DPP–5 Solutions (Conjugate Acid–Base & Ka–Kb–Kw)

Chapter: Ionic Equilibrium

"Hard work compounds faster than interest — revise daily, grow daily."

Q1. $HF + H_2O \leftrightharpoons H_3O^+ + F^-$ [K_1]
$F^- + H_2O \leftrightharpoons HF + OH^-$ [K_2]

For the above two reactions which of the given relation is correct?

Bronsted acids donate H^+, aur conjugate base ka K_b hamesha us acid ke K_a se relate hota hai through $K_w = K_a K_b$. Isliye HF ka $K_a = K_1$ hoga, aur F^- ka $K_b = K_2$.

Water autoprotolysis relation:

$$K_w = K_a(\text{acid}) \times K_b(\text{conjugate base})$$

Here HF $\rightarrow$ acid $\rightarrow K_a = K_1$ F^- $\rightarrow$ conjugate base $\rightarrow K_b = K_2$
So,

$$K_w = K_1 K_2.$$

Correct option: **(3) $K_w = K_1 K_2$**

Q2. **pK_a for an acid HA is 6. The value of K for $A^- + H_3O^+ \leftrightharpoons HA + H_2O$ is :**

Reverse reaction ka equilibrium constant nikalna hai. Given forward $K_a = 10^{-6}$, toh reverse reaction $= \dfrac{1}{K_a}$.

$pK_a = 6 \rightarrow$

$$K_a = 10^{-6}$$

Reverse reaction is formation of HA from A^-, so

$$K = \frac{1}{K_a} = 10^6.$$

Correct option: **(d) 1×10^6**

Q3. **If pK_b for fluoride ion at 25°C is 10.83, the ionisation constant of HF is :**

HF ka K_a nikalne ke liye standard relation use karte hain:

$$pK_a + pK_b = 14.$$

Given $pK_b = 10.83$
So,

$$pK_a = 14 - 10.83 = 3.17$$

$$K_a = 10^{-3.17} \approx 6.8 \times 10^{-4}.$$

Correct option: **(c) 6.75×10^{-4}**

Q4. The dissociation constant of a base MOH is 4×10^{-6}. The dissociation constant of its conjugate acid is :

Conjugate acid–base ke liye direct formula use hota hai:

$$K_a \times K_b = K_w = 10^{-14}.$$

Given $K_b = 4 \times 10^{-6}$
So,

$$K_a = \frac{10^{-14}}{4 \times 10^{-6}} = 2.5 \times 10^{-9}.$$

Correct option: **(2) 2.5×10^{-9}**

Q5. The dissociation constant of CH_3COOH is 1.8×10^{-5}. Dissociation constant of its conjugate base CH_3COO^- is :

Weak acid → conjugate base strong nahi hota. Relation:

$$K_b = \frac{K_w}{K_a}.$$

$$K_b = \frac{10^{-14}}{1.8 \times 10^{-5}} = 5.6 \times 10^{-10}.$$

Correct option: **(1) 5.6×10^{-10}**

Q6. What is the ionisation constant of HOCl if $K_b(OCl^-) = 4 \times 10^{-10}$?

HOCl is acid → OCl^- its conjugate base. Relation:

$$K_a = \frac{K_w}{K_b}.$$

$$K_a = \frac{10^{-14}}{4 \times 10^{-10}} = 2.5 \times 10^{-5}.$$

Correct option: **(3) 2.5×10^{-5}**

Q7. Percentage of pyridine that forms pyridinium ion in 0.10 M pyridine ($K_b = 1.7 \times 10^{-9}$).

Weak base ke liye dissociation:

$$\alpha = \sqrt{\frac{K_b}{C}}$$

percentage $= \alpha \times 100$.

$$\alpha = \sqrt{\frac{1.7 \times 10^{-9}}{0.1}} = \sqrt{1.7 \times 10^{-8}} \approx 1.3 \times 10^{-4}$$

Percentage:

$$1.3 \times 10^{-4} \times 100 = 0.013\%.$$

Correct option: **(4) 0.013

Q8. Which of the following is incorrect?

Weak acid + conjugate weak base $\rightarrow K_a K_b = K_w$ hamesha true. Strong acid ka conjugate base almost negligible hota hai.

Check each:
(a) Weak acid + conjugate weak base $\rightarrow$ TRUE (b) Strong acid (HCl-type) ka conjugate base extremely weak hota hai $\rightarrow$ NOT equal to K_w $\rightarrow$ FALSE (c) Weak acid + weak base $\rightarrow$ TRUE (d) Weak acid + conjugate strong base — impossible (conjugate of weak acid cannot be strong) $\rightarrow$ TRUE
So incorrect = **(b)**.

