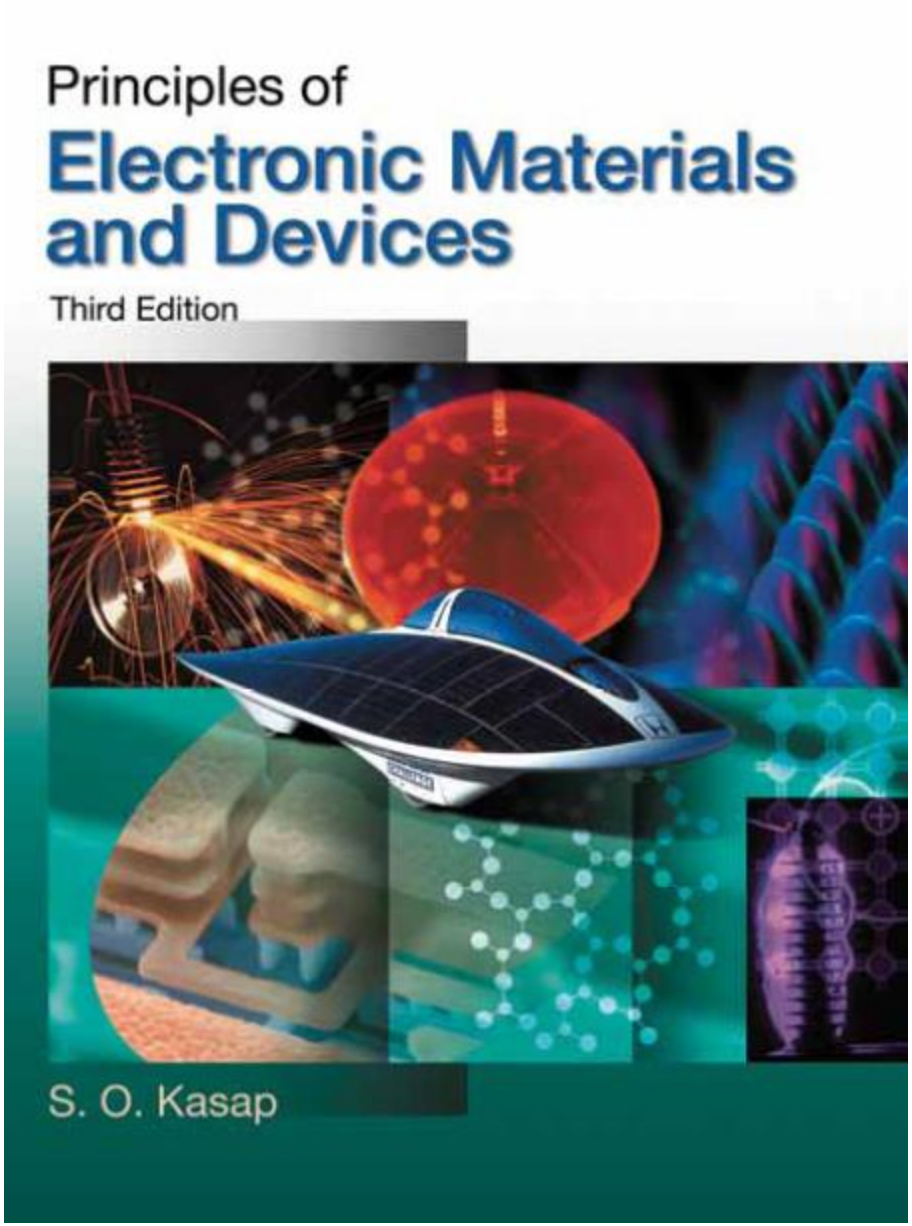
**Solid State Electronics EC210**
**Arab Academy for Science and Technology**
**AAST – Cairo**
**Fall 2016**

# Lecture 2
# Bonding

*Lecture Notes Prepared by:*
Dr. Amr Bayoumi, Dr. Nadia Rafat



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# Pages (Kasap)

