Literature survey history of zeolites biology essay

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The recognition of Zeolites as a new group of minerals was first observed by Cronstedt A. F. in 1756. This consisted of hydrated aluminosilicates of the alkali and alkaline earth material[1]. Zeolites are microporous crystalline aluminosilicates, composed of TO4 tetrahedra (T = Si, Al) with oxygen atoms connecting neighbouring tetrahedra[2].

Zeolites are formed naturally and found practically all over the world. Natural deposits of Zeolites are widely exploited, but large scale synthesis by controlled hydrothermal crystallization from solutions or precipitation from gels has proved most significant and enables the Si: Al lattice ratio to be modified, giving rise to variations in sorptive activity and ion exchange properties [3]. The precise geometry of the Zeolite structures enable them to differentially adsorb neutral molecules according to their size or structure, a property which gave rise to Zeolites being termed ' Molecular Sieves'. This property is the basis of many industrial uses such as gas and liquid phase operations to effect separation of hydrocarbons, drying, and as catalytic substrates for petrochemical cracking and reforming reactions [4].

Due to the amount of time it takes for a Zeolite to form and its need in various industries, an important development was achieved by synthesising the Zeolite mineral in laboratories. Zeolites were artificially synthesised in 1862 by St. Claire-Deville via the simulation of the geological conditions under which naturally occurring Zeolites were formed [1]. The experiment was based around a mixture of potassium silicate and sodium aluminate which were heated in a sealed glass tube to form the mineral under given conditions; but there were many other claims of Zeolite synthesis [4]. Though the early commercial interest for Zeolite was sought by the jewellery industry, two important characteristics were demonstrated in the mid 1800s and the early 1900s. Eichorn demonstrated in 1858 the use of Zeolites as ion exchangers using chabazite and natrolite while Weigel and Steinhoff used chabazite to show the use of Zeolites as a molecular sieve in 1925 [3]. These early observations were further extended and reported by R. M. Barrer in 1938. He gave the first definitive report with descriptions of the ion exchange, dehydration and gas-sorptive behaviour of natural Zeolites and a demonstration of the synthesis of some Zeolites to their natural counterparts [5]. These Zeolites were formed under the following conditions; high temperatures, high salt concentrations and self generating pressures [5]. This process was reversed by the Union Carbide workers under the supervision of R. M. Milton, who synthesised Zeolites under a low-temperature (~100°C) and low pressure hydrothermal process. A series of synthetic Zeolites were prepared using alkali aluminosilicate gels including Zeolites A, X and Y, which were commercialized in 1954 as a new class of industrial materials for purification and separation processes [1]. This advancement lead to the discovery of the catalysis attributes of Zeolites which boosted the need for this mineral in the industry and searches for Zeolite deposits in sufficient quantities for industrial use [3]. From the low silica Zeolite (A and X) synthesis conducted by Barrer, researches were then able to produce Zeolites which has higher contents of silica such as the intermediate silica Zeolites which could have a Si: Al ratio as high as 5. The synthesis of high silica Zeolites (Zeolite beta and ZSM-5, ZSM-11) was done by Mobil’s R&D labs where Zeolites with Si: Al ratio of 10 to 100 was produced [1]. The higher Si: Al ratio is said to alter the surface properties and gives an organophilic-hydrophobic characteristic to the Zeolites [6].

Presently, there are at least 194 synthetic Zeolites known that garnered their discovery from the early synthetic Zeolites such as A, X, Y, L and ZSM-5 [7].

Structure of Zeolites

The properties of a Zeolite are dependent on the topology of its framework, the size, shape and accessibility of its free channels, the location charge and size of cations within the framework, the presence of faults and occluded material, the ordering of T-atoms, and the local environment of T-atoms. Therefore, location charge and structural information are extremely important in understanding the ion exchange, adsorptive and catalytic properties of Zeolite catalysts. The primary building block of a typical Zeolite is a tetrahedron of four oxygen anions surrounding a small silicon or aluminium ion, see Figure 1. The Zeolites are formed into highly crystalline aluminosilicate materials based on the arrangement of these fundamental building blocks of tetrahedral SiO4 and AlO4 giving rise to a three dimensional network. The structural formula is given as;

Ma/n [(AlO2) b (SiO2) c] dH2O

where M is the cation of valence n, d is the number of water molecules, c/b is the silica to alumina ratio, (b+c) is the number of tetrahedra present in the unit cell [9]. From this three dimensional network, the crystal lattice accounts for the -2 oxidation state of oxygen whereby, each silicon ion has its +4 charge balanced by the four tetrahedral oxygen and the silica tetrahedral become neutral. In the case of the alumina, one residual charge of -1 will require a +1 charge from a cation in the structure to maintain neutrality. These cations are usually sodium in the Zeolites as it is initially prepared, but they can be readily replaced by ion exchange. Ion exchange represents the most direct and useful method for alteration of Zeolite properties.

