

2023 年度日本政府(文部科学省)奨学金留学生選考試験

QUALIFYING EXAMINATION FOR APPLICANTS FOR THE JAPANESE  
GOVERNMENT (MEXT) SCHOLARSHIP 2023

学科試験 問題

EXAMINATION QUESTIONS

(学部留学生 (理科系専攻) )

UNDERGRADUATE STUDENTS

数 学 (B)

MATHEMATICS (B)

注意 ☆試験時間は 60 分。

PLEASE NOTE: THE TEST PERIOD IS 60 MINUTES.



Nationality		No.		Marks	
Name	(Please print full name, underlining family name)				

Answer the following questions and fill in your responses in the corresponding boxes on the answer sheet.

1. Fill in the blanks with your answers.

- (1) The solution of the equation  $\log_{81} X = \frac{5}{8}$  is  $X = \boxed{\phantom{000}}$ .
- (2) Let  $O$  be the center of the circumscribed circle of a triangle  $ABC$ . If  $\angle BAC = \frac{11}{12}\pi$  and  $AO = 3$ , then the area of triangle  $BOC$  is  $\boxed{\phantom{000}}$ .
- (3) Consider a rectangle with vertices marked as  $A, B, C$  and  $D$  consecutively in the counterclockwise direction. Let  $P$  be a point between  $B$  and  $C$ , and  $Q$  be the intersection of  $AC$  and  $DP$ . If  $AB = 1$ ,  $\angle DAC = \frac{\pi}{6}$  and  $\angle AQP = \frac{5}{12}\pi$ , then the length of  $AD$  is  $\boxed{\textcircled{1}}$  and that of  $PD$  is  $\boxed{\textcircled{2}}$ .
- (4) When the curve  $C$  defined by  $y = x^3 - 3x^2 + 1$  and the line  $l$  meet at points  $(3, 1)$  and  $(-1, -3)$ , the coordinates of the other intersection of  $C$  and  $l$  is  $\boxed{\phantom{000}}$ .
- (5) For a real number  $a$  with  $-\frac{3}{2} \leq a \leq \frac{3}{2}$ , the minimum value of  $\frac{1}{4 - a^3}$  is  $\boxed{\phantom{000}}$ .
- (6) Consider the vectors  $\vec{a} = (x, -4)$ ,  $\vec{b} = (6, x - 7)$ , and  $\vec{c} = (3, -5)$ . Vectors  $\vec{a}$  and  $\vec{b} + \vec{c}$  are parallel if  $x = \boxed{\textcircled{1}}$ . In this case, the vector  $\vec{d} = (3, \boxed{\textcircled{2}})$  is orthogonal to  $\vec{a}$ .

2. Please answer ③ and ④ with “positive” or “negative” and in ⑨, ⑩ and ⑪ with “increasing” or “decreasing”.

Consider the function  $f(x) = \frac{1}{3}x^3 - 2x^2 + 3x - \frac{4}{3}$ .

$f(x)$  can be factorized into

$$f(x) = \frac{1}{3}(x - \text{①})^2(x - \text{②}).$$

Hence  $f(x)$  is ③ if  $x < \text{①}$ , and ④ if  $x > \text{②}$ .

The derivative of  $f(x)$  is

$$f'(x) = x^2 - \text{⑤}x + \text{⑥},$$

and this can be factorized into

$$(x - \text{⑦})(x - \text{⑧}),$$

with ⑦ < ⑧.

Thus  $f(x)$  is ⑨ if  $x < \text{⑦}$ , ⑩ if  $\text{⑦} < x < \text{⑧}$ , and ⑪ if  $x > \text{⑧}$ .

3. A fair die is rolled three times. The die is a standard six-sided die with an equal probability of rolling each of the numbers 1–6. Let  $a$ ,  $b$ , and  $c$  denote the numbers we get on the first, second, and third roll, respectively. Put  $X = 100a + 10b + c$  and  $Y = 100c + 10b + a$ .

(1) The probability that  $a < b < c$  is .

(2) The minimum value of  $X$ , which is a multiple of 4, is ①. The probability that  $X$  is a multiple of 4 is ②.

(3) The probability that  $X = Y$  is ①, and that  $X = Y + 198$  is ②.

(4) The maximum value of  $X - Y$  is .

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(学部留学生)

UNDERGRADUATE STUDENTS

化 学

CHEMISTRY

**注意** ☆試験時間は **60 分**。

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(6) Which of the following reactions described in 1) to 4) is not accompanied by the generation of gas?

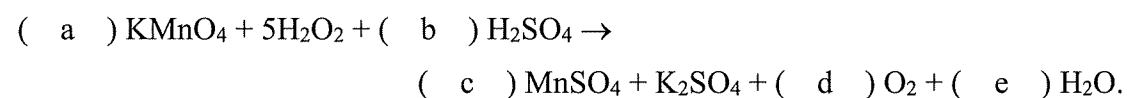
- 1) Adding concentrated nitric acid solution to iron.
- 2) Adding concentrated sulfuric acid solution to sodium chloride.
- 3) Adding sodium hydroxide aqueous solution to zinc.
- 3) Heating copper (II) oxide above 1000°C.

(7) Which of the following descriptions 1) to 4) is true for metallic crystals?

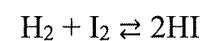
- 1) Most metallic crystals have low thermal conductivity.
- 2) Most metallic crystals are volatile.
- 3) The van der Waals interaction is predominant in a metallic bond.
- 4) Metallic crystals are ductile and malleable.

II Fill ( a ) to ( g ) in the following statements with the appropriate values. Answer the values to two significant figures for the calculation results of ( f ) and ( g ).

