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

平成 31 年度 4 月入学大学院修士課程入学試験問題（秋季入試）

平成 30 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

Specialized Subjects
［留学生用］
[For International Students]

・ **Environmental Science (Question 1 through 3) is a compulsory subject, and all 3 questions must be answered.**
・ **Two questions are given in each of the following 4 specific subject areas (1) Mathematics and Physics, (2) Ecology and Geography, (3) Environment and Society, and (4) Chemistry and Biology. Candidates are required to answer 1 out of these 8 questions (Question 4 through 11).**
・ **The total score of the 3 questions for Environmental Science (Compulsory) is equal to the score of the 1 question for the chosen subject area.**
・ **Use one answer sheet for each question.**
・ **The backside of the answer sheet can be used if necessary.**
・ **Specify the question number on each answer sheet.**

August 23, 2018

Environmental Science (Compulsory)

Question 1   Answer the questions (1) to (4).

(1) Waste management is based on the three Rs of resource use: Reduce, Reuse, and Recycle. Or four Rs are considered by adding Refuse. Explain each method of three Rs within three lines by giving one example for each.

(2) From an environmental standpoint, Reduce and Reuse are preferred. Explain why they are more important than Recycle within four lines.

(3) One of important properties of POPs (Persistent Organic Pollutants) is bioconcentration. Explain the term of bioconcentration within four lines.

(4) Use of pesticides has several advantages such as an increase of harvest, while it might affect the ecosystem or pesticide residues might cause health risk. Explain the reason why we do not have to consider health risk by pesticide residues at present within five lines.

Environmental Science (Compulsory)

Question 2   Read the following sentences and answer the questions (1) to (3).

　　【 A 】 is the name given to the nutrient enrichment of a shallow lake, a coastal area at the mouth of a river, or a slow-moving stream. It is caused mostly by runoff of plant nutrients such as 【 B 】 and 【 C 】 from land bordering such bodies of water. In contrast, an 【 D 】 condition is low in nutrients and its water is clear.

　　Near urban or agricultural areas, human activities can greatly accelerate the input of plant nutrients to water bodies. Such inputs involve mostly 【 B 】 and 【 C 】 -containing effluents from various sources, including farmland, feedlots, urban streets and parking lots, chemically fertilized lawns, mining sites, and municipal sewage treatment plants.

　　During hot weather or drought, this nutrient overload can produce dense growths, or "blooms", of organisms such as 【 E 】 and 【 F 】 . When they die, they are decomposed by swelling populations of oxygen-consuming bacteria, which deplete dissolved 【 G 】 in the water. <u>This can kill fish, shellfish, and other aerobic aquatic animals.</u>

(1)　Select the most appropriate terms for 【 A 】 to 【 G 】 from the following candidates.

　　　　toxic   eutrophication   oligotrophic   nitrates   phosphates   zooplankton
　　　　　　arsenic   acidic   algae   cyanobacteria CO_2 oxygen   iron

(2)　Why can the nutrient overload produce dense growths of organisms during hot weather or drought? Explain the reason in about four lines.

(3)　There are several ways to prevent or reduce the underlined situation. Describe one of the ways in about three lines.

Environmental Science (Compulsory)

Question 3   Read the following paragraph and answer the questions (1) to (5).

An ecosystem consists of the community of organisms in an area and the way they affect each other and the environment. Plants and animals drive material cycling within ecosystems (i)<u>by interacting with each other in various ways</u>, and they can be classified as producers, consumers, and【 A 】. Green plants and some species of bacteria are producers because they can produce organic compounds from energy and simple inorganic molecules. Animals are consumers and need to consume (eat) plants and/or animals. Species compositions of plants and animals vary substantially among different biomes because (ii)<u>various types of environmental factors, which are characteristic of respective biomes, act as limiting factors for growth and survivorship of organisms</u>. Currently, anthropogenic factors such as (iii)<u>habitat destruction and the introduction of exotic species</u> have led to biodiversity decline, resulting in more than 20% of organisms belonging to groups such as mammals and【 B 】 at risk of extinction. (iv)<u>Various efforts</u> have been made to protect organisms and reduce biodiversity loss.

(1)   Write down two words suitable to fill in the blanks【 A 】and【 B 】.

