

Complex and nomenclature

Definitions
Ligands
Chelating agent
Naming

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Definitions

Complex:

consists of a metal atom or a metal ion to which several ions or molecules (called ligands) are bonded with a coordination bond.

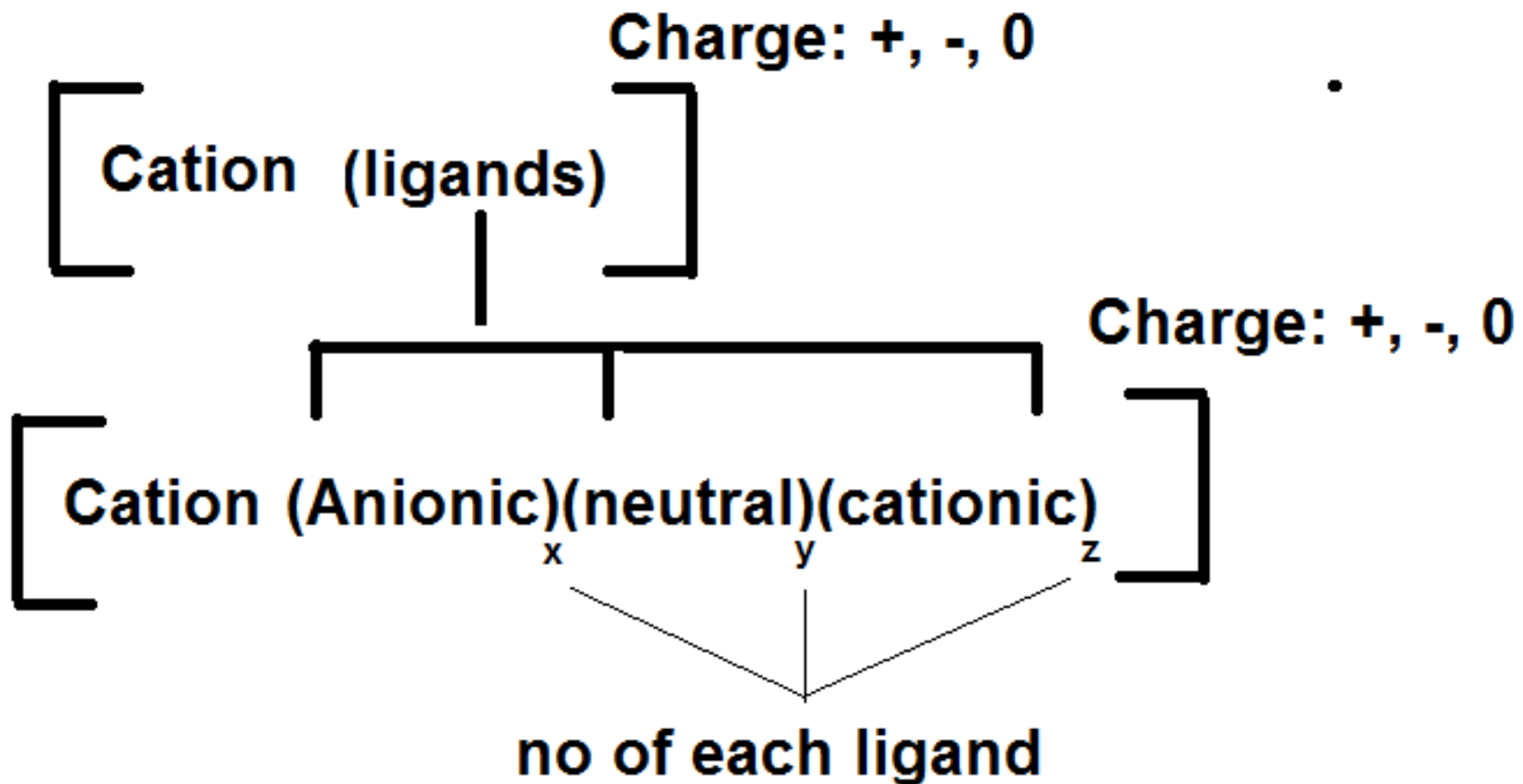
Ligands: substances that are capable of acting as lewis bases.

Ligands can be anionic, neutral, and in rare cases cationic

A complex had a charge can be cationic, anionic, or neutral.

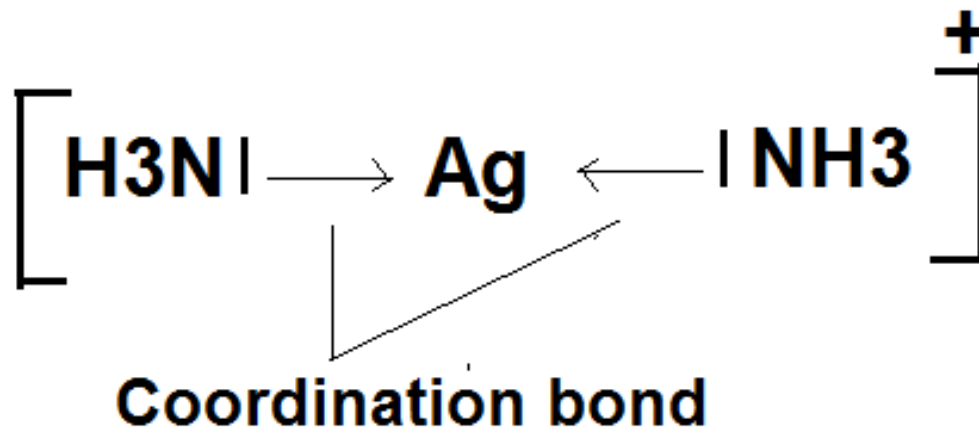
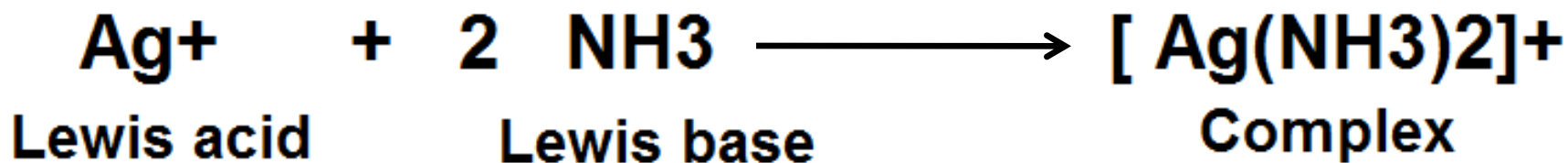
Complex Formula

