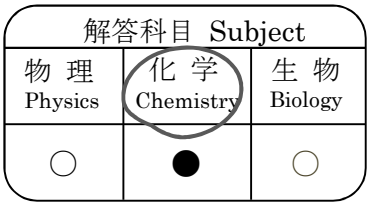
Chemistry

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 How many of the statements in the word group below illustrate Proust's "Law of Definite Proportions"? Select one correct answer from options ① to ⑥ below. 1

［Word group］

- The volume of 8 g of methane and 22 g of carbon dioxide at standard conditions is equal.
- The amount of heat generated when 16 g of methane is completely burned is 892 kJ.
- Regardless of how ammonia is synthesized, the mass ratio of its constituent elements is H : N = 3:14.
- When 2 L of carbon monoxide and 1 L of oxygen are reacted at standard conditions, 2 L of carbon dioxide is produced.
- When an aqueous solution of sodium chloride is electrolyzed, the amount of gas generated at the anode and the cathode is equal.

① 1　② 2　③ 3
④ 4　⑤ 5　⑥ None of the above

Q2 Boron has two isotopes: $^{10}_{5}B$ (relative atomic mass = 10) and $^{11}_{5}B$ (relative atomic mass = 11), with natural abundances of 19.6% and 80.4%, respectively. Chlorine also has two isotopes: $^{35}_{17}Cl$ (relative atomic mass = 35) and $^{37}_{17}Cl$ (relative atomic mass = 37), with natural abundances of 75.5% and 24.5%, respectively. Which of the following is the most appropriate relative molecular mass of boron trichloride (BCl_3), considering the most abundant isotopes in nature? Choose one correct answer from options ① to ⑨ below. 2

① 115　② 116　③ 117
④ 118　⑤ 119　⑥ 120
⑦ 121　⑧ 122　⑨ 123

Q3 Methanol is primarily synthesized from natural gas. When methane, the main component of natural gas, reacts with steam, the following reaction occurs:

$$CH_4(g) + H_2O(g) \longrightarrow CO(g) + 3H_2(g)$$

The mixture of carbon monoxide and hydrogen obtained from this reaction is called synthesis gas. When synthesis gas reacts using a catalyst, methanol is produced as follows:

$$CO\ (g) + 2H_2\ (g) \rightarrow CH_3OH\ (g)$$

In this methanol synthesis reaction, carbon monoxide and hydrogen react in a 1:2 molar ratio without any excess, but the mixture of carbon monoxide and hydrogen in synthesis gas has a ratio of 1:3. Therefore, in practice, carbon dioxide is added to the synthesis gas and the following reaction is carried out to adjust the molar ratio of carbon monoxide to hydrogen to 1:2 before the methanol synthesis reaction is performed:

$$CO_2\ (g) + H_2\ (g) \rightarrow CO\ (g) + H_2O\ (g)$$

In the process described above, what is the maximum amount of methanol (in moles) that can be synthesized from 3.0 mol of methane? Choose the correct answer from options ① to ⑨. 3

① 2.0	② 2.5	③ 3.5
④ 4.0	⑤ 5.0	⑥ 5.5
⑦ 6.0	⑧ 6.5	⑨ 7.0

Q4 The energy required to break 1 mol of covalent bonds in gaseous molecules is called bond energy. The bond energies for several bonds are shown below:

Bond	Bond Energy〔kJ/mol〕
C−C	368
C−H	411
O−H	459
O=O	494
C=O	799

When 1.0 mol of a gaseous straight-chain alkane was completely combusted, carbon dioxide (gas) and water (liquid) were produced, and the amount of heat released was 2777 kJ. Choose the correct name of this alkane from the options ① to ⑨. Assume that the heat absorbed when 1 mol of liquid water changes to gas is 44 kJ. 4

① Ethylene	② Hexane	③ Acetylene
④ Propylene	⑤ Methane	⑥ Propane
⑦ Butane	⑧ Isoprene	⑨ Ethane

