Acid and Base Reactions

Properties of Acids

- sour taste
- change color of litmus from blue to red
- give hydrogen on reaction with certain metals
- give carbon dioxide on reaction with carbonates and bicarbonates
- electrolytes (some strong, some weak)

Properties of bases

- bitter taste
- slippery to the touch
- change litmus from red to blue
- electrolytes (some strong, some weak)

Definitions of acids and bases

Svant Arrhenius (Sweden) 1859-1927

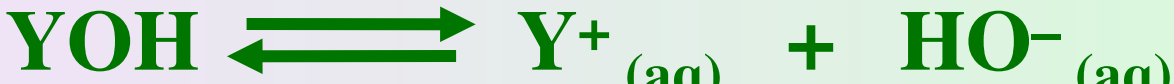
Johannes Bronsted (Denmark) 1879-1947

G. N. Lewis (U.S.) 1875-1946

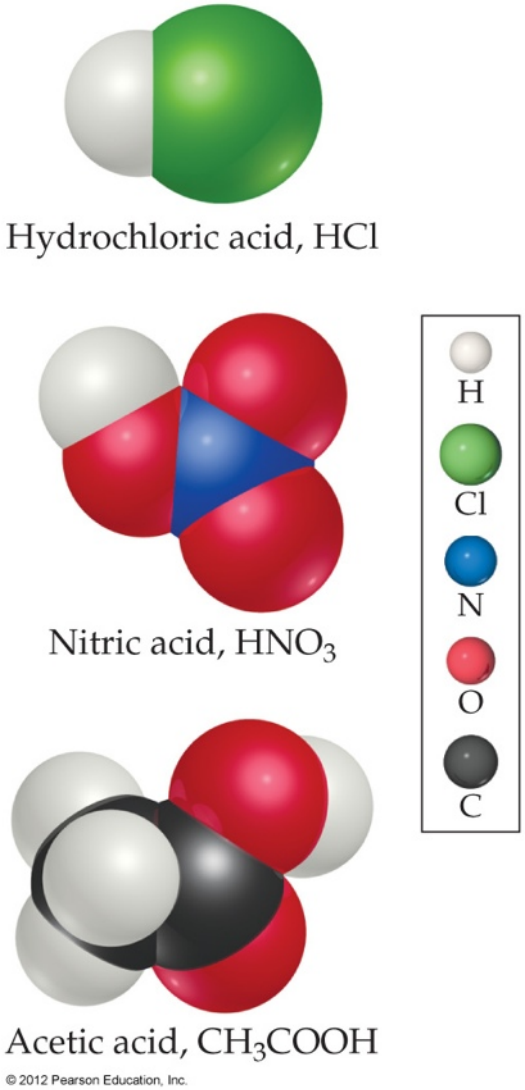
Arrhenius definitions of acids and bases

An acid dissolves in water to yield protons

A base dissolves in water to yield hydroxide ions

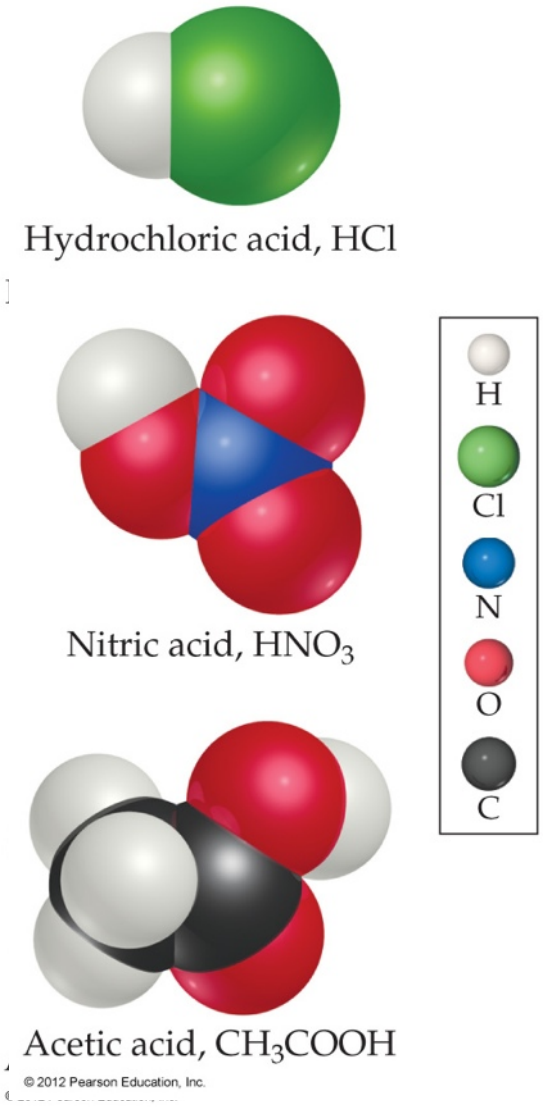


Acids



- The Swedish physicist and chemist S. A. Arrhenius defined acids as substances that increase the concentration of H^+ when dissolved in water.
- Both the Danish chemist J. N. Brønsted and the British chemist T. M. Lowry defined them as proton donors.

Acids



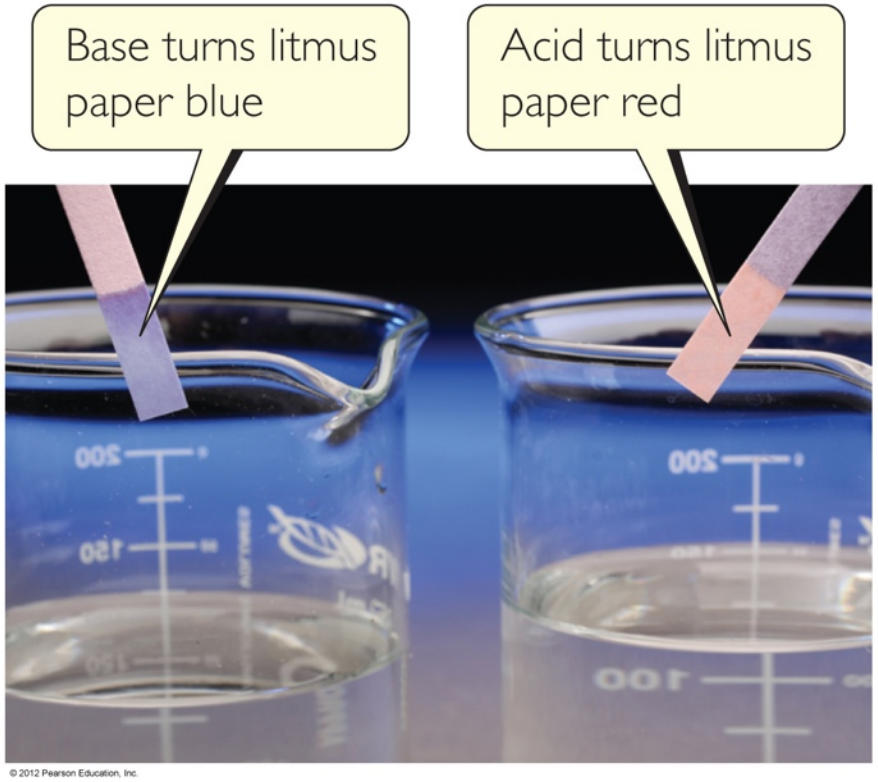
There are only seven strong acids:

- Hydrochloric (HCl)
- Hydrobromic (HBr)
- Hydroiodic (HI)
- Nitric (HNO_3)
- Sulfuric (H_2SO_4)
- Chloric ($HClO_3$)
- Perchloric ($HClO_4$)

Bases

The strong bases are the soluble metal salts of hydroxide ion:

