

E5 Lewis Acids and Bases

Session one

Pre-lab (p.141) due at start of lab.

Hour 1: Discussion of E4

Hours 2 & 3: Lab (Parts 1 and 2A)



Session two

Lab: Parts 2B, 3 and 4

Acids

Bronsted: Acids are proton donors.

Problem

- Compounds containing cations other than H^+ are acids!

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Acids

- Cations other than H^+ generate hydronium ions in aqueous solution!

Example: $Al^{3+} (aq) \approx pH\ 3!$



Deodorants and acid loving plant foods contain aluminum salts

Lewis Definition of Acids and Bases

Define acid/base without using the word proton:



- A BASE DONATES unbonded ELECTRON PAIR/S.
- An ACID ACCEPTS ELECTRON PAIR/S.

Lewis Acids

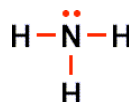
- Electron deficient species ; potential electron pair acceptors.

Examples: H^+ Cu^{2+} Al^{3+}

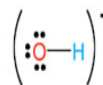


Lewis Bases

- Electron rich species; electron pair donors.



Ammonia
(ammine)



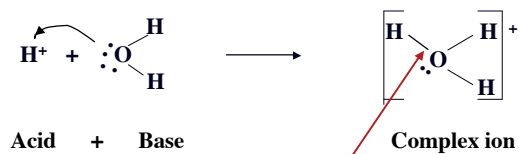
hydroxide ion
(hydroxo)



water
(aquo)

Lewis Acid-Base Reactions

Example

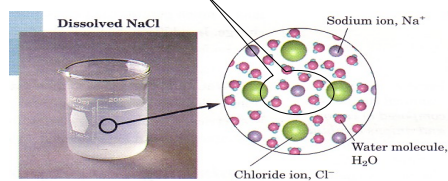


- The acid reacts with the base by bonding to one or more available electron pairs on the base.
- The acid-base bond is a coordinate covalent bond.
- The product is a complex or complex ion

Lewis Acids: Metal Ions

- Metal ions react with/bond to water molecules to form aquo complex ions in aqueous solution.

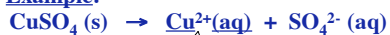
Example: $[\text{Na}(\text{H}_2\text{O})_6]^+$



Aquo Complex Ions

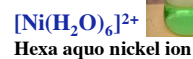
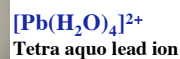
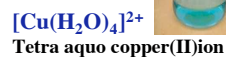
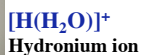
- When a salt dissolves, the metal ions in the salt solution react with/bond to water molecules to form aquo complex ions.

Example:



Aquo Complex Ions

Examples



- Colored aquo complex ions contain a transition metal ion with incompletely filled d orbitals.

Part 1. Acidity of Cations

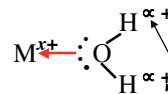
- Study the reaction of metal aquo complex ions with the Lewis base H_2O to produce hydronium ions.

- Collect pH data for different metal aquo complex ions in aqueous solution.

- pH versus periodic table position of ion's metal?
- pH versus metal ion size and charge?



Metal Ion Acid Strength



- The acid strength of a metal ion is dependent on its ability to attract electrons (oxidizing agent strength).
- The greater the acid strength of a metal ion the more polarized the bonded water molecules (and electron deficient the protons) in the aquo complex ion.

Reactions of Metal Aquo Complex Ions with Water

Reaction of Metal Aquo Complex Ion:



- Electron deficient proton/s in the polarized water molecules of the metal aquo complex ion react and bond to an electron pair in another water molecule
- When a proton bonds to a water molecule, a H_3O^+ ion is formed.

