

2024 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 2024

学科試験 問題

EXAMINATION QUESTIONS

(学部留学生)

UNDERGRADUATE STUDENTS

化 学

CHEMISTRY

注意 ☆試験時間は **60 分**。

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

CHEMISTRY	Nationality		No.		Marks	
	Name	(Please print full name, with underlined family name)				

I Select one correct answer and write the corresponding option number.

(1) Which nucleus of atoms 1) to 4) below has ten neutrons?

- 1) ^{13}C 2) ^{14}N 3) ^{16}O 4) ^{19}F

(2) Which of atoms 1) to 4) below has the largest atomic radius?

- 1) Mg 2) Ca 3) Sr 4) Ba

(3) Which of molecules 1) to 4) below has a trigonal planar shape?

- 1) H_2O 2) BF_3 3) CO_2 4) NH_3

(4) Which of substances 1) to 4) below is an acidic oxide?

- 1) MgO 2) Al_2O_3 3) SiO_2 4) PbO

(5) Which of descriptions 1) to 4) below is correct for bromine and iodine?

- 1) Both Br_2 and I_2 are in a solid state at ambient temperature and pressure.
- 2) Both Br_2 and I_2 are well soluble in water.
- 3) Both Br_2 and I_2 are well soluble in ethanol.
- 4) The oxidizing power of I_2 is stronger than that of Br_2 .

(6) Which of operations 1) to 4) below produces hydrogen?

- 1) Hydrochloric acid is added to calcium carbonate.
- 2) Dilute sulfuric acid is added to aluminum.
- 3) Dilute nitric acid is added to copper.
- 4) Ammonia water is added to zinc hydroxide.

(7) Which of descriptions 1) to 4) below is correct for the phase diagram of water?

- 1) The slope of the gas-liquid boundary is negative.
- 2) The slope of the gas-solid boundary is negative.
- 3) The slope of the solid-liquid boundary is positive.
- 4) There is a specific combination of temperature and pressure at which solid, liquid, and gas coexist.

II Fill (a) to (e) in the following statements with the appropriate values. Answer the values to three significant figures for the calculation results of (a) and (e). Show the chemical equation appropriate to (A). Use the following value if necessary; $\sqrt{3} = 1.73$.

(1) The bond energies of H-H, Cl-Cl, and H-Cl are 436, 243, and 432 kJ mol⁻¹, respectively. Hence, the heat of formation of HCl is estimated to be $\Delta H_f^\circ =$ (a) kJ mol⁻¹. HCl reacts with MnO₂ to produce MnCl₂ and Cl₂. The chemical equation of this reaction is written as follows:

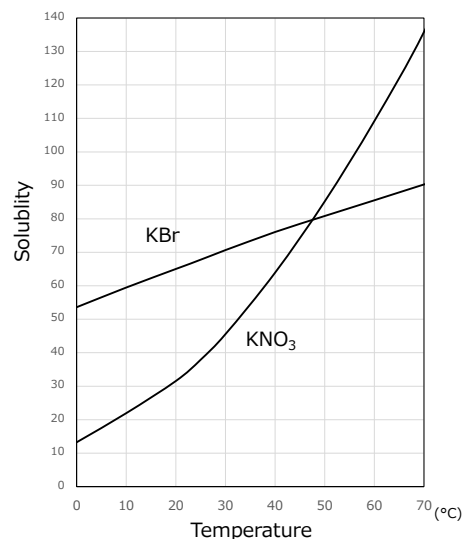
(A)

In this reaction, the oxidation number of Mn is changed from (b) to (c).

(2) The cubic unit cell of CsCl crystal contains one Cs⁺ ion and one Cl⁻ ion. One Cs⁺ ion is surrounded by (d) Cl⁻ ions in the crystal. The edge length of the unit cell of CsCl is 0.412 nm. Therefore, the distance between nearest neighboring Cs⁺ and Cl⁻ ions is (e) nm.

III Answer the following questions about the dissolution of gases and solids in water.

- (1) The figure on the right shows the relationship between solubility (maximum mass (g) of solute dissolved in 100 g of water) and temperature for potassium nitrate and potassium bromide.

