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Equilibrium — JEE (Main) Pattern Topic Test

FREE SAMPLE TEST · CHEMISTRY · PATTERN OF JEE (MAIN)

DURATION	MAXIMUM MARKS	QUESTIONS	NAME / ROLL NO.
60 minutes	100	25 (20 + 5)	

GENERAL INSTRUCTIONS

1. This question paper has two sections, A and B. All 25 questions are compulsory.
2. Section A has TWENTY (20) multiple-choice questions. Each has FOUR options, (1), (2), (3) and (4), of which ONLY ONE is correct.
3. Section B has FIVE (05) questions whose answer is a numerical value. Enter the value rounded off to the nearest integer.
4. Marking scheme for both sections: +4 for a correct answer, −1 for an incorrect answer, 0 if the question is not attempted.
5. Take $K_w = 1.0 \times 10^{-14}$ at 25 °C unless stated otherwise. Use of a calculator, log tables or any other aid is not allowed.
6. The answer key and worked solutions are at the end of this booklet. Attempt the paper in 60 minutes before you look at them.

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Topics covered: Physical equilibria · Henry's law · Law of chemical equilibrium · Kp and Kc · Degree of dissociation · Gibbs energy and equilibrium · Factors affecting equilibrium · Le Chatelier's principle · Acids and bases · Ionisation of weak acids · Ionisation of weak bases · Multistage ionisation · Ionic product of water · pH scale · Common ion effect · Hydrolysis of salts · Solubility product · Buffer solutions

SECTION A (Q1–20) · Multiple choice · +4 / 0 / −1

Each question has FOUR options. ONLY ONE of them is correct.

1. For $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$ at 500 K, $K_c = 0.0244$ mol/L. The value of K_p (in atm) at this temperature is about (R = 0.0821 L atm/(K mol))

(1) 0.0244

(2) 1.0

(3) 2.0

(4) 6.0×10^{-4}

2. 1.0 mol of H_2 and 1.0 mol of I_2 are heated in a closed 1 L flask. For $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$, $K_c = 64$ at the temperature used. The amount of HI at equilibrium is

(1) 0.8 mol

(2) 1.78 mol

(3) 1.6 mol

(4) 0.4 mol

3. For $N_2O_4(g) \rightleftharpoons 2NO_2(g)$, $\Delta H > 0$. The amount of NO_2 at equilibrium is increased by

(1) increasing the temperature

(2) increasing the total pressure by compression

(3) adding argon at constant volume

(4) adding a catalyst

4. For $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$, $K_c = 100$ at a certain temperature. At the same temperature, K_c for $SO_3(g) \rightleftharpoons SO_2(g) + \tfrac{1}{2}O_2(g)$ is

(1) 0.01

(2) 10

(3) −100

(4) 0.1

5. PCl_5 (molar mass 208.5 g/mol) dissociates on heating: $PCl_5 \rightleftharpoons PCl_3 + Cl_2$. The vapour density of the equilibrium mixture is 62. The degree of dissociation of PCl_5 is about

(1) 32%

(2) 68%

(3) 50%

(4) 84%

6. The pH of a 1.0×10^{-8} M aqueous solution of HCl at 25 °C is about

(1) 8.00

(2) 6.98

(3) 7.00

(4) 6.00

7. The pH of a 0.10 M aqueous solution of a weak monobasic acid with $K_a = 4.0 \times 10^{-5}$ is about (log 2 = 0.30)

(1) 3.0

(2) 5.4

(3) 2.7

(4) 1.35

8. The pH of a solution that is 0.20 M in acetic acid and 0.10 M in sodium acetate is (pK_a of acetic acid = 4.74, log 2 = 0.30)

