2014年度日本政府（文部科学省）奨学金留学生選抜試験

QUALIFYING EXAMINATION FOR APPLICANTS FOR JAPANESE GOVERNMENT (MONBUKAGAKUSHO) SCHLORSHIPS 2014

学科試験　問題

EXAMINATION QUESTIONS

（高等専門学校留学生）

COLLEGE OF TECHNOLOGY STUDENTS

化　学

CHMISTRY

注意　☆試験時間は60分。

PLEASE NOTE: THE TEST PERIOD IS 60 MINUTES.

(2014)

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

If necessary, use the following constants and periodic table to answer the questions.

Consider all gases ideal throughout the examination.

Avogadro constant: $N_A = 6.02\times10^{23}$ mol^{-1}

Gas constant: $R = 8.314$ J·K^{-1}·mol^{-1} $= 0.082$ L·atm·K^{-1}·mol^{-1}

Faraday constant: $F = 9.65\times10^{4}$ C·mol^{-1}

Standard temperature and pressure (abbreviated STP): 0 °C and 1 atm

Molar volume of ideal gas at STP: 22.4 L·mol^{-1} $= 22.4$ dm^3·mol^{-1}

Pressure: 1 atm $= 1.01\times10^{5}$ Pa

Zero of the Celsius scale: 0 °C $= 273$ K

Periodic table of the elements

1																	18
1 H 1.0	2				atomic number Symbol atomic weight							13	14	15	16	17	2 He 4.0
3 Li 6.9	4 Be 9.0											5 B 10.8	6 C 12.0	7 N 14.0	8 O 16.0	9 F 19.0	10 Ne 20.2
11 Na 23.0	12 Mg 24.3	3	4	5	6	7	8	9	10	11	12	13 Al 27.0	14 Si 28.1	15 P 31.0	16 S 32.1	17 Cl 35.5	18 Ar 40.0
19 K 39.1	20 Ca 40.1	21 Sc 45.0	22 Ti 47.9	23 V 50.9	24 Cr 52.0	25 Mn 54.9	26 Fe 55.9	27 Co 58.9	28 Ni 58.7	29 Cu 63.6	30 Zn 65.4	31 Ga 69.7	32 Ge 72.6	33 As 74.9	34 Se 79.0	35 Br 79.9	36 Kr 83.8
37 Rb 85.5	38 Sr 87.6	39 Y 88.9	40 Zr 91.2	41 Nb 92.9	42 Mo 96.0	43 Tc -	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	57-71	72 Hf 178.5	73 Ta 181.0	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po -	85 At -	86 Rn -
87 Fr -	88 Ra -	89-103	104 Rf -	105 Db -	106 Sg -	107 Bh -	108 Hs -	109 Mt -	110 Ds -	111 Rg -							

57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm -	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
89 Ac -	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np -	94 Pu -	95 Am -	96 Cm -	97 Bk -	98 Cf -	99 Es -	100 Fm -	101 Md -	102 No -	103 Lr -

General Directions

- This is a single-answer multiple-choice examination with four or five possible choices for each question.
- There is only one correct or best answer to each question.
- Choose the value listed that is closest to your calculated one.
- When you have selected your answer to each question, write its corresponding number in the designated answer box for each question.
- Any questions for which more than one response has been written for each question will not be counted in your score.

1. Answer the questions below. If necessary, use the periodic table.

(A) Which is the number of valence electrons for each element in Group 15 (N to Bi) of the periodic table?

① 3　② 4　③ 5　④ 6　⑤ 7

(B) Of the elements listed below, which has the highest first ionization energy?

① H　② Ba　③ Au　④ F　⑤ He

(C) Which of the four types of crystalline solids is excellent conductors both electricity and heat?

① ionic crystals　② covalent crystals　③ molecular crystals　④ metals

(D) Compounds composed of two different elements are classified as binary compounds. The names of all binary compounds end in the letters *ide*. Which of the following compounds is not a binary compound?

① H_2O ② SO_3 ③ CO ④ TiO_2 ⑤ O_2

(E) Which functional group does not include C=O double bonds?

① aldehyde ② ester ③ ether ④ ketone ⑤ amido

2. Answer the following questions concerning chemical bonding and molecular structure.

(A) Which of the following ionic compounds is composed of ions with the same electron configurations?

① LiCl ② ZnS ③ KCl ④ NaCl ⑤ KI

(B) Which of the following molecules has a bent or V-shaped structure?

① CO_2 ② HCl ③ CH_4 ④ H_2O ⑤ NH_3

(C) The oxygen molecule, O_2, is covalently bonded. O_2 is weakly attracted to strong magnetic fields, indicating that O_2 has unpaired electrons. In accordance with the octet rule and the number of valence electrons of O atom, select the proper Lewis structure for the O_2 molecule.

① :O:::O: ② ·Ö::Ö· ③ :Ö:Ö: ④ :Ö::Ö:

3. A spontaneous electron transfer accompanying with redox reaction leads to a chemical conversion, the amount of which is evaluated from balanced equation. Answer the following questions.

(A) Assuming the oxidation numbers of H^+ and O^{2-}, determine the oxidation number of Cl in a perchloric acid $HClO_4$.

① -1 ② 1 ③ +3 ④ +5 ⑤ +7

(B) The following unbalanced equation represents oxidation-reduction reaction:

$$\_K^+MnO_4^- + \_(H^+)_2SO_4^{2-} + \_K^+I^- \rightarrow \_Mn^{2+}SO_4^{2-} + \_H_2O + \_I_2 + \_(K^+)_2SO_4^{2-}$$

Balance the equation above by using the following half reactions.

$$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O \quad \text{(reduction reaction)}$$

$$2I^- \rightarrow I_2 + 2e^- \quad \text{(oxidation reaction)}$$

When the reaction is correctly balanced with the smallest possible whole number coefficients, what is the coefficient ratio of $KMnO_4$/KI?

