(2014)

CHEMISTRY

Nationality		No.	
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I Write the reference number of the correct answer in the appropriate box on the Answer Sheet below.

(1) Which of the elements 1) to 4) has no allotropes?

1) C 2) N 3) O 4) P

(2) When dissolved in water at the concentration of 1 mol L^{-1}, which of the substances 1) to 4) exhibits the lowest pH?

1) HCl 2) HF 3) CH_3COOH 4) H_2S

(3) Which of the substances 1) to 4) contains only single bonds?

1) carbon dioxide
2) phosphoric acid
3) hydrogen peroxide
4) nitrogen

(4) Which of the substances 1) to 4) has the highest melting point?

1) Ag 2) Al 3) Fe 4) Sn

(5) Which of the descriptions 1) to 4) is not correct for the properties of crystalline silicon?

1) A silicon atom is surrounded by its four nearest-neighbor silicon atoms.
2) High purity crystals are applied to solar cells.
3) Electrical conductivity can be tuned by doping boron or phosphorus.
4) Crystalline silicon is transparent to visible light.

(6) Which combination of the substances 1) to 4) produces chlorine when they react to evolve gases?

1) calcium hydroxide and ammonium chloride
2) manganese dioxide and hydrochloric acid
3) sodium chloride and sulfuric acid
4) zinc and hydrochloric acid

(7) Which of the properties 1) to 4) is not appropriate for ideal gas?

1) The volume of an individual atom or molecule is zero.
2) There is no interaction among the atoms and molecules.
3) It transforms into liquid or solid at low temperatures.
4) It obeys Boyle's law.

(1)		(2)		(3)		(4)	
(5)		(6)		(7)			

II Give the appropriate values for (a) and (b) in the sentences below to two significant figures. Use the following values for atomic weights: H=1.0, O=16.0, Na=23.0, S=32.0.

100 mL of 1.0 mol L^{-1} NaOH aq contains (a) g of NaOH. After mixing 100 mL of 1.0 mol L^{-1} H_2SO_4 aq with the first solution, the concentration of proton becomes (b) mol L^{-1}.

(a)		(b)	mol L^{-1}

III Give the appropriate name of the compounds or ions for (a) to (d) below using chemical formulas. The e^- denotes an electron.

The overall reaction in a fuel cell that uses KOH as electrolyte is written as follows;

$2\,H_2 + O_2 \rightarrow 2\,H_2O$.

At the anode, (a) is oxidized by the reaction;

(a) + 2 (b) $\rightarrow$ 2 (c) + 2 e^-.

At the cathode, (d) is reduced by the reaction;

(d) + 2 (c) + 4e^- $\rightarrow$ 4 (b).

(a)		(b)	
(c)		(d)	

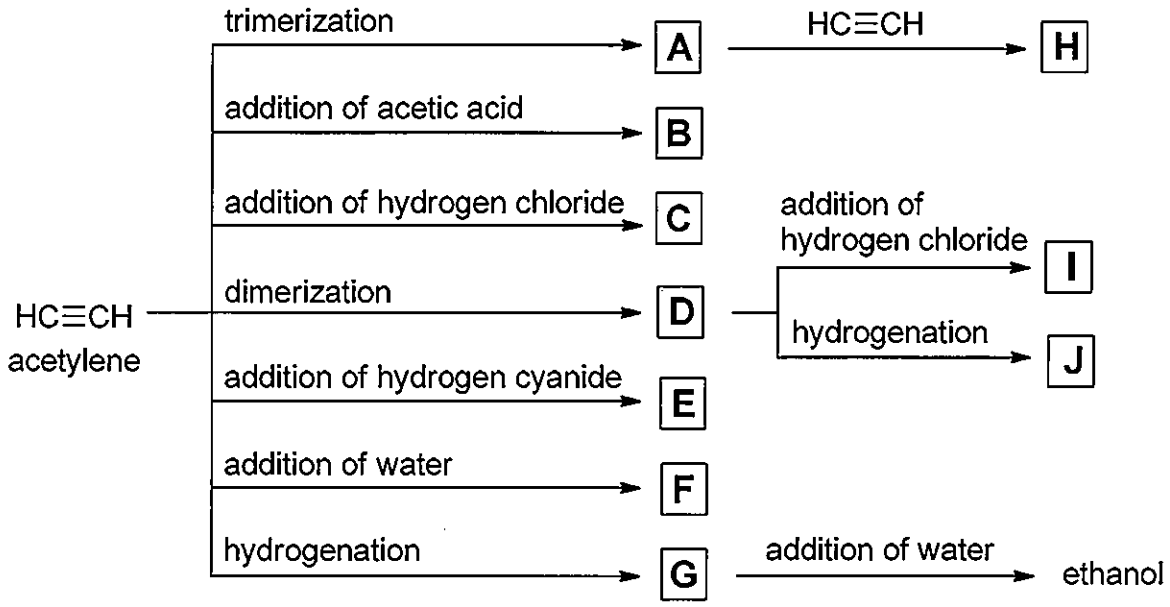
IV Think of a cubic unit cell of crystal that is composed of a single kind of atom. By placing atoms at every corner of the cube, a simple cubic lattice is formed. Assume that the atoms are perfect hard spheres with a radius r and that the atoms are in close contact to minimize the volume of the cube. Write the correct answers for (a) to (d) below to two significant figures.