p. 49 to 56

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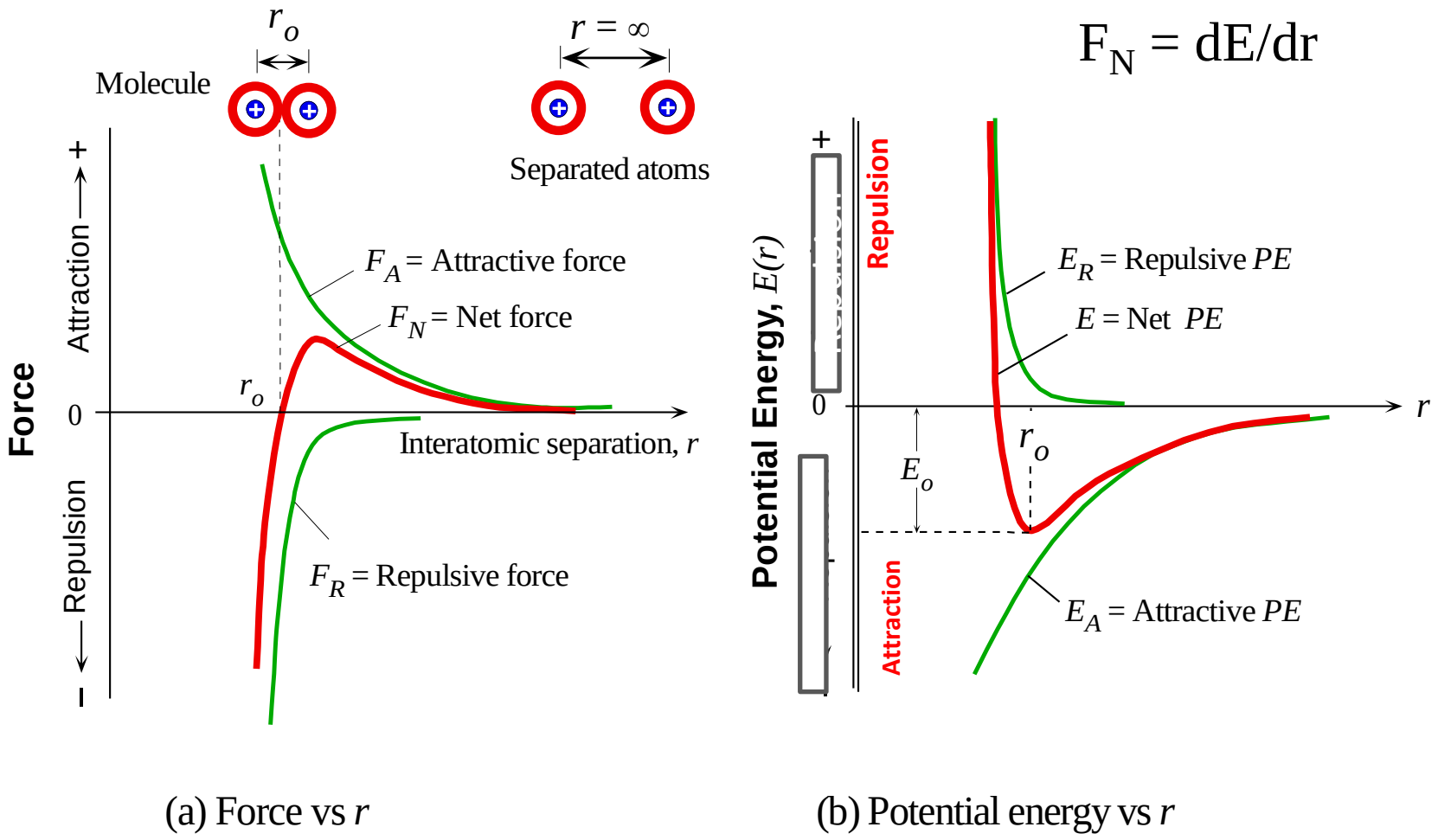
# Bond Force and Potential Energy

