Answer **all** questions.

1 A chemist set up an equilibrium system between dinitrogen tetroxide, N_2O_4, and nitrogen dioxide, NO_2, at 25 °C.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g)$$

The equilibrium concentrations were: $N_2O_4(g)$, 0.0390 mol dm^{-3}; $NO_2(g)$, 0.0150 mol dm^{-3}.

(a) (i) Write the expression for K_c in this equilibrium system.

[1]

(ii) Calculate K_c for this equilibrium State the units.

[2]

(b) The standard enthalpy changes of formation of N_2O_4 and NO_2 are given below.

compound	$\Delta H_f^{\ominus}$/kJ mol^{-1}
N_2O_4	+9
NO_2	+33

Calculate the standard enthalpy change for the forward reaction in this equilibrium.

[2]

(c) This equilibrium system was heated at constant pressure. How would you expect the relative proportions of N_2O_4 and NO_2 to change? Explain your answer.

change .....

explanation .....

.....

.....[3]

(d) NO_2 and N_2O_4 are both poisonous. After this investigation, the chemist needed to dispose of 0.00465 mol N_2O_4 safely. The chemist decided to do this by reacting the N_2O_4 with an alkali and chose aqueous sodium hydroxide.

$$N_2O_4(g) + 2NaOH(aq) \longrightarrow NaNO_3(aq) + NaNO_2(aq) + H_2O(l)$$

Calculate the minimum volume of 0.300 mol dm^{-3} NaOH(aq) required to dispose of this amount of N_2O_4.

[3]

[Total : 11]

For Examiner's Use

Answer **all** the questions.

1 *Syngas* is a mixture of carbon monoxide and hydrogen gases, used as a feedstock for the manufacture of methanol.

A dynamic equilibrium was set up between carbon monoxide, CO, hydrogen, H_2, and methanol, CH_3OH. The equilibrium system is shown by Equilibrium 1.1 below.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \textbf{Equilibrium 1.1}$$

The equilibrium concentrations of the three components of this equilibrium are shown below.

component	CO(g)	$H_2(g)$	$CH_3OH(g)$
equilibrium concentration /mol dm^{-3}	3.1×10^{-3}	2.4×10^{-2}	2.6×10^{-5}

(a) State **two** features of a system that is in *dynamic equilibrium.*

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.....[2]

(b) **(i)** Write the expression for K_c for this equilibrium system.

[2]

(ii) Calculate the numerical value of K_c for this equilibrium.

[2]

(c) The pressure was increased whilst keeping the temperature constant. The system was left to reach equilibrium. The equilibrium position of Equilibrium 1.1 shifted to the right.

(i) Explain why the equilibrium moved to the right.

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.....[2]

(ii) What is the effect, if any, on K_c?

.....[1]

(iii) State and explain the effect on the rates of the forward and reverse reactions

- when the pressure was first changed
- when the system reached equilibrium.

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.....[4]

(d) The temperature was increased whilst keeping the pressure constant. The system was left to reach equilibrium. The value of K_c for Equilibrium 1.1 decreased.

(i) Explain what happens to the equilibrium position of Equilibrium 1.1.

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.....[2]

(ii) Deduce the sign of the enthalpy change for the forward reaction shown in Equilibrium 1.1. Explain your reasoning.

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.....[1]

(iii) Explain how the partial pressure of $CH_3OH(g)$ would change as the system moves towards equilibrium.

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.....[1]

[Total: 17]