Q5 Disodium hydrogen phosphate is an [a] salt. In its aqueous solution, the salt undergoes [b], resulting in a [c] property. Choose the correct combination of terms for [a] to [c] from options ① to ⑥. [5]

	[a]	[b]	[c]
①	Acidic	Ionization	Acidic
②	Acidic	Hydrolysis	Basic
③	Neutral	Ionization	Acidic
④	Neutral	Hydrolysis	Basic
⑤	Basic	Ionization	Acidic
⑥	Basic	Hydrolysis	Basic

Q6 You pulverized 10 g of a food containing lactic acid and placed it in a flask. After adding 50 mL of water and mixing well, a few drops of phenolphthalein solution were added. Using a 0.100 mol/L sodium hydroxide solution, you performed a neutralization titration, which reached the endpoint at 11.2 mL. What is the percentage of lactic acid (mass percent) in this food? Choose the correct answer from options ① to ⑨. Assume that the food contains no other acids besides lactic acid. [6]

① 1.0	② 2.4	③ 3.2
④ 4.0	⑤ 4.7	⑥ 5.1
⑦ 6.3	⑧ 7.0	⑨ 8.6

Q7 A Daniell cell is constructed by separating a zinc sulfate solution and a copper(II) sulfate solution with a porous ceramic plate, immersing a zinc electrode in the zinc sulfate solution, and a copper electrode in the copper(II) sulfate solution. Among the following statements (a) to (e) about the Daniell cell, choose the correct combination of statements from options ① to ⑩. 7

(a) The electromotive force is approximately 1.1 V.

(b) Replacing the porous ceramic plate with a glass plate does not change the electromotive force.

(c) During discharge, sulfate ions move from the copper(II) sulfate solution to the zinc sulfate solution.

(d) During discharge, gas is produced at the positive electrode.

(e) If the copper electrode is replaced with a platinum electrode, the current will flow in the opposite direction.

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

Q8 At 0°C and 1.0×10^{5} Pa, the amount of nitrogen and oxygen that dissolve in 1.0 L of water is 1.03×10^{-3} mol and 2.18×10^{-3} mol, respectively. When 2.0 L of water is in contact with air at 0°C and 1.0×10^{5} Pa and reaches dissolution equilibrium, choose the appropriate total mass of dissolved gases (in mg) from options ① to ⑨. Assume that the composition of air is nitrogen : oxygen = 4:1 by volume. 8

① 16	② 34	③ 57
④ 68	⑤ 74	⑥ 88
⑦ 93	⑧ 106	⑨ 118

Q9 When a few drops of 30% ferric chloride ($FeCl_3$) solution are added to boiling water, a reddish-brown solution is obtained. Among the following statements (a) to (e) about this solution, choose the correct combination of statements from options ① to ⑩. 9

(a) It shows basicity.
(b) Adding hydrogen peroxide causes chemiluminescence to be observed.
(c)Adding sodium sulfate results in the formation of a precipitate.
(d) When electrodes are immersed and a direct current voltage is applied, the reddish-brown substance moves toward the cathode.
(e) When placed in a cellophane bag and immersed in pure water, the solution inside the bag becomes colorless.

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

Q10 When hydrochloric acid is added to ammonia water and exactly neutralized, choose the correct combination of the following ion concentration equations (a) to (e) from options ① to ⑩. 10

(a) $[H^+] = [OH^-]$
(b) $[NH_3] + [NH_4^+] = [Cl^-]$
(c) $[NH_3] = [NH_4^+]$
(d) $[NH_4^+] + [H^+] = [Cl^-] + [OH^-]$
(e) $[H^+] = [Cl^-]$

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

Q11 Sodium chloride is gradually added to a saturated solution of silver chloride until the sodium ion concentration is adjusted to 1.0×10^{-2} mol/L. What is the appropriate concentration of silver ions (mol/L) in this solution? Choose one correct answer from options ① to ⑨ below. Assume the solubility product of silver chloride is $K_{sp}=8.2\times10^{-11}$ $(\text{mol/L})^2$. 11

