

Calculating of a CIPW norm from a bulk chemical analysis

This is a set of instructions for calculating a basic norm. For the more production-minded, here are two spreadsheet programs that will calculate norms for you: a [simple one](#) for individual analyses, and a [macro-enabled one](#) for automatically calculating norms for a large number of analyses at once.

A norm is essentially a set of idealized mineral-like components that are calculated from a bulk chemical analysis of a rock. Norms are usually used for classification or comparison purposes. Norms are commonly calculated for glassy or fine-grained volcanic rocks that are otherwise difficult to classify, and for metamorphosed igneous rocks that no longer have their original igneous mineralogy. The normative 'minerals' are calculated to represent, in some ways, the actual minerals that might crystallize if the rock were cooled under perfect dry equilibrium conditions at low pressure. For example, in natural rocks the following mineral pairs are mutually exclusive:

Real mutually exclusive minerals	Normative equivalents
Quartz and Mg-rich olivine	<i>Quartz</i> and any <i>olivine</i>
Quartz and nepheline	<i>Quartz</i> and <i>nepheline</i>
Al-silicates and augite	<i>Corundum</i> and <i>diopside</i>
Orthopyroxene and nepheline	<i>Orthopyroxene</i> and <i>nepheline</i>

Normative 'minerals' are shown here in italics. These mutually exclusive mineral pairs result in four common normative assemblages:

Normative assemblages	What they mean
<i>Quartz–corundum–orthopyroxene</i>	Silica-saturated, peraluminous, subalkaline
<i>Quartz–diopside–orthopyroxene</i>	Silica-saturated, subaluminous, subalkaline
<i>Olivine–diopside–orthopyroxene</i>	Silica-undersaturated, subaluminous, subalkaline
<i>Olivine–diopside–nepheline</i>	Silica-undersaturated, subaluminous, peralkaline

Norm calculation procedure

The following is similar to the original CIPW norm procedure and works for most common igneous rocks. It does not include the methods to calculate, for example, normative *leucite* in strongly silica-undersaturated rocks, *aegirine* in alumina-poor alkalic rocks, or *hematite* in highly oxidized rocks. The procedure below also departs from the original CIPW norm in that normative *pyroxenes*, *plagioclase*, and *olivine* are calculated as their solid solutions rather than their end member components. If you are unfortunate enough to be doing a norm calculation by hand, you should do the calculations to at least five decimal places to avoid rounding error problems. To begin, make a table with the 11 major oxides, and below that a list of the normative 'minerals' (*quartz*, *orthoclase*, *albite*, *anorthite*, *plagioclase*, *corundum*, *nepheline*, *diopside*, *orthopyroxene*, *olivine*, *magnetite*, *ilmenite*, *apatite*). Space will also be needed for FMO and other calculated intermediate values.

1. Use only the eleven major element oxides, for which the gram formula weights are:

SiO ₂	60.0843
TiO ₂	79.8988
Al ₂ O ₃	101.9613
Fe ₂ O ₃	159.6922
FeO	71.8464
MnO	70.9374
MgO	40.3044
CaO	56.0794
Na ₂ O	61.9789
K ₂ O	94.1960
P ₂ O ₅	141.9445

- Take the oxide weight percents in the chemical analysis and divide them by their respective formula weights to give molar oxide proportions. Use these molar oxide proportions in all subsequent calculations.
- Add MnO to FeO. MnO is now zero. The combined FeO and MnO will still be called FeO.
- Apatite*: Subtract 3.333 times P₂O₅ from CaO. Multiply P₂O₅ by 0.6667, and put this number in *apatite*. P₂O₅ is now zero.
- Ilmenite*: Subtract TiO₂ from FeO. Put the TiO₂ value in *Ilmenite*. TiO₂ is now zero.
- Magnetite*: Subtract Fe₂O₃ from FeO. Put the Fe₂O₃ value in *magnetite*. Fe₂O₃ is now zero.
- Orthoclase*: Subtract K₂O from Al₂O₃. Put the K₂O value in *orthoclase*. K₂O is now zero.
- Albite* (provisional): Subtract Na₂O from Al₂O₃. Put the Na₂O value in *albite*. Retain the Na₂O value for possible normative *nepheline*.
- Anorthite*:
 - If CaO is more than the remaining Al₂O₃, subtract the Al₂O₃ value from CaO. Put all Al₂O₃ into *Anorthite*. Al₂O₃ is now zero.
 - If Al₂O₃ is more than the remaining CaO, subtract CaO from Al₂O₃. Put all CaO into *anorthite*. CaO is now zero.
- Corundum*: If Al₂O₃ is not zero, put the remaining Al₂O₃ into *corundum*. *Diopside* and Al₂O₃ are now zero.
- Calculate the current ratio of Mg/(Mg+Fe²⁺). This ratio is called Mg' and will be the Mg/(Mg+Fe²⁺) ratio for all normative silicates.
- Calculate the mean formula weight of the remaining FeO and MgO. This combined Fe–Mg oxide, called FMO, will be used in subsequent calculations.

