Acid-Base Properties of Salts

Definition

A salt is an ionic compound formed by the reaction of an acid and a base.

Salts sometimes react with water.

When this occurs, we speak of the hydrolysis of a cation, an anion, or both.

Salt hydrolysis usually affects the pH of a solution.

Salts that Produce Neutral solutions

Neutral solutions

salts of this type dissolve in water to give neutral solutions

M^+ is a Group 1A or 2A metal ion

$M^+ X^-$

X^- is the conjugate base of a strong acid

NaCl **KNO_3** **$Mg(ClO_4)_2$**

Neutral solutions

salts of this type dissolve in water to give neutral solutions

M^+ is a Group 1A or 2A metal ion

$M^+ X^-$

X^- is the conjugate base of a strong acid

these ions show little tendency to react with water (are not hydrolyzed)

Salts that Produce Basic solutions

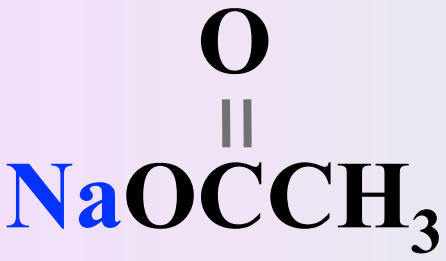
Basic solutions

salts of this type dissolve in water to give basic solutions

M^+ is a Group 1A or 2A metal ion

$M^+ X^-$

X^- is the conjugate base of a weak acid



Basic solutions

salts of this type dissolve in water to give basic solutions

M^+ is a Group 1A or 2A metal ion

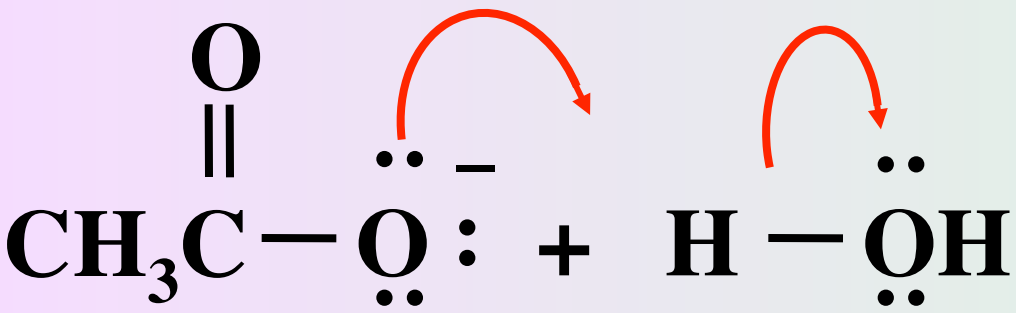
$M^+ X^-$

X^- is the conjugate base of a weak acid

these ions are not hydrolyzed

these are

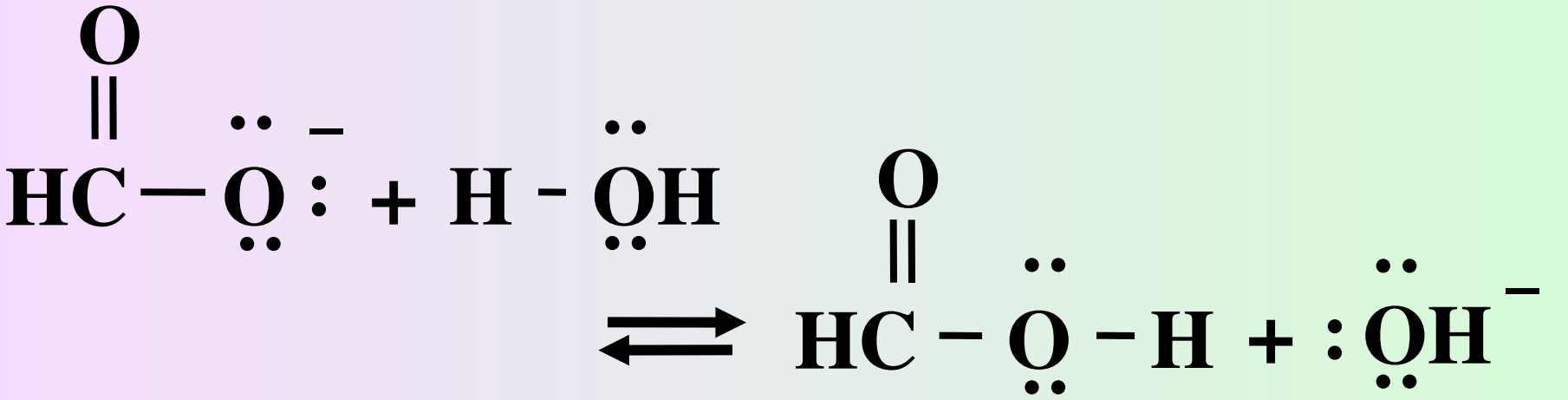
Sodium acetate dissolves in water to give a basic solution



