

北海道大学大学院環境科学院環境起学専攻

Division of Environmental Science Development
Graduate School of Environmental Science, Hokkaido University
Course in Human and Ecological Systems, Course in Environmental Adaptation Science,
and Course in Global Environmental Management

令和 8 年度大学院修士課程入学試験問題（秋季入試）

令和 7 年度 10 月入学大学院修士課程入学試験問題

Entrance Examination

専門科目 解答例

Specialized Subjects Example Answers

Environmental Science

Question 1

(1)

① 2.0, ② pre-industrial, ③ 1.5, ④ genetic resources, ⑤ Montreal, ⑥ persistent organic pollutants (POPs)

(2)

- a) It is an index that evaluates human resource demand in light of the Earth's capacity to regenerate resources. It is calculated by summing the area required to supply renewable resources for human use, the area indicated by infrastructure development, and the area required to absorb waste.
- b) It is the concept that the health of animals, people, and ecosystems should be considered as one, and should be balanced and healthy. The concept of health for humans is expanded to include the health of wildlife and ecosystems. The One Health Manhattan Principle has been established as a guideline.
- c) It is thresholds of abrupt or irreversible environmental changes. Nine major systems were identified with these critical thresholds: climate change, biodiversity, land system change, freshwater use, biogeochemical flows, ocean acidification, atmospheric aerosol, stratospheric ozone loss and “novel entities”.
- d) It is a concept that refers to the cyclical dynamics of various substances in nature, and can be expressed in terms of elemental units such as the carbon cycle and nitrogen cycle, or in terms of compound units such as the water cycle. The material cycle involves the flow of energy.
- e) It is an acronym for Environment (E), Society (S) and Governance (G). Sustainability, social responsibility, and good governance are important issues in the business world. It is a concept that provides a framework for assessing and managing these issues.

Question 2

- a) Large dam construction provides multiple benefits such as flood control, hydroelectric power generation and water storage for multiple purposes such as drinking, irrigation and industrial uses. Dam construction can alter water flow, sediment transport and impact fish migration in downstream. Sediment accumulation in dams can reduce dam storage capacity and affect hydropower production.
- b) A confined aquifer is an aquifer below the land surface that is saturated with water. Layers of impermeable material are both above and below the aquifer, causing it to be under pressure so that when the aquifer is penetrated by a well, the water will rise above the top of the aquifer. An unconfined aquifer is an aquifer whose upper water surface (water table) is at atmospheric pressure, and thus is able to rise and fall.

- c) Point source discharge pollution from specific locations (identifiable source), such as drainpipes, ditches, or sewer outfalls into water bodies. Examples: Factories, power plants, sewage treatment plants. Nonpoint sources of water pollution are scattered or diffuse, having no specific location where they discharge into a particular body of water. Examples: Runoff from farm fields and livestock feedlots.
- d) Ozone in the troposphere is considered as a pollutant because it irritates living tissues and contributes to smog. However, in the stratosphere, ozone absorbs harmful ultraviolet (UV) solar energy that has high-energy and can damage plant and animal tissues, including the eyes and skin. Therefore, ozone in the stratosphere can be considered as a critical protective shield against UV radiation.
- e) There are many waterborne diseases such as typhoid, cholera, bacterial and amoebic dysentery, enteritis, infectious hepatitis, and schistosomiasis. The most common among them is cholera, caused by *Vibrio cholerae* bacteria. The main source of this disease is untreated or improperly treated human wastes. Similarly, typhoid is caused by *Salmonella typhi* bacteria and main source of this disease is also untreated or improperly treated human wastes.
- f) Dissolved oxygen is the amount of oxygen dissolved in water. It is considered as an indicator of water quality and of the kinds of life it will support by assessing its level. Water with an oxygen content above 6 parts per million (ppm) will support game fish and other desirable forms of aquatic life. Water with less than 2 ppm oxygen will support mainly worms, bacteria, fungi, and other detritus feeders and decomposers.

Physics

Question 3

(1)

A geostationary satellite orbits Earth at the same rotational speed as the Earth, about 36,000 km above the surface. At this altitude, gravitational and centrifugal forces are balanced. Its main advantage is the ability to continuously observe the same region from space.

The level of free convection (LFC) is the altitude where a rising air parcel becomes warmer than the surrounding environment. Above this level, the parcel gains positive buoyancy and can ascend freely. This process enables vertical cloud development without external lifting mechanisms.

Hadley circulation is the dominant atmospheric circulation between the tropics and subtropics. It features rising air near the equator driven by strong solar heating and deep convection. This air descends in the subtropics, suppressing convection and contributing to dry climates there.

Doppler radar measures upper atmospheric winds by detecting motion in precipitation particles. When droplets move toward the radar, the returned signal frequency increases due to the Doppler effect. This shift reveals wind speed and direction aloft.

