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Structure 2.1

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Ions

Positive ions (cations)

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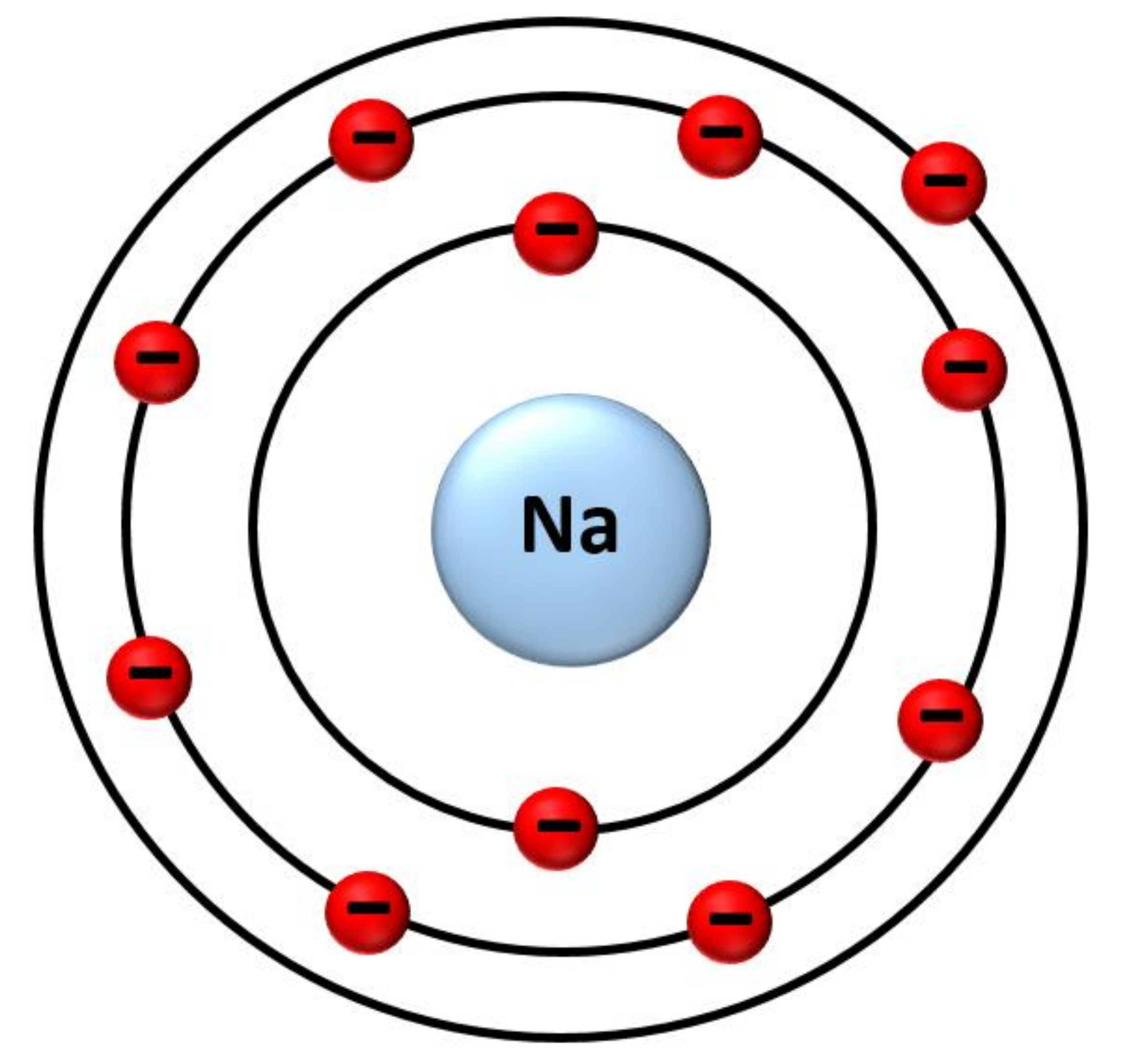
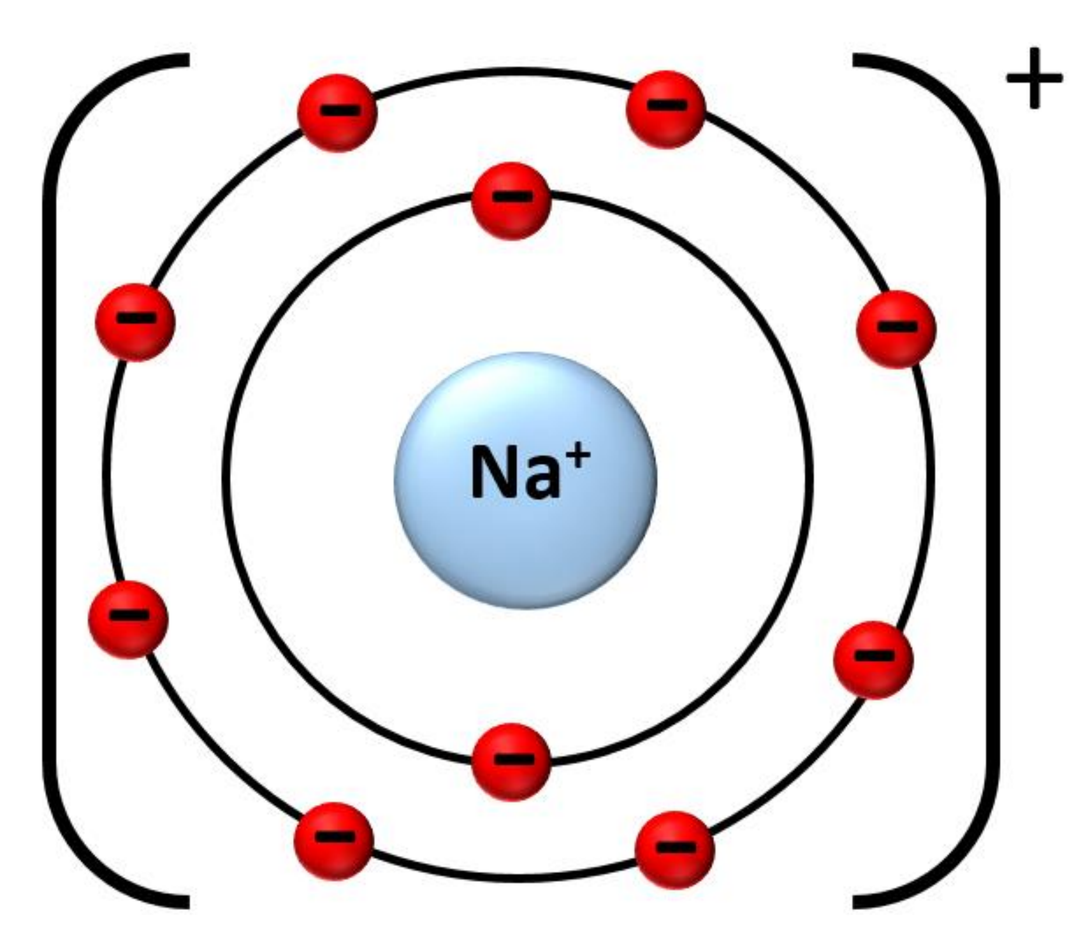
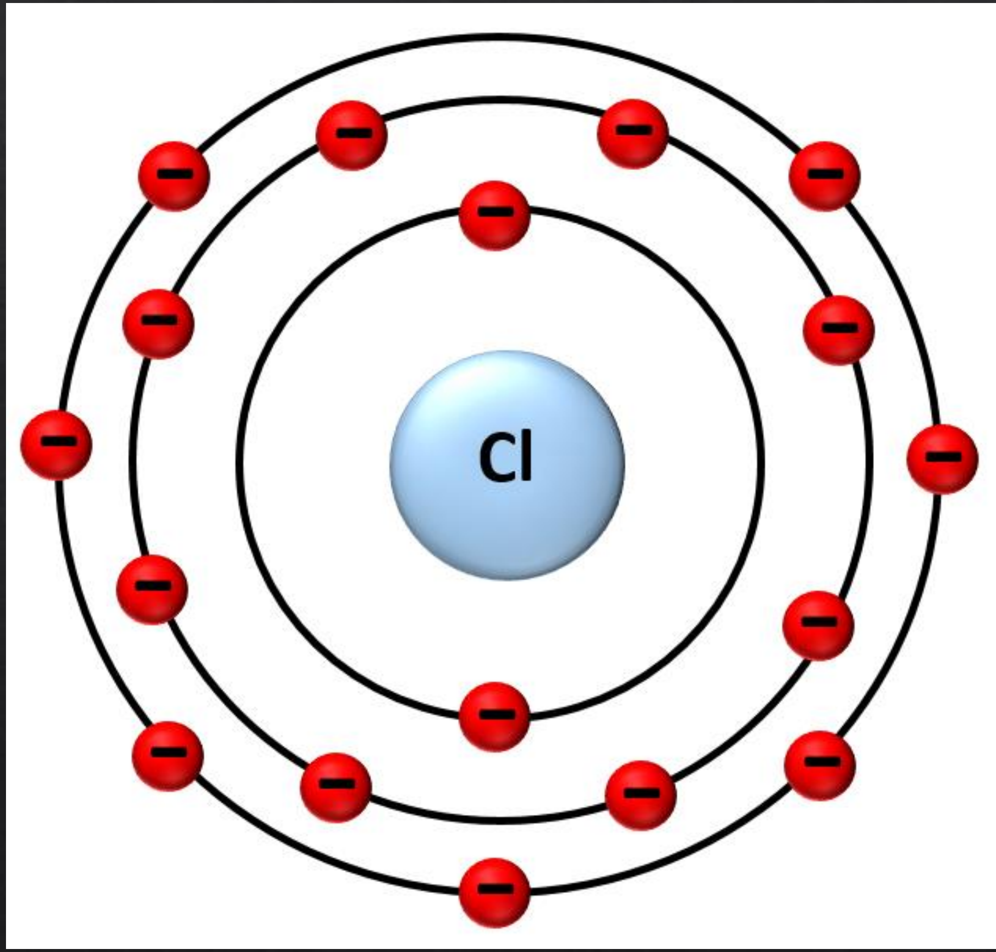