- Alkali metals
- Calcium
- Strontium
- Barium

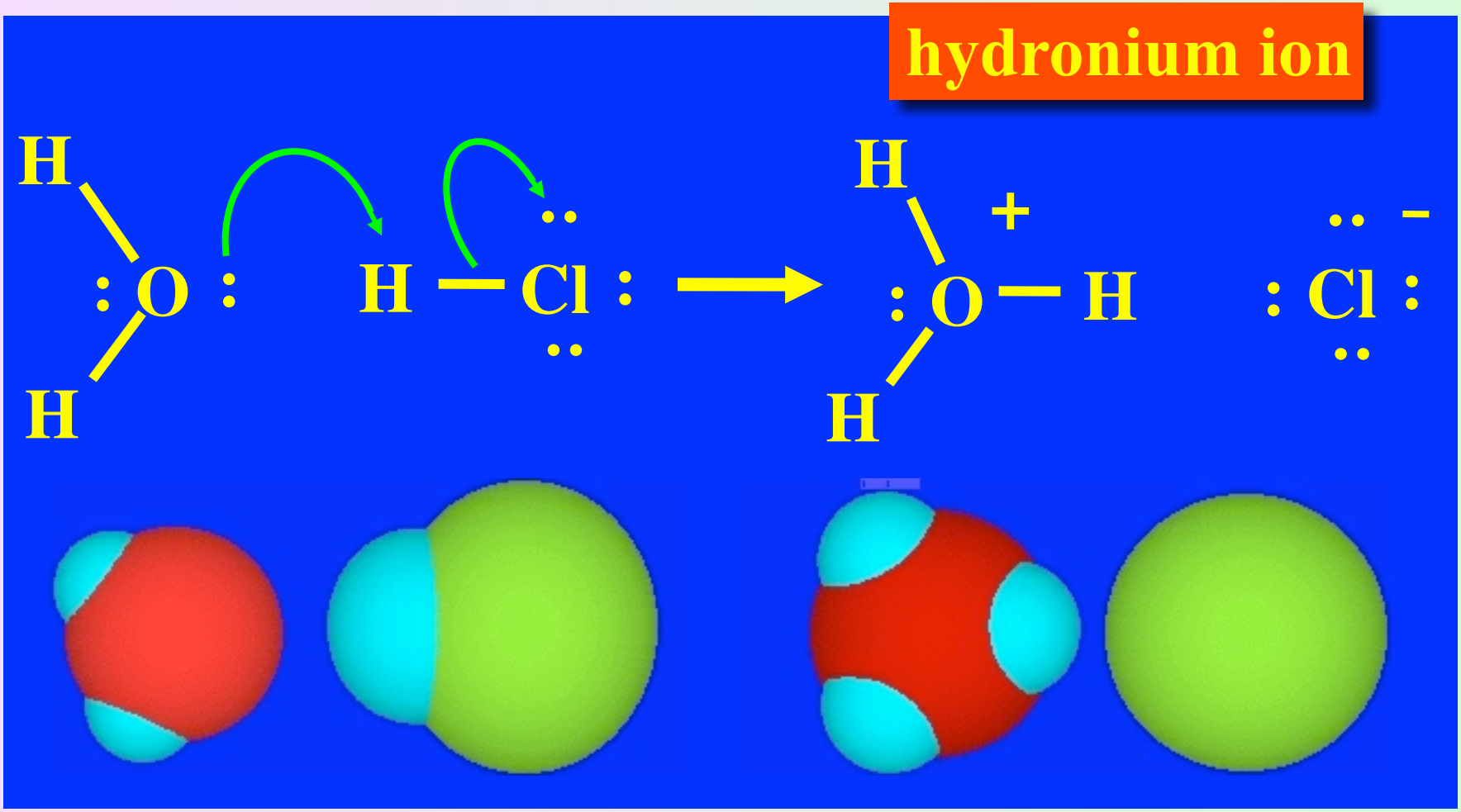


Bronsted Definition

An acid is a proton donor

An base is a proton acceptor

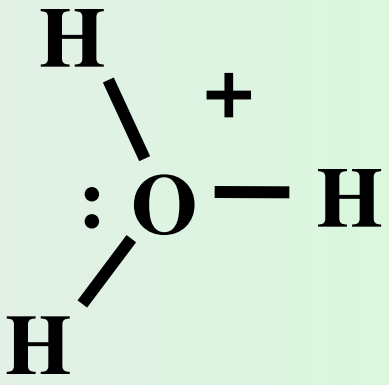
Proton transfer from HCl to water.



Hydronium Ion (H_3O^+)

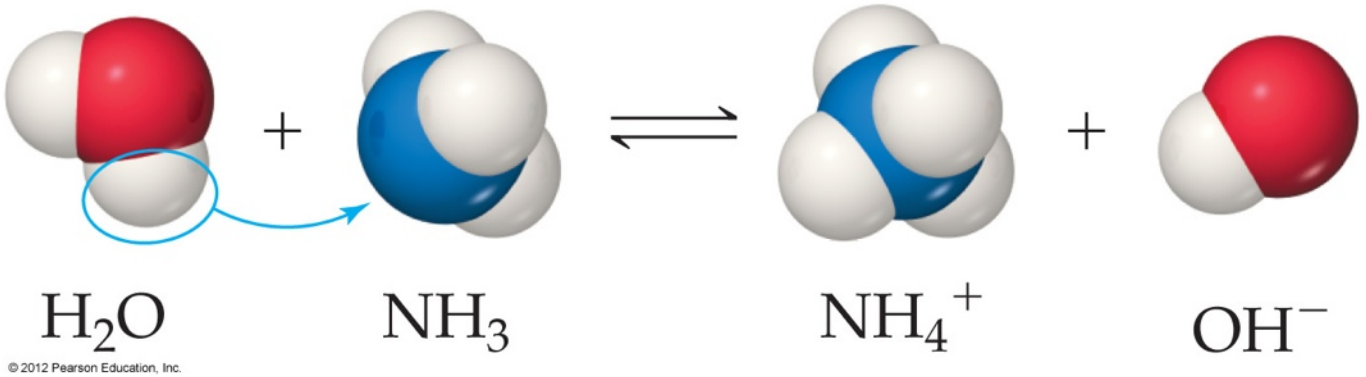
for convenience $H^+_{(aq)}$ represents the hyrated proton

But H_3O^+ is closer to reality



Acid-Base Reactions

In an acid–base reaction, the acid donates a proton (H^+) to the base.



Monoprotic acids

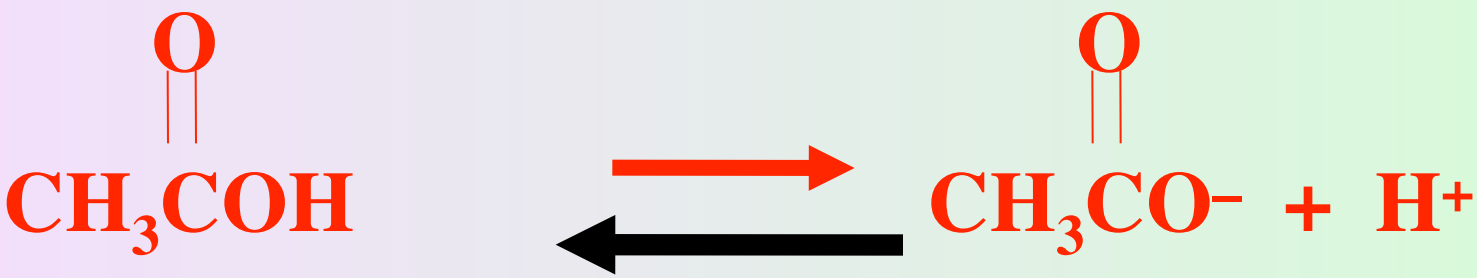
Have one proton that can be lost (Arrhenius) or donated (Bronsted) in water

