Chemical Bonding I: Basic Concepts

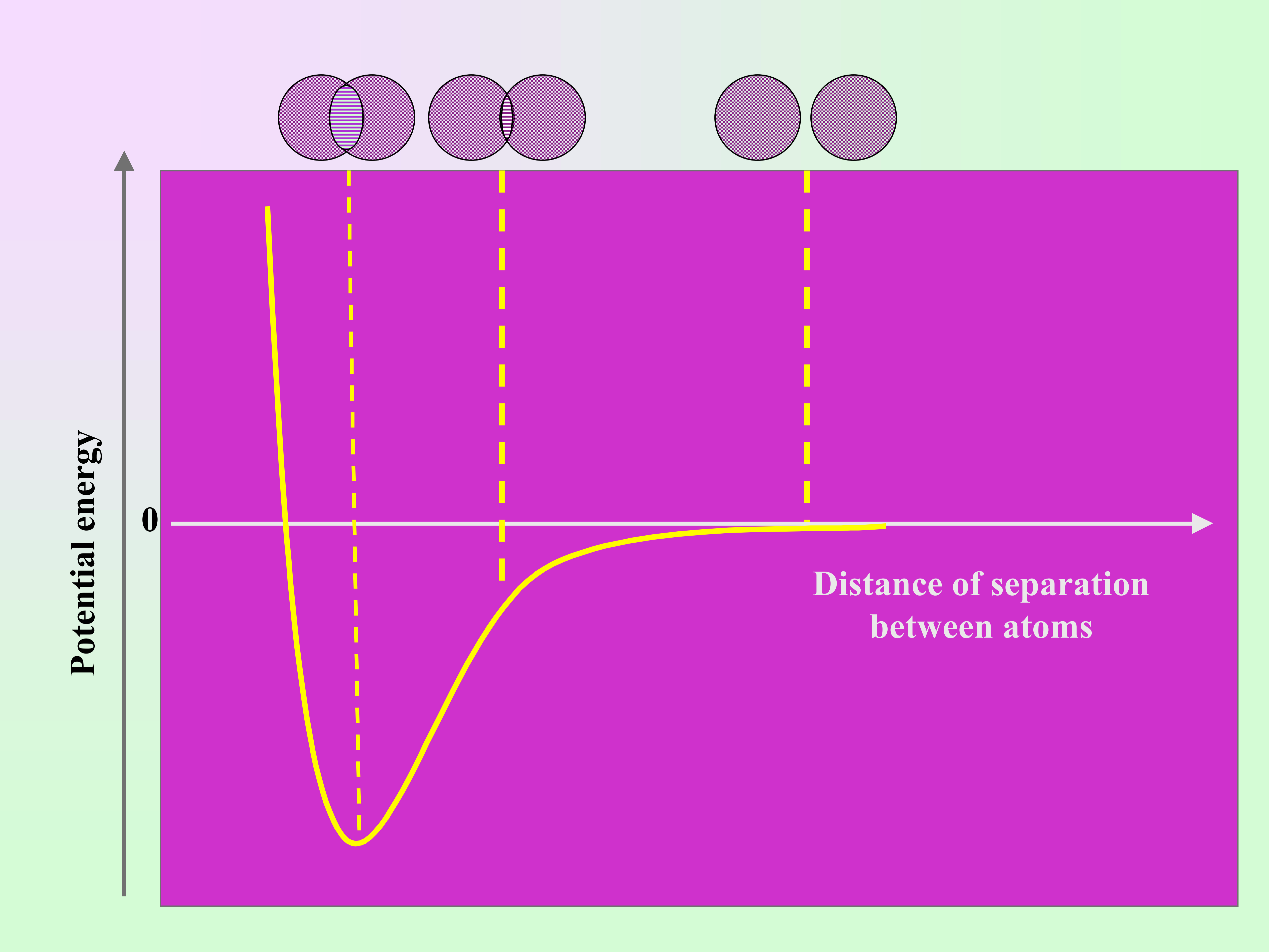
Types of Chemical Bonds

Why do atoms form chemical bonds ?

so that the system can achieve the lowest possible potential energy

Example covalent bonding in H_2

H •   • H


Potential energy
0
Distance of separation
between atoms

Lewis Dot Symbols

A Lewis dot symbol consists of the symbol of an element and one dot for each valence electron in an atom of the element.

