Benha university
Faculty of science
Geology Dept.

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Model answer of Geochemistry (433 G) Exam for the 4th level students (special Geology), Jan 2020.
Note: The exam in 4 pages

4th Level
Date: 1 / 1 /2020
Time: Two Hours

The exam Answer the following questions.

1) Choose the best answer for the followings: (30 Marks)

1. **Which of the following statements is not true about the spider diagrams**
   a. Compare elements with large differences of absolute abundance (log scale)
   b. See many elements at a time
   c. **Show only the abundances of trace elements of only one sample**
   d. Elements are arranged in order of increasing compatibility.
2. **Double-chain silicates occur when tetrahedra form ------.**
   a. chains by sharing two oxygen atoms each
   b. **chains by sharing two or three oxygen atoms each**
   c. share three oxygen atoms each
   d. share all 4 oxygen atoms with its neighbors
3. **In island-arc or subduction-related magmas, ------- is/are usually the dominant gas/gases.**
   a. **H_2O**
   b. CO_2
   c. H_2O and CO_2
   d. F and Cl
4. **In -----------, melting temperatures increase with increasing pressure, except there is a range of temperature over which there exists a partial melt.**
   a. melting of dry minerals
   b. **melting of dry rocks**
   c. melting of wet minerals
   d. melting of wet rocks
5. **Rhyolitic magma forms as a result of ---------------.**
   a. **wet melting of continental crust**
   b. dry melting of continental crust
   c. dry partial melting of the mantle
   d. wet partial melting of the mantle
6. **In peraluminous rocks, we expect to find an Al_2O_3 rich mineral present as a modal mineral such as – – – or an Al_2SiO_5 mineral like – – – – – .**
   a. diopside – corundum
   b. corundum– diopside
   c. **topaz – sillimanite**
   d. corundum – topaz
7. **Basalts with normative compositions that contain no Qtz or Opx, but contain Ne are silica undersaturated (the volume Ne– Plag– Cpx– Ol) they may be – – – – – – .**
   a. **Basanites**
   b. Hornblendite
   c. Quartz Tholeiites.
   d. Olivine Tholeiites.

8. In basic magmas the alkaline elements such as K and Na behave as – – – – – – elements, so crystallization of Mg & Fe-rich phases tends to cause both SiO_2 and alkalis to – – – – – .

a. compatible – increase
b. compatible – decrease
c. incompatible – decrease
d. **incompatible – increase**

9. ------------is formed through wet partial melting of the mantle

a. Komatitic magma
b. **Andesitic magma**
c. Rhyolitic magma
d. Basaltic magma

10. Melting can also result from a ---------- in pressure. Since pressure favors solids, mineral melting points ---------- with decreasing pressure. This decompression melting occurs when hot mantle rock moves upward.

a. decrease- increase
b. **decrease- decrease**
c. increase- decrease
d. increase- increase

11. Potassium never forms its own phase in – – – – ; its concentration rarely exceeding 1500 ppm; but K is certainly not – – – – – element in granites

a. MORB – trace
b. **MORB – incompatible**
c. OIB – trace
d. OIB– incompatible

12. Two factors control compatibility of an ion: its valence and its ionic radius Both must approximate those of the – – – – – element for the – – – – element to be compatible in the mineral.

a. compatible –trace
b. incompatible –major
c. **major– trace**
d. trace – major

13. If two ions have a similar radius but different valence, the ion with the higher charge is more readily incorporated into the solid over the liquid. Thus, ---- and --- are usually preferred in solids as compared to liquids.

a. Mg^{2+} – Ni^{2+}
b. Fe^{2+} – Ni^{2+}
c. K – Rb
d. **Cr^{+3} – Ti^{+4}**

14. Hf usually does not form its own mineral; it is – – – – – – – in zircon.

a. precipitated
b. **camouflaged**
c. admitted
d. captured

15. $K^+ + Si^{4+} \leftrightarrow Sr^{2+} + Al^{3+}$ is good example for– – – – – – to balance charge.

a. free substitution
b. **coupled substitution**
c. compatible substitution
d. incompatible substitution

16. – – – – – – – – involves entry of a foreign ion with an ionic potential less than that of the major ion.

