

# **Naming inorganic compounds**

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## **Atom**


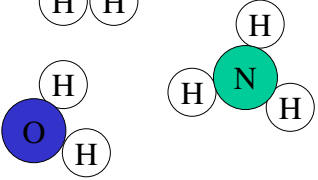
- **Smallest particle of a pure element having its chemical properties**
- **Positively charged nucleus (protons, neutrons)**
- **Negatively charged electron shell:**
  - Electron is wave/particle
  - Behavior of electron described by quantum mechanics (... wave function, quantum numbers)
  - Orbital: space area within the atom shell where occurrence of an electron or pair of electrons is more probable
- **Structure of electron shell determines chemical properties**
  - Valence electrons
  - The octet rule

## Periodic table of elements

Group→	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period																		
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	*	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	* *	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo
			*	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
			**	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

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## Molecular (covalent) compounds

- Consist of particles (molecules) made of several atoms connected with **covalent bonds**
- Examples of molecules:
  - Gases: diatomic 
  - H<sub>2</sub>O, NH<sub>3</sub> etc. 
  - Covalently-bonded crystals: diamond
  - Macromolecules of proteins and nucleic acids

## Diamond and graphite

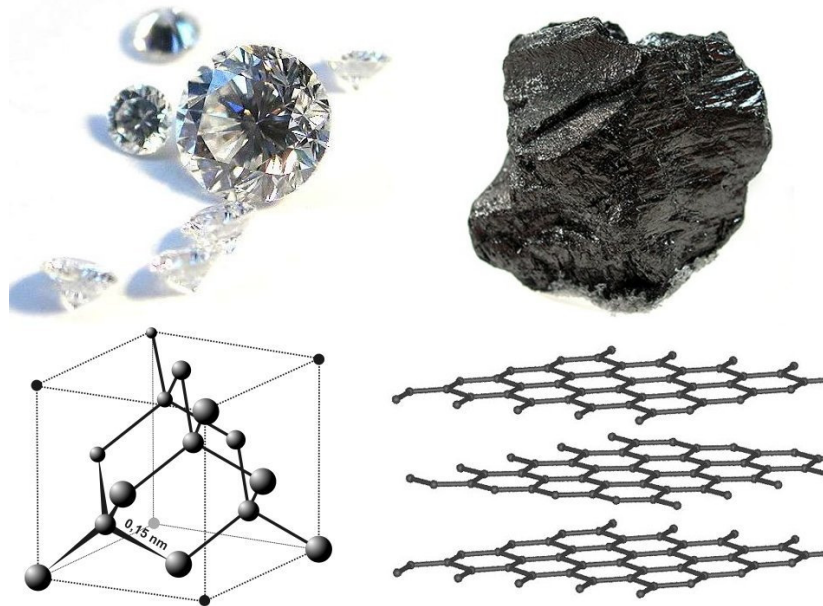
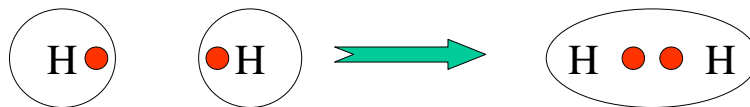


Fig. from Wikipedia

## Covalent chemical bond

- Most often between two non-metals
- Chemical bond that results from two nuclei attracting the same pair(s) of electrons
- Based on electron sharing



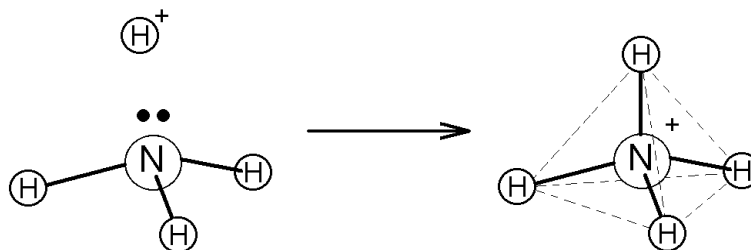
- If more pairs shared ... double or triple bonds
- Some atoms may also have nonbonding (lone) electron pairs

## Valence

- Number of covalent bonds formed by an atom
- The octet rule: tendency to achieve electron configuration of the nearest noble gas
  - e.g. H-F: H achieves configuration of He, F configuration of Ne
- Therefore O usually bivalent, N trivalent, C tetravalent etc.

