UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Chemistry of Marine Environment

2627-1-F7504Q001

Aims

Objectives

The course aims at providing fundamental knowledges concerning the ocean chemistry, the processes and the mechanisms regulating the chemical composition of the seas and oceans as well as the most important chemical reaction occurring within them at at their interface.
A special attention is given to the climate change impact on the chemistry of the Oceans. In particular the Ocean chemistry is detailed in order to enable the students to acquire and develop knowledge and critical thinking with respect to the follwing topics:

- Stable Isotopes and Clathrates
- Salinity metrological determination as an already opened scientific question
- Chemical equilibrium and steady state in the oecans
- Seawater major consituents and effect on acoustic wave transmission and osmosis
- Gas fluxes between the ocean and the atmosphere, 222Rn and gases at the hydrotermal vents
- Dissolved inorganic carbon system, ocean acidification, alkalinity and geoengineering in the ocean context
- Biological Carbon Pump, pH changes and nutrient cycles
- Marine pollution and litter
- Marine emissions

Knowledge and Understanding (Dublin Descriptor 1)
At the end of the course, the student understands:

- Unconventional water properties
- The stable isotopes fractionation
- The main reactions of compounds present in the oceans
- The use of apparent equilibrium constants and the effect of temperature, salinity and pressure on them
- The multilpe concept behind the salinity
- The residence times of the major constituents of the Ocean

- The role of the ocean chemistry in attenuating the acoustic waves at different frquencies and the relationship with biota in an ocean acidification perspective
- The role of ocean chemistry on osmosis, osmolytes and the possibile use of the osmotic pressure in the context of the blue economy
- The gas concentration at the equilibrium and relationship with the biota
- The gas fluxes and relationship with meterological variables
- The gas laws in the deep ocean at high pressure, their role in hydrotermal vents for prebiotic molecule formation
- The acid-base reactions in the oceans
- The ocean acidification, from the qualitative concept till the quantification and future projections
- The ocean acidification and connection with the degree of saturation of calcite and aragonite; their link with trophic chanes
- The lysocline, and CCD
- The ocean acidification and paleoclimate and future scenarios related to bioconstructors
- The Alkalinty: from measurements till computation
- The biogeochemical processes affecting alkalinity, from a qualitative to a quantitative description
- The role of alkalinty in buffering the ocean pH
- The oceans in a geoengineering climate perspective: from CO2 deep lake pools, to alkalinity enhancement and iron fertilization. A critical assessment of environmental risks and future perspectives
- The nutrient definition and cyle in the ocean
- The coupling effect of deep currents, upwelling and nutrients redistribution
- The role of the ocean on our climate via sea-related aerosol emissions, cloud formation and hydrological cycle
- The pollution fate within the ocean and beyond

Furthermore, students acquire, review, and strengthen their knowledge regarding:

- the relationship between the ocean chemistry, biology and geology
- the relationship between ocean features and atmospheric properties
- the effect of ocean chemistry canges on trophic changes
- the potential of remote sensing for estimating chemical properties of the oceans

Applied Knowledge and Understanding (Dublin Descriptor 2)
At the end of the course, the student will be able to:

- Calculate the residence time of different elements within the ocean system
- Obtain the proper apparent equlibrum constants for each chemical reaction happening within sewater
- Determine the pH of the ocean at the equilibrium
- Determine the Dissolved Inorganic Carbon speciation in function of the pH
- Determine the pH of the ocean given a future CO2 scenario
- Determine the degree of saturation of calcite and aragonite in function of the CO2 levels, temperature, salinity and pressure
- Connect and interpret data of paleoclimate reconstructions with the present scenario
- Know how to critically analyze the evolution of ocean chemistry in response to evolving energy and environmental policies at the national and supranational levels
- Evaluate the spatio-temporal evolution of chemical species in the ocean using equilibrium and/or the stability of non-equilibrium steady states
- Understand the chemical-physical aspects of climate change and critically interpret the interactions between various environments and climate change, with particular attention to the ocean
- Ability to access remote sensing resources for estimating ocean chemical parameters
- Ability to make logical connections between topics in Ocean Chemistry and those in environmental sciences