Figure : Primary Building Block of Zeolites

The tetrahedra are arranged so that the Zeolites have an open framework structure, which defines the pore structure with a high surface area. Cations and water molecules can be found in the channels and cages of the Zeolite. The presence of mobile cations determines the property of Zeolite as ion-exchanger where the quantity of aluminium will affect the ion-exchange capacity. Water molecules which are trapped inside the Zeolite channels can be removed by heating between 250-350°C. As mentioned earlier, the amount and position of water molecules is also influenced by: the architecture of Zeolite; size and shape of cavities and channels (4) and the amount and characteristic of cations present.

The silica and alumina tetrahedra are combined into more complicated units known as the secondary building units (SBUs). These are shown in Figure 2 below. These secondary building units (SBUs) were first described by Meier in 1968 and they are based on the geometric arrangement of the tetrahedral. The SBUs describe all the possible known Zeolite frameworks (11). Zeolites were then classified by Breck in 1974 and this was based on their framework topology for which the structures are known and these were categorised into seven groups as shown in table 1.

Figure : Framework Structure of Zeolite Secondary Building Units[7]

It can be noted that SBUs are non-chiral (neither left nor right “ handed”). A unit cell always contains the same number of SBUs, and although rare, some materials can have different combinations of SBUs within the Zeolite framework. The framework may be considered in terms of large polyhedral building blocks forming characteristic cages. For example, sodalite, Zeolite A (LTA) and Zeolite X / Y (Faujasite) can all be generated by the truncated octahedron known as the)¢-cage. (http://www. ch. ic. ac. uk/vchemlib/course/zeolite/structure. html)

Table : Classification of Zeolite Structures by Breck (1974)

Group	**Secondary Building Unit (SBU)**
1	Single 6-ring, S 6R
2	Single 4-ring, S 4R
3	Double 4-ring, D 4R
4	Double 6-ring, D 6R
5	

Complex 4-1, T5O10 unit

6

Complex 5-1, T8O16 unit

7

Complex 4-4-1, T10O20 unit

2. 2. 1. Structure of Zeolite A

Zeolite A exhibits the LTA (Linde Type A, Figure 3) structure. It has a 3-dimensional pore structure with pores running perpendicular to each other in the x, y, and z planes, and is made of secondary building units 4, 6, 8, and 4-4. http://izasc. ethz. ch/fmi/xsl/IZA-SC/FWmain_images/LTA_sod_100. gif

Figure : Linde Type A Zeolite FrameworkThe pore diameter is defined by an eight member oxygen ring and is small at 4. 2Å. This leads into a larger cavity of minimum free diameter 11. 4Å. The cavity is surrounded by eight sodalite cages (truncated octahedral) connected by their square faces in a cubic structure. The unit cell is cubic (a = 24. 61Å) with Fm-3c symmetry. Zeolite A has a void volume fraction of 0. 47, with a Si/Al ratio of 1. 0. It thermally decomposes at 700°C [7].

2. 2. 2. Structure of Zeolite Y

Zeolite Y exhibits the FAU (Faujasite, Figure 4) structure which has a 3-dimensional pore structure with pores running perpendicular to each other in the x, y, and z planes similar to LTA, and is made of secondary building units

4, 6, and 6-6. http://izasc. ethz. ch/fmi/xsl/IZA-SC/FWmain_images/FAU_111. gif

Figure : FAU Zeolite Y FrameworkThe pore diameter is large at 7. 4Å since the aperture is defined by a 12 member oxygen ring, and leads into a larger cavity of diameter 12Å. The cavity is surrounded by ten sodalite cages (truncated octahedral) connected on their hexagonal faces. The unit cell is cubic (a = 24. 7Å) with Fd-3m symmetry. Zeolite Y has a void volume fraction of 0. 48, with a Si/Al ratio of 2. 43. It thermally decomposes at 793â)°C [7].