The formula is written in [] as below, first cation followed by ligands. When different types of ligands in one complex, then they have the following order: anionic, neutral then cationic



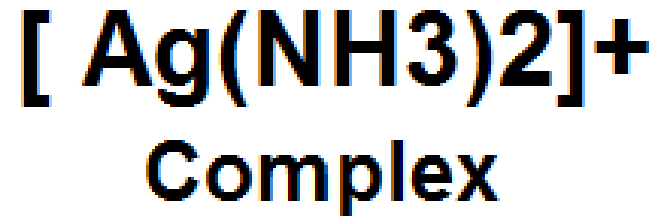
Complex formation reaction

The reaction of producing a complex is lewis acid lewis base reaction



Coordination number

Number of coordination bonds surrounding the metal ion or central atom.



In this complex coordination number is 2

Coordination numbers can be 2,4, or 6.

Examples of Complex

$[\text{Fe}(\text{CN})_6]^{-3}$: anionic complex, coordination number 6, oxidation number of Fe = +3

$[\text{Cr}(\text{OH})_3(\text{H}_2\text{O})_3]$: neutral complex, coordination number 6, oxidation number of Cr = +3

$[\text{Cu}(\text{NH}_3)_4]^{+2}$: cationic complex, coordination number 4, oxidation number of Cu = +2

$[\text{CrCl}_2(\text{NH}_3)_4]^{+}$: cationic complex, coordination number 6, oxidation number of Cr = +3

Examples of Complex



cationic complex, coordination number 6, oxidation number of Co=+3

Note:

Complex formulae is in [] first cation then ligands and has +1 charge.

Two types of ligands anionic: (–Br, and –Cl) and neutral : H₂O

–Br is written in formulae followed by –Cl. This order is alphabetical.

H₂O is written in () because it is polyatomic but –Br is not.

Examples of Complex

Note:

Metal ion is written first in complex inside [] followed by anionic then neutral ligand.

When different ligands of the same type (anionic, neutral) are present then they are listed in alphabetical order.

When ligands are **polyatomic**, their formulae are enclosed in **parentheses**.

Types of ligands

Ligands are classified according to their charge (anionic, neutral, and rarely cationic) ligands.

Anionic Ligands	Names
Br^-	bromo
F^-	fluoro
O^{2-}	oxo
OH^-	hydroxo
CN^-	cyano
$\text{C}_2\text{O}_4^{2-}$	oxalato
CO_3^{2-}	carbonato
CH_3COO^-	acetato

Types of ligands

Ligands are classified according to their charge (anionic, neutral, and rarely cationic) ligands.

Neutral Ligands	Names
NH_3	ammine
H_2O	aqua
NO	Nitrosyl
CO	Carbonyl
O_2	dioxygen
N_2	dinitrogen
$\text{C}_5\text{H}_5\text{N}$	pyridine
$\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2$	ethylenediamine

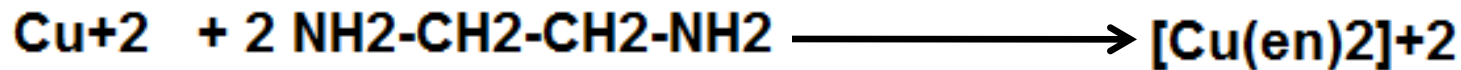
Types of ligands

Ligands are classified according to the number of electron donating group which can form coordination bonds.

Ligand builds only one coordination bond is monodentate ligand (NH_3 , H_2O , Cl , CO , Br , CN , SCN , OH ,----)