HF, HCl, HBr, HI

HNO_3

Acetic acid is a monoprotic acid

Acetic acid:



>99% **<1%**

Sulfuric acid is a diprotic acid

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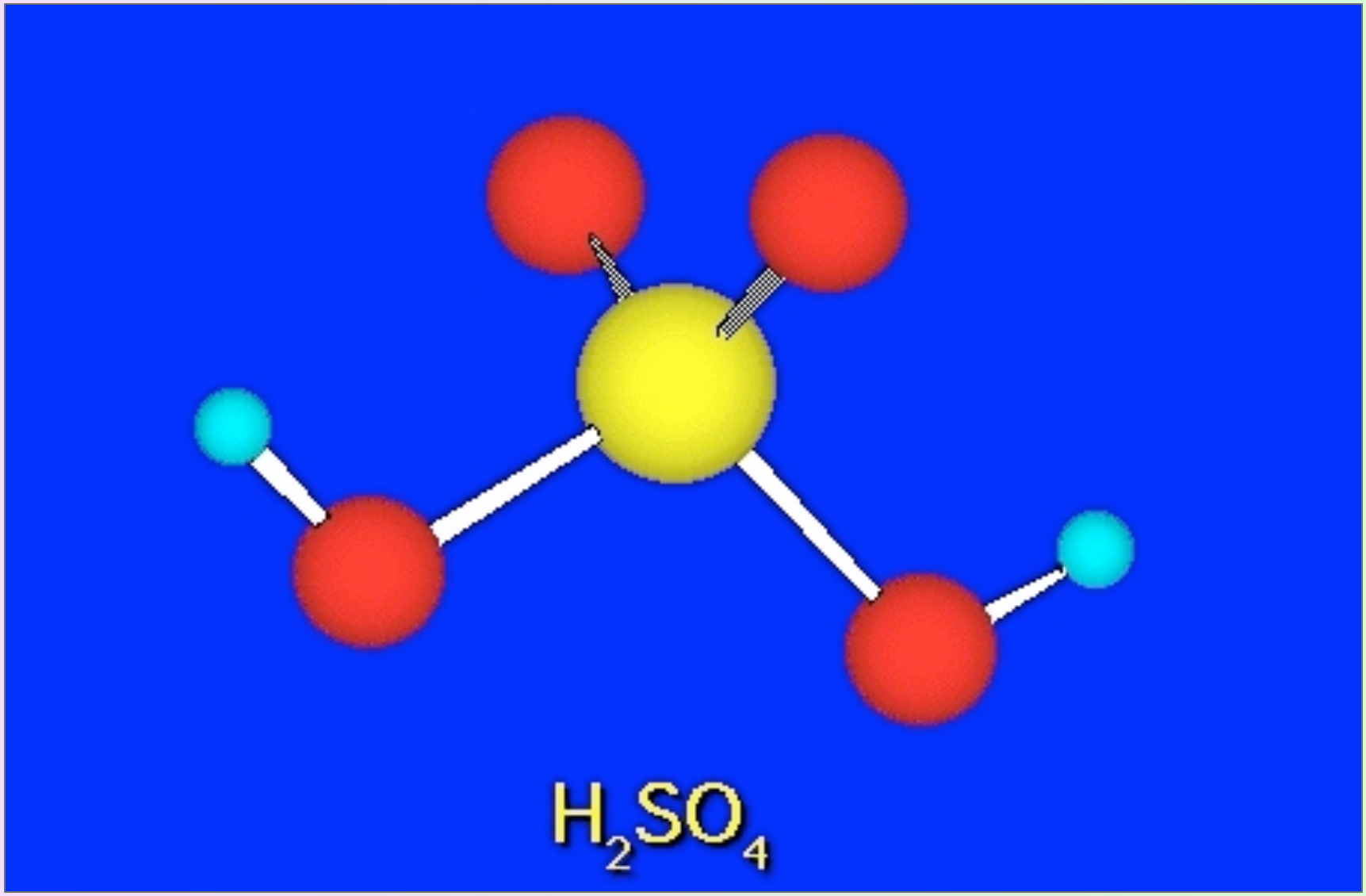

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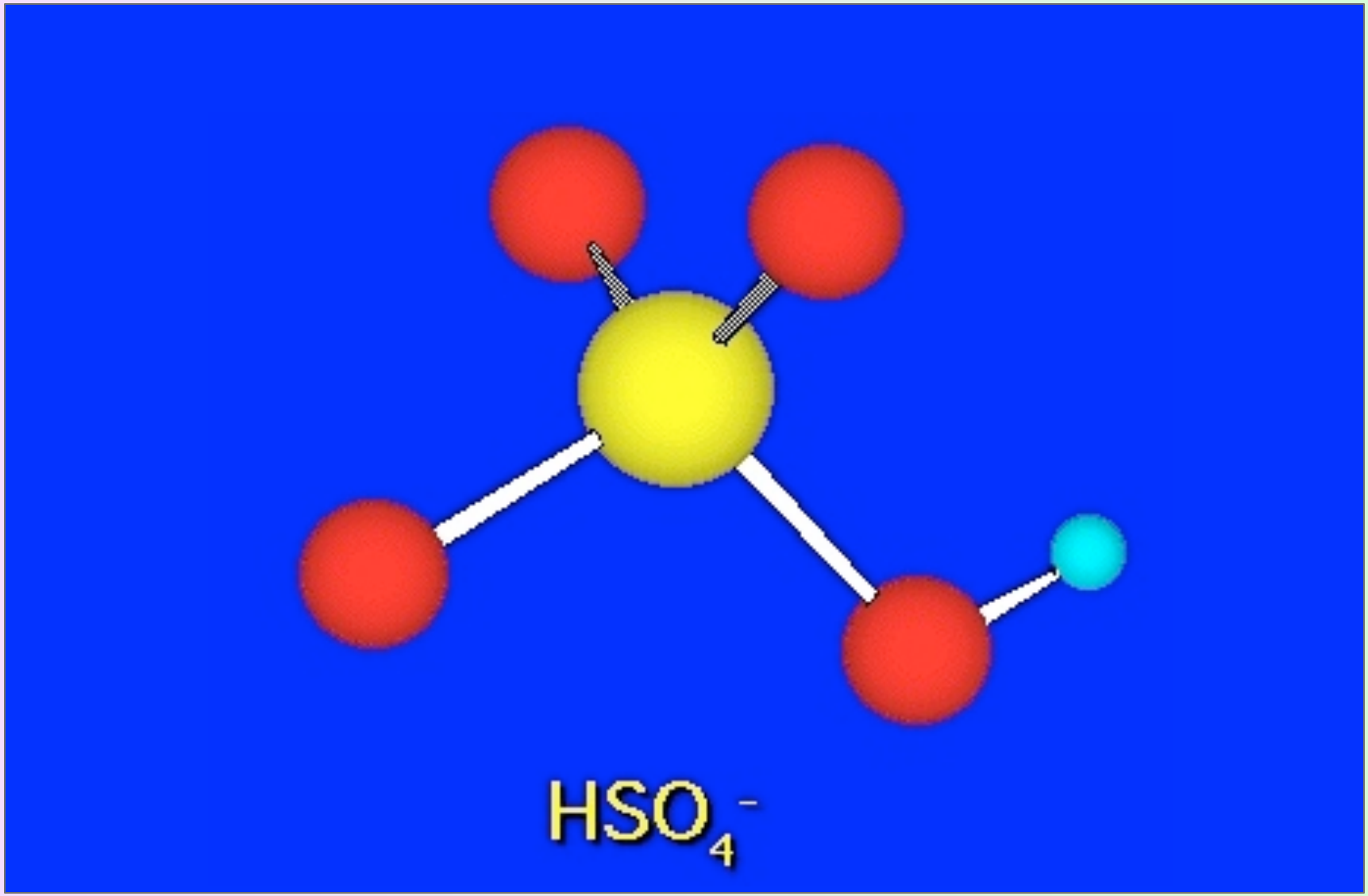

