UNIVERSITY OF GHANA

SCHOOL OF ENGINEERING SCIENCES

BSc. (ENG) MATERIALS SCIENCE AND ENGINEERING

SECOND SEMESTER EXAMINATIONS: 2014/2015

MTEN 314: Ceramics Processing Principles (3 Credits)

Time Allowed: 3 hours

Answer Question ONE (1) and ANY OTHER TWO (2) Questions

Q1. A ceramics manufacturing company is to start the production of semi-vitreous sanitary wares. As the Ceramics Engineer of the company, you are to provide a suitable body composition for the sanitary ware. The company has access to the following raw materials: Saltpond kaolin, Mouri feldspar, Eikwe silica sand, and Anfoega plastic clay.

a) Using the feldspar-kaolin-silica triaxial diagram in Figure 1, suggest a body composition from the range of semi-vitreous white ware, and add 20 % of plastic clay to the composition. *[10 marks]*

b) With the aid of a flow diagram, describe the various steps encountered in the processing of the body from raw materials preparation to the fired ware; and briefly explain the role that each of the raw materials play in the manufacture of the sanitary wares. *[10 marks]*

c) Discuss the five (5) phenomena (phase transition) that occur during the firing of the wares from room temperature to the maturing temperature of 1280°C. *[10 Marks]*

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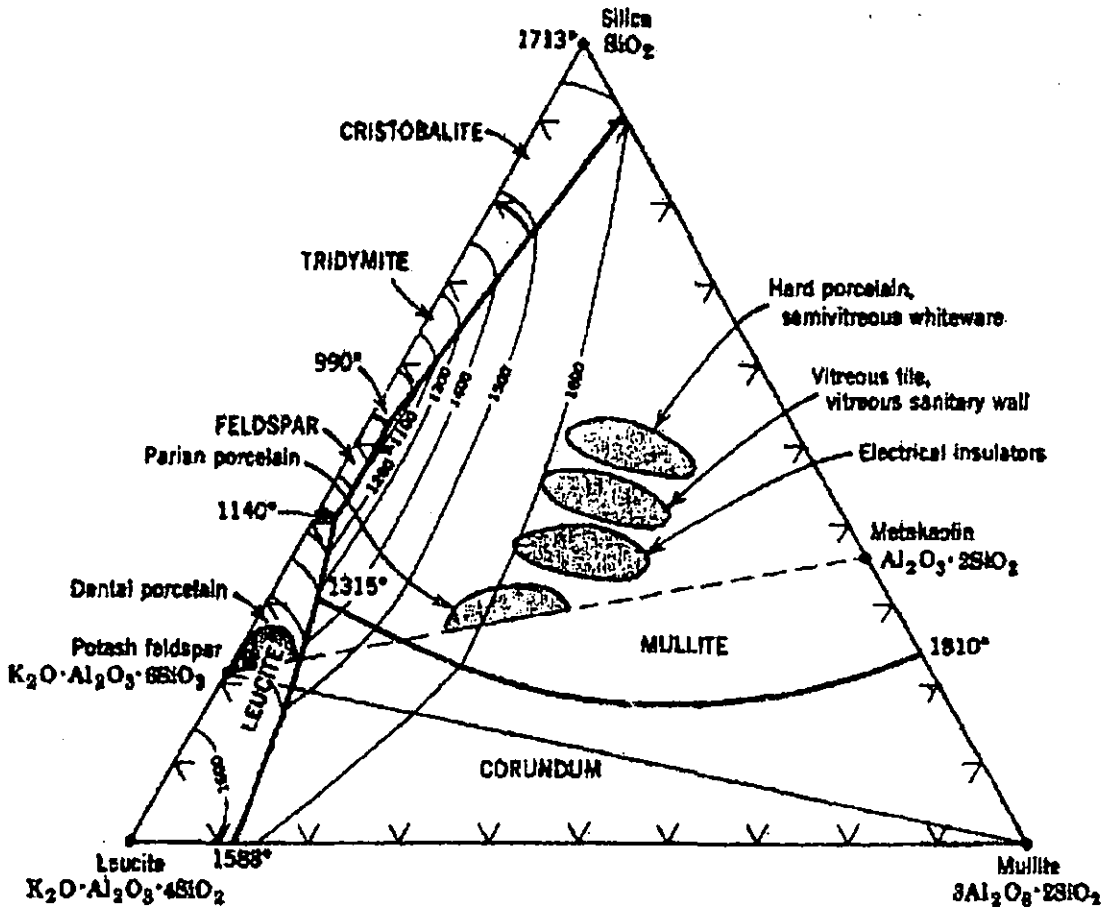

Fig. 1: **Feldspar-kaolin-silica Triaxial diagram**

(Leucite-mullite-cristobalite portion of the K_2O-Al_2O_3-SiO_2 phase diagram)

d) Calculate the chemical composition of your suggested sanitary ware body. The chemical analysis of the raw materials involved is given in Table 1.