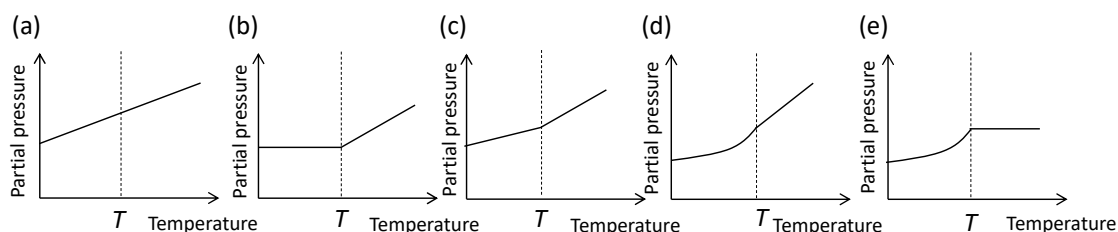


- (1-1) Solubility increases with increasing temperature. This dissolution is an [(a) exothermic, (b) endothermic] reaction. Choose the appropriate word in brackets and answer with (a) or (b).
- (1-2) Considering the temperature dependence of solubility, [(a) potassium nitrate, (b) potassium bromide] is easier to purify by recrystallization than the other. Choose the appropriate word from the brackets and answer with (a) or (b).
- (1-3) 1.6 g of potassium nitrate was completely dissolved in 5.0 g of water. The mixture was then cooled. Answer the temperature at which crystals began to precipitate.
- (1-4) A saturated aqueous solution at 60 °C containing 66 g of potassium nitrate was prepared. When the solution was heated up to evaporate water then cooled to 20 °C, 58 g of potassium nitrate precipitated. Find the mass of the water that evaporated to two significant figures.
- (2) Aqueous solutions of (A) potassium chloride, (B) magnesium chloride, and (C) urea were prepared at a concentration of 0.10 mol/kg. Which of the following (a) to (f) is appropriate if the aqueous solutions are arranged in order of decreasing boiling point?
(a) $A > B > C$, (b) $A > C > B$, (c) $B > A > C$, (d) $B > C > A$, (e) $C > A > B$, (f) $C > B > A$
- (3) When 1.0 L of water at 18 °C is in contact with 2.0×10^5 Pa of air, find the mass (mg) of oxygen dissolved in the water to two significant figures.
Air can be assumed as a mixture of oxygen and nitrogen in a volume ratio of 20 : 80. When the partial pressure of oxygen is 1.0×10^5 Pa, its solubility in 1.0 L of water at 18 °C is 1.5×10^{-3} mol. The molecular weight of oxygen is 32.

IV Answer the following questions about the reaction of methanol and the pressure of the reaction vessel. Use the following values if necessary: the atomic weights of C, O, and H are 12, 16, and 1.0, respectively.

Methanol (3.2 g) was injected into a closed vessel with a volume of 11.2 L containing 6.4 g of oxygen and all of methanol was completely combusted. The temperature was then kept at 0 °C. All gases are assumed to be ideal gases, and the amount of gas dissolved in water is assumed to be negligible. The saturated vapor pressure of water at 0 °C is assumed to be low and negligible.

- (1) Show the chemical equation for the combustion of methanol.
 - (2) Find the mass (g) of oxygen consumed by the combustion to two significant figures.
 - (3) Find the total amount (mol) and pressure (Pa) of gases remained after combustion at 0 °C to two significant figures. Here, the gas constant is $R = 8.31 \times 10^3 \text{ Pa} \cdot \text{L}/(\text{K} \cdot \text{mol})$
 - (4) After the reaction, the vessel was heated from 0 °C to 200 °C. During the heating, all water was vaporized. How many times greater was the pressure of the vessel at 200 °C than that at 0 °C? Choose one from the following options (a) to (e).
- (a) 1.3 times (b) 1.7 times (c) 2.3 times (d) 3.4 times (e) 4.0 times
- (5) Which figures show the temperature dependence of the partial pressures of water and oxygen, respectively during heating? Choose one appropriate option among figures (a) to (e) for water and oxygen, respectively. T in the figures is the temperature at which all water has vaporized.



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) Useful compounds such as ethylene, propylene, and benzene are produced by the cracking or reforming of naphtha obtained in petroleum refining.

(1-1) The compounds shown in the **Groups A** to **C** below are produced from ethylene, propylene, or benzene. Select the most appropriate combination of raw material substances commonly used in these productions among options 1) to 9).

Group A: phenol, salicylic acid

Group B: vinyl chloride, ethylene glycol

Group C: acetone, acrylic acid

	Group A	Group B	Group C
1)	ethylene	propylene	benzene
2)	ethylene	benzene	propylene
3)	ethylene	ethylene	benzene
4)	propylene	ethylene	propylene
5)	propylene	benzene	ethylene
6)	propylene	benzene	benzene
7)	benzene	ethylene	propylene
8)	benzene	ethylene	ethylene
9)	benzene	propylene	propylene

(1-2) For descriptions 1) to 7) below, select one correct combination of descriptions among options
Ⓐ to Ⓕ that apply to either phenol or salicylic acid.

1) Solid at room temperature

2) Has a hydroxy group

- 3) Has a carboxyl group
- 4) Soluble in sodium hydroxide aqueous solution
- 5) Color develops when an aqueous solution of iron (III) chloride is added
- 6) When an aqueous solution of sodium hydrogen carbonate is added, a gas is generated
- 7) Esters are formed when reacted with acetic anhydride

Ⓐ 1), 2) Ⓑ 2), 3) Ⓒ 3), 4) Ⓓ 3), 6) Ⓔ 4), 6) Ⓕ 5), 7)

(1-3) For descriptions 1) to 7) below, select one correct combination of descriptions among options Ⓐ to Ⓕ that apply to either acetone or acrylic acid.

