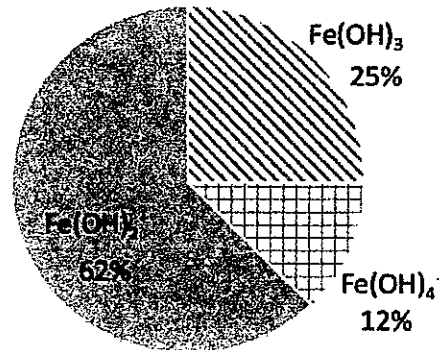
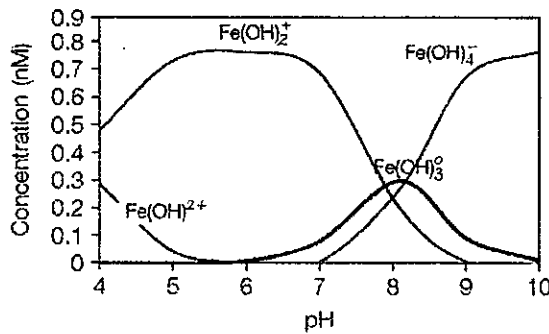


Part A. Multiple choice questions (40 points, 2 points each question) 本大題請於試卷內之「選擇題作答區」依序作答。

- Assuming that the total volume of water in the ocean is $1.37 \times 10^9 \text{ km}^3$ and the annual water flux to the ocean is $3.7 \times 10^4 \text{ km}^3/\text{yr}$, what is the approximate water residence time in the ocean?
(A) 3500 years (B) 35000 years (C) 350000 years (D) 3500000 years
- Which ones of the following devices are specially designed to avoid surface contamination during seawater sampling?
(A) Niskin bottle (B) Niskin-X bottle (C) Nansen bottle (D) GO-Flo bottle
- Which of the following statements about seawater salinity are **incorrect**?
(A) Marquet's Principle suggests that the major salts of seawater are present in constant proportions to each other in the global oceans.
(B) Conductivity method provides the most precise method to determine seawater salinity.
(C) Seawater at 15°C and chlorinity of 19.37ppt has a lower absolute salinity value than practical salinity value.
(D) Gravimetric method is not a very accurate method for determining seawater salinity, because it loses some volatile compounds due to evaporation.
- Using the following equation, what is the ionic strength of a mixed solution 0.05 mol/L Na_2SO_4 and 0.02 mol/L KCl?
(A) 0.07 M (B) 0.12M (C) 0.14M (D) 0.17M

$$I = \frac{1}{2} \sum_{\text{all ions}}^n C_i Z_i^2$$

- Changes in Fe speciation reflect the values of seawater pH. According to the following figure for Fe speciation concentration and seawater pH, what is the approximate seawater pH value based on the speciation of Fe in the given pie chart?
(A) 4.5 (B) 7.5 (C) 8.5 (D) 9.5



- Winkler Titration is commonly used to measure dissolved O_2 in seawater. Which of the following reagents are **NOT** required for Winkler Titration?
(A) MnSO_4 (B) NaI or KI (C) AgNO_3 (D) $\text{Na}_2\text{S}_2\text{O}_3$
- The valence of an element is the measure of its ability to combine with other atoms. In the following list, the valence numbers are labelled in the brackets for each element of interest, but one of them is labelled incorrectly. Please select the incorrect labels.
(A) Sulfur (+6) in SO_4^{2-} (B) Nitrogen (-3) in NH_3 (C) Gold (+4) in AuCl_4^- (D) Manganese (0) in Mn
- The concept of the "oceanic biological pump" refers to the role of marine organisms in: (A) Carbon sequestration (B) Oxygen production (C) Nutrient cycling (D) Temperature regulation
- The process of nitrification in the ocean involves the conversion of ammonia to: (A) Nitrite (B) Nitrate (C) Nitrous oxide (D) Nitrogen gas

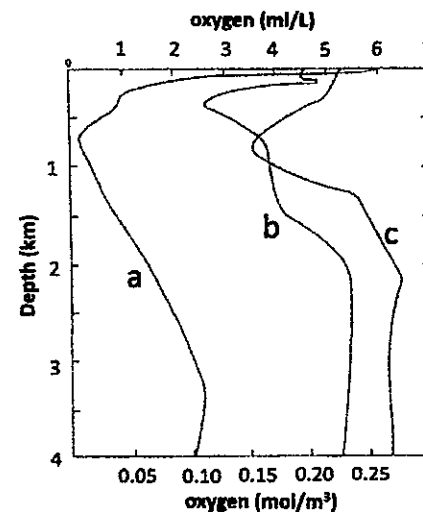
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10. Which one of the following statements about element cycling is **incorrect**?

