

$$= 0.157 \text{ L} = 157 \text{ mL HCl solution}$$

Another examples: A soluble silver compound was analyzed for the percentage of silver by adding sodium chloride solution to precipitate the silver ion as silver chloride. If 1.583 g of silver compound gave 1.788 g of silver chloride, what is the mass percent of silver in the compound?

- Molar mass of silver chloride (AgCl) = 143.32 g

$$1.788 \text{ g AgCl} \times \frac{1 \text{ mol AgCl}}{143.32 \text{ g AgCl}} \times \frac{1 \text{ mol Ag}}{1 \text{ mol AgCl}} \times \frac{107.9 \text{ g Ag}}{1 \text{ mol Ag}}$$
$$= 1.346 \text{ g Ag in the compound}$$

$$\frac{1.346 \text{ g Ag}}{1.583 \text{ g silver compound}} \times 100\%$$
$$= 85.03\% \text{ Ag}$$

TABLE 6-1 Representative gravimetric analyses

Species analyzed	Precipitated form	Form weighed	Some interfering species
K ⁺	KB(C ₆ H ₅) ₄	KB(C ₆ H ₅) ₄	NH ₄ ⁺ , Ag ⁺ , Hg ²⁺ , Tl ⁺ , Rb ⁺ , Cs ⁺
Mg ²⁺	Mg(NH ₄)PO ₄ · 6H ₂ O	Mg ₂ P ₂ O ₇	Many metals except Na ⁺ and K ⁺
Ca ²⁺	CaC ₂ O ₄ · H ₂ O	CaCO ₃ or CaO	Many metals except Mg ²⁺ , Na ⁺ , K ⁺
Ba ²⁺	BaSO ₄	BaSO ₄	Na ⁺ , K ⁺ , Li ⁺ , Ca ²⁺ , Al ³⁺ , Cr ³⁺ , Fe ³⁺ , Sr ²⁺ , Pb ²⁺ , NO ₃ ⁻
Cr ³⁺	PbCrO ₄	PbCrO ₄	Ag ⁺ , NH ₄ ⁺
Mn ²⁺	Mn(NH ₄)PO ₄ · H ₂ O	Mn ₂ P ₂ O ₇	Many metals
Fe ³⁺	Fe(HCO ₂) ₃	Fe ₂ O ₃	Many metals
Co ²⁺	Co(1-nitroso-2-naphtholate) ₃	CoSO ₄ (by reaction with H ₂ SO ₄)	Fe ³⁺ , Pd ²⁺ , Zr ⁴⁺
Ni ²⁺	Ni(dimethylglyoximate) ₂	Same	Pd ²⁺ , Pt ²⁺ , Bi ³⁺ , Au ³⁺
Cu ²⁺	CuSCN	CuSCN	NH ₄ ⁺ , Pb ²⁺ , Hg ²⁺ , Ag ⁺
Zn ²⁺	Zn(NH ₄)PO ₄ · H ₂ O	Zn ₂ P ₂ O ₇	Many metals
Al ³⁺	Al(8-hydroxyquinolate) ₃	Same	Many metals
Sn ⁴⁺	Sn(cupferron) ₄	SnO ₂	Cu ²⁺ , Pb ²⁺ , As(III)
Pb ²⁺	PbSO ₄	PbSO ₄	Ca ²⁺ , Sr ²⁺ , Ba ²⁺ , Hg ²⁺ , Ag ⁺ , HCl, HNO ₃
NH ₄ ⁺	NH ₄ B(C ₆ H ₅) ₄	NH ₄ B(C ₆ H ₅) ₄	K ⁺ , Rb ⁺ , Cs ⁺
Cl ⁻	AgCl	AgCl	Br ⁻ , I ⁻ , SCN ⁻ , S ²⁻ , S ₂ O ₃ ²⁻ , CN ⁻
Br ⁻	AgBr	AgBr	Cl ⁻ , I ⁻ , SCN ⁻ , S ²⁻ , S ₂ O ₃ ²⁻ , CN ⁻
I ⁻	AgI	AgI	Cl ⁻ , Br ⁻ , SCN ⁻ , S ²⁻ , S ₂ O ₃ ²⁻ , CN ⁻
SCN ⁻	CuSCN	CuSCN	NH ₄ ⁺ , Pb ²⁺ , Hg ²⁺ , Ag ⁺
CN ⁻	AgCN	AgCN	Cl ⁻ , Br ⁻ , I ⁻ , SCN ⁻ , S ²⁻ , S ₂ O ₃ ²⁻
F ⁻	(C ₆ H ₅) ₃ SnF	(C ₆ H ₅) ₃ SnF	Many metals (except alkali metals), SiO ₄ ⁴⁻ , CO ₃ ²⁻
ClO ₄ ⁻	KClO ₄	KClO ₄	
SO ₄ ²⁻	BaSO ₄	BaSO ₄	Na ⁺ , K ⁺ , Li ⁺ , Ca ²⁺ , Al ³⁺ , Cr ³⁺ , Fe ³⁺ , Sr ²⁺ , Pb ²⁺ , NO ₃ ⁻
PO ₄ ³⁻	Mg(NH ₄)PO ₄ · 6H ₂ O	Mg ₂ P ₂ O ₇	Many metals except Na ⁺ , K ⁺
NO ₂ ⁻	Nitron nitrate	Nitron nitrate	ClO ₄ ⁻ , I ⁻ , SCN ⁻ , CrO ₄ ²⁻ , ClO ₃ ⁻ , NO ₂ ⁻ , Br ⁻ , C ₂ O ₄ ²⁻