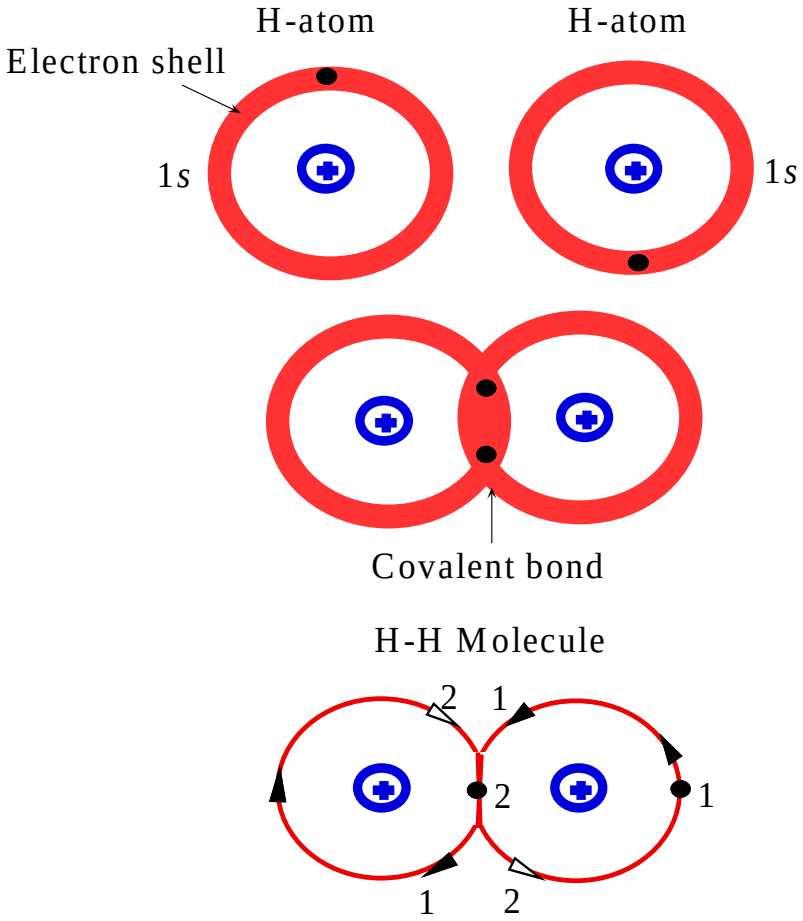



(a) Force vs $r$ (b) Potential energy vs $r$

(a) Force vs interatomic separation and (b) Potential energy vs interatomic separation.

Fig 1.3

# Covalent Bonding



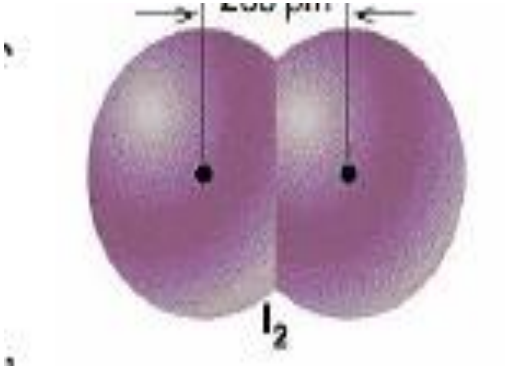




Fig. 1.4: Formation of a covalent bond between two H atoms leads to the $H_2$ molecule. Electrons spend majority of their time between the two nuclei which results in a net attraction between the electrons and the two nuclei which is the origin of the covalent bond .

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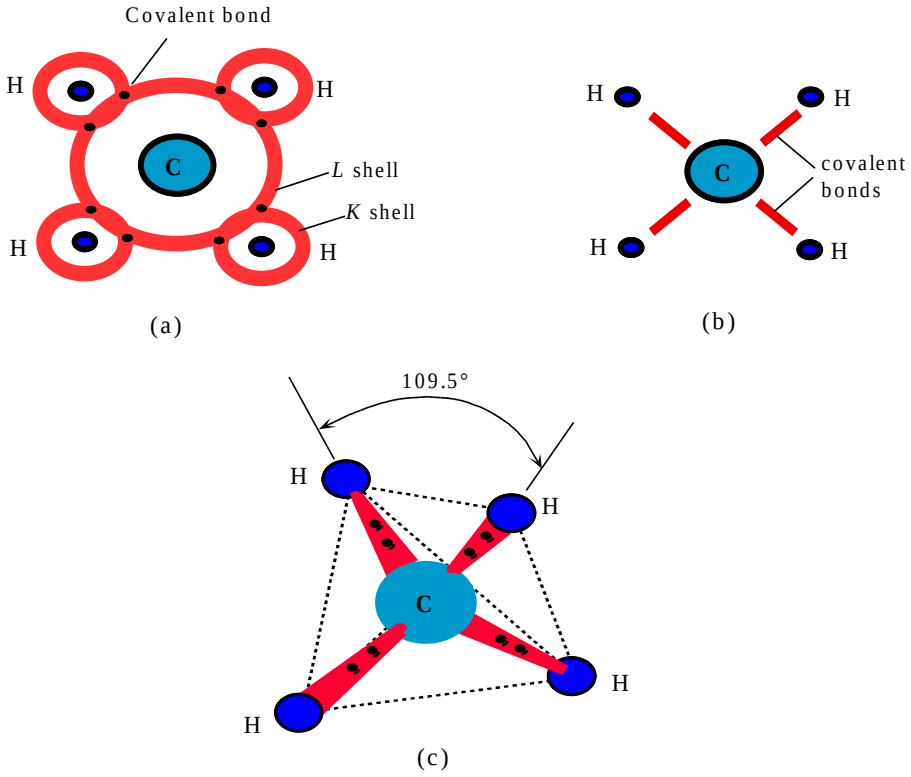
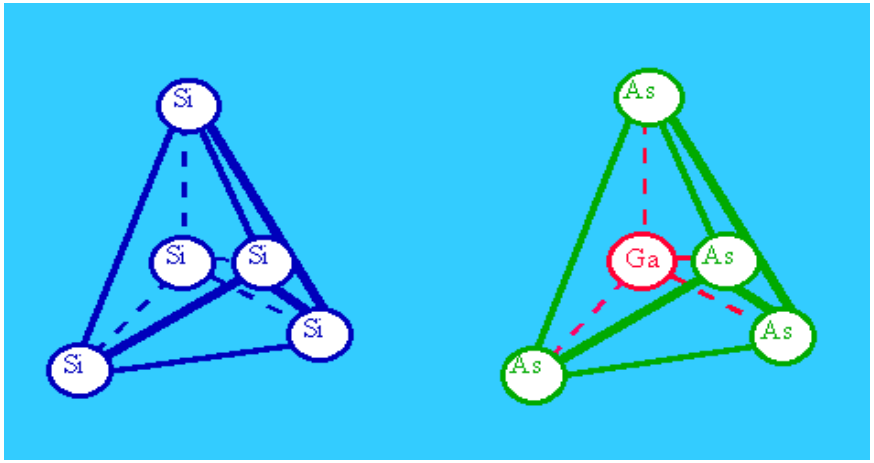
A covalent bond is formed when electrons are shared between atoms.