(2)   Concerning the underlined (i), write down four words describing major types of interactions.

(3)   Concerning the underlined (ii), write down two important environmental factors in this context. Also, describe the scientific definition of a limiting factor in about three lines.

(4)   Concerning the underlined (iii), there is a possibility that climate change is enhancing the negative effects of these factors. Describe one concrete example and a mechanism involved in about five lines.

(5)   Concerning the underlined (iv), describe one concrete example in this context, and objective(s) and contents (or activities) in about five lines.

Mathematics and Physics

Question 4   Answer the following questions (1) to (4).

(1) Answer questions (a) and (b).

(a) When $y = (x + \sqrt{x^2 - 1})^n$, prove $\sqrt{x^2 - 1}\dfrac{dy}{dx} = ny$ and $(x^2 - 1)\dfrac{d^2 y}{dx^2} + x\dfrac{dy}{dx} = n^2 y$.

(b) When $\dfrac{dy}{dx} = f(u)$ and $u = \dfrac{y}{x}$, prove $\dfrac{du}{dx} = \dfrac{f(u) - u}{x}$.

(2) Obtain the following indefinite integrals.

(a) $\displaystyle\int \sin\sqrt{x}\, dx$ (b) $\displaystyle\int \dfrac{\log x}{\sqrt{x - 1}}\, dx$

(3) Answer the following questions on a matrix $\mathbf{A} = \begin{pmatrix} 2 & -2 & 0 \\ 1 & -2 & -1 \\ -2 & 1 & -2 \end{pmatrix}$.

(a) Obtain the eigenvalues and eigenvectors of $\mathbf{A}$.

(b) Prove that the eigenvectors obtained in (a) are linearly independent.

(4) Measuring two variates, x and y, for n samples, we obtain n points, $(x_i,\ y_i)\ (i = 1,\ 2,\ \cdots,\ n)$, in two-dimensional plane (see the right figure). The method of least squares is a standard approach in regression analysis, where a linear function $y = ax + b$ is obtained to fit the n points best. Answer the following questions on the method of least squares.
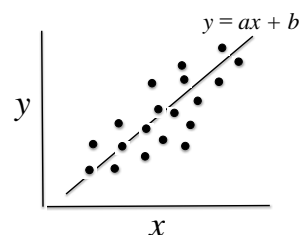
(a) The purpose of the method of least squares is to obtain a and b that minimize $L = \sum_{i=1}^{n} \{y_i - (ax_i + b)\}^2$. Describe what L means within three lines.

(b) Obtain $\dfrac{\partial L}{\partial a}$ and $\dfrac{\partial L}{\partial b}$.

(c) A set of parameters $a = a^*$ and $b = b^*$ that minimizes L satisfies the following two equations simultaneously: $\left.\dfrac{\partial L}{\partial a}\right|_{a = a^*,\ b = b^*} = 0$ and $\left.\dfrac{\partial L}{\partial b}\right|_{a = a^*,\ b = b^*} = 0$. Describe the reason within three lines.

(d) Obtain $(a^*,\ b^*)$ from $\left.\dfrac{\partial L}{\partial a}\right|_{a = a^*,\ b = b^*} = 0$ and $\left.\dfrac{\partial L}{\partial b}\right|_{a = a^*,\ b = b^*} = 0$.

Mathematics and Physics

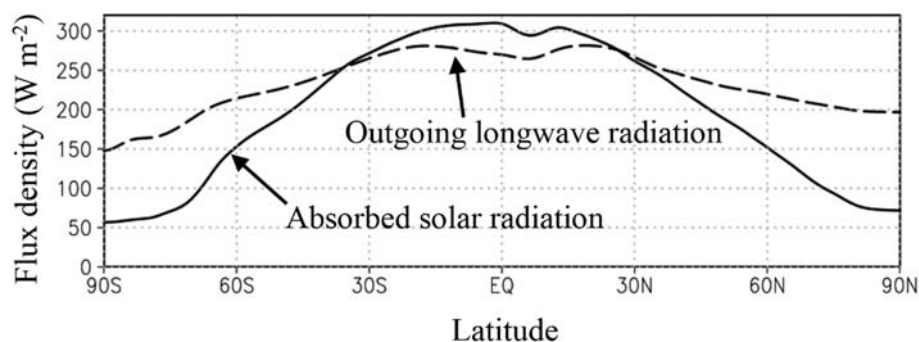**Question 5**   Answer the following questions (1) to (3).