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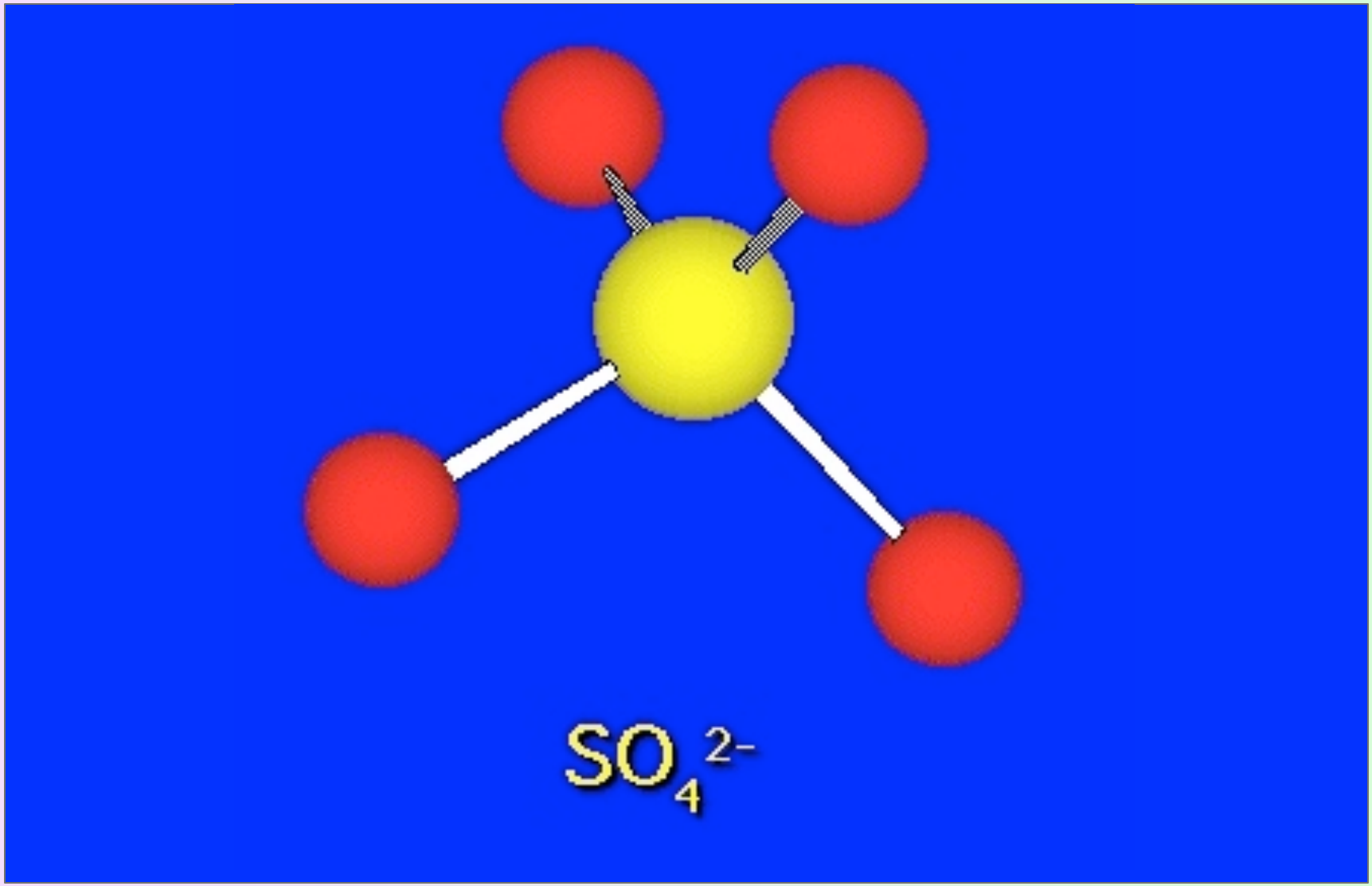

Phosphoric acid is a triprotic acid

$$H_3PO_{4\,(aq)} \rightleftharpoons H^+_{(aq)} + H_2PO_4^-{}_{(aq)}$$

$$H_2PO_4^-{}_{(aq)} \rightleftharpoons H^+_{(aq)} + HPO_4^{2-}{}_{(aq)}$$

$$HPO_4^{2-}{}_{(aq)} \rightleftharpoons H^+_{(aq)} + PO_4^{3-}{}_{(aq)}$$

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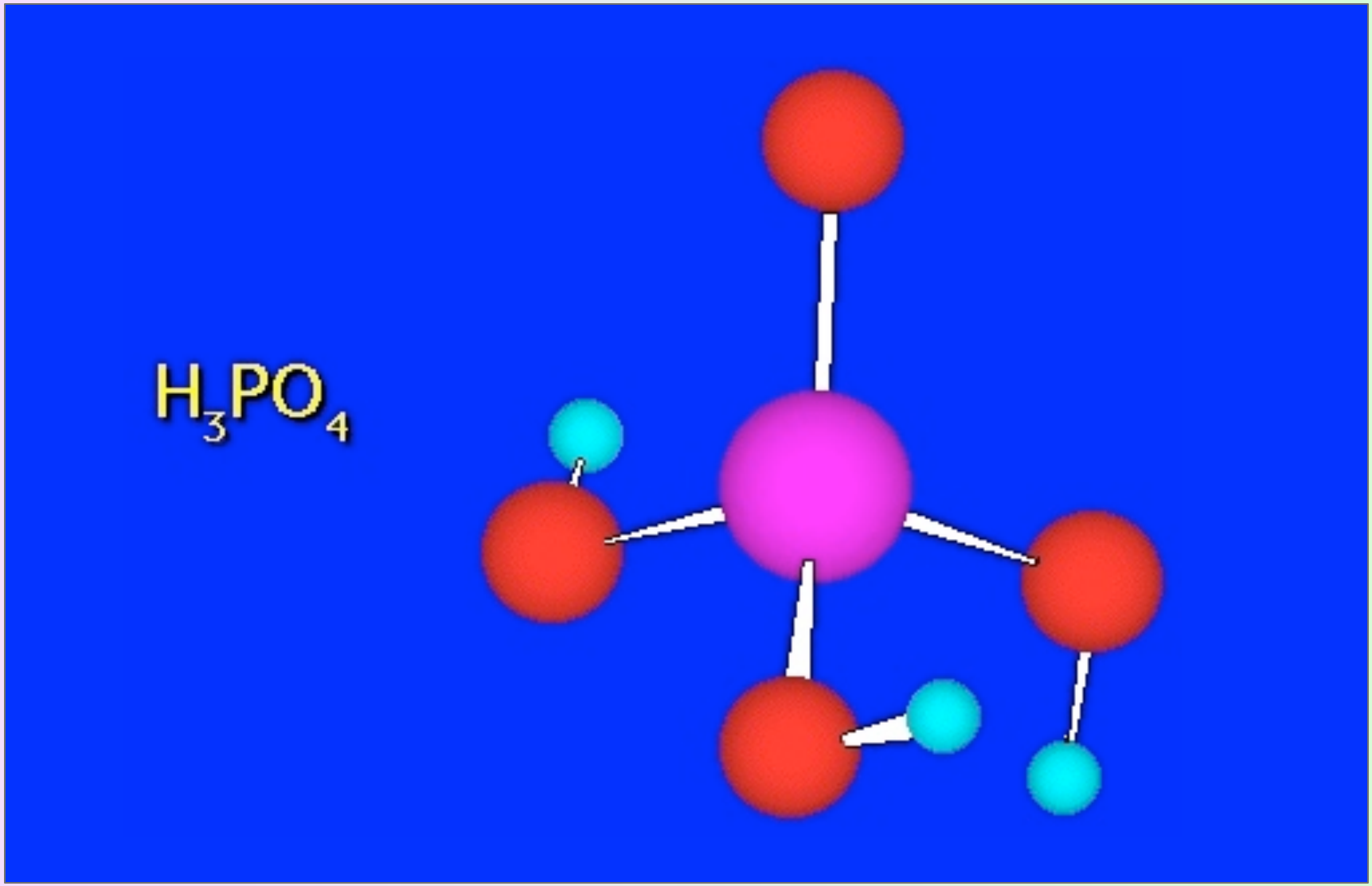

