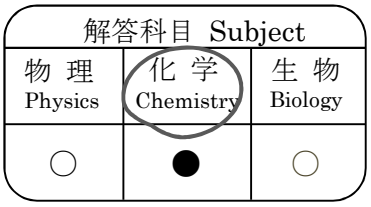
Chemistry

Making Your Choice of Subject on the Answer Sheet

Choose two subjects from Physics, Chemistry, and Biology, and answer the questions for each. Use the front of the answer sheet for one subject and the back e for the other.

As shown in the example on the right, if you answer the Chemistry questions, circle "Chemistry" and completely fill in the oval under the subject name.

＜解答用紙記入例＞



If you do not fill in the correct oval, your answers will not be graded.

Use the following values if necessary. Also, unless otherwise instructed, you may treat gases as ideal gases.

Avogadro's constant : $N_A = 6.02 \times 10^{23}$ /mol

Faraday's constant : $F = 9.65 \times 10^4$ C/mol

Gas constant : $R = 8.3 \times 10^3$ Pa·L/(mol·K)

Molar volume of an ideal gas at standard conditions (0℃, 1.013×10^5 Pa) : 22.4 L/mol

Atomic weights :

H＝1.0, He＝4.0, Li＝7.0, Be＝9.0, B＝10.8, C＝12.0, N＝14.0, O＝16.0,
F＝19.0, Ne＝20.2, Na＝23.0, Mg＝24.0, Al＝27.0, Si＝28.0, P＝31.0, S＝32.0,
Cl＝35.5, Ar＝40.0, K＝39.0, Ca＝40.0, Sc＝45.0, Ti＝48.0, V＝51.0, Cr＝52.0,
Mn＝55.0, Fe＝56.0, Co＝58.9, Ni＝58.7, Cu＝64.0, Zn＝65.0, Br＝80.0, Ag＝108,
Cd＝112, Sn＝119, I＝127, Ba＝137, Hg＝200, Pb＝207

Q1 Select the sentence that contains an error from the options ① to ⑥ below. 1

① Water and hydrogen peroxide are made of the same elements, so they are allotropes.
② Allotropes have different physical and chemical properties from each other.
③ A mixture of powdered white phosphorus and red phosphorus is a mixture.
④ The elements that make up hydrochloric acid are three in total.
⑤ The process of separating nitrogen and oxygen from liquid air is called fractional distillation.
⑥ The process of separating pure water from a sodium chloride solution is called distillation.

Q2 Select the appropriate atom that is likely to form a divalent cation and has the same number of protons and neutrons in its ion from the options ① to ⑥ below. 2

① $^{7}_{3}\mathrm{Li}$	② $^{17}_{8}\mathrm{O}$	③ $^{24}_{12}\mathrm{Mg}$
④ $^{42}_{20}\mathrm{Ca}$	⑤ $^{32}_{16}\mathrm{S}$	⑥ $^{12}_{6}\mathrm{C}$

Q3 Select the appropriate statement about the melting points and boiling points of substances under standard atmospheric pressure (1.013×10^{5} Pa) from the options ① to ⑥ below. 3

① The melting point of silicon dioxide is about 80℃.
② The boiling point of sodium chloride is lower than that of hydrogen chloride.
③ The melting point of sodium chloride is higher than that of sodium oxide.
④ The boiling point of diethyl ether is higher than that of ethanol.
⑤ he melting point of sodium is lower than that of aluminum.
⑥ The boiling point of water is lower than that of hydrogen sulfide.

Q4 Regarding a hydrocarbon gas, the mass of 2.0 L at 27℃ and 2.49×10^{5} Pa was measured to be 6.0 g. Select the appropriate total number of atoms constituting the molecule of this hydrocarbon from the options ① to ⑥ below. 4

① 2	② 4	③ 6
④ 8	⑤ 10	⑥ 12

Q5 A solution was prepared by dissolving 0.585 g of sodium chloride in 500 g of pure water. Upon cooling, the solution eventually began to freeze, and ice started to form. After further cooling, the temperature of the solution reached −0.200℃. Select the appropriate mass of the ice formed [g] from the options ① to ⑧ below. Assume that sodium chloride is completely ionized in the solution, and the molal freezing point depression constant of water is 1.85 K･kg/mol. 5

① 59	② 94	③ 120	④ 158
⑤ 201	⑥ 273	⑦ 315	⑧ 393

Q6 In a closed container with a constant volume, three types of gases, X, Y, and Z, were placed and maintained at a certain temperature. A reversible reaction expressed by

$$X + Y \rightleftarrows 2Z$$

reached equilibrium, with 5.00 mol of X, 7.20 mol of Y and 6.00 mol of Z present in the container. If 2.20 mol of X was added to the container and the temperature was kept the same, the system reached a new equilibrium. Select the appropriate amount of gas Z [mol] present at the final equilibrium from the options ① to ⑧ below. 6