① 4.1×10^{-5} ② 8.2×10^{-5} ③ 4.1×10^{-7}
④ 8.2×10^{-7} ⑤ 4.1×10^{-9} ⑥ 8.2×10^{-9}
⑦ 4.1×10^{-11} ⑧ 8.2×10^{-11} ⑨ 4.1×10^{-13}

Q12 In the Haber-Bosch process for ammonia production, unreacted nitrogen and hydrogen gases are mixed with the produced ammonia. Which method is used to separate ammonia from the unreacted gases? Choose one correct answer from options ① to ⑥ below. 12

① Cool and condense. ② Dissolve in hot water to separate.
③ Centrifuge. ④ Convert to ammonium chloride and solidify.
⑤ Use a semipermeable membrane for dialysis.
⑥ Lower the pressure to condense.

Q13 Which of the following reactions produces the gas with the largest molecular weight? Choose one correct answer from options ① to ⑥ below. 13

① Add dilute nitric acid to copper.
② Add concentrated nitric acid to copper.
③ Add dilute hydrochloric acid to iron(II) sulfide.
④ Add dilute sulfuric acid to zinc.
⑤ Add dilute sulfuric acid to sodium bisulfite.
⑥ Heat manganese(IV) oxide with concentrated hydrochloric acid.

Q14 When a pure copper plate is immersed in 200 mL of silver nitrate solution, 3.24 g of silver is deposited on the surface. What is the concentration of copper ions (mol/L) in the solution at this point? Assume the volume of the solution remains 200 mL. Choose one correct answer from options ① to ⑨ below. 14

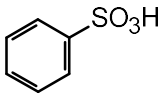
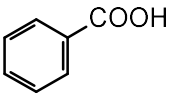
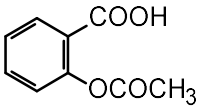
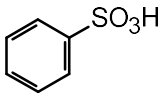
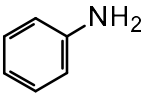
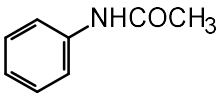
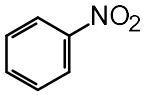
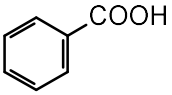
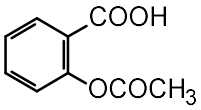
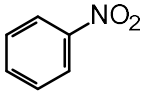
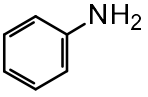
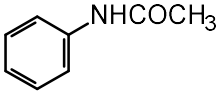
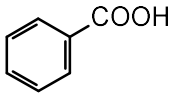
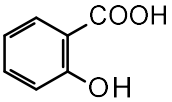
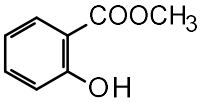
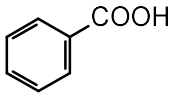
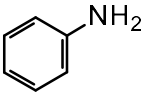
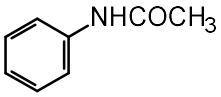
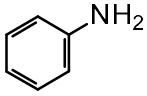
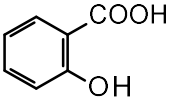
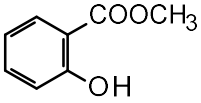
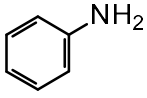
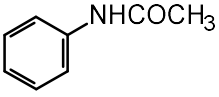
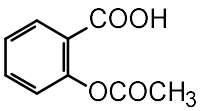
① 2.3×10^{-1}	② 5.4×10^{-1}	③ 9.7×10^{-1}
④ 7.5×10^{-2}	⑤ 8.2×10^{-2}	⑥ 9.6×10^{-2}
⑦ 6.1×10^{-3}	⑧ 7.0×10^{-3}	⑨ 8.8×10^{-3}