$1s^2\ 2s^2\ 2p^6\ 3s^1$

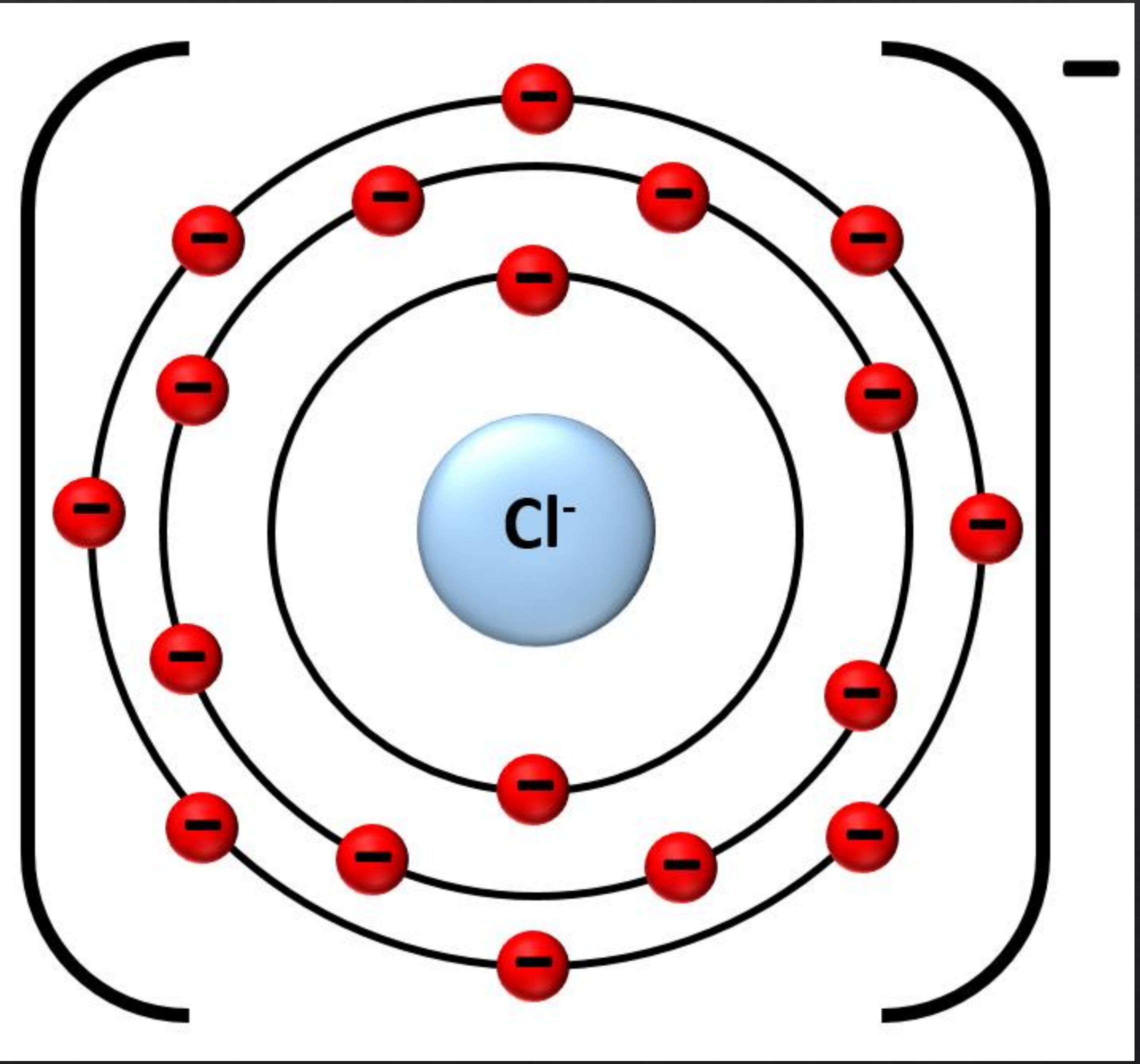


$1s^2\ 2s^2\ 2p^6$

Negative ions (anions)



$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$



$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

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Ions

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	1+	2+											3+		3-	2-	1-	
1	1 H 1.01																	2 He 4.00
2	3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.63	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.90
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.96	43 Tc (98)	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
6	55 Cs 132.91	56 Ba 137.33	57 † La 138.91	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.20	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)	89 ‡ Ac (227)	104 Rf (267)	105 Db (268)	106 Sg (269)	107 Bh (270)	108 Hs (269)	109 Mt (278)	110 Ds (281)	111 Rg (281)	112 Cn (285)	113 Uut (286)	114 Uuq (289)	115 Uup (288)	116 Uuh (293)	117 Uus (294)	118 Uuo (294)

†	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05	71 Lu 174.97
‡	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

Key:
Atomic number
Element
Relative atomic mass

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Ions

Group number	Number of valence electrons	Charge on ion	Example
1	1	1+	Li^+
2	2	2+	Mg^{2+}
13	3	3+	Al^{3+}
15	5	3-	P^{3-}
16	6	2-	O^{2-}
17	7	1-	F^-

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Ions

Name of ion	Charge on ion	Formula
carbonate ion	2-	CO_3^{2-}
sulfate ion	2-	SO_4^{2-}
nitrate ion	1-	NO_3^-
hydrogen carbonate ion	1-	HCO_3^-
phosphate ion	3-	PO_4^{3-}
hydroxide ion	1-	OH^-
ammonium ion	1+	NH_4^+

Ions

Metals have low electronegativity values, therefore, they lose electrons to form positive ions.

Non-metals have high electronegativity values, therefore, they gain electrons to form negative ions.

By either losing or gaining electrons, the ions achieve the electron configuration of a noble gas.

The oppositely charged ions are attracted by an electrostatic attraction (ionic bonding).