(2)

(a) Mineral dust, forest fires, sea spray

(b) An increase in cloud area enhances the reflection of shortwave radiation, reducing solar energy at the surface and cooling the Earth surface. Clouds also regulate the longwave radiation budget. Thick low-level clouds, with relatively warm tops, emit more longwave radiation to space. Therefore, the increase in such clouds contributes to surface cooling, while a decrease may lead to warming.

(c) The atmospheric window is a range of wavelengths where longwave radiation from the Earth escapes with minimal absorption by atmospheric gases. This allows clearer detection of surface signals from space. It is widely used in satellite-based Earth observations, as the effect of greenhouse gas is limited in this band.

(d) Letting the solar constant be S and Earth radius be R , the total solar radiation energy reaching the Earth is $\pi R^2 S$. Figure 1 shows the global mean energy flux as 340 W/m^2 , which represents the average of the entire Earth surface area $4\pi R^2$. Therefore, $\pi R^2 S = 340 \times 4\pi R^2$, and thus, S is approximately four times greater than 340.

(e) Land use and land cover changes influence surface albedo, altering the absorption of shortwave radiation at the Earth's surface. Historical human activities, such as deforestation and agricultural

expansion, have generally increased surface albedo, contributing to surface cooling.

(3)

(a) i

(b) ii

(c) $2\Omega v \sin \theta$

(d) Near the Earth's surface, wind speed decreases due to surface friction, which weakens both the Coriolis and centrifugal forces. As a result, the pressure gradient force becomes dominant, directing air toward the low-pressure center.

Ecology and Geography

Question 4

(1)

- a. ① Erosion
② Wave
③ Mass movement (or gravitational deformation)
- b. Meandering: Lateral erosion of rivers mainly occurs on the outer bends of meanders, where riverbanks are eroded. This causes the river to bend further. When meandering progresses and the neck of a meander is cut off, the old channel becomes isolated, forming features such as oxbow lakes.
- c. When a large volume of rock debris reaches a river valley, it can temporarily block the river to create a natural (landslide) dam. If the dam collapses, it may trigger debris flows or floods downstream. In addition, the increased volume of transported sediments can raise the riverbed downstream, potentially altering the river course and increasing flood risk.

(2)

- a. A
- b. Hummocks are composed of rock blocks that originally made up the mountain body, and typically have underdeveloped soil and steep slopes, making them less suitable for land use. As a result, urban and agricultural land development is limited, and such areas often remain as natural forests or green spaces.
- c. Alluvial fan
- d. The alluvial fan formed *after* the sector collapse, because the fan covers the terminal part of the landslide body, and it is supposed to have formed from sediments deposited by rivers that flowed over the surface or along the side of the landslide body.

Question 5

(1)

- (i) Photosynthetically active radiation is light that can be used by plants for photosynthesis, and net primary production is the amount of organic matter obtained using that light.
- (ii) Interspecific competition is a phenomenon in which different species compete for resources, and niche partitioning is a mechanism whereby species coexist by dividing resources and space in order to mitigate competition. (As interspecific competition intensifies, niche partitioning progresses, and the ecological roles and habitats of each species become more specialized.)
- (iii) The meso-scale disturbance hypothesis is a theory that suggests that biodiversity is maximized in ecosystems where the frequency and intensity of disturbances are moderate. If

disturbances are too small, dominant species monopolize the ecosystem, and if they are too strong, only resistant species survive, leading to a decline in biodiversity. Conversely, meso-scale disturbances promote biodiversity.

(2)

(a) Land use changes can fragment habitats, leading to isolation of populations and potentially hindering gene flow. As a result, genetic diversity may decline, weakening the environmental responsiveness and resilience of the entire community. Fragmented populations are also at greater risk of inbreeding and local extinction.

(b) Resilience refers to the ability of an ecosystem to recover to its original state after a disturbance, while resistance refers to the ability to withstand disturbances. Populations with high resistance to biological invasions are less likely to be colonized by invasive species, and those with high resilience are more likely to recover from temporary impacts. When invasive species have an impact, the regenerative capacity of a population is determined by the balance between these two forces.

(c) Provisioning functions: Food, water, wood, and other ecosystem products that can be used directly by humans. Regulating functions: Climate moderation, water purification, pest control, and other functions that stabilize ecosystems.

(d) When nitrogen concentrations increase due to fertilizer loading, species adapted to low-nitrogen environments, such as Sphagnum moss, disappear. On the other hand, plants with high nitrogen preference become dominant, leading to a decrease in species diversity. Furthermore, this change alters the nitrogen cycle in wetlands, affecting ecosystem functions and stability.

(3)

(a)

(i) Topography affects precipitation distribution, and the windward side of mountains exposed to sea breezes receives abundant precipitation, which facilitates vegetation growth and enriches resources. On the other hand, the leeward side receives less precipitation, resulting in scarce resources and limited vegetation, which causes differences in the distribution of organisms.

(ii) The risk of species extinction increases with smaller population sizes. Therefore, protecting large areas of habitat enables the stable maintenance of populations and reduces the risk of extinction. For this reason, the protection of large habitats is a priority in species conservation.

