COURSE GUIDE

Chemical Processes in Soil-Water-Atmosphere
SOQ-22306

Department of Soil Quality
www.soq.wur.nl
For whom is it and why?

Soil, water and the atmosphere play for live on earth a central role as source and controller of flows of elements. Chemical processes strongly determine the variety of forms of substances and its dynamics in soil, water, and atmosphere. Knowledge of geochemical characteristics is a prerequisite to be able to understand the main function of the main global compartments in relation to soil-, water- and air-quality. The disciplines are of interest for many students with different interests.

In the first place, the course is meant for students who have soil, water, and/or atmosphere as a central theme of study in which they recognize the role of all kinds processes related tow water-, geo-, soil-, and atmospheric chemistry: students in Soil, Water, and Atmosphere.

In addition, chemical interactions are of large interest for students in Environmental sciences like Environmental System Analysis and Environmental Technology, because chemical processes lead to distribution and exchange of substances between environment compartments and this needs insight in e.g. binding, fixation, volatilization, or extraction etc.

It is also of interest for students studying Global biogeochemical cycles, Forest- and Nature Conservation, and Biology, because biogeochemical interactions strong influence live on earth.

Furthermore, for students of molecular sciences, because here part of their knowledge is applied to natural systems.

Language of instruction

English, but student may ask questions in Dutch. The written exam is also given in English but students may answer in Dutch.

Study load / Credit points: 6 ects

Period/Time: 2 (October – November), morning (8.30 – 12.15 h)

Coordinator/Examiner: Tjisse Hiemstra

Components: lectures (50%), Tutorials (50%)

Lecturers

Tjisse Hiemstra and Meindert Keizer (Soil Chemistry and Chemical Soil Quality)
Bart Koelmans (Aquatic Ecology & Water Quality Management)
Bert van Hove (Meteorology & Air Quality)

Assumed knowledge:

A number of introductory courses are of help to understand some basic terminology that is used, e.g. PCC-10306 General and Physical Chemistry, SIL-10806 Soil and Water I, AEW-21306 Soil and Water II, MAQ-10306 Introduction Atmosphere

NB

A text (“Chapter 0”) is available at the EDU website to test the required skills in Applied Mathematics and the assumed level in Basic Chemistry. The additional text may serve as reference.
Continuation courses:
AEW-20306 Processes in Aquatic Systems, MAQ-21306 Atmospheric Chemistry and Air Quality, and SOQ-34806 Applications in Soil and Water Chemistry. How to obtain the chemical speciation of realistic natural systems in an easy way with software is explained in the latter course.

Educational activities:
Attend lectures, attend the additional homework hours, do reading and exercises at home, and attend the tutorial hours for feedback and summary. The total workload during the lecturing weeks will be at least 4 hours per day.

Profile of the course
The course is a combination of lectures and tutorials. During the lectures (6 weeks with daily 1 hour), the most important interactions and concepts are discussed and illustrated in examples. After each lecture, you have the opportunity to study the topic in one or two homework hour(s) focusing on the exercises. These can be discussed in small groups and a teacher is available to answer your questions. In addition, you study the relevant lecture text and remaining exercises at your own at home. During the first 4 weeks, there is one homework hour after the lecture but in addition, the next morning there is a tutorial for which you prepare at home. The tutorial hour starts with a brief summary and next, you answer the questions prepared at home and these are briefly discussed plenary in about 4 alternating sessions of about 10 minutes. The exercises in weeks 1-4 are classified as follows:

▲ Home work. Generally not discussed further during the plenary tutorial unless questions have arisen. The homework is done in organized homework hour after the lectures and is an extra service of the teachers. Next, you will continue on your own in which you have to 1) finish the home work exercises (if not yet done), 2) to study the main lecture text, and 3) to prepare a second set of exercises that will be discussed the next morning (first hour) in a plenary tutorial.

☼ Tutorial exercise for the plenary session. Prepare for it at home by reading the question in advance. You have completely read the second set of exercises and that you are able to formulate the questions your own words. In addition, you concentrate on the possible procedure to answer the questions by asking yourself:
- What is precisely asked in detail?
- Can I split up the question/exercise in smaller pieces that can be solved separately?
- Which information is available? Do I see any relevant data? List these.
- Which part(s) of the lecture text is probably involved? (Read it)
- Which equations might be relevant? Look to the meaning symbols and corresponding definitions. What are the units in the equations?
- Compare the parameters of the equations with the information in the question or in the relevant text. Which parameter values do I need?
- Can I get them directly from the information in the exercise? or is there extra information in the text? or should I combine data to find a parameter value?
- Do I have to express some parameter values first in other units by recalculation?
- Should information be combined to get the proper parameter value to be used in the equation?
In conclusion, concentrate on finding steps of a possible procedure, i.e. not on the actual calculation details. The latter will be done at the second tutorial the next morning during first hour. Finally, you check whether your guesses on the possible procedure are correct by looking to the approach given in the answer(s).