(1) 4.44

(2) 5.04

(3) 4.74

(4) 4.14

9. The pH of a 0.10 M aqueous solution of sodium acetate at 25 °C is about (pK_a of acetic acid = 4.74)

(1) 9.37

(2) 8.87

(3) 5.13

(4) 11.13

10. The solubility product of Ag_2CrO_4 is 3.2×10^{-11}. Its solubility in pure water is

(1) 5.7×10^{-6} M

(2) 3.2×10^{-4} M

(3) 4.0×10^{-4} M

(4) 2.0×10^{-4} M

11. The solubility of AgCl ($K_sp = 1.8 \times 10^{-10}$) in 0.10 M NaCl solution is

(1) 1.3×10^{-5} M

(2) 1.8×10^{-10} M

(3) 1.8×10^{-9} M

(4) 1.8×10^{-11} M

12. Equal volumes of 2.0×10^{-4} M $BaCl_2$ and 2.0×10^{-4} M Na_2SO_4 are mixed. K_sp of $BaSO_4$ is 1.1×10^{-10}. Then

(1) $BaSO_4$ precipitates, since the ionic product (1.0×10^{-8}) exceeds K_sp

(2) no precipitate forms, since the ionic product (1.0×10^{-8}) is less than K_sp

(3) $BaSO_4$ precipitates, since the ionic product (4.0×10^{-8}) exceeds K_sp

(4) the solution is exactly saturated

13. Which of the following is a Lewis acid but NOT a Brønsted–Lowry acid?

(1) HCl

(2) NH_4^+

(3) BF_3

(4) H_2O

14. Which of the following is NOT a conjugate acid–base pair?

(1) HNO_3 / NO_3^-

(2) NH_4^+ / NH_3

(3) HSO_4^- / SO_4^{2-}

(4) H_3O^+ / OH^-

15. At 60 °C the ionic product of water is 1.0×10^{-13}. At this temperature, pure water has

(1) pH 7.0 and is neutral

(2) pH 6.5 and is neutral

(3) pH 6.5 and is acidic

(4) pH 7.5 and is basic

16. Statement I: For a reaction mixture with reaction quotient Q less than K, the reaction proceeds in the forward direction.
Statement II: At equilibrium, $\Delta G = 0$ and $\Delta G^\circ = -RT \ln K$.
In the light of the above statements, choose the correct answer from the options given below:

(1) Statement I is true but Statement II is false

(2) Statement I is false but Statement II is true

(3) Both Statement I and Statement II are false

(4) Both Statement I and Statement II are true

17. The Henry's law constant of N_2 in water at 298 K is 1.0×10^5 atm. The mole fraction of N_2 dissolved in water in contact with air in which the partial pressure of N_2 is 0.80 atm is

(1) 8.0×10^{-5}

(2) 1.25×10^{-6}

(3) 8.0×10^{-6}

(4) 1.25×10^5

18. Assertion A: Increasing the pressure on a mixture of ice and water at 0 °C makes some ice melt.
Reason R: Ice has a lower density than liquid water, so melting decreases the volume of the system.
In the light of the above statements, choose the correct answer from the options given below:

(1) Both A and R are true and R is the correct explanation of A

(2) A is true but R is false

(3) Both A and R are true but R is NOT the correct explanation of A

(4) A is false but R is true

19. For H_2S, $K_a1 = 1.0 \times 10^{-7}$ and $K_a2 = 1.3 \times 10^{-13}$. In a 0.10 M aqueous solution of H_2S, the concentration of S^{2-} is about

(1) 1.0×10^{-4} M

(2) 1.3×10^{-13} M

(3) 1.3×10^{-20} M

(4) 1.0×10^{-7} M

20. Consider the following statements.

(A) A catalyst does not change the value of the equilibrium constant.

(B) The equilibrium constant of a reaction changes with temperature.

(C) Adding more $CaCO_3(s)$ to the equilibrium $CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$ increases the pressure of CO_2.

(D) For an exothermic reaction, the equilibrium constant decreases as the temperature rises.

(E) $K_p = K_c$ for a reaction in which the number of moles of gas does not change.

Choose the correct answer from the options given below:

(1) (A), (B) and (C) only

(2) (A), (B), (D) and (E) only

(3) (B), (C) and (E) only

(4) (A), (C), (D) and (E) only

SECTION B (Q21–25) · Numerical value · +4 / 0 / −1

The answer to each question is a NUMERICAL VALUE. Enter it rounded off to the nearest integer.

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21. 100 mL of 0.10 M NaOH is mixed with 100 mL of 0.080 M HCl at 25 °C. The pH of the resulting solution is _____.

