Geochemistry (1): Composition of Earth's materials

Structure of atoms: protons, neutrons, electrons
One element = given number of protons = nb of electrons = charge (or atomic number) = chemical properties
Atomic mass = nb protons + nb neutrons
Different isotopes of a same element have the same atomic number (= nb of electrons/protons) but different masses (= nb of neutrons)

I. Analytical tools in geochemistry

(See separate document for a list of common instruments)

Detection:

- Optical spectrometry
- X-ray spectrometry
- Mass spectrometry

Excitation processes (for electromagnetic spectrometry):

- X-ray beam
- Electron beam
- Plasma

Ion generation (for mass spec)

- Plasma
- Filament

II. Composition of a rock

A. A typical rock analysis

Composition expressed as mass, or as moles

Composition domined by oxygen
Role of O in crystalline systems
Use of oxides wt% by convention (historical legacy)

Accuracy: typically 1-5%

A few major elements represent > 98 % of the rock; lot of other things are present.

B. Definitions

Classical definition: major > 1 wt%.
A more "petrological" definition:

- Major elements: are used to build important mineral phases (quartz, feldpars, biotite, amphibole, pyroxenes…). Commonly 7 (+ O): Si, Al, Fe, Mg, Ca, Na, K. Sometimes other play a role (Cr, Ni)

- Minor elements: build accessory minerals. A somehow imprecise definition. Includes Mn, Ti, P; Zr or Th could sometimes be regarded as belonging to this group!
- Trace elements: do not have mineral phases of their own, but substitute for other elements.

Differences in abundance: at least 3-4 orders of magnitude (from 10^{-1} to 10^{-4} or 10^{-5}, i.e. 10 wt% to 0.1 ppm)

III. Differences and similarities between rocks

A. Comparison of two common igneous rocks

- Major elements are the same, with rather limited range of variation (SiO2: 50-70 %, K2O: 1-10 %)
- Trace elements have more diversity. Some are nearly absent, some are rather abundant. Variations by two orders of magnitude not uncommon.

B. Composition of Earth's shells

1. The crusts:

- Can be directely sampled/studied
- Continental crust : ca. 30 km, mostly granitic (SiO2 = 70 %).
- Oceanic crust: ca. 5-7 km, basaltic (SiO2 = 50%, some FeO)

2. The mantle:

- Few samples (in volcanoes)
- Peridotites (SiO2 = 45 %, FeO, MgO)

3. The core:

- Fe+Ni alloy
- Minor amounts of light elements

Also differences in trace elements!

IV. Origin of elements and geochemical diversities

A. Nucleosynthesis and the origin of elements

- Nuclear reactions in stars (light nuclei combine to form heavy atoms)
- Bethe's cycle (favors even-numbered atoms)
- Evolution towards the more stable atoms (Fe)

B. Earth accretion and differenciation

- Planetary nebula
- Condensation
- Accretion of proto-planets
- Differenciation in three/four main units: core, mantle/crust, atmosphere s.l., as a function of chemical affinities (Fe/Silicates/lights)

“Primitive” solar system material: the chondrites.