occurs with ammonia.

.....  
[4]

[Total: 11]

- 3 Methanol, CH<sub>3</sub>OH, can be produced industrially by reacting carbon monoxide, CO, with hydrogen, H<sub>2</sub>.



The process is carried out at  $4 \times 10^3$  kPa (40 atmospheres) and 1150 K.

- (a) (i) State Le Chatelier's Principle.

.....  
.....  
..... [2]

- (ii) From your understanding of Le Chatelier's Principle, state the conditions of temperature and pressure that could be used in order to produce an increased yield of methanol in this process.

In **each** case, explain why the yield would increase.

temperature .....

explanation .....

.....

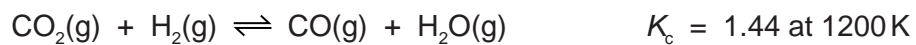
pressure .....

explanation .....

.....

[4]

- (b) The carbon monoxide for use in the production of methanol may be formed by reacting carbon dioxide with hydrogen.



A mixture containing 0.70 mol of  $\text{CO}_2$ , 0.70 mol of  $\text{H}_2$ , 0.30 mol of  $\text{CO}$  and 0.30 mol of  $\text{H}_2\text{O}$  was placed in a  $1 \text{ dm}^3$  flask and allowed to come to equilibrium at 1200 K.

Calculate the amount, in moles, of each substance present in the equilibrium mixture at 1200 K.

	$\text{CO}_2$	+	$\text{H}_2$	$\rightleftharpoons$	$\text{CO}$	+	$\text{H}_2\text{O}$
initial moles	0.70		0.70		0.30		0.30

[4]

[Total: 10]

4 Because of the lack of reactivity of the nitrogen molecule, extreme conditions need to be used to synthesise ammonia from nitrogen in the Haber process.

(a) Suggest an explanation for the lack of reactivity of the nitrogen molecule, N<sub>2</sub>.

.....  
.....

[1]

(b) Under conditions of high temperature, nitrogen and oxygen react together to give oxides of nitrogen.

(i) Write an equation for a possible reaction between nitrogen and oxygen.

.....

(ii) State **two** situations, one natural and one as a result of human activities, in which nitrogen and oxygen react together.

.....  
.....

(iii) What is the main environmental effect of the presence of nitrogen oxides in the atmosphere?

.....

[4]

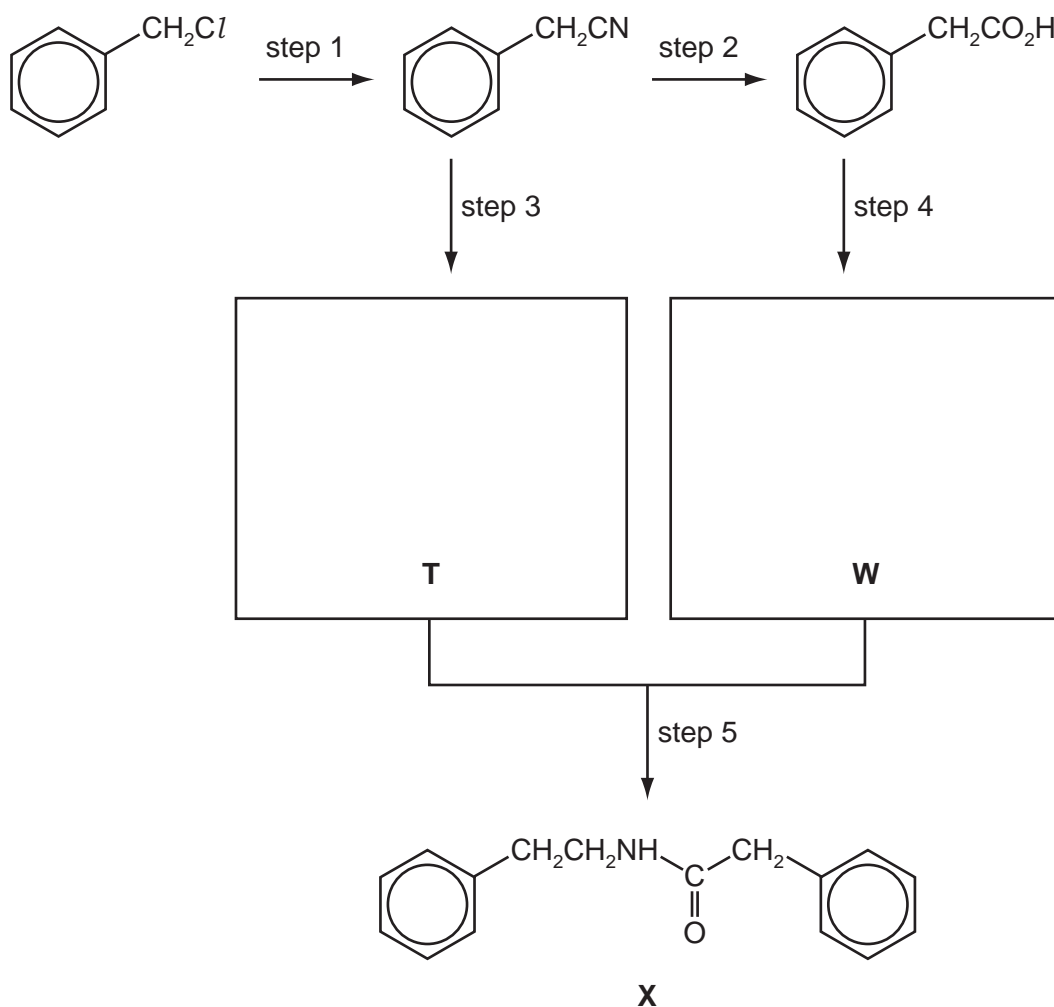
(c) Describe and explain how the basicities of ethylamine and phenylamine compare to that of ammonia.

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.....  
.....  
.....  
.....

[4]



- (d) Compound **X** is a useful intermediate in the synthesis of pharmaceuticals.  
**X** can be synthesised from chloromethylbenzene according to the following scheme.



- (i) What *type of reaction* is each of the following?

step 1 .....

step 2 .....

- (ii) Suggest reagents and conditions for

step 1, .....

step 2. ....

- (iii) Draw the structures of the intermediates **T** and **W** in the boxes above.

[6]

[Total: 15]