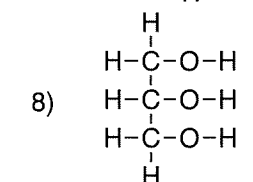
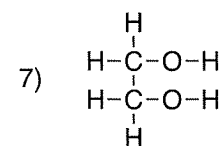
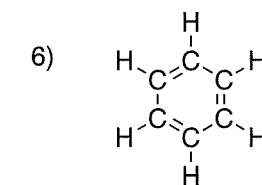
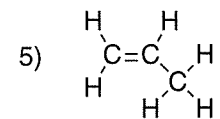
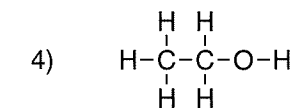
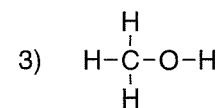
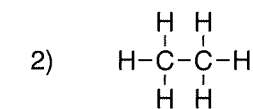
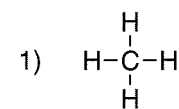
(1) The reaction of potassium permanganate with hydrogen peroxide in a sulfuric acid aqueous solution is written as follows:



(2) In a sealed vessel, 4.0 mol of hydrogen and 4.0 mol of iodine, both in a gaseous state, were kept at a constant temperature for long enough to reach an equilibrium according to the following reaction:



The hydrogen iodide formed by the reaction was also in a gaseous state. The equilibrium constant was 25 at the reaction temperature. In equilibrium, the amounts of hydrogen and hydrogen iodide were ( f ) mol and ( g ) mol, respectively.



(4) Ethyl acetate can be synthesized from acetic acid and ethanol using a concentrated sulfuric acid solution as catalyst. When 150 g of acetic acid and 460 g of ethanol were reacted, 132 g of ethyl acetate was obtained. What percentage of acetic acid was converted to ethyl acetate? Calculate the percentage to two significant figures.

(5) The addition of aqueous iron (III) chloride solution to an aromatic compound with a molecular weight of 94 resulted in a purple color reaction. Substitution reaction occurred when a sufficient amount of bromine water was added to this compound. Select the suitable value of the molecular weight of the obtained compound among options 1) to 5).

- 1) 173   2) 252   3) 331   4) 411   5) 490

(6) Select one incorrect description about fats and oils and soap among options 1) to 5).

- 1) When cooking oil was added to soapy water and stirred vigorously, it was emulsified.
- 2) When soap was dissolved in water, the resulting aqueous solution showed weak acidity.
- 3) When an aqueous solution of calcium chloride was added to soapy water, precipitation occurred.
- 4) When hydrogen was added in the presence of catalysts to fats and oils that were liquid at room

V Answer the following questions about organic compounds. Use the following values if necessary: the atomic weights of C, O, H, and Br are 12, 16, 1.0, and 80, respectively.

(1) There is a compound with chemical formula  $C_8H_nO_2$ . When 51 mg of the compound was combusted completely with dry oxygen, 27 mg of  $H_2O$  was generated. What is the number  $n$  of hydrogen in the chemical formula?

(2) Hydrolysis of an ester having a molecular formula of  $C_5H_{10}O_2$  gave a carboxylic acid with a reducing ability and an alcohol. Select the molecular formula of the alcohol obtained here from 1) - 5). Next, how many structural isomers does the alcohol have?

1)  $CH_3OH$  2)  $C_2H_5OH$  3)  $C_3H_7OH$  4)  $C_4H_9OH$  5)  $C_5H_{11}OH$

(3) Select the most appropriate chemical structure of the organic compound applicable to the following compounds **A**, **B**, **C**, and **D** among the options 1) to 8). The same one may be selected repeatedly.

**A** is a substance produced by the fermentation of starch and is contained in alcoholic beverages.

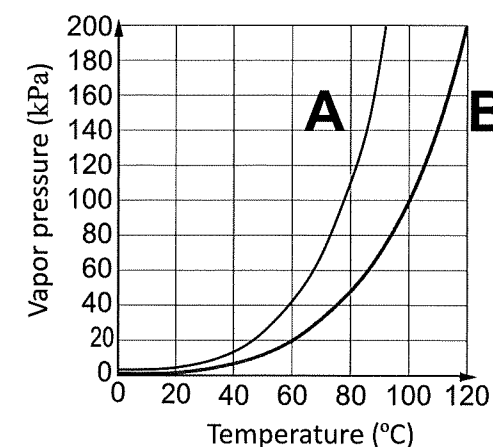
The polymer produced by the addition polymerization of **B** is used for tableware and plastic films.

**C** gives ethylene when heated at 160-170 °C in concentrated sulfuric acid solution.

**D** is an alcohol produced from carbon monoxide and hydrogen as raw materials in the presence of a catalyst.

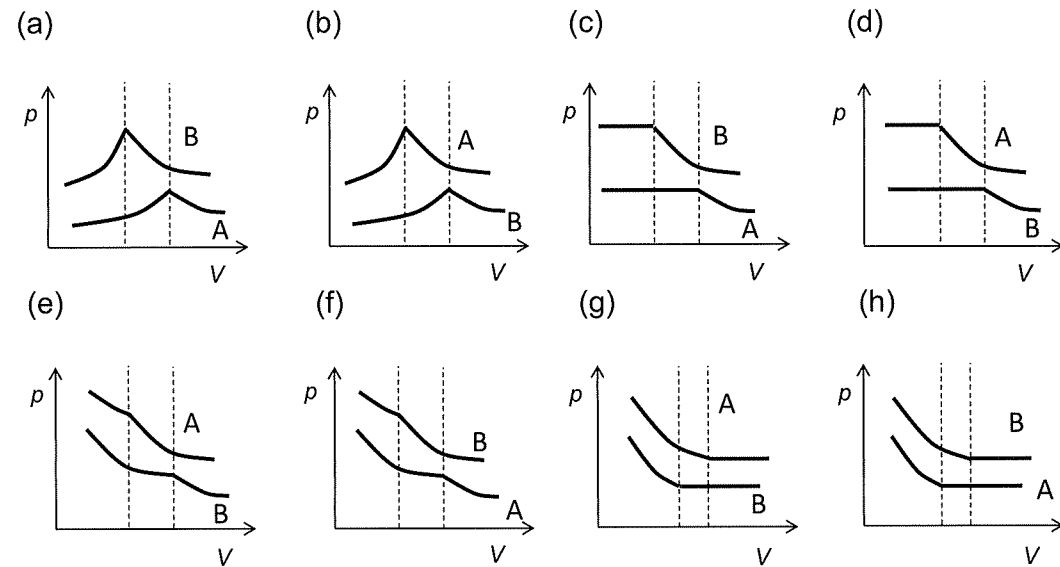
III Answer the following questions about saturation pressure.

The figure below shows the vapor pressure curves of molecules A and B. The saturation pressures of molecule B at 60°C and 100°C are 20 kPa and 101 kPa, respectively. Even if liquefied components appear due to the operations in each question, their volumes can be ignored.

