



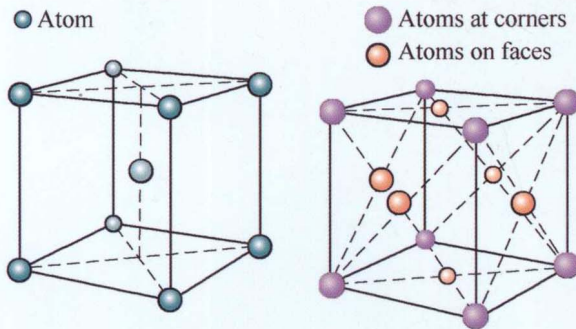
普通高等教育“十二五”规划教材

PUTONG GAODENG JIAOYU "12·5" GUIHUA JIAOCAI

Intensive Reading for Materials Science and
Engineering Specialty English

材料科学与工程专业英语精读

刘科高 田清波 主编



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2012

内 容 提 要

本书精选了材料科学与工程专业不同领域的英语课文，主要内容分为三部分，第一部分为无机非金属材料，内容涉及硅酸盐物理化学及相图、混凝土、玻璃、水泥、陶瓷、玻璃陶瓷、化学建材等；第二部分为金属材料及热处理，内容涉及金属材料及 Fe-C 相图、热处理原理、奥氏体相变、马氏体相变、回火转变、钢的淬透性及热处理、钢的化学热处理、钢的表面硬化等；第三部分为表面工程，内容涉及金属的腐蚀与防护、电沉积、化学镀、铝氧化、铬钝化技术、磷化、涂装工艺、PVD 和 CVD、表面工程中的废水处理、电化学分析方法等。

本书既可作为大中专院校材料科学与工程等相关专业的教学用书，也可供相关专业的科研、工程技术管理人员参考。

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前 言

随着世界经济一体化的发展,国内制造业的产品出口份额迅速增加,同时也涌现了大量的合资及外资企业。加上国有大中型企业产品结构的调整,这些企业作为用人单位,对毕业生的外语提出了更高的要求,精通专业外语已成为对大中型企业工程技术人员的基本要求。

为了满足高等院校材料科学与工程及相关专业本、专科教学需要,我们编写了本书。其中精选了无机非金属材料、金属材料及热处理、表面工程等方面的专业英语课文,并在文后对重要的词汇进行了注释,提出了思考题;课文的选用按覆盖面广、代表性强和短而精的原则,重点突出了与上述三个实际生产应用较多、就业率较高的专业方向有关的经典英语课文。对于材料科学与工程领域的技术人员来说,也可在生产实践中参考本书。

本书由山东建筑大学刘科高、田清波主编,无机非金属材料部分由田清波、刘巧玲、张丰庆、井敏、徐丽娜和岳雪涛编写;金属材料及热处理部分由刘科高、田彬、蔡元兴、孙齐磊和王志刚编写;表面工程部分由王玥、徐勇、郭晓斐编写。山东建筑大学的许斌教授认真审阅了本书,并提出了许多宝贵意见。

在本书编写的过程中,参考了国内外众多专家和同行的研究成果和著作,在此表示感谢。除所列参考文献之外,还参考了网络媒体上的讲义等文献资料,因这些资料来源难以考证,无法指明其准确出处,编者在此一并向其作者表示衷心的感谢。

由于编者水平有限,书中难免存在纰漏之处,恳请广大读者批评指正。

编 者
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Nonmetal Materials

Unit 1.1 Physical Chemistry of Silicate

Silicates are the most common form of minerals in the earth's system, and probably also beyond. Chemically, they consist of silica tetrahedras (SiO_4) which are combined with metal cations, such as Mg^{2+} or Fe^{2+} in a lattice structure. In crystalline lattice structures, the tetrahedras can share their oxygen atoms with other tetrahedras to form different structures of silicates: Nesosilicates (Island Silicates), Sorosilicates (Double Island Silicates), Cyclosilicates (Ring Silicates), Inosilicates (Chain Silicates), Phyllosilicates (Sheet Silicates), Tectosilicates (Framework Silicates) and Isomorphous Replacement. The replacement of one cation by another is extremely common in silicates, which constitutes the variety of silicate minerals.

