Ionic Equilibria

Q. 1. What is meant by the conjugate acid-base pair? Find the conjugate acid/base for the following species:

$HNO_2, CN^-, HClO_4, F^-, OH^-, CO_3^{2-}, \text{and } S^-$

Ans. A conjugate acid-base pair is a pair that differs only by one proton. The conjugate acid-base for the given species is mentioned in the table below.

Species	**Conjugate acid-base**
HNO_2	NO_2^- (base)
CN^-	HCN (acid)
$HClO_4$	ClO_4^- (base)
F^-	HF (acid)
OH^-	H_2O (acid) /O2$^-$ (base)
CO_3^{2-}	HCO_3^- (acid)
S^{2-}	HS^- (acid)

Q. 2. Which of the followings are Lewis acids? H_2O, BF_3, H^+, and $NH^{+}4$

Ans. Lewis acids are those acids which can accept a pair of electrons. For example, BF_3, H^+, $NH^{+}4$
and are Lewis acids.

Q. 3. What will be the conjugate bases for the Brönsted acids: HF, H_2SO_4 and HCO_3?

Ans. The table below lists the conjugate bases for the given Bronsted acids.

Bronsted acid	**Conjugate base**
HF	F^-
H_2SO_4	

	HSO_4^-
HCO_3^-	CO_3^{2-}

Q. 4. Write the conjugate acids for the following Brönsted bases: NH_2^-, NH_4 and $HCOO^-$.
The table below lists the conjugate acids for the given Bronsted bases.

Ans .

Bronsted base	**Conjugate base**
NH_2^-	NH_3
NH_3	NH_4^+
$HCOO^-$	HCOOH

Q. 4. Classify the following species into Lewis acids and Lewis bases and show how these act as Lewis acid/base: (a) OH^-(b) F^- (c) H^+ (d) BCl_3.

Ans. (a) OH^- is a Lewis base since it can donate its lone pair of electrons.
(b) F^- is a Lewis base since it can donate a pair of electrons.
(c) H^+ is a Lewis acid since it can accept a pair of electrons.
(d) BCl_3 is a Lewis acid since it can accept a pair of electrons.

Q. 5. The concentration of hydrogen ion in a sample of soft drink is 3.8×10^{-3} M. what is its pH?

Ans. Given,
$$\left[H^+\right] = 3.8 \times 10^{-3} \text{ M}$$
pH value of soft drink
$$= -\log\left[H^+\right]$$
$$= -\log\left(3.8 \times 10^{-3}\right)$$
$$= -\log 3.8 - \log 10^{-3}$$
$$= -\log 3.8 + 3$$
$$= -0.58 + 3$$
$$= 2.42$$

Q. 6. The pH of a sample of vinegar is 3.76. Calculate the concentration of hydrogen ion in it.

Ans. Given, pH = 3.76 It is known that,

$$pH = -\log\left[H^+\right]$$

$$\Rightarrow \log\left[H^+\right] = -pH$$

$$\Rightarrow \left[H^+\right] = \text{antilog}(-pH)$$

$$= \text{antilog}(-3.76)$$

$$= 1.74 \times 10^{-4}\ M$$

Hence, the concentration of hydrogen ion in the given sample of vinegar is 1.74×10^{-4} M.

Q. 7. The ionization constant of HF, HCOOH and HCN at 298K are 6.8×10^{-4}, 1.8×10^{-4} and 4.8×10^{-9} respectively. Calculate the ionization constants of the corresponding conjugate base.

Ans. It is known that,

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

Given,

K_a of HF = 6.8×10^{-4}

Hence, K_b of its conjugate base F^-

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

$$= \frac{10^{-14}}{6.8 \times 10^{-4}}$$

$$= 1.5 \times 10^{-11}$$

Given, K_a of HCOOH = 1.8×10^{-4}

Hence, K_b of its conjugate base $HCOO^-$

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

$$= \frac{10^{-14}}{1.8 \times 10^{-4}}$$

$$= 5.6 \times 10^{-11}$$

Given, K_a of HCN = 4.8×10^{-9}

Hence, K_b of its conjugate base CN^-

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

$$= \frac{10^{-14}}{4.8 \times 10^{-9}}$$

$$= 2.08 \times 10^{-6}$$

Q. 8. Calculate the pH of the following solutions:
a) 2 g of TlOH dissolved in water to give 2 litre of solution.
b) 0.3 g of $Ca(OH)_2$ dissolved in water to give 500 mL of solution.
c) 0.3 g of NaOH dissolved in water to give 200 mL of solution.
d) 1mL of 13.6 M HCl is diluted with water to give 1 litre of solution.

Ans. (a) For 2g of TlOH dissolved in water to give 2 L of solution:

$$\left[\text{TlOH}_{(aq)}\right] = \frac{2}{2} \text{g/L}$$

$$= \frac{2}{2} \times \frac{1}{221} \text{M}$$

$$= \frac{1}{221} \text{M}$$

$$\text{TlOH}_{(aq)} \longrightarrow \text{Tl}^+_{(aq)} + \text{OH}^-_{(aq)}$$

$$\left[\text{OH}^-_{(aq)}\right] = \left[\text{TlOH}_{(aq)}\right] = \frac{1}{221} \text{M}$$

$$K_w = \left[\text{H}^+\right]\left[\text{OH}^-\right]$$

$$10^{-14} = \left[\text{H}^+\right]\left(\frac{1}{221}\right)$$

$$221 \times 10^{-14} = \left[\text{H}^+\right]$$

$$\Rightarrow \text{pH} = -\log\left[\text{H}^+\right] = -\log\left(221 \times 10^{-14}\right)$$

$$= -\log\left(2.21 \times 10^{-12}\right)$$

$$= 11.65$$

(b) For 0.3 g of $Ca(OH)_3$ dissolved in water to give 500 mL of solution:

$$Ca(OH)_2 \longrightarrow Ca^{2+} + 2OH^-$$

$$[Ca(OH)_2] = 0.3 \times \frac{1000}{500} = 0.6M$$

$$[OH^-_{aq}] = 2 \times [Ca(OH)_{2aq}] = 2 \times 0.6$$

$$= 1.2M$$

$$[H^+] = \frac{K_w}{[OH^-_{aq}]}$$

$$= \frac{10-14}{1.2} M$$

$$= 0.833 \times 10^{-14}$$

$$pH = -\log(0.833 \times 10^{-14})$$

$$= -\log(8.33 \times 10^{-13})$$

$$= (-0.902 + 13)$$

$$= 12.098$$

(c) For 0.3 g of NaOH dissolved in water to give 200 mL of solution:

$$NaOH \longrightarrow Na^+_{(aq)} + OH^-_{(aq)}$$

$$[NaOH] = 0.3 \times \frac{1000}{200} = 1.5M$$

$$[OH^-_{aq}] = 1.5M$$

$$\text{Then,} [H^+] = \frac{10^{-14}}{1.5}$$

$$= 6.66 \times 10^{-13}$$

$$pH = -\log(6.66 \times 10^{-13})$$

$$= 12.18$$

(d) For 1mL of 13.6 M HCl diluted with water to give 1 L of solution:

13.6 × 1 mL = M_2 × 1000 mL
(Before dilution) (After dilution)
13.6 × 10^{-3} = M_2 × 1L
M_2 = 1.36 × 10^{-2}
[H+] = 1.36 × 10_3
pH = – log (1.36 × 10^{-2})
= (– 0.1335 + 2)
= 1.866 _ 1.87