Lewis Dot Symbols

1A	2A	3A	4A	5A	6A	7A	8A
H							He
Li	Be	B	C	N	O	F	Ne
Na	Mg	Al	Si	P	S	Cl	Ar
K	Ca	Ga	Ge	As	Se	Br	Kr
Rb	Sr	In	Sn	Sb	Te	I	Xe
Cs	Ba	Tl	Pb	Bi	Po	At	Rn
Fr	Ra						

Ionic Bonding

Ionic compounds

Any compound when melted that conducts electricity is considered ionic

Example : $NaCl_{(s)} \longrightarrow NaCl_{(l)}$

$NaCl_{(s)}$ **is made up of** Na^+ **and** Cl^- **ions**

Ionic Bonding

electrostatic attraction between oppositely charged ions

cation **anion**

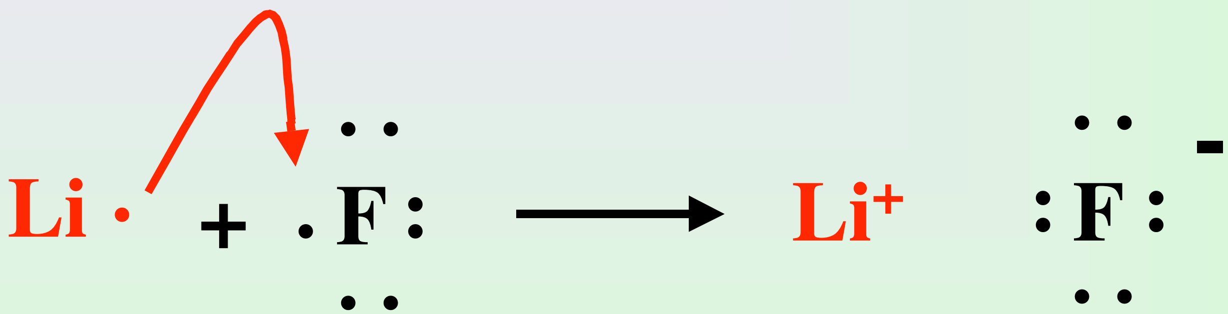
Ionic Bonds

Especially prevalent in compounds formed between group 1A and 2A elements with group 6A and 7A elements.

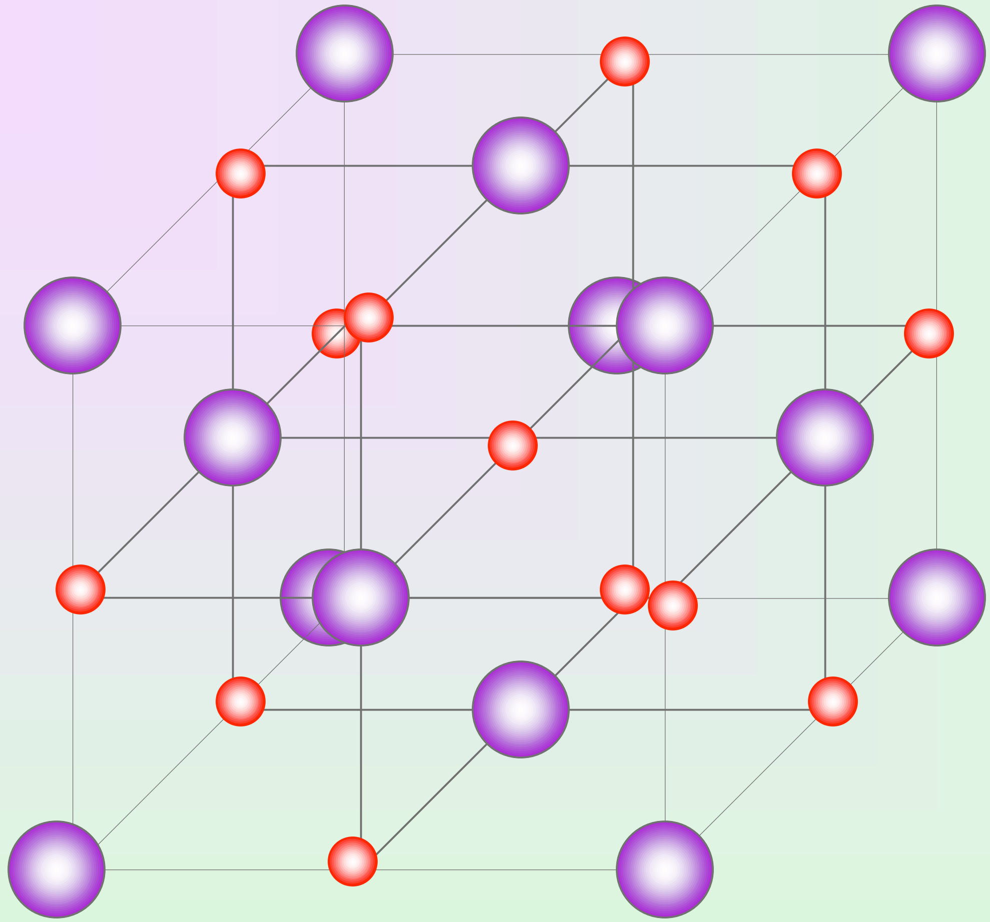
between Elements with the biggest difference in electronegativity