- (A) Nitrogen, phosphorus, and silicon are required by the growth of plankton in the surface ocean. However, because of their low concentrations in the surface ocean, they are considered as biolimiting elements.
- (B) Calcium is required by the growth of calcifying organisms, so it is also a biolimiting element.
- (C) Element oceanic residence time and recycling efficiency are determined by both physical and biological processes.
- (D) Biolimiting elements tend to have a lower surface-ocean recycling efficiency (g) and a lower particle flux to sediments (f)

11. The figure to the right shows three depth profiles of dissolved oxygen from the global oceans (a, b and c). Which of the following is the correct sequence from the South of California, the Eastern part of the South Atlantic and the Gulf Stream?

- (A) a-b-c (B) c-b-a (C) a-c-b (D) b-c-a



12. Continuing with the question 11, if the offset of oxygen between a and c around 1km depth is purely driven by the respiration of organic matter, how much phosphate ($\mu\text{mol/L}$) is regenerated according to the Redfield model?

- (A) 0.5 (B) 1.0 (C) 1.5 (D) 2.0

13. The Gibbs free energy change in chemical reactions involving marine redox couples is crucial for understanding: (A) Biological diversity (B) Ocean circulation (C) Thermodynamics of reactions (D) Gas solubility

14. If a phytoplankton bloom in a certain region has a molar C:N ratio of 6:1, what would be the corresponding molar ratio of phosphorus to carbon (P:C) based on the Redfield ratio? (A) 0.01:1 (B) 0.06:1 (C) 0.1:1 (D) 0.6:1

15. The phenomenon of "dead zones" in the ocean, characterized by low oxygen concentrations, is primarily linked to the excessive input of (A) Iron (B) Nitrogen (C) Silicon (D) Calcium

16. The role of coccolithophores in the ocean is closely tied to the production of: (A) Methane (B) Dimethyl sulfide (C) Nitrous oxide (D) Carbon monoxide

17. The concept of "ocean alkalinity" is closely related to the long-term regulation of atmospheric: (A) Oxygen levels (B) Carbon dioxide levels (C) Nitrogen concentrations (D) Methane concentrations

18. The term "chromophoric dissolved organic matter" (CDOM) is associated with organic compounds that: (A) Exhibit fluorescence when exposed to ultraviolet light (B) Act as electron acceptors in anaerobic respiration (C) Form stable complexes with trace metals (D) Absorb visible light and contribute to water color

19. In the process of "anaerobic ammonium oxidation" (anammox), what is the role of nitrite (NO_2^-)? (A) Electron acceptor (B) Electron donor (C) Catalyst (D) Inhibitor

20. Considering the information for each element below, which element has the shortest residence time in seawater?

- (A) calcium; vertical distribution: conservative type; average concentration: 10.3 mmol/kg
- (B) sodium; vertical distribution: conservative type; average concentration: 469 mmol/kg
- (C) lead; vertical distribution: scavenged type; average concentration: 13 pmol/kg
- (D) nickel; vertical distribution: nutrient type; average concentration: 8.2 nmol/kg

Part B. Short answer questions (60 points) 本大題請於試卷內之「非選擇題作答區」標明題號依序作答。

1. Calcium carbonate in seawater (18 points)

Seawater dissolved carbonate concentration controls the preservation and sedimentation rates of calcite in the oceans. (1) Use the information below (the figure, table, and equation) to calculate the calcite saturation index (Ω) at 0m, 1000m and 6000m in the North Atlantic and the North Pacific respectively, assuming that seawater Ca concentration is constant (12 points). (2) Which ocean basin has a lower fraction of calcite in sediments and why (6 points)?