a. Free substitution
b. Camouflage

c. **Admission**
d. Capture

17. Melt of amphibole- bearing rock will increase ---- in the partial melt.

a. **K/Rb**
b. K/Ba
c. Ba/Sr
d. Pyroxene/Hornblende

18. The ratio --------- increases with crystallization of plagioclase

a. K/Rb
b. K/Ba
c. **Ba/Sr**
d. Cr/Sc

19. – – – – – substitutes for Ca in plagioclase (but not in pyroxene), and, to a lesser extent, for K in K-feldspars.

a. **Sr**
b. Ba
c. Ti
d. Sc

20. – – – – – – commonly incompatible (like HREE), strongly partitioned into garnet and amphibole.

a. U
b. Th
c. **Y**
d. Ni

21. The HREE readily substitute for – – – – – – in garnet, and hence can be concentrated on it.

a. Fe^{2+}
b. **Al^{3+}**
c. Cr^{3+}
d. Ti^{4+}

22. MORB exhibits a LREE ---- pattern, however upper continental crust is LREE ---- with a negative Eu anomaly

a. enriched– deplete
b. **depleted – enriched**
c. enriched – enriched
d. depleted – depleted

23. Removal of early formed olivine would --------- the Mg/Fe^{2+} concentration.

a. increase
b. **decrease**
c. stabilize
d. not affect

24. The ------- shows <u>a large LREE depletion</u>, and a positive slope.

a. E–MORB
b. **N–MORB**
c. OIB
d. OIA

25. In MORB and OIB, CO_2 and H_2O concentrations may be roughly similar and are quite--------.

a. low <5%
b. **low <0.5%**
c. high >5%
d. high <0.5%

26. Magma viscosity increases with increasing SiO_2 concentration in the magma. This is because---.

a. viscosity is the resistance to flow.

b. viscosity depends on the composition of the magma, and temperature.
c. lower SiO_2 content magmas have higher viscosity than higher SiO_2 content.
d. **lower temperature magmas have higher viscosity than higher temperature**.

27. Certain minerals are practically confined to deep-seated intrusive rocks, e.g., -----------and ------.

a. **muscovite and Microcline**
b. microcline and orthoclase
c. albite and muscovite
d. leucite and olivine

28. Trace elements will prefer ………

a. liquid phase.
b. solid phase.
c. **either solid or liquid phase**.
d. to have own structure phase.

29. Which of the following statements is not true about the trace element?

a. can be substituted for network-forming cations in mineral structures
b. **appear in the mineral's chemical formula**
c. the same elements could be compatible or incompatible.
d. could be plotted on both Spider and Harker diagrams.

30. Which pairs of the following is not true during the ascending of magma?

a. Temperature Drops - Increase in viscosity
b. **Crystallization begins -Decrease in viscosity**
c. More polymerized- Increase in viscosity
d. H2O concentration drops - Increase in viscosity

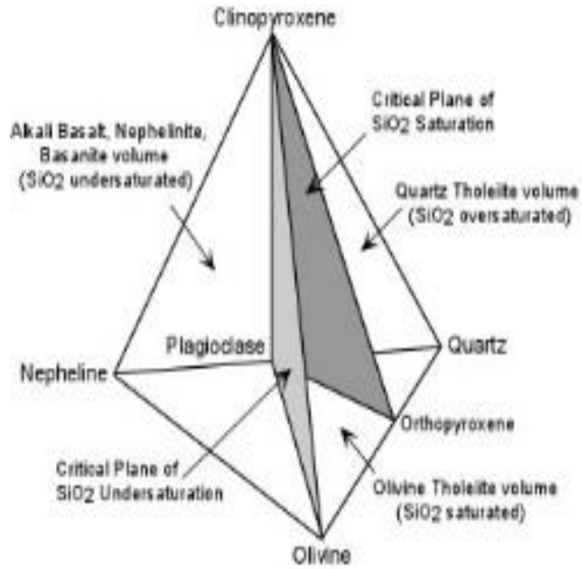
2) Discuss in detail, the different types of trace **elements based on their geochemical characteristics**? **(6 marks)**