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Ionic bonding

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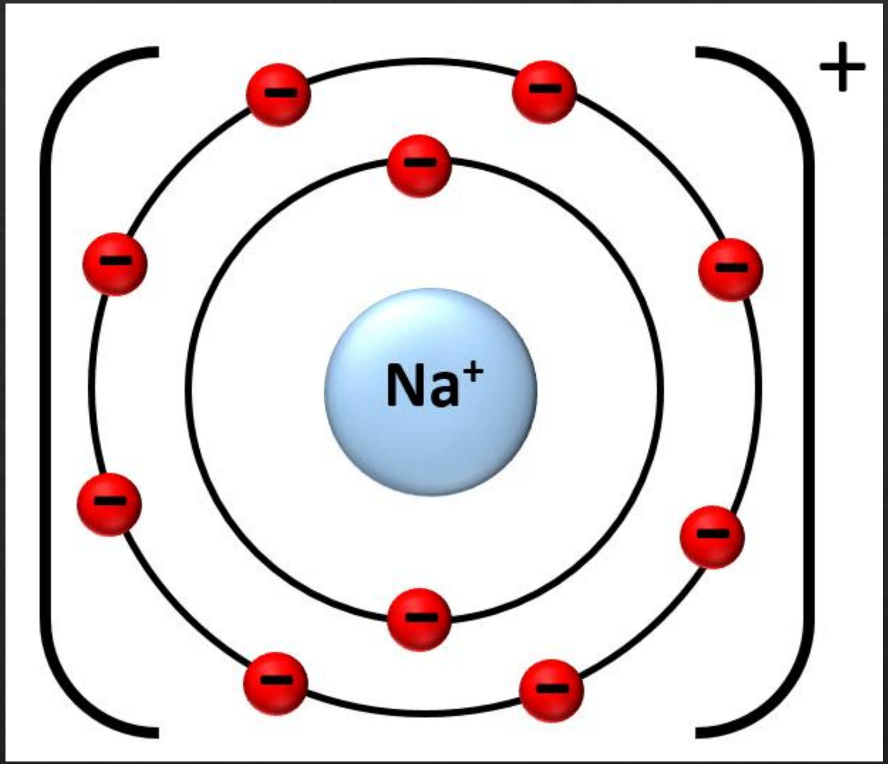
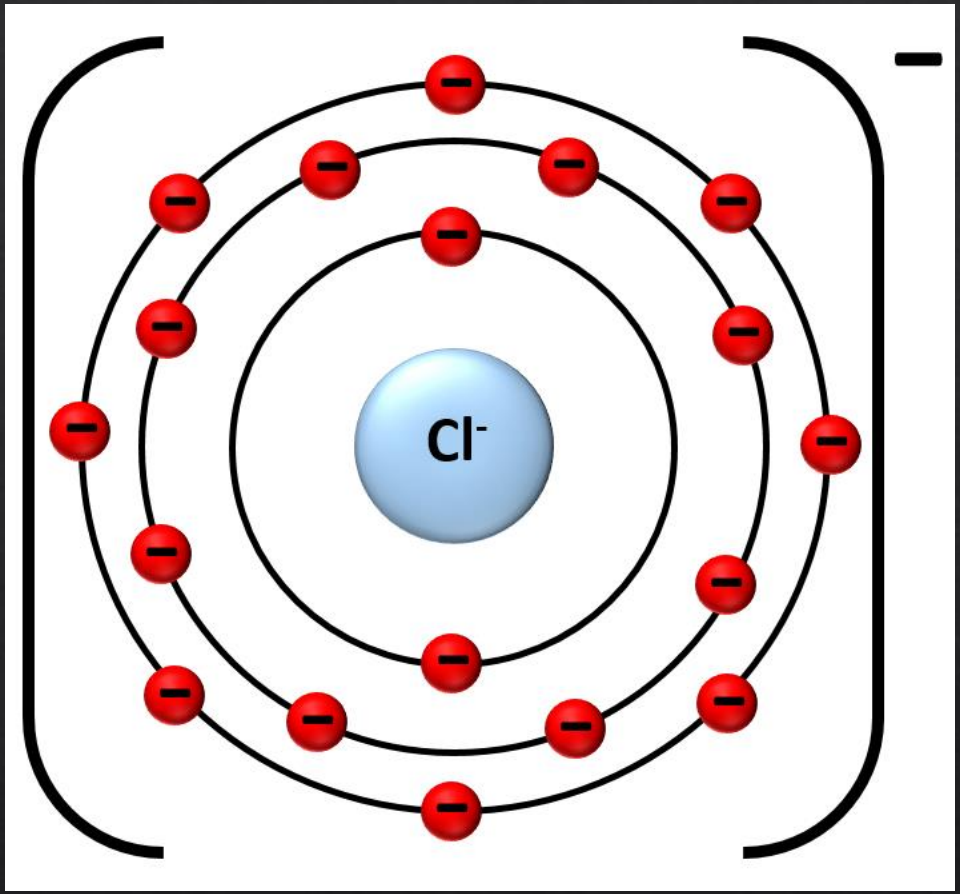
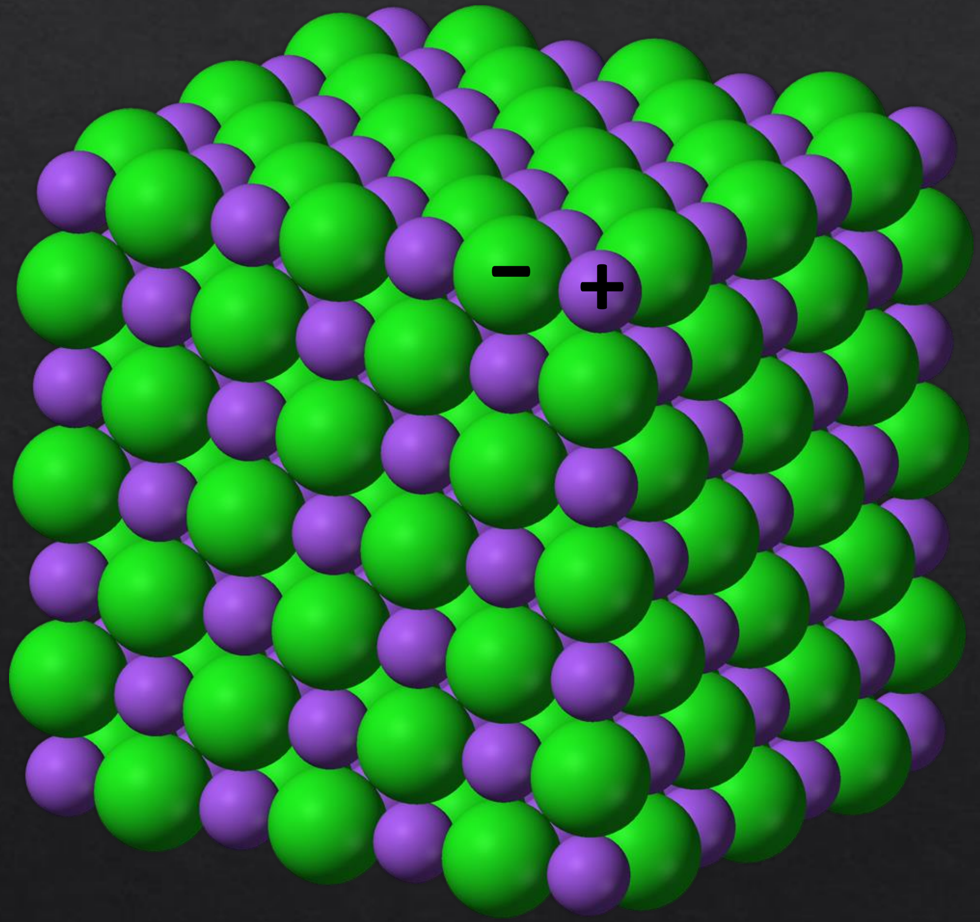
Ionic bonding





An ionic bond is the electrostatic attraction between oppositely charged ions.

Ionic bonding



Ionic compounds have a lattice structure.

The lattice is held together by the positive and negative charges of the oppositely charged ions.

Ionic compounds are solids under standard conditions - they have high melting and boiling points.

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Writing formulas of ionic compounds

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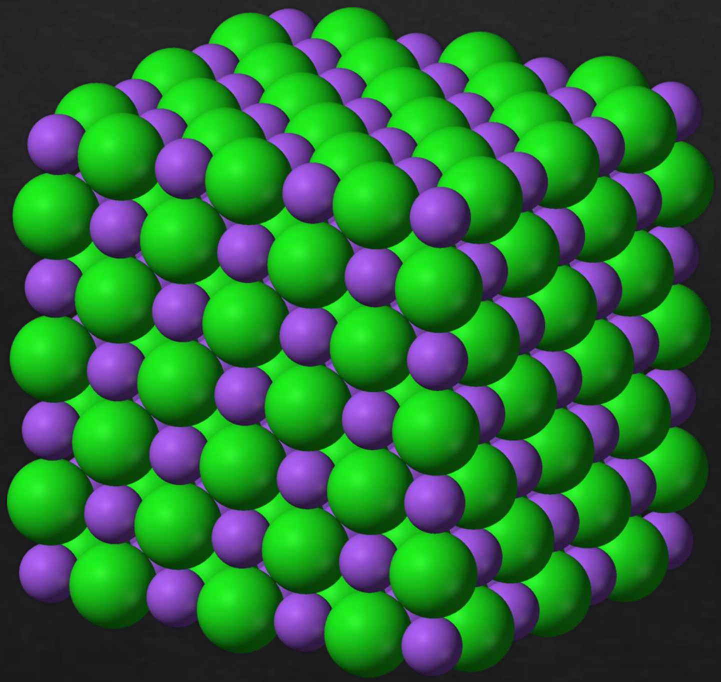
Formulas of ionic compounds

Ionic compounds consist of a lattice of oppositely charged ions held together by electrostatic attractions. A formula unit is the lowest whole number ratio of ions in an ionic compound.