(1) Explain the terms below within three lines for each.

【Terms】   Equivalent potential temperature
Level of free convection (LFC)
Cloud condensation nuclei
Valley wind

(2) Figure 1 illustrates the annual mean flux densities of absorbed solar radiation and outgoing
longwave radiation as a function of latitude. Answer the questions (i) to (iii).

(i) Describe the reason within three lines why absorbed solar radiation decreases from the equator
to the poles.

(ii) Describe the reason within three lines why outgoing longwave radiation decreases from the
equator to the poles.

(iii) According to Figure 1, there must be a surplus of absorbed solar radiation relative to outgoing
longwave radiation at low latitudes and a deficit at high latitudes. Explain within four lines
how the Earth climate system re-distributes the energy and smoothen the latitudinal imbalance
of radiative energy budget.

Figure 1

(3) Figure 2 illustrates gradient wind (V) and the balance of forces (A to C) acting to air parcel circulating around the low pressure in the Northern Hemisphere. Answer the questions (i) to (v).

(i)   Assuming that the force C is centrifugal force, answer the names of forces A and B.

(ii) For each of the following descriptions (a) to (c), answer as "yes" for the appropriate description and "no" for the inappropriate description.

    (a) When the centrifugal force C is small and negligible, V is referred to as geostrophic wind.

    (b) The force A is stronger near the ground because stronger surface friction is acting to air parcel.

    (c) Magnitude of the force B is proportional to the cosine of the latitude at the point O.

(iii)   Draw a figure of gradient wind and the balance of forces like Figure 2 but for around the high pressure in the Northern Hemisphere. You must specify the wind V and the three forces A to C in the figure.

(iv)   The cyclostrophic wind is observed in tornado in which the radius of horizontal rotation of air parcel is very small. Describe the balance of forces required for the cyclostrophic wind within three lines. You may draw figures in the answer sheet if necessary.

(v)   In middle latitudes, developed extratropical cyclones (i.e., low pressure) sometimes induce strong winds while anticyclones (i.e., high pressure) do not. Explain the reason by taking account of the balance of forces in Figure 2 and the resultant constraint of wind speed (V). Denote the angular velocity of the Earth as Ω, and also denote the distance between air parcel and the center of the cyclones/anticyclones as r. You must write down all calculation steps as well as the answer. You may draw figures in the answer sheet if necessary.

Figure 2

6
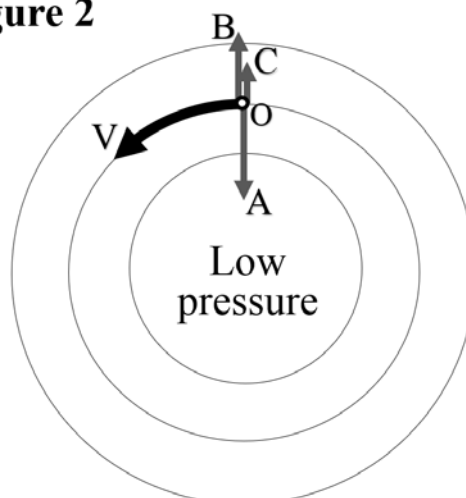
Ecology and Geography

Question 6   Answer all the questions (1) through (3).

(1) Explain or define each of the five ecological terms (i) to (v).

      (i) soil   (ii) litter   (iii) C_3 plant

      (iv) β-diversity   (v) keystone species

(2) Answer the questions (a) to (f), based on the text.

> In a late-   (X)   community such as a forest, dominated by (i)*K-selected species*, disturbance opens up gaps that are colonized by (ii)<u>pioneer species</u>. These are later (iii)<u>replaced by other species</u>. Species richness in the gap is (iv)<u>initially low, reaching a peak in mid-stage and falling by climax species takes place</u>.
>
> In fresh gaps, regrowth occurs from three sources: (Y) , plants established prior to gap formation and the growth of branches of trees on the gap periphery. Larger gaps remain open sufficiently long for (v)<u>buried seeds</u> to germinate and contribute to the gap community.
>
> Modified from Instant Notes in Ecology (2012)

(a) Fill an appropriate word(s) in each of the blanks (X) and (Y).