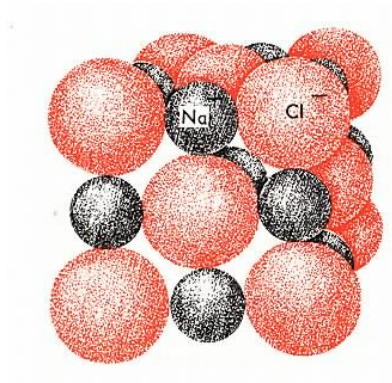
## Coordination covalent bond

- (also dative, donor-acceptor bond)
- Both bonding electrons provided by one of the atoms (donor), whereas the other atoms provides an empty orbital (akceptor)



## Ionic compounds

- Consist of charged particles (ions) held together by **ionic bonds**
- Metal + non-metal(s)
- Cations (+) and anions (-) combine in space to achieve electroneutrality

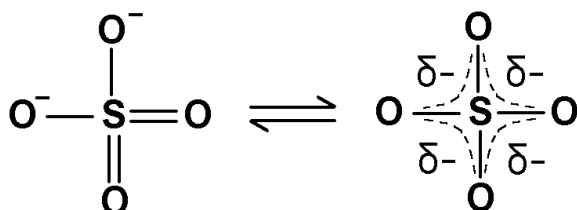


## Ions

- Charged because number of electrons does not match number of protons
- Tendency to form ions depends on **electronegativity** of element
- Monoatomic:  $\text{Na}^+$ ,  $\text{Cl}^-$ ,  $\text{H}^+$ ,  $\text{Fe}^{2+}$
- Polyatomic:  $\text{NO}_3^-$ ,  $\text{SO}_4^{2-}$
- Complex:  $[\text{Fe}(\text{CN})_6]^{4-}$

## Polyatomic ions of oxo-acids:

e.g. sulfate,  $\text{SO}_4^{2-}$  :



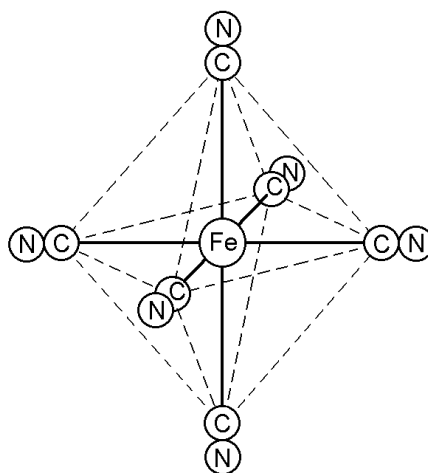
resonance stabilization of sulfate ion

..similar is nitrate  $\text{NO}_3^-$ , phosphate  $\text{PO}_4^{3-}$ , carbonate  $\text{CO}_3^{2-}$ , etc.

## Coordination (complex) ions

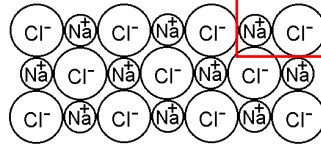
e.g.  $[\text{Fe}(\text{CN})_6]^{4-}$

- central atom of transition metal providing empty orbitals
- ligands providing free electron pairs
- Number of ligands (coordination number) is usually 4 or 6

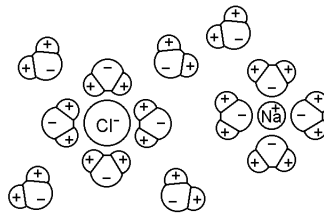


## Ionic salts: no true molecule

- **Crystal lattice of NaCl:** Na<sup>+</sup> Cl<sup>-</sup> **Formula unit**

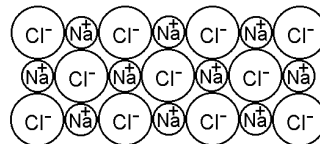
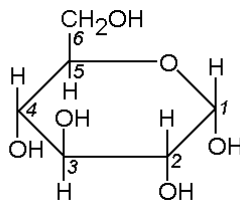