Sodium chloride – $NaCl$

The ratio of Na^{+} to Cl^{-} ions is 1:1

Magnesium chloride – $MgCl_2$

The ratio of Mg^{2+} to Cl^{-} ions is 1:2

Formulas of ionic compounds

How to determine the formula of an ionic compound:

1. You need to know the charges on the ions (cation and anion) in the compound.
2. Ionic compounds are neutral (no overall charge) so you need to balance out the positive and negative charges on the cation and anion.
3. Formulas need to be written using subscripts and brackets (where necessary).

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Formulas of ionic compounds

Sodium iodide

Na^{+} I^{-}

NaI

Lithium chloride

Li^{+} Cl^{-}

LiCl

Calcium sulfide

Ca^{2+} S^{2-}

CaS

Magnesium oxide

Mg^{2+} O^{2-}

MgO

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Formulas of ionic compounds

Lithium oxide

Li^{+} O^{2-}

Li_2 O_1

Li_2O

Ratio of Li^{+} : O^{2-} ions is 2:1

Calcium chloride

Ca^{2+} Cl^{-}

Ca_1 Cl_2

$CaCl_2$

Ratio of Ca^{2+} : Cl^{-} ions is 1:2

Formulas of ionic compounds

Magnesium nitride

Mg^{2+} N^{3-}

Mg_3 N_2

Mg_3N_2

Ratio of Mg^{2+} : N^{3-} ions is 3:2

Aluminium bromide

Al^{3+} Br^-

Al_1 Br_3

$AlBr_3$

Ratio of Al^{3+} : Br^- ions is 1:3

Formulas of ionic compounds

Zinc sulfate

Zn^{2+} SO_4^{2-}

$ZnSO_4$

Ratio of Zn^{2+} : SO_4^{2-} ions is 1:1

Aluminium phosphate

Al^{3+} PO_4^{3-}

$AlPO_4$

Ratio of Al^{3+} : PO_4^{3-} ions is 1:1

Formulas of ionic compounds

Iron(II) nitrate		Ammonium carbonate	
Fe^{2+}	NO_3^-	NH_4^+	CO_3^{2-}
Fe_1	$(NO_3)_2$	$(NH_4)_2$	CO_3
$Fe(NO_3)_2$		$(NH_4)_2CO_3$	
Ratio of Fe^{2+} : NO_3^- ions is 1:2		Ratio of NH_4^+ : CO_3^{2-} ions is 2:1	

Formulas of ionic compounds

Aluminium nitrate		Zinc phosphate	
Al^{3+}	NO_3^-	Zn^{2+}	PO_4^{3-}
Al_1	$(NO_3)_3$	Zn_3	$(PO_4)_2$
$Al(NO_3)_3$		$Zn_3(PO_4)_2$	

Ratio of Al^{3+} : NO_3^- ions is 1:3

Ratio of Zn^{2+} : PO_4^{3-} ions is 3:2

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Polyatomic ions

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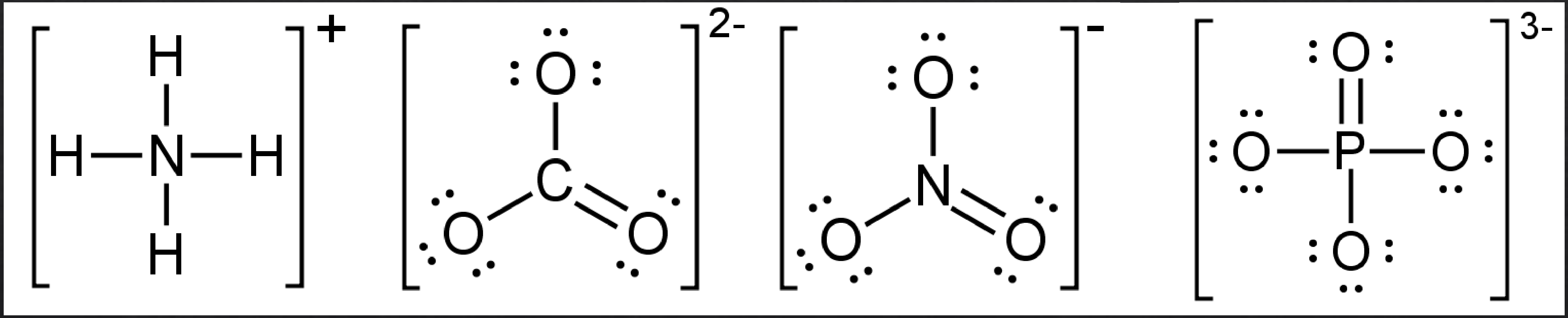
Polyatomic ions

Polyatomic ions (molecular ions) are ions that consist of two or more atoms bonded together with covalent bonds.



Ammonium ion NH_4^+	Carbonate ion CO_3^{2-}	Nitrate ion NO_3^-	Phosphate ion PO_4^{3-}

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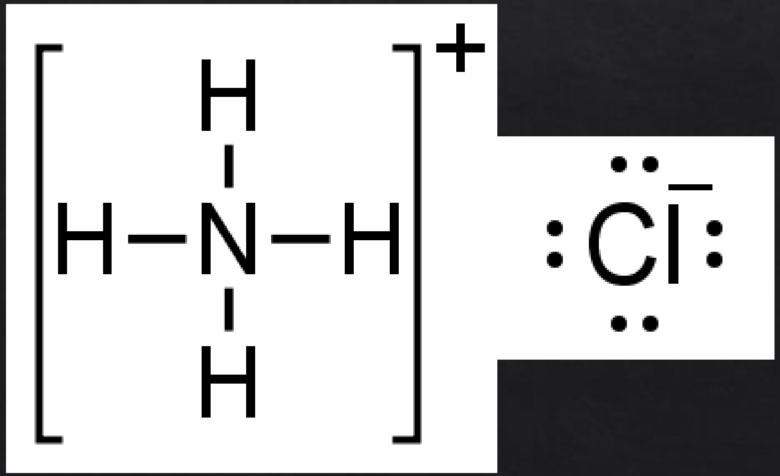
Polyatomic ions

The atoms in a polyatomic ion are bonded with covalent bonds.

The bonding between the ions in a compound that contains a polyatomic ion is ionic.