1. **Large ion lithophile elements (LILE):** These elements are characterized by large ionic radii, and low charges, and will therefore preferentially concentrate in the liquid until a particular phase with large enough sites to accommodate them begins to crystallize. These elements will therefore be largely "incompatible" particularly with respect to mantle phases (Ol, Opx, Cpx, Gt, .. etc). Examples include: K, Rb, Sr and Ba.
2. **High field strength elements (HFSE):** These are elements which have large cations, but also large charges, and are also excluded from mantle phases and more concentrated in residual liquids (i.e. they will be more incompatible). These elements are concentrated in accessory phases as sphene, zircon, and apatite. Examples include Zr, Hf, Nb, Ta, Th and U.
3. **Transition elements**: Trace elements which are also transition elements are characterized by relatively small ionic radii, and are either bi- or tri-valent. These elements are strongly partitioned in the solid phases that crystallize during the early stages of magmatic evolution, and are therefore "compatible" with mantle phases. Examples include Ni, Co, Cr, and Sc.
4. **Rare earth elements (REE):** This is a group of elements with atomic numbers between 57 (La) and 72 (Lu) characterized by relatively large ionic radii, and valences of either +2 or +3. They have proven to be very important for petrogenetic interpretations. However, these elements occur in very low concentrations in igneous rocks

3) On a chemical basis, basalts can be classified into three broad groups based on the degree of silica saturation. **Discuss in detailed these groups?** **(6 Marks)**

On a chemical basis, basalts can be classified into three broad groups based on the degree of silica saturation. This is best seen by first casting the analyses into molecular CIPW norms (the same thing as CIPW norms except the results are converted to mole % rather than weight %). On this basis, most basalts consist predominantly of the normative minerals - Olivine, Clinopyroxene, Plagioclase, and Quartz or Nepheline.

1. The plane Cpx-Plag-Opx is the critical plane of silica saturation. Compositions that contain Qtz in their norms plot in the volume Cpx-Plag- Opx-Qtz, and would be considered silica oversaturated. Basalts that plot in this volume are called ***Quartz Tholeiites***.
2. The plane Ol - Plag - Cpx is the critical plane of silica undersaturation. Normative compositions in the volume between the critical planes of silica undersaturation and silica saturation are silica saturated compositions (the volume Ol - Plag - Cpx - Opx). Silica saturated basalts are called ***Olivine Tholeiites.***
3. Normative compositions that contain no Qtz or Opx, but contain Ne are silica undersaturated (the volume Ne-Plag-Cpx-Ol). ***Alkali Basalts, Basanites, Nephelinites***, and other silica undersaturated compositions lie in the silica undersaturated volume.



4) a. Discuss the general characteristics of A– , S– , M– and I– type granites? **(2 Marks)**

Table 2.1 **Classification of granite types**

	I-type	S-type	M-type	A-type
	Igneous	Sedimentary	Mantle	Anorogenic or anhydrous
Mineralogy and field character-istics	Amphibole and biotite; enclaves of diorite and gabbro	Biotite and muscovite, sometimes with cordierite and garnet; metasedimentary enclaves	Biotite and plagioclase, little to no alkali feldsapr	Alkali pyroxene and amphibole
Geochem-istry	Metaluminous to weakly peraluminous, relatively sodic, wide range of silica contents. Moderate $^{87}Sr/^{86}Sr$, $^{143}Nd/^{144}Nd$, $d^{18}O$.	Peraluminous, potassic, high silica, low CaO, Na_2O and Sr. High $^{87}Sr/^{86}Sr$, low $^{143}Nd/^{144}Nd$, high $d^{18}O$. Relatively oxidised.	Metaluminous. Moderate $^{87}Sr/^{86}Sr$, $^{143}Nd/^{144}Nd$, mantle-like $d^{18}O$.	Peralkaline or calc-alkaline. High alkalis, moderate to high silica. $^{87}Sr/^{86}Sr$, $^{143}Nd/^{144}Nd$, $d^{18}O$.
Origin	From (metaigneous source rocks, typically basaltic	From metasedimentary source rocls	From the mantle, or from crystallisation of basaltic magma	Intruded in intraplate setting after orogenesis

Or;