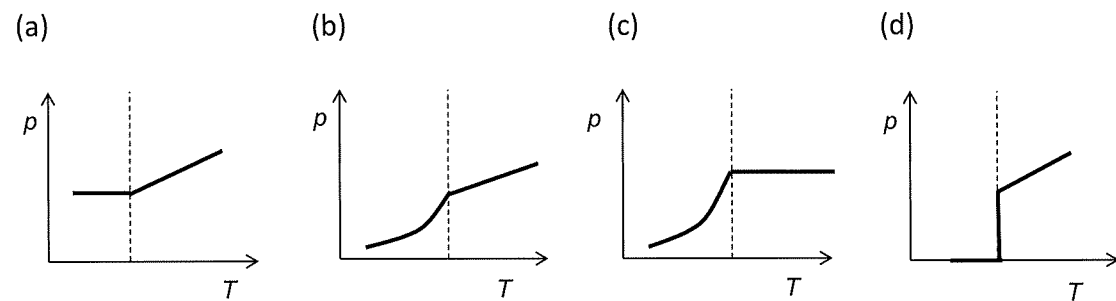


(1) When molecule B was added at 60°C into a volume-variable vacuum vessel X with a frictionless piston, molecule B was vaporized entirely. Afterwards, the volume of the vessel was reduced while maintaining the temperature at 60°C. Molecule B started to condense when the volume of the vessel reached 80 ml. The amount of molecule B is  $\frac{x}{333R}$  mol. Find the value of  $x$  to two significant figures.  $R$  [kPa L/ K mol] is the gas constant.

(2) When molecules A and B were added separately into two variable-volume vacuum vessels X at a certain temperature, molecules A and B were vaporized entirely. Afterwards, the volumes of the vessels were reduced while maintaining the initial temperature. Which of graphs (a) to (h) below shows the relation between the volume ( $V$ ) of the vessel and pressure ( $p$ ) of each molecule in this process?



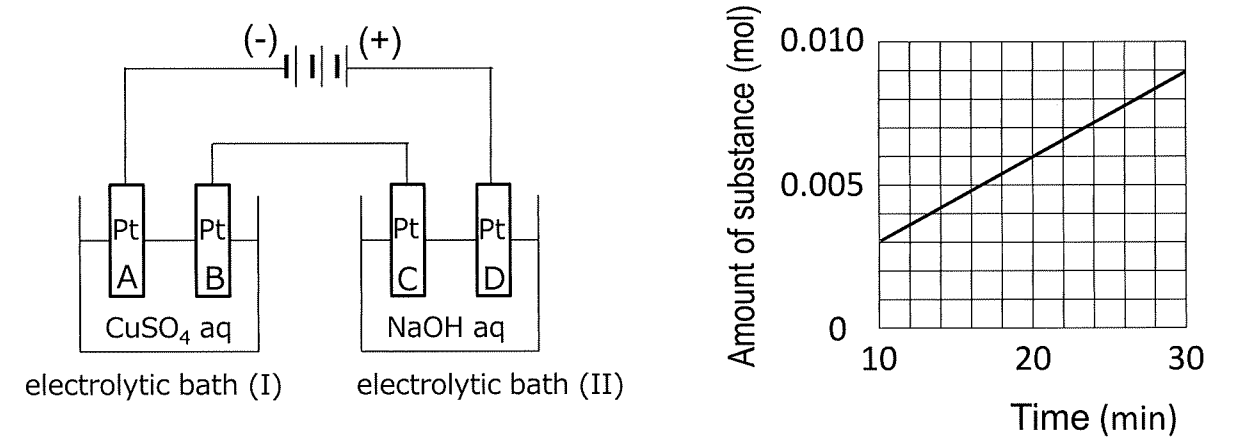
(3) When molecule A was added at a certain temperature into a vacuum vessel X, molecule A was vaporized entirely. Afterwards, the temperature of the vessel was lowered while maintaining the initial volume. Which of graphs (a) to (d) in the figure below shows the relation between temperature ( $T$ ) of the vessel and pressure ( $p$ ) of molecule A in this process?



(4) When molecule B and He gas were added at  $60^\circ\text{C}$  into a volume-variable vacuum vessel X, the total pressure was 120 kPa in the presence of liquid B. Afterwards, when the temperature of the vessel was raised to  $100^\circ\text{C}$  while maintaining the initial volume, liquid was still remained. Find the total pressure in the vessel at  $100^\circ\text{C}$  to three significant figures.

#### IV Answer the following questions on electrolysis.

The apparatus for electrolysis is shown on the left below. Copper (II) sulfate aqueous solution is in electrolytic bath I and sodium hydroxide aqueous solution is in electrolytic bath II. All electrodes are platinum. The current was applied at 0.965 A for 30 min under constant current conditions. The amount of substance deposited on electrode A with time is shown in the right-hand-side figure below.

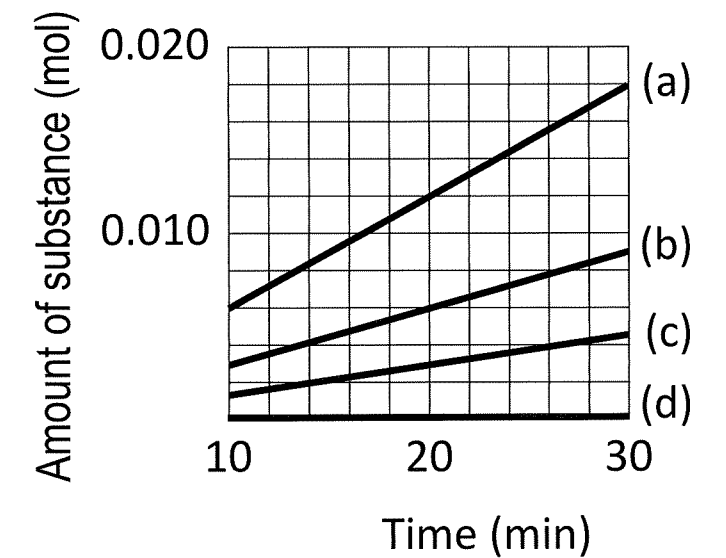


(1) Show the chemical equation of the reaction that occurred at electrode A.

(2) Find the electric charge [C] required for the deposition of  $5.00 \times 10^{-3}$  mol of the substance on electrode A to three significant figures. The Faraday constant is 96500 C/mol.