Ammonium chloride NH_4Cl

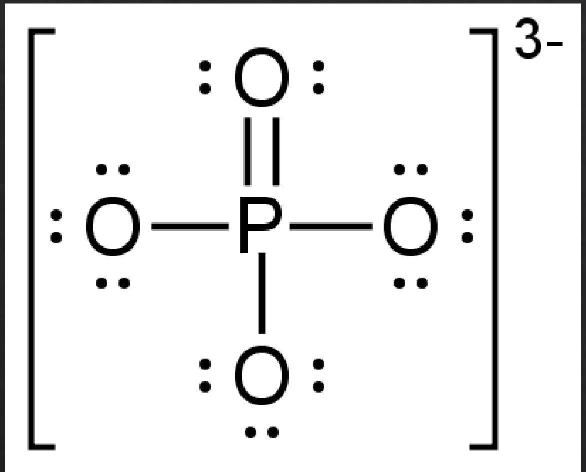


The bonds between the N and H atoms are covalent bonds.

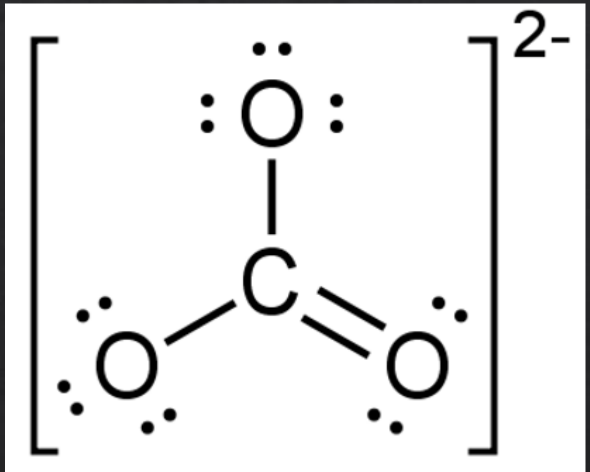
The bonds between the NH_4^+ and Cl^- ions are ionic.

Polyatomic ions

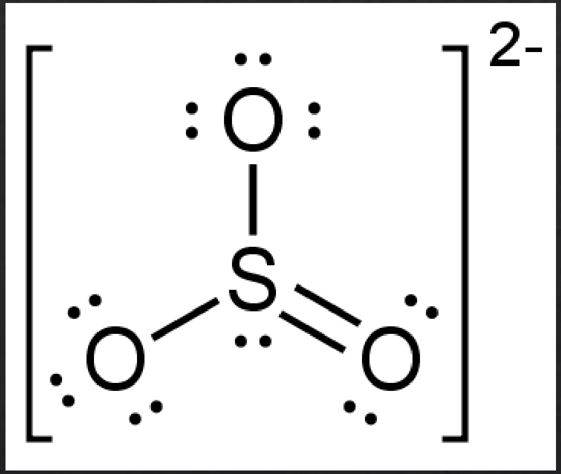
The geometry of a polyatomic ion depends on the number of electron domains around the central atom.



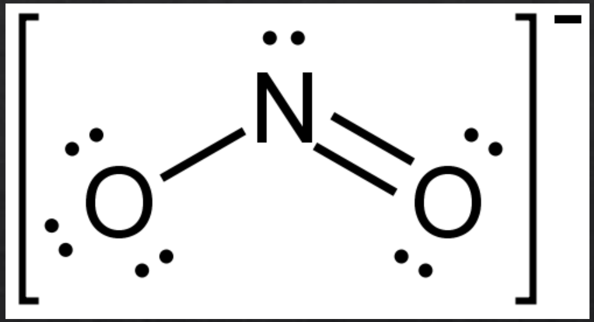
Tetrahedral



Trigonal planar



Tetrahedral
Trigonal pyramidal



Trigonal planar
Bent

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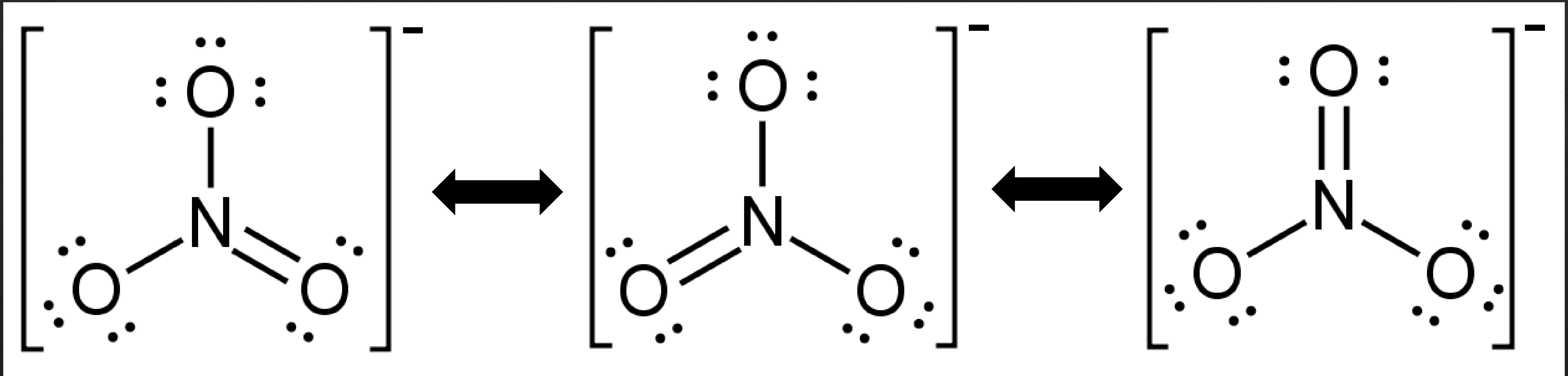
Polyatomic ions

Polyatomic ions with more than one position for a multiple bond exist as resonance structures.



The N-O bonds are identical – intermediate in length and strength between a single and a double bond.