(b) On the underline (i), show the opposite term and then explain why (i) are dominant.

(c) On the underline (ii), show the three characteristics.

(d) Explain the mechanisms of underline (iii) by using "resource ratio hypothesis".

(e) On the underline (iv), explain why we see this fluctuation pattern of species richness.

(f) The underline (v) can be classified into two types: persistent and transient. Explain which one is more important for ecosystem recovery after disturbances and why it is more important.

(Continue to the following page)

(3) Answer the following (a) to (d) after carefully examining the text below.

The ☐ (A) ☐ of an individual will be high if that individual gives rise to many offspring which themselves are reproductively successful. Thus, individuals may have relatively high ☐ (A) ☐ due to their possession of genes which give advantages for better survivorship. As a result, the same species could occasionally have different heritable traits in different habitat. An example of this occurs in (i)populations of the fly *Drosophila melanogaster*. They are often found in association with wine production, where they are exposed to unusually high levels of ethanol. (ii)Such populations have an elevated ethanol detoxification ability because of the possession of higher activity levels of effective enzyme. This means *D. melanogaster* has their own (iii)niche in such places.

Modified from Instant Notes in Ecology (2012)

(a) Describe one word suitable to fill a blank (A).

(b) Concerning the underlined (i), population size fluctuates near the carrying capacity of the environment. First, describe definitions of two terms "population" and "carrying capacity" in ecology. Second, explain how such a fluctuation takes place in about five lines by referring to one likely mechanism.

(c) Concerning the underlined (ii), describe a mechanism behind by referring to both of two terms "gene" and "natural selection".

(d) Concerning the underlined (iii), explain why the realized niche of organisms is more spatially restricted compared to the fundamental niche for them in about five lines.

Ecology and Geography

Question 7   Provide answers to both questions (1) and (2).

(1) The following text describes desertification. Read the text and answer the questions (A) to (C).

In 1992 the United Nations Environmental Programme (UNEP) defined desertification as _____(a)_____. The most significant causes of desertification in recent decades appear to have been ____(b)____, inappropriate dryland cultivation, and ____(c)____.

Desertification results in the destruction of the environmental balance upon which the indigenous people have based their economies. As their land becomes degraded, they are no longer able to produce ____(d)____ and large scale migration occurs in an attempt to avoid ____(e)____. It is currently estimated that 20% of the world's population lives within areas threatened by desertification.
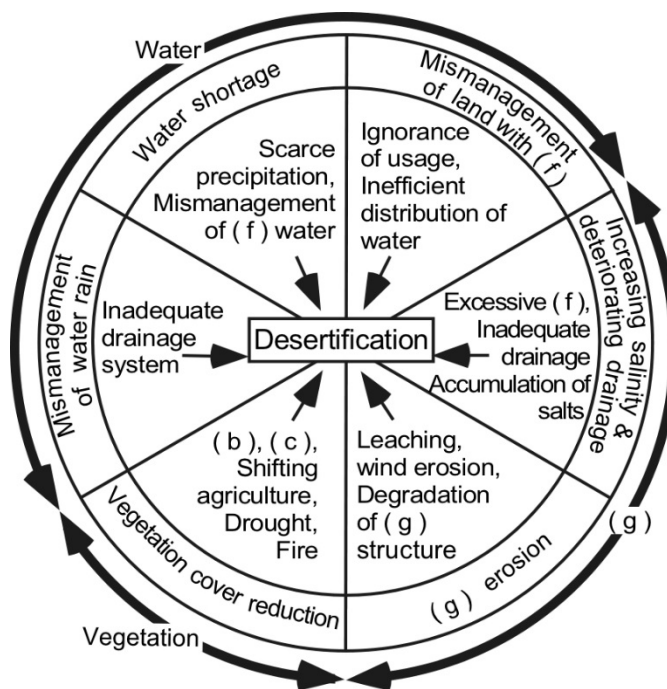

Figure 1: The causes of desertification

(Modified from "A Level Geography" (1996) Letts Educational)

(A) Describe (a) above in about two lines.
(B) Insert appropriate terms in (b) to (g) in the text and Figure 1.
(C) Pick up a region where desertification occurs on the planet and describe the underlying cause in about three lines.

