



## 5A Solutions and Stoichiometry

King

### 考点一：Chemical formula

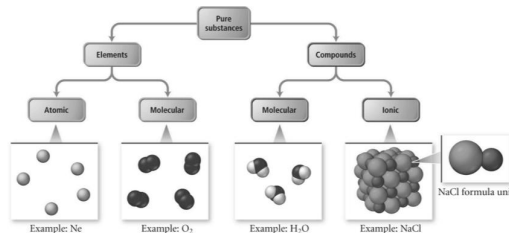
5.1 identify and write **chemical symbols** or **molecular formulae** of common elements or compounds

5.2 represent chemical reactions and the conservation of mass using **molecular models**, and **balanced symbolic** equations

#### 1. Molecular and Atomic Elements

- Certain elements occur as 2 atom molecules
- Other elements occur as polyatomic molecules

$P_4, S_8, Se_8$



#### 2. Writing Formulas for Ionic Compounds

- Write the **symbol** for the **metal cation** and its **charge**
- Write the **symbol** for the **nonmetal anion** and its **charge**
- Charge** (without sign) becomes **subscript** for other ion
- Reduce subscripts to **smallest whole number ratio**
- Check that the **sum of the charges** of the cation **cancels** the sum of the anions

$Al^{+3}$  column 3A

$O^{2-}$  column 6A



$Al = (2) \cdot (+3) = +6$

$O = (3) \cdot (-2) = -6$

#### --Binary Ionic Compounds

##### a. Metals with Invariant Charge

name of cation (metal)      base name of anion (nonmetal) + *-ide*

TABLE 3.2 Metals Whose Charge Is Invariant from One Compound to Another

Metal	Ion	Name	Group Number
Li	$Li^+$	Lithium	1A
Na	$Na^+$	Sodium	1A
K	$K^+$	Potassium	1A
Rb	$Rb^+$	Rubidium	1A
Cs	$Cs^+$	Cesium	1A
Be	$Be^{2+}$	Beryllium	2A
Mg	$Mg^{2+}$	Magnesium	2A
Ca	$Ca^{2+}$	Calcium	2A
Sr	$Sr^{2+}$	Strontium	2A
Ba	$Ba^{2+}$	Barium	2A
Al	$Al^{3+}$	Aluminum	3A
Zn	$Zn^{2+}$	Zinc	*
Sc	$Sc^{3+}$	Scandium	*
Ag	$Ag^+$	Silver	*

##### b. Metals with Variant Charge

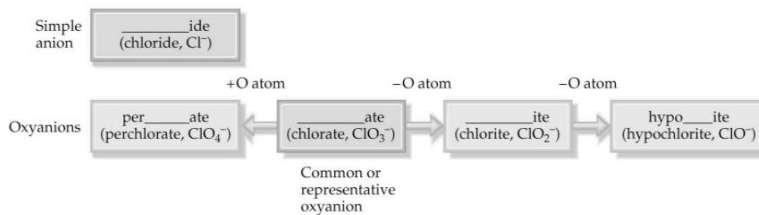
name of cation (metal)      charge of cation (metal) in roman numerals in parentheses      base name of anion (nonmetal) + *-ide*

TABLE 3.4 Some Metals That Form Cations with Different Charges

Metal	Ion	Name	Older Name*
Chromium	$Cr^{2+}$	Chromium(II)	Chromous
	$Cr^{3+}$	Chromium(III)	Chromic
Iron	$Fe^{2+}$	Iron(II)	Ferrous
	$Fe^{3+}$	Iron(III)	Ferric
Cobalt	$Co^{2+}$	Cobalt(II)	Cobaltous
	$Co^{3+}$	Cobalt(III)	Cobaltic
Copper	$Cu^+$	Copper(I)	Cuprous
	$Cu^{2+}$	Copper(II)	Cupric
Tin	$Sn^{2+}$	Tin(II)	Stannous
	$Sn^{4+}$	Tin(IV)	Stannic
Mercury	$Hg_2^{2+}$	Mercury(I)	Mercurous
	$Hg^{2+}$	Mercury(II)	Mercuric
Lead	$Pb^{2+}$	Lead(II)	Plumbous
	$Pb^{4+}$	Lead(IV)	Plumbic