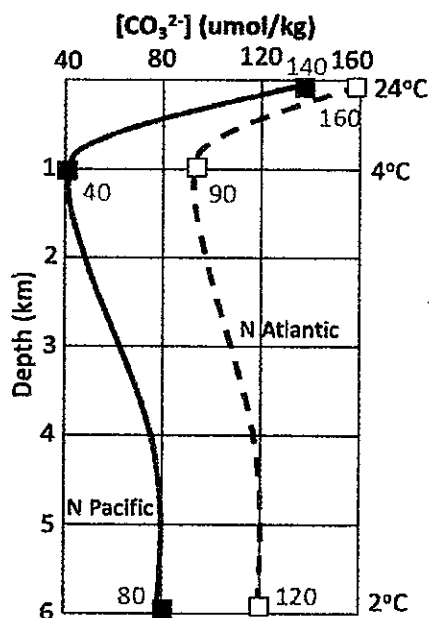


Table Saturation Concentrations of Carbonate Ion in Seawater ($\mu\text{mol/kg}$) as a Function of temperature and Pressure. ($S = 35$)

Calcite	Temperature (°C)				
	24°C	10°C	4°C	2°C	0°C
0m	41.5	41.9	41.8	41.7	41.6
1000m	48.7	50.0	50.5	50.6	50.7
6000m	101.2	112.4	119.0	121.5	124.2

$$\Omega = \frac{[\text{CO}_3^{2-}]_{\text{observed}}}{[\text{CO}_3^{2-}]_{\text{saturation}}}$$

2. Dissolved oxygen in the oceans (15 points)

A station in the North Pacific is reported to have a concentration of $\text{O}_2 = 80 \mu\text{mol/L}$ at 4000 m depth. This water mass is originated from the region where the temperature is at 15 degrees. (1) Use the data from the NAEC table given below to calculate the apparent oxygen utilization (AOU) for this station (5 points). (2) Following the Redfield model, how much organic matter was oxidized (5 points)? (3) If the P concentration at this station is $2.37 \mu\text{mol/L}$, how much of the phosphate is from the preformed phosphate (5 points)?

Table NAECs of Gases in Seawater at a Salinity of 35.0.

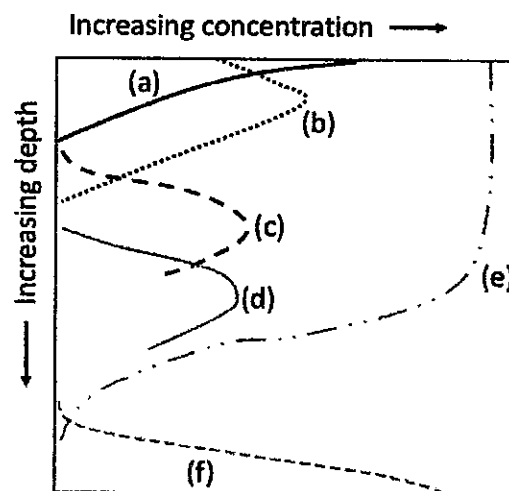
T(°C)	Concentrations in mmol/m ³					
	0	5	10	15	20	25
N₂	635.7	565.6	508.3	460.7	420.4	385.7
O₂	355.6	313.2	278.7	250.0	225.9	205.1
CO₂	23.37	19.26	16.09	13.6	11.61	10.00
Ar	17.01	14.98	13.33	11.96	10.81	9.81

3. Residence time of Ba in the ocean (10 points)

The main source of barium (Ba) in the ocean is the dissolved Ba transported by rivers. The flux of river water to the ocean is of the order of $10^6 \text{ m}^3 \text{ s}^{-1}$. The average Ba concentration is $1.0 \times 10^{-7} \text{ mol kg}^{-1}$ in seawater and $4.4 \times 10^{-7} \text{ mol kg}^{-1}$ in river water. The volume of the ocean is approximately $1.36 \times 10^{18} \text{ m}^3$. (1) Calculate the residence time of Ba in the ocean (5 points). (2) Compare this time to the ocean mixing time. What can you conclude about the distribution of Ba in the ocean (5 points)?

4. Redox processes in marine sediments (17 points)

Oxidation reactions of sedimentary organic matter require electron acceptors, and hence some reactants and products follow a particular sequence in marine sediments due to the availability of electron acceptors. In the transition from oxygenic to anoxic environments, the depth profiles of several contents in the sediment pore fluids reflect this sequence and the change of oxidation reactions. For instance, the figure in this section shows 6 unknown profiles (labelled a-f), which relate to **oxygen, iron, manganese, nitrate, sulfate, and methane**. (1) Identify the contents in each of these profiles (a-f) (12 points). (2) Based on your understanding of the Gibbs free energy between these reactions, briefly explain why these profiles follow a particular sequence (5 points).



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