Q15 A sample of 175 mg of an alkene A was measured as a gas at 27°C and 5.0×10^{4} Pa, with a density of 1.4 g/L. How many possible isomers (including cis-trans isomers) of alkene A can exist? Choose one correct answer from options ① to ⑧ below. 15

① 1	② 2	③ 3	④ 4
⑤ 5	⑥ 6	⑦ 7	⑧ 8

Q16 When benzene is reacted with concentrated nitric acid and concentrated sulfuric acid, compound [d] is produced. When [d] is heated with hydrochloric acid and tin pieces, the solution becomes homogeneous. When sodium hydroxide solution is added, an oily compound [e] separates. Reacting [e] with acetic anhydride produces compound [f], which has antipyretic and analgesic properties.

Which combination of structures corresponds to compounds [d] to [f]? Choose one correct answer from options ① to ⑧ below. [16]

	d	e	f
①			
②			
③			
④			
⑤			
⑥			
⑦			
⑧			

Q17 Trehalose is used as a food additive and has a structure in which two molecules of α-glucose are dehydrated and condensed, similar to maltose. However, unlike maltose, its aqueous solution does not exhibit reducing properties. Which glycosidic bond does trehalose possess? Choose one correct answer from options ① to ⑨ below. 17

① α-1,1-glycosidic bond ② α-1,4-glycosidic bond ③ α-1,6-glycosidic bond
④ α-2,2-glycosidic bond ⑤ α-2,4-glycosidic bond ⑥ α-3,4-glycosidic bond
⑦ α-4,4-glycosidic bond ⑧ α-4,6-glycosidic bond ⑨ α-6,6-glycosidic bond

Q18 Cellulose was reacted with acetic anhydride, and all the hydroxyl groups in the cellulose were completely esterified to produce triacetyl cellulose. This was partially hydrolyzed to form diacetyl cellulose, and 246 g of acetate fiber was obtained after drying. What is the mass of cellulose (in grams) originally used as the raw material? Choose one correct answer from options ① to ⑨ below. 18

① 104 ② 120 ③ 138
④ 149 ⑤ 155 ⑥ 162
⑦ 180 ⑧ 208 ⑨ 222

Q19 Which of the following statements (a) to (e) about proteins are correct? Choose the most appropriate combination from options ① to ⑩ below. 19

(a) All constituent amino acids contain a chiral carbon atom.
(b) The sequence of amino acids is called the primary structure.
(c) A partial helical structure (α-helix) is called the tertiary structure.
(d) All proteins have a complex folded three-dimensional structure.
(e) Hemoglobin is a protein with a quaternary structure.

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

Q20 Nucleic acids include RNA and DNA, both of which are linear polymers composed of many nucleotides. Nucleotides are made up of a sugar, [g], and a base. The bases in the nucleotides that make up DNA include adenine, guanine, thymine, and [h], with complementary adenine and thymine forming [i] hydrogen bonds in the double helix structure of DNA. Which combination of words corresponds to [g], [h], and [i]? Choose one correct answer from options ① to ⑧ below. [20]

	[g]	[h]	[i]
①	Phosphate	Glycine	2
②	Phosphate	Glycine	3
③	Phosphate	Cytosine	2
④	Phosphate	Cytosine	3
⑤	Amino	Glycine	2
⑥	Amino	Glycine	3
⑦	Amino	Cytosine	2
⑧	Amino	Cytosine	3

Q21　Figure 1 is the phase diagram of carbon dioxide. Which of the following statements (a) to (e) about this diagram are correct? Choose the most appropriate combination from options ① to ⑩ below. 21