2. 2. 3. Structure of Zeolite ZSM-5

2. 3. Properties of Zeolites

Applications of Zeolites

Zeolites are used in three major applications and these are due to their physical and chemical properties.

Ion exchangers: Zeolites can interact with water to absorb or release ions. Ion exchangers are insoluble materials carrying reversibly fixed ions. These ions can be stoichiometrically exchanged for other ions of the same sign. (from page 30 onwards of zaragodni)

Molecular sieves: Due to their porosity and the size of their apertures, Zeolites can selectively absorb ions that fit into their structural cavities

Catalysis: They can hold large molecules and help in the breaking down process to aid in the reaction mechanism of the given process

The most well known use for Zeolites is in water softeners. Calcium in water can cause it to be “ hard” and capable of forming scum and other problems. Zeolites charged with the much less damaging sodium ions can allow the hard water to pass through its structure and exchange the calcium for the sodium ions. This process is reversible. In a similar way Zeolites can absorb ions and molecules and thus act as a filter for odour control, toxin removal and as a chemical sieve. Zeolites can have the water in their structures driven off by heat with the basic structure left intact. Then other solutions can be pushed through the structure. The Zeolites can then act as a delivery system for the new fluid. This process has applications in medicine, livestock feeds and other types of research. Zeolites added to livestock feed have been shown to absorb toxins that are damaging and even fatal to the growth of the animals, while the basic structure of the Zeolite is biologically neutral.

Industrial applications make use of synthetic Zeolites of high purity, which have larger cavities than the natural Zeolites. These larger cavities enable synthetic Zeolites to absorb or hold molecules that the natural Zeolites do not. Some Zeolites are used as molecular sieves to remove water and nitrogen impurities from natural gas. Because of their ability to interact with organic molecules, Zeolites are important in refining and purifying natural gas and petroleum chemicals. The Zeolites are not affected by these processes, so they are acting as catalysts. Zeolites are used to help break down large organic molecules found in petroleum into the smaller molecules that make up gasoline, a process called catalytic cracking. Zeolites are also used in hydrogenating vegetable oils and in many other industrial processes involving organic compounds.

Table : Cation exchange capacities of some natural and synthetic Zeolites

Zeolite	**Capacity (meq g-1)**
Natural	
Analcime	4. 95
Chabazite	4. 95
Phillipsite	4. 67
Clinoptilolite	2. 64
Mordenite	2. 62
Synthetic	
Zeolite A	4. 95
Zeolite X	

6. 34

Zeolite Y

4. 10

Characterisation Techniques

Information on the structural, chemical and catalytic characteristics of Zeolites is essential for deriving relations between their chemical and physiochemical properties on the one side and the sorptive and catalytic properties on the other. Such relations are of high importance, as they allow the rational development of sorbents, catalysts and advanced structural materials.

Individual analysis techniques typically probe only a particular aspect of the material and consequently, a combination of methods is necessary to give a balanced description of the frequently complex Zeolite. In general, the characterization of a Zeolite has to provide information about:

Its structure and morphology

Its chemical composition

Its ability to absorb and retain molecules

Its ability to chemically convert these molecules

A major difficulty arises from the fact that the latter two are surface chemical properties. The micropore surface of a Zeolite is, however, a periodic three-dimensional intrinsic property of a material and, thus, cannot be directly probed with surface sensitive techniques. Therefore, many of the approaches chosen rely on bulk characterization techniques and focus on the description of the interaction of the Zeolite with atomic or molecular probes. Typical analytical approaches and the probed chemical or structural information are summarised in the table below.

Technique

Structure

Pore Size

Chemical Composition

Functional Groups

Electron microscopy (HRTEM, SEM, EDX)

Nuclear magnetic resonance

(MAS-NMR)

Sorption of probe molecules

Model reactions

Thermogravimetry, Differential scanning calorimetry

(TGA/DSC)

Temperature programmed

Vibrational spectroscopy

X-ray absorption spectroscopy (XAS)

X-ray diffraction (XRD)

X-ray fluorescence spectroscopy (XRF)

X-ray photoelectron spectroscopy (XPS)

Inductively coupled plasma spectroscopy (ICP)

For the purpose of this research, the synthesised Zeolites were characterised using the X-Ray Diffraction Method (XRD), Scanning Electron Microscopy (SEM)/Electron Dispersive Spectroscopy (EDS), and Inductively Coupled Plasma Spectroscopy (ICP). These three equipments will be further discussed in this chapter.

