Year 12 Science: Equilibrium, acids, bases and pH

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Write the Kc expression for $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$.

2. What is the pH of 0.0050 mol L^{-1} HCl?

3. What is the pH of 0.10 mol L^{-1} KOH?

4. Find $[H_3O^+]$ in a solution of pH 9.20.

5. For $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$, which way does the equilibrium shift when the pressure is increased?

Exam-style question: making methanol

Methanol, a fuel and solvent, is made industrially from carbon monoxide and hydrogen: $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$. The forward reaction is exothermic.

6. Write the Kc expression for this equilibrium.

7. In a test vessel at equilibrium, [CO] = 0.20, $[H_2]$ = 0.30 and $[CH_3OH]$ = 0.045 mol L^{-1}. Calculate Kc and say what it shows.

8. Explain why the process is run at high pressure.

9. Discuss how raising the temperature affects the amount of methanol at equilibrium, the value of Kc, and the rate.

10. Equipment is rinsed with 0.010 mol L^{-1} NaOH. Calculate its pH.

Fix the mistake

11. Correct this statement: "At equilibrium the concentrations of reactants and products are equal."

12. Correct this statement: "Adding more reactant increases Kc."

13. Correct this statement: "The pH of 0.020 mol L^{-1} NaOH is –log(0.020) = 1.70."

14. Correct this statement: "A weak acid is the same as a dilute acid."

Answer key (for parents and tutors)

1. Write the Kc expression for $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$.
   $K_c = [HI]^2 \div ([H_2][I_2])$.
2. What is the pH of 0.0050 mol L^{-1} HCl?
   pH = −log(0.0050) = 2.30.
3. What is the pH of 0.10 mol L^{-1} KOH?
   $[OH^-] = 0.10$ mol L^{-1}, so $[H_3O^+] = 1.0 \times 10^{-14} \div 0.10 = 1.0 \times 10^{-13}$ mol L^{-1} and the pH is 13.00.
4. Find $[H_3O^+]$ in a solution of pH 9.20.
   $[H_3O^+] = 10\text{^}-9.20 = 6.31 \times 10^{-10}$ mol L^{-1}.
5. For $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$, which way does the equilibrium shift when the pressure is increased?
   To the right: 3 mol of gas become 2, and fewer gas particles lower the pressure.
6. Write the Kc expression for this equilibrium.
   $K_c = [CH_3OH] \div ([CO][H_2]^2)$ (Achieved).
7. In a test vessel at equilibrium, $[CO] = 0.20$, $[H_2] = 0.30$ and $[CH_3OH] = 0.045$ mol L^{-1}. Calculate Kc and say what it shows.
   $K_c = 0.045 \div (0.20 \times 0.30^2) = 0.045 \div 0.018 = 2.5$; Kc is a little above 1, so products are slightly favoured at this temperature (Achieved for the value, Merit for the meaning).
8. Explain why the process is run at high pressure.
   The left side has 3 mol of gas and the right side 1 mol. Raising the pressure favours the side with fewer moles of gas, which lowers the pressure again, so the forward reaction is favoured and more methanol forms; the higher concentration of gas also speeds up the reaction (Merit).
9. Discuss how raising the temperature affects the amount of methanol at equilibrium, the value of Kc, and the rate.
   The forward reaction is exothermic, so heating favours the endothermic reverse reaction, which absorbs some of the added heat: less methanol forms and Kc gets smaller. But particles move faster and more collisions have at least the activation energy, so the rate rises and equilibrium is reached sooner; the plant runs at a compromise temperature (Excellence for weighing yield against rate).
10. Equipment is rinsed with 0.010 mol L^{-1} NaOH. Calculate its pH.
    $[OH^-] = 0.010$ mol L^{-1}, so $[H_3O^+] = 1.0 \times 10^{-14} \div 0.010 = 1.0 \times 10^{-12}$ mol L^{-1} and the pH is 12.00 (Achieved).
11. Correct this statement: "At equilibrium the concentrations of reactants and products are equal."
    The forward and reverse rates are equal; the concentrations are constant but usually different.
12. Correct this statement: "Adding more reactant increases Kc."
    Only temperature changes Kc; adding reactant shifts the position of equilibrium and Kc stays the same.
13. Correct this statement: "The pH of 0.020 mol L^{-1} NaOH is −log(0.020) = 1.70."
    That uses $[OH^-]$. Find $[H_3O^+] = 1.0 \times 10^{-14} \div 0.020 = 5.0 \times 10^{-13}$ mol L^{-1} first, so the pH is 12.30.
14. Correct this statement: "A weak acid is the same as a dilute acid."
    Weak means it reacts only partly with water; a weak acid can be concentrated and a strong acid can be dilute.