普通高等教育“十一五”国家级规划教材
卫生部“十一五”规划教材 辅导系列
全国高等医药教材建设研究会规划教材

基础化学学习与解题指南

（双语版）

冯清 刘绍乾◎主编

Study Guide for Basic Chemistry

华中科技大学出版社
http://www.hustp.com

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（双语版）

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华中科技大学出版社
中国·武汉

图书在版编目(CIP)数据

基础化学学习与解题指南(双语版)/冯　清　刘绍乾　主编.—武汉:华中科技大学出版社,2009年9月
ISBN 978-7-5609-5718-0

Ⅰ.基…　Ⅱ.①冯…　②刘…　Ⅲ.化学-高等学校-教学参考资料-英、汉
Ⅳ.O6

中国版本图书馆 CIP 数据核字(2009)第 175245 号

基础化学学习与解题指南(双语版)　　冯　清　刘绍乾　主编

策划编辑:胡章成　　封面设计:范翠璇
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出版发行:华中科技大学出版社(中国·武汉)
武昌喻家山　邮编:430074　电话:(027)87557437

录　排:华中科技大学惠友文印中心
印　刷:华中科技大学印刷厂

开本:710mm×1000mm　1/16　印张:20.25　字数:398 000
版次:2009年9月第1版　印次:2009年9月第1次印刷　定价:32.00元
ISBN 978-7-5609-5718-0/O·508

前　言

为进一步推进医学基础化学理论教学的改革和发展，逐渐与国际接轨，以适应将来国际交流的需要，本书根据国家教育部有关医药院校和生命科学相关专业基础化学、无机化学和分析化学的教学规划，结合编者多年基础化学教学改革、双语教学实践，以及医药专业学生时间紧、课程多的特点编写而成。

本书是与冯清和刘绍乾主编的《Basic Chemistry》配套的学习指导书，其章节编排顺序与教材相同，可供医学、生物学及药学全英语和双语学习学生使用，也可供教师教学参考。本书由 Performance Goals、Overview of the Chapter、Solutions to Problems、Self-help Test、Answers for Self-help Test、自测题、自测题参考答案等七部分组成。主要特点如下。

1. 本书自测题由中文和英文两大部分构成，通过灵活取舍分别供中文、全英文和双语教学使用。

2. 各章的目的要求和要点回顾根据大纲要求，简明扼要地阐明本章基本内容、要点、重点、难点及易混淆之处，清晰实用，力求使读者一目了然，起到提纲挈领的作用。

3. 习题解答特别注重解题思路，有助于学生掌握解题方法和技巧，培养学生科学的思维方法，启发学生的创新思维。

4. 自测题分为选择题、填空题、判断题、简答题和计算题等类型。所选习题注重和医学及生物学相结合，具有典型性、代表性、趣味性、实用性、启发性和科学性，力求帮助读者在掌握理论知识的同时，引导学生进行创新性学习，在科学思维方式上有所突破。

本书在整个筹划编写过程中得到华中科技大学化学与化工学院全体同仁的大力支持和帮助，夏淑贞教授对全书的编写、审核工作提出许多宝贵的意见，在此一并表示衷心的感谢。

尽管在本教材的编写过程中，我们力求做到选材恰当、翻译准确，但由于编者学识水平有限，教材中难免存在欠妥甚至错误之处，恳请同行专家及读者批评指正。

编　者

2009 年 7 月

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Chapter 1 Introduction

Performance Goals

1. Describe the SI units of measurement.

2. Express the concentration of a solution in several different ways(such as molarity, molality, and mole fraction).

3. Convert between different concentration units.

4. Be able to name ionic compounds, acids and binary molecular compounds.

Overview of the Chapter

1. SI units consist of seven base units and numerous derived units. Exponential notation and prefixes based on powers of 10 are used to express very small and very large numbers. The SI base unit of length is the meter(m). Length units on the atomic scale are the nanometer(nm) and picometer(pm). Volume units are derived from length units; the most important volume units in chemistry are the cubic meter(m^3) and the liter(L). Thus the units milliliter and cubic centimeter can be used interchangeably when expressing volume.

