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

平成 **25** 年度大学院修士課程入学試験問題（秋季入試）

平成 **24** 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**]**

- **Environmental science is a compulsory subject, and all 3 questions must be answered.**
- **Two questions will be set in each of the 4 specific subject areas of (1) mathematics and physics, (2) ecology and geography, (3) environment and society, and (4) chemistry and biology. Candidate shall answer 1 question among 8 questions.**
- **The allocation of total 3 questions of Environmental science and 1 question of specific subject areas is equivalent in score.**
- **Use one answer sheet for each question.**
- **Specify the question number on each answer sheet.**

August 27, 2012

Environmental Science（Compulsory)

Question 1 Answer the following questions by referring to the text and the table below from "Annual Report on the Environment, the Sound Material-Cycle Society and the Biodiversity in Japan 2011".

Biodiversity regulates drastic environmental changes and keeps the environment in a good status. This function is referred to as biodiversity's (A) services. The well-known example is the (B) function of forests. Here we will take a look at the example of the Bekanbeushi River Basin.

The Bekanbeushi River Basin consists of planted forest, natural forest and wetlands. The ratio of area of agricultural land is no more than 7.6 percents. Meanwhile, most part of the Obetsu River Basin, which is a branch river of the Bekanbeushi River, consists of agricultural land. The ratio of agricultural land is two-thirds of the river basin.

Table Amounts of Rainwater River Flows in Obetsu River and Bekanbeushi River

	Obetsu River	Bekanbeushi River
Area of river basin	38.68km^2	378.97km^2
Ratio of agricultural land	65.7%	7.6%
Total amount of rain in river basin	2,530,000t	24,830,000t
Amount of flow within 24 hours	23.5%	3.2%
Amount of flow within 48 hours	53.4%	8.2%
Amount of flow within 72 hours	66.0%	12.8%

Source: Study of Associations among Forests, Countryside, and the Sea, edited by Field Science Education and Research Center, Kyoto University, Chief Editor Yo Yamashita

(1) Describe the difference of the runoff (river flows) characteristics and the cause for the difference between the Obetsu and Bekanbeushi River Basins in about 7 lines.

(2) Select appropriate terms in (A) and (B) from the following terms.
Water purification, Water regulation, Regulating, Harmonization, Symbiosis

(3) List two more ecosystem services besides (A).

Environmental Science (Compulsory)

Question 2 Read the following and answer the questions below the text.

From the time that agriculture began until the present, we had a serious problem concerning how to obtain the nutrient salts necessary for fertilization. The three major elements necessary for growing plants are (A) , (B) and (C). (B) is an element that is found in greater amounts in land areas than in the sea. (A) is an element that is circulated through the air and soil by bacteria that can fix (A) from the air to the ground. However, (C) is abundant in the sea but scarce in land areas, and natural cycle systems for circulating from ocean to land were limited.

Chile and Peru have large amounts of mineral ore derived from bird excrement called "guano" that sea birds such as Cormorant built up over the past several thousand years. Since the era of the Inca Empire, "guano" has been used as precious (C) and (A) fertilizer. It is believed that on Chincha Island, which is one of the islands that has guano, there were accumulation derived from bird excrement that exceeded 30m in thickness. From the 19th century to the 20th century, countries mainly in Europe imported this mineral ore as a resource necessary for fertilizer. It contributed greatly to the increase of food production in the European region at that time and was treated as important mineral resource for the region.

In Japan as well, it was a known wisdom from long ago to use the excrement of water birds in solving problems related to a shortage of (C).

The Great Cormorant is a fish-eating water bird that inhabits all of Japan. It dives into the water to catch fish across a wide range of water areas from ocean to brackish water in coastal regions and in freshwater in inland regions. It is also known that they cause enormous damage to inland fishery because of the greedy appetite. In order to raise their chicks, Great Cormorants build nests in the tree crowns of forests near waterfronts, and in recent years in Japan they have formed a giant colony of tens of thousands of birds on Chikubu Island in Shiga Prefecture.

Amounts of excrement of Great Cormorants is so large that it causes large negative impact on vegetation and trees around the colony. On the other hand, since long ago the excrement has been utilized as very valuable in the form of (D) for agriculture.

(1) Select a word for (A), (B) and (C) from words below.
Nitrogen, Silicon, Copper, Phosphorus, Potassium, Chlorine, Oxygen

(2) Answer one animal name transporting nutrients from sea to land.

(3) Answer the appropriate words in (D).

(4) Describe the other example for symbiotic relation between human and animals in natural material cycles.

Environmental Science (Compulsory)

Question 3 Answer the following questions.

（1） Describe the transboundary air pollution which caused a problem in North America and Europe in the 1960s and 1970s in about three lines.

（2） Describe the positive and negative impacts by utilizing biomass resources in about five lines.

Mathematics and Physics

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

(1) Let $\mathbf{R}(\theta) = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix}$, then

(a) Calculate an inverse matrix of $\mathbf{R}(\theta)$.