① 3.60	② 4.70	③ 5.60	④ 6.80
⑤ 7.20	⑥ 7.65	⑦ 8.10	⑧ 8.45

Q7 The reaction where ammonia is produced from nitrogen and hydrogen is exothermic and can be expressed as the following reversible reaction:

$$N_2 + 3H_2 \rightleftarrows 2NH_3$$

When this reversible reaction has reached equilibrium in a closed container, how many of the following changes in conditions will shift the equilibrium towards the forward reaction (to the right)? Choose the correct number from the options ① to ⑥ below.

［List of Conditions］
- Keep the volume constant and increase the temperature.
- Keep the temperature constant and decrease the volume.
- Keep the temperature and volume constant and add nitrogen.
- Keep the temperature and volume constant and add argon.
- 温 Keep the temperature and total pressure constant and add argon.

① 1	② 2	③ 3
④ 4	⑤ 5	⑥ None

Q8 A 5.0 g sample of an organic substance containing nitrogen was mixed with concentrated sulfuric acid and heated to convert all the nitrogen into ammonium sulfate. The mixture was then heated with concentrated sodium hydroxide solution, and the resulting gas was completely absorbed in 25 mL of 1.00 mol/L dilute sulfuric acid. This dilute sulfuric acid was titrated with 0.50 mol/L sodium hydroxide solution, and the endpoint was reached at 20 mL. Select the appropriate nitrogen content (mass percentage) of the organic sample from the options ① to ⑨ below. 8

① 11	② 17	③ 22
④ 30	⑤ 38	⑥ 43
⑦ 51	⑧ 56	⑨ 64

Q9 A buffer solution of 200 mL was prepared by mixing 150 mL of 0.10 mol/L acetic acid solution and 50 mL of 0.10 mol/L sodium hydroxide solution. After adding 2.5 mL of 0.50 mol/L hydrochloric acid to this buffer solution, select the appropriate pH from the options ① to ⑨ below. Assume the ionization constant of acetic acid is $K_a = 2.7 \times 10^{-5}$ mol/L. Use $\log_{10}2 = 0.30$, $\log_{10}3 = 0.48$, $\log_{10}7 = 0.85$ if necessary. 9

① 1.9	② 2.4	③ 3.7
④ 4.1	⑤ 5.0	⑥ 6.2
⑦ 7.3	⑧ 8.0	⑨ 9.5

Q10 The following experiments were conducted with five metals, A through E. First, when these metals were placed in water at room temperature, only E reacted vigorously, releasing gas. Next, when reactivity with hydrochloric acid was tested, only A, B, and E dissolved. When A and B were placed in contact on a damp filter paper, A corroded faster than when placed alone on the filter paper. Furthermore, when C was placed in a solution of D's nitrate, D precipitated on the surface of C. Based on these results, select the appropriate metal as the fourth in order of decreasing reactivity (ionization tendency) from the options ① to ⑤ below. 10

① A	② B	③ C	④ D	⑤ E

Q11 A battery was made using 100 mL of 4.00 mol/L potassium hydroxide solution as the electrolyte, 20.2 g of nickel(Ⅲ) oxyhydroxide (NiO(OH)) as one electrode, and 15.0 g of cadmium (Cd) as the other electrode. During discharge, the NiO(OH) electrode reacts with water to form nickel(Ⅱ) hydroxide, and the Cd electrode reacts with hydroxide ions to form cadmium(Ⅱ) hydroxide. After discharging this battery with a current of 1.0 A for 4 hours, 1 minute, and 15 seconds, select the correct mass of the positive electrode [g] from the options ① to ⑨ below. 11

① 10.4	② 14.7	③ 16.8
④ 17.5	⑤ 18.3	⑥ 19.9
⑦ 20.4	⑧ 22.0	⑨ 24.2

Q12 When chlorine gas (Cl_2) is passed through a heated potassium hydroxide (KOH) solution, potassium chloride (KCl) and potassium chlorate ($KClO_3$) are formed. Select the correct coefficient of potassium chlorate in the chemical reaction equation representing this change from the options ① to ⑨ below. 12

① 1	② 2	③ 3	④ 4	⑤ 5
⑥ 6	⑦ 7	⑧ 8	⑨ 9	

Q13 Among the allotropes of carbon, fullerene includes several types, with C_{60} fullerene being one in which the molecular structure consists of 60 carbon atoms, each bonded to three other carbon atoms to form pentagons and hexagons. In each hexagon, three pentagons and hexagons are alternately connected. Select the correct number of bonds between carbon atoms within a single C_{60} fullerene molecule from the options ① to ⑨ below. 13

