Topic 4: Chemical Bonding and Structure

4.1 Ionic Bonding and Structure （离子键及其结构）

Understanding (Learning Objectives):

- Positive ions (cations) form by metals losing valence electrons.
- Negative ions (anions) form by non-metals gaining electrons.
- The number of electrons lost or gained is determined by the electron configuration of the atom.
- The ionic bond is due to electrostatic attraction between oppositely charged ions.
- Under normal conditions, ionic compounds are usually solids with lattice structures.

1. Formation of Ions

a. 原理解释:

Electrons are negative → Lose an electron → Form a positive ion (cation)

→ Gain an electron → Form a negative ion (anion)

Key to Answer: Transfer of electrons from A to B（单方面的给予）

b. 根据大多数的 electron configuration 规律可以推出:

Metals form cations by losing electrons. **Lithium: Li (2, 1) → Li^+ (2)**

Nonmetals for anions by gaining electrons. **Nitrogen: N (2, 5) → N^{3-} (2, 8)**

1.3 Charge of ions determined by: the number of gained/lost electrons

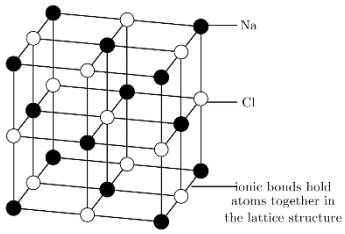
2. Ionic Bonding

a. Nature of Ionic Bonding （本质内容）

Key to Answer: Electrostatic attraction between oppositely charged ions.

Electrostatic attraction（静电吸引）可以理解为正负微粒间的吸引。

b. Structure of Ionic Bonding



Key to Answer: Most ionic bonds have lattice structure

Coordination Number 在这里是（6，6）

表明 1 个 Na^+被 6 个 Cl^-环绕，一个 Cl^-被 6 个 Na^+环绕

3. Polyatomic Ions（多原子离子）

Ions that are made up of more than one atom which together have experienced a loss or gain of electrons and so carry a charge.

Common charges on Polyatomic Ions（要背的！）

Polyatomic ion name	Charge on ion	Symbol
nitrate	1–	NO_3^-
hydroxide	1–	OH^-
hydrogencarbonate	1–	HCO_3^-
carbonate	2–	CO_3^{2-}
sulfate	2–	SO_4^{2-}
phosphate	3–	PO_4^{3-}
ammonium	1+	NH_4^+

口诀：负一硝酸氢氧根，负二硫酸碳酸根，负三是个磷酸根，正一价的是铵根。

4. Physical Properties of Ionic Bonds Reflect their Lattice Structure *(Skip for test)*

4.1 相关习题

2018 May PP2 TZ1 2a

a. Describe the nature of ionic bonding.

a. electrostatic attraction ***AND*** oppositely charged ions

2015 May PP2 TZ2 6b(iv)

b.iv Describe the ionic bonding present in potassium chloride and how the ions are formed.

b.iv (electrostatic) attraction between positive and negative ions/oppositely charged ions/cations and anions;

formed as a result of transfer of an electron from a K atom to a Cl atom / *OWTTE*;

2013 Nov. PP1 11

Which compounds have an ionic lattice structure in the solid state?

I. Silicon dioxide

II. Sodium fluoride

III. Ammonium nitrate

A. I and II only

B. I and III only

C. II and III only

D. I, II and III

答案选 C，这里是判断哪些是 ionic bond，ionic bond 是金属和非金属（铵根 NH_4 除外），所以只有 I 不是

2009 May PP1 TZ1 11

What are the correct formulas of the following ions?

答案选 D。

	Ammonium	Hydrogencarbonate	Phosphate
A.	NH_4^+	HCO_3^{2-}	PO_4^-
B.	NH_3^+	HCO_3^-	PO_4^{3-}
C.	NH_4^+	HCO_3^{2-}	PO_4^{2-}
D.	NH_4^+	HCO_3^-	PO_4^{3-}

2013 May PP1 TZ1 10

Which statement best describes ionic bonding?

A. It is the electrostatic attraction between positive ions and delocalized electrons and occurs by the transfer of electrons.