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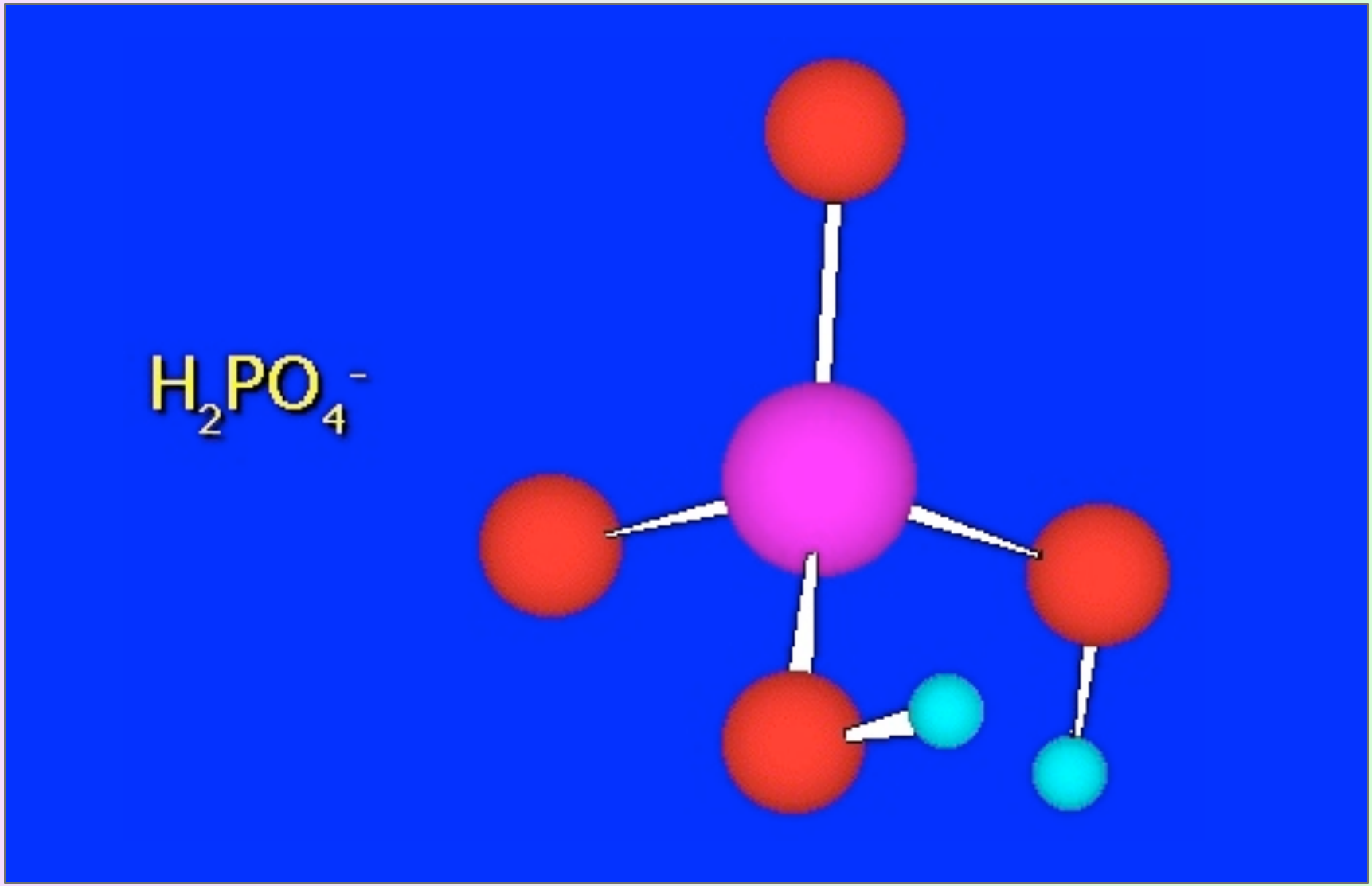

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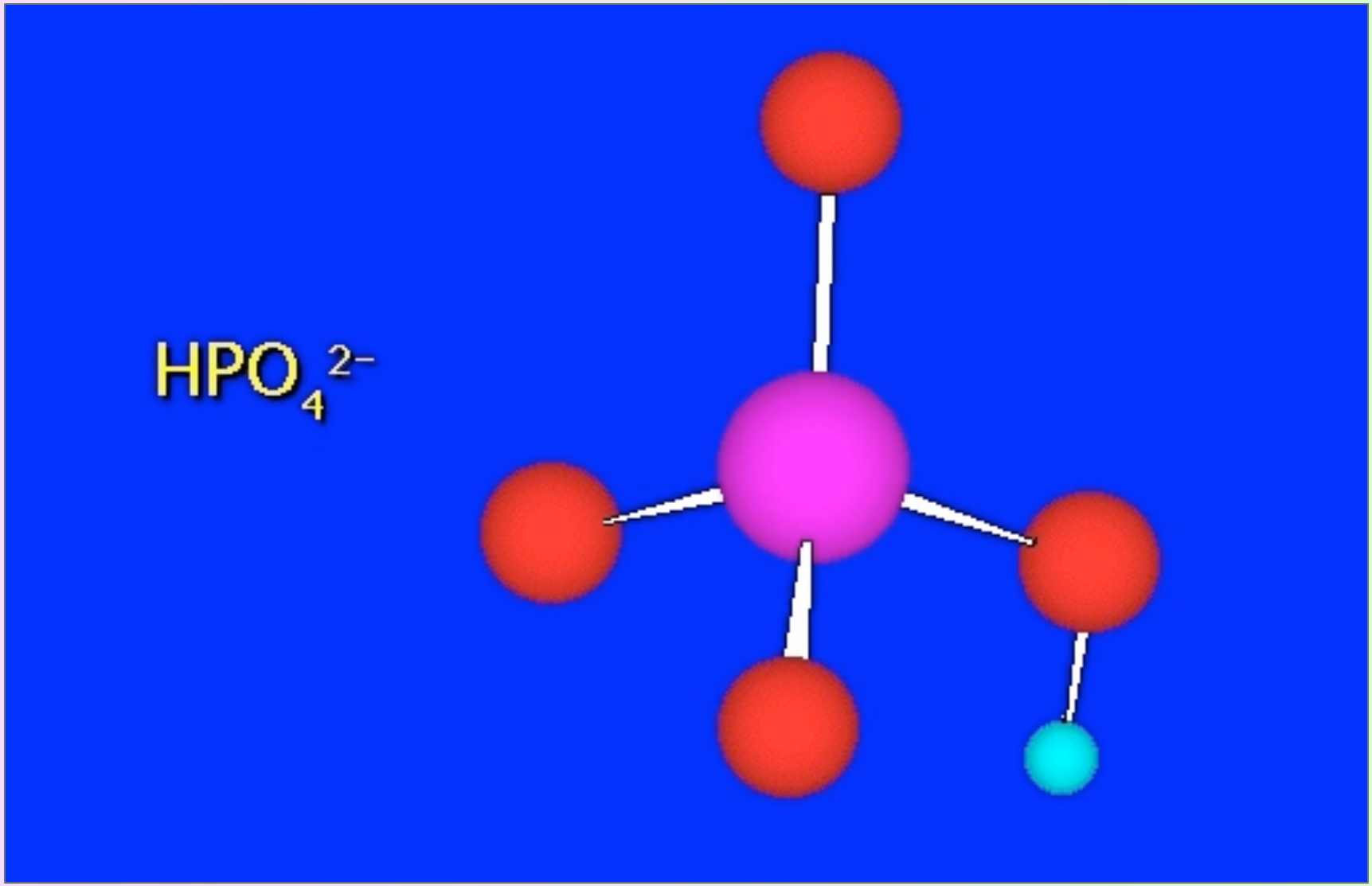