$$1\ m^3=10^3\ L=10^6\ cm^3 \qquad 1\ L=1000\ mL=1000\ cm^3$$

The mass of an object, a measure of the quantity of matter present in it, is constant. The SI unit of mass is the kilogram(kg). In chemistry, temperature is measured in Kelvins(K) or degrees Celsius(℃). The SI unit of temperature is the Kelvin. The relationship between Celsius and Kelvin temperature is:

$$T=t+273.15$$

2. The concentration of a solution is independent of the amount of solution and can be expressed by molarity(mol solute/L solution) and molality(mol solute/kg solvent), as well as percent by mass(mass of solute/mass of solution), percent by volume(volume of solute/volume of solution), and mole fraction(mol solute/(mol solute+mol solvent)). The units for concentration are as follows:

Concentration	Numerator units (solute in each case)	Denominator units
$\text{Molarity}=\dfrac{\text{moles of solute}}{\text{liters of solution}}$	moles	1 L of solution
$\text{Molality(m)}=\dfrac{\text{moles of solute}}{\text{kilograms of solvent}}$	moles	1 kg of solvent
$x_A=\dfrac{\text{moles of substance A}}{\text{total moles of solution}}$	moles	1 mol of solution

The choice of units depends on convenience or the nature of the solution. If, in addition to the quantities of solute and solution, the solution density is also known, all concentration units are interconvertible.

When performing conversion from one concentration unit to another, always write the units in the form of fraction. Then the units of the numerator and denominator can be changed separately. Keep these points in mind:

(1) To convert a unit based on amount(mol) to one based on mass, we need the molar mass. These conversions are similar to mass-mole conversions we've done earlier.

$$\text{No. of moles} = \frac{\text{mass(g)}}{\text{molar mass}(\text{g}\cdot\text{mol}^{-1})}$$

(2) To convert a unit based on mass to one based on volume, we need the solution density. Given the mass of a solution, the density(mass/volume) gives the volume, or vice versa.

(3) Molality involves quantity of solvent, whereas the others involve quantity of solution.

(4) Total moles of solution = moles of solvent + moles of solute.

(5) Mass of solution = mass of solute + mass of solvent.

3. Chemical formulas describe the simplest atom ratio (empirical formula), actual atom number (molecular formula), and atom arrangement (structural formula) of one unit of a compound.

An ionic compound is named with cation first and anion last. For metals that can form more than one ion, the charge is shown with a Roman numeral. An older method still widely used for distinguishing between two differently charged ions of a metal is to apply the ending -ous or -ic. These endings represent the lower and higher charged ions, respectively. Oxoanions have suffixes, and sometimes prefixes, attached to the element root name to indicate the number of oxygen atoms. With two oxoanions in the family:

(1) The ion with more O atoms takes the nonmetal root and the suffix -ate.

(2) The ion with fewer O atoms takes the nonmetal root and the suffix -ite.

With four oxoanions in the family (usually a halogen bonded to O):

(1) The ion with most O atoms has the prefix per-, the nonmetal root, and the suffix -ate.

(2) The ion with one fewer O atom has just the root and the suffix -ate.

(3) The ion with two fewer O atoms has just the root and the suffix -ite.

(4) The ion with least (three fewer) O atoms has the prefix hypo-, the root,

and the suffix -ite.

Names of hydrates give the number of water molecules with numerical prefixes.

Acid names are based on anion names. Binary acid solutions form when certain gaseous compounds dissolve in water. The name consists of the following parts:

Prefix hydro-+nonmetal root+suffix -ic+separate word acid

hydro + chlor + ic + acid

Oxoacid names are similar to those of the oxoanions, except for two suffix changes:

(1) -ate in the anion becomes -ic in the acid;

(2) -ite in the anion becomes -ous in the acid.

Names of covalent compounds have the element that is leftmost or lower down in the periodic table first, and prefixes show the number of each atom.

Solutions to Problems

1. Ethylene, C_2H_4, is used for such diverse applications as ripening of citrus fruits and the preparation of plastics. What is the mass of 3.22 mol of ethylene?