(3) Choose the appropriate graph from (a) to (d) in the figure below that shows the relation of the amount of gas or solid produced on electrodes B and C with time. If no gas or solid is produced, choose graph (d).

- (3-1) Gas produced on electrode B
- (3-2) Gas produced on electrode C
- (3-3) Solid produced on electrode C



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物 理

PHYSICS

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(5) Next,  $S_2$  was opened, and then  $S_1$  was closed. After that,  $C_1$  and  $C_2$  were fully charged. Find the charge on  $C_2$ .

- (a)  $\frac{1}{8}CV$       (b)  $\frac{3}{8}CV$       (c)  $\frac{5}{8}CV$   
 (d)  $\frac{1}{4}CV$       (e)  $\frac{3}{4}CV$       (f)  $\frac{5}{4}CV$

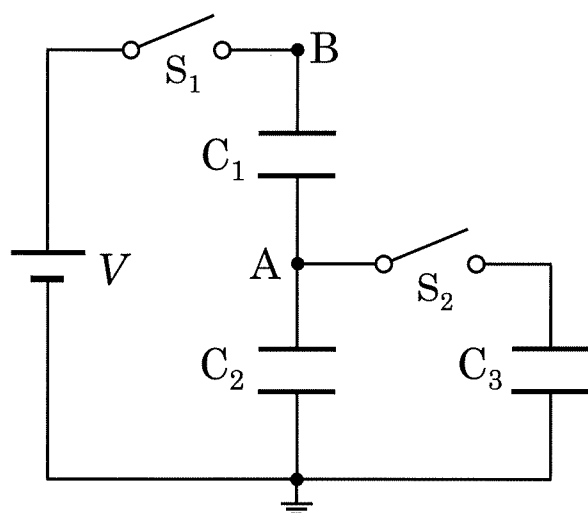


Fig. 2

3. An artificial satellite with mass  $m$  is circulating the Earth as shown in Fig. 3. The satellite rotates around the Earth in the direction of the Earth's rotation. The satellite's height above the Earth is  $h$ . The shape of the Earth is assumed to be a perfect sphere with radius  $R$ . The mass of the Earth is  $M$  and the Earth's rotation period is  $T$ . The gravitational constant is denoted by  $G$ . Answer the following questions.

(1) Find the angular velocity of the Earth's rotation.

- (a)  $\frac{1}{T}$       (b)  $\frac{4\pi^2}{T^2}$       (c)  $\frac{R}{T}$   
 (d)  $\frac{2\pi}{T}$       (e)  $\frac{2\pi R}{T}$       (f)  $\frac{4\pi R^2}{T}$

(2) Find the speed of the satellite.

- (a)  $\frac{GM}{R}$       (b)  $\sqrt{\frac{GM}{R+h}}$       (c)  $\sqrt{\frac{GMm}{R+h}}$   
 (d)  $\sqrt{\frac{GMm}{R}}$       (e)  $\sqrt{\frac{GM}{R}}$       (f)  $\frac{GM}{h}$

(3) Find the period of the satellite's orbit,  $T_s$ .

- (a)  $2\pi(R+h)\sqrt{\frac{R+h}{GMm}}$       (b)  $2\pi\sqrt{\frac{R+h}{GM}}$       (c)  $2\pi\sqrt{\frac{R+h}{GMm}}$   
 (d)  $2\pi R\sqrt{\frac{R}{GMm}}$       (e)  $2\pi R\sqrt{\frac{R}{GM}}$       (f)  $2\pi(R+h)\sqrt{\frac{R+h}{GM}}$

(4) Find the formula for  $h$  when  $T_s = T$ .

- (a)  $\left(\frac{GMT^2}{4\pi^2}\right)^{\frac{1}{3}} - R$       (b)  $\left(\frac{GMT^2}{4\pi^2}\right)^{\frac{1}{3}}$       (c)  $\left(\frac{GmMT^2}{4\pi^2}\right)^{\frac{1}{3}}$   
 (d)  $\left(\frac{GmMT^2}{4\pi^2}\right)^{\frac{1}{3}}$       (e)  $\left(\frac{GMT^2}{4\pi^2}\right)^{\frac{1}{3}} - R$       (f)  $\left(\frac{GmMT^2}{4\pi^2}\right)^{\frac{1}{3}} - R$

(5) Find the speed of the satellite when  $T_s = T$ .

- (a)  $\left(\frac{2\pi GM}{T}\right)^{\frac{1}{3}}$       (b)  $\left(\frac{2\pi GmM}{T}\right)^{\frac{1}{3}}$       (c)  $\left(\frac{2\pi GM}{T}\right)^{\frac{1}{2}}$   
 (d)  $\left(\frac{2\pi GmM}{T}\right)^{\frac{1}{2}}$       (e)  $\frac{2\pi GmM}{T}$       (f)  $\frac{2\pi GM}{T}$

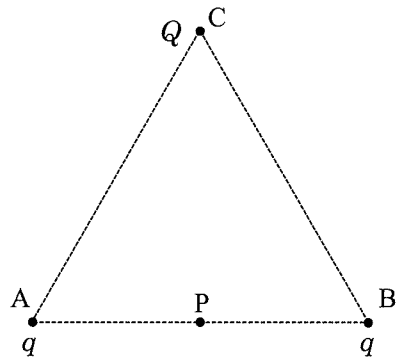


Fig. 1-3

- (4) As shown in Fig. 1-4, a cylindrical container filled with an ideal gas is divided into two parts, A and B, by a frictionless piston. Initially, the gas in A and B had a pressure of  $p_0$  and a temperature of  $T_0$ . The length from the both ends of the container to the piston was  $L$ . Then, the temperature of the gas in B is increased and fixed at  $T$  ( $> T_0$ ), while that of the gas in A is kept at  $T_0$ . How far does the piston move, and to which direction?