# Covalent Bonding




Examples: diamond, silicon, germanium, silicon carbide.

Fig. 1.5: (a) Covalent bonding in methane, $CH_4$, involves four hydrogen atoms sharing electrons with one carbon atom. Each covalent bond has two shared electrons. The four bonds are identical and repel each other. (b) Schematic sketch of $CH_4$ on paper. (c) In three dimensions, due to symmetry, the bonds are directed towards the corners of a tetrahedron.

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# Covalent Bonding

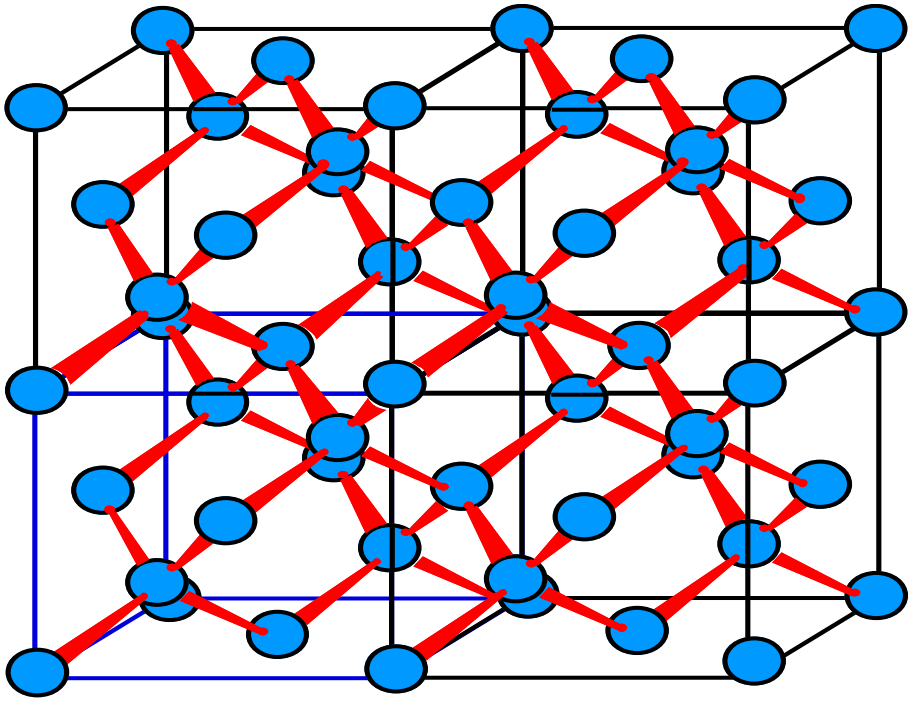

Fig. 1.6: The diamond crystal is a covalently bonded network of carbon atoms. Each carbon atom is bonded covalently to four neighbors forming a regular three dimensional pattern of atoms which constitutes the diamond crystal.