Answer: _____

22. 1.0 mol each of A and B are placed in a 1 L vessel. At equilibrium for $A + B \rightleftharpoons C + D$, 0.60 mol of C is present. The equilibrium constant K_c is $x \times 10^{-2}$. The value of x is _____.

Answer: _____

23. A solution contains 0.10 M Mg^{2+}. K_{sp} of $Mg(OH)_2$ is 1.0×10^{-11}. The pH at which $Mg(OH)_2$ just begins to precipitate (at 25 °C) is _____.

Answer: _____

24. At a total pressure of 1.0 atm, N_2O_4 is 20% dissociated into NO_2 at a certain temperature. K_p for $N_2O_4(g) \rightleftharpoons 2NO_2(g)$ is $x \times 10^{-3}$ atm. The value of x is _____ (to the nearest integer).

Answer: _____

25. The pH of a 0.010 M aqueous solution of a weak base B ($K_b = 1.0 \times 10^{-6}$) at 25 °C is _____ (to the nearest integer).

Answer: _____

END OF THE QUESTION PAPER

ANSWER KEY

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
(2)	(3)	(1)	(4)	(2)	(2)	(3)	(1)	(2)	(4)

Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20
(3)	(1)	(3)	(4)	(2)	(4)	(3)	(1)	(2)	(2)

Q21	Q22	Q23	Q24	Q25
12	225	9	167	10

WORKED SOLUTIONS

Q1. Answer (2). $K_p = K_c(RT)^{\Delta n}$ with $\Delta n = 2 - 1 = 1$: $K_p = 0.0244 \times 0.0821 \times 500 \approx 1.0$ atm.

Q2. Answer (3). If x mol of H_2 reacts: $(2x)^2/(1 - x)^2 = 64$, so $2x/(1 - x) = 8$ and $x = 0.8$. HI = 2x = 1.6 mol.

Q3. Answer (1). A rise in temperature favours the endothermic forward reaction. Compression favours the side with fewer gas molecules (N_2O_4). An inert gas at constant volume does not change any partial pressure, and a catalyst does not shift the equilibrium.

Q4. Answer (4). Reversing the equation inverts K (1/100), and halving the coefficients takes the square root: $K = (1/100)^{(1/2)} = 0.1$.

Q5. Answer (2). Average molar mass = 2 × 62 = 124. One mole of PCl_5 gives $1 + \alpha$ mol of gas, so $208.5/124 = 1 + \alpha$ and $\alpha \approx 0.68 = 68\%$.

Q6. Answer (2). Such a dilute acid cannot make the solution alkaline: the H^+ from water must be counted. $[H^+] = 10^{-8} + [OH^-]$ with $[H^+][OH^-] = 10^{-14}$ gives $[H^+]^2 - 10^{-8}[H^+] - 10^{-14} = 0$, $[H^+] \approx 1.05 \times 10^{-7}$ M, pH ≈ 6.98.

Q7. Answer (3). $[H^+] \approx \sqrt{(K_a\, c)} = \sqrt{(4 \times 10^{-6})} = 2 \times 10^{-3}$ M (2% ionised, so the approximation holds). pH = 3 − log 2 = 2.7.

Q8. Answer (1). Henderson equation: $pH = pK_a + \log([salt]/[acid]) = 4.74 + \log(0.5) = 4.74 - 0.30 = 4.44$.

Q9. Answer (2). Acetate is a weak base: $pH = 7 + \tfrac{1}{2}(pK_a + \log c) = 7 + \tfrac{1}{2}(4.74 - 1) = 8.87$.

Q10. Answer (4). $Ag_2CrO_4 \rightleftharpoons 2Ag^+ + CrO_4^{2-}$: $K_sp = (2s)^2 s = 4s^3$. $s^3 = 8 \times 10^{-12}$, $s = 2.0 \times 10^{-4}$ M. ($\sqrt{K_sp} = 5.7 \times 10^{-6}$ would apply to a 1 : 1 salt.)

Q11. Answer (3). $[Cl^-] \approx 0.10$ M from NaCl, so $s = K_sp/[Cl^-] = 1.8 \times 10^{-9}$ M, about 10^4 times less than in pure water (1.3×10^{-5} M).