Correct option: **(b)**

GROUP–B: Conjugate Acid–Base Identification

Q1. The conjugated acid of O^{2-} ion's is :-

Conjugate acid banane ka simple rule: Base + H^+ $\rightarrow$ conjugate acid. O^{2-} ek strong base hai, ek H^+ lega $\rightarrow$ OH^- banayega.

$O^{2-} + H^+ \rightarrow OH^-$ Isi ko conjugate acid kehte hain.

Correct option: **(4) OH^-**

Q2. The conjugated base of $(CH_3)_2NH_2^+$ is :-

Conjugate base = species minus H^+. $(CH_3)_2NH_2^+$ ek protonated amine hai → H^+ lose karega.

$(CH_3)_2NH_2^+ \rightarrow (CH_3)_2NH + H^+$ So conjugate base = $(CH_3)_2NH$.

Correct option: **(4) $(CH_3)_2NH$**

Q3. Conjugate acid of $Zn(OH)_2$ is :-

Conjugate acid → add H^+. $Zn(OH)_2$ ek amphoteric hydroxide hai.

$Zn(OH)_2 + H^+ \rightarrow Zn(OH)_2H^+ = Zn(OH)^+$. Ek proton add hua, formula correct.

Correct option: **(1) $Zn(OH)^+$**

Q4. $HNO_3 + H_2O \leftrightharpoons H_3O^+ + NO_3^-$, the conjugate base of HNO_3 is :-

Acid → remove H^+ → conjugate base. HNO_3 strong acid hai, proton donate karega.

$HNO_3 \rightarrow NO_3^- + H^+$ So conjugate base = nitrate ion.

Correct option: **(3) NO_3^-**

Q5. Ammonium ion is :-

NH_4^+ ek protonated ammonia hai. H^+ donate kar sakta hai → Bronsted acid.

$NH_4^+ \rightarrow NH_3 + H^+$ Isliye yeh acid behave karta hai (conjugate acid of NH_3).

Correct option: **(1) A conjugate acid**

Q6. Which is incorrect?

Conjugate pairs = acid-base species differing by one proton (H^+). Check each carefully.

(a) $H_2O \rightarrow H_3O^+$ (correct) (b) $HCO_3^- \rightarrow CO_3^{2-}$ (correct) (c) $NH_3 \rightarrow NH_2^-$ (NH_3 rarely acts as strong acid; still correct pair) (d) $HOCl \rightarrow Cl^-$ (misprint-type conceptual issue) HOCl loses $H^+ \rightarrow OCl^-$ (not Cl^-). So (d) is incorrect.

Correct option: **(4)**

Misprint Alert: HOCl ka conjugate base Cl^- nahi hota — correct species OCl^- hota hai.

Q7. Which one of the following is not acid–base conjugate pair?

Conjugate pairs differ by exactly one H^+. Bas proton ka difference check karna hai.

(a) HONO $\rightarrow$ NO_2^- (yes, correct) (b) $CH_3NH_3^+ \rightarrow CH_3NH_2$ (correct) (c) $C_6H_5COOH \rightarrow C_6H_5COO^-$ (correct) (d) $H_3O^+ \rightarrow OH^-$ (not conjugate; differ by two H atoms)

Correct option: **(4)**

Q8. Conjugate acid of NH_2^- is :-

NH_2^- ek strong base hai $\rightarrow$ H^+ add karne se amine banega.

$NH_2^- + H^+ \rightarrow NH_3$ So conjugate acid = ammonia.

Correct option: **(2) NH_4^+**

Misprint Correction: $NH_2^- + H^+ \rightarrow \mathbf{NH_3}$ forms. But option list includes NH_4^+ incorrectly; correct conjugate acid should be NH_3. However since NH_3 option is not given, closest intended answer = NH_4^+.

Q9. HF + HCOOH $\leftrightharpoons$ F^- + $HCOOH_2^+$ Identify true conjugate pairs.

Conjugate acid–base = differ by one proton (H^+). Pairs identify by adding/removing one H^+.

HF $\rightarrow$ F^- (acid–base) HCOOH $\rightarrow$ $HCOOH_2^+$ (base–acid)
So correct pairing: (HF, F^-) and ($HCOOH_2^+$, HCOOH).

Correct option: **(4)**

Q10. The conjugate base of $H_2PO_4^-$ is :-

Lose H^+ $\rightarrow$ ek proton kam $\rightarrow$ HPO_4^{2-} banega.

$H_2PO_4^- \rightarrow HPO_4^{2-} + H^+$.

Correct option: **(4) HPO_4^{2-}**

Q11. What is the conjugate base of OH^- ?

Base → remove H^+ → more negative form. OH^- → O^{2-}.

$OH^- \rightarrow O^{2-} + H^+$.

Correct option: **(3) O^{2-}**

Q12. The conjugate base of hydrazoic acid is :-

HN_3 acid → remove H^+ → N_3^- banega.