(1) In the simple cubic lattice, the volume occupied by the atoms is (a) % that of the cube, and the length of the edge of the cube is (b) r.

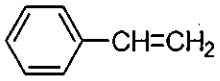
(2) To the simple cubic lattice described above, atoms are added to all the face-center positions of the cube. In the resulting lattice, the volume occupied by the atoms is (c) % of the cube, and the length of the edge of the cube is (d) r.

(a)	%	(b)	r
(c)	%	(d)	r

V Outlined here are synthetic processes of organic compounds. Select the structural formulas for the compounds **A** to **J** from (1)-(24).



(1) CH_3CH_2Cl (2) $CH_3CH_2OCH_3$ (3) CH_3CH_2CN (4) $BrHC{=}CHBr$ (5) $\left[CH_2{-}CH_2\right]_n$

(6) CH_3CHO (7) CH_3COOH (8) CH_3CH_2Br (9)  (10) $H_2C{=}CHCOCH_3$

(11) $H_2C{=}CH{-}C{\equiv}CH$ (12) $H_2C{=}CH_2$ (13) $H_2C{=}CHCN$ (14) CH_3OH (15) $H_3C{-}C(=O){-}CH_3$

(16) $CH_3CH_2CH_3$ (17)  (18) $H_2C{=}CH{-}C(Cl){=}CH_2$ (19) $H_2C{=}CHCl$ (20) $H_2C{=}CHOCCH_3$ (with O)

(21) CH_3CH_2OH (22) CH_3CH_2Cl (23) CH_2BrCH_2Br (24) $H_2C{=}CH{-}CH{=}CH_2$

A	B	C	D	E
F	**G**	**H**	**I**	**J**

VI Elementary analysis of the organic compound **X**, which is a liquid at room temperature and consists of carbon, hydrogen, and oxygen, shows C: 68.18%, H: 13.64 %, O: 18.18%. The molecular weight of **X** is 60. Answer questions (1)-(4). Use the following values for atomic weights: C: 12.0, H: 1.00, O: 16.0.

(1) Select the molecular formula of the compound **X**.
(a) C_2H_6O (b) $C_4H_{10}O$ (c) $C_5H_{12}O$ (d) $C_6H_{14}O$ (f) C_3H_8O (g) C_3H_7Cl

(2) The reaction of **X** with metallic sodium generates a gas. Which of the following gases are generated?
(a) oxygen (b) nitrogen (c) hydrogen chloride (d) chlorine (e) carbon dioxide (f) hydrogen

(3) Which of the following functional groups does **X** have?
(a) carboxylic acid (b) ester (c) alcohol (d) amine (e) aldehyde

(4) How many structural isomers of **X** have a chiral carbon center?

(1)	(2)	(3)	(4)

VII Answer the following questions about the amino acids ①—⑥.

① Alanine ② Glycine ③ Glutamic acid
④ Tyrosine ⑤ Methionine ⑥ Lysine

(1) Which of the descriptions (a) to (e) is not correct for the common properties of these amino acids?
(a) All are α-amino acids.
(b) Optical isomers (enantiomers) exist.
(c) All are water soluble.
(d) All consist of one amino group and one carboxylate group.
(e) All become purple when heated with ninhydrin test solution followed by cooling.

(2) Which has the smallest molecular weight?

(3) Which contains sulfur atoms?

(4) Which sodium salt is used as a synthetic seasoning?

(5) Which becomes yellow when heated with concentrated nitric acid?

(1)	(2)	(3)	(4)	(5)