- **Dissolution of NaCl in water: electrolytic dissociation producing hydrated independent ions Na<sup>+</sup>, Cl<sup>-</sup>**



## Chemical formulas

- **Stoichiometric (empirical):**
  - e.g.: glucose  $\text{CH}_2\text{O}$ ; sodium chloride  $\text{NaCl}$
- **Molecular:**
  - e.g.: glucose  $\text{C}_6\text{H}_{12}\text{O}_6$ ; sodium chloride  $\text{NaCl}$
- **Structural:**



## Polarity of chemical bond

*Determined by difference in electronegativity  
of the two connected atoms:*

< 0.4 nonpolar covalent bond

e.g. H-H, carbon-hydrogen


0.4 - 1.7 polar covalent bond

e.g. H-O-H, NH<sub>3</sub>, carbon-oxygen, carbon-nitrogen

>1.7 ionic bond

e.g. NaCl...

Gradual  
transition !



## Oxidation number (formal valency)

- Oxidation number of element in compound equals its charge after giving all bonding electron pairs to the more electronegative atom
- Can be zero, positive or negative integer
- Basis for nomenclature of inorganic compounds
- Redox reactions: oxidation number increases in oxidation, decreases in reduction



### Rules for determination of oxidation numbers

- Free electroneutral atom, or atom in molecule of pure element: oxidation number = 0
- Oxidation number of a monoatomic ion equals its charge
- In heteroatomic compounds the bonding electrons are given to the more electronegative atom, practically:
  - H has nearly always oxidation number I (only in metallic hydrides -I)
  - O almost always -II (only in peroxides -I)
  - F always -I
  - Alkali metals (Na, K..) always I
  - Alkaline earth elements (Ca, Mg..) always II

### Rules for determination of oxidation numbers

Examples:



Sum of oxidation numbers of all atoms in electroneutral molecule is 0, in polyatomic ion equals the ion charge



## Czech nomenclature of oxides:

Oxidation number	Suffix	General formula
I	-ný	$X_2O$
II	-natý	$XO$
III	-itý	$X_2O_3$
IV	-ičitý	$XO_2$
V	-ečný/-ičný	$X_2O_5$
VI	-ový	$XO_3$
VII	-istý	$X_2O_7$
VIII	-ičelý	$XO_4$

## Naming Binary Ionic Compounds

- Compounds of one metallic element and one nonmetal (e.g. metallic oxides, hydroxides, halogenides, sulfides)
- Name of metal + stem of nonmetal + **-ide**
- Examples:
  - $Al_2O_3$ , aluminum oxide
  - $Ba(OH)_2$ , barium hydroxide
  - $KCl$ , potassium chloride
  - $ZnS$ , zinc sulfide

## Naming Binary Ionic Compounds

- Numerical prefixes are never used.
- If the metal can exist in more oxidation states, its oxidation number is included to the name
- Examples:
  - $\text{FeCl}_3$ , iron(III) chloride (ferric chloride)
  - $\text{FeCl}_2$ , iron(II) chloride (ferrous chloride)
  - $\text{CuO}$ , copper(II) oxide (cupric oxide)
  - $\text{Cu}_2\text{O}$ , copper(I) oxide (cuprous oxide)

## Naming Binary Molecular Compounds

- Compounds of two nonmetals (e.g. oxides of nonmetals)
- Name of less electronegative element + stem of the other element + **-ide**
- Numerical prefixes precede names of both nonmetals
- Examples:
  - $\text{CO}$ , carbon monoxide
  - $\text{N}_2\text{O}_5$ , dinitrogen pentoxide
  - $\text{CCl}_4$ , carbon tetrachloride
  - $\text{H}_2\text{S}$ , hydrogen sulfide

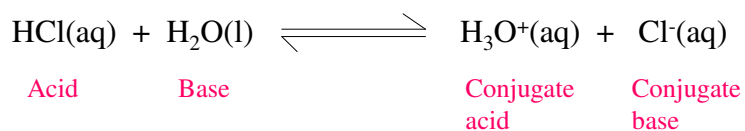
## Numerical prefixes:

Number	Prefix
1	mono-
2	di-
3	tri-
4	tetra-
5	penta-
6	hexa-
7	hepta-
8	octa-
8	nona-
10	deca-

## Naming acids and their salts

Brønsted-Lowry concept of acids and bases:

- Acid is a proton donor
- Base is a proton acceptor



Salt: ionic compound, product of neutralization reaction between acid and base (the acidic proton replaced with metal cation)

## Naming acids and their salts

### A) hydroacids:

Gaseous nonmetallic hydrides whose aqueous solutions are acidic

E.g. HCl, hydrochloric acid (aqueous hydrogen chloride), salts: chloride

Likewise:

- HBr, hydrobromic acid, salts bromides
- H<sub>2</sub>S, hydrosulfuric acid, salts sulfides
- HCN, hydrocyanic acid, salts cyanides

## Naming acids and their salts

### B) oxo-acids:

Central atom + -OH groups, protons dissociate from oxygen. In salts appear as polyatomic anions

If only one oxidation state of the central atom is possible:

Stem of the central atom + **-ic acid**

E.g. H<sub>2</sub>CO<sub>3</sub>, carbonic acid, salt: carbonate

## Naming acids and their salts

### B) oxo-acids:

If there are two possible oxidation states of the central atom:

Higher ox. number: **-ic acid**, salt: **-ate**

Lower ox. number: **-ous acid**, salt: **-ite**

Example:

$\text{H}_2\text{SO}_4$ , sulfuric acid, salt: sulfate

$\text{H}_2\text{SO}_3$ , sulfurous acid, salt: sulfite

## Naming acids and their salts

### B) oxo-acids:

If there are more than two possible oxidation states of the central atom, prefixes are used:

$\text{HClO}$ , hypochlorous acid, salt: hypochlorite

$\text{HClO}_2$ , chlorous acid, salt: chlorite

$\text{HClO}_3$ , chloric acid, salt: chlorate

$\text{HClO}_4$ , perchloric acid, salt: perchlorate

**The oxidation numbers can also be used with metals in anions:**

$\text{MnO}_4^{2-}$ : **manganate(VI)** or just **manganate**

$\text{MnO}_4^-$ : **manganate(VII)** or **permanganate**

$[\text{Fe}(\text{CN})_6]^{4-}$ : **hexacyanoferrate(II)**  
or **ferrocyanide**

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

**Naming coordination compounds**

- Names of neutral ligands:
  - $\text{H}_2\text{O}$  aqua
  - $\text{NH}_3$  ammin
  - $\text{NO}$  nitrosyl
  - $\text{CO}$  carbonyl
- Names of anionic ligands always end in –o:
  - $\text{F}^-$  fluoro
  - $\text{Cl}^-$  chloro
  - $\text{Br}^-$  bromo
  - $\text{I}^-$  iodo
  - $\text{OH}^-$  hydroxo
  - $\text{CN}^-$  cyano
  - etc..

## Naming coordination compounds

### 1. Complex particle is cation:

e.g.  $[\text{Cu}(\text{NH}_3)_4]\text{SO}_4$

$[\text{Cu}(\text{NH}_3)_4]^{2+} + \text{SO}_4^{2-}$

Tetraamminecopper(II) sulfate

### 2. Complex particle is anion:

e.g.  $\text{K}_3[\text{CoF}_6]$

$3 \text{K}^+ + [\text{CoF}_6]^{3-}$

Potassium hexafluorocobaltate(III)

## Naming coordination compounds

### 3. Both cation and anion are complexes:

e.g.  $[\text{Pt}(\text{NH}_3)_4][\text{PtCl}_4]$

$[\text{Pt}(\text{NH}_3)_4]^{2+} + [\text{PtCl}_4]^{2-}$

Tetraammineplatinum(II) tetrachloroplatinate(II)

### 4. Neutral complexes:

e.g.  $[\text{CrCl}_3(\text{H}_2\text{O})_3]$

Triaquatrchlorochromium(III) complex