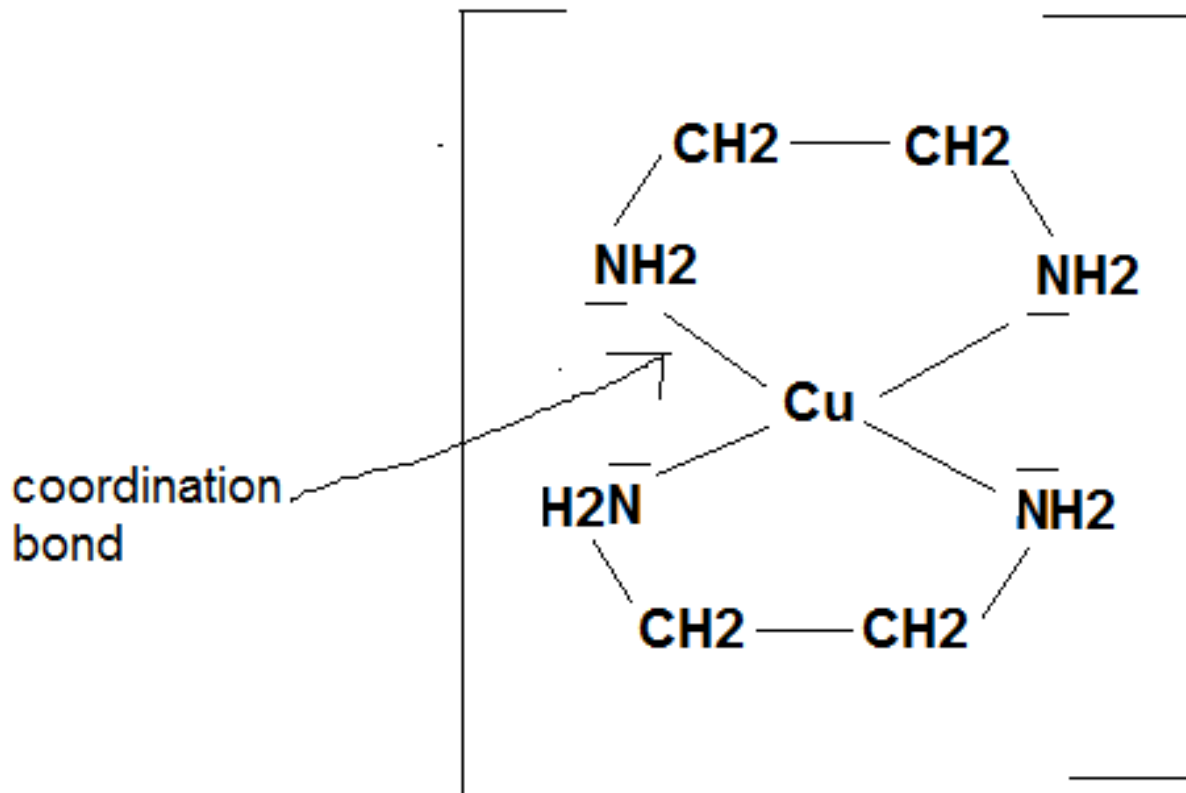
Ligand builds many coordination bonds is multidentate ligand (called also chelating agent) like C_2O_4 , ethylenediamine, EDTA

Types of ligands



bisethylenediaminecopper(II) ion

+2



Coordination number is 4

number of ligands is 2

ligands is a bidentate ligand (chelating agent) since it builds two coordination bonds

complex is called chelate

Nomenclature of complex

Name the ligands first, in alphabetical order and then name the metal atom or cation.

The name of some common ligands

Anionic ligands end in (-o)

Cl^- Chloride ion, $-\text{Cl}$: Chloro,

OH^- : hydroxide ion, $-\text{OH}$: hydroxo

NO_3^- : nitrate ion, $-\text{NO}_3$: nitrato

NO_2^- : nitrite ion, $-\text{NO}_2$: nitrito

Nomenclature of complex

The name of some common ligands

neutral ligands use the name of molecule like ethylenediamine.

Exceptions

H₂O: Water, -H₂O: Aqua-

NH₃: Ammonia, -NH₃: Ammine

CO: Carbon monoxide, -CO: carbonyl

Nomenclature of complex

The Greek prefixes di, tri,-- are used to designate the number of each type of ligand in the complex

When ligand is polydentate then use prefixes bis, tris, tetrakis,--

Numerical Prefixes

Number	Prefix	Number	Prefix	Number	Prefix
1	mono	5	penta (pentakis)	9	nona (ennea)
2	di (bis)	6	hexa (hexakis)	10	deca
3	tri (tris)	7	hepta	11	undeca
4	tetra (tetrakis)	8	octa	12	dodeca

Nomenclature of complex

After naming ligands, name the central atom.

If complex is cationic use the English name of element.

Cobalt: cobalt, iron : iron,

If complex is anionic, the name of metal ends with suffix –ate.

Cobalt: cobaltate, Platin: platinate

For some metals latin names of metals are used in anionic complexes.

Following the name of element the oxidation state of element is given in Roman numeral in parentheses

Nomenclature of complex

Name of Metals in Anionic Complexes

Name of Metal	Name in an Anionic Complex
Iron	Ferrate
Copper	Cuprate
Lead	Plumbate
Silver	Argentate
Gold	Aurate
Tin	Stannate

Nomenclature of complex

$[\text{CoCl}_4(\text{NH}_3)_2]^-$ diamminetetrachlorocobaltate(III) ion

There are two types of ligands. In formulae anionic ligand before neutral.

Name ligands alphabetically so ammine first then chloro followed by metal ion.

Use prefix di, tetra to indicate number of each ligand in complex.

Oxidation state of cobalt is +3

Complex is anionic name of metal ends with suffix -ate.

Nomenclature of complex

$[\text{Cr}(\text{OH})_3(\text{H}_2\text{O})_3]$ Triaquatrihydroxochromium(III)

There are two types of ligands. In formulae anionic ligand before neutral.

Name ligands alphabetically so aqua first then hydroxo followed by metal ion.

Use prefix tri to indicate number of each ligand in complex.

Oxidation state of Cr is +3

Complex is neutral name of metal in English name.