① 30	② 45	③ 60
④ 76	⑤ 90	⑥ 110
⑦ 120	⑧ 156	⑨ 180

Q14 Among the following statements (a) to (e) about sodium, select the correct combination from the options ① to ⑩ below. 14

(a) Sodium naturally exists mainly as a free element in large quantities in seawater.
(b) Heating sodium carbonate produces sodium bicarbonate.
(c) Electrolysis of an aqueous sodium chloride solution yields metallic sodium.
(d) Adding hydrochloric acid to an aqueous sodium bicarbonate solution produces sodium chloride.
(e) Adding carbon dioxide to an aqueous sodium hydroxide solution produces sodium carbonate.

① a, b	② a, c	③ a, d	④ a, e	⑤ b, c
⑥ b, d	⑦ b, e	⑧ c, d	⑨ c, e	⑩ d, e

Q15 The crystal structure of iron changes from face-centered cubic to body-centered cubic with changes in temperature. Among the following statements (a) to (e) regarding this change in crystal structure, select the correct combination from the options ① to ⑩ below. 15

(a) The oxidation state of the iron atoms changes.
(b) The mass remains unchanged.
(c) The volume remains unchanged.
(d) The density decreases.
(e) The packing efficiency increases.

① a, b	② a, c	③ a, d	④ a, e	⑤ b, c
⑥ b, d	⑦ b, e	⑧ c, d	⑨ c, e	⑩ d, e

Q16 Under standard temperature and pressure (STP), how many of the following substances mix well with water? Select the correct number from the options ① to ⑧ below. 16

[List of Substances] Ethanol, Acetaldehyde, Diethyl ether, Acetone, Ethyl acetate
Ethylene glycol, Benzenesulfonic acid, Nitroglycerin

① 1	② 2	③ 3	④ 4
⑤ 5	⑥ 6	⑦ 7	⑧ 8

Q17 An analysis of a pure fat, A, showed a saponification value of 191 and an iodine value of 174. The saponification value represents the mass of potassium hydroxide (in mg) required to completely saponify 1 g of fat, while the iodine value represents the mass of iodine (in g) that can be added to 100 g of fat. Assuming that the fat A consists of only one type of fatty acid, select the appropriate molecular formula of this fatty acid from the options ① to ⑨ below. 17

① $C_{16}H_{32}O_2$	② $C_{16}H_{30}O_2$	③ $C_{16}H_{28}O_2$
④ $C_{18}H_{36}O_2$	⑤ $C_{18}H_{34}O_2$	⑥ $C_{18}H_{32}O_2$
⑦ $C_{20}H_{40}O_2$	⑧ $C_{20}H_{38}O_2$	⑨ $C_{20}H_{36}O_2$

Q18 Complete combustion of 21.2 g of an aromatic compound X produced 18.0 g of water and 70.4 g of carbon dioxide. Additionally, another experiment determined that the molecular weight of X is approximately 100. When one hydrogen atom attached to the benzene ring in X was replaced with a bromine atom, two different compounds were obtained in total. Furthermore, oxidation of X with potassium permanganate yielded compound Y, which, upon heating, produced compound Z. Select the appropriate molecular weight of compound Z from the options ① to ⑨ below. 18

① 120	② 132	③ 148
④ 154	⑤ 164	⑥ 170
⑦ 182	⑧ 190	⑨ 210

Q19 When Fehling's solution is added to an aqueous solution of reducing sugars such as glucose and heated, a red precipitate of copper(I) oxide is obtained, with 1 mol of sugar producing 1 mol of copper(I) oxide. Solution A contains 0.10 mol of maltose, 0.20 mol of lactose, and 0.10 mol of sucrose. After adding maltase and lactase to A and allowing the enzyme reactions to proceed to completion, the reaction solution was dialyzed to separate the enzymes and sugars, resulting in solution B containing only sugars. When an excess of Fehling's solution is added to B and heated, select the appropriate mass of the red precipitate [g] formed from the options ① to ⑨ below. 19

① 18	② 35	③ 52
④ 63	⑤ 77	⑥ 86
⑦ 96	⑧ 112	⑨ 140

Q20 Select the appropriate polymer compound that is synthesized by ring-opening polymerization of a monomer with a ring structure from the options ① to ⑧ below. 20