Text 1 Silicate Structures and Structural Formula

(1) As we discussed in a previous lecture, the relative abundance of elements in the earth's crust determines what minerals will form and what minerals will be common. Because Oxygen and Silicon are the most abundant elements, the silicate minerals are the most common. Table 1.1.1 gives the contents of elements in the earth's crust. Since oxygen is the most abundant element in the crust, oxygen will be the major anion that coordinates the other cations.

Table 1.1.1 The contents of elements in the crust

Element	Wt. %	At. %	Volume%	Element	Wt. %	At. %	Volume%
O	46.60	62.55	~94	Na	2.83	2.34	
Si	27.72	21.22	~6	K	2.59	1.42	
Al	8.13	6.47		Mg	2.09	1.84	
Fe	5.00	1.92		Total	98.59	100.00	100
Ca	3.63	1.94					

In order to discuss the silicates and their structures it is first necessary to remember that each atom or ion-the silicates are most probably built up of ions-tries to surround itself with ions of opposite charge in such a manner that all bring their maximum influence to bear on one another. We might say that their spheres of influence are in contact. The radii of these spheres are significant but more important are the ratios of the radii, which depend on the way atoms are packed together or coordinated by larger anions, of the cations to those of the anions which surround them. In the common silicates the cations are usually smaller than the most abundant anion O. Table 1. 1. 2 and Table 1. 1. 3 list the radii of the most important ions and the radius ratio of the cation to the anion, R_x/R_z in silicates.

Table 1. 1. 2 Effective radii of ions of some of the elements in silicates (nm)

Be ²⁺	0.034	Fe ²⁺	0.083	K ⁺	0.133
Si ⁴⁺	0.039	Zn ²⁺	0.083	Ba ²⁺	0.143
Al ³⁺	0.057	Sc ³⁺	0.083	O ²⁻	0.132
Ti ⁴⁺	0.064	Zr ⁴⁺	0.087	F ⁻	0.133
Fe ³⁺	0.067	Mn ²⁺	0.091	OH ⁻	0.14 ~ 0.15
Mn ³⁺	0.070	Na ⁺	0.098	S ²⁻	0.174
Mg ²⁺	0.078	Ca ²⁺	0.106	Cl ⁻	0.181
Li ⁺	0.078	Sr ²⁺	0.127		

Table 1. 1. 3 Radius ratio of the cation to the anion, R_x/R_z , C. N. and type of crystallization structures

R_x/R_z	C. N.	Type	R_x/R_z	C. N.	Type
1.0	12	Hexagonal or cubic closest packing	0.414 ~ 0.225	4	Tetrahedral
1.0 ~ 0.732	8	Cubic	0.225 ~ 0.155	3	Triangular
0.732 ~ 0.414	6	Octahedral	< 0.155	2	Linear

Thus, for the major ions that occur in the crust, we can make the following Table 1. 1. 4 showing the coordination and coordination polyhedra that are expected for each of the common cations.

Table 1. 1. 4 The typical cations's C. N., coordination and coordination polyhedra

Ion	C. N. (with oxygen)	Coord. polyhedron	Ionic radius (nm)
K ⁺	8 ~ 12	cubic to closest	1.51(8) ~ 1.64(12)
Na ⁺	8 ~ 6	cubic to octahedral	1.18(8) ~ 1.02(6)
Ca ²⁺	8 ~ 6		1.12(8) ~ 1.00(6)
Mn ²⁺	6	octahedral	0.83
Fe ²⁺	6		0.78
Mg ²⁺	6		0.72
Fe ³⁺	6		0.65
Ti ⁴⁺	6		0.61
Al ³⁺	6		0.54
Al ³⁺	4	tetrahedral	0.39
Si ⁴⁺	4		0.26
C ⁴⁺	3	triangular	0.08