Solution The molar mass, which expresses the equivalent relationship between 1 mol of a substance and its mass in grams, can be used as a conversion factor. The molar mass of C_2H_4 is 28 g · mol^{-1}.

$$\text{Mass of ethylene} = \text{No. of moles} \times \text{molar mass}$$
$$= 3.22 \times 28\ \text{g} = 90.16\ \text{g}$$

2. The substance KSCN is frequently used to test for iron in solution because a distinctive red color forms when it is added. As a laboratory assistant, we need to prepare 1.00 L of 0.20 mol · L^{-1} KSCN solution. What mass, in grams, of KSCN is needed?

Solution Molarity is moles of solute per liter of solution. To solve this problem, the mass of solute must be converted to moles, and the volume of solution must be expressed in liter. Write down the formula for molarity and what we have been given, and then solve for what's requested.

$$\text{Moles of KSCN} = 0.20 \times 1.00\ \text{mol} = 0.20\ \text{mol}$$
$$\text{Mass of KSCN} = 97 \times 0.20\ \text{g} = 19.4\ \text{g}$$

3. An aqueous solution is 0.120 m glucose, $C_6H_{12}O_6$. What are the mole fractions of each component in the solution?

Solution A 0.120 m glucose solution contains 0.120 mol of glucose in 1.00 kg of water. After converting 1.00 kg H_2O to moles, calculate the mole fraction using its definition.

The moles of H_2O in 1.00 kg of water is

$$\frac{1000}{18.02}\ \text{mol}=55.5\ \text{mol}$$

$$\text{Mole fraction of glucose}=\frac{0.120}{0.120+55.5}=0.002$$

$$\text{Mole fraction of water}=\frac{55.5}{0.120+55.5}=0.998$$

4. Calculate the concentration in (a) the molality, (b) the mole fraction and (c) the molarity of a concentrated solution of specific gravity $1.84\ \text{g}\cdot\text{mL}^{-1}$ containing 98.3% H_2SO_4 by mass.

Solution

(a) $\text{Molality of } H_2SO_4=\frac{\text{moles of solute}}{\text{kilograms of solvent}}=\frac{98.3/98.08}{100-98.3}\ \text{mol}\cdot\text{kg}^{-1}$

$=589.6\ \text{mol}\cdot\text{kg}^{-1}$

(b) $x_B=\frac{\text{moles of } H_2SO_4}{\text{total moles of solution}}$

$=\frac{98.3/98.08}{(100-98.3)/18.02+98.3/98.08}=0.914$

(c) $\text{Molarity of } H_2SO_4=\frac{\text{moles of solute}}{\text{liters of solution}}=\frac{98.3/98.08}{100/1.84}\ \text{mol}\cdot\text{L}^{-1}$

$=18.4\ \text{mol}\cdot\text{L}^{-1}$

5. A sulfuric acid solution containing 571.6 g of H_2SO_4 per liter of solution at 20 ℃ has a density of $1.3294\ \text{g}\cdot\text{mL}^{-1}$. Calculate (a) the molarity, (b) the molality, (c) the percent by mass, and (d) the mole fraction for the solution.

Solution

(a) $\text{Molarity of } H_2SO_4=\frac{\text{moles of solute}}{\text{liters of solution}}=\frac{571.6/98.08}{1}\ \text{mol}\cdot\text{L}^{-1}$

$=5.828\ \text{mol}\cdot\text{L}^{-1}$

(b) $\text{Molality of } H_2SO_4=\frac{\text{moles of solute}}{\text{kilograms of solvent}}=\frac{571.6/98.08}{1\times1.3294\times10^3-571.6}\ \text{mol}\cdot\text{kg}^{-1}$

$=7.691\ \text{mol}\cdot\text{kg}^{-1}$

(c) $\text{Percent by mass}=\frac{\text{mass of solute}}{\text{mass of solution}}\times100\%$

$=\frac{571.6}{1\times1.3294\times10^3}\times100\%=43.00\%$

(d) $\text{Mole fraction of } H_2SO_4=\frac{\text{moles of solute}}{\text{total moles of solution}}$

$$=\frac{571.6/98.08}{(1\times1.3294\times10^3-571.6)/18.02+571.6/98.08}$$

$$=\frac{5.828}{42.05+5.828}=0.1217$$

6. What is the molarity of an aqueous solution that is 2 m HCl? The density of this solution is 1.034 $g \cdot mL^{-1}$.

Solution The molality tells us that the solution contains 2 mol HCl in 1 kg of water. Take the mass of solution that contains 1 kg of water(the mass of 2 mol HCl plus 10^3 g H_2O) and use the density to convert the mass of solution to volume. Molarity equals moles of solute(HCl) divided by volume of solution in liters.