X-ray diffraction (XRD)

The technical development of the X-ray diffraction analyser is one that has developed immensely in recent times. In 1896, details of the most important characteristics of X-rays were first described by the German physicist, Wilhem Conrad Röntgen. The following theories were established:

absorption of x-rays directly proportional to the molecular weight of exposed material

effect of x-rays on photographic emulsions

discharged electrified bodies

scattering of x-rays by matter in radiating directions[8].

These led to further work and successful experiments carried out by Friedrich and Knipping using crystals as natural lattices for diffraction. They obtained the first x-ray diffraction photograph which later formed the basis of work by W. H. Bragg and M. von Laue, a former a professor at the University of Manchester, who used x-ray diffraction to deduce the structure of a number of crystalline salts[9].

A hypothesis of x-rays being short pulses of electromagnetic radiation and reflected by the sheets of atoms present in crystalline compounds was studied by William Lawrence Bragg, son of W. H. Bragg. This concept led to the insight of the geometric behaviour of diffracted x-rays and its ability to analyse crystal structures with the x-ray diffraction becoming a key instrument in determination of crystal structures.

In 1919 A. W. Hull gave a paper titled, " A New Method of Chemical Analysis". Here he pointed out that

"…. every crystalline substance gives a pattern; the same substance always gives the same pattern; and in a mixture of substances each produces its pattern independently of the others."

The X-ray diffraction pattern of a pure substance is, therefore, like a fingerprint of the substance. The powder diffraction method is thus ideally suited for characterization and identification of polycrystalline phases. http://epswww. unm. edu/xrd/xrdbasics. pdf

For determining the long-range order and the phase purity of Zeolites, XRD provides the most comprehensive description of members of Zeolite groups. The theory is based on the elastic scattering of X-rays from structures that have long range order. XRD is used to monitor the phase purity and crystallization and the purity of the Zeolite particles. XRD also gives information of the particle strain and lattice size

2. 3. 1. 1 Principle of XRD

When a crystal is bombarded with X-rays of a fixed wavelength (similar to spacing of the atomic-scale crystal lattice planes) and at certain incident angles, intense reflected X-rays are produced when the wavelengths of the scattered X-rays interfere constructively (Figure 5).

Figure : Schematics of the X-ray diffraction spectrometer (British Museum 2005)

In order for the waves to interfere constructively, the differences in the travel path must be equal to integer multiples of the wavelength. When this constructive interference occurs, a diffracted beam of X-rays will leave the crystal at an angle equal to that of the incident beam. The general relationship between the wavelengths of incidence X-rays, angle of incidence and spacing between the crystal lattice planes of atoms is known as Bragg’s law:

n. Î» = 2d. sinÎ¸

Where:

n (an integer) is the “ order” of reflection

Î» is the wavelength of the incident X-rays

d is the inter-planar spacing of the crystal and

Î¸ is the angle of incidence.

The diffracted x-rays detected by the equipment produce a series of peaks that build a characteristic “ fingerprint”.

Such peaks are generated according to Bragg’s law of diffraction[10], schematised in figure 2. 2. The incoming x-rays collide with several planes of atoms, so that the deeper the plane, the longer the distance travelled by the beam, which may result in the reflected beams being out of phase (meaning that the crests and troughs of the waves will not be in alignment).

2

Figure 6: Schematic representation of Bragg’s law. X-rays are only scattered in phase at certain angles, depending on the distance between atomic planes.

X-ray diffraction patterns may be obtained both from single crystals or form a powder sample, depending on the sort of analysis that is desired. Single crystals are used when a detailed analysis of the molecular structure is required, and has been the basis for determining the atomic arrangement within crystalline materials. Powder x-ray diffraction has a more limited reach and is used mainly to identify materials given their fingerprint pattern.

Diffraction patterns can offer a lot of information: arrangement of atoms, nature of chemical bonds and orientation of molecules can be visualised directly; hence the variety of scientific areas where XRD is an indispensable tool.

In the case of zeolites, XRD has played a key role in the interpretation of framework symmetry. Given that the majority of zeolite species share similar or equal chemical composition, the only way to differentiate them is their crystalline structure. In-situ XRD studies are also becoming a useful tool in the study of synthesis mechanisms[11].