#### --Compounds Containing Polyatomic Ions

Name	Formula
acetate	$C_2H_3O_2^-$
carbonate	$CO_3^{2-}$
hydrogen carbonate (aka bicarbonate)	$HCO_3^-$
hydroxide	$OH^-$
nitrate	$NO_3^-$
nitrite	$NO_2^-$
chromate	$CrO_4^{2-}$
dichromate	$Cr_2O_7^{2-}$
ammonium	$NH_4^+$
hypochlorite	$ClO^-$
chlorite	$ClO_2^-$
chlorate	$ClO_3^-$
perchlorate	$ClO_4^-$
sulfate	$SO_4^{2-}$
sulfite	$SO_3^{2-}$
hydrogen sulfate (aka bisulfate)	$HSO_4^-$
hydrogen sulfite (aka bisulfite)	$HSO_3^-$





### 3. Naming Molecular Compounds

#### Binary molecule

- The name consists of **two** words.
- First** word: name of the element that appears **first** in the formula.
- Second** word: stem of the name of the **second** element, ending with **-ide**.
- Names are further modified by adding **prefixes** to denote the **numbers of atoms** of each element in the molecule.
- Rule of thumb: the element that is **farthest down** and to the **left** on the periodic table is usually **written first**.

Number of Atoms	Prefix	Examples <sup>a</sup>
1	mono	NO nitrogen monoxide
2	di	NO <sub>2</sub> nitrogen dioxide
3	tri	N <sub>2</sub> O <sub>3</sub> dinitrogen trioxide
4	tetra	N <sub>2</sub> O <sub>4</sub> dinitrogen tetroxide
5	penta	N <sub>2</sub> O <sub>5</sub> dinitrogen pentoxide
6	hexa	SF <sub>6</sub> sulfur hexafluoride
7	hepta	IF <sub>7</sub> iodine heptafluoride
8	octa	P <sub>4</sub> O <sub>8</sub> tetraphosphorus octoxide
9	nona	P <sub>4</sub> S <sub>9</sub> tetraphosphorus nonasulfide
10	deca	As <sub>4</sub> O <sub>10</sub> tetraarsenic decoxide

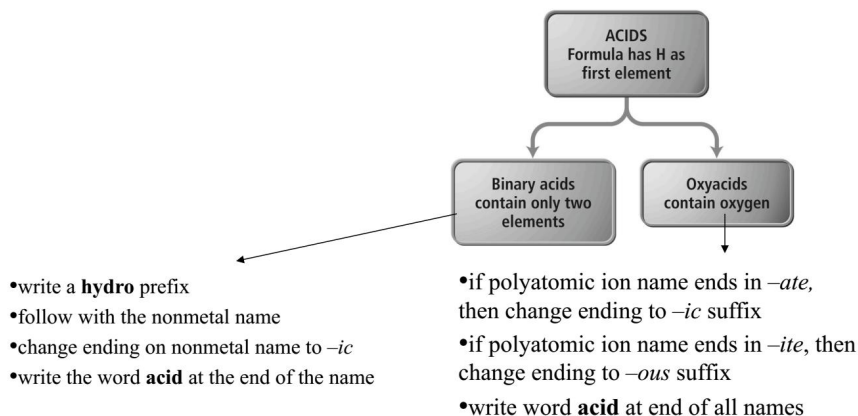
#### Hydrates

in name attached waters indicated by **suffix -hydrate** after name of ionic compound