Making Judgements (Dublin Descriptor 3)
At the end of the course, the student will be able to:

- Identify which are the most aboundant chemical compounds present in the oceans
- Identify which chemical constituents dominates the sound attenutation in the oceans
- Use in a proper way the equiibrium or steady state approach
- Determine the speciation of a compound in function of the pH
- Determine the proper chemical apparent equilibrium constant to be used
- Examine the synergy between the chemical and physical parameters of the oceans
- Assess the pH variation at the equilibrium
- Compute the alkalinity
- Apply an appropriate scientific method to interpret ocean chemistry data
- Assess the impact of ocean acidification on ecosystems
- Independently choose the most appropriate methodological geoengineering approach related to oceans
- Independently choose the most appropriate methodological, technological, or modeling approach to assess and solve problems related to ocean chemistry
- Integrate ocean chemistry into an interdisciplinary framework (chemistry, biology, geology, ecology, physics, law, economics) to address complex environmental problems and the relationship between humans and the environment in the oceanic sector
- Critically analyze scientific literature and technical-regulatory documents
- Independently evaluate policies, plans, and programs in the ocean sector (legal, economic, energy), including in terms of sustainability and the UN Agenda 2030
- Independently develop the project and methodology for the final exam, critically evaluating the results obtained and integrating them with scientific literature

Communication Skills (Dublin Descriptor 4)
At the end of the course, the student will be able to:

- Be able to clearly and concisely explain, with appropriate language, the main chemical reactions of anthropogenic and natural compounds and transport processes in the oceans
- Be able to clearly and concisely explain, with appropriate language, the main effects of ocean acidification and pollution on the environment
- Scientific communication skills in English at a B2 level, both verbally and in writing, in technical and scientific contexts
- Ability to interact and collaborate with third parties.

Learning Skills (Dublin Descriptor 5)
At the end of the course, the student will be able to:

- Be able to apply acquired knowledge of ocean chemistry to determine the impact of human activities on the oceanic chemical system. Understand the topics presented in the scientific literature on ocean chemistry, both past and present. Be able to apply the acquired knowledge to new areas, different from those covered in the course, independently integrating it with other sources of knowledge
- Consult international scientific literature, databases, and technical reports from research centers, local authorities, governments, and international organizations
- Work both in groups and independently, using the scientific method as a working tool

Contents

The course CHEMISTRY OF MARINE ENVIRONMENT provides an understanding of the chemical composition of seawater and related chemical reactions. Equlibrium and steady state conditions in aqueous solution are discussed and applied to obtain the residence times of the major constituents of the oceans. A particular attention is also given to priority and emerging pollutants and ocean chemical changes with respect to the climate change scenario. The course CHEMISTRY OF MARINE ENVIRONMENT enables the students to connect unconventional water properties with equilibrium constant variations, the stable isotopes fractionation with paleocliate records, the main

reactions of compounds present in the oceans. Metrological open questions related to salinity are discussed; the salinity is connected with acoustic waves attenuation at different frequencies and the relationship with biota in an ocean acidification perspective; salinity is also connected to the osmosis, osmolytes and the possibile use of the osmotic pressure in the context of the blue economy.
The gas concentration at the equilibrium and relationship with the biota is discussed together with the gas fluxes and relationship with meterological variables.
The course CHEMISTRY OF MARINE ENVIRONMENT enables the ocean acidification quantification connecting it with the degree of saturation of calcite and aragonite and their link with trophic changes even with respect to paleoclimate and future scenarios.
Alkalinty, from measurements till computation, is one of the major topic connected with the biogeochemical processes affecting it, its role in buffering the ocean pH and therefore the possible applications of geoengineering techniques. The nutrient definition and cyle in the ocean is coupled with deep currents redistribution.
Finally, the role of the ocean on our climate via sea-related aerosol emissions, cloud formation and hydrological cycle is discussed tgether with the pollution fate within the ocean and beyond.