- 1) Liquid at room temperature
- 2) Has a double bond.
- 3) Produced by the cumene process
- 4) Easily oxidized by oxygen in the air at room temperature
- 5) Has a hydroxy group
- 6) When sodium is added, hydrogen is generated
- 7) When reacted with acetic anhydride, an amide is formed

Ⓐ 1), 2), 4) Ⓑ 2), 3), 6) Ⓒ 3), 5), 6)
 Ⓓ 3), 4), 7) Ⓔ 4), 6), 7) Ⓕ 5), 6), 7)

(2) For the descriptions about production of plastics 1) to 4) below, select one correct combination among options Ⓐ to Ⓕ.

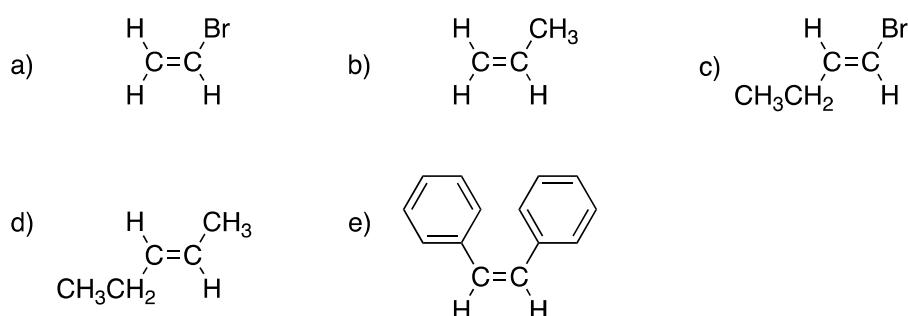
- 1) Polyethylene is produced by condensation polymerization of ethylene.
- 2) Polypropylene is produced by addition polymerization of propylene.
- 3) Polyethylene terephthalate (PET) is produced by addition polymerization of ethylene and terephthalic acid.
- 4) Polyvinyl chloride is produced by addition polymerization of vinyl chloride.

Ⓐ 1), 2) Ⓑ 1), 3) Ⓒ 1), 4) Ⓓ 2), 3) Ⓔ 2), 4) Ⓕ 3), 4)

(3) Select one compound containing only single bonds among options 1) to 5).

- 1) acetone
- 2) cyclohexane
- 3) formic acid
- 4) ethyl acetate
- 5) aniline

(4) The addition reaction of a bromine molecule to an alkene occurs in the form of two bromine atoms being added to opposite faces of the double bond of the alkene. In the following questions, we will consider the products of the addition of a bromine molecule to the following compounds a) to e).



(4-1) Select two compounds among compounds a) to e) that will produce a molecule with only one asymmetric carbon atom through the addition reaction. Here, asymmetric carbon atom is defined as a carbon atom that covalently binds four different types of atoms or groups of atoms.

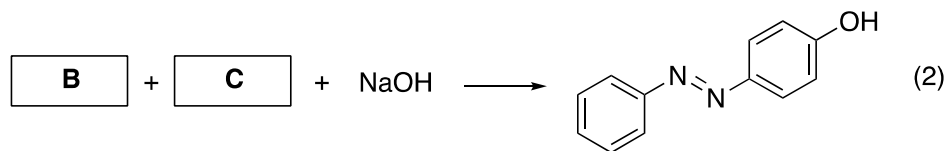
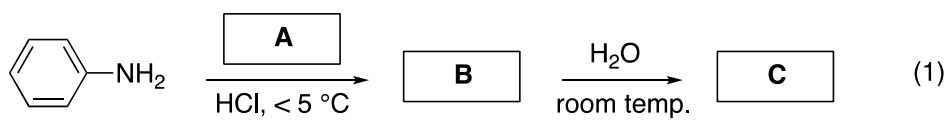
(4-2) Among compounds a) to e), how many compounds produce two types of enantiomer through the addition reaction with a bromine molecule?

(5) There is a compound that satisfies all the conditions a) to d) as follows. How much oxygen is consumed when 32.4 g of the compound is completely combusted? Answer the amount of oxygen with mol to two significant figures.

- a) It is an alicyclic hydrocarbon.
- b) In the molecular formula, the number of hydrogen atoms is four more than the number of carbon atoms.
- c) It has one ring structure.
- d) It has two double bonds, and the rest are all single bonds.

(6) For the reaction of aromatic compounds, select the compounds among 1) to 8) that apply to **A**, **B**,

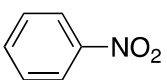
and **C** in formulas (1) and (2) below.

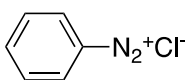


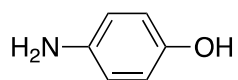
1) NaNO_3

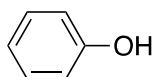
2) NaNO_2

3) NaHCO_3

4) 

5) 

6) 

7) 

8) 