B. It is the electrostatic attraction between positive ions and negative ions and occurs by the transfer of electrons.

C. It is the electrostatic attraction between positive ions and negative ions and occurs by the sharing of electrons.

D. It is the electrostatic attraction between positive nuclei and electrons and occurs by the sharing of electrons.

选 B,注意是+和-的 ions 的吸引，而且本质是 electron 的 transfer

4.2 Covalent Bonding （共价键）

Understanding (Learning Objectives):

• A covalent bond is formed by the electrostatic attraction between a shared pair of electrons and the positively charged nuclei.

• Single, double and triple covalent bonds involve one, two and three shared pairs of electrons respectively.

• Bond length decreases and bond strength increases as the number of shared electrons increases.

• Bond polarity results from the difference in electronegativities of the bonded atoms.

1. Formation of Covalent Bonds

Key to Answer: Electrostatic attraction between a shared pair of electrons and the positively charged nuclei. （mostly 2 non-metals）

需要和 ionic bond 区分的是，它是一对电子和带正电的原子核之间的静电吸引。

2. Molecules（记住称呼即可）

Molecules have 2 atoms → Diatomic

Molecules have 3 atoms → Triatomic

3. Octet Rule

When atoms react, they tend to achieve an outer shell with 8 electrons.

（outliers 在 4.3 会讲到）

4. Multiple Covalent Bonds

根据 Octet Rule，几乎每一个原子都要达到 8 个的稳定状态，所以有一些原子要共享超过一对电子。

Share 2 electron pairs → Double Bond　　O=O (O_2)

Share 3 electron pairs → Triple Bond　　N≡N (N_2)

Bond Length: the average distance between nuclei of two bonded atoms in a molecule.

Number of elctrons in the bond increases

	C—O	C═O
Bond length / pm	143	122
Bond enthalpy / kJ mol^{-1}	358	804

➔ More negative charges in the bond
Bond Length decreases

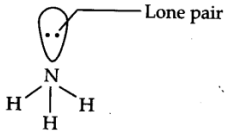
➔ Bond length: Single ($2e^-$) >Double ($4e^-$) >Triple ($6e^-$)

➔ More attraction between electrons and the nucleus of each atom

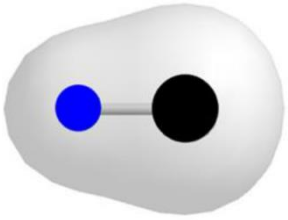
结论：the shorter the bond, the greater the bond strength or energy

5. Lone Pair

The outer shell electrons not used in bonding are called lone pairs.



6. Bond Polarity



Polar Covalent Bond

electrons

a. Concept of Polar Bonds

Polar bond occurs when there's a difference in the electronegativities of bonded atoms. (Unequal sharing of electrons)

Same Electronegativity → Non-polar Bonds (比如 H_2，O_2 这些双原子单质)

Different Electronegativity → Polar Bonds:

- The one has bigger electronegativity → more pull on

b. Bond Polarity

在这里我们要引入 Dipole（偶极）这个概念，指的是 Polar bond 中两个原子分别带正负电(partial charge)。Dipole 用符号 δ 表示，读作 delta。

Less electronegative atom：δ+ delta positive

More electronegative atom：δ− delta negative

c. IF there are more than 1 covalent bonds:

- The polarity of each bond
- Shape and geometry of the molecule

4.2 相关习题

2015 May PP2 TZ2 6b(iii)

b.iiiDescribe the covalent bond present in the chlorine molecule and how it is formed.

b.iii(electrostatic) attraction between positively charged nuclei and a pair of electrons;

formed as a result of electron sharing;

2016 May PP1 10

Which compound contains both ionic and covalent bonds?

选 B, Na^+和 NO_3^-是 ionic bond

NO_3^-内部是 covalent bond

A. SiH_4

B. $NaNO_3$

C. H_2CO

D. Na_2S

2017 May PP1 TZ1 10

Which two atoms form the most polar bond?

选 C，Databooklet 上面 electronegativity 的差值

A. C and F

B. C and Cl

C. Si and F

D. Si and Cl