Formation of LiF

$$Li(s) + 1/2\ F_2(g) \longrightarrow LiF(s)$$



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



Solid structure of LiF

Crystal lattice

the ions are packed together to maximize (+) (-) attractions and minimize (+) (+) and (-) (-) repulsions

Coulomb's Law

Energy of electrostatic attraction is directly proportional to product of charge and inversely proportional to distance

$$\text{lattice energy} = k \frac{Q_1 Q_2}{r}$$

$k = (2.31 \times 10^{-19}\ \text{J nm})$

therefore, strong lattices are favored when the ions have a high charge to size ratio

Coulomb's Law Example:

sodium-chlorides energy of interaction is equal to

$$\textbf{lattice energy} = (2.31 \times 10^{-19}\ \text{J nm}) \left(\frac{(Na^{+})(Cl^{-})}{r} \right)$$

Coulomb's Law Example:

For Example: sodium-chlorides energy of interaction is equal to

$$\textbf{lattice energy} = (2.31 \times 10^{-19}\ \text{J nm}) \left(\frac{(+1)(-1)}{r} \right)$$

Coulomb's Law Example:

For Example: sodium-chlorides energy of interaction is equal to

$$\textbf{lattice energy} = (2.31 \times 10^{-19}\ \text{J nm}) \left(\frac{(+1)(-1)}{0.276\ \text{nm}}\right)$$

$$= -8.37 \times 10^{-19}\ \text{J}$$

The negative sign indicates an attractive force

i.e. the ion pair has a lower potential energy

Lattice Energy of Ionic Compounds

Review : Electron affinity

is the energy change that occurs when an electron is accepted by an atom in the gaseous state (kJ/mol).

$$\mathbf{X(g) + \mathit{e}^{-} \longrightarrow X^{-}(g)}$$

The more negative the electron affinity ,the greater the tendency of the atom to accept an electron .

Note:

chlorine **has the greatest electron affinity of any element:**

$$Cl(g) + e^- \longrightarrow Cl^-(g) \qquad \Delta H = -349\ kJ$$

No metal has an ionization energy low enough to make electron transfer to chlorine exothermic

$$Cs(g) \longrightarrow Cs^+(g) + e^- \qquad \Delta H = +382\ kJ$$

Lattice energy

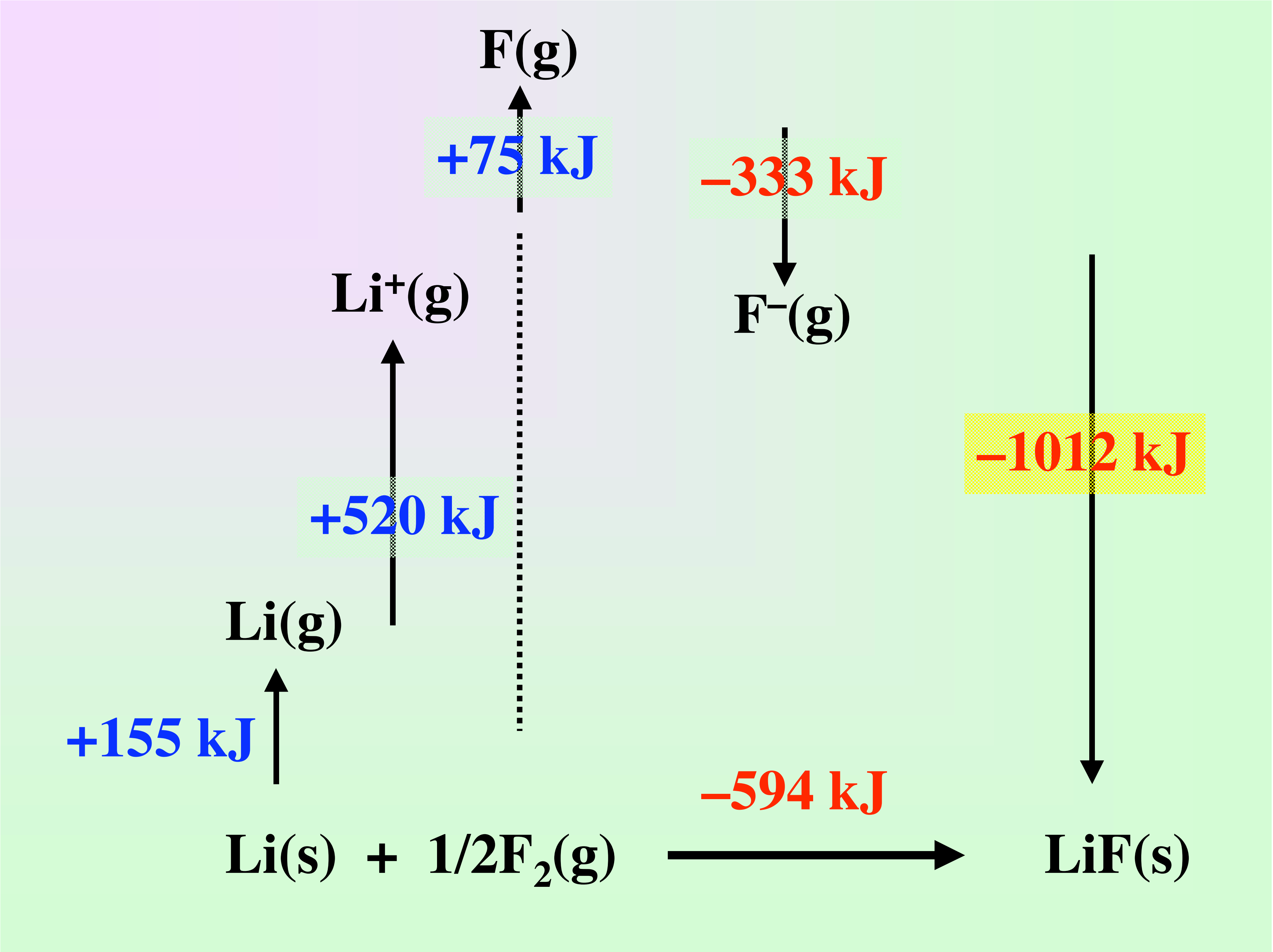
the energy required to completely separate one mole of a solid ionic compound into gaseous ions.