Nomenclature of complex

$[\text{Fe}(\text{CN})_6]^{-3}$: hexacyanoferrate(III) ion

$[\text{Fe}(\text{oxo})_3]^{-3}$: Trisoxalatoferrate (III) ion

$[\text{CuBr}_4]^{-3}$: tetrabromocuprate (I) ion

$\text{Na}[\text{Ag}(\text{CN})_2]$: sodium dicyanoargenate

$[\text{CoCl}(\text{NH}_3)_5]\text{Cl}_2$: Pentaamminechlorocobalt(III) chloride

$\text{K}_4[\text{Fe}(\text{CN})_6]$: Potassium hexacyanoferrate(II)

Questions

Write the chemical formula for the following:

Triaquatritiocyanatoiron (III)

tetraflourooxocobaltate(III) ion

Bis(ethylenediamine)dinitroiron(III) ion

Bromochlorodicyanonickelate(II) ion

Sodium dithiosulfatoargenate(I)

Questions

Diaquadichlorodithiocyanatochromate(III) ion

Tetrahydroxozincate(II) ion

Hexaaquachromium (III) hexacyanoferrate (III)

Diamminediaquadichlorocobalt(III) ion

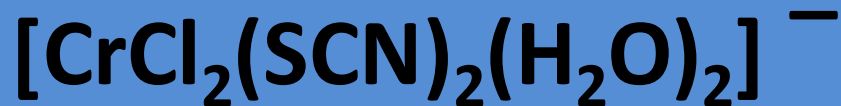
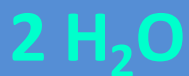
Ammonium carbonylpentacyanomanganate(II)

Hexaaquanickel(II) phosphate

Calcium diaquatetracyanocobaltate(III)

Questions

Diaquadichlorodithiocyanatochromate(III) ion



Questions

Sodium dithiosulfatoargenate(I)

Na^+
Cation

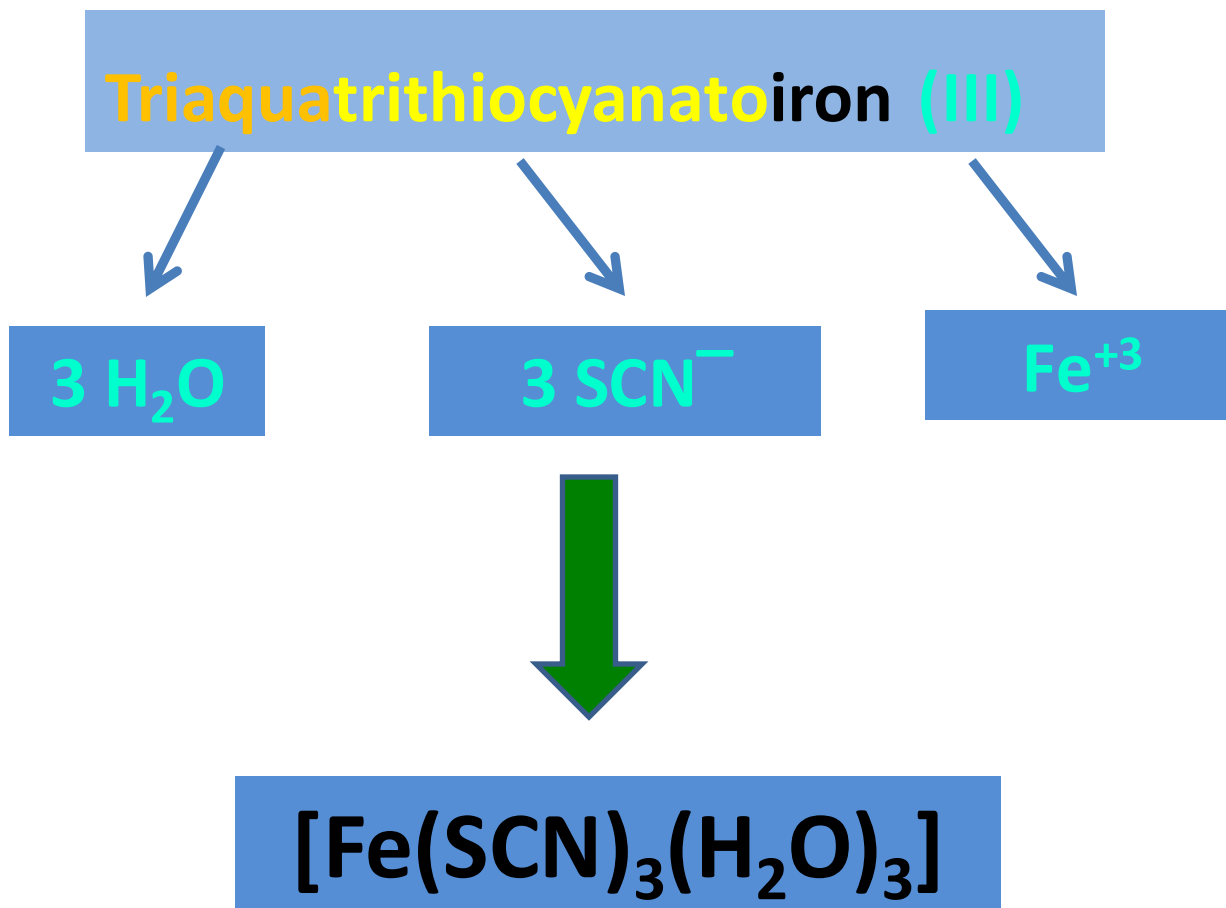
$[\]^-$
Anion

$[\text{Ag}(\text{S}_2\text{O}_3)_2]^{-3}$

Salt

$\text{Na}_3[\text{Ag}(\text{S}_2\text{O}_3)_2]$

Questions



Questions

Hexaaquanickel(II) phosphate

[]⁺
Cation

PO₄⁻³
Anion

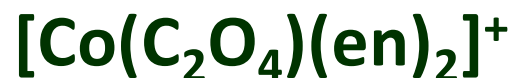
[Ni(H₂O)₆]⁺²

Salt

[Ni(H₂O)₆]₃(PO₄)₂

Questions

Give the IUPAC name, Coordination and oxidation-number:



Questions



Tetrabromo

Cuprate(II)

Tetrabromocuprate(II) ion

Questions



Tetraammine

Copper(II)

Tetraamminecopper(II) ion

Questions



dicyano

argenate(I)

dicyanoargenate(I) ion

Questions



diammine

silver(I)

A large green arrow points downwards from the space between the 'diammine' and 'silver(I)' boxes to a final blue box at the bottom.

Diamminesilver(I) ion

Questions



Trisethylenediamine

Cobalt(III)

Trisethylenediaminecobalt(III) ion

Questions



Tetrahydroxo

Plumbate(II)

Tetrahydroxoplumbate(III) ion

Questions

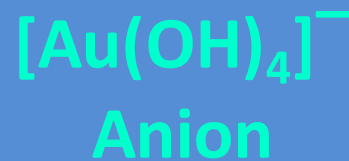
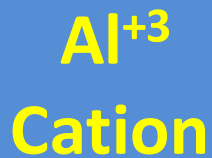


Trisoxalato

stannate(IV)

Trioxalatostannate(IV) ion

Questions



Salt

Aluminium tetrahydroaurate(III)

Questions



4 F^- : Tetrafluoro
 O^{-2} : oxo

Cobalt(III)

tetrafluorooxocobaltate(III) ion

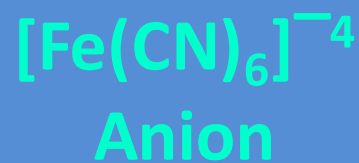
Questions



Salt

Potassium hexachloroplatinate(II)

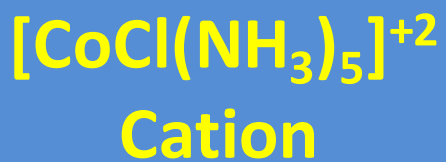
Questions



Salt

Potassium hexacyanoferrate(II)

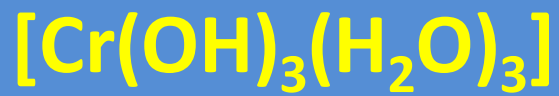
Questions



Salt

Pentaamminechlorocobalt(III) chloride

Questions



Triaquatrihydroxochromium(III)

Nomenclature of inorganic compounds

Dr. Mai Ramadan

Nomenclature of inorganic compounds

Common and systematic names

Laughing gas	N_2O	Dinitrogen monoxide
Alumina	Al_2O_3	Aluminum oxide
Caustic soda	NaOH	Sodium hydroxide
Table salt	NaCl	Sodium chloride
Potash	K_2CO_3	Potassium carbonate

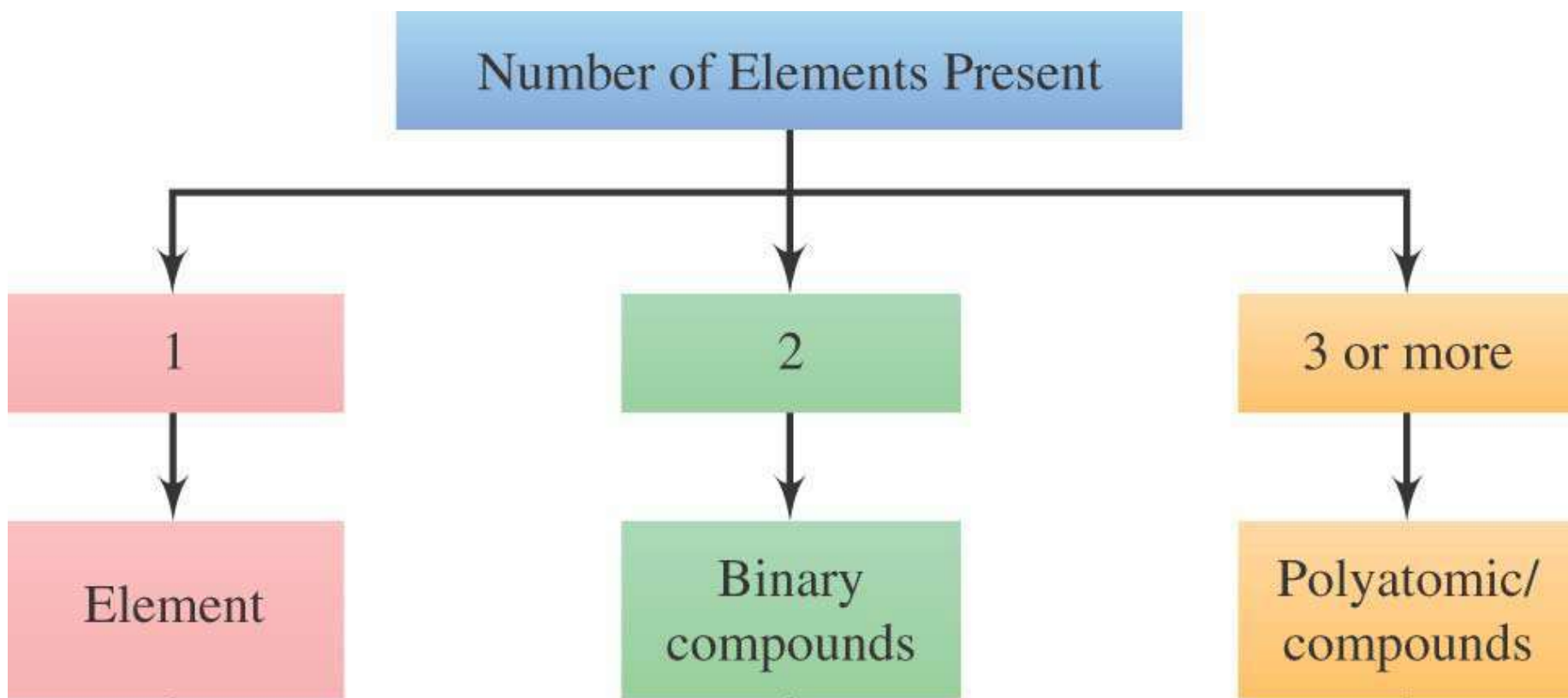
Table 6.1 Common Names, Formulas, and Chemical Names of Familiar Substances