(b)

(i) In an ecosystem food chain, for example, when a higher-level predator suppresses

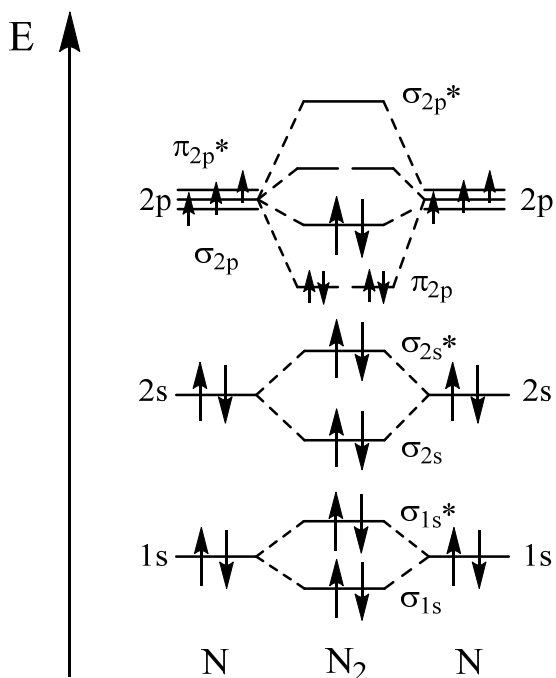
organisms at lower trophic levels, the effect spreads down the chain, controlling the overall structure and flow of matter in the ecosystem.

(ii) Wolves, as top predators in the food chain, control the population and behavior of ungulates, thereby suppressing excessive grazing pressure on vegetation and triggering a “trophic cascade.” Wolf predation induces interspecific interactions that alter the density and behavior of prey species, leading to an increase in the establishment of *Populus* trees. As a result, changes in wolf populations due to extinction or reintroduction regulate the population dynamics of prey species, thereby promoting the recovery of *Populus* forest structure.

Chemistry

Question 6

(1)

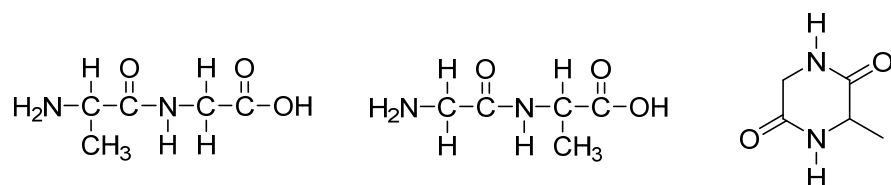


The bond orders of N_2 , N_2^- , N_2^{2-} are 3, 2.5, 2, respectively. Since the larger the bond order, the shorter the bond, the greater or smaller the average inter-nuclear distance (= bond distance) is $N_2 < N_2^- < N_2^{2-}$.

(2)

Amino acids are organic compounds having at least one amino group NH_2 and at least one carboxy group $COOH$.

The dipeptides produced by the condensation of glycine and alanine have the following three structures.

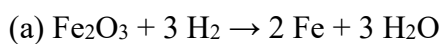


(3)

(a) The total pressure = $0.32 + 0.15 + 0.42 = 0.89$ atm, the mole fraction of N_2 : $0.32 / 0.89 = 0.359... = 0.36$, the mole fraction of He : $0.15 / 0.89 = 0.168... = 0.17$, the mole fraction of Ne : $0.42 / 0.89 = 0.471... = 0.47$

(b) From $P_1 V_1 / T_1 = P_2 V_2 / T_2$, the volume at standard state (273.15 K, 1 atm) is calculated using the equation $0.57 * 2.5 / 288.15 = 1 * x / 273.15$ to be $x = 1.35... = 1.4$ [L]

(4)



(b)

$$\Delta H^\circ = \{2 \Delta_f H^\circ[\text{Fe(s)}] + 3 \Delta_f H^\circ[\text{H}_2\text{O(g)}]\} - \{\Delta_f H^\circ[\text{Fe}_2\text{O}_3(\text{s})] + 3 \Delta_f H^\circ[\text{H}_2(\text{g})]\}$$

$$= \{2 \times 0 + 3 \times (-241.8)\} - \{-824.2 + 3 \times 0\}$$

$$= 98.8 \text{ [kJ]}$$

$$\Delta S^\circ = \{2 S^\circ[\text{Fe(s)}] + 3 S^\circ[\text{H}_2\text{O(g)}]\} - \{S^\circ[\text{Fe}_2\text{O}_3(\text{s})] + 3 S^\circ[\text{H}_2(\text{g})]\}$$

$$= \{2 \times 27.3 + 3 \times 188.7\} - \{87.4 + 3 \times 130.6\}$$

$$= 141.5 \text{ [J/K]}$$

$$\text{Thus, } \Delta G^\circ = \Delta H^\circ - T \Delta S^\circ = 98.8 - 298.15 \times 0.1415 = 53.6... > 0$$

Since the reaction proceeds spontaneously when $\Delta G^\circ < 0$, this reaction does not proceed spontaneously under standard conditions at 25 °C.