09 Chemical Equilibria

Set B **Exam practice**

Name	Time 1 hour	Total 27 marks	Score ____ / 27

A Data Booklet may be used.

Marks by notes section For the marker: total each row. A score below the target means that section of the notes needs revising.

Notes section	Questions	Marks	Target	Score
2 Equilibrium Constants	5(a)	1	1	
3 Calculations with K	2, 4, 5(b), 7(a), 7(b)	7	5	
4 Le Chatelier's Principle	1, 3, 6(b), 6(c), 7(c)	9	6	
5 The Haber Process	8	2	2	
6 K and Gibbs Free Energy	5(c), 9(b)(i), 9(b)(ii), 9(b)(iii)	5	3	
4 Hess' Law *(Topic 07)*	6(a), 9(a)(i)	2	2	
9 Gibbs Free Energy *(Topic 07)*	9(a)(ii)	1	1	

A Multiple choice

4 MARKS

1 COMMON Consider the reaction W + X ⇌ Y + Z. Which of the following statements is incorrect when a catalyst is added to the reaction mixture?

A The catalyst alters the mechanism of the reaction.

B The addition of a catalyst lowers the activation energy of the forward reaction but not that of the reverse reaction.

C The enthalpy change of reaction remains unchanged.

D The catalyst does not alter the proportion of W, X, Y or Z at equilibrium.

Answer ☐ [1]

/1

Source: AJC 2017 Promo, via Chemical Equilibria Topical Revision Booklet, Q1

2 A 0.0113 mol sample of ammonium nitrate is introduced into an evacuated vessel with a volume of 0.83 dm^3. The vessel, of constant volume, is heated to a constant temperature such that the equilibrium below is established. $NH_4NO_3(s) \rightleftharpoons NH_3(g) + HNO_3(g)$

Given that the percentage dissociation of ammonium nitrate at equilibrium is 66.8%, what is the value of the equilibrium constant, K_c?

A 5.70×10^{-5} **B** 8.27×10^{-5} **C** 0.0152 **D** 0.0183

Answer [1]

/1

Source: MJC 2017 Promo, via Chemical Equilibria Topical Revision Booklet, Q7

3 The key stage in the manufacture of sulfuric acid is $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$, $\Delta H = -197$ kJ mol^{-1}. Which of the following statements are correct for an increase in temperature?

1 The equilibrium constant increases.

2 The rate constant for the forward reaction increases.

3 The rate constant for the backward reaction increases.

4 The activation energy for the forward reaction decreases.

A 1, 2, 3 and 4 **B** 2, 3 and 4 only **C** 2 and 3 only **D** 3 only

Answer [1]

/1

Source: MJC 2017 Promo, via Chemical Equilibria Topical Revision Booklet, Q8

4 In an experiment, 2 mol of compound P were placed in a vessel and heated. Compound P decomposed partially to give compounds Q and R. At equilibrium, the mixture was found to contain x mol of R and the total amount present was (2 + x). Which equilibrium represents this equilibrium? All compounds are gases.

A $P \rightleftharpoons 2Q + R$ **B** $2P \rightleftharpoons 2Q + R$ **C** $2P \rightleftharpoons Q + R$ **D** $2P \rightleftharpoons Q + 2R$

Answer [1]

/1

Source: EJC 2022 JC1 Chemical Equilibria Tutorial, A2

B Structured questions

23 MARKS

5 COMMON 0.200 mol of carbon monoxide and 0.200 mol of steam were placed in a reaction vessel and allowed to react at a temperature of 800 K. The percentage of carbon monoxide reacted was found to be 77.5%. $CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$

(a) Write the expression for the equilibrium constant, K_c, for this reaction.

[1]

(b) Calculate the value of the equilibrium constant, K_c, at 800 K.

[2]

(c) The Gibbs free energy change of this reaction is −18.4 kJ mol^{-1} at 600 K. The relationship between the equilibrium constant and the Gibbs free energy change of this reaction can be expressed as $\Delta G = -RT \ln K_c$. Calculate the value of K_c at 600 K.

[1]

/4

Source: 2025 NJC J2 Prelim P2 Q4(c)

6 In the gaseous state, NO_2 can form a dimer. $2NO_2(g) \rightleftharpoons N_2O_4(g)$. NO_2 is brown and N_2O_4 is colourless.

(a) Calculate the enthalpy change, ΔH, for the dimerisation, using $\Delta H_f(NO_2) = +33.2$ kJ mol^{-1} and $\Delta H_f(N_2O_4) = +9.2$ kJ mol^{-1}.

[1]

(b) Predict, with reasons, whether the dimerisation is favoured by high or low pressure, and by high or low temperature.

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[2]

(c) Two sealed tubes each contain a mixture of NO_2 and N_2O_4. One is placed in iced water and the other in hot water. Deduce the colour expected in each tube. Explain your answers.

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[2]

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Source: EJC 2022 JC1 Chemical Equilibria Tutorial, A10(a) and (b)

7 Steam can react with carbon monoxide under appropriate conditions according to the following reversible reaction. $H_2O(g) + CO(g) \rightleftharpoons CO_2(g) + H_2(g)$ $\Delta H = -40$ kJ mol^{-1}

(a) Calculate the amount of CO in the equilibrium mixture if 4 moles each of CO(g) and $H_2O(g)$ were placed in a vessel of constant volume at a temperature at which K_c is 9.0.

[2]

(b) What are the mole fractions of all the reactants and products?

[1]

(c) The reaction is repeated as before, except that (i) the temperature is lowered, (ii) the volume of the vessel is decreased, (iii) a catalyst is added, with other factors remaining constant. For each change, describe and explain the effect on the amount of CO_2 at equilibrium and on the time taken to reach equilibrium.

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

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Source: RJC H2 Chemistry Tutorial 7 (Chemical Equilibria), Q4(a), (b) and (d), adapted

8 In the Haber process, a mixture of H_2 and N_2 reacts to form ammonia.

$$3H_2(g) + N_2(g) \rightleftharpoons 2NH_3(g) \quad \Delta H = -92 \text{ kJ mol}^{-1}$$

COMMON The spontaneity of the reaction would be higher if the temperature were reduced. Yet the temperature used in the Haber process is still fairly high, between 400 and 500 °C. Give one advantage and one disadvantage of using a temperature much lower than this range.

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Source: 2023 CJC J2 Prelim P3 Q2(b)(iii)

9 CHALLENGE In the Contact process, SO_2 is oxidised to SO_3 using a vanadium(V) oxide catalyst. $SO_2(g) + \frac{1}{2}O_2(g) \rightleftharpoons SO_3(g) \quad \Delta S = -93.5 \text{ J K}^{-1} \text{ mol}^{-1}$

(a)(i) Given that at 298 K, $\Delta H_f(SO_2) = -297 \text{ kJ mol}^{-1}$ and $\Delta H_f(SO_3) = -396 \text{ kJ mol}^{-1}$, calculate ΔH for this reaction. Include the units.

[1]

(ii) Hence calculate ΔG for this reaction at 298 K. Include the units.

[1]

(b)(i) For any reaction, ΔG is related to the equilibrium constant by $\Delta G = -2.303RT \log_{10} K_c$. Calculate a value of K_c for the oxidation of SO_2 at 298 K.

[2]

(ii) What is the significance of the magnitude of your answer in (b)(i)?

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(iii) Suggest why, when sulfur is heated in air, SO_2 is formed but not SO_3.

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Source: EJC 2022 JC1 Chemical Equilibria Tutorial, A11