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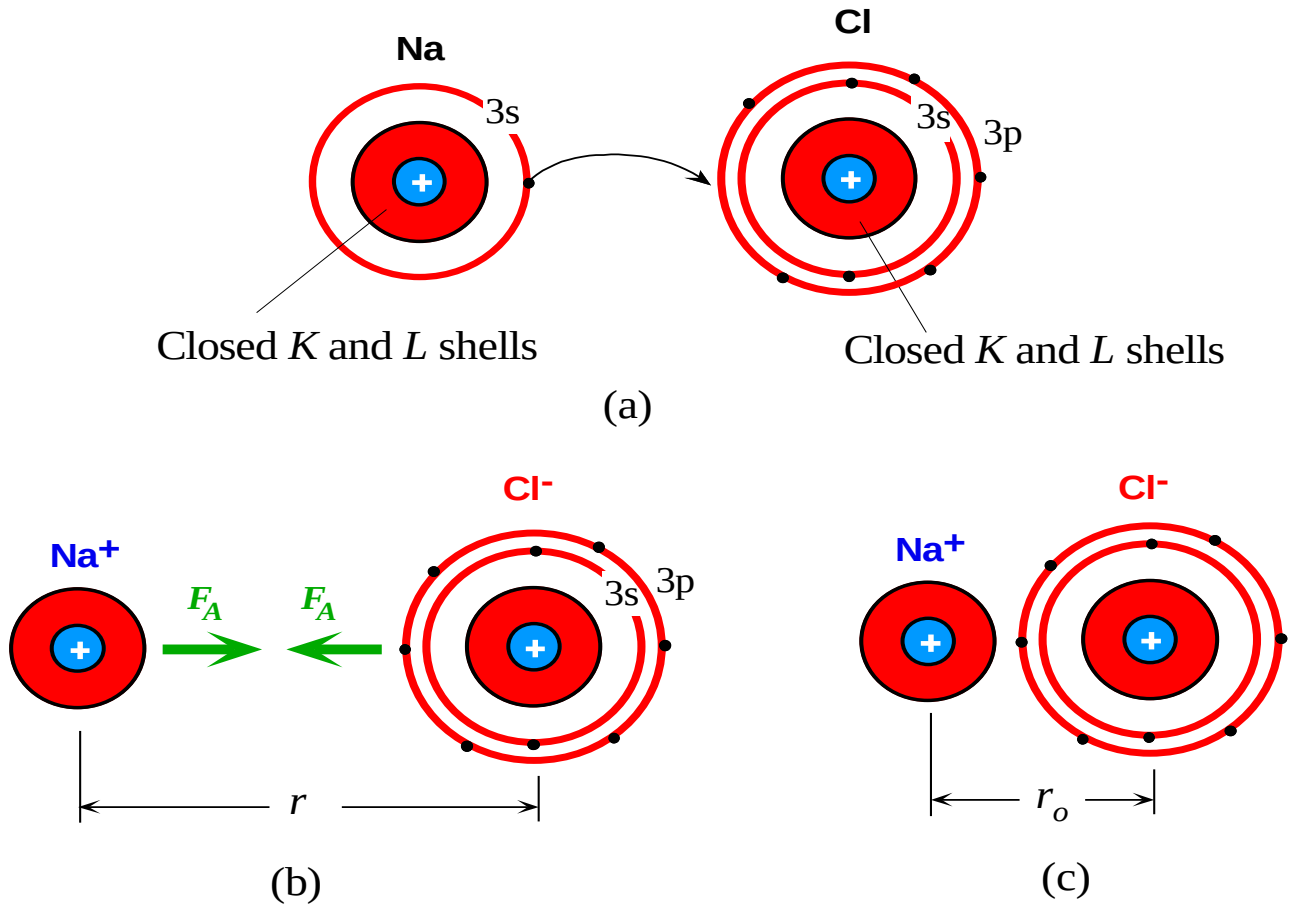
# Ionic Bond




An ionic bond is formed when electrons are transferred from one atom to the other.

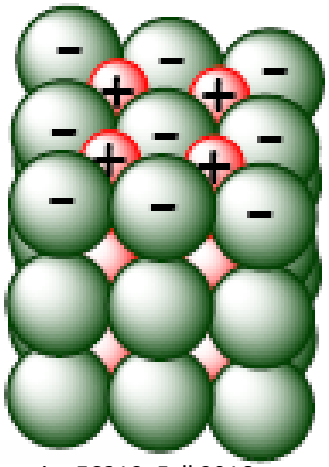


Fig. 1.8: The formation of an ionic bond between Na and Cl atoms in NaCl. The attraction is due to coulombic forces.