The mass of HCl is

$$2\times36.5\ g=73\ g$$

The total mass of the solution equals the mass of water plus the mass of HCl.

$$(1000+73)\ g=1073\ g$$

The volume of solution equals the mass divided by the density of the solution.

$$1073/1.034\ mL=1038\ mL=1.038\ L$$

Hence, the molarity of the solution is

$$2/1.038\ mol\cdot L^{-1}=1.927\ mol\cdot L^{-1}$$

7. Give the systematic names for the formulas or the formulas for the names of the following compounds: (a) NH_4Br; (b) Cr_2O_3; (c) $Co(NO_3)_2$; (d) potassium sulfide; (e) calcium hydrogen carbonate; (f) nickel(Ⅱ) perchlorate.

Solution Each compound is ionic and is named using the guidelines we have already discussed. In naming ionic compounds, it is important to recognize polyatomic ions and to determine the charge of cations with variable charge. In going from the name of an ionic compound to its chemical formula, we must know the charges of the ions to determine the subscripts.

(a) NH_4^+ is ammonium; Br^- is bromide. The name is ammonium bromide.

(b) Cr^{3+} is chromium(Ⅲ) or chromic; O^{2-} is oxide. The name is chromium(Ⅲ) oxide or chromic oxide.

(c) Co^{2+} is cobalt(Ⅱ) or cobaltous; NO_3^- is nitrate. The name is cobalt(Ⅱ) nitrate or cobaltous nitrate.

(d) Potassium is K^+; sulfide is S^{2-}. Because ionic compounds are electrically neutral, two K^+ ions balance one S^{2-} ion. Therefore, the formula is K_2S.

(e) Calcium is Ca^{2+}; hydrogen carbonate is HCO_3^-. Because ionic compounds are electrically neutral, two HCO_3^- ions balance one Ca^{2+} ion. Therefore, the formula is $Ca(HCO_3)_2$.

(f) Nickel(Ⅱ) is Ni^{2+}; perchlorate is ClO_4^-. Because ionic compounds are electrically neutral, two ClO_4^- ions balance one Ni^{2+} ion. Therefore, the formula is $Ni(ClO_4)_2$.

8. State why the second part of each statement is incorrect, and correct it:

(a) Ammonium phosphate is $(NH_3)_4PO_4$;

(b) Aluminum hydroxide is $AlOH_3$;

(c) $Mg(HCO_3)_2$ is manganese(Ⅱ) carbonate;

(d) $Cr(NO_3)_3$ is chromic(Ⅲ) nitride;

(e) $Ca(NO_2)_2$ is cadmium nitrate.

Solution

(a) The ammonium ion is NH_4^+, not NH_3. The correct formula is $(NH_4)_3PO_4$.

(b) The hydroxide ion is polyatomic, so it requires parentheses. The correct formula is $Al(OH)_3$.

(c) Mg^{2+} is magnesium (Ⅱ), not manganese (Ⅱ); HCO_3^- is hydrogen carbonate, not carbonate. The correct name is magnesium (Ⅱ) hydrogen carbonate.

(d) NO_3^- is nitrate, not nitride. The correct name is chromic(Ⅲ) nitrate.

(e) Ca^{2+} is calcium, not cadmium; NO_2^- is nitrite, not nitrate. The correct name is calcium nitrite.

9. Give the chemical formulas for (a) hydrobromic acid; (b) carbonic acid; (c) silicon tetrabromide.

Solution

(a) HBr; (b) H_2CO_3; (c) $SiBr_4$.

