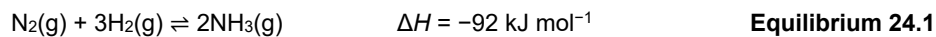


Equilibrium

1. This question is about ammonia, NH_3 .

In industry, ammonia is made from nitrogen and hydrogen. This is a reversible reaction, as shown in **equilibrium 24.1** below.



- i. Explain how Le Chatelier's principle can be used to predict the conditions of temperature and pressure for a maximum **equilibrium** yield of ammonia.

[4]

- ii. Using certain conditions, **equilibrium 24.1** has the equilibrium concentrations in the table.

Substance	Equilibrium concentration / mol dm^{-3}
$\text{N}_2(\text{g})$	1.25
$\text{H}_2(\text{g})$	2.75
$\text{NH}_3(\text{g})$	0.862

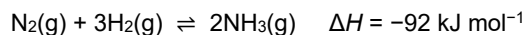
Calculate the numerical value for K_c for **equilibrium 24.1** under these conditions.

Give your answer to an **appropriate** number of significant figures and in **standard form**.

$$K_c = \dots\dots\dots [2]$$

3.2.3 Chemical Equilibrium

3. Nitrogen can be reacted with hydrogen in the presence of a catalyst to make ammonia in the Haber process.



A mixture of N_2 and H_2 was left to react until it reached equilibrium. The equilibrium mixture had the following composition:

N_2	1.20 mol dm^{-3}
H_2	2.00 mol dm^{-3}
NH_3	$0.877 \text{ mol dm}^{-3}$

- i. Calculate a value for K_c for this equilibrium.

$$K_c = \dots\dots\dots \text{dm}^6 \text{ mol}^{-2} \quad \mathbf{[3]}$$

- ii. Explain how the following changes would affect the amount of NH_3 present in the equilibrium mixture.

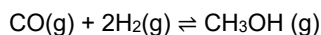
Use of a catalyst:

A higher temperature:

[3]

3.2.3 Chemical Equilibrium

4. A chemist investigates the equilibrium that produces methanol:



The chemist mixes CO(g) with H₂(g) and leaves the mixture to react until equilibrium is reached. The equilibrium mixture is analysed and found to contain the following concentrations.

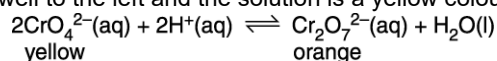
Substance	Concentration/mol dm ⁻³
CO (g)	0.310
H ₂ (g)	0.240
CH ₃ OH(g)	0.260

Calculate the numerical value of K_c for this equilibrium.

Give your answer to an **appropriate** number of significant figures.

$$K_c = \dots\dots\dots \text{dm}^6 \text{mol}^{-2} \text{ [2]}$$

- 5(a). When potassium chromate(VI), K₂CrO₄, is dissolved in water an equilibrium is set up. The position of equilibrium is well to the left and the solution is a yellow colour.



The addition of aqueous acid turns the solution an orange colour.
Aqueous alkali is then added and the solution turns a yellow colour.

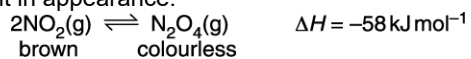
Explain these observations in terms of le Chatelier's principle.

[2]

3.2.3 Chemical Equilibrium

(b). This question is about equilibrium and catalysts.

The equilibrium between NO_2 and N_2O_4 gases is set up in a gas syringe at room temperature. The two gases are different in appearance.



Using le Chatelier's principle, predict and explain how the following changes would affect the appearance of the equilibrium mixture.

- i. The gas mixture is compressed by pushing in the plunger of the gas syringe.

[2]

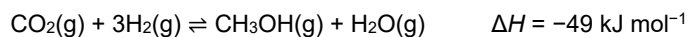
- ii. The gas syringe is placed in a warm water bath.

[2]

3.2.3 Chemical Equilibrium

- (b). Methanol, CH₃OH, is an important feedstock for the chemical industry.

In the manufacture of methanol, carbon dioxide and hydrogen are reacted together in the reversible reaction shown below.



High pressures and low temperatures would give a maximum equilibrium yield of methanol.

- i. Explain this statement in terms of le Chatelier's principle.

[3]

- ii. Explain why the actual conditions used by the chemical industry might be different.

[2]

- 8 A student mixes hydrogen and iodine at room temperature and pressure and allows the mixture to reach dynamic equilibrium.



- i. A closed system is required for dynamic equilibrium to be established.

State **one** other feature of this dynamic equilibrium.

[1]

3.2.3 Chemical Equilibrium

- ii. The student heats the equilibrium mixture keeping the volume constant.

Predict how the composition of the equilibrium mixture changes on heating.

Explain your answer.

[2]

- iii. Predict and explain what effect, if any, an increase in the pressure would have on the position of the equilibrium.

effect

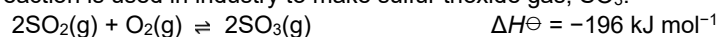
.....
.....

explanation

.....
.....

[1]

9. The following reaction is used in industry to make sulfur trioxide gas, SO₃.



This preparation is carried out in the presence of a catalyst.

* Explain the conditions of temperature and pressure that could be used to obtain the maximum equilibrium yield of sulfur trioxide.

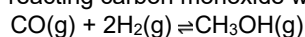
Discuss the importance of a compromise between equilibrium yield and reaction rate when deciding the operational conditions for this process.

3.2.3 Chemical Equilibrium

[6]

10(a). This question looks at equilibrium reactions used by industry for preparing important chemicals.

Methanol can be manufactured by reacting carbon monoxide with hydrogen.



An equilibrium mixture contains $3.10 \times 10^{-3} \text{ mol dm}^{-3}$ CO, $2.40 \times 10^{-3} \text{ mol dm}^{-3}$ H₂ and an unknown concentration of CH₃OH.

- i. Write an expression for the equilibrium constant, K_c .

[1]

- ii. The value of K_c for this equilibrium is $14.6 \text{ dm}^6 \text{ mol}^{-2}$.

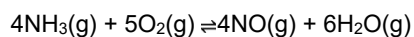
Determine the equilibrium concentration methanol, CH₃OH(g).

Give your answer to **three** significant figures.

equilibrium concentration of CH₃OH(g) = $\text{dm}^6 \text{ mol}^{-2}$
[2]

3.2.3 Chemical Equilibrium

- (b). Ammonia is used in the manufacture of nitric acid. The first stage of this process is a dynamic equilibrium.



- i. When the temperature is increased, K_c for this reaction decreases.

State the effect, if any, on the equilibrium yield of NO in this reaction.

Explain your answer.

----- [1]

- ii. Which element has been oxidised and which element has been reduced in the reaction?

Include signs with the oxidation numbers.

Oxidised Oxidation number change from to
Reduced Oxidation number change from to

[2]

END OF QUESTION PAPER