Common names	Formula	Chemical name
Acetylene	C_2H_2	ethyne
Lime	CaO	calcium oxide
Slaked lime	$Ca(OH)_2$	calcium hydroxide
Water	H_2O	water
Galena	PbS	lead(II) sulfide
Alumina	Al_2O_3	aluminum oxide
Baking soda	$NaHCO_3$	sodium hydrogen carbonate
Cane or beet sugar	$C_{12}H_{22}O_{11}$	sucrose
Borax	$Na_2B_4O_7 \cdot 10 H_2O$	sodium tetraborate decahydrate
Brimstone	S	sulfur
Calcite, marble, limestone	$CaCO_3$	calcium carbonate
Cream of tartar	$KHC_4H_4O_6$	potassium hydrogen tartrate
Epsom salts	$MgSO_4 \cdot 7 H_2O$	magnesium sulfate heptahydrate
Gypsum	$CaSO_4 \cdot 2 H_2O$	calcium sulfate dihydrate
Grain alcohol	C_2H_5OH	ethanol, ethyl alcohol
Hypo	$Na_2S_2O_3$	sodium thiosulfate
Laughing gas	N_2O	dinitrogen monoxide
Lye, caustic soda	$NaOH$	sodium hydroxide

IUPAC nomenclature

system for inorganic nomenclature was devised by IUPAC
[International Union of Pure and Applied Chemistry]

Rules for naming inorganic substance



IUPAC nomenclature

Elements and ions

Elements occurring as polyatomic molecules

Hydrogen H_2

Chlorine Cl_2

Sulfur S_8

oxygen O_2

Fluorine F_2

phosphorus P_4

nitrogen N_2

Bromine Br_2

Iodine I_2

IUPAC nomenclature

Elements and ions

Elements and cations

K potassium

K^+ potassium ion

Mg magnesium

Mg^{2+} magnesium ion

Al aluminum

Al^{3+} aluminum ion

Common polyatomic cations

NH_4^+ ammonium ion

H_3O^+ hydronium ion

Hg_2^{2+} mercury (I) ion

IUPAC nomenclature

Elements and ions

Element	English name	Latin name
Fe	Iron	Ferrum

IUPAC

Fe^{+2}	Iron (II) ion	Fe^{+3}	Iron (III) ion
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Classical

Fe^{+2}	Ferrous ion	Fe^{+3}	Ferric ion
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Classical names:

Stem of Latin name of element followed by suffix –ous, -ic

Stem: Ferr

IUPAC nomenclature

Table 6.4 Names and Charges of Some Common Metal Ions That Have More Than One Type of Cation

Formula	Stock System name	Classical name
Cu^{1+}	copper(I)	cuprous
Cu^{2+}	copper(II)	cupric
$\text{Hg}^{1+} (\text{Hg}_2)^{2+}$	mercury(I)	mercurous
Hg^{2+}	mercury(II)	mercuric
Fe^{2+}	iron(II)	ferrous
Fe^{3+}	iron(III)	ferric
Sn^{2+}	tin(II)	stannous
Sn^{4+}	tin(IV)	stannic
Pb^{2+}	lead(II)	plumbous
Pb^{4+}	lead(IV)	plumbic
As^{3+}	arsenic(III)	arsenous
As^{5+}	arsenic(V)	arsenic
Ti^{3+}	titanium(III)	titanous
Ti^{4+}	titanium(IV)	titanic

IUPAC nomenclature

Elements and ions

Elements and anions

Cl	chlorine	Cl^-	chloride ion
F	fluorine	F^-	fluoride ion
Br	bromine	Br^-	bromide ion
I	iodine	I^-	iodide ion
O	oxygen	O^{2-}	oxide ion
N	nitrogen	N^{3-}	nitride ion

IUPAC nomenclature

Elements and ions

Table 6.2 Examples of Elements Forming Anions

Symbol	Element	Stem	Anion name
Br	bromine	brom	bromide
Cl	chlorine	chlor	chloride
F	fluorine	fluor	fluoride
H	hydrogen	hydr	hydride
I	iodine	iod	iodide
N	nitrogen	nitr	nitride
O	oxygen	ox	oxide
P	phosphorus	phosph	phosphide
S	sulfur	sulf	sulfide