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# Ionic Bonding

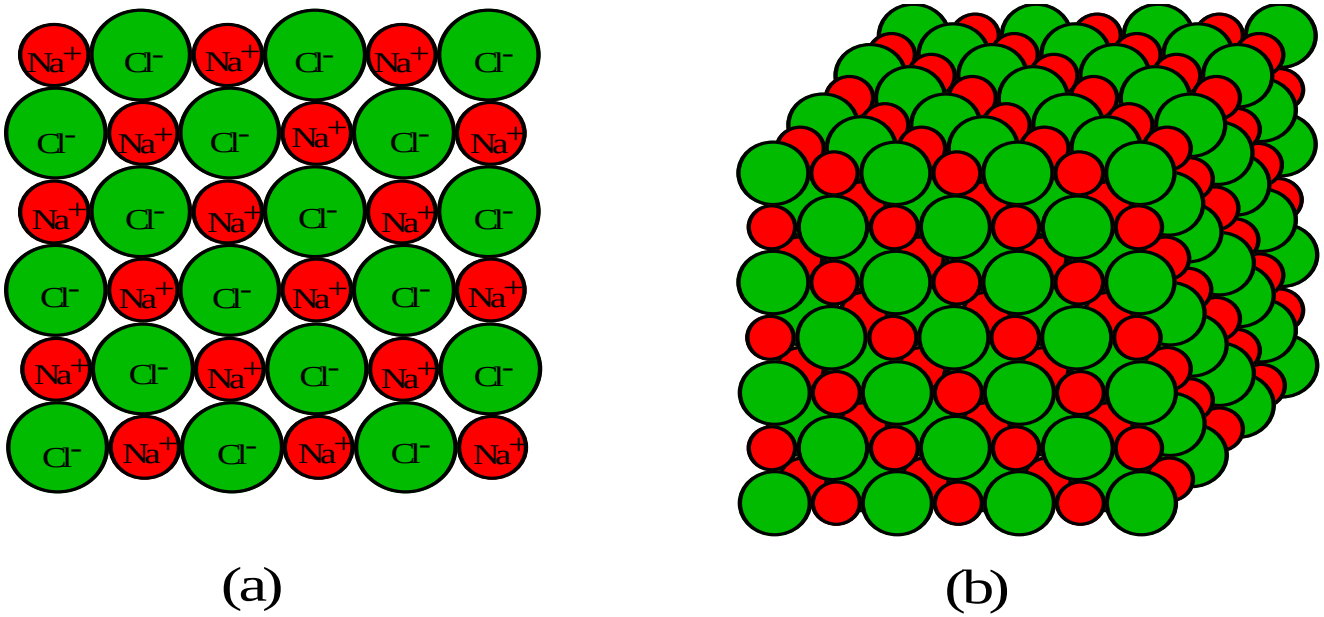


Fig. 1.9: (a) A schematic illustration of a cross section from solid NaCl. NaCl solid is made of $Cl^-$ and $Na^+$ ions arranged alternatingly so that the oppositely charged ions are closest to each other and attract each other. There are also repulsive forces between the like-ions. In equilibrium the net force acting on any ion is zero. (b) Solid NaCl.