(Continue to the following page)

(2) Figure 2 below is the map of Rishiri Island, northern Hokkaido, which was downloaded from the portal site of the Geospatial Information Authority of Japan. Answer the following questions (A) to (D).
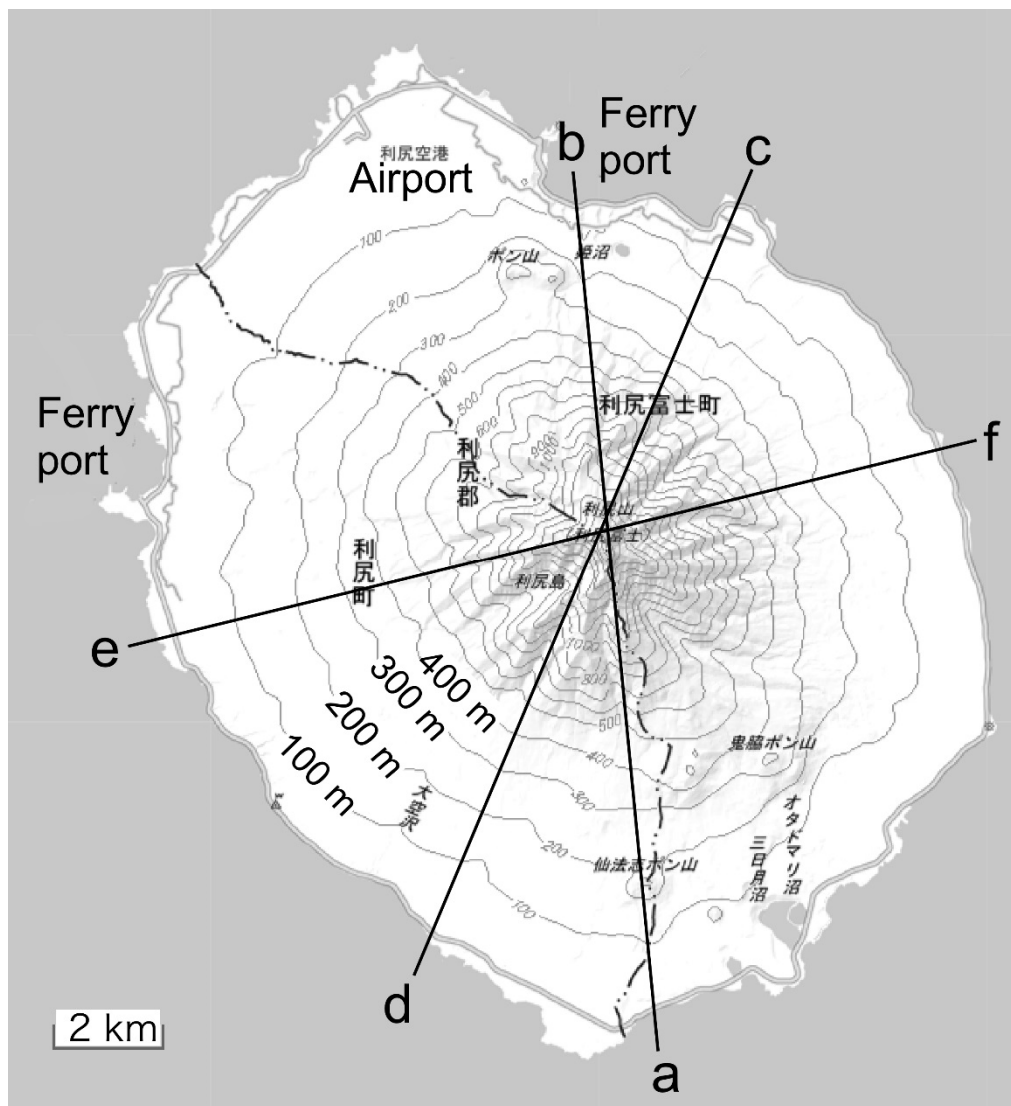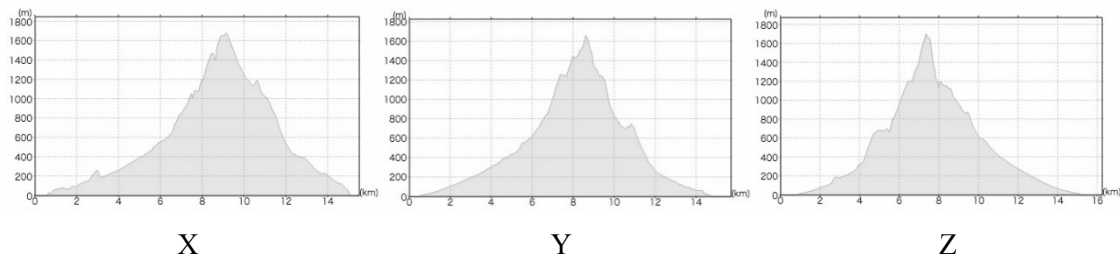