$$K_b = \frac{[HOAc]\,[OH^-]}{[OAc^-]}$$

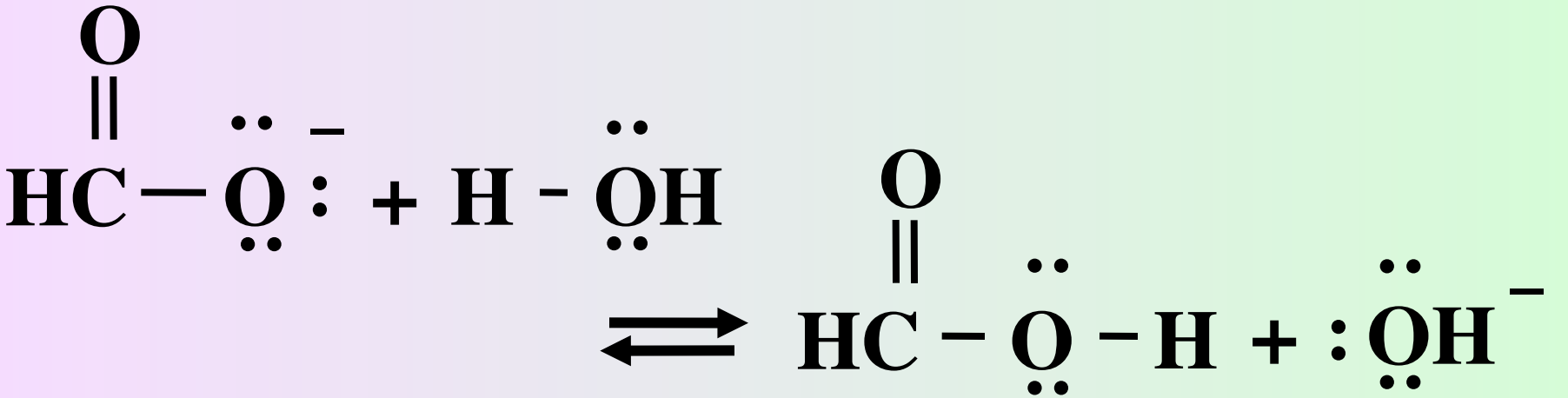
$$K_b = 5.6 \times 10^{-10}$$

Calculate the pH of a 0.24 *M* solution of sodium formate.



$$K_b = \frac{[OH^-]\,[HCO_2H]}{[HCOO^-]} = 5.9 \times 10^{-11}$$

Calculate the pH of a 0.24 *M* solution of sodium formate.