(b) Prove that $\mathbf{R}(\theta)$ is an orthogonal matrix.

(c) Prove that the lengths of $\mathbf{a}$ and $\mathbf{Ra}$ are the same when $\mathbf{a} = \begin{pmatrix} a_1 \\ a_2 \end{pmatrix}$ is an arbitrary two-dimensional vector.

(d) Prove $\theta = \theta'$ by obtaining an interior product, $c = (\mathbf{a}, \mathbf{Ra})$, when θ' is an angle between $\mathbf{a}$ and $\mathbf{Ra}$.

(2) The dynamics of radioactive decay in an atomic nucleus can be described by the following differential equations:

$$\begin{cases} \dfrac{dA}{dt} = -k_1 A \\ \dfrac{dB}{dt} = k_1 A - k_2 B \\ \dfrac{dC}{dt} = k_2 B \end{cases} \quad \rightarrow \quad \frac{d\mathbf{x}(t)}{dt} = Q\mathbf{x},$$

where $\mathbf{x}(t) = \begin{pmatrix} A(t) \\ B(t) \\ C(t) \end{pmatrix}$ and $\mathbf{Q} = \begin{pmatrix} -k_1 & 0 & 0 \\ k_1 & -k_2 & 0 \\ 0 & k_2 & 0 \end{pmatrix}$.

(a) Prove that $\mathbf{x}(t) = \sum_{i=1}^{3} c_i \mathbf{u}_i e^{\lambda_i t}$ is the solution of the above differential equations, where λ_i and $\mathbf{u}_i$ represent the eigenvalues and eigenvectors of a matrix $\mathbf{Q}$.

(b) Solve the differential equations when $k_1 = 2,\ k_2 = 1$ and the initial condition is $A(0) = 2,\ B(0) = C(0) = 0$.

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(3) Human is a diploid organism and has two alleles at each locus on each chromosome, which are inherited from father and mother respectively. Suppose that there are two alleles, A and a, at a focal locus and denote genotypes AA, Aa and aa as 1, 2 and 3, respectively. Furthermore, let d_{ik} be the conditional probability that an offspring is of genotype *k* when the father is of genotype *i*.

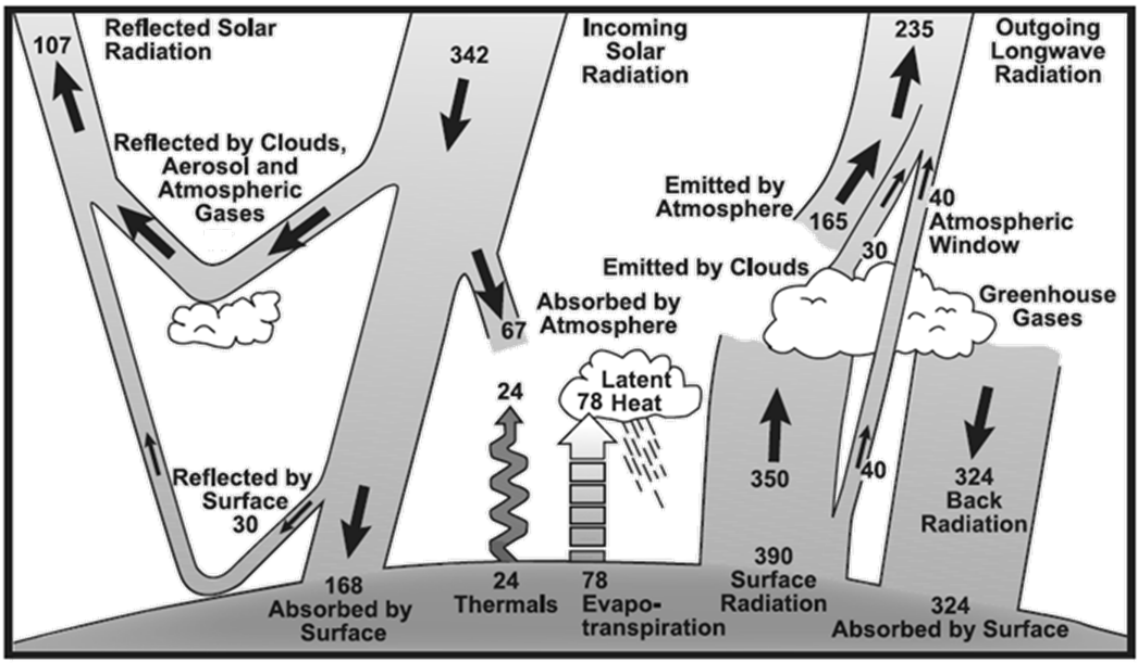
(a) Assume that the father is of genotype 1 and that $x_1,\ x_2,\ x_3$ are the probabilities that the mother is of genotype 1, 2, 3, respectively. Then, the following probabilities can be calculated as $d_{11} = x_1 \times 1 + x_2 \times 0.5 + x_3 \times 0$, $d_{12} = x_1 \times 0 + x_2 \times 0.5 + x_3 \times 1$, and $d_{13} = x_1 \times 0 + x_2 \times 0 + x_3 \times 0$. Calculate the rest of conditional probabilities, $d_{2k},\ d_{3k}(k = 1,2,3)$, where $x_1 + x_2 + x_3 = 1$ and each allele is inherited with the probability of 0.5.