Figure 2: Rishiri Island, Hokkaido

(A) Match the following three landform profiles (X, Y, and Z) and the locations of profiles a-b, c-d, and e-f in the map.

X Y Z

(B) How was the landform of this island developed? Explain by giving the characteristics of the land surface morphology in about three lines.

(C) In this island, which drainage of the following (1) to (3) could be developed? Also, provide the reason in about five lines.

(1) radial drainage, (2) rectangular drainage, (3) trellis drainage

(D) Tourists can visit the island by ferry or small airplane. Discuss how you can increase the number of tourists visiting the island in about 15 lines. Refer to sustainability of the island to be influenced by the increase of the tourist number as well.

Environment and Society

Question 8   Read sentences below and answer the questions.

   Current transportation activity is mainly driven by internal combustion engines powered by (A), one of the fossil resources that emit high greenhouse gas (GHG). Motor vehicles are driven by internal combustion engine and their ownership increases with (B) per capita. In developed economies, motor vehicle ownership approaches five to eight cars for every ten inhabitants. In the developing world, non-motorized transport plays a significant role. (i)The demand for motorization of transport in the developing world is, however, expected to grow rapidly in the coming decades as incomes grow.

   (ii)The increase of the transportation that relies predominantly on the single fossil resource causes many problems as well as GHG emission. Solutions therefore need for (iii) comprehensive improvement of transportation problems as a whole, not just GHG emissions.

(1) Fill appropriate term into (A) and (B).

(2) Concerning to underline (i), when incomes grow, why do the demand and the use of the car increase? Considering the value of the user, explain in two to three lines.

(3) Concerning to underline (ii), list two problems other than GHG emissions.

(4) According to underline (iii), various innovative technologies and business were currently developed in order to solve transportation related problems. Give the examples of the technology and business, and explain 1) their effectiveness, 2) barriers that inhibit to become popular and 3) the way for the popularization. State logically in around 15 lines in total.

Environment and Society

Question 9   Answer the questions (1) through (4).

(1) Choose a protocol that was agreed in the United Nations Framework Convention on Climate Change from the following options.
   (a) Nagoya Protocol   (b) Kyoto Protocol   (c) Montreal Protocol
   (d) Cartagena Protocol   (e) Madrid Protocol

(2) Choose a case that contributed to the establishment of traditional approach of international laws to environmental problems.
   (a) The Trail Smelter Case   (b) Climategate   (c) Global warming
   (d) Minamata Disease   (e) Ocean acidification

(3) As two means for tackling global warming, explain about mitigation and adaptation, respectively, by using two terms each from options below in around four lines each.

   CO_2 capture and storage, sea level rise, agriculture, forestry, fisheries,
   tourism, renewable energy, fossil fuels, developing countries, advanced counties,
   global, local, geoengineering, temperature rise, nuclear power,
    ocean fertilization, energy conservation, infection, dike (bank), tree planting

   (Continue to the following page)