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Polyatomic ions

Name of ion	Formula	Charge
carbonate ion	CO_3^{2-}	2-
sulfate(VI) ion	SO_4^{2-}	2-
sulfate(IV) ion	SO_3^{2-}	2-
nitrate ion	NO_3^-	1-
nitrite ion	NO_2^-	1-
hydrogen carbonate ion	HCO_3^-	1-
phosphate ion	PO_4^{3-}	3-
hydroxide ion	OH^-	1-
ammonium ion	NH_4^+	1+

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Properties of ionic compounds

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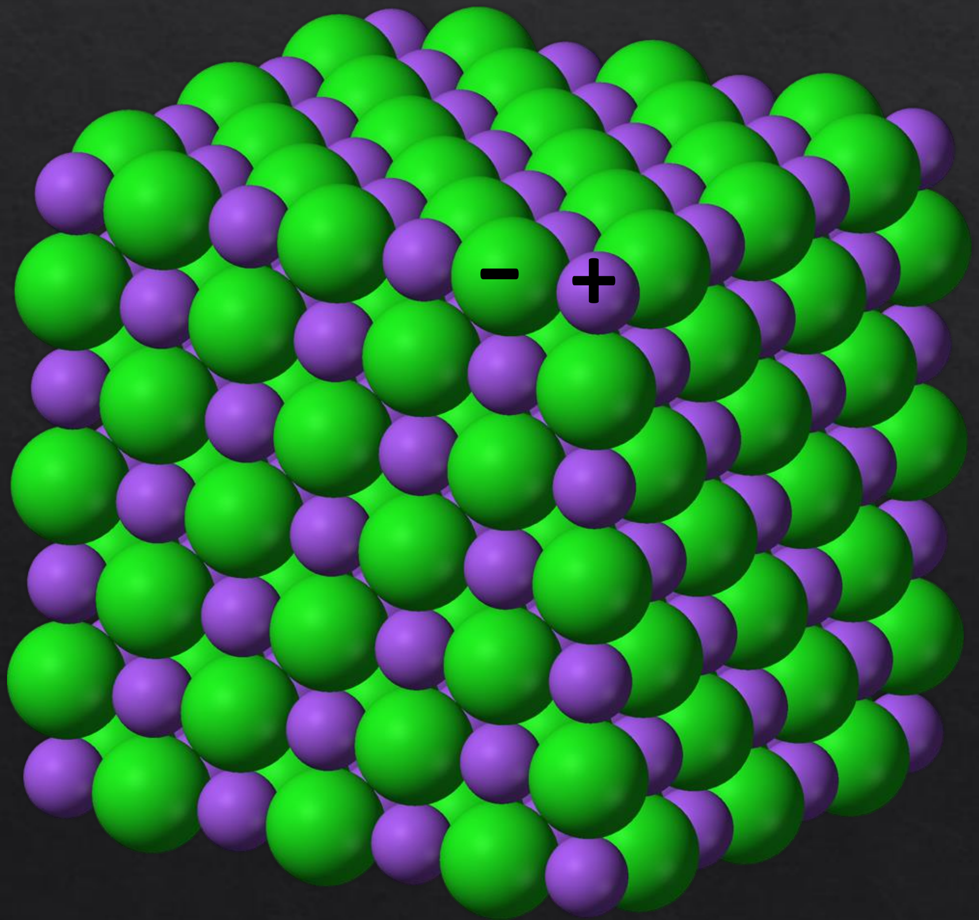
Ionic compounds

Lattice structure of an ionic compound

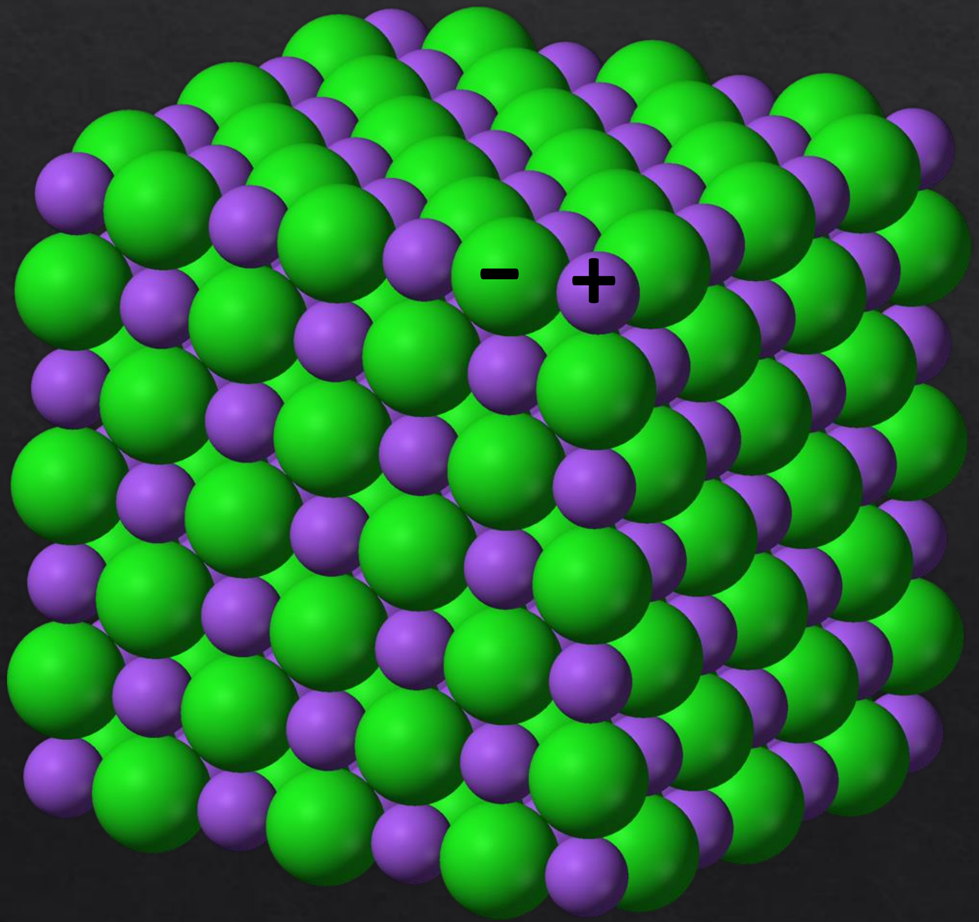


An ionic bond is the electrostatic attraction between oppositely charged ions.

The ions in the lattice structure are held in place by the strong electrostatic attractions.

Ionic compounds

Lattice structure of an ionic compound



An ionic bond is the electrostatic attraction between oppositely charged ions.

The ions in the lattice structure are held in place by the strong electrostatic attractions.

Ionic compounds

Electrical conductivity

- Solid ionic compounds do not conduct electricity because the ions are held in fixed positions.
- They only conduct electricity when melted or dissolved in water.
- When melted or dissolved, the ions are free to move and conduct electricity.