Type	SiO_2	K_2O/Na_2O	Ca, Sr	A/(C+N+K)*	Fe^{3+}/Fe^{2+}	Cr, Ni	$\delta^{18}O$	$^{87}Sr/^{86}Sr$	Misc	Petrogenesis
M	46-70%	low	high	low	low	low	< 9‰	< 0.705	Low Rb, Th, U Low LIL and HFS	Subduction zone or ocean-intraplate Mantle-derived
I	53-76%	low	high in mafic rocks	low: metal-uminous to peraluminous	moderate	low	< 9‰	< 0.705	high LIL/HFS med. Rb, Th, U hornblende magnetite	Subduction zone Infracrustal Mafic to intermed. igneous source
S	65-74%	high	low	high peraluminous	low	high	> 9‰	> 0.707	variable LIL/HFS high Rb, Th, U biotite, cordierite Als, Grt, Ilmenite	Subduction zone Supracrustal sedimentary source
A	high → 77%	Na_2O high	low	var peralkaline	var	low	var	var	low LIL/HFS high Fe/Mg high Ga/Al High REE, Zr High F, Cl	Anorogenic Stable craton Rift zone

* *molar* $Al_2O_3/(CaO+Na_2O+K_2O)$ Data from White and Chappell (1983), Clarke (1992), Whalen (1985)

b. Hypothetical garnet lherzolite = 60% olivine, 25% orthopyroxene, 10% clinopyroxene, and 5% garnet (all by weight), using the data in the next table determine the bulk distribution coefficient for dysprosium in garnet lherzolite? **<u>(2 Marks)</u>**

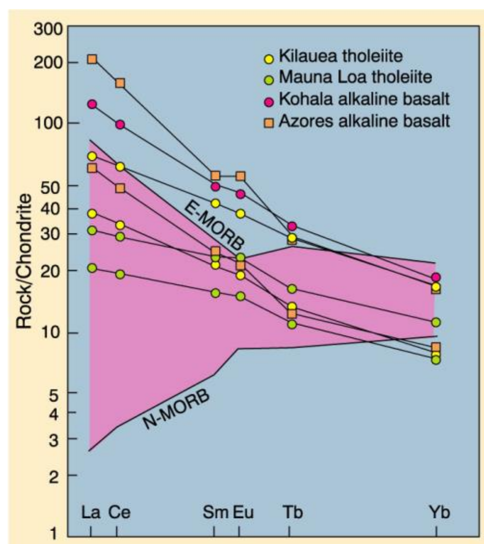
	Olivine	Opx	Cpx	Garnet	Plag	Amph	Magnetite
Sm	0.007	0.05	0.445	0.102	0.039	1.804	1
Eu	0.007	0.05	0.474	0.243	0.1/ 1.5 *	1.557	1
Dy	0.013	0.15	0.582	1.940	0.023	2.024	1
Er	0.026	0.23	0.583	4.700	0.020	1.740	1.5
Yb	0.049	0.34	0.542	6.167	0.023	1.642	1.4
Lu	0.045	0.42	0.506	6.950	0.019	1.563	

Data from Rollinson (1993). * Eu^{3+}/Eu^{2+}

$\bar{D}_{Er}$ = (0.6 * 0.013) + (0.25 * 0.15) + (0.10 * 0. 582) + (0.05 * 1.940) = 0.2005

c. Based on your study of trace element geochemistry; briefly point to the main differences between MORB and OIB? **<u>(2 Marks)</u>**

- HFS elements (Th, U, Ce, Zr, Hf, Nb, Ta, and Ti) are also incompatible, and are enriched in OIBs > MORBs.
- OIAs tend to be depleted in Ni and Cr relative to OITs and MORBs, which, along with the higher Mg#s, suggests they have experienced fractionation of these phases prior to eruption.
- Ratios of these elements are also used to distinguish mantle sources
- The Zr/Nb ratio
- N-MORB generally quite high (>30)
- OIBs are low (<20)
- The alkaline basalts have steeper slopes and greater LREE enrichment than the OIT's. Some fall within the upper MORB field, **but most are distinct**
- La /Yb (the overall slope on the REE diagram) is crudely proportional to the degree of silica undersaturation in OIBs.
- Highly undersaturated magmas can have La / Yb in excess of 30, whereas OIA ratios are closer to 12, and OITs about 4.
- Note also that the *heavy* REEs are also fractionated in the OIB samples in attached Figure. (as compared to the flat HREE patterns in N- and E-MORB).
- This indicates that garnet was a residual phase because it is one of the few common minerals that differentially incorporates HREE.



– Good Luck–

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