The radius ratio of Si^{4+} to O^{2-} requires that Si^{4+} be coordinated by 4O^{2-} ions in tetrahedral coordination whose edge is $0.26 \sim 0.27\text{nm}$ in length. In order to neutralize the $+4$ charge on the Si cation, one negative charge from each of the Oxygen ions will reach the Si cation. Thus, each oxygen will be left with a net charge of -1 , resulting in a SiO_4^{4-} tetrahedral group that can be bonded to other cations. It is this SiO_4^{4-} tetrahedron that forms the basis of the silicate structures including quartz and other SiO_2 modifications, as is shown in Fig. 1. 1. 1.

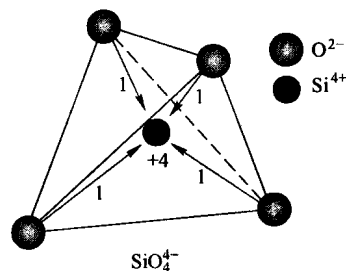


Fig. 1. 1. 1 SiO_4^{4-} tetrahedral group

Since Si^{4+} is a highly charged cation, Pauling's rules state that it should be separated as far as possible from other Si^{4+} ions. Thus, when these SiO_4^{4-} tetrahedrons are linked together, only corner oxygens will be shared with other SiO_4^{4-} groups. Several possibilities exist and give rise to the different silicate groups.

(2) In orthosilicates, SiO_4 groups are never in direct contact with one another. How two SiO_4 tetrahedra may have one corner in common forming an Si_2O_7 group is shown in Fig. 1. 1. 2. This grouping exists in the melilite silicates. Fig. 1. 1. 2b shows a linking of three SiO_4 groups giving one large Si_3O_9 aggregate as found in benitoite. A ring of six SiO_4 tetrahedra resulting in a Si_6O_{18} group has been discovered in beryl.

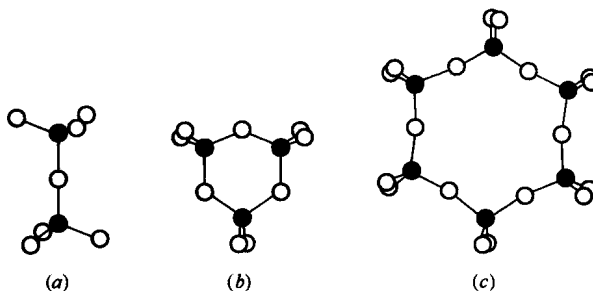


Fig. 1. 1. 2 (a) Si_2O_7 group; (b) Si_3O_9 group; (c) Si_6O_{18} group (beryl ring)

Single chains (Fig. 1. 1. 3) exist in the pyroxenes. Due to this linking of the tetrahedra the ratio of $\text{Si} : \text{O}$ becomes $1 : 3$, which is that of the metasilicates. The discovery of endless double chains (Fig. 1. 1. 4) in the amphiboles has added much to the understanding of these complex structures. The unit Si_4O_{11} occurs in them as will be shown later. Endless sheets of SiO_4 groups in which three of the four tetrahedral corners of each SiO_4 group are linked to adjoining SiO_4 groups are shown in Fig. 1. 1. 5. They give rise to Si_4O_{10} units as in the micas and talc. Another complex type of SiO_4 grouping is the feldspar type which consists of frameworks of SiO_4 groups (Fig. 1. 1. 6). Each tetrahedron shares its four corners with four adjacent SiO_4 tetrahedra resulting in a ratio $1 : 2$ for Si to O . Cations other than Si may have four or more valency coordinates. Their coordinate number seems to depend less on chemical valency than on their sizes and more complicated factors, some of them little understood. Aluminum may be the center of a tetrahedral AlO_4 group which strongly re-