- |   |   |
|---|---|
| (a) $\frac{T - T_0}{T + T_0}L, A \rightarrow B$ | (b) $\frac{T + T_0}{T - T_0}L, A \rightarrow B$ |
| (c) $\frac{2T_0}{T + T_0}L, A \rightarrow B$    | (d) $\frac{T - T_0}{T + T_0}L, A \leftarrow B$  |
| (e) $\frac{T + T_0}{T - T_0}L, A \leftarrow B$  | (f) $\frac{2T_0}{T + T_0}L, A \leftarrow B$     |

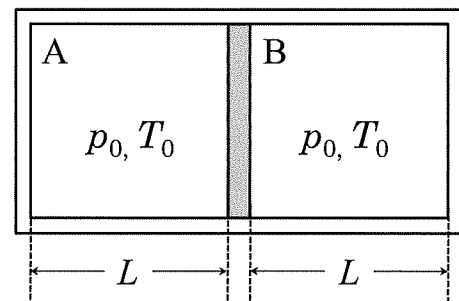


Fig. 1-4

Consider a circuit shown in Fig. 2, consisting of three same capacitors  $C_1$ ,  $C_2$ , and  $C_3$  of capacitance  $C$ , a battery of voltage  $V$ , and switches  $S_1$  and  $S_2$ . Capacitors  $C_2$  and  $C_3$  are grounded as shown in the figure. At the beginning,  $S_1$  and  $S_2$  were open, and all the capacitors were uncharged. Answer the following questions.

First, only  $S_1$  was closed, and then,  $C_1$  and  $C_2$  were fully charged. Find the charge on  $C_2$ .

- |                     |                     |                     |
|---------------------|---------------------|---------------------|
| (a) $CV$            | (b) $2CV$           | (c) $3CV$           |
| (d) $\frac{1}{4}CV$ | (e) $\frac{1}{2}CV$ | (f) $\frac{1}{3}CV$ |

Find the total energy stored in  $C_1$  and  $C_2$  after the operation in (1).

- |                       |                       |                       |
|-----------------------|-----------------------|-----------------------|
| (a) $CV^2$            | (b) $2CV^2$           | (c) $3CV^2$           |
| (d) $\frac{1}{4}CV^2$ | (e) $\frac{1}{2}CV^2$ | (f) $\frac{1}{3}CV^2$ |

Next,  $S_1$  was opened, and then  $S_2$  was closed. Find the charge on  $C_2$  after this operation.

- |                     |                     |                     |
|---------------------|---------------------|---------------------|
| (a) $CV$            | (b) $2CV$           | (c) $3CV$           |
| (d) $\frac{1}{4}CV$ | (e) $\frac{1}{2}CV$ | (f) $\frac{1}{3}CV$ |

Find the electric potentials  $V_A$  and  $V_B$  at points A and B, respectively, with reference to the ground after the operation in (3)

- |  |  |
|--|--|
| (a) $V_A = \frac{1}{2}V, V_B = V$            | (b) $V_A = V, V_B = \frac{1}{2}V$            |
| (c) $V_A = \frac{1}{2}V, V_B = \frac{3}{2}V$ | (d) $V_A = \frac{3}{2}V, V_B = \frac{1}{2}V$ |
| (e) $V_A = \frac{1}{4}V, V_B = \frac{3}{4}V$ | (f) $V_A = \frac{3}{4}V, V_B = \frac{1}{4}V$ |

- (2) As shown in Fig. 1-2, a ball collided with the floor at a speed of 2.0 m/s at an angle of  $60^\circ$ , and bounced off at an angle of  $30^\circ$ . Find the coefficient of restitution between the ball and the floor. The velocity component in the parallel direction to the floor does not change before and after the collision.

- (a) 0                      (b) 0.25                      (c) 0.33  
 (d) 0.66                      (e) 0.75                      (f) 0.8

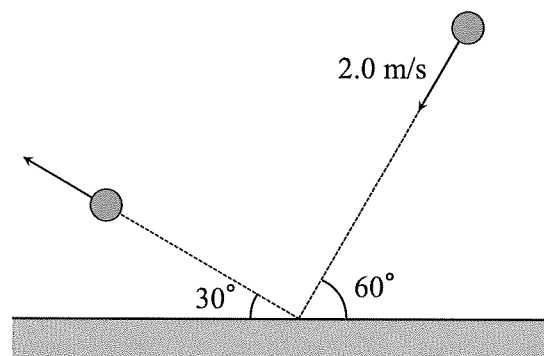


Fig. 1-2

- (3) As shown in Fig. 1-3, there is an equilateral triangle ABC with side  $l$ , and point P is the midpoint between points A and B. Two particles of equal charge  $q$  ( $>0$ ) are fixed at points A and B, respectively. Find the amount of work required to move the positive charge of  $Q$  from point C to point P. Coulomb's constant is denoted as  $k(= \frac{1}{4\pi\epsilon_0})$ , where  $\epsilon_0$  is the permittivity of a vacuum.

- (a)  $\frac{kqQ}{l}$                       (b)  $\frac{2kqQ}{l}$                       (c)  $\frac{3kqQ}{l}$   
 (d)  $\frac{kqQ}{l^2}$                       (e)  $\frac{2kqQ}{l^2}$                       (f)  $\frac{3kqQ}{l^2}$

5. In vacuum, laser light with wavelength  $\lambda$  passes through two slits,  $S_1$  and  $S_2$ , and reaches the screen as shown in Fig. 5. Two slits,  $S_1$  and  $S_2$ , are separated by  $d$ . The distance between the slits and the screen is  $R$ , and  $R$  is much larger than  $d$ . The position of the point P on the screen is denoted by  $x$ , which is measured from the center of the screen, O.  $L_1$  and  $L_2$  are the distances of  $S_1P$  and  $S_2P$ , respectively. Answer the following questions.

- (1) Using the approximation formula,  $(1+a)^p \simeq 1+pa$ , in which  $|a| \ll 1$ , find the expression of  $L_2 - L_1$ .

- (a)  $\frac{dx}{R}$                       (b)  $\frac{Rx}{d}$                       (c)  $\frac{Rd}{x}$   
 (d)  $\frac{(x+d)^2}{R}$                       (e)  $\frac{(x-d)^2}{R}$                       (f)  $\frac{dx^2}{R^2}$

- (2) On the screen bright interference fringes are observed. Find the formula for the spacing between fringes.

- (a)  $d$                       (b)  $2d$                       (c)  $\lambda$   
 (d)  $\frac{d\lambda}{R}$                       (e)  $\frac{R\lambda}{d}$                       (f)  $\frac{d^2}{R}$

We then do the same experiment in a medium with refractive index  $n(>1)$ .

- (3) Find the formula for the spacing between bright interference fringes on the screen.