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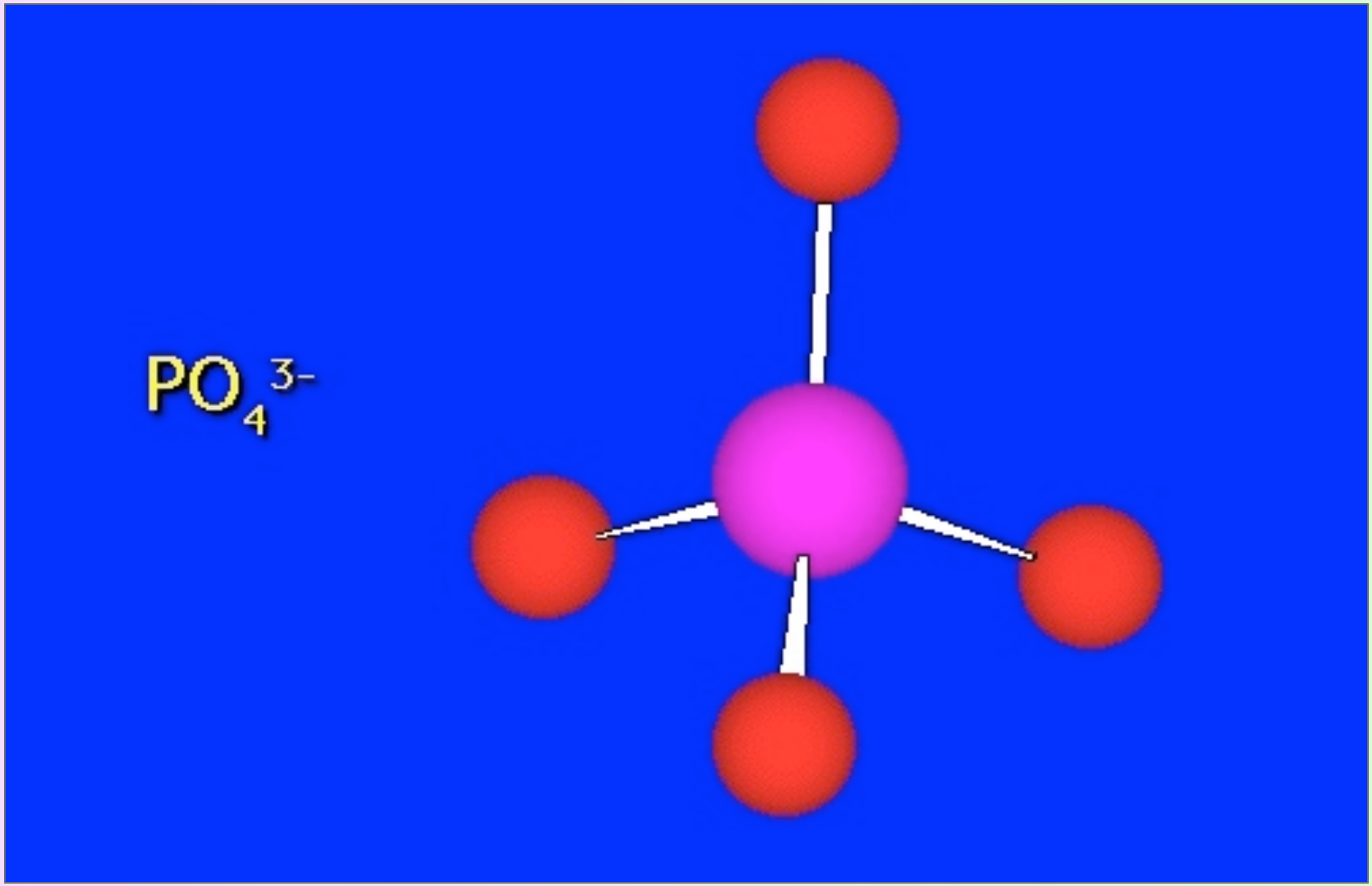
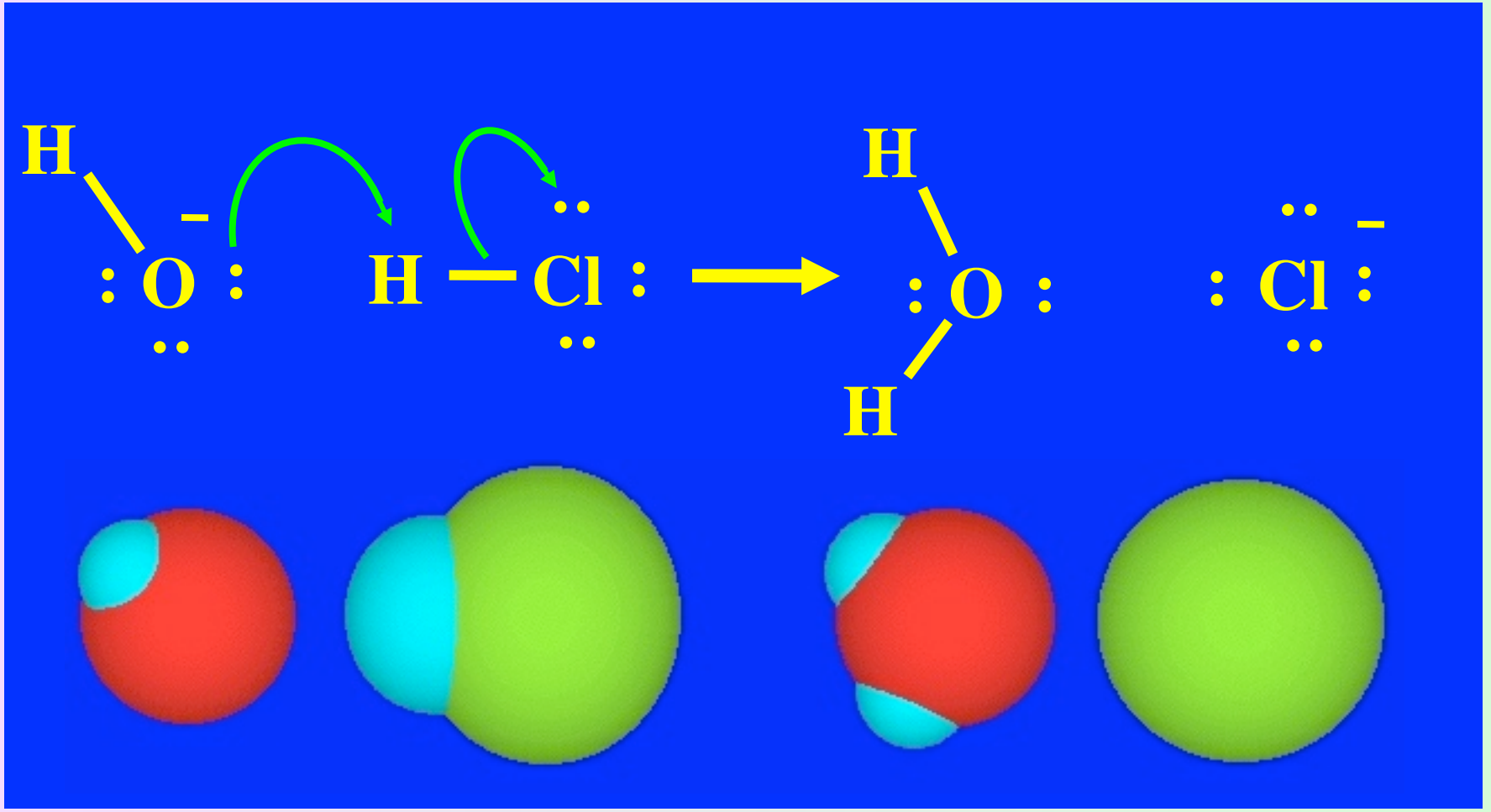