sembles the SiO_4 group. It is, however, slightly larger and more distorted on account of the larger size of the Al cation. Aluminum frequently is the center of a somewhat distorted octahedron in which position it has a valency of six valency coordinates to the six corners of the octahedron. These corners are the centers of O, F, or OH anions as a rule. The behavior of Al shows that an element may have more than one coordinate number even in the same structure as will be shown in andalusite, for example, in which half of the Al ions have the coordinate number 5, the other half the number 6. Mg, Fe^{2+} and Na usually behave like Al with six coordinates, while Ca more often has eight coordinates. Beryllium on the other hand, is at the center of a tetrahedron like Si. Boron behaves the same way though it may have only three coordinates. The reader may have noticed that as a general rule the larger cations have the larger number of valency coordinates. This is a natural consequence of the empirical law stated earlier that each cation tries to gather as many anions about itself as will closely fit around it.

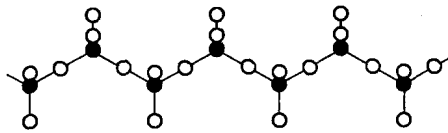


Fig. 1. 1. 3 SiO_4 endless chain in pyroxenes

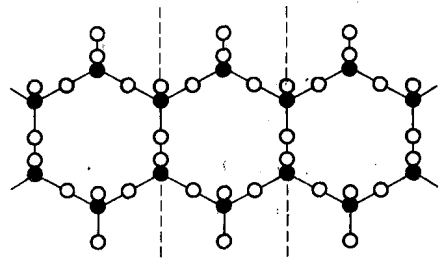


Fig. 1. 1. 4 Si_4O_{11} endless chain in amphiboles

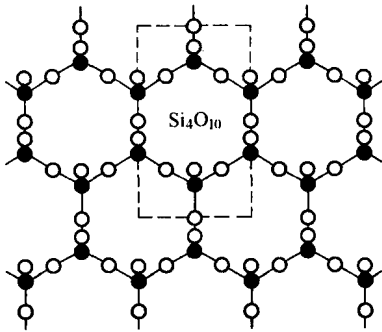


Fig. 1. 1. 5 Si_4O_{10} endless sheet in mica

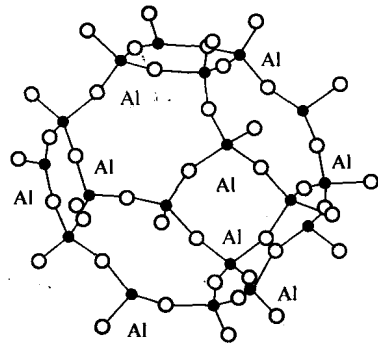


Fig. 1. 1. 6 $\text{Si}_6\text{Al}_6\text{O}_{24}$ framework in sodalite

Notwithstanding the fact that in crystals an ion with a certain chemical valency may be replaced by one with a different valency, the total positive and negative valencies must balance in any stable structure. Pauling has gone farther and has proposed his “rule of compensation of electrostatic valency” which has been found valid within certain limits for the structures investigated. It states that in a stable structure, the electric charge of each anion is approximately or exactly compensated by the strength of the electrostatic valency bonds reaching it from the cations to which it is linked directly. An example will illustrate this rule in olivine (forsterite,

Mg_2SiO_4) each O ion is linked to one Si and three Mg ions. Si has a valency 4, and each of its four bonds has a value 1. Mg has a valency 2. Each of its six coordinates is equal to one-third of a positive charge. The two negative charges of O are compensated exactly by $(3 \times 1/3 + 1) = 2$ positive charges.

Vocabulary:

silicate ['silikit]n. 硅酸盐	tetrahedral ['tetrə'hedrəl]adj. 有四面的,四面体的
minerals ['minərəl] n. 矿物,矿产,矿产品	neutralize ['nu:trə,laiz,'nju:-]vt. 使失效,抵消,中和
silica ['silikə]n. 硅石,二氧化硅	bonded ['bɒndid]adj. (材料)接合的
cation ['kætaɪən]n. 阳离子	quartz [kwɔ:ts]n. (矿)石英
lattice ['lætɪs]n. 1. 格子框架;2. 类似格子框架的设计	melilite ['melilait]n. 黄长石
crystalline ['krɪstəlɪn,-ləɪn,-li:n]adj. 水晶的,似水晶的,结晶质的 n. 结晶性,结晶度	mica ['maɪkə]n. 云母
nesosilicates [化]岛硅酸盐(各 SiO_4^{4-} 之间无共用氧原子)	talc [tælk]n. 滑石,云母
cyclosilicates 环硅酸盐	feldspar ['feldspɑ:]n. 长石
formula ['fɔ:mjʊlə]n. 1. 准则,原则;2. 公式,方程式;3. 配方	adjacent [ə'dʒeɪsənt]adj. 邻近的
anion [ə'naɪən]n. 阴离子	valency ['veɪlənsi]n. 价,化合价
maximum ['mæksɪməm]adj. 最大值的,大量的 n. 最大的量,体积、强度等	resemble [ri'zembəl]vt. 像...,类似于
radii ['reɪdiəɪ]n. 半径	octahedron [ɒktə'hedrən]n. 八面体
polyhedra [ˌpɒli'hi:dreɪ]n. 多面体 (polyhedron 的复数)	andalusite [ˌændə'lu:sait]n. 红柱石
	beryllium [bə'rɪljəm]n. 铍(元素符号 Be)
	crystal ['krɪstəl]n. 水晶,结晶(体)
	electrostatic [ɪ'lektreɪ'stætɪk]adj. 静电的,静电学的
	olivine [ˌɒli'vi:n]n. 橄榄石,黄绿

Questions:

1. Which factors influence their structures of the Silicates?
2. Please give the difference among Si_2O_7 , Si_3O_9 , Si_6O_{18} group.

Text 2 The Classification of Silicates

(1) The Classification of Silicates

Nesosilicates (Island Silicates, Orthosilicate): If the corner oxygens are not shared with other SiO_4^{4-} tetrahedrons, each tetrahedron will be isolated. Thus, this group is often referred to as the island silicate group. The basic structural unit is then SiO_4^{4-} . In this group the oxygens are shared with octahedral groups that contain other cations like Mg^{2+} , Fe^{2+} , or Ca^{2+} . Olivine is a good example: $(\text{Mg}, \text{Fe})_2\text{SiO}_4$.

Sorosilicates (Double Island Silicates): If one of the corner oxygens is shared with another tet-

rahedron, this gives rise to the sorosilicate group. It is often referred to as the double island group because there are two linked tetrahedrons isolated from all other tetrahedrons. In this case, the basic structural unit is $\text{Si}_2\text{O}_7^{6-}$. A good example of a sorosilicate is the mineral hemimorphite- $\text{Zn}_4\text{Si}_2\text{O}_7(\text{OH}) \cdot \text{H}_2\text{O}$. Some sorosilicates are a combination of single and double islands, like in epidote $-\text{Ca}_2(\text{Fe}^{3+}, \text{Al})\text{Al}_2(\text{SiO}_4)(\text{Si}_2\text{O}_7)(\text{OH})$.

Cyclosilicates (Ring Silicates): If two of the oxygens are shared and the structure is arranged in a ring, such as that shown here, we get the basic structural unit of the cyclosilicates or ring silicates. Shown here is a six membered ring forming the structural group $\text{Si}_6\text{O}_{18}^{12-}$. Three membered rings, $\text{Si}_3\text{O}_9^{6-}$, four membered rings, $\text{Si}_4\text{O}_{12}^{8-}$, and five membered rings $\text{Si}_5\text{O}_{15}^{10-}$ are also possible. A good example of a cyclosilicate is the mineral Beryl- $\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$.

Inosilicates (Single Chain Silicates): If two of the oxygens are shared in a way to make long single chains of linked SiO_4 tetrahedra, we get the single chain silicates or inosilicates. In this case the basic structural unit is $\text{Si}_2\text{O}_6^{4-}$ or SiO_3^{2-} . This group is the basis for the pyroxene group of minerals, like the orthopyroxenes $(\text{Mg}, \text{Fe})\text{SiO}_3$ or the clinopyroxenes $\text{Ca}(\text{Mg}, \text{Fe})-\text{Si}_2\text{O}_6$.