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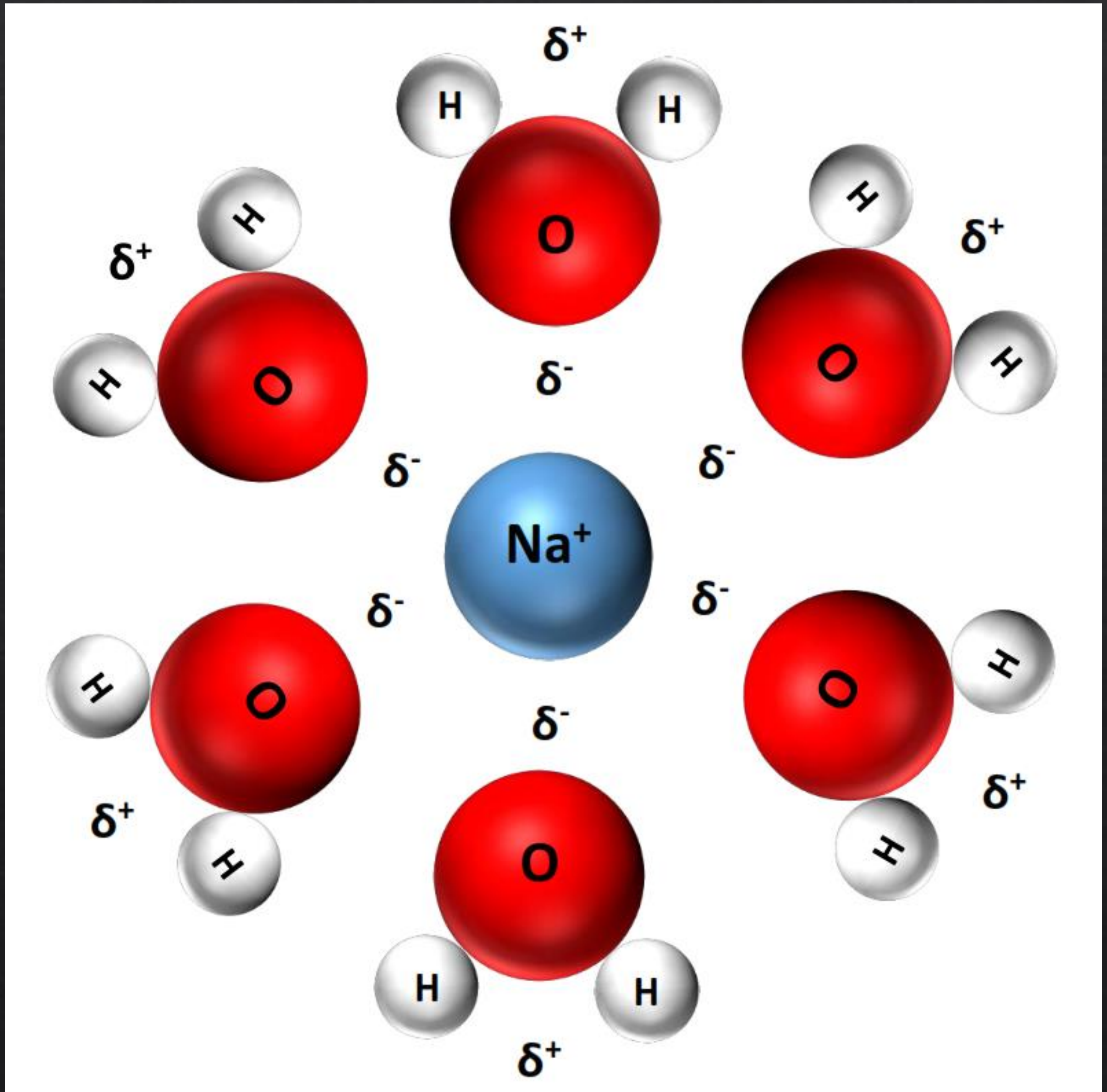
Ionic compounds



Ionic compounds are soluble in polar solvents. The ions are separated from the lattice structure by the polar water molecules. The ions are then surrounded by water molecules (hydration).

Ionic compounds

Effect of ionic charge on melting point

Ionic compound	Cation charge	Anion charge	Melting point (°C)
Na_2O	Na^+	O^{2-}	1132
MgO	Mg^{2+}	O^{2-}	2800

The greater the charge on the ion, the stronger the electrostatic attraction between the oppositely charged ions and the higher the melting point.

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Ionic compounds

Effect of ionic radius on melting point

Ionic compound	Cation radius ($\times 10^{-12}$ m)	Anion radius ($\times 10^{-12}$ m)	Melting point (°C)
NaF	102	133	992
KF	138	133	857

The smaller the ionic radius of the ion, the stronger the electrostatic attraction between the oppositely charged ions and the higher the melting point.

Ionic compounds

Ionic compounds only conduct electricity when molten or dissolved in solution.
They are soluble in polar solvents (such as H_2O).
Ionic compounds have high melting points because of the strong electrostatic attractions between ions.
The greater the charge on the ion and the smaller the ionic radius, the higher the melting point.

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Factors that affect lattice enthalpy

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Lattice enthalpy

Lattice enthalpy, ΔH_{lat}, is the enthalpy change when one mole of a solid ionic compound is broken into its constituent gaseous ions.

$NaCl(s) \rightarrow Na^{+}(g) + Cl^{-}(g)$ $\Delta H_{lat} = +790\ kJ\ mol^{-1}$

$MgCl_2(s) \rightarrow Mg^{2+}(g) + 2Cl^{-}(g)$ $\Delta H_{lat} = +2540\ kJ\ mol^{-1}$

$CaO(s) \rightarrow Ca^{2+}(g) + O^{2-}(g)$ $\Delta H_{lat} = +3401\ kJ\ mol^{-1}$

Lattice enthalpy

Effect of ionic radius on ΔH_{lat}

Ionic compound	Anion radius ($\times 10^{-12}$ m)	Cation radius ($\times 10^{-12}$ m)	ΔH_{lat} (kJ mol^{-1})	Melting point (°C)
NaF	133	102	+930	993
KF	133	138	+829	858

The smaller the ionic radius of the ion, the stronger the electrostatic attraction between the oppositely charged ions and the higher the melting point.

Lattice enthalpy

Effect of ionic charge on ΔH_{lat}

Ionic compound	Anion charge	Cation charge	ΔH_{lat} (kJ mol^{-1})	Melting point (°C)
Na_2O	2-	1+	+2481	1132
MgO	2-	2+	+3791	2852

The greater the charge on the ion, the stronger the electrostatic attraction between the oppositely charged ions and the higher the melting point.