- (a)  $\frac{d\lambda}{nR}$                       (b)  $\frac{nd^2}{R}$                       (c)  $\frac{R\lambda}{nd}$   
 (d)  $nd$                       (e)  $\frac{2d}{n}$                       (f)  $n\lambda$

- (4) Find the wavelength  $\lambda$  when  $d = 1.0 \times 10^{-4}$  m,  $n = 1.2$ ,  $R = 2.4$  m, and the spacing between fringes is  $1.0 \times 10^{-2}$  m.

- (a)  $\lambda = 5.0 \times 10^{-6}$  m    (b)  $\lambda = 5.0 \times 10^{-7}$  m    (c)  $\lambda = 5.0 \times 10^{-8}$  m  
 (d)  $\lambda = 2.4 \times 10^{-6}$  m    (e)  $\lambda = 2.4 \times 10^{-7}$  m    (f)  $\lambda = 2.4 \times 10^{-8}$  m

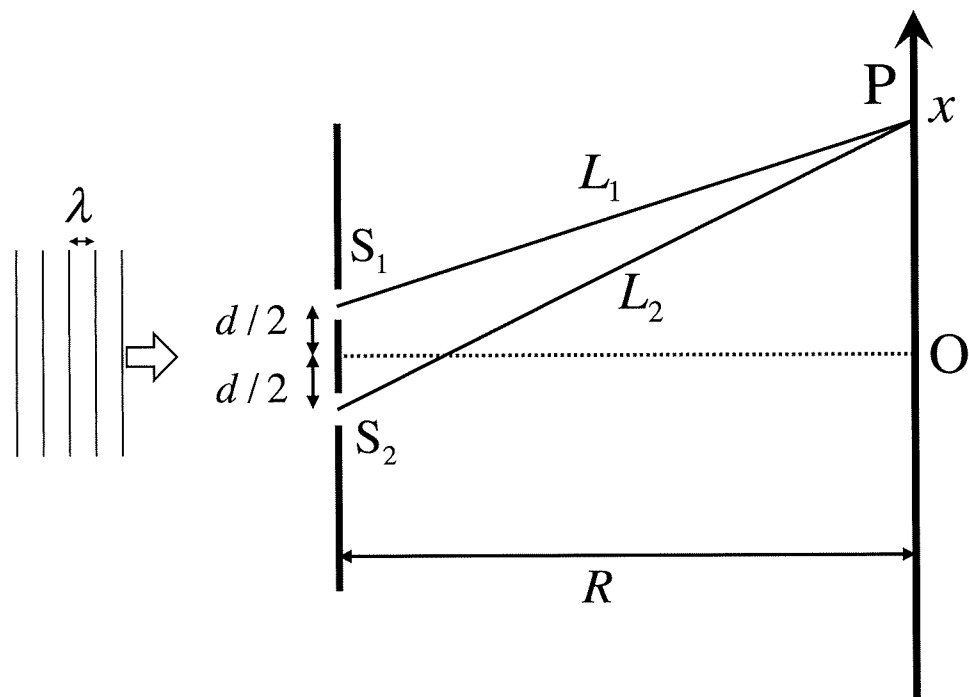


Fig. 5

(2023)

Physics	Nationality		No.		Marks	
	Name	(Please print full name, underlining family name)				

Before you start, fill in the necessary details (nationality, examination number, name etc.) in the box at the top of this examination sheet and on the answer sheet.

For each question, select the correct answer and write the corresponding letter in the space provided on the answer sheet.

1. Answer the following questions.

(1) Figure 1-1 shows the velocity  $v$  (m/s) of an object moving along the  $x$ -axis as a function of time  $t$  (s). The object departed from the origin ( $x = 0$ ) at  $t = 0$  s. Find the position  $x$  (m) of the object at  $t = 8.0$  s.

- (a) 0 m                      (b) 1 m                      (c) 2 m  
 (d) 4 m                      (e) 6 m                      (f) 8 m

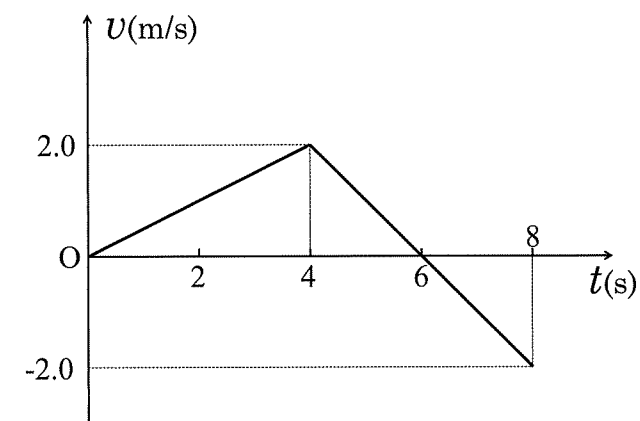


Fig. 1-1

2023 年度日本政府(文部科学省)奨学金留学生選考試験

QUALIFYING EXAMINATION FOR APPLICANTS FOR THE JAPANESE  
GOVERNMENT (MEXT) SCHOLARSHIP 2023

学科試験 問題

EXAMINATION QUESTIONS

(学部留学生)

UNDERGRADUATE STUDENTS

生 物

BIOLOGY

**注意** ☆試験時間は **60 分**。

**PLEASE NOTE: THE TEST PERIOD IS 60 MINUTES.**

3. From the list given below, choose three invasive species mentioned in the underlined sentence number 3), and write down the corresponding letters (A–F) in the designated space (III-2 (3)) on the answer sheet.

- A. alligator snapping turtle (*Macrochelys temminckii*) in Japan
- B. Brahminy blind snake (*Indotyphlops braminus*) in tropical regions
- C. brown tree snake (*Boiga irregularis*) in Guam
- D. domestic rabbit (*Oryctolagus cuniculus*) in Australia
- E. European honey bee (*Apis mellifera*) in Japan
- F. kudzu or Japanese arrowroot (*Pueraria montana*) in the U.S.A.

IV. Read the following passage and answer the subsequent questions (1–4).

Ecological disturbance is a temporary change in environmental conditions that sometimes causes a pronounced change in an ecosystem. 1)Major disturbances destroy [ 1 ] and affect the [ 2 ] of an ecosystem. Damaged ecosystems recover gradually for a long time by ecological [ 3 ].

Major disturbances reduce [ 2 ]. In contrast, 2)minor disturbances increase the variety of [ 1 ], and [ 2 ] becomes higher. For example, paddy fields grown by traditional agriculture provide an environment for freshwater animals to live, leading to a higher [ 2 ].