Q. Complete a balanced equation to show formation of hydronium ions:



Metal Ion Acid Strength

Q. Given the reducing agent strength $\text{Na} > \text{Mg} > \text{Al}$, indicate the Lewis acid strength of Na^+ , Mg^{2+} , and Al^{3+}

Metal Ion Acid Strength: $\text{Al}^{3+} > \text{Mg}^{2+} > \text{Na}^+$

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Aquo Complex Ion Reactions

Acid strength

→

↑

→

↓

1A																		VIIIA																	
1H																		2He																	
IIA																		IIIA IVA VA VIA VIIA VIIIA																	
3Li		4Be																5B		6C		7N		8O		9F		10Ne							
11Na		12Mg																13Al		14Si		15P		16S		17Cl		18Ar							
19K		20Ca		21Sc		22Ti		23V		24Cr		25Mn		26Fe		27Co		28Ni		29Cu		30Zn		31Ga		32Ge		33As		34Se		35Br		36Kr	
37Rb		38Sr		39Y		40Zr		41Nb		42Mo		43Tc		44Ru		45Rh		46Pd		47Ag		48Cd		49In		50Sn		51Sb		52Te		53I		54Xe	
55Cs		56Ba		57La*		58Ce		59Pr		60Nd		61Pm		62Sm		63Eu		64Gd		65Tb		66Dy		67Ho		68Er		69Tm		70Yb		71Lu		72Hf	
73Ta		74W		75Re		76Os		77Ir		78Pt		79Au		80Hg		81Tl		82Pb		83Bi		84Po		85At		86Rn		87Fr		88Ra		89Ac*			
89Ac*		90Th		91Pa		92U		93Np		94Pu		95Am		96Cm		97Bk		98Cf		99Es		100Fm		101Md		102No		103Lr		104Rf		105Db			

* Element synthesized, but no official name assigned

Part 2 A.
Studies of complex formation with NH_3 and OH^- .

- Study the reactions of metal aquo complex ions with Lewis bases (NH_3 , OH^- , ...).

DISCUSSION

- What kinds of observations allow you to infer that a complexation reaction is occurring?
- Predict the reactions of a metal ion with Lewis bases based on the position of its element in the Periodic Table



Reaction of Lewis Acids (metal ions) with Lewis Bases

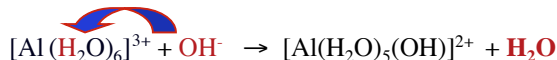
- Extent of reaction differs because of acid strength differences.
- Pattern of reactivity with bases (e.g. OH^- and NH_3) differs due to differences in metal ion electron configurations.

1A	2A	3A	4A	5A	6A	7A	8A	9A	10A	11A	12A	13A	14A	15A	16A	17A	18A
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H	He	Li	Be	B	C	N	O	F	Ne	Na	Mg	Al	Si	P	S	Cl	Ar
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72
Cs	Ba	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf
73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90
Fr	Ra	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	Rf

Metal Aquo Complex Ion Reactions with OH^-

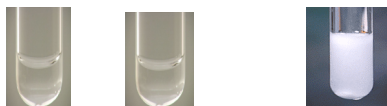
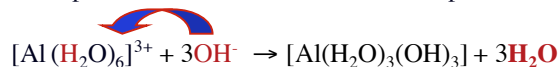
- If reaction occurs with a charged base such as OH^- , the product may be a soluble complex ion or an uncharged insoluble complex depending on reaction stoichiometry.

Example 1: Formation of a soluble complex ion:

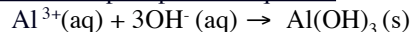


Aquo Complex Ion Reactions with OH^-

Example 2: Formation of an insoluble complex:

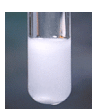
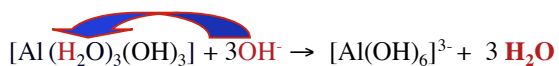


Traditional net precipitation equation:

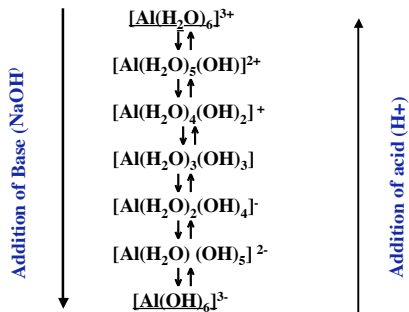


Aquo Complex Ion Reactions with OH⁻

Example 3: Addition of excess hydroxide ions to the precipitated hydroxide complex results in formation of a soluble complex ion:



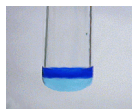
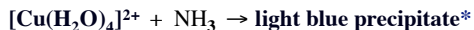
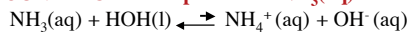
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- Precipitation reactions are Lewis Acid-Base reactions
- The reactions are reversible equilibrium systems
- The equilibrium point depends on the reactants (strength...) and reaction conditions (concentration...)