◊ Additional exercises that can be studied to prepare for the midterm and/or full exam.

Principle themes
The lectures are based on a series of chapters covering six themes:

1 Chemical Composition and Speciation of Natural aqueous solutions:
   1.1 The Chemical Equilibrium. The thermodynamic basis of the equilibrium condition, non-ideality and temperature dependency.
   1.2 Water in the Natural Environment. Natural water composition in the hydro-geochemical cycle, water quality (alkalinity, macro- & micro-elements), anthropogenic influence (nutrients in soil and landscape, salts and heavy metals).
   1.3 Speciation processes. Solving chemical equilibria. Chemical forms of substances, processes (e.g. hydrolysis, complexation)

2 Mineral-Water Interactions (dissolution and precipitation)
   2.1 Defining and solving chemical equilibria
   2.3 CO₂ & carbonate chemistry. CO₂ in the carbon cycle. Reactivity in open and closed systems, pH dependency dissolution & precipitation of lime, temperature dependency, karst phenomena, biogenic formation of Ca carbonate.

3 Adsorption at Mineral-Water interfaces and by Organic Matter
   3.2 Ion adsorption at mineral surfaces. Structure of the electrical double layers. Models for ion exchange at clay minerals and specific adsorption models at oxide surfaces (CD model and Langmuir model)
   3.3 Humus & heterogeneous adsorption. Type, size, structure, chemical heterogeneity, charge, CEC. Interaction cations and anions and heterogeneous adsorption modeling.
4 Chemical Processes in Sediments (redox chemistry and hydrophobic binding)
4.1 Redox processes. Biogeochemical reduction processes and principles, pH-pe stability diagrams of Fe, Mn, and S, behavior heavy metals, & metalloids.

5 Tropospheric chemistry
5.2 The oxidizing power of the troposphere Basic chemical processes Free radicals. Chemistry Nitrogen oxides. Global budget of ozone.
5.3 Deposition of trace gases and aerosol particles Overview of the different pathways. Wet and dry deposition.

6 Cloud and precipitation chemistry
6.2 Oxidation of Sulphur. Chemical composition of precipitation. Precipitation data and trends

Learning outcomes:
After finishing this course, the student is able to recognize the role of chemistry in processes acting in soil, water, and atmosphere and is able to describe, explain, and quantify by calculations the major chemical processes in practical applications under simplified conditions. This implies that the student is able to:
- Describe quantitatively the chemical composition and equilibrium speciation of the water phase in the system Soil-Water-Atmosphere.
- Explain and evaluate graphically major speciation processes related to mineral dissolution and formation in a quantitative manner.
- Describe and apply basic processes of adsorption, regulating the behavior of minor components in the system Soil-Water-Atmosphere.
- Explain and evaluate quantitatively in graphs the basic redox processes in water-sediment systems.
- Describe and explain the chemical composition of troposphere in relation to the key processes
- Describe and explain quantitatively the dynamics and chemical equilibrium processes in clouds and precipitation.
Assessment strategy

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<th>Learning outcomes</th>
<th>Midterm</th>
<th>Final</th>
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Contribution to the overall mark

| Contribution to the overall mark | 0-33% | 67-100% |

Examination process

- Written-Open-Book-Exam(s). The main text can only be used without additional own notes related to the exercises. The use of the book with Answers and Tables is not allowed.
- The course and exam focuses on a quantitative approach and therefore, you need a calculator. Take it with you! The exam is in English but a student may answer in Dutch. Take a dictionary (hardcopy) with you if needed.
- During the course period, there are 2 moments of evaluation, i.e. at the end and in addition, a midterm test held in week 3, covering the theme I and II (=33%). If you pass, you only have to concentrate on the remaining part (67%) that will be examined at the end in the official exam. Those who do not pass, have to do the complete final exam (100%). The midterm result is only valid for 1 year. To pass an exam: mark \( \geq 5.5 \)

Syllabi

1 Lecture: Chemical processes in Soil-Water-Atmosphere. Lecture notes and Index.
2 Tutorial: Chemical processes in Soil-Water-Atmosphere. Answers and Tables
Lecture and tutorial programme

L : Lecture;  T : Tutorial;  S : Selfstudy;  H : Homework

Hour 1:  8.30 –  9.15 h  
Hour 2:  9.30 – 10.15 h  
Hour 3: 10.30 – 11.15 h  
Hour 4: 11.30 – 12.15 h

For the precise information, see EDU-web

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7 Self Study week: Preparation for the Exam
8 Final (100%) exam (Theme 1-6) or Partial (67%) exam*” (Themes 3-6)

*”1 MT-Exam: Themes 1 and 2.
Only the use of Book 1 (main text and index) is allowed without additional own notes.
Use of Book 2 with Answers is not allowed.
Please, take a calculator with you and, if needed, a non-electronic dictionary.

*”2 Only for those who passed (mark ≥ 5.5) the Midterm Test.