[ 4 ] are those that humans move intentionally or accidentally from the species' native locations to new areas. Without the predators, parasites, and pathogens that limit its population, a species may spread rapidly in a new area. 3)Invasive species disrupt their new community, often by preying on native organisms or outcompeting them for resources.

1. Fill in the blank ([ 1 ]–[ 4 ]) in the above passage using the most suitable term from the list given below and write down the corresponding letters (A–I).

- A. biodiversity
- B. climax community
- C. habitats
- D. introduced species
- E. keystone species
- F. native species
- G. population
- H. refugia
- I. succession

2. From the list given below, choose each four causes of major and minor disturbances, which are mentioned in the underlined parts number 1) and 2) of the passage above, and write down the corresponding letters (A–H) in the designated spaces (IV-2 (1) and (2)) on the answer sheet.

- A. drought
- B. epidemic
- C. flood
- D. intense forest fire
- E. landslide
- F. pollution
- G. small wildland fire
- H. volcanic eruption

(2023)

Biology	Nationality		No.		Marks
	Name	(Please print your name, underlining your family name)			

Answer the subsequent questions (I–IV) using the answer sheet.

I. Read the following two passages, (A) and (B), and write down your answers to the subsequent questions on the answer sheet.

(A) A gene can be defined as a DNA region carrying information for one [ 1 ] strand or a region on DNA carrying information on one or more functional RNA molecules. In the former case, the first step expressing genetic information is the transcription of a template strand of DNA by [ 2 ]. [ 2 ] is directed to the appropriate position on the DNA by binding to the [ 3 ] region. The [ 2 ] moves in the 3' to 5' direction along the template strand of DNA, assembling a complementary, antiparallel strand of RNA that grows from its 5' terminus to the 3' terminus.

There are three types of RNA that are directly involved in the translation of genetic information into proteins. Those are rRNA, mRNA, and [ 4 ]. rRNA is a major component of the two large and small [ 5 ] of the ribosome. Amino acids are transported to the ribosome by [ 4 ], where they form [ 6 ] and are arranged based on the information of mRNA. mRNA is the transcription product of a base sequence containing protein information from a DNA template. mRNA consists of a [ 7 ] region that contains the information that determines the amino acid sequence and a non-[ 7 ] region that is involved in the initiation and regulation of translation.

[ 4 ] is responsible for binding to a specific amino acid and transporting it to the ribosome. Amino acids form [ 6 ] based on the information of DNA transcribed into mRNA to [ 8 ] proteins.

(B) 1)Each cell of an individual organism has a different set of genes, depending on the required function. The body maintains relatively constant blood pressure, blood sugar, electrolytes, energy, hormones, oxygen, proteins, temperature, etc. All body systems

need to respond well to a variety of environmental stimuli in order for the body to function properly and survive. They also need to be maintained at the same level at all times under various signals. Therefore, 2) gene expression is always kept constant under various conditions. This phenomenon is called "homeostasis." Such gene expression begins with the transcription of DNA, then is translated into a protein. 3) A series of basic processes, such as intracellular DNA replication, transcription of genetic information, and translation into proteins, is called "metabolism."

1. Choose the most suitable term from the list given below to answer ([ 1 ] to [ 8 ]) on the paragraph above and write down the appropriate letter (A–W) in the designated spaces (I-1 (1) to (8)) on the answer sheet.

- |              |                   |                   |
|--------------|-------------------|-------------------|
| A. cDNA      | B. coding         | C. digest         |
| D. DNA       | E. DNA polymerase | F. double         |
| G. enzyme    | H. ester bonds    | I. ether bonds    |
| J. examine   | K. ligase         | L. lipid          |
| M. lysosomes | N. peptide bonds  | O. polypeptide    |
| P. promoter  | Q. RNA            | R. RNA polymerase |
| S. sRNA      | T. subunits       | U. synthesize     |
| V. triple    | W. tRNA           |                   |

2. Which of the above sentences from 1) to 3) is/are incorrect? Write down the letter "T" for the correct sentence and the letter "F" for the incorrect sentence in the designated spaces (I-2 (1) to (3)) on the answer sheet.

1. Fill in the blank ([ 1 ]–[ 11 ]) in the above passage with the most suitable term from the list given below and record the corresponding letters (A–Q).

- |                            |                        |                       |
|----------------------------|------------------------|-----------------------|
| A. aerobic bacteria        | B. anaerobic bacteria  | C. amphibians         |
| D. banded iron formation   | E. cyanobacteria       | F. Cambrian explosion |
| G. collision of meteorite  | H. infrared            | I. iron oxide         |
| J. multicellular organisms | K. ozone layer         | L. reptiles           |
| M. snowball earth          | N. stromatolites       | O. ultraviolet        |
| P. unicellular organisms   | Q. volcanic activities |                       |

2. From the list given below, choose one animal fossil that belongs to the groups mentioned on the underlined sentences number 1) and 2) in the passage above, and write down the corresponding letters (A–G) in the designated spaces (III-2 (1) and (2)) on the answer sheet.

- |                        |                        |                         |                       |
|------------------------|------------------------|-------------------------|-----------------------|
| A. Ammonite            | B. <i>Anomalocaris</i> | C. Coelacanth           | D. <i>Dickinsonia</i> |
| E. <i>Ichthyostega</i> | F. Trilobite           | G. <i>Tyrannosaurus</i> |                       |

3. From the list given below, choose four terrestrial phyla of animals mentioned on the underlined sentence number 3) in the passage above, and write down the corresponding letters (A–H) in the designated space (III-3) on the answer sheet.

- |                  |                 |             |             |
|------------------|-----------------|-------------|-------------|
| A. Annelida      | B. Arthropoda   | C. Chordata | D. Cnidaria |
| E. Echinodermata | F. Hemichordata | G. Mollusca | H. Porifera |

4. From the list given below, choose an index fossil of Paleozoic era, which is mentioned on the underlined sentence number 4) in the passage above, and write down the corresponding letters (A–G) in the designated space (III-4) on the answer sheet.