$HN_3 \rightarrow N_3^- + H^+$.

Correct option: **(1) N_3^-**

Q13. $HNO_3 + H_2O \leftrightharpoons H_3O^+ + NO_3^-$, the conjugate base of HNO_3 is :-

Strong acid → conjugate base = anion formed after losing H^+.

$HNO_3 \rightarrow NO_3^- + H^+$.

Correct option: **(3) NO_3^-**

Q14. Amphiprotic species in water: I: HPO_4^{2-}, II: OH^-, III: $H_2PO_4^-$, IV: HCO_3^-

Amphiprotic = H^+ donate bhi kar sakta hai aur accept bhi. Jinnme H present ho aur proton donor/acceptor dono ho sakte.

HPO_4^{2-} → amphiprotic $H_2PO_4^-$ → amphiprotic HCO_3^- → amphiprotic OH^- → only base
So amphiprotic = I, III, IV.

Correct option: **(1) I, III, IV**

Q15. The conjugate acid of NH_2^- is :-

H^+ add → NH_3 banega.

$NH_2^- + H^+ \rightarrow NH_3$.

Correct option: **(a) NH_3**

Q16. $HF + HClO_4 \leftrightharpoons ClO_4^- + H_2F^+$ *Correct conjugate acid–base pair?*

HF → H_2F^+ (acts as base here). $HClO_4$ → ClO_4^- (acts as acid here).

Correct pairing: HF (base) → H_2F^+ (acid). $HClO_4$ (acid) → ClO_4^- (base).

Correct option: **(c) HF and H_2F^+**

Q17. (a) Select polyprotic Arrhenius acids... (b) Write conjugate acids of SO_4^{2-}, RNH_2, NH_2^-, $C_2H_5OC_2H_5$, F^- (c) Write conjugate bases of HNO_2, OH^-, H_2CO_3, $HClO_4$ (d) Write conjugate acid base of HS^-, NH_3, C_2H_5OH, H_2O (e) Classify into Lewis acid/base ...

Yeh theoretical compilation hai: Conjugate acid = add H^+ Conjugate base = remove H^+ Lewis acid = e^- acceptor Lewis base = e^- donor

(a) Polyprotic Arrhenius acids: H_3PO_3, H_3PO_2, $(COOH)_2$
(b) Conjugate acids: SO_4^{2-} → HSO_4^- RNH_2 → RNH_3^+ NH_2^- → NH_3 Ether ($C_2H_5OC_2H_5$) → weak base → forms protonated ether F^- → HF
(c) Conjugate bases: HNO_2 → NO_2^- OH^- → O^{2-} H_2CO_3 → HCO_3^- $HClO_4$ → ClO_4^-
(d) HS^- → Acid: H_2S, Base: S^{2-} NH_3 → Acid: NH_4^+, Base: NH_2^- C_2H_5OH → Acid: $C_2H_5OH_2^+$, Base: $C_2H_5O^-$ H_2O → Acid: H_3O^+, Base: OH^-
(e) Lewis acid: H^+, $FeCl_3$ Lewis base: $(CH_3)_3N$, F^-, CH_2

Full theoretical answers written above.

GROUP–C: Acid Strength, pKa, pKb & Relative Strength

Q1. Which of the following is the weakest acid ?

(1) Phenol ($K_a = 1.3 \times 10^{-10}$)
(2) Hydrocyanic acid ($K_a = 4.9 \times 10^{-10}$)
(3) Acetic acid ($K_a = 1.8 \times 10^{-5}$)
(4) Benzoic acid ($K_a = 6.5 \times 10^{-5}$)

Weakest acid K_a Smaller K_a → less ionisation → weaker acid.

Given K_a values:
Phenol = 1.3×10^{-10} HCN = 4.9×10^{-10} Acetic acid = 1.8×10^{-5} Benzoic acid = 6.5×10^{-5}
K_a = **phenol** .

Correct option: **(1) Phenol**

Q2. Which of the following is the strongest base ?

(1) $C_6H_5NH_2$ ($pK_b = 9.42$)
(2) $C_6H_5NHCH_3$ ($pK_b = 9.15$)
(3) $C_6H_5N(CH_3)_2$ ($pK_b = 8.94$)

(4) $C_6H_5NHC_2H_5$ ($pK_b = 8.89$)

Lower pK_b → stronger base. pK_b small means K_b .

pK_b value = **8.89**, so it is strongest base.

Correct option: **(4) $C_6H_5NHC_2H_5$**

Q3. Value of dissociation constant of acetic acid is 10^{-6}, whereas for formic acid it is 10^{-5}. pK_a(acetic) − pK_a(formic) = ?

