

4.3 Equilibrium amounts, K_c and K_p

Name: _____ Class: _____ Date: _____ **Total: 19 marks**

KEY WORDS partial pressure

Objective

Calculate an equilibrium constant from the actual equilibrium composition. Questions and marking guidance are original.

1 Key knowledge and worked examples

Write the balanced equation before the expression. Raise each concentration or partial pressure to its coefficient; omit pure solids and liquids. Constants refer to a specified temperature. A catalyst leaves K unchanged.

■ Worked method

For $A(g) + B(g) \rightleftharpoons C(g)$, initially 0.500 mol each A and B in 2.00 dm³ gives 0.200 mol C at equilibrium. The equilibrium amounts are A = 0.300, B = 0.300, C = 0.200 mol.

$$K_c = \frac{[C]}{[A][B]} = \frac{0.200/2.00}{(0.300/2.00)^2} = 4.44 \text{ dm}^3 \text{ mol}^{-1}$$

For gases, $p_i = x_i P$ where $x_i = n_i/n_{\text{total}}$. Derive K_p units from the powers and use the specified pressure unit. For an exothermic forward reaction, raising temperature lowers K. Concentration/pressure changes cause a shift while the same K is restored at fixed temperature.

2 Practice

2.1 Write K_c for $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$, and derive its units for concentrations in mol dm⁻³. [3]

2.2 A gas mixture contains 2.0 mol X and 3.0 mol Y at total pressure 5.0 atm. Calculate each partial pressure. [2]

2.3 Write K_p for $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$. Explain the omitted terms. [2]

3 Exam-style questions

3.1 For $N_2O_4(g) \rightleftharpoons 2NO_2(g)$, equilibrium amounts are 0.60 mol N₂O₄ and 0.40 mol NO₂ at 2.50 atm total pressure. Calculate K_p with units. [4]

3.2 For $A + B \rightleftharpoons C$, 0.40 mol each A and B initially in 1.50 dm³ produces 0.10 mol C. Calculate K_c. Explain why simply using the equilibrium mole amounts in the expression fails. [4]

3.3 An appropriately standardised dimensionless equilibrium constant is $K = 20.0$ at 298 K. Use $\Delta S(\text{total}) = R \ln K$ and $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$ to calculate total entropy. The forward reaction is endothermic. Explain the predicted change in K when temperature rises, assuming ΔH and system entropy are approximately constant. [4]