(b) Let c_{ik} be the conditional probability that the grandchild is of genotype *k* when the grandfather is of genotype *i,* and it is given by $c_{ik} = d_{i1}d_{1k} + d_{i2}d_{2k} + d_{i3}d_{3k}$ .When $\mathbf{C}$ and $\mathbf{D}$ are 3 by 3 matrices with elements of c_{ik} and d_{ik} respectively, show $\mathbf{C} = \mathbf{D}^2$. Obtain $\mathbf{C}$ using p and *q*. Note that $x_1 = p^2,\ x_2 = 2pq,\ x_3 = q^2\ (p + q = 1)$.

(c) Let b_{ik} be the conditional probability that the descendant of the *n*th generation is of genotype *k* when a specified ancestor is of genotype *i.* Obtain b_{ik} using p and *q*.

Mathematics and Physics

Question 2 The following figure shows the estimates of Earth's annual and global mean energy balance. Answer following questions.



After IPCC(2007)

(1) Write appropriate words to fill boxes (A) to (I).

The values in the figure represent the amount of radiation whose unit is (A). The amount of solar energy reaching top of Earth's atmosphere is about 342. The amount of solar radiation reflected by clouds, aerosols, and atmospheric gases is (B). The planetary albedo is approximately (C) if clouds, aerosols, and atmospheric gases are regarded as a part of the Earth. The solar radiation reflected by the Earth's surface becomes (D) as surface albedo decreases. The Earth radiates primarily in the (E) part of the spectrum. Since some of atmospheric gases, such as (F) and (G), well absorb the (E) radiation, much of the radiation emitted by the land and ocean is absorbed by the atmosphere, including clouds, and reradiated back to Earth. This is called the (H) effect. Consequently, mean surface temperature is (I) than that of the Earth without atmosphere.

(2) Explain the following words in about two lines for each.

(i) Latent heat

(ii) Evapotranspiration

(iii) Aerosol

(iv) Long wave radiation

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(3) The radiation budget at top of Earth's atmosphere is described as $342-107-235=0$, when incoming radiation is expressed with positive sign. Write down the radiation budget at the Earth's surface as the sum of components.

(4) Explain the physical characteristics of the "surface radiation" in about four lines.

(5) Explain the roles of clouds on the Earth's radiation balance in about five lines.

Ecology and Geography

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

(1) Answer the following (A) and (B).

(A) Describe each of the five ecological words (a) to (e).

(a) fitness

(b) field capacity

(c) temperature coefficient (Q_{10})

(d) rhizosphere

(e) allelopathy

(B) Dr. Gause observed the fluctuations of numbers of individuals on two *Paramecium* species in an aquarium as shown in the figure below. A single feed was supplied into the aquarium sufficiently during the experiment. Answer the questions (a) to (c), based on the figure.

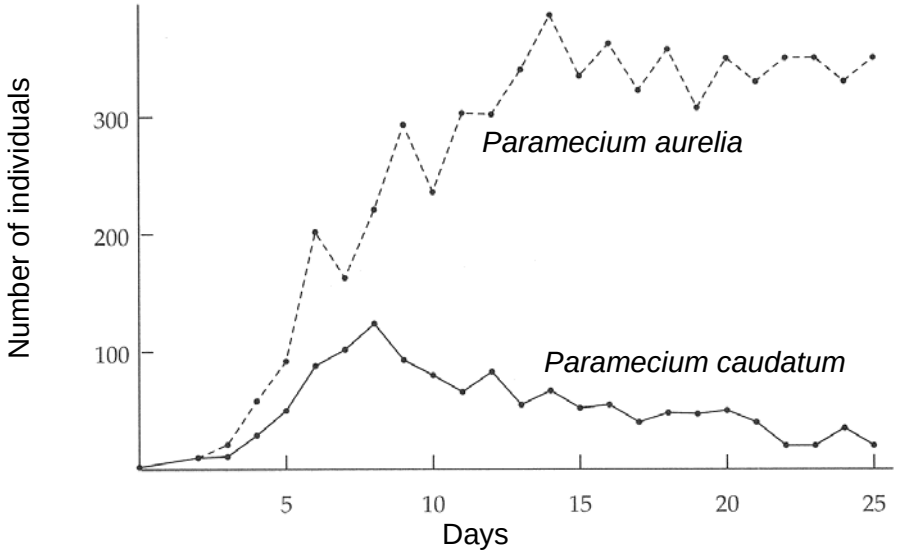

Fig 1. Daily fluctuations of numbers of individuals on two Paramecium species, *P. aurelia* and *P. caudatum* (Gause 1934).