Nosilicates (Double Chain Silicates): If two chains are linked together so that each tetrahedral group shares 3 of its oxygens, we can form double chains, with the basic structural group being $\text{Si}_4\text{O}_{11}^{6-}$. The amphibole group of minerals are double chain silicates, for example the tremolite-ferroactinolite series- $\text{Ca}_2(\text{Mg}, \text{Fe})_5\text{Si}_8\text{O}_{22}(\text{OH})_2$.

Phyllosilicates (Sheet Silicates): If 3 of the oxygens from each tetrahedral group are shared such that an infinite sheet of SiO_4 tetrahedra are shared we get the basis for the phyllosilicates or sheet silicates. In this case the basic structural group is $\text{Si}_2\text{O}_5^{2-}$. The micas, clay minerals, chlorite, talc, and serpentine minerals are all based on this structure. A good example is biotite- $\text{K}(\text{Mg}, \text{Fe})_3(\text{AlSi}_3)\text{O}_{10}(\text{OH})_2$. Note that in this structure, Al is substituting for Si in one of the tetrahedral groups.

Tectosilicates (Framework Silicates): If all of the corner oxygens are shared with another SiO_4 tetrahedron, then a framework structure develops. The basic structural group then becomes SiO_2 . The minerals quartz, cristobalite, and tridymite all are based on this structure. If some of the Si^{4+} ions are replaced by Al^{3+} then this produce charge imbalance and allows for other ions to be found coordinated indifferent arrangements within the framework structure. Thus, the feldspar and feldspathoid minerals are also based on the tectosilicate framework.

(2) Isomorphous Replacement

The replacement of one cation by another is extremely common in silicates. There seems to be little doubt that the amount of O in a silicate is practically a constant and should be treated as such. The O ion is so large that it is improbable that additional O ions could enter a stable structure. The F ion or the OH radical, which are of about the same size as O, could possibly take its place, but it is more common for F to replace OH, or vice versa. We only need to mention the plagioclase feldspars in which Na and Si are replaced by Ca and Al, respectively. It is not possible, however, for Ca to

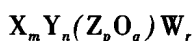
replace Na without a corresponding substitution of Al for Si. In general such replacements may be complicated. For example in the micas the number of O ions in the unit cell remained practically constant. The greatest possible variation exists in micas, however, not only in the amount of substitution of one metal for another, but also in the number of metals that may replace one another. The metals which are difficult to assign in the determination of a structure are those whose cations have two different coordinate numbers. Aluminum is a typical example. It frequently takes the place of Si with four coordinates, but it may also replace Mg, Mn, Fe³⁺, Ti and Cr with six. Table 1. 1. 4 which gives the radii of common ions is helpful in this respect. An ion will replace another only if the difference between their radii is relatively small.

(3) General Formula for Silicates

Based on these basic structural units, we can construct a general structural chemical formula for the silicates. But one substitution in particular tends to mess things up a bit. This is Al³⁺, the third most abundant element in the Earth's crust. Al³⁺ has an ionic radius that varies between 0.54nm and 0.39nm depending on the coordination number. Thus, it could either fit in 6-fold coordination with oxygen or 4-fold coordination with oxygen. Because Al³⁺ will go into 4-fold coordination with oxygen, it sometimes substitutes for Si⁴⁺. If such a substitution takes place, it creates a charge imbalance that must be made up elsewhere in the silicate structure.

The other common elements in the Earth's crust that enter the silicates do so in other types of coordination. Ions like Al³⁺, Mg²⁺, Fe²⁺, Fe³⁺, Mn²⁺, and Ti⁴⁺ enter into 6-fold or octahedral sites. Larger ions like Ca²⁺, and Na⁺, are found in octahedral coordination or 8-fold, cubic coordination sites. Very large cations like K⁺, Ba²⁺, and sometimes Na⁺ are coordinated by 12 oxygens in 12-fold coordination sites.