IUPAC nomenclature

Elements and ions

polyatomic ion – ion that contains two or more elements

some common polyatomic ions

Table 6.6 Names, Formulas, and Charges of Some Common Polyatomic Ions

Name	Formula	Charge	Name	Formula	Charge
Acetate	$\text{C}_2\text{H}_3\text{O}_2^-$	-1	Cyanide	CN^-	-1
Ammonium	NH_4^+	+1	Dichromate	$\text{Cr}_2\text{O}_7^{2-}$	-2
Arsenate	AsO_4^{3-}	-3	Hydroxide	OH^-	-1
Hydrogen carbonate	HCO_3^-	-1	Nitrate	NO_3^-	-1
Hydrogen sulfate	HSO_4^-	-1	Nitrite	NO_2^-	-1
Bromate	BrO_3^-	-1	Permanganate	MnO_4^-	-1
Carbonate	CO_3^{2-}	-2	Phosphate	PO_4^{3-}	-3
Chlorate	ClO_3^-	-1	Sulfate	SO_4^{2-}	-2
Chromate	CrO_4^{2-}	-2	Sulfite	SO_3^{2-}	-2

IUPAC nomenclature

Elements and ions

polyatomic ion – ion that contains two or more elements

some common polyatomic ions

PO_4^{-3} Phosphate ion

H_2PO_4^- Dihydrogen phosphate ion

HPO_4^{-2} Monohydrogen phosphate ion

NO_3^- Nitrate ion

NO_2^- Nitrite ion

AsO_4^{-3} Arsenate ion

AsO_3^{-3} Arsenite

IUPAC nomenclature

Elements and ions

Oxyanion

Oxidation state of Cl-atom

ClO^- : hypochlorite ion +1

ClO_2^- : chlorite ion +3

ClO_3^- : chlorate ion +5

ClO_4^- : perchlorate ion +7

Remember:

SO_4^{2-} : **Sulfate ion**

SO_3^{2-} : **Sulfite ion**

IUPAC nomenclature

Writing chemical formula from names of compounds

a chemical compound must have a net charge of zero

formula writing of ionic compounds

(a) calcium chloride



(b) magnesium oxide



(c) barium phosphide



(d) Silver chromate



IUPAC nomenclature

Naming binary compounds

binary compounds contain only two different elements

A. binary ionic compounds

Metal forms one type of cation

NaCl sodium chlor**ide**

CaBr₂ calcium brom**ide**

Mg₃N₂ magnesium nitr**ide**

Li₂O lithium ox**ide**

IUPAC nomenclature

Naming binary compounds

Table 6.3 Examples of Compounds with Names Ending in *-ide*

Formula	Name	Formula	Name
AlCl_3	aluminum chloride	BaS	barium sulfide
Al_2O_3	aluminum oxide	LiI	lithium iodide
CaC_2	calcium carbide	MgBr_2	magnesium bromide
HCl	hydrogen chloride	NaH	sodium hydride
HI	hydrogen iodide	Na_2O	sodium oxide

IUPAC nomenclature

Naming binary compounds

B. binary ionic compounds

a metal that can form two or more types of cations

Formula	IUPAC Name	classical name
FeCl_2	iron(II) chloride	ferrous chloride
FeCl_3	iron(III) chloride	ferric chloride
CuCl	copper(I) chloride	cuprous chloride
CuCl_2	copper(II) chloride	cupric chloride

IUPAC nomenclature

Naming binary compounds

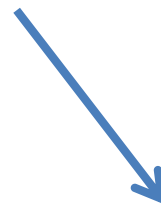
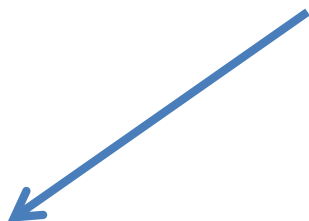
B. binary ionic compounds

a metal that can form two or more types of cations



iron(II) chloride

ferrous chloride



Cation

English name (oxidation number

In Latin numbers) **iron(II)** ion

Cation

Stem of latin name of metal

Fe **Ferrum**

Followed by suffix

-ous lower oxid. state

-ic higher oxid. state

Ferrous ion

IUPAC nomenclature

Naming binary compounds

C. binary compounds containing two nonmetals

Si B P H C S I Br N Cl O F

the element that occurs first in this series is written and name first, the name of the second element retains the –
ide ending

Latin prefix indicates the number of atoms of the element

1 *mono*

2 *di*

3 *tri*

4 *tetra*

5 *penta*

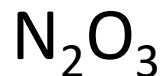
6 *hexa*

7 *hepta*

8 *octa*

9 *nona*

10 *deca*



dinitrogen trioxide



phosphorus pentachloride

IUPAC nomenclature

Naming binary compounds

D. acids derived from binary compounds

HCl(g) hydrogen chloride

HCl(aq) hydrochloric acid

H₂S(g) hydrogen sulfide

H₂S(aq) hydrosulfuric acid

IUPAC nomenclature

Naming binary compounds

D. acids derived from binary compounds

Table 6.5 Names and Formulas of Selected Binary Acids

Formula	Acid name	Formula	Acid name
HF	Hydrofluoric acid	HI	Hydroiodic acid
HCl	Hydrochloric acid	H ₂ S	Hydrosulfuric acid
HBr	Hydrobromic acid	H ₂ Se	Hydroselenic acid