Detailed program

The detailed programme is as follows:

1. Properties of Water that are fundamental for chemistry of the ocean: cooperative nature of hydrogen bond, cluster model of water, hydration shell, electrostriction, gas hydrates and clathrates (and their stability zone) isotopes in seawater, fractionation, and their usage for paleoclimate reconstruction
2. Equilibrium and steady state models: their usage in chemistry of the oceans in dirrent context. The concept of activity, apparent equilibrium constants in seawater; box model and residence time in seawater
3. Salinity and major constituents of seawater: salinity definitions through history till now, actual definitions and metrological perspectives, Marcet principle, conservative elements and major constituents of sewater definition and their use for paleoclimate in ice cores
4. Acustic wave transmission in the sea in function of the seawater chemical composition, the role of magnesium sulfate and tetraborate, effect on biota, change frequencies of whale's communations; osmotic pressure and Vant'Hoff equation and log equation of osmotic pressure. Osmotic green energy
5. Air-sea exchange of gases: Henry's law, Fluxes, exchange coefficient, laminar layer, bubble entrainment. Deep ocean gases and hydrotermal vents, supercritical CO2 in deep conditions and prebiotic molecules formation, 222Rn.
6. Acid-base reactions: pH, chemical composition, buffer intensity in the oceans.
7. CO?,HCO??, CO?²? equilibria in oceans and seawater. Log C – pH diagrams in the deep ocean and at the surface.
8. Acidity and alkalinity. Concept of ocean acidification and its calculation in function of the atmospheric rising of CO?. Effect on biota and trophic changes. Effect on seafloor geochemistry. Geoengineering climate applied to the oceans.
9. Organic matter in the sea. Nutrients, bio-limiting concept, solubility-pH of trace metals and their ion speciation
10. Microplastics. Organic pollutants (i.e. hydrocarbons, pesticides, dioxins and PCBs, flame retardants, and endocrine substances). Reaction in anoxix environment.
11. Atmospheric-ocean interaction: marine aerosols and their chemistry and their activity in the hydrological cycle. Atmospheric aerosol as a source of nutrients.

Prerequisites

Prerequisites include knowledge and/or review of:

- environmental chemistry
- inorganic chemistry
- organic chemistry

Teaching form

The teaching form is constituted by:
6 CFU (42 h, 21 two-hours lessons) of in person, Delivered Didactics, with frontal lessons even by videoconference and recorded. During these lessons questions and discussion with the students are encouraged with Interactive Teaching and discussions.

Textbook and teaching resource

Slides and two textbooks:

1- An Introduction to the Chemistry of the Sea, 2?? ed., Michael EQ Pilson, Cambridge University Press, 2013.

2- Chemical Oceanography, 4th Ed., Frank J. Millero, CRC press, Taylor & Francis Group, 2013

Semester

Second semester

Assessment method

Oral exam with written parts. The written parts are part of the oral exam during which the students have to demonstrate the capability to mange the most important chemical equilibrium equations concerning the chemistry of the sea or they have to write the most important equations concernig the Alkalinity or draw the vertical profile behaviour of the most important chemical components od seawater in different oceans.

In the oral examination, the student will be assessed on the basis of the following criteria: 1) knowledge and understanding; 2) connection of the different concepts; 3) reasoning autonomy; 4) ability to use scientific language

Mark range: 18-30/30 with laude

Office hours

Office at 3rd floor of U1 building (Piazza della Scienza 1, Milano).
By appointment via e-learning or contacting me at my mail address (luca.ferrero@unimib.it)

Sustainable Development Goals

CLEAN WATER AND SANITATION | CLIMATE ACTION | LIFE BELOW WATER