NATIONAL UNIVERSITY OF DISTANCE EDUCATION

Compuestos Inorgánicos de Estructura Compleja

Idioma: EN

INSTRUCTIONS:
No general instructions specified in the form, but there are 5 questions in the exam.

Question 1

Structure and bonding of silicates

STUDENT RESPONSE:

Silicates are inorganic compounds that contain silicon (Si) and oxygen (O) as their main structural units. The basic structural unit is the silicon-oxygen tetrahedron (SiO_4^{4-}), where each silicon atom is bonded to four oxygen atoms. These tetrahedra can be linked together in various ways to form different silicate structures.

The bonding in silicates is primarily covalent, with strong Si-O bonds. The silicon atom has four valence electrons, and each oxygen atom has six valence electrons. In the silicon-oxygen tetrahedron, each oxygen atom donates two electrons to the silicon atom, forming a shared electron pair. This results in a total of eight valence electrons around the silicon atom, satisfying the octet rule.

The oxygen atoms in the tetrahedron are shared with other tetrahedra, forming different silicate structures. These structures can be classified into four main categories:

1. Isolated tetrahedra: Each silicon-oxygen tetrahedron is independent and not linked to any other tetrahedra.
2. Single chains: Tetrahedra are linked together in a single chain, with each tetrahedron sharing two oxygen atoms with adjacent tetrahedra.
3. Double chains: Tetrahedra are linked together in parallel double chains, with each tetrahedron sharing two oxygen atoms with adjacent tetrahedra in the same chain and two oxygen atoms with tetrahedra in the adjacent chain.
4. Sheets: Tetrahedra are linked together in two-dimensional sheets, with each tetrahedron sharing three oxygen atoms with adjacent tetrahedra.
5. Three-dimensional frameworks: Tetrahedra are linked together in a three-dimensional network, with each tetrahedron sharing all four oxygen atoms with adjacent tetrahedra.

The bonding and structure of silicates determine their physical and chemical properties, such as hardness, melting point, and reactivity.

Question 2

What is a borane? Classification of boranes

STUDENT RESPONSE:

A borane is a chemical compound composed exclusively of boron and hydrogen. Boranes are classified based on the number of boron atoms in the molecule, ranging from diborane (B2H6) to complex cluster compounds. Diborane is the simplest borane, featuring bridging hydrides and a B-B bond. Higher boranes, such as B5H9 and B10H14, exhibit cyclic and cluster structures. Boranes are highly reactive and play key roles in organic synthesis and materials science.

Question 3

Give examples of the use of inorganic heterocycles in the synthesis of the corresponding polymers

STUDENT RESPONSE:

Inorganic heterocycles, such as polysilazanes (e.g., SiNH)n) and polysilanes (e.g., SiH)n), are precursors for the synthesis of inorganic polymers like polysilanes (e.g., SiH)n) and polysilazanes (e.g., SiNH)n). For example, polysilazanes can be thermally decomposed to form cross-linked silicon nitride networks, while polysilanes can be oxidized to produce silicon oxide networks. Additionally, polythiophenes (e.g., (C4H2S)n) are used to synthesize conductive polymers like polythiophene, which has applications in electronics. Polyphenylenes (e.g., (C6H4)n) are precursors for the synthesis of poly(p-phenylene), a high-temperature-resistant polymer. Finally, polyphosphazenes ((R-N=P-O)n) are used to create biocompatible polymers like poly(dichlorophosphazene), which has applications in drug delivery and tissue engineering.

Question 4

Crystalline defects

STUDENT RESPONSE:

Crystalline defects are irregularities in the arrangement of atoms within a crystal structure. They can be classified into two main types: point defects and extended defects. Point defects occur at individual lattice sites and include vacancies (missing atoms), interstitials (extra atoms occupying non-lattice sites), and impurities (foreign atoms substituting for host atoms). Extended defects involve distortions in the periodic arrangement of atoms over a larger region, such as dislocations (linear defects) and grain boundaries (planar defects). These defects influence properties like electrical conductivity, mechanical strength, and optical behavior.

Question 5

Explain the polymerization of vanadates, VO43- as a function of concentration and pH

STUDENT RESPONSE:

The polymerization of vanadates (VO_4^{3-}) is a complex process influenced by concentration and pH. At low concentrations, the VO_4^{3-} tetrahedra remain isolated due to electrostatic repulsion. However, as concentration increases, the repulsion decreases, allowing for the formation of dimers (e.g., $V_2O_7^{4-}$) and higher-order polymers.

At high pH (>pH 7), the vanadate ion is deprotonated ($VO_4^{3-} \rightarrow VO_4^{2-}$), reducing the charge density and increasing the likelihood of polymerization. The process involves the formation of bridging oxo ligands (e.g., V-O-V linkages), leading to the creation of extended structures such as polyoxovanadates (e.g., $[V_3O_9]^{6-}$).

At low pH (<pH 3), protonation occurs ($VO_4^{3-} \rightarrow H_2VO_4^{2-}$), stabilizing the tetrahedral structure and inhibiting polymerization. The optimal pH for polymerization lies between 3 and 7, where partial protonation allows for controlled bridging.

The polymerization can be represented as:
$VO_4^{3-} \rightarrow [V_2O_7]^{4-} \rightarrow [V_3O_9]^{6-} \rightarrow [V_{10}O_{28}]^{8-}$
(where the square brackets indicate polyoxovanadate clusters).

The final answer is: The polymerization of VO_4^{3-} proceeds via dimerization (e.g., $V_2O_7^{4-}$) and further bridging at moderate pH (3–7), forming extended polyoxovanadates. At high pH, deprotonation enhances polymerization, while low pH stabilizes the monomeric form.