(a) The two species increased the numbers of individuals from 5th to 8th days. Explain why the increases occurred.

(b) *P. caudatum* decreased the number of individuals after 8th day, and finally became extinct. Explain 'Gause's law' based on these results.

(c) There have been few reports that the patterns of population dynamics in the nature are interpreted by Gause's law. Explain the reason(s).

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

(A) Provide ecological definitions for each of the words (a) to (e) within 3 lines.

(a) interior species

(b) edge species

(c) population

(d) metapopulation

(e) community

(B) A species-area curve between lake size and species richness of aquatic plants for oxbow lakes along a large river is provided below. Each plot denotes individual lake, with the solid line indicating a statistically significant regression line. Examine the figure and answer the questions (a) to (c).

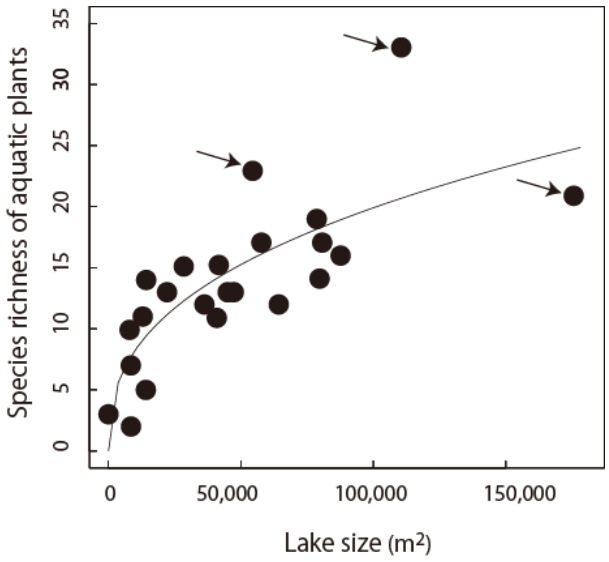


Fig 2. A relationship between lake size and species richness of aquatic plants.

(a) Provide explanations for the ecological processes behind such a relationship within 5 lines. You may refer to island biogeography theory or metapopulation theory.

(b) Provide definitions for alpha diversity, beta diversity, and gamma diversity, respectively, and explain which diversity types the species richness on the vertical axis of the figure corresponds within 7 lines.

(c) Consider the hypothetical situation that some of those oxbow lakes were lost as a result of land development. In such a case, one may prioritize conservation of lakes with highest species richness (e.g. those accompanied by an arrow in the figure). Describe a case in which such a conservation approach is not effective when aiming to conserve regional-scale species diversity within 7 lines.

Ecology and Geography

Question 2 Answer the following all questions, (1) to (3).

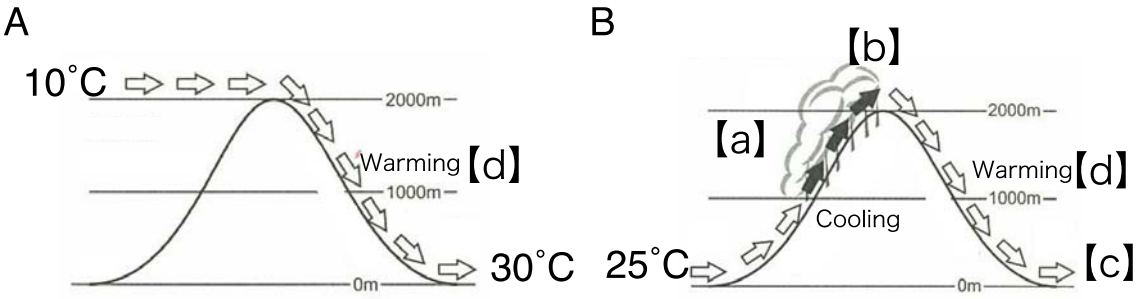
(1) Answer the following questions.

(A) The following is an incomplete sentence including six blanks marked as (i) to (vi) which should be filled with a term or a symbol given beneath the sentence. Choose one term or symbol that would best keep the meaning of the sentence.

A (i) wind is a type of dry down-slope wind that occurs in the downwind side of a mountain range. It is a rain shadow wind that is resulted from the subsequent adiabatic warming of air that has dropped most of its (ii) on the windward slope. As a consequence of the different (iii) lapse rates of moist air (Figure (iv)) and dry air (Figure (v)), the air on the leeward slope becomes (vi) than equivalent elevations on the windward slope.