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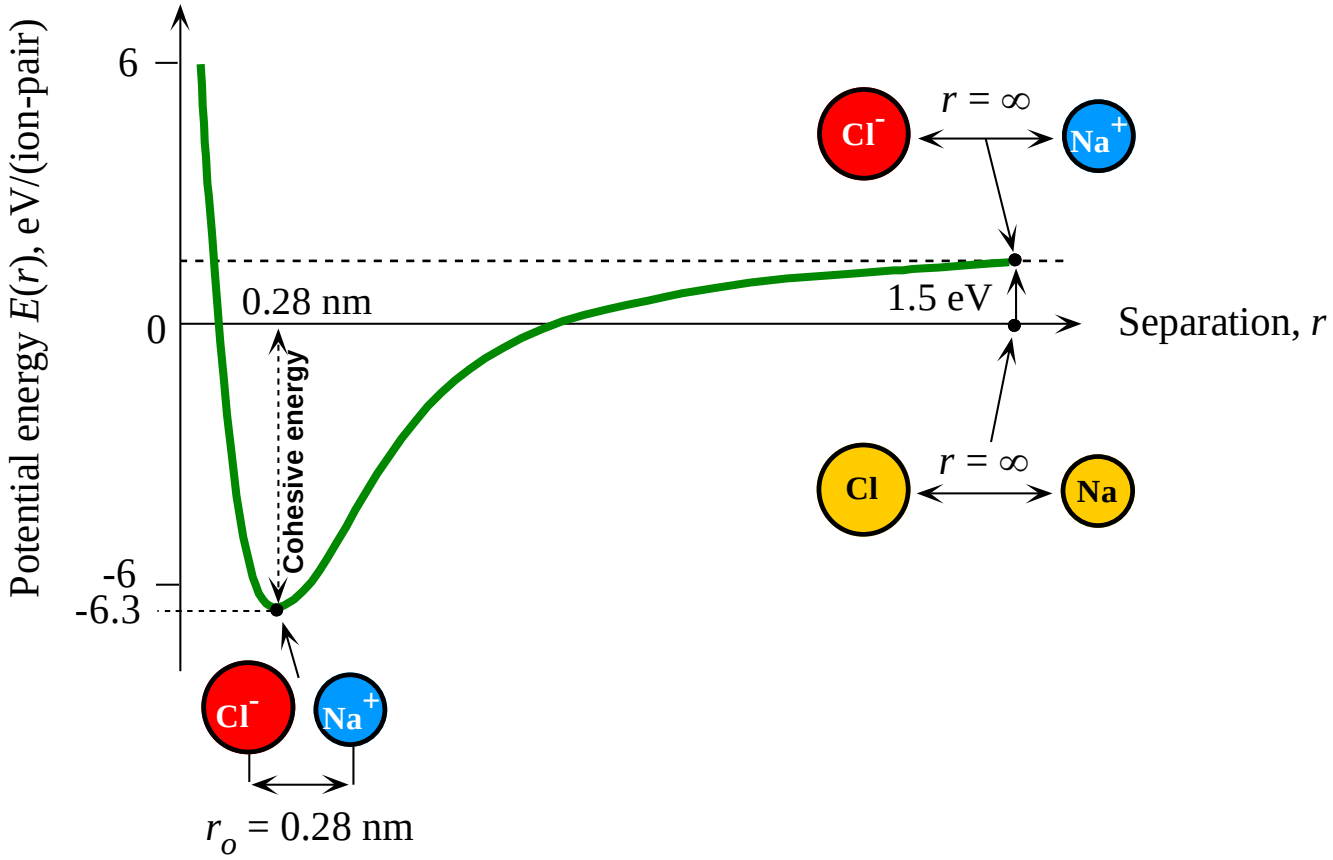
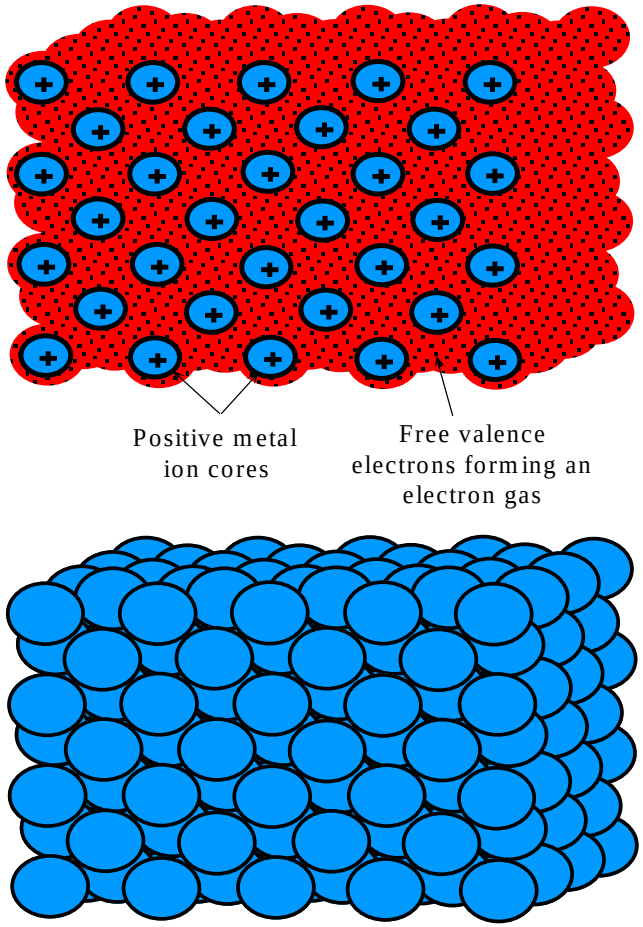
# Ionic Bond




Sketch of the potential energy per ion-pair in solid NaCl. Zero energy corresponds to neutral Na and Cl atoms infinitely separated.

# Metallic Bonding



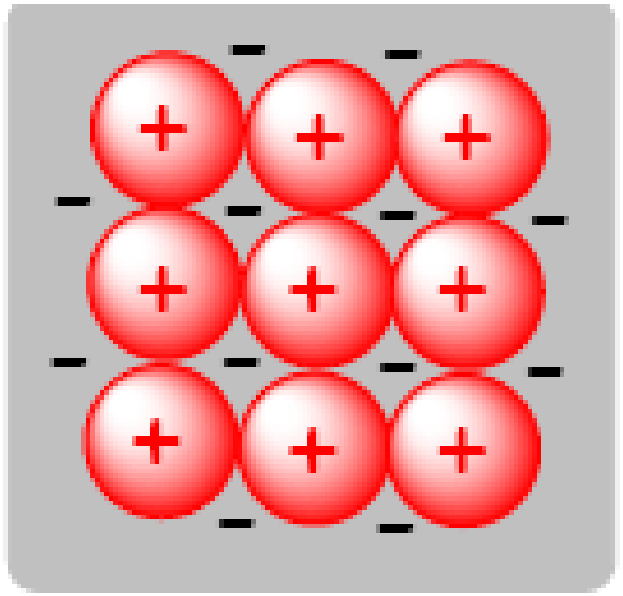



Fig. 1.7: In metallic bonding the valence electrons from the metal atoms form a "cloud of electrons" which fills the space between the metal ions and "glues" the ions together through the coulombic attraction between the electron gas and positive metal ions.