✓ CoCl<sub>2</sub>·6H<sub>2</sub>O = cobalt(II) chloride hexahydrate

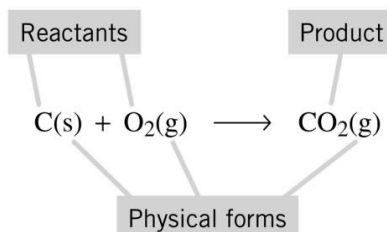
✓ CaSO<sub>4</sub>·½H<sub>2</sub>O = calcium sulfate hemihydrate

#### Acids



### 2. Chemical equation

A **chemical equation** is a shorthand description of a **chemical reaction**, using symbols and formulas to represent the elements and compounds involved.



- If an element is present in just **one compound** on each side of the equation, try balancing that **element first**.
- Balance any reactants or products that exist as the **free element last**.
- In some reactions, certain **groupings of atoms** (such as polyatomic ions) remain **unchanged**. In such cases, treat these groupings **as a unit**.
- At times, an equation can be balanced by first using a **fractional coefficient(s)**. The fraction is then cleared by **multiplying** each coefficient by a common factor.



## 考点二 : Solution

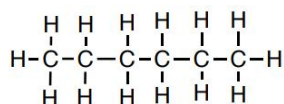
- 5.4 describe the process of **dissolving**, using concepts of **intramolecular** and **intermolecular forces**
- 5.5 define the concept of **equilibrium** as it pertains to solutions
- 5.6 explain **solubility**, using the concept of **equilibrium**
- 5.7 explain how different **factors** affect solubility, using the concept of **equilibrium**
- 5.8 determine the **molar solubility** of a **pure substance** in water
- 5.9 explain the **variations in the solubility** of various **pure substances**, given the same solvent
- 5.10 use the **solubility generalizations** to predict the formation of **precipitates**
- 5.11 explain the effect of solutes on the **melting point** of solid water, using **intermolecular forces**

### 1. Intermolecular forces

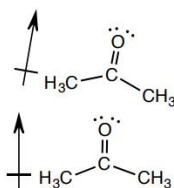
**Intermolecular forces** are attractive forces between **molecules**. They are largely responsible for the observed **boiling points** and **solubility** properties of molecules.

**Dipole:** "two-pole";  
**Polar molecule**--Arises from unequal distribution of shared electrons

**1). London Dispersion:** Attraction between molecules that form due to a **temporary dipole** on one molecule inducing a **temporary dipole** in **neighboring** molecules



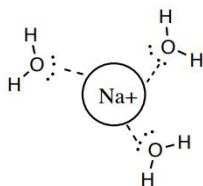
**2). Dipole-Dipole:** Attraction between two **polar molecules** (dipoles)



**3). Hydrogen Bonding:** Attraction between two **polar molecules**, specifically one molecule having a **H bonded** directly to an **electronegative atom** (eg. **H-O-**, **H-N-**, **HF**), and the other having a **nonbonding electron pair** on an electronegative atom.



**4). Ion-Dipole:** Attraction between an **ion** and a **polar molecule**.



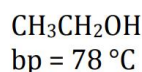
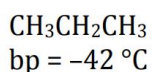
Relative Strengths of Intermolecular Forces

- |   |  |
|---|--|
| <ul style="list-style-type: none"> <li>• London dispersion</li> <li>• Dipole-dipole</li> <li>• Hydrogen-bond</li> <li>• Ion-dipole</li> </ul> | <p>Weakest</p> <p>↓</p> <p>Strongest</p> |
|---|--|

### Intermolecular Forces: Effect on Boiling Point

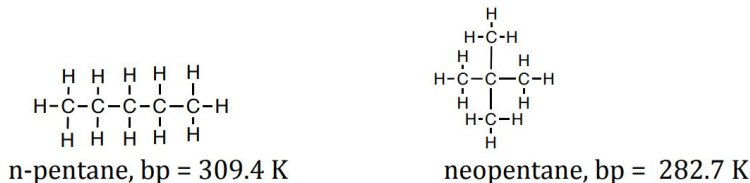
Trends:

1. Between two molecules of **similar mass**, the one with the **stronger** type of **intermolecular force** has a **higher** boiling point





2. Between two **nonpolar molecules** of **similar mass**, the **more extended** molecule will have the **higher boiling point** (more extended → more **surface area** for London dispersion interaction).