Reaction of Aquo Metal Complex Ions with NH₃

- If a precipitate forms upon addition of NH₃(aq), the metal aquo complex ion is reacting with the SMALL AMOUNT of OH⁻ ions present in NH₃(aq):



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Q. * What is the formula for the hydroxide precipitate?



- Lewis acids bond to the best available base.
- an acid does not react (bond) to any base.



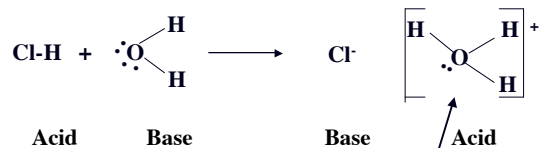
▪ If a better base is available a Lewis acid will react (exchange partners)!



Acid-Base + better Base → Reaction



Q. The acid exchanging base partners is H^+ . Which is the BEST base, Cl^- or HOH ?

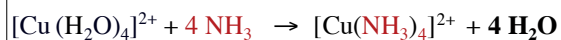


H^+ bonds to water (best base) rather than Cl^- .

• The bonded base-acid product = complex ion.

Aquo Complex Ion Replacement Reactions

Example 1: Replacement of water with ammonia molecules.



Tetra aquo Cu(II) ion

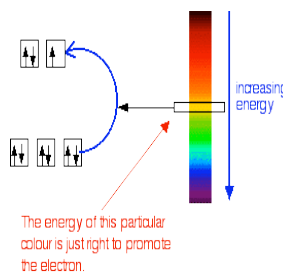


Tetra ammine Cu(II) ion

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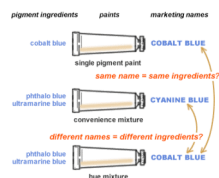
Aquo Complex Ion Reactions

Example: Replacement of water with ammonia molecules.



$[Cu(NH_3)_4]^{2+}$
Tetrammine copper (II) ion

Complex Ions



- Complex ions are the chemical basis for colorful paint pigments.

Aquo Complex Ion Reactions

- Colored transition metal ions alter color upon bonding to a different Lewis base.

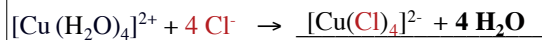


- The charge on a complex ion will equal that of the metal ion when the metal ion is bonded to an uncharged Lewis base such as H_2O or NH_3 .

Aquo Complex Ion Replacements Reactions

Example 2: Replacement of water with chloride ions.

Q. Complete the equation below:



Tetra aquo copper(II) ion



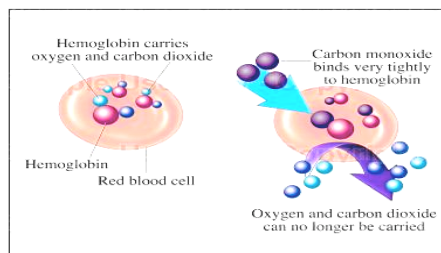
Tetra chloro copper(II) ion

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- The charge on the complex ion alters due to reaction with a charged Lewis base

Lewis Acid-Base Reactions

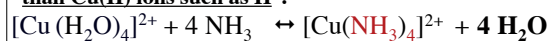
- Complexes react if a better partner (acid or base) is available so as to form a more stable bond.



Hemoglobin is a complex of Fe that binds to/ transports oxygen

Aquo Complex Ion Replacement Reactions

Example 4: The base ammonia in the Cu(II) product (ammine complex ion) will react and bond to a better acid than Cu(II) ions such as H^+ :



Q. What will you observe upon adding acid (H^+) to the deep violet-blue ammine product?

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Questions?

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