Self-help Test

Multiple Choice

1. How many atoms are there in 5 moles of sulphur atoms? (　　)

A. 1.20×10^{23}　　B. 3.01×10^{23}　　C. 6.02×10^{115}　　D. 3.01×10^{24}

2. Which one of the following is not the same number as the rest? (　　)

A. the number of molecules in 4 moles of CO_2

B. the number of hydrogen atoms in 2 moles of H_2O

C. the number of chloride ions in 4 moles of $CaCl_2$

D. the number of hydrogen atoms in 0.5 mole of C_3H_8

3. What is the name of the SO_3^{2-} ion? (　　)

A. sulfate　　B. sulfite　　C. sulfur trioxide　　D. sulfide

4. If the formula of praseodymium oxide is PrO_2, what is the formula of

praseodymium sulfate? (   )

A. Pr_2SO_4 B. $PrSO_4$ C. $Pr_2(SO_4)_3$ D. $Pr(SO_4)_2$

5. One drop of water weighs 0.040 g. How many molecules are there in one drop, taking the molar mass of water as exactly 18.0 g · mol^{-1}? (   )

A. 1.3×10^{21} B. 2.4×10^{22} C. 3.3×10^{23} D. 3.9×10^{22}

6. How many moles of hydrochloric acid are present in 0.80 L of a solution with a concentration of 0.40 mol · L^{-1}? (   )

A. 0.32 B. 0.50 C. 0.80 D. 2.0

7. Which of the following is NOT an SI base unit? (   )

A. kg B. s C. L D. K

8. What are the units of molarity? (   )

A. mol · kg^{-1} B. percent C. mol · L^{-1} D. none

9. The number 57230.357 is best shown in scientific notation as (   ).

A. 5.7230357×10^{-4} B. 57230357×10^{-3}

C. 5.7230357×10^{4} D. 5.7230357×10^{8}

10. A 20.00 mL portion of 0.100 mol · L^{-1} $Ba(NO_3)_2$ is mixed with 30.00 mL of 0.400 mol · L^{-1} NH_4NO_3. What is the $[NO_3^-]$ in the resulting solution? (   )

A. 0.270 mol · L^{-1} B. 0.280 mol · L^{-1}

C. 0.320 mol · L^{-1} D. 0.400 mol · L^{-1}

11. A solution is prepared by dissolving 1.864 g of KCl(M=74.55 g · mol^{-1}) and 8.293 g of K_2CO_3 (M=138.21 g · mol^{-1}) in enough water to make the final volume 500.00 mL. What is the $[K^+]$ in the solution? (   )

A. 0.2900 mol · L^{-1} B. 0.1200 mol · L^{-1}

C. 0.1450 mol · L^{-1} D. 0.1700 mol · L^{-1}

12. How many grams of potassium permanganate, $KMnO_4$ (M = 158.04 g · mol^{-1}), are needed to prepare 250.00 mL of a 0.1000 mol · L^{-1} solution? (   )

A. 3.951 B. 9.877 C. 15.80 D. 39.51

13. The density of an aqueous solution of acetone, CH_3COCH_3 (M=58.09 g · mol^{-1}), that is 10.00% acetone by mass, is 0.9867 g · mL^{-1} at 20 ℃. What is the molarity of acetone in this solution at 20 ℃? (   )

A. 0.1722 mol · L^{-1} B. 0.9867 mol · L^{-1}

C. 1.699 mol · L^{-1} D. 3.332 mol · L^{-1}

14. Procaine hydrochloride, $C_{13}H_{20}N_2O_2$ · HCl(M=272.77 g · mol^{-1}), is used as a local anesthetic. Calculate the molarity of a 4.666 mol · kg^{-1} solution which has a density of 1.1066 g · mL^{-1}. (   )

A. 2.272 mol · L^{-1} B. 4.056 mol · L^{-1}

C. 4.216 mol · L^{-1} D. 4.666 mol · L^{-1}

15. An aqueous solution of ethanol, CH_3CH_2OH(M=46.08 g · mol^{-1}), that is 12.00% ethanol by mass, has a density of 0.9808 g · mL^{-1} at 20 ℃. What is the molality of ethanol in this solution? ( )