0.24 - x + x + x

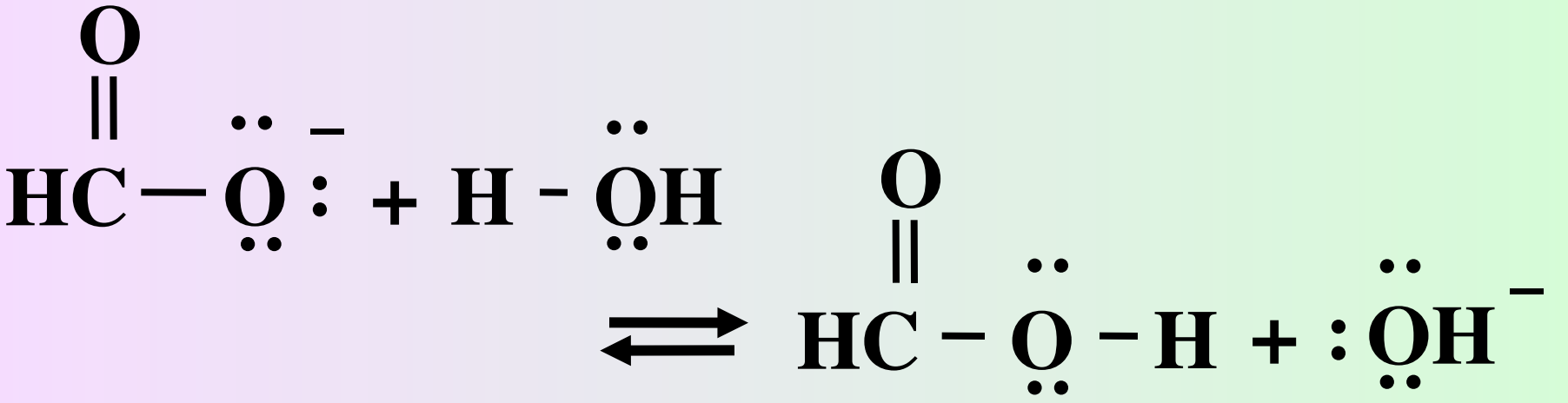
$$5.9 \times 10^{-11} = \frac{x^2}{0.24 - x}$$

$x = [HO^-] = 3.8 \times 10^{-6}$

pOH = 5.42

pH = 8.58

What is the percent hydrolysis of a 0.24 *M* solution of sodium formate.



0.24 *M*

3.8 x 10^{-6} *M*

$$\frac{3.8 \times 10^{-6}}{0.24} \times 100 = 1.6 \times 10^{-3}\ \%$$

Salts that Produce Acidic solutions

Acidic solutions

salts of this type dissolve in water to give acidic solutions

M^+ is the conjugate of a weak base

↑

these are

$M^+ X^-$

NH_4Cl

X^- is the conjugate base of a strong acid

↑

these ions are not hydrolyzed

Ammonium ion is a weak acid

$$NH_4^+(aq) \rightleftharpoons NH_3(aq) + H^+(aq)$$

$$K_a = 5.6 \times 10^{-10} = \frac{[NH_3]\,[H^+]}{[NH_4^+]}$$

What is the pH of a 0.10 M NH_4Cl solution?