① 8/10 ② 2/10 ③ 2/8 ④ 5/6 ⑤ 3/4

(C) How many grams of I_2 would be formed by the reaction of 50.0 g $KMnO_4$?

① 80.3 g ② 135.5 g ③ 200.8 g ④ 245.6 g ⑤ 375.5 g

4. Global warming is considered to be responsible for increasing concentrations of greenhouse gases such as carbon dioxide released from burning fossil fuels. Using the thermochemical equations below, answer the following questions:

$C(s) + O_2(g) = CO_2(g) + 394\ kJ$ $(\Delta H = -394\ kJ)$

$H_2(g) + \frac{1}{2}O_2(g) = H_2O(l) + 286\ kJ$ $(\Delta H = -286\ kJ)$

$C(s) + 2H_2(g) = CH_4(g) + 75\ kJ$ $(\Delta H = -75\ kJ)$

$3C(s) + 4H_2(g) = C_3H_8(g) + 105\ kJ$ $(\Delta H = -105\ kJ)$

(A) Calculate the heat of combustion of $CH_4(g)$, Q kJ, according to the following combustion equation:

$CH_4(g) + 2O_2(g) = CO_2(g) + 2H_2O(l) + Q\ kJ$ $(\Delta H = -Q\ kJ)$

① -222 kJ/mol ② 469 kJ/mol ③ 891 kJ/mol ④ 2,221 kJ/mol

(B) Which of the following fuels would be the most powerful energy source? Compare the thermal energy released when one gram of substance burns ($kJ \cdot g^{-1}$).

① H_2 ② C ③ CH_4 ④ C_3H_8

5. Hydrogen is one of the promising clean energies to achieve a sustainable development. It is too reactive to exist for long time in its diatomic molecule, H_2, in the presence of the other elements and compounds. The lightest H_2 gas also diffuses or effuses from the earth's surface. Thus, to obtain H_2 gas for use as a benign fuel, we must extract it from hydrogen-containing compounds such as water, hydrocarbon, hydride, and so on.

(A) In a laboratory hydrogen generation is carried out a reaction of zinc metal, Zn, with a dilute sulfuric acid, H_2SO_4, solution as following the equation:

$$Zn(s) + H_2SO_4(l) \rightarrow ZnSO_4(s) + H_2(g)$$

When 5 mL of 3 mol/L H_2SO_4 was added into excess Zn, how many grams of zinc sulfate, $ZnSO_4(s)$, were formed, supposing that the reaction proceeded completely?

① 0.30 g ② 0.61 g ③ 1.21 g ④ 2.42 g

(B) A simple way of hydrogen production is a reaction of alkaline metal with water, H_2O, at atmospheric pressure (1 atm) and room temperature (25 °C). For instance sodium, Na, reacts vigorously with H_2O to produce hydrogen gas, H_2, according to the following equation:

$$2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$$

2.3 g piece of Na(s) was added into 1.0 L of $H_2O(l)$. What is the pH of the resulting solution, assuming that the amount of solution and the ion product constant for water (K_w) were invariable after the evolution of H_2?

($K_w = 1\times10^{-14}$ mol^2·L^{-2} at 25 °C)

① 0 ② 1 ③ 7 ④ 13 ⑤ 14

(C) The H_2 gas reformed from natural gases is used for the industrial production of ammonia according to the following reactions:

$$N_2(g) + 3H_2(g) \overset{\text{catalyst}}{\rightleftharpoons} 2NH_3(g)$$

Which of the following catalysts would favor the forward reaction to achieve cost-effective production of $NH_3(g)$?

① Pt ② MnO_2 ③ V_2O_5 ④ Cu ⑤ Fe

(D) The H_2 gas is also produced by electrolysis. A moderately concentrated aqueous solution of NaCl was electrolyzed using inert electrodes with a constant current of 9.65 A for 1 h at 1 atm and 25 °C. Which of the following theoretical estimation is correct for reactions and products at each electrode, supposing that the molar volume of any gas is 24.5 L at conditions of 25 °C and 1 atm?

	Electrode	Reaction	Product
①	anode:	$4OH^-(aq) \rightarrow O_2(g) + 2H_2O(l) + 4e^-$	2.2 L O_2
	cathode:	$2H^+(aq) + 2e^- \rightarrow H_2(g)$	4.4 L H_2
②	anode:	$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$	4.4 L Cl_2
	cathode:	$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$	4.4 L H_2
③	anode:	$2H_2O(l) \rightarrow O_2(g) + 4H^+(aq) + 4e^-$	2.2 L O_2
	cathode:	$2H_2O(l) + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$	4.4 L H_2
④	anode:	$2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$	4.4 L Cl_2
	cathode:	$2H^+(aq) + 2e^- \rightarrow H_2(g)$	4.4 L H_2

6. Answer the following questions related to structural determination of organic compound.

(A) A certain gaseous compound subjected to elemental analysis was found to be composed of only two elements, C and H. Mass analysis showed that 20.0 mg of the compound contains 17.1 mg of C. What is its empirical formula?

① CH ② C_2H_2 ③ CH_2 ④ C_2H_3 ⑤ C_3H_4

(B) At STP conditions, 2.0 L of the gaseous compound with the empirical formula determined above has a mass of 5.0 g. What is the molecular weight of this compound?

① 30 ② 56 ③ 72 ④ 84 ⑤ 102

(C) How many non-cyclic compounds containing geometric isomers exist for the molecular formula determined above?

① 2 ② 3 ③ 4 ④ 5 ⑤ 6