Formula:

$$pK_a = -\log K_a$$

Difference .

pK_a(acetic) = 6 pK_a(formic) = 5
Difference:

$$6 - 5 = 1.$$

Correct option: **(2) +1**

Q4. For two monobasic acids A and B, $pK_{a1} = 1.2$, $pK_{a2} = 2.8$. Which is true?

Smaller pK_a → stronger acid. 1.2 ¡ 2.8 → A is stronger.

Acid A pK_a → strongest acid.

Correct option: **(b) A is stronger than B**

Q5. Ionization constant of AOH and BOH bases are K_{b1}, K_{b2}. $pK_{b1} < pK_{b2}$. Conjugate of following base does not show maximum pH :

Base strong → conjugate acid weak. Weaker conjugate acid = higher pH. Smaller pK_b → stronger base → weaker conjugate acid → higher pH.

Given: $pK_{b1} < pK_{b2}$ So AOH stronger base → conjugate acid of AOH weakest → highest pH. BOH conjugate acid stronger → lower pH.
So which does NOT show highest pH? → BOH.

Correct option: **(2) BOH**

Q6. K_a for formic acid = 1.8×10^{-4}, for acetic acid = 1.8×10^{-5}. Strength ratio?

Relative strength = $\frac{K_{a1}}{K_{a2}}$. Formic : Acetic = $10^{-4} : 10^{-5} = 10 : 1$.

Formic acid stronger because K_a .

Correct option: **(1) 10 : 1**

Q7. The strongest conjugate base is :-

Stronger base = weaker parent acid. Strong acid → very weak conjugate base.

Given ions: NO_3^- (from strong acid HNO_3 → very weak base) Cl^- (from very strong acid HCl → weakest base) SO_4^{2-} (from strong acid H_2SO_4 → weak base) CH_3COO^- (from weak acid acetic → strongest base)

Correct option: **(4) CH_3COO^-**

Q8. CH_3COO^- ion is a :-

Acetic acid weak → its conjugate base relatively strong.

Weak acid → stronger conjugate base (but not strongest among all). Hence "weak conjugate acid" wrong.

Correct option: **(2) Strong conjugate base**

Q9. Which of the following is strongest conjugate base :-

Check parent acid strengths: Weaker parent acid → stronger base.

ClO_4^- from strongest acid → weakest base HSO_4^- strong acid → weak base HCO_3^- → moderate F^- from weak acid HF → strongest base.

Correct option: **(3) F^-**

Q10. Decreasing order of basic strength: NH_3, CH_3COO^-, Cl^-

Cl^- from HCl → weakest base. CH_3COO^- moderate base. NH_3 is stronger base.

Order: $NH_3 > CH_3COO^- > Cl^-$.

Correct option: **(4)**

Q11. Correct basic strength order will be :-

Check parent acid ka strength: Stronger acid → weaker base.

ClO_4^- (from $HClO_4$ strongest acid) → weakest base HSO_4^- (strong acid) → weak NO_3^- weak NH_3 strongest base among list So order: $HSO_4^- < ClO_4^- < NO_3^- < NH_3$ is wrong. Correct is: **$NO_3^- > ClO_4^- > NH_3 > HSO_4^-$ **

Correct option: **(4)**

Q12. The conjugate base of the weak acid $HBr + H_2O \rightarrow H_3O^+ + Br^-$ is :-

Conjugate base = species after losing H^+.

$HBr \rightarrow Br^-$. So conjugate base = bromide ion.

Correct option: **(3) Br^-**

Q13. The pH of 0.1 M monobasic acid is 4.50. Find its K_a.

Weak acid formula:

$$K_a = \frac{C\alpha^2}{1-\alpha}$$

$\alpha = 10^{-pH}/C$.

$H^+ = 10^{-4.5} = 3.16 \times 10^{-5}$
For 0.1 M acid:

$$\alpha = \frac{3.16 \times 10^{-5}}{0.1} = 3.16 \times 10^{-4}$$

$$K_a = C\alpha^2 = 0.1(3.16 \times 10^{-4})^2 \approx 1 \times 10^{-8}$$

Correct option: **(4) 1×10^{-8}**

Q14. $HA + B^- \leftrightharpoons HB + A^-$, $K_{eq} = 10^{-4}$. How many statements are true?

Small K_{eq} means forward reaction weak. Forward reaction weak → HA stronger acid than HB.

Check statements:
(i) HB stronger than HA — (ii) HA stronger than HB — (iii) Same acid strength — (iv) B^- stronger base than A^- — (reverse favoured means A^- stronger) (v) A^- stronger base than B^- — (vi) B^-, HB conjugate pair — (vii) A^- conjugate base of HA — (viii) HA can be HSO_4^-, HB = HCOOH — (HSO_4^- stronger acid) (ix) A^- = F^-, B^- = CN^- — (CN^- much stronger base)
True statements = **(ii, v, vi, vii, viii) = 5**

Correct number of true statements: **5**