(4) Figure 1 shows CO_2 emissions of gasoline-powered, diesel-powered, hybrid, and fuel cell vehicles. Answer the following questions by referring to the figure.
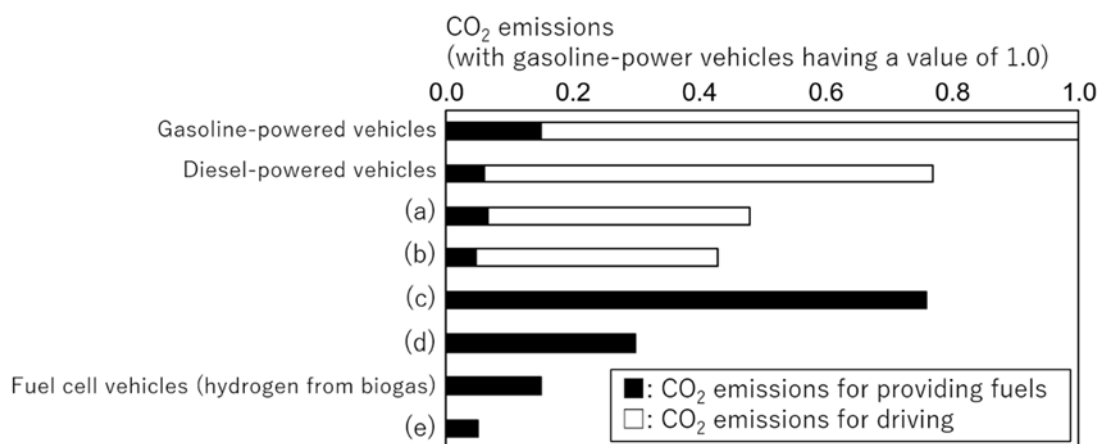

Figure 1. A life cycle assessment-type comparison of the CO_2 emissions of gasoline-powered vehicles with those of diesel-powered, hybrid, and fuel cell (differs according to feedstock and manufacturing method) vehicles (Source: Yoshida, F., Ikeda, M. (Eds.) (2009) "Sustainable Low-Carbon Society", partly modified).

(A) Choose each appropriate number that fits (a) through (e) in Figure 1, respectively, from the following options ① through ⑤.
   ① Fuel cell vehicles (hydrogen from natural gas)
   ② Hybrid diesel vehicles
   ③ Fuel cell vehicles (hydrogen from wind power)
   ④ Fuel cell vehicles (hydrogen from coal)
   ⑤ Hybrid gasoline vehicles

(B) Describe two characteristics of hydrogen energy in around three lines each.

(C)   Write the reason why benefits in installing fuel cells are relatively great in colder regions in around four lines.

(D) Write another benefit besides (B) and (C) above in utilizing hydrogen energy generated by waste biomass energy in around four lines.

14

Chemistry and Biology

Question 10 Answer the following questions (1) to (4). In the case of numerical calculations, describe the calculation processes and the reasons. If necessary, use the following values, $\ln 2 = 0.69$, $\ln 3 = 1.1$, $\ln 5 = 1.6$.

(1) The composition percentage of a mellitic acid, a kind of carboxylic acid, is C 42.12 %, H 1.77 %, and O 56.11 %. Calculate the empirical formula of mellitic acid.

(2) Describe the electronic configuration of F_2 in the ground state as in the following example. Besides, the average internuclear distances of F_2 and its ions, F_2^+ and F_2^-, follow the order of $F_2^- > F_2 > F_2^+$. Explain this order in the context of a bond order.

example:
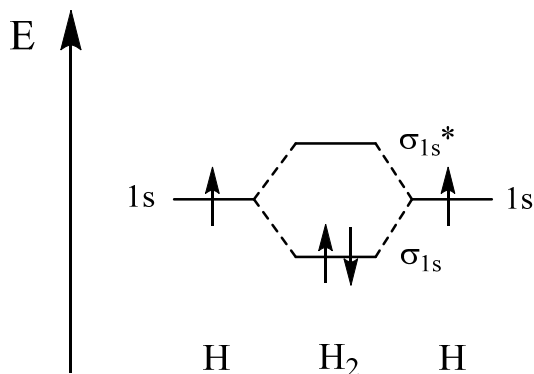
(3) Write structural formulas of the following compounds.
   (a) 4-ethyl-3-methylheptane   (b) 2-amino-1-butene
   (c) *m*-chloronitrobenzene   (d) cyclohexanol

(4) Consider the first-order reaction "A $\longrightarrow$ product".
   (a) Describe the reaction rate expression when the rate constant is k and the concentration of A is [A].
   (b) When the rate constant is 2.0×10^{-4} s^{-1} at a temperature, calculate how many minutes it takes to convert 60% of A to the product.
   (c) At another temperature, the rate constant was 2.0×10^{-2} s^{-1}. When the initial concentration of A is 0.10 mol L^{-1}, calculate the half-life of this reaction. Answer with two significant digits.