A, B, moisture, cloud, rain, snow, sun, warmer, cooler, kinematic, mountain, melting point, dew points, lapse rates, adiabatic, metabolic, anabatic, katabatic, foehn

(B) Obtain the numbers for (a) to (d) in Figure B.
The unit of (a) to (c) is ˚C. The unit of (d) is ˚C/100 m. (d) is dry (iii) lapse rate common among A and B (white arrows). Use 0.5˚C/100 m for moist (iii) lapse rate (black arrows). (a) = 1000 m a.s.l., (b) = 2000 m a.s.l., (c) = 0 m a.s.l.



Figure

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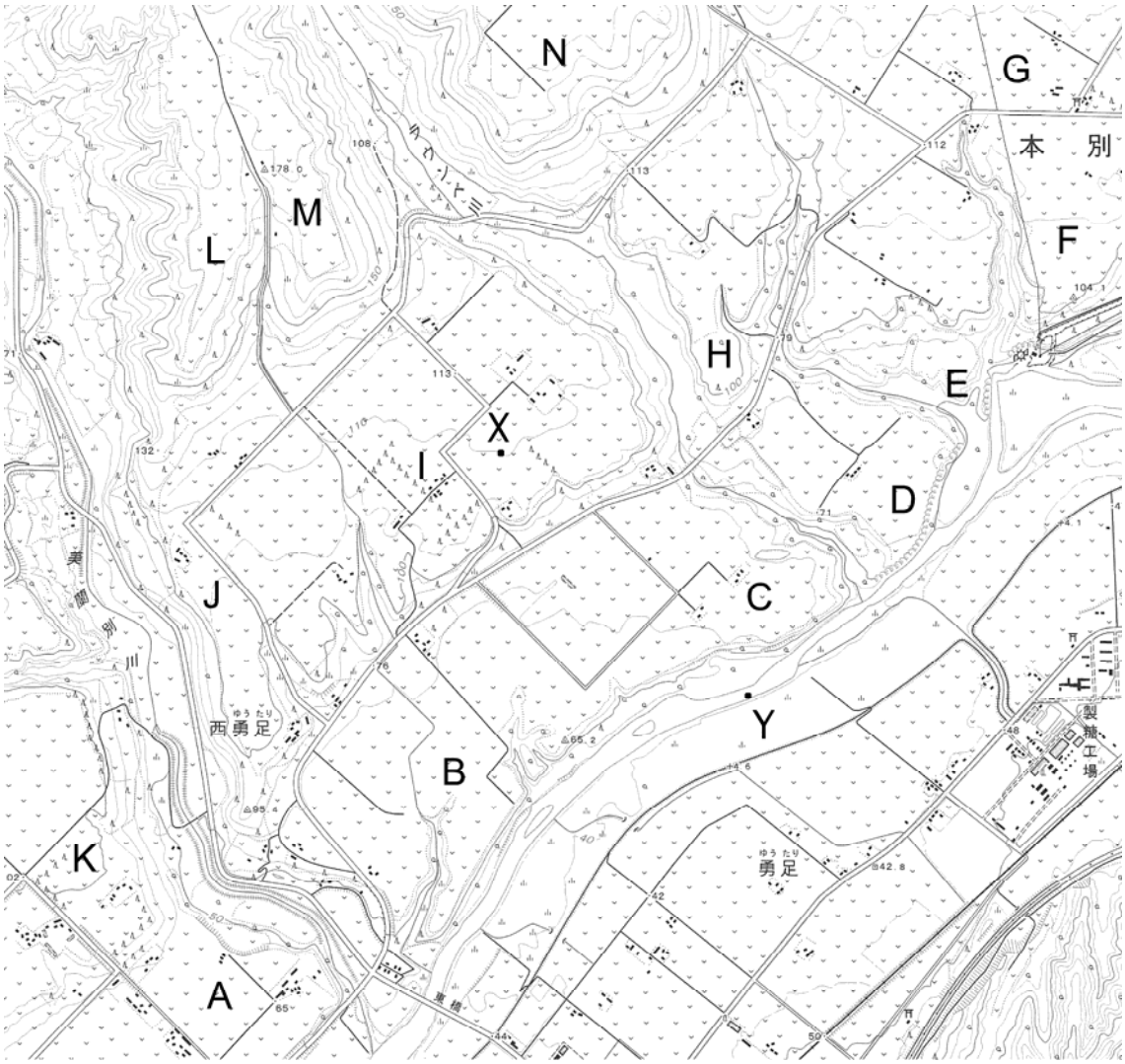
(2) Use the topographic map below when responding to this question. The topographic map, originally 1:25,000 in scale, is reduced by 20% by a photocopy machine. Answer (A) to (E).



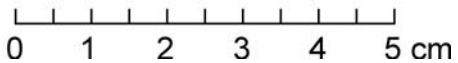
(A) Calculate approximate horizontal length between X and Y.

(B) Sites A to N show flat to relatively flat land surface. Provide a geomorphological term to describe such a land surface.

(C) Classify the land surfaces of sites A to N.

(D) To evaluate the classification above, what kind of field surveys do you propose?