$$NH_4^+(aq) \rightleftharpoons NH_3(aq) + H^+(aq)$$

$0.10 - x$ $\quad + x \quad$ $+ x$

$$5.6 \times 10^{-10} = \frac{x^2}{0.1 - x}$$

pH = 5.12

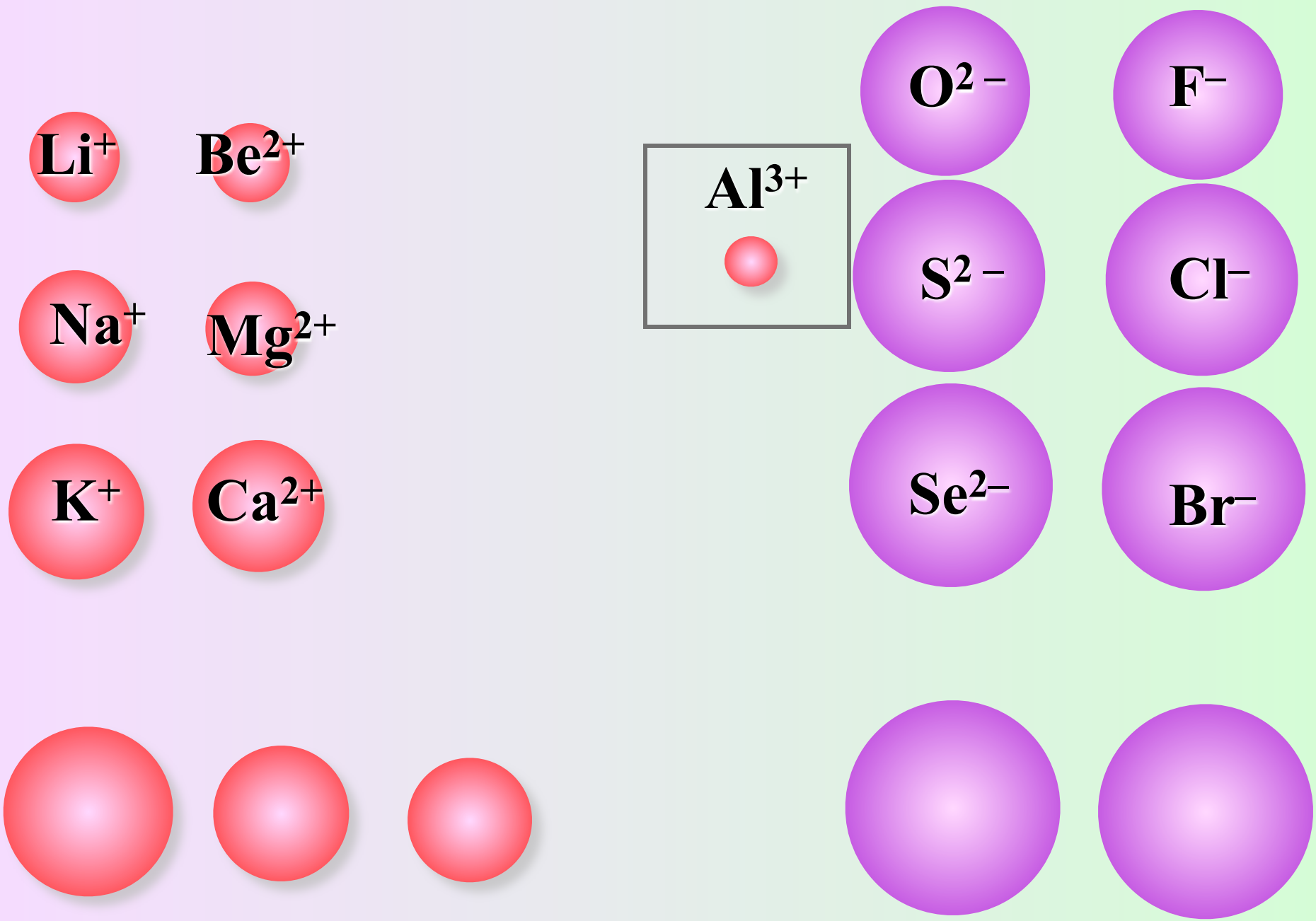
$x = [H^+] = 7.5 \times 10^{-6}\ M$

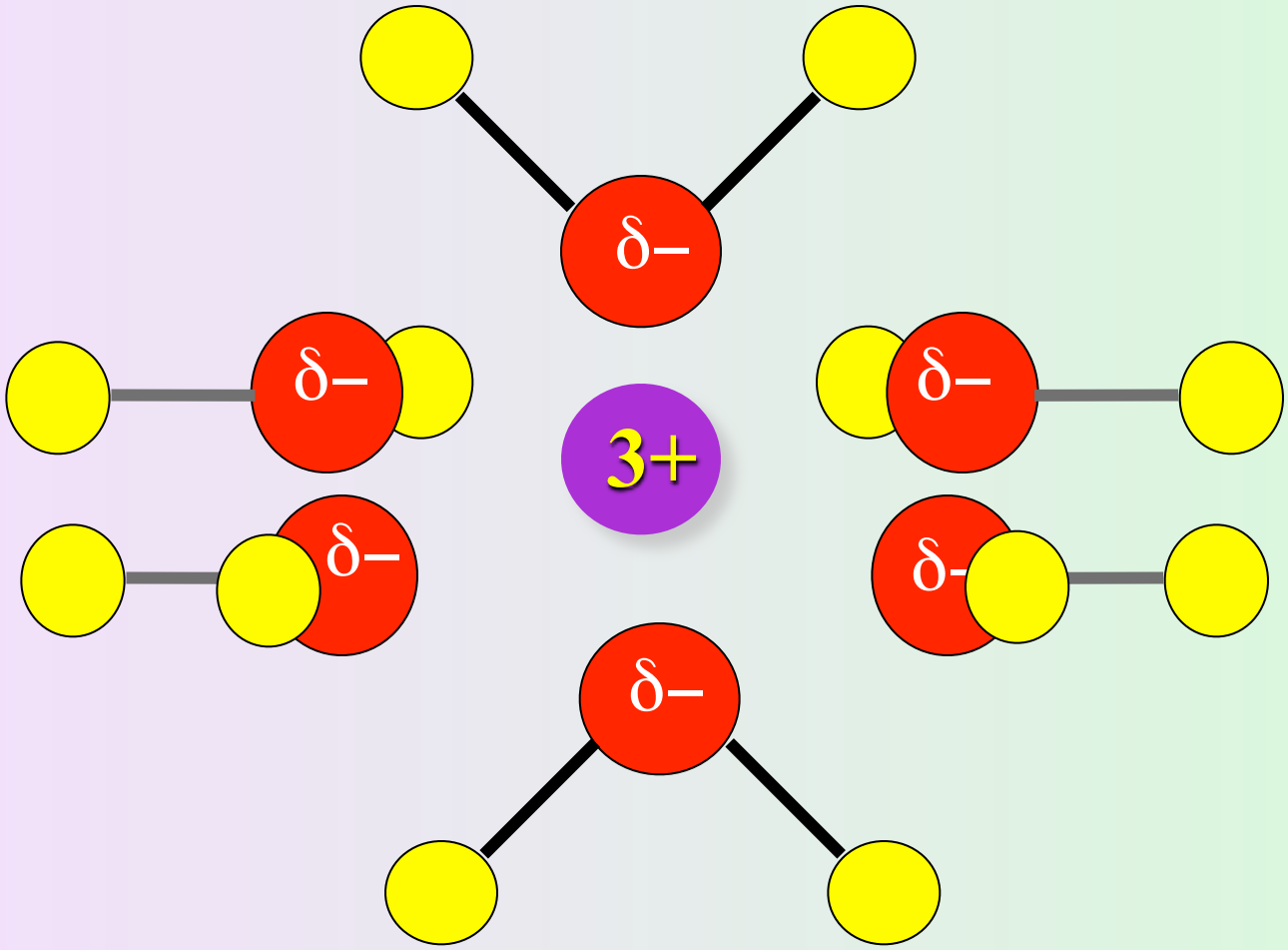
Salts of highly charged metal ions

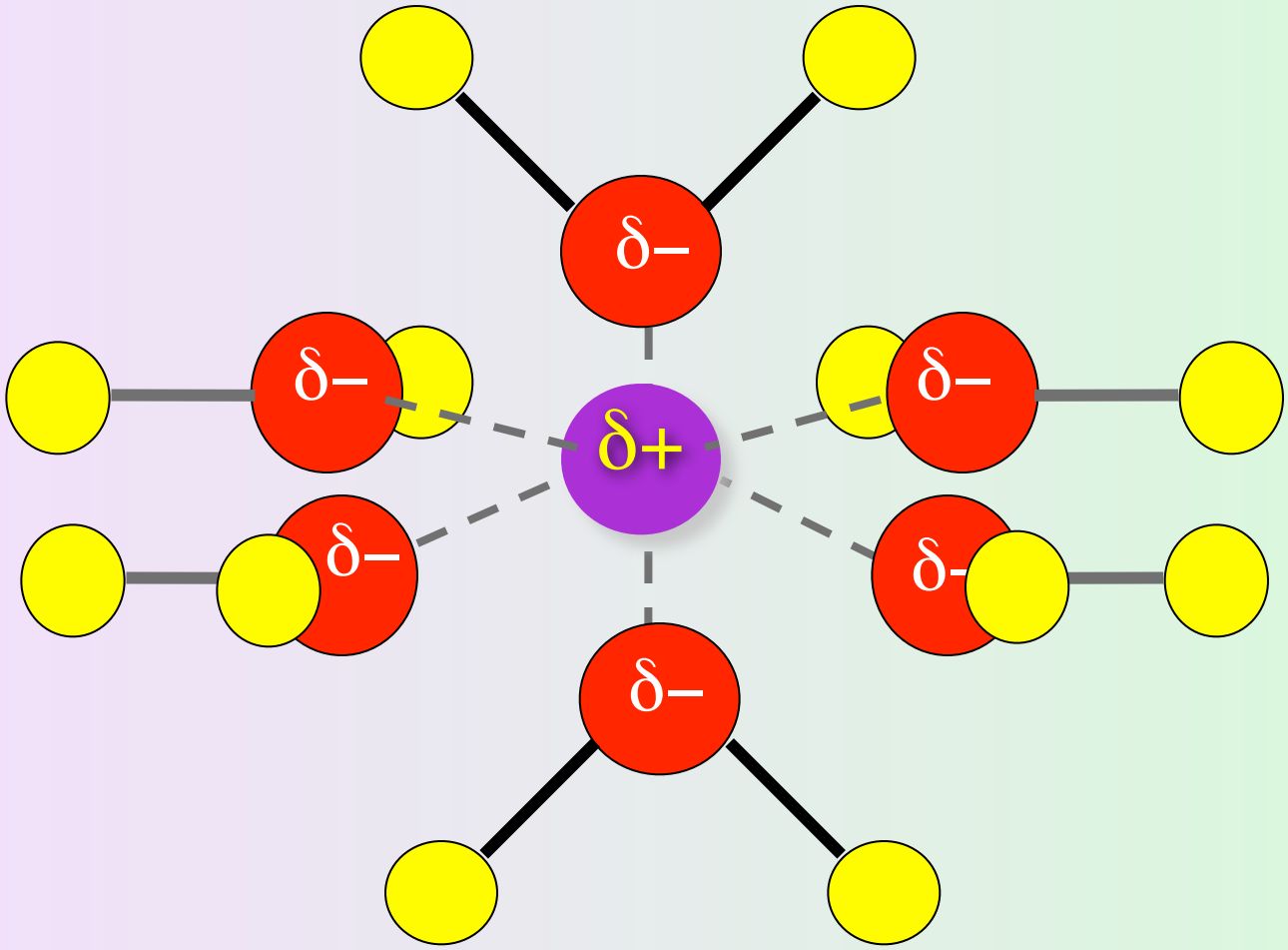
give acidic solutions

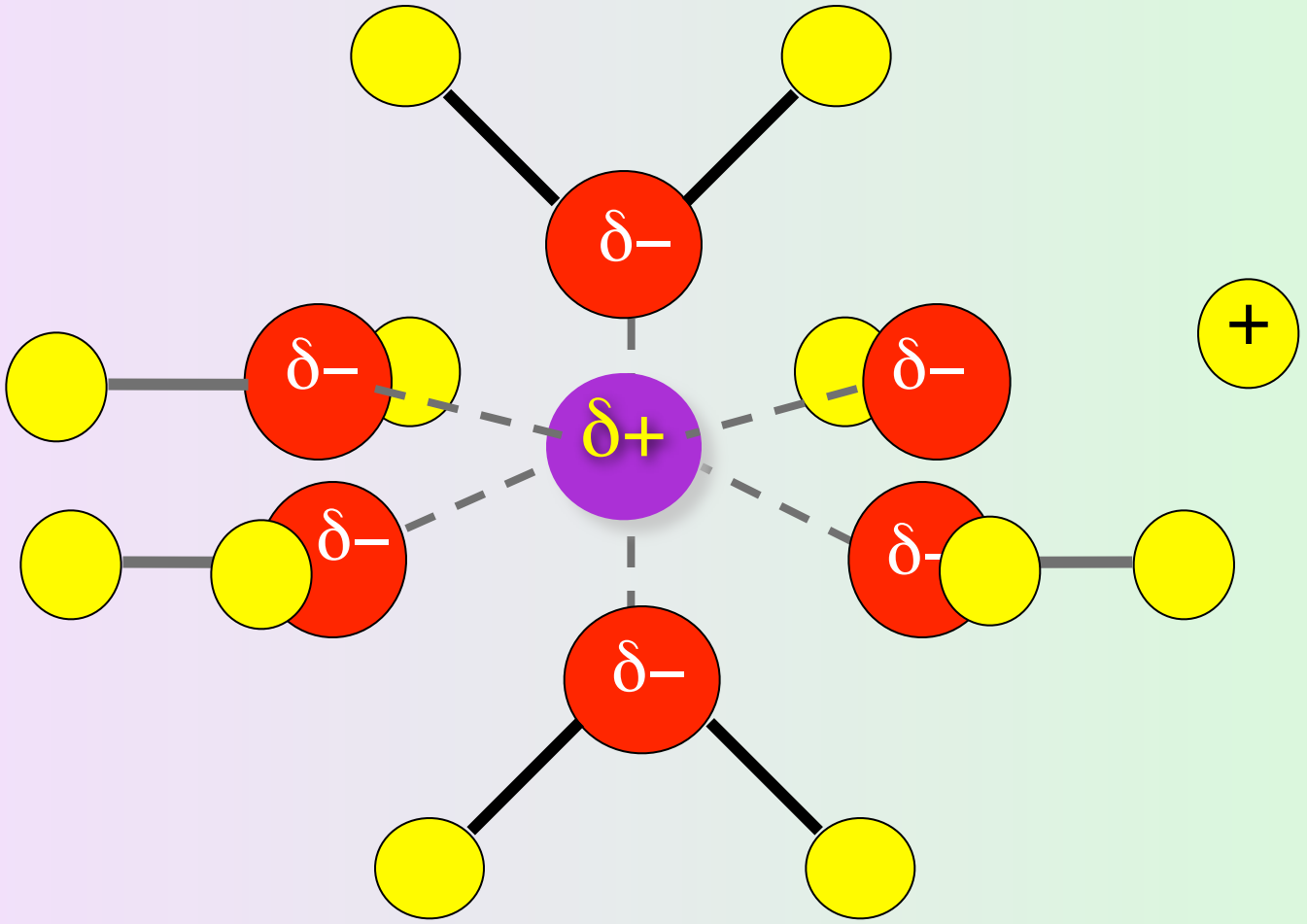