A. 0.05063 mol · kg^{-1} B. 0.1200 mol · kg^{-1}

C. 2.555 mol · kg^{-1} D. 2.959 mol · kg^{-1}

16. The concentration of a solution in moles of solute per kilogram of solvent is known as ( ).

A. neutrality B. molality C. normality D. molarity

17. Concentrated H_3PO_4 is 85.0% H_3PO_4(M=97.99 g · mol^{-1}) by mass and has a density of 1.70 g · mL^{-1}. How many grams of this solution are required to prepare 250.0 mL of a 2.00 mol · L^{-1} H_3PO_4 solution? ( )

A. 52.4 B. 42.5 C. 57.6 D. 46.4

18. A saturated solution of NaCl at 30 ℃ is 6.25 mol · kg^{-1}. What is the mole fraction of NaCl? ( )

A. 0.120 B. 0.142 C. 0.320 D. 0.101

19. The common name of common salt is( ).

A. carbon dioxide B. carbon monoxide

C. sodium bicarbonate D. sodium chloride

20. Which of the following matched pairs of name and formula has an error? ( )

A. $HClO_2$, hypochlorous acid B. H_2SO_3, sulfurous acid

C. HNO_3, nitric acid D. $HBrO_3$, bromic acid

True or False

( )1. For all dilute solutions in which the solvent has a density near 1.0 g · mL^{-1}, the molality and molarity of a solution are nearly the same.

( )2. An older method still widely used for distinguishing between two differently charged ions of a metal is to apply the ending -ous or -ic. These endings represent the higher and lower charged ions, respectively.

( )3. A 1.00 mol · L^{-1} solution of sodium hydroxide contains 40.0 g of NaOH(M=40.0 g · mol^{-1}) dissolved in 1 L of water.

( )4. Equal volumes of any 1 mol · L^{-1} solutions contain an equal number of molecules of solute.

( )5. The correct name for CCl_4 is carbon(I) chloride.

( )6. The compound tin(Ⅳ) chlorate has the formula $Sn(ClO_3)_4$.

( )7. ClO_4^- is a perchlorate ion; the corresponding acid name is hypochlorous acid, $HClO_4$.

( )8. The molality of a solution is independent of temperature.

( )9. One mole of carbon-12 weighs exactly 12 grams.

( )10. A liter is a volume equal to 100 cm^3.

( )11. The SI unit of temperature is the degrees Celsius.

( )12. The mole is defined as the amount of substance in a system that contains as many elementary particles(atoms, molecules, or formula units) as the quantity of $^{12}_{6}C$ atoms in exactly 12 grams of carbon-12.

( )13. Sodium sulfide has the formula $(Na)_2SO_3$.

( )14. If 1.0 mol of $FeCl_3$ dissolves in water to make a liter of solution, then the concentration of chloride ion is 3.0 mol · kg^{-1}.

( )15. If the weight of a sample of iron is 1.0×10^{-3} grams, we can say the sample has a picogram of mass.

Fill in the blanks

1. The system of weights and measures that scientists use throughout the world is the ________ system.

2. The Kelvin scale is a system used to measure ________.

3. A mole of $KClO_3$ contains ________ atoms of oxygen.

4. When salt (NaCl) is dissolved in water to form a solution, the salt is known as the ________ and water is called the ________.

5. In chemical stoichiometric calculations, the following definitions are commonly used: (a) density=______; (b) number of moles=________/molar mass.

6. When the prefix micro-(μ) is used in the metric system, a fundamental unit of measurement is multiplied by a factor of ________.

7. Practice for both types of compounds.

Formula	Name	Formula	Name
K_2S			magnesium perchlorate
S_2Cl_2			potassium permanganate

8. A 4.00 mol · L^{-1} solution of H_3PO_4 will contain ________ g of H_3PO_4 (M= 97.99 g · mol^{-1}) in 0.250 L of solution.

9. ________ g of acetic acid(CH_3COOH, M=60.05 g · mol^{-1}) must be dissolved in 250.0 g of water to produce a 0.150 mol · kg^{-1} solution.

10. Fill in the blanks in the table. Aqueous solutions are assumed.

Compound	Molality	Percent by mass	Mole fraction
NaI	0.15		
C_2H_5OH		5.0%	
$C_{12}H_{22}O_{11}$	0.15		