(E) Discuss what kind of land use would be suitable on the flat land surfaces.



You may use the left scale for your reference.

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(3) Answer the following questions regarding volcanism.

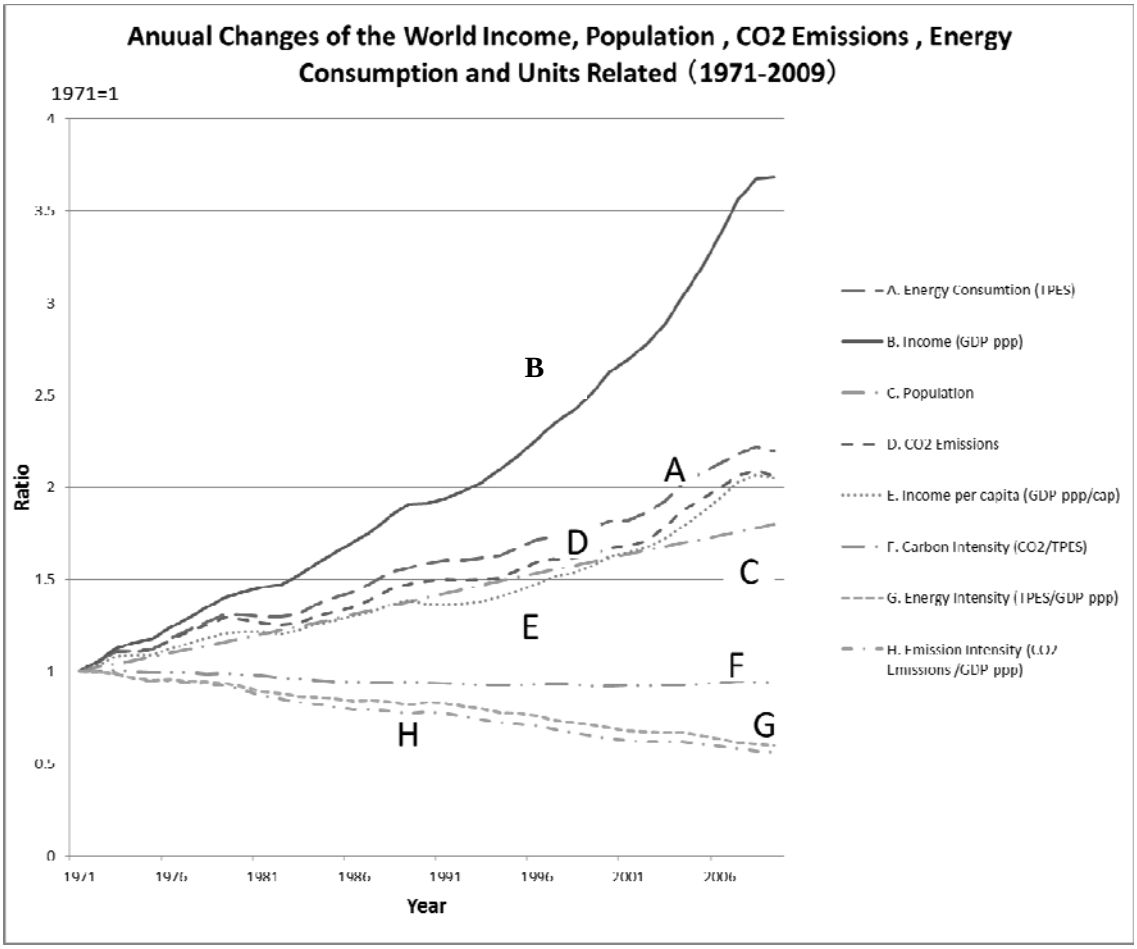
(A) What is flood basalt? Also, provide at least one example of it.

(B) Define and contrast the following: lava flow and pyroclastic flow.

(C) Name the major types of volcanic hazards.

Environment and Society

Question 1 Refer to the following figure and answer the questions below.



Note 1: Vertical line shows the ratio to 1971 value (1971=1)

Note 2: GDP-ppp: GDP calculated using purchasing power parities (GDP of countries were converted to price levels of 2000, then converted to US Dollars by using the purchasing power parities and accumulated)

Note 3: TPES: Total Primary Energy Supply

Source: Summary for Policymakers, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007 (modified by using data of CO_2 Emissions from Fuel Combustion Highlights (2011 Edition), IEA 2011)

(1) Explain the changes of term values, i.e. Population (C), Income per capita (E), Energy intensity (G) and CO_2 (carbon dioxide) emissions (D) in the period of the figure (1971~2009) in about five lines.

(2) Write down an equation which shows the relation between CO_2 emissions (D) and Population (C), Income per capita (E) and appropriate basic units ((F) through (H)).

