



Attempt all questions before checking the answer key. At 298 K use $K_w = 1.0 \times 10^{-14}$. Assume dilute ideal solutions; write equilibrium expressions before substitution.

A. Very short answers - 1 mark each

1. What is dynamic equilibrium?
2. Does a catalyst change the equilibrium constant at fixed temperature?
3. Write the conjugate base of H_2PO_4^- .
4. Define pH for a dilute aqueous solution.
5. What is the common-ion effect?
6. Define a buffer solution.

B. Short answers / practice - 2 marks each

7. Write K_c for $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$.
8. Write K_c for $\text{CaCO}_3(\text{s}) \rightleftharpoons \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$, explaining omission of solids.
9. Find pH of 1.0×10^{-3} M HCl at 298 K.
10. Find pH of 2.0×10^{-3} M NaOH; use $\log 2 = 0.3010$.
11. Explain the effects of pressure increase and catalyst addition on the ammonia equilibrium.
12. Give conjugate acid-base pairs for $\text{NH}_3 + \text{H}_2\text{O} \rightleftharpoons \text{NH}_4^+ + \text{OH}^-$.
13. Find pH of 0.01 M HCl at 298 K.
14. Find pOH if $\text{pH}=9$ at 298 K.
15. Does equilibrium mean that molecular reactions stop?
16. For $K=4$, find K for the reversed reaction.
17. A solution has $[\text{OH}^-]=10^{-4}$ M at 298 K. Find pH.
18. Explain how adding a common ion decreases a sparingly soluble salt's solubility.

C. Short answers - 3 marks each

19. For $\text{H}_2 + \text{I}_2 \rightleftharpoons 2\text{HI}$, equilibrium concentrations are 0.2, 0.2 and 0.8 M respectively. Find K_c and state how it changes if the equation is reversed.
20. Derive $K_p = K_c(RT)^{\Delta n}$ for ideal gases. Apply it to $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$.
21. A 0.10 M weak monoprotic acid has $K_a = 1.0 \times 10^{-5}$. Estimate $[\text{H}^+]$, pH and degree of ionisation; check the approximation.

22. For AgCl, $K_{sp} = 1.8 \times 10^{-10}$. Find molar solubility in pure water and approximately in 0.10 M NaCl.

23. Explain why NH_4Cl solution is acidic, CH_3COONa solution basic and NaCl solution approximately neutral at 298 K.

24. For a buffer containing equal concentrations of CH_3COOH and CH_3COONa , find pH if $K_a = 1.8 \times 10^{-5}$ and $\log 1.8 = 0.2553$. Explain resistance to a small acid addition.

D. Long answers - 5 marks each

25. One mole of N_2O_4 is placed in a 1 L vessel; its degree of dissociation into NO_2 is 0.20 at equilibrium. Find equilibrium concentrations and K_c . Predict the effect of doubling volume at unchanged temperature.

26. Explain Le Chatelier's principle using exothermic ammonia synthesis. Discuss changes in pressure, temperature, reactant concentration and catalyst; distinguish yield from reaction speed.

27. For a weak acid HA, derive the relation between K_a , concentration and degree of ionisation. Obtain the dilute weak-ionisation approximation and explain the effect of dilution.

28. Explain buffer action for $\text{CH}_3\text{COOH}/\text{CH}_3\text{COONa}$ with equations. Derive the Henderson-Hasselbalch form and calculate pH when $[\text{salt}]/[\text{acid}] = 10$ and $\text{p}K_a = 4.76$.

29. For CaF_2 , $K_{sp} = 4 \times 10^{-11}$. Derive its molar-solubility expression and calculate solubility in pure water. Explain qualitatively the effect of added NaF.

30. Compare Arrhenius, Brønsted-Lowry and Lewis acid-base concepts with examples. Identify the acid/base roles in $\text{NH}_3 + \text{H}^+ \rightarrow \text{NH}_4^+$ and $\text{BF}_3 + \text{NH}_3 \rightarrow \text{F}_3\text{B} \leftarrow \text{NH}_3$.

ANSWER KEY - Numerical / short answers

2) No. 9) 3.00. 10) 11.301. 13) 2. 14) 5. 15) No; forward and reverse rates are equal. 16) 1/4. 17) 10. 19) 16; reversed constant=1/16. 20) $K_p = K_c RT$ for $\text{N}_2\text{O}_4 \rightleftharpoons 2\text{NO}_2$. 21) $[\text{H}^+] \approx 1.0 \times 10^{-3}$ M; $\text{pH} \approx 3$; $\alpha \approx 0.010$ (1%); approximation valid. 22) 1.34×10^{-5} M; about 1.8×10^{-9} M in NaCl. 24) 4.7447. 25) $[\text{N}_2\text{O}_4]=0.80$ M, $[\text{NO}_2]=0.40$ M; $K_c=0.20$; expansion favours further dissociation. 28) $\text{pH}=5.76$. 29) $s=(K_{sp}/4)^{1/3}=2.15 \times 10^{-4}$ mol/L.