Formula weight of FMO = $(Mg' * 40.3044) + ((1 - Mg') * 71.8464)$

13. Add FeO and MgO to make FMO.
14. *Diopside*: If CaO is not zero, subtract CaO from FMO. Put all CaO into *diopside*. CaO is now zero.
15. *Orthopyroxene* (provisional): Put all remaining FMO into *orthopyroxene*. Retain the FMO value for the possible normative *olivine*.
16. Calculate the amount of SiO₂ needed for each of the normative silicates so far:

Orthoclase * 6
Albite * 6
Anorthite * 2
Diopside * 2
Orthopyroxene * 1

17. Sum the five SiO₂ values just calculated, and call this number 1pSi for the first provisional SiO₂.
18. *Quartz*:
 - A. If 1pSi in #17 is less than SiO₂, then there is excess silica. Subtract pSi1 from SiO₂, and put the remaining SiO₂ in *quartz*. SiO₂, *nepheline*, and *olivine* are now zero. Skip to #23.
 - B. If 1pSi in #17 is more than SiO₂, then the rock is silica-undersaturated. Proceed to #19.
19. *Olivine, orthopyroxene* (final): If 1pSi calculated in #17 is more than SiO₂, then *quartz* is now zero. Calculate a 2pSi value, like 1pSi in #17, but omitting *orthopyroxene*.

Orthoclase * 6
Albite * 6
Anorthite * 2
Diopside * 2

20. Sum the four SiO₂ values just calculated to get 2pSi. Subtract 2pSi from SiO₂ to get the amount of SiO₂ available for *olivine* and *orthopyroxene*, called 3pSi.
 - A. If FMO is greater than or equal to 2 times 3pSi, then put all FMO in *Olivine*. FMO and *Orthopyroxene* are now zero. Proceed to #21.
 - B. If FMO is less than 2 times pSi3, then *nepheline* is zero. Calculate the amount of *orthopyroxene* and *olivine* as follows:

Orthopyroxene = $((2 * 3pSi) - FMO)$

$Olivine = (FMO - orthopyroxene)$
 Skip to #23.

21. *Nepheline, albite* (final): If you reached this step, then turning *orthopyroxene* into *olivine* in #20A did not yield enough silica to make *orthoclase, albite, anorthite, diopside, and olivine*. Calculate 4pSi:

Orthoclase * 6
Anorthite * 2
Diopside * 2
Olivine * 0.5

22. Sum the four SiO₂ values just calculated to get 4pSi. Subtract 4pSi from SiO₂ to get 5pSi, which is the amount of SiO₂ available for *albite* and *nepheline*.

$Albite = (5pSi - (2 * Na_2O)) / 4$
 $Nepheline = Na_2O - Albite$

23. Multiply *orthoclase, albite, and nepheline* by two. Divide *olivine* by two.

24. Calculate An', which is the Ca/(Ca+Na) ratio in normative plagioclase:

$An' = Anorthite / (Anorthite + Albite)$

25. *Plagioclase*: Add *albite* to *anorthite* to make *plagioclase*. Retain the *albite* value, but *anorthite* is now zero.

26. Calculate the formula weight of *plagioclase*, using the An' value from #24.

Formula weight of *plagioclase* = $(An' * 278.2093) + ((1 - An') * 262.2230)$

27. Multiply all of the normative 'mineral' values by their respective formula weights. The formula weight of FMO is from #12.

'Mineral'	Formula weight	Formula
<i>Quartz</i>	60.0843	SiO ₂
<i>Orthoclase</i>	278.3315	KAlSi ₃ O ₈
<i>Plagioclase</i>	Calculated in #26	(Ca,Na)(Al,Si) ₄ O ₈
<i>Corundum</i>	101.9613	Al ₂ O ₃
<i>Nepheline</i>	142.0544	NaAlSiO ₄
<i>Diopside</i>	176.2480 + formula weight of FMO	Ca(Fe,Mg)Si ₂ O ₆
<i>Orthopyroxene</i>	60.0843 + formula weight of FMO	(Fe,Mg)SiO ₃
<i>Olivine</i>	60.0843 + (2 * formula weight of FMO)	(Fe,Mg) ₂ SiO ₄
<i>Magnetite</i>	231.5386	Fe ₃ O ₄
<i>Ilmenite</i>	151.7452	FeTiO ₃
<i>Apatite</i>	504.3125	Ca ₅ (PO ₄) ₃ F

28. This is your weight norm, which you may want to normalize to a sum of 100%. This might be published along with four other useful parameters:

Total: The sum of all normative component weights, calculated in #27. Within rounding error the Total should be the same as the original total of the weight % of the oxides from the chemical analysis.

Mg'%: $100 * \text{Mg}'$ From #11.

An'%: $100 * \text{An}'$ from #24.

DI: The Differentiation Index of Thornton and Tuttle (1960). This is the weight ratio: $(\text{quartz} + \text{orthoclase} + \text{albite} + \text{nepheline})/\text{total}$. Albite is from #23 multiplied by 262.2230.

29. The weight norm is the way norms are usually expressed. If you want to compare norms to modes, which are volume fractions, you should divide each normative mineral by its density and normalize the total back to 100%. The density of plagioclase and the Fe-Mg silicates can be approximated by linearly interpolating from the end member densities.

Remember that the Excel spreadsheet programs listed near the top can calculate the norms for you. If you find any mistakes in this procedure, please let me know.

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