Scanning electron microscope / Energy dispersive X-ray analysis (SEM/EDAX)

Scanning Electron Microscopy is a versatile and well-established complementary technique to light optical microscopy.

The first optical microscope by Robert Hooke became an insufficient resource due to the resolution of the microscope and limited wave nature of light. This led to further studies and research carried out by Max Knoll and Ernst Ruska, who built the first Transmission Electron Microscope as part of a PhD project. Since most of the samples are non-conductive and imagery depends on electrons, the samples were then coated with a thin layer of evaporative metal, commonly gold, before analysis. Many more sophisticated preparation methods have been devised, turning electron microscopy a useful technique in medicine and biology, materials science, etc[12].

By using a beam of electrons instead of photons, samples can be imaged at far higher magnifications. For most of the cases, electrons are emitted from a heated tungsten filament. The accelerated beam travels through a series of condenser and objective lenses that, by creating a symmetric electromagnetic field, focus and shape the electron flow, so that when it reaches the specimen, it has a diameter of only few nanometres. It then scans the sample, which is kept in a vacuum chamber[13-15]. The reflected/emitted electrons are received by a detector, the resulting signal amplified and then interpreted.

Energy Dispersive X-ray Analysis (EDX) is employed in Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) for local elemental identification. The incident electron beam induces X-ray fluorescence in the sample which is energy-analyzed using a cooled semiconductor detector. The element-specific spectral lines are then identified to give the local elemental composition. EDX is used in many different application areas such as in the chemical, electronic and food industries as well as refineries. It can be used with solid, powder and frozen liquid samples.

2. 3. 2. 1 Principle of SEM and EDAX

SEM can use different signals to generate contrast mechanisms. The back-scattered electron and secondary electron signals can be used to form images that can give information about the structure, topography and compositional features of a sample.

2

Figure : Electron signals produced from specimen interaction with incident beam

The secondary images can be easily interpreted since it contains light and shades that resemble optical imagery. Secondary electrons are rather abundant and the most commonly used signal in SEM.

Most EDX equipments are fitted in conjunction to a scanning electron microscope (SEM). The EDX measures the energy of X-rays that are generated by the atoms of the sample during interactions with the electron beam. The X-ray spectra formed are characteristic of the atoms that formed them, allowing the chemical composition of the sample to be determined.

Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES)

The inductively coupled plasma – optical emission spectrometer (ICP-OES) is used to determine concentrations of a wide range of elements in solution. ICP-OES is a fast multi-element technique with a dynamic linear range and moderate-low detection limits (~0. 2-100 ppb).

The instrument uses an ICP source to dissociate the sample into its constituent atoms or ions, exciting them to a level where they emit light of a characteristic wavelength.

Figure : Process taken when sample droplet is introduced to the ICP-OES

Inductively Coupled Plasma Optical Emission Spectrometry is a technique ideally suited to the analysis of naturally occurring materials, including water, sediments, soils, rocks, minerals and biological matter. A number of features distinguish ICP-OES from AAS and most of these are derived from the structure and characteristics of the light source plasma.

Simultaneous, sequential analysis of multiple elements possible

Wide linear region of analytical curve

Few chemical interference or ionization interference, making analysis of high-matrix samples possible

High sensitivity (low limit of detection for majority of elements is 10ppb or lower)

High number of measurable elements that are difficult to analyze in AAS such as Zr, Ta, rare earth, P and B can be easily analysed

Stable http://www. siint. com/en/products/icp/tec_descriptions/descriptions1_e. html

2. 3. 3. 1 Principle of ICP

The main features of the ICP-OES are the nebuliser, spray chamber, ring torch, and detector. When plasma energy is applied to a sample, the component elements (atoms) are excited. When the excited atoms return to low energy position, emission rays (spectrum rays) are released and the emission rays that correspond to the photon wavelength are measured. The element type is determined based on the position of the photon rays, and the content of each element is determined based on the rays' intensity.

Figure : Major components of an ICP-OES equipment

Before this can be achieved, the sample which is usually in liquid form is pumped via a pump (1ml/min) into the nebulizer where it is converted into a fine aerosol by its contact with argon gas. The sample, which must usually must be in a liquid form. The fine droplets of the aerosol, which represent only 1-2% of the sample, are separated from larger droplets by means of a spray chamber. The fine aerosol exits the spray chamber and passed through the ring torch. The plasma is used to generate photons of light by the excitation of electrons of a ground-state atom to a higher energy level. When the electrons “ fall” back to ground state, wavelength-specific photons are emitted that are characteristic of the element of interest.