IUPAC nomenclature

D. acids derived from binary compounds

Name the following oxoanions and their corresponding acids:

ClO^- : *hypochlorite* ion

HClO : hypochlorous acid

ClO_2^- : chlor*ite* ion

HClO_2 : chlorous acid

ClO_3^- : chlor*ate* ion

HClO_3 : chloric acid

ClO_4^- : *perchlorate* ion

HClO_4 : perchloric acid

IUPAC nomenclature

Acids

acid formulas often begin with H

binary acids HCl H₂S

oxy-acids H₂SO₄ HNO₃

polyatomic anion acid -ate \longrightarrow -ic acid
 -ite \longrightarrow -ous acid

PO_4^{-3}	Phosph <u>ate</u> ion	H_3PO_4	Phosph <u>ic</u> acid
SO_4^{-2}	Sulf <u>ate</u> ion	H_2SO_4	Sulfur <u>ic</u> acid
SO_3^{-2}	Sulf <u>ite</u> ion	H_2SO_3	Sulfur <u>ous</u> acid

Acids

Table 6.9 Comparison of Acid and Anion Names for Selected Oxy-Acids

Acid	Anion	Acid	Anion
H_2SO_4 Sulfuric acid	SO_4^{2-} Sulfate ion	H_3PO_4 Phosphoric acid	PO_4^{3-} Phosphate ion
H_2SO_3 Sulfurous acid	SO_3^{2-} Sulfite ion	H_3PO_3 Phosphorous acid	PO_3^{3-} Phosphite ion
HNO_3 Nitric acid	NO_3^- Nitrate ion	HIO_3 Iodic acid	IO_3^- Iodate ion
HNO_2 Nitrous acid	NO_2^- Nitrite ion	$\text{HC}_2\text{H}_3\text{O}_2$ Acetic acid	$\text{C}_2\text{H}_3\text{O}_2^-$ Acetate ion
H_2CO_3 Carbonic acid	CO_3^{2-} Carbonate ion	$\text{H}_2\text{C}_2\text{O}_4$ Oxalic acid	$\text{C}_2\text{O}_4^{2-}$ Oxalate ion
H_3BO_3 Boric acid	BO_3^{3-} Borate ion	HBrO_3 Bromic acid	BrO_3^- Bromate ion

IUPAC nomenclature

Naming of compound

Compound	Ions	Name
NaHCO_3	Na^+ ; HCO_3^-	sodium hydrogen carbonate
NaHS	Na^+ ; HS^-	sodium hydrogen sulfide
MgNH_4PO_4	Mg^{2+} ; NH_4^+ ; PO_4^{3-}	magnesium ammonium phosphate
NaKSO_4	Na^+ ; K^+ ; SO_4^{2-}	sodium potassium sulfate

IUPAC nomenclature

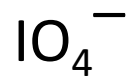
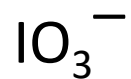
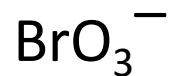
Naming of compound

Table 6.8 Names of Selected Compounds That Contain More Than One Kind of Positive Ion

Formula	Name of compound
KHSO_4	potassium hydrogen sulfate
$\text{Ca}(\text{HSO}_3)_2$	calcium hydrogen sulfite
NH_4HS	ammonium hydrogen sulfide
MgNH_4PO_4	magnesium ammonium phosphate
NaH_2PO_4	sodium dihydrogen phosphate
Na_2HPO_4	sodium hydrogen phosphate
KHC_2O_4	potassium hydrogen oxalate
$\text{KAl}(\text{SO}_4)_2$	potassium aluminum sulfate
$\text{Al}(\text{HCO}_3)_3$	aluminum hydrogen carbonate

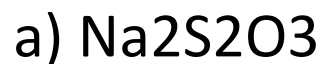
Questions

Name the following:

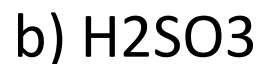


Questions

Determine the oxidation number of S in each of the following:



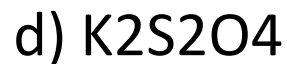
a) _____



b) _____



c) _____



d) _____



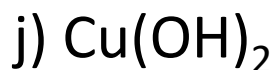
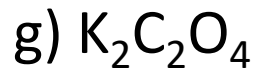
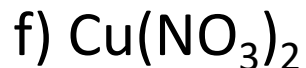
e) _____



f) _____

Questions

Name the following compounds.



Questions

Write formulas for the following compounds.

a) ammonium sulfide

b) magnesium phosphate

c) mercury(II) thiocyanate

d) sodium iodate

e) chromium(III) chloride

f) potassium permanganate

g) zinc bromide

h) cobalt(II) perchlorate

i) Mercury(I) chloride

j) Plumbous sulfide

Questions

Write formulas for the following acids and bases.

a) nitrous acid

b) phosphoric acid

c) sodium hydroxide

d) bromic acid

e) tin(II) hydroxide

f) hydroiodic acid

g) hypobromous acid

h) aluminum hydroxide

i) zinc hydroxide

Questions

Name the following acids and bases.

a) H_2SO_3

b) $\text{Sn}(\text{OH})_4$

c) HNO_3

d) KOH

e) HIO_4

f) HF

g) $\text{Fe}(\text{OH})_3$

h) H_2SO_4

i) H_3PO_3

j) $\text{HC}_2\text{H}_3\text{O}_2$

k) HClO