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# Van der Waals Hydrogen Bonding

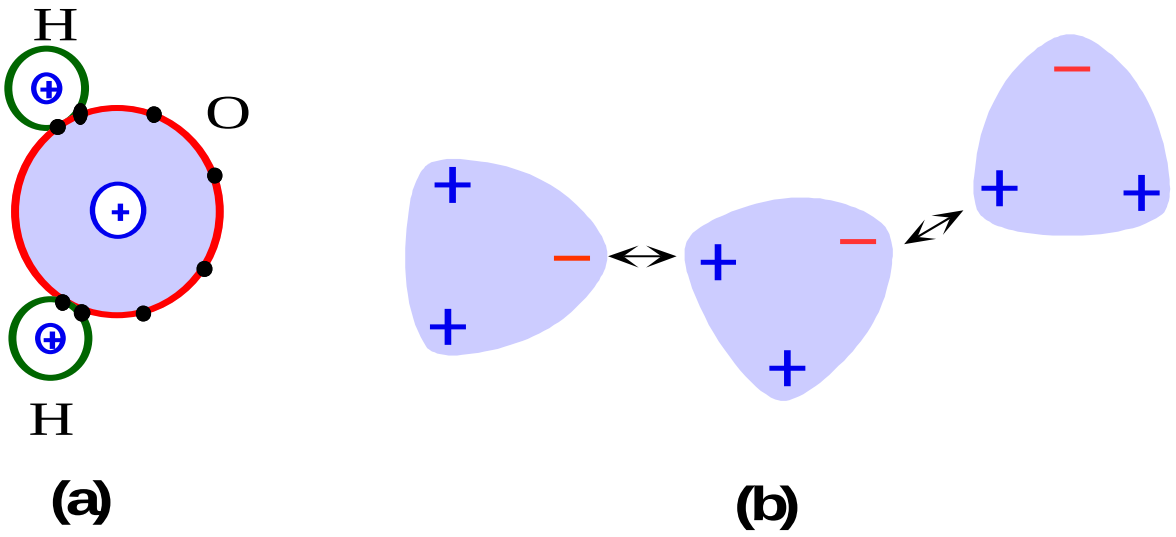


**Fig. 1.12:** The origin of van der Waals bonding between water molecules. (a) The $H_2O$ molecule is polar and has a net permanent dipole moment. (b) Attractions between the various dipole moments in water gives rise to van der Waals bonding.

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# Van der Waals Bonding

Even inert gases become liquids and even form crystals at low temperatures.

What force holds the molecules together?

- "Van der Waals Hydrogen bonding," Asymmetry of the molecule gives rise to a non uniform charge distribution and a polarity.

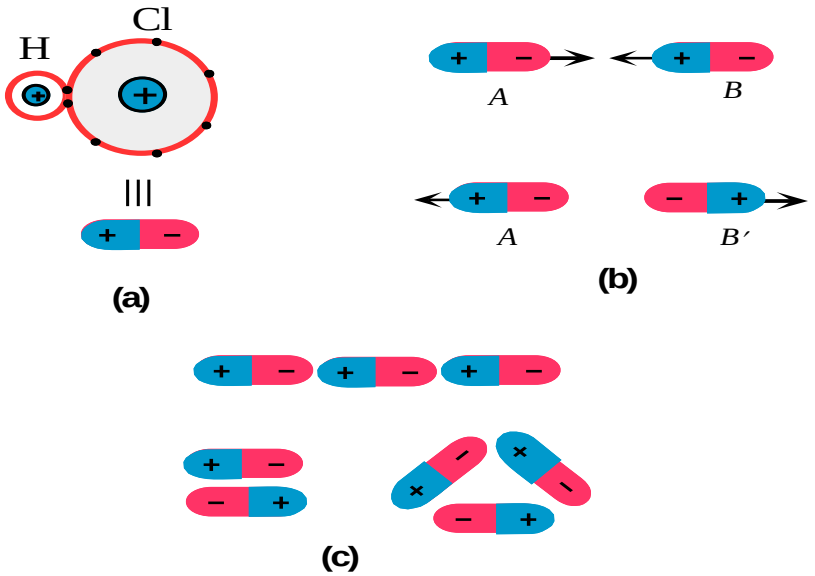


**Fig. 1.11:** (a) A permanently polarized molecule is called a an electric dipole moment. (b) Dipoles can attract or repel each other depending on their relative orientations. **c** Suitably oriented dipoles attract each other to form van der Waals bonds.

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