2. 4. Synthesis of Zeolites

Zeolite synthesis occurs by a hydrothermal process with reagents being a silica source, an alumina source, a mineralizing agent such as OH- or F- , and, for higher Si/Al ratio Zeolites, and organic molecules as structure-directing agents. The role of inorganic metal cations, such as Na+, or K+, is quite profound. Below is a standard schematic for Zeolite processes (Auerbach et. al). Synthesis proceeds at elevated temperatures (60-200â)°C) where crystals grow through nucleation. The Zeolite synthesis involves two steps: nucleation and crystallization. Nucleation is a process where small aggregates of precursors give rise to nuclei (embryos), which become larger with time (Szostak, 1989). Crystallization is the formation of the Zeolite crystals.

Produce schematic of a generic process

Effect of synthesis parameters on Zeolite crystallisation

The main factors influencing Zeolite formation are (Szostak, 1989)

Composition of the reaction mixture

Temperature

Time

History-dependent factors

Composition

Temperature

Time

History-dependant factors

Preparation of Zeolites

Even when the reaction mixture is "fixed" a large number of variables can impact on Zeolite crystallisation. Of these variables, the temperature and time employed are the most obvious – this is because of the metastable nature of Zeolites. However, the raw material sources (purities, re-activities), order of mixing and the agitation employed can also have major effects. A simple explanation can be provided for the impact that may be observed for variations in raw material sources and/or order of mixing. We have seen that Zeolites are metastable species and that many of the known topologies actually have very similar compositions (e. g. LTL and MOR). Bearing this in mind it can be seen that a specific raw material is employed that has a slower rate of dissolution (for example for silica) then the initial gel may not have the " target" composition but may be deficient in silica thus providing a lower effective silica-alumina ratio. If the rate of dissolution of the silica is slow compared to the induction period for a phase formed from a lower silica-alumina ratio then the target phase may not be produced. Similarly, if a viscous gel is produced from the reaction mixture but mixing is inadequate or, indeed, absent then an inhomogeneous reaction mixture may result with pockets of gel having di¬€erent compositions each ” pocket” acting like a ” mini-reactor” and generating phases corresponding to the composition in that mini-reactor [8].

Vitrification

Vitrification is the conversion of a siliceous material into a glass-like solid. Crystallisation occurs at temperatures above 800â)°C, resulting in very strong bonds between the glass and any impurities contained within. These bonds are resistant to chemical and biological degradation, immobilising hazardous elements[16]. Even though it can be applied to a variety of pollutants, the high amounts of energy involved in the process make vitrification a viable alternative only for very toxic residues like radioactive elements.

Vitrification of nuclear wastes is thus a wide-spread method that offers a number of advantages. When contained in a glass matrix, radioactive isotopes can remain stable for long periods of time; besides, a large amount of heavy ions can be loaded into glass-forming oxides, and the compact arrangement of atoms in the glass network results in an important reduction of volume for a more convenient storage[17, 18].

The technique has evolved from cement solidification, which was developed in the 1950s[19] and has been used in the nuclear facilities of France, China and other countries for several decades[20]. It has been proven that zeolites are among the most favourable media for vitrification: when zeolites are present in the vitreous phase, the diffusion of radioactive ions into the outer medium (leaching) decreases significantly, even after periods as long as 3 years[21].

Table : Factors affecting Zeolite synthesis

Factor

Sub-factors

Reaction/gel composition

SiO2/Al2O3 sources

OH- concentration

Cations (both organic and inorganic)

Anions other than OH-(for example fluoride)

Water concentration

Time

Varies, depending on type of Zeolite

Temperature

Varies, depending on type of Zeolite

Ambient (25 – 60â)°C)

Low (90 – 120â)°C)

Medium (120 – 200â)°C)

High (250â)°C and higher)

History-dependent factors.

Ageing, stirring, nature of mixture, order of mixing

Kaolin as a Source of Zeolite Synthesis

Key talking point

Kaolin as an alternative and cheaper source of raw material for zeolite production

Process of zeolitization from kaolin : metkaolinization and hydrothermal reaction

State previous work on the synthesis of zeolite A and zeoilite Y from kaolin and stress that Ahoko Nigerian kaolin is being used for the time to prepare zeolotes

Need to talk about vitrification

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