$$AlCl_3\,(s) + H_2O\,(l) \longrightarrow Al(H_2O)_6^{3+}\,(aq)$$

$$H_2O\,Al(H_2O)_5^{3+} \rightleftharpoons HO\,Al(H_2O)_5^{2+} + H^+$$


Li+
Be2+
Na+
Mg2+
K+
Ca2+
Al3+
O2 –
F–
S2 –
Cl–
Se2–
Br–


δ–
δ–
δ–
3+
δ–
δ-
δ–


δ–
δ–
δ–
δ+
δ–
δ-
δ–


δ–
δ–
δ–
δ+
δ–
δ–
δ–
+

Reactions of Cations with Water

TABLE 16.6 • Acid-Dissociation Constants for Metal Cations in Aqueous Solution at 25 °C

Cation	K_a
Fe^{2+}	3.2×10^{-10}
Zn^{2+}	2.5×10^{-10}
Ni^{2+}	2.5×10^{-11}
Fe^{3+}	6.3×10^{-3}
Cr^{3+}	1.6×10^{-4}
Al^{3+}	1.4×10^{-5}

- Greater charge and smaller size make a cation more acidic.

Salts in which both the Cation and Anion Hydrolyze

General rules

- If K_b for the anion is greater than K_a for the cation, the solution is basic.

Example

ammonium cyanide (NH_4CN) dissolves in water to give a basic solution

$$K_a = 5.5 \times 10^{-10}$$

$$NH_4^+ \rightleftharpoons NH_3 + H^+$$

$$CN^- + H_2O \rightleftharpoons HCN + OH^-$$

$$K_b = 1.6 \times 10^{-5}$$

General rules

- If K_b for the anion is greater than K_a for the cation, the solution is basic.

- If K_b for the anion is less than K_a for the cation, the solution is acidic.

- If K_a and K_b are similar, the solution is close to neutral.