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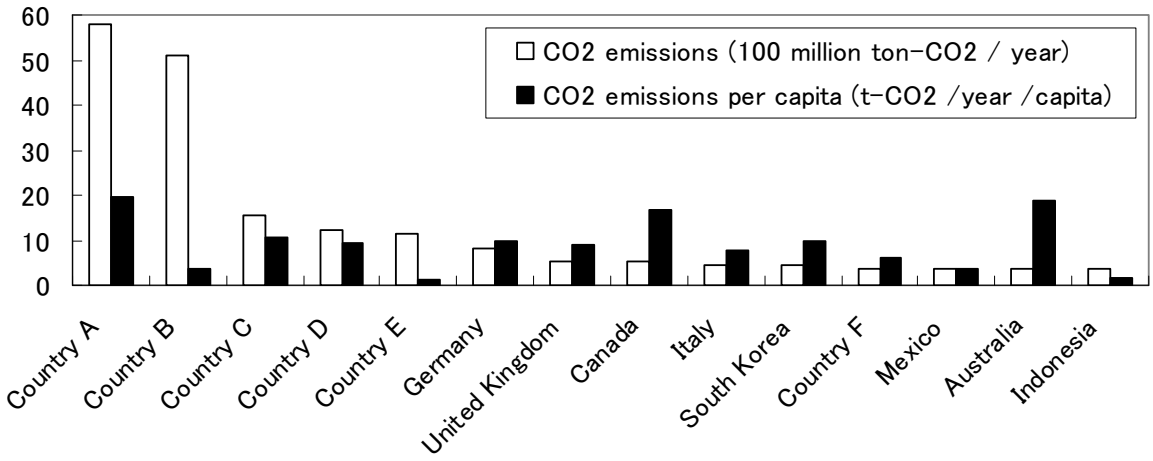
(3) Explain realistic procedures to reduce CO_2 emissions (D), referring to the equation obtained in (2) in about five lines.

(4) In addition to mitigation measures of greenhouse gases mentioned above, another sort of actions are considered important as climate change measures. Describe the name of the measures, outline and reasons of necessity of the measures in about five lines.

(5) Mitigation measures against climate change are one of the important approaches to achieve a sustainable society. While they have possible positive effects on aspects of sustainability (synergy effects), they may also have negative effects (trade-offs). Show example(s) of both synergy effects and trade-offs of mitigation measures in about five lines.

Environment and Society

Question 2 The following figure shows CO_2 (carbon dioxide) emissions by 14 major countries and CO_2 emissions by the countries per capita in Year 2005. Answer the following questions. Note that Countries A through F include: China, France, India, Japan, Russia, and United States of America.



(Modified from International Energy Agency Statistics)

（1） Among the 14 countries, Country A, Country B, Country E, South Korea, Mexico, and Indonesia do not have numerical target for reducing CO_2 emissions by country governed by an international framework that is important for combating global warming and has the force of law. Write the name of the international framework.

（2） In Year 2010, Country B was considered to have greater CO_2 emissions than Country A had. Write the name of Countries A and B. Also, write a procedure that was defined by the international framework mentioned in (1) and is considered to be effective to reduce CO_2 emissions by Country B in about five lines.

（3） Describe differences in CO_2 emissions per capita among the countries and the possible reasons that cause the differences in about five lines.

（4） CO_2 emissions per capita by Country F are relatively smaller than those by Germany, United Kingdom and Italy. Describe the possible reasons in about five lines.

（5） Describe scientific reasons why we need to reduce global CO_2 emissions by half in future than present in about five lines. Also, explain about differences in preferable procedures in applying for Country A and Country E, for example, considering a principle called “common but differentiated responsibility”, in about five lines.

Chemistry and Biology

Question 1 Answer the following questions **(A)** to **(C).**

(A) Answer the questions (a) to (e) about the chemical equilibrium of ideal gas mixture shown in reaction (1).

$$\frac{1}{2}\,O_2 + \frac{1}{2}\,N_2 \leftrightarrows NO \qquad (1)$$

Write in calculated values with two significant digits and don't omit the calculation process and the reasons in the description.

(a) Calculate the standard entropy change, ΔS^o, for the formation of nitrogen monoxide at 298 K under atmospheric pressure (1 bar; 1.0×10^5 Pa), using the following standard entropy values: 205.2, 191.6, and 210.4 $J\cdot K^{-1}mol^{-1}$ for molecular oxygen, molecular nitrogen, and nitrogen monoxide, respectively.

(b) The standard enthalpy of formation, ΔH^o, for nitrogen monoxide is 90.28 kJ mol^{-1}. Calculate the standard Gibbs free energy, ΔG^o, of formation at 298 K under atmospheric pressure (1 bar; 1.0×10^5 Pa).

(c) Write down how the pressure-equilibrium constant, *Kp*, is defined in mathematical form according to the reaction (1), when the partial pressures of molecular oxygen, molecular nitrogen, and nitrogen monoxide are P_{O_2}, P_{N_2}, and P_{NO}, respectively, in equilibrium system at T K. Assuming that the influences of formation reaction of nitrogen oxides other than nitrogen monoxide are negligible.