TABLE 6-2 Common organic precipitating agents

Name	Structure	Some ions precipitated
Dimethylglyoxime		Ni ²⁺ , Pd ²⁺ , Pt ²⁺
Cupferron		Fe ³⁺ , VO ₂ ⁺ , Ti ⁴⁺ , Zr ⁴⁺ , Ce ⁴⁺ , Ga ³⁺ , Sn ⁴⁺
8-Hydroxyquinoline (oxine)		Mg ²⁺ , Zn ²⁺ , Cu ²⁺ , Cd ²⁺ , Pb ²⁺ , Al ³⁺ , Fe ³⁺ , Bi ³⁺ , Ga ³⁺ , Th ⁴⁺ , Zr ⁴⁺ , UO ₂ ²⁺ , TiO ₂ ²⁺
1-Nitroso-2-naphthol		Co ²⁺ , Fe ³⁺ , Pd ²⁺ , Zr ⁴⁺
Nitron		NO ₃ ⁻ , ClO ₄ ⁻ , BF ₄ ⁻ , WO ₄ ²⁻
Sodium tetraphenylborate	Na ⁺ B(C ₆ H ₅) ₄ ⁻	K ⁺ , Rb ⁺ , Cs ⁺ , NH ₄ ⁺ , Ag ⁺ , organic ammonium ions
Tetraphenylarsonium chloride	(C ₆ H ₅) ₄ As ⁺ Cl ⁻	Cr ₂ O ₇ ²⁻ , MnO ₄ ⁻ , ReO ₄ ⁻ , MoO ₄ ²⁻ , WO ₄ ²⁻ , ClO ₄ ⁻ , I ₃ ⁻

Acids and bases:

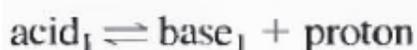
In 1923, two chemists, J. N. Bronsted in Denmark and J. M. Lowry in England proposed independently a theory of acid/base behavior that is particularly useful in analytical chemistry. According to the Bronsted-Lowry theory, an acid is a proton donor and a base is a proton acceptor. For a molecule to behave as an acid, it must encounter a proton acceptor (or base). Likewise, a molecule that can accept a proton behaves as a base if it encounters an acid.

A salt is produced in the reaction of an acid with a base. Examples: include NaCl, Na_2SO_4 , and NaOOCCH_3 (sodium acetate).

An acid donates protons only in the presence of a proton acceptor (a base). Likewise, a base accepts protons only in the presence of a proton donor (an acid).

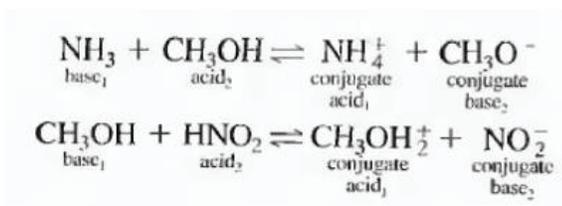
Conjugate acid is formed when a base accepts a proton.

A conjugate base is formed when an acid loses a proton. For example, acetate ion is the conjugate base of acetic acid; similarly, ammonium ion is the conjugate acid of the base ammonia.

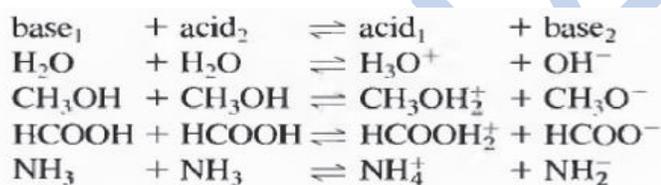


A zwitterion is an ion that bears both a positive and a negative charge.

Amphiprotic solvents behave as acids in the presence of basic solutes and bases in the presence of acidic solutes.



Amphiprotic solvents undergo self-ionization, or autoprotolysis, to form a pair of ionic species. Autoprotolysis is yet another example of acid/base behavior, as illustrated by the following equation:



Strength of acids and bases:

The first two are *strong acids* because reaction with the solvent is sufficiently complete that no undissociated solute molecules are left in aqueous solution. The remainder are *weak acids*, which react incompletely with water to give solutions containing significant quantities of both the parent acid and its conjugate base. Note that acids can be cationic, anionic, or electrically neutral. The same holds for bases.