A base is a proton acceptor

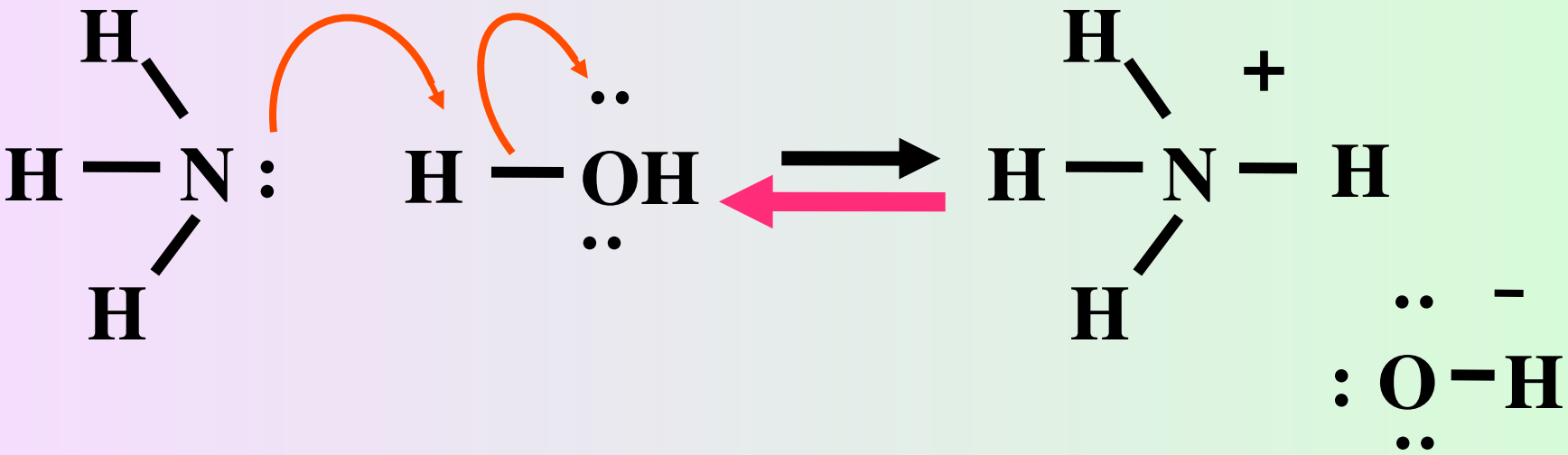
an example is NaOH

a source of hydroxide ions (OH^-)

A base is a proton acceptor



Ammonia is a Bronsted base



A Weak Base

Neutralization Reactions

Generally, when solutions of an acid and a base are combined, the products are a salt and water:

$$CH_3COOH(aq) + NaOH(aq) \longrightarrow CH_3COONa(aq) + H_2O(l)$$

Acid + Base ⟶ Salt + Water

Example of Neutralization

Acid + Base ⟶ Salt + Water

$$HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$$

Complete ionic equation

$$Na^+(aq) + OH^-(aq) + H^+(aq) + Cl^-(aq) \longrightarrow$$

$$Na^+(aq) + Cl^-(aq) + H_2O(l)$$

Cancel Spectator ions

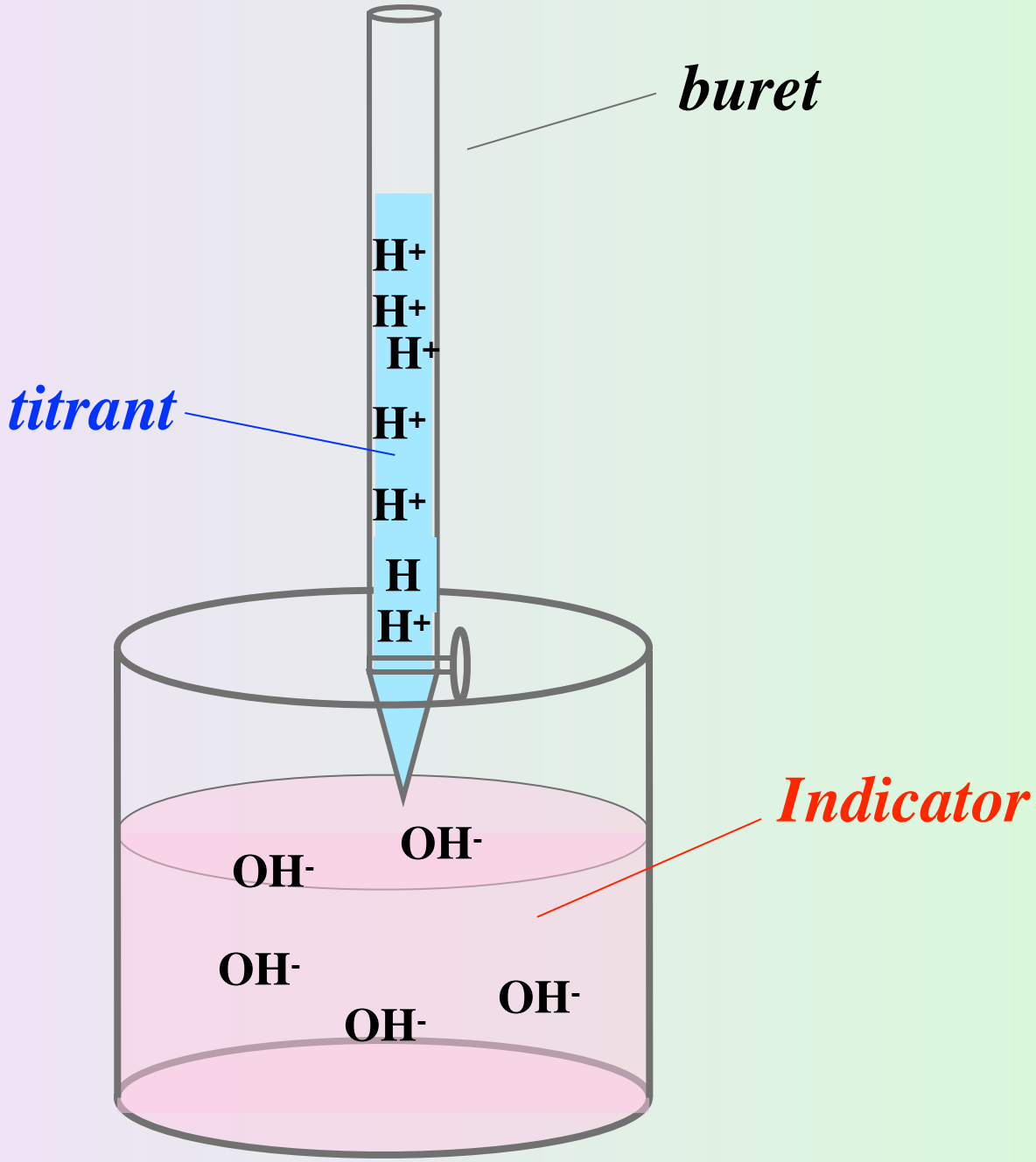
Net ionic equation

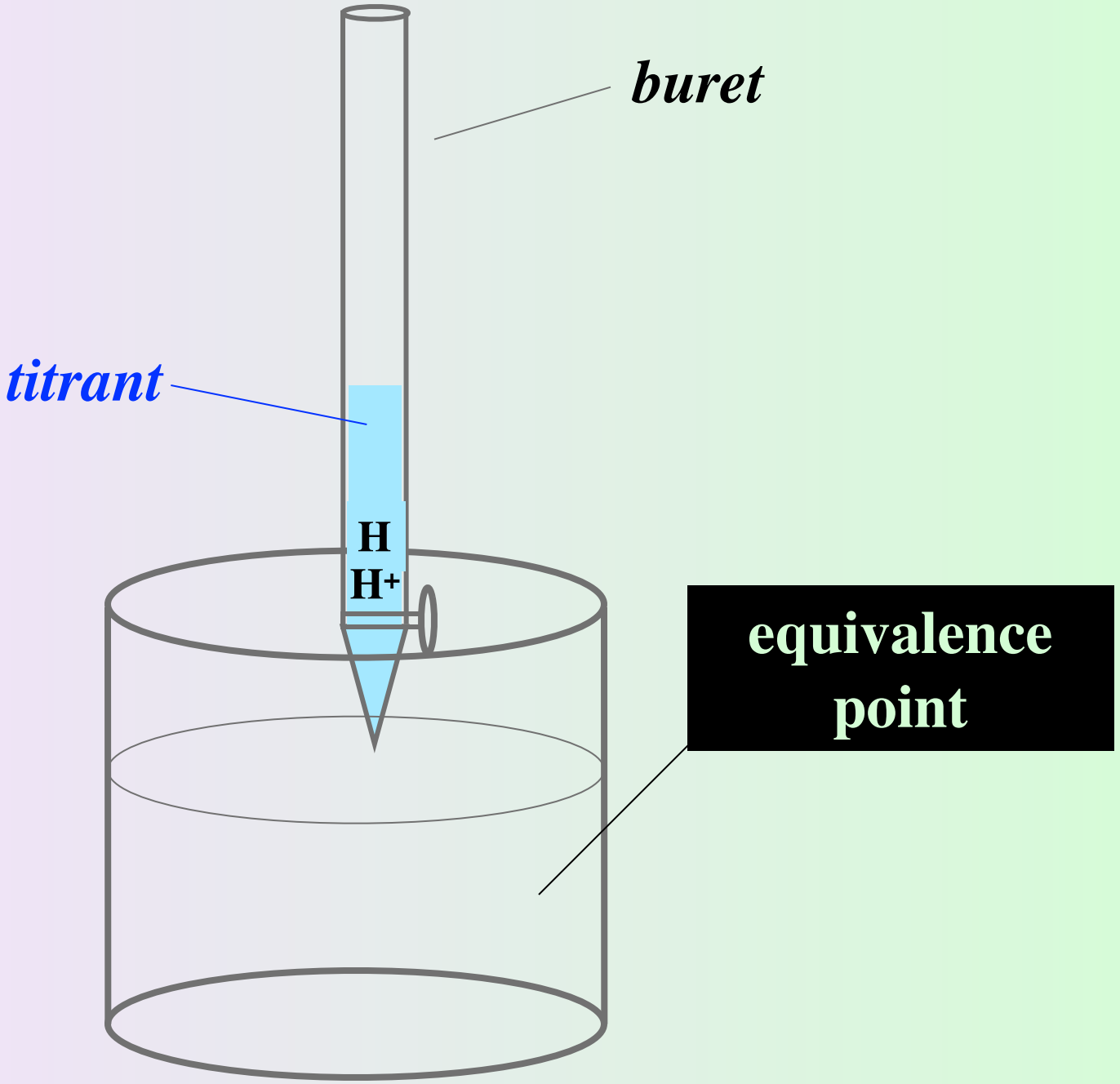
$$OH^-(aq) + H^+(aq) \longrightarrow H_2O(l)$$

Acid-Base Titrations

a solution of accurately known concentration, called a *standard solution*, is added gradually to another solution of unknown concentration, until the chemical reaction between the two solutions is complete(the *equivalence point*).

Indicators **are substances that have distinctly different colors in a basic or acidic environment used to indicate the equivalence point.**


buret
titrant
H+
H+
H+
H+
H+
H
H+
Indicator
OH-
OH-
OH-
OH-
OH-


buret
titrant
H
H+
equivalence point

Acid-Base Titrations

if we know the volumes of the standard and the unknown

along with the concentration of the standard solution

we can calculate the concentration of the unknown

Example

In a titration experiment a student finds that 0.5468g KHP(a monoprotic acid MW 204.2g) is needed to completely neutralize 23.48ml of a NaOH. What is the molarity of the NaOH solution.

$$OH^-(aq) + H^+(aq) \longrightarrow H_2O(l)$$

$$0.5468\text{g KHP} \times \frac{1\text{mol KHP}}{204.2\text{g KHP}} \times \frac{1\text{mol } H^+}{1\text{mol KHP}} \times \frac{1\text{mol } OH^-}{1\text{mol } H^+}$$

$$\times \frac{1}{0.02348\text{L}} = \boxed{0.1141\text{ mol/L } OH^-}$$

Example

How many milliliters of a 0.610*M* NaOH solution are needed to completely neutralize 20.0ml of a 0.245*M* H_2SO_4 solution.

$$H_2SO_4(aq) + 2NaOH(aq) \longrightarrow Na_2SO_4\,(aq) + 2H_2O\,(l\,)$$

$$.020\text{L} \times \frac{0.245\text{mol } H_2SO_4}{\text{L}} \times \frac{2\text{mol NaOH}}{1\text{mol } H_2SO_4} \times \frac{1\text{L NaOH}}{0.610\text{mol NaOH}}$$

$$\times \frac{1000\text{ml}}{\text{L}} = \boxed{16.1\text{ml}}$$

Gas-Forming Reactions

- Some metathesis reactions do not give the product expected.
- In this reaction, the expected product (H_2CO_3) decomposes to give a gaseous product (CO_2):

$$CaCO_3(s) + HCl(aq) \longrightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

Gas-Forming Reactions

When a carbonate or bicarbonate reacts with an acid, the products are a salt, carbon dioxide, and water:

$$CaCO_3(s) + HCl(aq) \longrightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

$$NaHCO_3(aq) + HBr(aq) \longrightarrow NaBr(aq) + CO_2(g) + H_2O(l)$$

Gas-Forming Reactions

Similarly, when a sulfite reacts with an acid, the products are a salt, sulfur dioxide, and water:

$$SrSO_3(s) + 2HI(aq) \longrightarrow SrI_2(aq) + SO_2(g) + H_2O(l)$$

Gas-Forming Reactions

- This reaction gives the predicted product, but you had better carry it out in the hood, or you will be *very* unpopular!
- But just as in the previous examples, a gas is formed as a product of this reaction:

$$Na_2S(aq) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + H_2S(g)$$