(d) Calculate the ln*Kp* of the reaction (1) at 298 K and atmospheric pressure (1 bar; 1.0×10^5 Pa). Next, calculate the ln*Kp* of the reaction (1) at 4000 K and atmospheric pressure (1 bar; 1.0×10^5 Pa). Assume that ΔH is independent of temperature in the range given. Take general gas constant, $R = 8.31\ J\cdot K^{-1}\cdot mol^{-1}$, on the answer of question (c).

(e) Main sources of nitrogen monoxide in urban atmosphere are automobile emission and combustor gas. Also, wildfire and thunder are natural sources of nitrogen monoxide in the atmosphere. Explain why these things and phenomena can be the sources of nitrogen monoxide in the atmosphere on the answer of question (d) in two or three lines.

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(B) Barium ion has strong toxicity and is absorbed together with water through the cell of stomach walls. Therefore, barium is specified as the toxic substance of fatal dose 1 g, and needs to prevent mixing in food and drink. In the case that someone swallows barium chloride accidentally in a chemical laboratory, sodium sulfate solution is to be prescribed for the patient as an antidote, by mouth or using a gastrolavage tube. Why does this solution become an effective antidote for toxic barium ion? Use your knowledge of Le Chatelier's principle to explain the reason in three to five lines, with showing the associated ionic equation. Incidentally, *K*sp value of barium sulfate is around 1×10^{-10}.

(C) The equilibrium shown in the reaction (2) is formed between ammonia and the ammonium ion:

$$NH_3 + H^+ \leftrightarrows NH_4^+ \qquad (2)$$

There is a cell membrane between blood in capillary and urine in renal tubules that carry urine to the bladder in human body. Answer the questions (a) to (c).

(a) The normal pH of human blood and the urine in the kidney tubules are 7.4 and between 5.5 and 6.5, respectively. Explain in which condition, in the blood or in the urine, the equilibrium reaction (2) is driven to the left. Answer the reason in two lines.

(b) Ammonia can pass through cell membranes, but ammonium ion cannot. Explain the migration of ammonia through the cell membranes in one or two lines.

(c) Explain how ammonia is removed from the blood into the kidney tubules based on your answer of question (a) and (b). Answer it in several lines.

Chemistry and Biology

Question 2 Answer the following questions,(1) to (3).

(1) Explain meanings of the following terms from (A) to (F) within 3 lines.

(A) Hormones
(B) Signal transduction in cells
(C) Citric acid cycle
(D) Central dogma of molecular biology
(E) Intron in gene
(F) RNA splicing

(2) Answer the questions from (A) to (E) after reading the following sentences.

Proteins are important biological macromolecules present in all organisms, and polymers of amino acids. Each protein polymer –also known as a (a) – consists of a sequence formed from 20 possible amino acids. For chains under 40 residues the term peptide is frequently used instead of protein. These amino acid sequences are called (b) of the protein. The sequences in the proteins contain α-helix and (c) structure. To be able to perform their biological function, proteins fold into one or more specific spatial conformations, driven by a number of non-covalent interactions such as (i)hydrogen bonding, ionic interactions, van der Waals forces, and hydrophobic packing. To understand the functions of proteins at a molecular level, it is often necessary to determine their three-dimensional structure using X-ray crystallography and (d).

The number of amino acid residues may contribute that the protein expresses their important biochemical function. The size of protein in itself ranges from around 40 to several thousand residues residues. (ii)Very large aggregates can be formed from protein subunits: for example, many thousand G-actin molecules assemble into a microfilament (F-actin). A protein may undergo reversible structural changes in performing its biological function.

(A) Fill adequate word(s) in the blanks from (a) to (d).
(B) In the part of underline (i), explain each meaning of 4 terms within around 3 lines.
(C) Answer what the structure shown in part of underline (ii) is called. In addition, give two examples of proteins consisting of two or more than two subunits.
(D) Answer three amino acids participating in glycosylation in proteins.
(E) Describe a cause of protein denature, and explain the reason of denaturing within around 2 lines.

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(3) Answer the following question.

In order to evaluate an intracellular peroxidative state, 5,5'-dithiobis (2-nitro benzoic acid)(DTNB) was used to measure contents of free SH group in cells. When DTNB was used, the molar extinction coefficient in 412 nm to measure free SH group contents was 13,600 (It means that absorbance of 1M SH group is 13,600). Reaction mixture was consisting of 50 μL of cell-homogenized supernatant (2.5 mg/mL of protein concentration) and 50 μL of 20 mM phosphoric acid buffer, pH 7.2, including 2.5 mM DTNB. The mixture was reacted at room temperature for one hour and the absorbance of it was measured. The obtained result was 1.260. Calculate the contents of free SH group per 1 mg of protein in the cells. In addition, should be remained all of the process of the calculating formulae in the answer sheet.