① Polyethylene terephthalate
② Vinylon
② Polyvinyl chloride
④ Polystyrene
⑤ Nylon 6
⑥ Nylon 66
⑦ Phenol resin
⑧ Butadiene rubber

Q21 Figure 1 shows the relationship between the concentration c and the degree of ionization α of a weak acid HA. Among the following statements (a) to (e) regarding the aqueous solution of HA, select the correct combination from the options ① to ⑩ below. Note that the ionization of water is to be ignored. 21

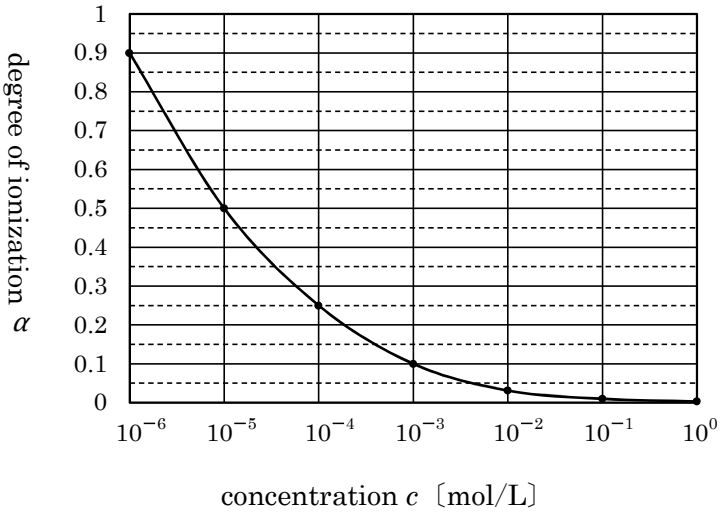


Figure 1

(a) The degree of ionization increases indefinitely as the concentration decreases.
(b) As the concentration decreases, the hydrogen ion concentration increases.
(c) The pH of a 10^{-3} mol/L solution is approximately 4.
(d) The concentration of A^- produced by ionization is the same in solutions with concentrations of 10^{-3} mol/L and 10^{-4} mol/L
(e) In a 10^{-5} mol/L solution, the concentration of undissociated HA molecules and the concentration of hydrogen ions are the same.

① a, b ② a, c ③ a, d ④ a, e ⑤ b, c
⑥ b, d ⑦ b, e ⑧ c, d ⑨ c, e ⑩ d, e

Q22 Figure 2 shows the relationship between the pressure P and volume V of a gas. Among the following statements (a) to (e) regarding this figure, select the correct combination from the options ① to ⑩ below. 22

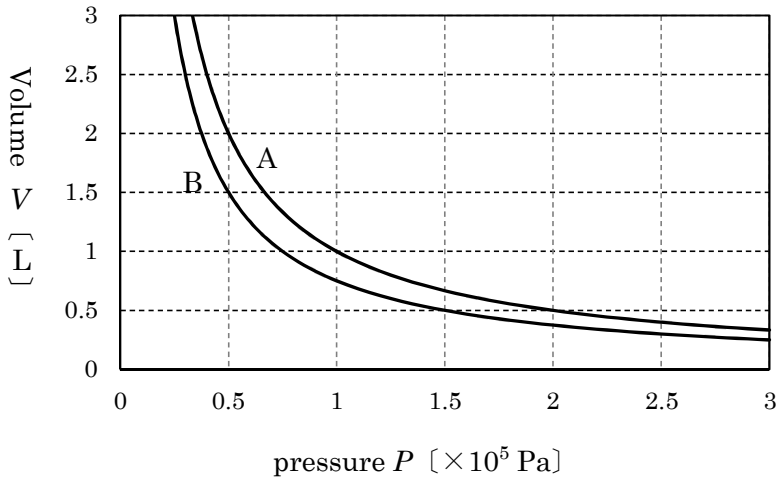


Figure 2

(a) If A and B are graphs of different gases at the same mass and temperature, A represents the gas with the larger molecular weight.

(b) If A and B are graphs of the same gas at the same mass, A represents the gas at the higher temperature.

(c) If A and B are graphs of the same gas at the same temperature, B represents the gas with the larger amount of substance.

(d) If A is the graph at 0℃, the molecular weight of the gas can be determined.

(e) If B is the graph at 27℃, the volume of the gas at standard conditions can be determined.

① a, b	② a, c	③ a, d	④ a, e	⑤ b, c
⑥ b, d	⑦ b, e	⑧ c, d	⑨ c, e	⑩ d, e

End of Chemistry questions. Leave the answer spaces 23 ~ 75 blank.

Please check once more that you have properly marked the name of your subject as "Chemistry" on your answer sheet.

Do not take this question booklet out of the room.