Chemistry and Biology

Question 11   Answer the following all questions (1) to (3). In the case of numerical calculations, describe the calculation processes and the reasons.

(1) Read the following sentences, and answer questions (A) to (D).

In 1956, Kornberg and his colleagues carried out that the soluble fractions of *Esherichia coli* cells were reacted with dATP, dTTP, dGTP and dCTP labeled with ^{32}P at all α phosphate groups, and after a certain period of time the reaction mixtures were treated with trichloroacetic acid. The precipitate including synthesized DNA was collected, and the radio activity was measured in the precipitate. This experiment is noteworthy as succeeding in the first DNA synthesis in cell-free system.

(A)   Currently ethanol is used under slightly acidic conditions to precipitate DNA. Answer the reason in about one line.

(B)   When an arbitrary one base was completely removed from the four bases used in the reaction, the radioactivity was not measured in the precipitation. Answer the reason within two lines.

(C)   The four bases were present, but the radiolabel was done only with dATP. In this case, answer whether radioactivity can be measured in the precipitation or not, and also answer the reason within two lines.

(D)   When ^{32}P was labeled at β or γ position of phosphate, answer whether radioactivity can be detected in the precipitation or not, and write the reason within two lines.

(2) Answer the following questions (A) and (B).

(A)   Sodium bicarbonate (NaHCO$_3$, Molecular weight: 84) is a chemical used for antacid tablets. One antacid tablet contains 0.84 g of sodium bicarbonate. Calculate how many antacid tablets are necessary to reduce excess stomach acid (0.2 M HCl) 200 mL to 0.1 M.

(B)   Above reaction will be confirmed in the laboratory. There was only concentrated HCl in the laboratory. Calculate how much mL of concentrated HCl is required to make 200 mL of 0.2 M HCl from the concentrated HCl. The concentration of concentrated HCl was 35.5%, and the specific gravity was 1.18. The molecular weight of HCl should be 36.5.

16

Chemistry and Biology

(3) The saturation curves using different substrates in catalysis of an enzyme are shown in the figure. Answer the questions (A) to (D) based on Michaelis–Menten's equation.
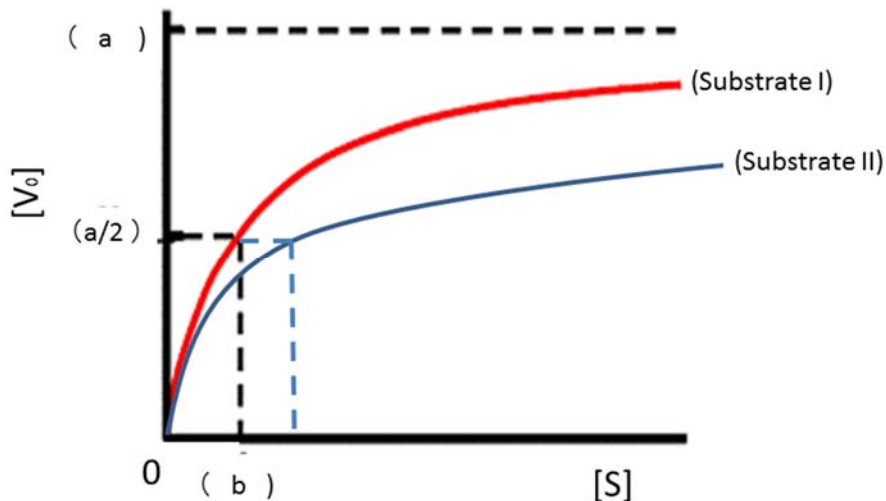
[S]: concentration of substrate

(A) Insert appropriate word(s) into (a) and (b) based on Michaelis–Menten's equation.

(B) Which substrate has higher affinity to the enzyme due to the difference between (b) of substrates I and II? Describe the answer and the reason within three lines.

(C) In the case of allosteric enzymes, explain how the curve shown in the figure changes and the reasons within two lines.

(D) Explain the mode of inhibitions of the enzyme; (i) competition inhibition, (ii) noncompetitive inhibition and (iii) uncompetitive inhibition in about two to three lines each.