- |                        |                        |                         |                       |
|------------------------|------------------------|-------------------------|-----------------------|
| A. Ammonite            | B. <i>Anomalocaris</i> | C. Coelacanth           | D. <i>Dickinsonia</i> |
| E. <i>Ichthyostega</i> | F. Trilobite           | G. <i>Tyrannosaurus</i> |                       |

III. Read the following passage and answer the subsequent questions (1–4).

Mass extinctions occurred several times in geological history. In the Precambrian age, [ 1 ] started to appear 3.5 billion years ago and left layered rocks known as [ 2 ]. They produced oxygen that exterminated most of [ 3 ]. The accumulated oxygen oxidized iron ion soluble in seawater into [ 4 ], which became sediments of [ 5 ] in shallow waters.

The extremely cold climate had frozen the lands and sea waters of the earth three times during the Precambrian age. After the last age of snowball earth, fossils of [ 6 ] appeared, and they were known as the 1)Ediacaran biota from Australia. The fossils of many animals from multiple phyla appeared in the Cambrian period of the Paleozoic era. This event is known as [ 7 ]. The 2)Burgess shale fauna are the famous Cambrian fossils found in the Canadian Rockies.

Photosynthetic organisms such as algae, plants, and euglena became abundant and oxygen accumulated in the atmosphere. Then, [ 8 ] was formed in the stratosphere and absorbed [ 9 ] rays. As the [ 9 ] rays that reached land were reduced, plants started colonizing land in the Silurian period, followed by 3)the colonization of land by animals in the Silurian and Devon periods. A group of fishes developed lungs, legs, and fingers and evolved to [ 10 ].

4)The mass extinction in the late Permian era, which is the boundary of Paleozoic and Mesozoic eras, destroyed most members of fauna and flora in lands and waters caused by large-scale [ 11 ].

II. Read the following passage and answer the subsequent questions (1–4).

In the living cells, various substances are being synthesized and degraded. The overall process of these biological reactions is termed metabolism, and many metabolic pathways, a series of consecutive chemical reactions, proceed in an integrated manner to maintain the activities of living cells.

Metabolic pathways are divided into two categories: one is called [ 1 ], in which 1)cell constituents and nutrients are broken down into their components and inorganic substances, and the other is called [ 2 ], in which 2)complex biomolecules are synthesized from simpler constituents and compounds.

The chemical reactions in [ 2 ] are thermodynamic processes that [ 3 ] energy. Therefore, an external energy supply is required for the reaction to proceed. Conversely, the chemical reactions in [ 1 ] are the processes to [ 4 ] energy, and the resulting energy is conserved through the synthesis of [ 5 ] and NADPH (NADH), which are often utilized to drive the chemical reactions in [ 2 ]. The processes of two metabolic categories are thus coupled through [ 5 ], which is called the biological energy currency.

Most reactions in metabolic pathways are mediated by corresponding enzymes. Enzymes are known as biological catalysts and can function efficiently under conditions preferable for the cell's biological performance. They differ from chemical catalysts, which often function under non-biological conditions such as high temperature and high pressure. The catalytic activities of many enzymes are well regulated in response to the internal environment of the cell to maintain the homeostasis of metabolism as a whole. In recent years, 3)many studies on the functions and structures of enzymes in the atomic and molecular levels have been carried out, and several important achievements have been obtained.

1. Fill in the blank ([ 1 ]-[ 5 ]) in the above passage using the most suitable term from the list given below and record the corresponding letters (A-I).

- |              |                         |                          |
|--------------|-------------------------|--------------------------|
| A catabolism | B anabolism             | C conversion             |
| D store      | E transform             | F extract                |
| G adenosine  | H adenosine diphosphate | I adenosine triphosphate |

2. Metabolic pathways (1) to (5) given below are the main examples for metabolic pathways. Determine whether each of them belongs to the underlined sentence 1) or sentence 2) of the above passage. Write down X if it belongs to sentence 1) or Y if it belongs to sentence 2) in the designated spaces (II-2(1) – (5)) on the answer sheet.

- (1) Calvin-Benson cycle
- (2) Krebs cycle (TCA cycle, Citric acid cycle)
- (3) Urea cycle
- (4) Alcoholic fermentation
- (5) Glycolysis

3. Judge whether the following sentences concerning enzyme functions are correct or wrong, and write down “T” for the correct sentence and “F” for the incorrect one in the designated spaces (II-3(1) – (5)) on the answer sheet.

(1) The rates of enzymatically-catalyzed reactions are greater by the factors of  $10^6$  to  $10^{12}$  than those of the corresponding reactions without a catalyst. This is due to the shift of the equilibrium constant of the reaction toward product formation.

(2) Enzymes have greater efficiency in the catalytic reaction for a certain substrate. Such a substrate specificity is due to the presence of the enzyme’s active site with a structure complementary to that of the substrate.

(3) There are substances that reduce an enzyme’s activity. Such substances, known as inhibitors, can act with mainly two different mechanisms: one is to bind to the enzyme’s active site in a competitive manner with a normal substrate, and the other is to bind to the region other than the active site in a non-competitive manner.

(4) All enzymes consist of single or multiple polypeptides. Some enzymes play a catalytic role in association with vitamins or metal ions.

(5) Enzymes are generally inactivated when the enzyme solution is heated. This is due to the low conformational stability of proteins. However, certain species of organisms known as hyperthermophiles that grow in hot springs have special enzymes that can function at temperatures higher than  $80^{\circ}\text{C}$ . Such enzymes consist of heat-stable macromolecules that are not proteins.

4. Judge whether the following sentences concerning research achievements for the underlined part 3 in the above passage are correct or wrong, and write down “T” for the correct sentence and “F” for the incorrect one in the designated spaces (II-4(1) – (5)) on the answer sheet.

(1) In order to obtain an enzyme

of a certain animal, we can extract the enzyme from the tissues of the animal biochemically, or we can prepare the enzyme by a genetic recombination method from a heterologous organism such as *E. coli*.

(2) The 3D structures of many substances can be determined by X-ray crystallographic analysis. However, this method is hardly applied for the structural determination of enzymes since it is difficult to crystalize enzymes.

(3) Several metabolic disorders are caused by the dysfunction of certain enzymes. Many mutations of the genes encoding the corresponding enzymes have been elucidated by the tailor-made genomic analysis of the corresponding patients.

(4) Studies of enzyme functions have been carried out using new methods, such as by rapid analysis of millisecond-order reactions and direct observation of enzyme molecules labeled with visualization probes.

(5) The genomes of many organisms contain multiple open reading frames encoding nonidentified proteins that are homologous with a certain enzyme of known function. These homologs can be considered to have the same function as the enzyme.