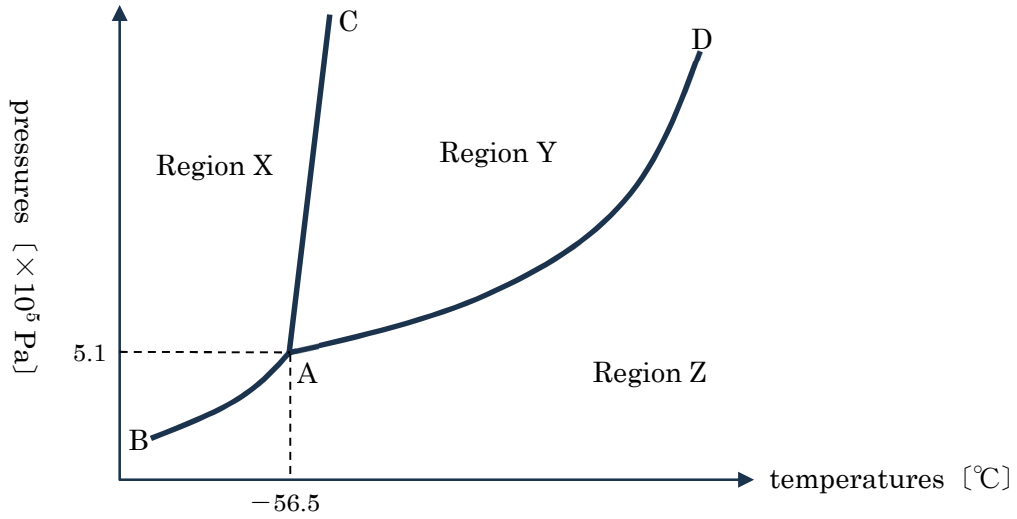


Figure 1　Phase Diagram of Carbon Dioxide

(a)　Region X represents gas, Y represents liquid, and Z represents solid.

(b)　Carbon dioxide can be liquefied at pressures lower than 5.1×10^5 Pa.

(c)　Carbon dioxide gas can be liquefied by increasing pressure at temperatures above −56.5℃.

(d)　The melting point of solid carbon dioxide increases as pressure is applied.

(e)　The curve AB is called the sublimation curve, and the curve AD is called the melting curve.

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 Nitrogen gas is placed in a container with a variable volume, and while maintaining a constant temperature, the volume is gradually decreased. The pressure changes as shown in Figure 2. Which of the following statements (a) to (e) about this are correct? Choose the most appropriate combination from options ① to ⑩ below. 22

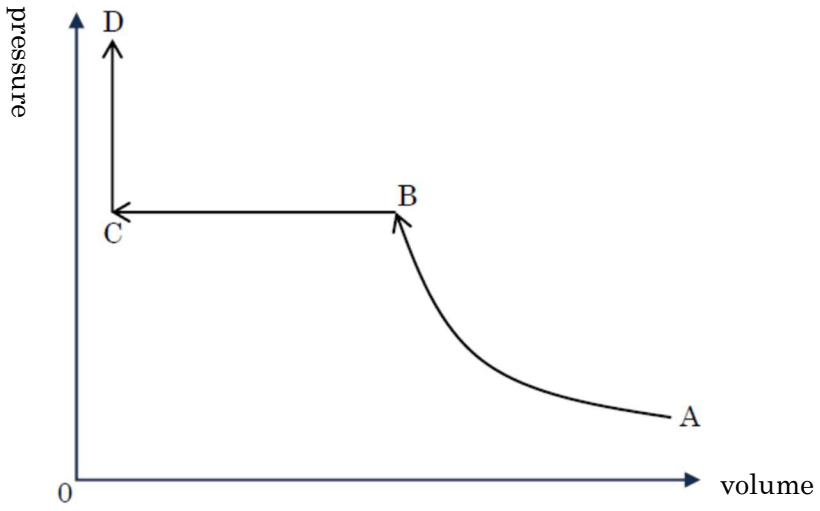


Figure 2

(a) Between A and B, the density of the gas does not change even as the volume decreases.
(b) The pressure at point B changes depending on the temperature.
(c) Between B and C, the container needs to be heated to maintain a constant temperature.
(d) Boyle's law holds between B and C.
(e) Between C and D, nitrogen is in a liquid state.

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.