3. Between two **nonpolar molecules** of **different masses**, the **larger molecule** will have the **higher boiling point** (larger molecule → more electrons → more polarizability → more London dispersion forces)



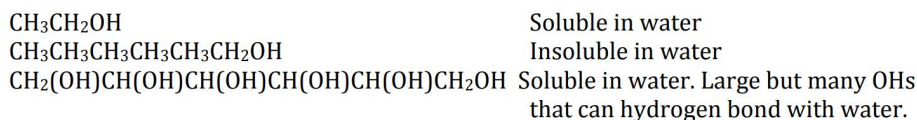
### Intermolecular Forces: Effect on Solubility

- **Polar** molecules are soluble in **polar** solvents
- **Nonpolar** molecules are soluble in **nonpolar** solvents
- Polar molecules and nonpolar molecules **do not mix**.

**Like dissolves like** (相似相溶) — substances usually dissolve best in solvents with **similar** intermolecular forces

#### Trends:

1. Between two **polar molecules**, the molecule with the **smaller hydrocarbon portion** (or the larger polar portion) is **more soluble** in water.



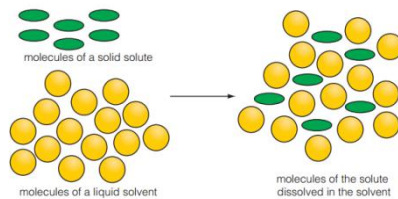
2. If completely **nonpolar**, insoluble in water (and soluble in nonpolar solvents).



## 2. Solubility

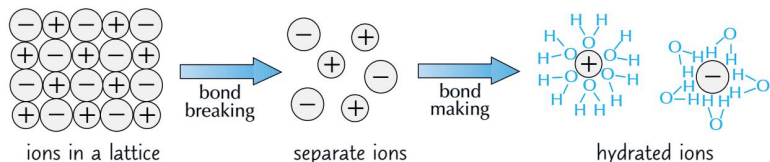
For one substance to dissolve in another, all these things have to happen:

- bonds in the **substance** have to break,
- bonds in the **solvent** have to break, and
- new bonds have to form between the **substance and the solvent**.



一个物质溶于水，只有两种方法：

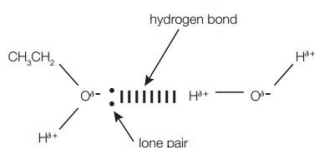
### 1. Hydration(离子化合物);



溶解过程:

**Break ionic bond** → **hydration** (ions are surrounded by water molecules/ion-dipole)

### 2. Hydrgen bond(分子).



解释酒精为什么溶于水: because the polar O-H bond in an alcohol can form **hydrogen bond** with water.

The solubility of alcohols in water **decreases** with increasing **hydrocarbon chain length** as London forces **predominate** between the alcohol molecules.



考点三：Stoichiometric calculations

- 5.3 define **molar mass** and perform **mole-mass** inter-conversions for **pure substances**
- 5.12 identify **mole ratios** of reactants and products from balanced **chemical equations**
- 5.13 perform **stoichiometric calculations** related to **chemical equations**, including **limiting reagent** and **yield** calculations
- 5.14 identify various **stoichiometric** applications
- 5.15 predict how the **yield** of a particular chemical process can be **maximized**

1. THE AVOGADRO CONSTANT



One mole each of helium, sulfur, copper, and mercury.