or the energy released when an ionic solid forms from its ions

negative sign (-)

The Born-Haber Cycle for Determining Lattice Energies

Relates lattice energies of ionic compounds to ionization energies, electron affinities, and other atomic and molecular properties.


F(g)
+75 kJ
–333 kJ
Li+(g)
F–(g)
–1012 kJ
+520 kJ
Li(g)
+155 kJ
–594 kJ
Li(s) + 1/2F2(g)
LiF(s)

Formation of ionic compounds

requires Coulombic attractive energy (lattice energy) to be sufficiently large to overcome ionization energy of the element that forms the cation.

balance between energy input (ionization energies) and stability gained from formation of the solid

Formation of ionic compounds

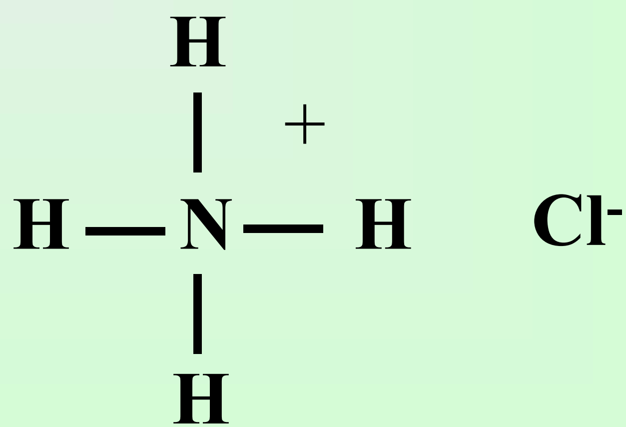
The main impetus for the formation of an ionic compound rather than a covalent compound results from the strong mutual attraction among the ions

Polyatomic ions

Ionic bonding involving polyatomic ions is some what ambiguous

example (ammonium-chloride) NH_4Cl

being that NH_4^+ is held together by covalent bonds



Example

bonding in $MgCl_2$ is ionic;

bonds in $AlCl_3$ are polar covalent

Ionization energies (I.E.)

$$Mg(g) \longrightarrow Mg^{2+}(g) + 2e^-$$

$$\Delta H = I.E._1 + I.E._2$$

$$= 753 + 1435 = +2180 \text{ kJ/mol}$$

$$Al(g) \longrightarrow Al^{3+}(g) + 3e^-$$

$$\Delta H = I.E._1 + I.E._2 + I.E._3$$

$$= 580 + 1815 + 2740 = +4125 \text{ kJ/mol}$$

Example

bonds in $AlCl_3$ are polar covalent

energy input (ionization energies) out weighs stability gained from formation of an ionic solid

$$Al(g) \longrightarrow Al^{3+}(g) + 3e^-$$

$$\Delta H = I.E._1 + I.E._2 + I.E._3$$

$$= 580 + 1815 + 2740 = +4125 \text{ kJ/mol}$$