We can thus write a general structural formula for the silicates as follows:



where X represents an 8-fold to 12-fold coordination site for large cations like K⁺, Rb⁺, Ba²⁺, Na⁺, and Ca²⁺. Y represents a 6-fold (octahedral) site for intermediate sized cations like Al³⁺, Mg²⁺, Fe²⁺, Fe³⁺, Mn²⁺, and Ti⁴⁺. Z represents the tetrahedral site containing Si⁴⁺, and Al³⁺. The ratio $p : q$ depends on the degree of polymerization of the silica (or alumina) tetrahedrons, or the silicate structural type as discussed above. O is oxygen, and W is a hydroxyl (OH⁻) site into which can substitute large anions like F⁻ or Cl⁻. The subscripts m , n , and r depend on the ratio of p to q and are chosen to maintain charge balance.

This is summarized in the Table 1. 1. 5 shown here. In this table note that there is very little substitution that takes place between ions that enter the X, Y, and Z sites. The exceptions are mainly substitution of Al³⁺ for Si⁴⁺, which is noted in the Table, and whether the X site is large enough to accept the largest cations like K⁺, Ba²⁺, or Rb⁺.

Table 1.1.5 The typical ion and their site at a general structural formula

Site	C. N.	Ion	Site	C. N.	Ion
Z	4	Si ⁴⁺	X	8	Na ⁺
		Al ³⁺			Ca ²⁺
Y	6	Al ³⁺		8 ~ 12	K ⁺
		Fe ³⁺			Ba ²⁺
		Fe ²⁺			Rb ⁺
		Mg ²⁺			
		Mn ²⁺			
		Ti ⁴⁺			

Vocabulary:

classification [, klæsifi ' keifən] n. 分类, 分级, 类别, 种类, 门类
 orthosilicate [, ɔ : θə ' siləkeit] n. 正硅酸盐
 sorosilicate [, sɔrə ' silikit] n. 侏硅酸盐
 hemimorphite [, hemi ' mɔ : fait] n. 异极矿
 epidote [' epidəut] n. 绿帘石
 inosilicates 链硅酸盐
 pyroxene [pai ' rɔksi : n] n. 辉石
 amphibole [' æmfibəul] n. 闪石
 ferroactinolite [, feræk ' tinə , lait] n. 铁阳起石
 clay [klei] n. 黏土, 泥土

chlorite [' klɔ : rait] n. 亚氯酸盐, 绿泥石
 biotite [' baiətait] n. 黑云母
 cristobalite [kris ' təubəleit] n. 方石英
 tridymite [' traidə , mait] n. 鳞石英
 feldspathoid [feld ' spæθɔid] n. 似长石
 vice versa [, vaisə ' vɜ : sə , vais] adv. 反过来也
 一样
 plagioclase [' pleidziəukleis] n. 斜长岩
 polymerization [, pɔlimərai ' zeifən] n. 聚合
 subscript [' sʌb , skript] adj. 下标的, 脚注的
 n. 下标, 脚注

Questions:

1. How to distinguish the different kind of silicates?
2. What is the general formula for silicates?

Text 3 The Typical of Silicates Forming Minerals

(1) The Typical of Silicates Forming Minerals

Orthosilicates: We now turn our discussion to a systematic look at the most common rock forming minerals. In orthosilicates the ratio Si : O is 1 : 4 or greater. The SiO₄ tetrahedra are separated from one another by the remaining cations of the structure which will just neutralize the negative charges of the SiO₄ groups. As discussed above, orthosilicates are based on the isolated SiO₄⁴⁻ tetrahedral groups, also called the nesosilicates or island silicates. Among these are the olivines, garnets, Al₂SiO₅ minerals, staurolite, and sphene.

Olivine Group. In the olivines, the remaining corner oxygens form octahedral groups that coordinate Mg²⁺ and Fe²⁺ ions. They consist of a complete solid solution between Mg₂SiO₄ (forsterite, Fo) and Fe₂SiO₄ (fayalite, Fa). There is limited substitution of the following end members: