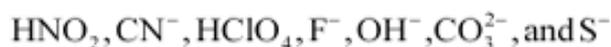


Ionic Equilibria

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



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) $/\text{O}^{2-}$ (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 Brønsted bases: NH_2^- , NH_3 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,

$$[\text{H}^+] = 3.8 \times 10^{-3} \text{ M}$$

pH value of soft drink

$$= -\log[\text{H}^+]$$

$$= -\log(3.8 \times 10^{-3})$$

$$= -\log 3.8 - \log 10^{-3}$$

$$= -\log 3.8 + 3$$

$$= -0.58 + 3$$

$$= 2.42$$

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,

$$\text{pH} = -\log[\text{H}^+]$$

$$\Rightarrow \log[\text{H}^+] = -\text{pH}$$

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

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

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

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

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,

$$K_a \text{ of HF} = 6.8 \times 10^{-4}$$

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^-

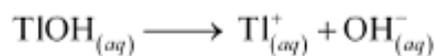
$$\begin{aligned}
&= \frac{K_w}{K_a} \\
&= \frac{10^{-14}}{4.8 \times 10^{-9}} \\
&= 2.08 \times 10^{-6}
\end{aligned}$$

Q. 8. Calculate the pH of the following solutions:

- 2 g of TIOH dissolved in water to give 2 litre of solution.
- 0.3 g of $\text{Ca}(\text{OH})_2$ dissolved in water to give 500 mL of solution.
- 0.3 g of NaOH dissolved in water to give 200 mL of solution.
- 1 mL of 13.6 M HCl is diluted with water to give 1 litre of solution.

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

$$\begin{aligned}
[\text{TIOH}_{(aq)}] &= \frac{2}{2} \text{ g/L} \\
&= \frac{2}{2} \times \frac{1}{221} \text{ M} \\
&= \frac{1}{221} \text{ M}
\end{aligned}$$



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

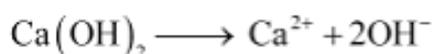
$$K_w = [\text{H}^+][\text{OH}^-]$$

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

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

$$\begin{aligned}
\Rightarrow \text{pH} &= -\log[\text{H}^+] = -\log(221 \times 10^{-14}) \\
&= -\log(2.21 \times 10^{-12}) \\
&= 11.65
\end{aligned}$$

(b) For 0.3 g of $\text{Ca}(\text{OH})_2$ dissolved in water to give 500 mL of solution:



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

$$[\text{OH}^-_{aq}] = 2 \times [\text{Ca(OH)}_{2aq}] = 2 \times 0.6 \\ = 1.2\text{M}$$

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

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

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

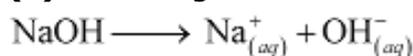
$$\text{pH} = -\log(0.833 \times 10^{-14})$$

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

$$= (-0.902 + 13)$$

$$= 12.098$$

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



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

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

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

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

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

$$= 12.18$$

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

$$13.6 \times 1 \text{ mL} = M_2 \times 1000 \text{ mL}$$

(Before dilution) (After dilution)

$$13.6 \times 10^{-3} = M_2 \times 1\text{L}$$

$$M_2 = 1.36 \times 10^{-2}$$

$$[\text{H}^+] = 1.36 \times 10^{-2}$$

$$\text{pH} = -\log(1.36 \times 10^{-2})$$

$$= (-0.1335 + 2)$$

$$= 1.866 \approx 1.87$$