Q12. Answer (1). Mixing equal volumes halves each concentration: $[Ba^{2+}] = [SO_4^{2-}] = 1.0 \times 10^{-4}$ M. Ionic product = $1.0 \times 10^{-8} > 1.1 \times 10^{-10}$, so $BaSO_4$ precipitates.

Q13. Answer (3). BF_3 has an empty orbital on boron and accepts an electron pair (from NH_3, F^-, …) but has no proton to donate. HCl, NH_4^+ and H_2O can all donate a proton.

Q14. Answer (4). A conjugate pair differs by exactly one proton. H_3O^+ and OH^- differ by two ($H_3O^+ \rightarrow H_2O \rightarrow OH^-$); the conjugate base of H_3O^+ is H_2O.

Q15. Answer (2). In pure water $[H^+] = [OH^-] = \sqrt{(10^{-13})} = 3.16 \times 10^{-7}$ M, so pH = 6.5. It is still neutral, because $[H^+] = [OH^-]$; the neutral pH falls as K_w rises with temperature.

Q16. Answer (4). $\Delta G = \Delta G^\circ + RT \ln Q = RT \ln(Q/K)$. If $Q < K$, $\Delta G < 0$ and the forward reaction is spontaneous (I true). At equilibrium $Q = K$, $\Delta G = 0$ and $\Delta G^\circ = -RT \ln K$ (II true).

Q17. Answer (3). $p = K_H x$, so $x = 0.80/(1.0 \times 10^5) = 8.0 \times 10^{-6}$.

Q18. Answer (1). By Le Chatelier's principle, an increase in pressure favours the change that reduces volume. Water occupies less volume than the ice it came from, so ice melts (the melting point falls with pressure). Both are true and R explains A.

Q19. Answer (2). The first step gives $[H^+] \approx [HS^-] \approx \sqrt{(10^{-7} \times 0.1)} = 10^{-4}$ M. In the second step $K_a2 = [H^+][S^{2-}]/[HS^-]$, and since $[H^+] \approx [HS^-]$, $[S^{2-}] \approx K_a2 = 1.3 \times 10^{-13}$ M.

Q20. Answer (2). (A) A catalyst speeds up both directions equally. (B), (D) $d \ln K/dT = \Delta H°/RT^2$: K changes with T and falls for $\Delta H° < 0$. (C) is false: $K_p = p(CO_2)$ and a pure solid does not enter the expression. (E) $K_p = K_c(RT)^{\Delta n}$ with $\Delta n = 0$.

Q21. Answer 12. OH^- left = 10 − 8 = 2 mmol in 200 mL: $[OH^-] = 0.010$ M, pOH = 2, pH = 12.

Q22. Answer 225. C = D = 0.60, A = B = 0.40 mol/L. $K_c = 0.36/0.16 = 2.25 = 225 \times 10^{-2}$.

Q23. Answer 9. Precipitation starts when $[Mg^{2+}][OH^-]^2 = K_sp$: $[OH^-] = \sqrt{(10^{-11}/0.1)} = 10^{-5}$ M, pOH = 5, pH = 9.

Q24. Answer 167. Per mole of N_2O_4: 0.8 N_2O_4 and 0.4 NO_2, total 1.2 mol. Partial pressures: 0.8/1.2 and 0.4/1.2 atm. $K_p = (1/3)^2/(2/3) = 1/6 \approx 0.1667$ atm $= 167 \times 10^{-3}$ atm. (In general $K_p = 4\alpha^2P/(1 - \alpha^2)$.)

Q25. Answer 10. $[OH^-] \approx \sqrt{(K_b\, c)} = \sqrt{(10^{-8})} = 10^{-4}$ M (1% ionised), pOH = 4, pH = 10.

All questions are original and © Master Testing Agency. Free to download and use for personal practice; not for resale. Every answer in this paper was checked independently by computer: equilibrium compositions were solved exactly from the equilibrium law, pH values from the full charge balance including the ionisation of water, and solubilities from Ksp, all by numerical root-finding rather than the approximations used in the solutions.