The number of **particles** in one mole is  $6.02 \times 10^{23}$ . This number is the **Avogadro constant, L**.

$$n = \frac{N}{L}$$

mole
number of particles
 $6.02 \times 10^{23}$

A **mole (mol)** is an amount of substance that contains as many elementary entities as there are atoms in **exactly 12 g** of the carbon-12 isotope

2. Molar Mass is the Mass of **One Mole**

$$\text{amount of substance in moles} = \frac{\text{mass in grams}}{\text{molar mass}} \text{ or } n = \frac{m}{M}$$

3. REACTING MASS (三步法)

- 1) Mole; 2) Ratio; 3) Mass

4. THEORETICAL YIELD, ACTUAL YIELD AND PERCENTAGE YIELD

$$\frac{\text{actual yield}^{\text{题目给}}}{\text{theoretical yield}^{\text{自己算}}} = \text{percentage yield}$$

5. ATOM ECONOMY

$$\text{atom economy} = \frac{\text{molar mass of the desired product}}{\text{sum of the molar masses of all products}} \times 100$$

6. EMPIRICAL FORMULAE (画表法)

An empirical formula shows the smallest whole number ratio of the atoms of each element in a compound.

mass of copper oxide = 4.28 g  
 mass of copper = 3.43 g  
 mass of oxygen removed is 4.28 - 3.43 = 0.85 g

	Cu	O
mass of element / g	3.43	0.85
relative atomic mass	63.5	16.0
division by $A_r$	0.0540	0.0531
ratio	1	1



## 7. MOLECULAR FORMULAE

The molecular formula of a compound shows the actual numbers of the atoms of each element in the compound.

hydrogen peroxide	empirical formula is HO	molecular formula is H <sub>2</sub> O <sub>2</sub>
butane	empirical formula is C <sub>2</sub> H <sub>5</sub>	molecular formula is C <sub>4</sub> H <sub>10</sub>

$$x = \frac{\text{Mr (E.F.)}}{\text{Mr (M.F.)}}$$

*(Empirical and Molecular Formulae are Ratios)*

## 8. MOLAR VOLUME, V<sub>m</sub>

If temperature and pressure stay the same, **one mole** of **any** gas always has the **same volume**.

At **room temperature and pressure** (r.t.p.), this happens to be **24 dm<sup>3</sup> mol<sup>-1</sup>** (r.t.p. is 293 K (20 °C) and 101.3 kPa).

$$n = \frac{V}{V_m} \quad \begin{matrix} \text{dm}^3 \\ \text{mole} \quad 24 \end{matrix}$$

## 9. THE IDEAL GAS EQUATION pV = nRT

$pV = nRT$  Where:  $p$  = pressure (Pa)       $V$  = volume (m<sup>3</sup>)       $n$  = number of moles  
 $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$        $T$  = temperature (K)

CONVERSION	HOW TO DO IT
kPa → Pa	multiply by 10 <sup>3</sup>
cm <sup>3</sup> → m <sup>3</sup>	divide by 10 <sup>6</sup> or multiply by 10 <sup>-6</sup>
dm <sup>3</sup> → m <sup>3</sup>	divide by 10 <sup>3</sup> or multiply by 10 <sup>-3</sup>
°C → K	add 273

## 10. CONCENTRATIONS OF SOLUTIONS

--CALCULATIONS USING MASS CONCENTRATION (g dm<sup>-3</sup>)

$$\text{mass concentration} = \frac{m}{V}$$

$$\text{(molar) concentration} = \frac{\text{amount}}{\text{volume}} \text{ or } c = \frac{n}{V}$$

--CALCULATIONS USING MOLAR CONCENTRATION (mol dm<sup>-3</sup>)

CONCENTRATIONS IN PPM

$$\text{concentration in ppm} = \frac{\text{mass of solute} \times 1000000}{\text{mass of solvent}}$$

$$\text{concentration in ppm} = \frac{\text{volume of gas} \times 1000000}{\text{volume of air}}$$

"单位统一，相除，乘上百万"