Table 1: **Chemical Analysis (%) of the raw materials involved.**

Raw material	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2	L.O.I
Eikwe silica sand	98.0	0.4	0.62	---	0.03	---	---	---	---
Mouri feldspar	73.92	14.61	0.13	0.18	0.05	6.66	4.16	0.01	0.28

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Saltpond kaolin	42.21	38.91	0.58	0.18	0.03	0.69	0.02	0.01	13.37
Anfoega Clay	67.0	15.86	3.43	3.04	0.96	3.64	3.61	0.56	5.24

[10 marks]

e) Using the calculated chemical composition of your body, work out the mineralogical analysis of the sanitary ware, given the following information for your calculation?

Table 2: **The Chief Minerals Present in the Raw Materials**

Minerals	**Formula ("ideal"unsubstituted)**	**Molecular Weight**
Kaolinite	$Al_2O_3 . 2SiO_2 . 2H_2O$	258.17
Soda mica	$Na_2O. 3Al_2O_3 . 6SiO_2 . 2H_2O$	764.43
Potash mica	$K_2O . 3Al_2O_3 . 6SiO_2 . 2H_2O$	796.65
Quartz	SiO_2	60.10
Hematite	$Fe_2O_3 . 3H_2O$	213.70
Rutile	TiO_2	79.90
Calcium phosphate	$3CaO . P_2O_5$	310.30
Potassium carbonate (pearl ash)	$K_2O . CO_2$	138.10
Sodium carbonate	$Na_2O . CO_2$	106.0

Table 3: **The Oxides Involved with their Molecular Weights**

Oxides	**Molecular Weight**
SiO_2	60.10
Al_2O_3	101.90
Fe_2O_3	159.70
CaO	56.10
MgO	40.30
Na_2O	61.98

K_2O	94.20
TiO_2	79.90
P_2O_5	142.0

Table 4: **Conversion Factors for Calculation of the Mineralogical Analysis**

Constituent Sought	Found As	Conversion Factor
i. Soda mica ($Na_2O.3Al_2O_3.6SiO_2.2H_2O$)	Na_2O	12.33
ii. Potash mica ($K_2O.3Al_2O_3.6SiO_2.2H_2O$)	K_2O	8.46
iii. Alumina (Al_2O_3)	soda mica	0.400
iv. Alumina (Al_2O_3)	potash mica	0.384
v. Kaolinite ($Al_2O_3.2SiO_2.2H_2O$)	Al_2O_3	2.534
vi. Silica (SiO_2)	soda mica	0.471
vii. Silica (SiO_2)	potash mica	0.452
viii. Silica (SiO_2)	kaolinite	0.465
ix. Quartz (SiO_2)	SiO_2	1.0

[20 marks]

Q2. Discuss the transition of feldspar from the parent rock to the formation of gibbsite sheet.

[20 marks]

Q3a. Even though the actual formation of $BaTiO_3$ involves many different intermediate phases, we can write the final reaction as:

$$BaCO_3(s) + TiO_2(s) \rightarrow BaTiO_3(s) + CO_2(g)$$

How much barium carbonate and titanium dioxide should be ball-milled and calcined if we want to make 1000 kilograms of $BaTiO_3$ ceramic from $BaCO_3$ and TiO_2 ?

Chemical Formula	Formula Weight
Ba	137.36
C	12.0
O	16.0
Ti	47.90

[5 marks]

Q3b. *"Underlying many of the properties found in ceramics are the strong primary bonds that hold the atoms together and form the ceramic material"*. Discuss this statement. *[15 marks]*

Q4. *"The history of human exploitation of materials is the history of advancement and growth of civilization."* Relate this statement to the foundation of the ceramics discipline and the complex nature of ceramic materials. *[20 marks]*