

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 of the following ions has the same electron configuration as Ne atom?

- 1) K^+ 2) Mg^{2+} 3) Fe^{3+} 4) Cl^-

(2) Which of the following molecules has the longest bond distance?

- 1) H_2 2) N_2 3) F_2 4) Cl_2

(3) Which of the following substances is regarded as a molecular crystal at ambient temperature and pressure?

- 1) silicon 2) sodium chloride 3) calcium 4) iodine

(4) Which of the aqueous solutions of the following compounds has the lowest acidity?

- 1) HF 2) HCl 3) HBr 4) HI

(5) Which of the following descriptions is correct for phosphorus and sulfur?

- 1) Both are group 16 elements.
- 2) Both have allotropes.
- 3) Both oxides exist as solid at ambient temperature and pressure.
- 4) Both oxides produce basic solutions when dissolved into water.

(6) Which of the following reactions is accompanied by the generation of oxygen?

- 1) Blowing fluorine into water.
- 2) Addition of sulfuric acid to zinc.
- 3) Addition of water to potassium.
- 4) Addition of hydrochloric acid to copper(II) oxide.

(7) Which of the following descriptions on industrial smelting process is not correct?

- 1) Sodium is obtained by electrolysis of molten salt.
- 2) Aluminum is extracted by reducing aluminum oxide with chromium.
- 3) Iron is extracted by reducing iron oxide with coke.
- 4) Blister copper is purified by electrolysis refining.

II Give the appropriate values for (a) to (g) in the following statements. Calculate the values to two significant figures for (f) and (g). Use the following values if necessary; $\sqrt{2}=1.4$, the atomic weight of Au is 197, and the Avogadro constant is $6.0 \times 10^{23} \text{ mol}^{-1}$.

(1) Ammonia reacts with oxygen to form nitric oxide and water. The chemical reaction equation is as follows:



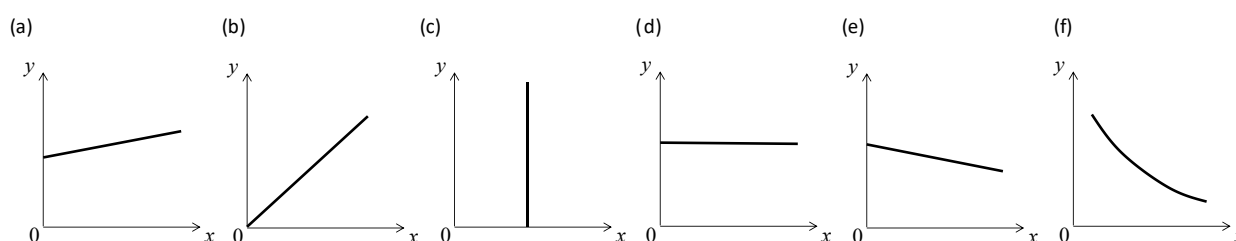
(2) A face-centered cubic structure contains (d) atoms in its unit cell. In the structure, one atom is surrounded by (e) nearest-neighboring atoms. Gold crystallizes in the face-centered cubic structure under ambient conditions. The edge length of the cubic unit cell of gold is 0.41 nm. The atomic radius of gold atom is (f) nm, and the density of crystalline gold is (g) g cm^{-3} .

III Answer the following questions about ideal gas, where P is pressure, V is volume and T is absolute temperature.

(1) Which of graphs (a) to (f) in the figure below shows the relation between P (x -axis) and V (y -axis) for a fixed amount of gas at constant T ?

(2) Which of graphs (a) to (f) in the figure below shows the relation between T (x -axis) and P (y -axis) for a fixed amount of gas at constant V ?

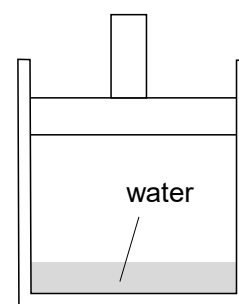
(3) Which of graphs (a) to (f) in the figure below shows the relation between P (x -axis) and PV/T (y -axis) for a fixed amount of gas?



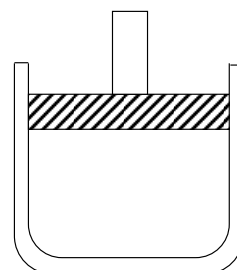
(4) When nitrogen and water were added into a volume-variable reactor with a smooth piston as shown in the figure below, the volume of gas was 3.0 L and the total pressure was 4.3×10^4 Pa. Temperature was kept at 27°C . The saturated vapor pressure of water is 3.0×10^3 Pa at 27°C . Dissolution of N_2 gas in water is negligible.

(4-1) Calculate the partial pressure of nitrogen to two significant figures.

(4-2) The piston was moved to decrease the volume of gas to 2.0 L at constant temperature of 27°C . Calculate the total pressure to two significant figures.



IV First, 3.0 moles of N_2 and 9.0 moles of H_2 were added into a volume-variable reactor with a smooth piston as shown in the figure below. Next, the ammonia synthesis reaction ($\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$ $\Delta H = -92 \text{ kJ}$) proceeded at constant temperature and constant pressure in the presence of a solid catalyst. After the reaction reached to an equilibrium state, the mole fraction of NH_3 was 50%. The volume of the mixed gas was 3.0 L before the reaction. All gases can be regarded as ideal gases.



(1) Calculate the number of moles for N_2 , H_2 and NH_3 after the reaction to two significant figures.

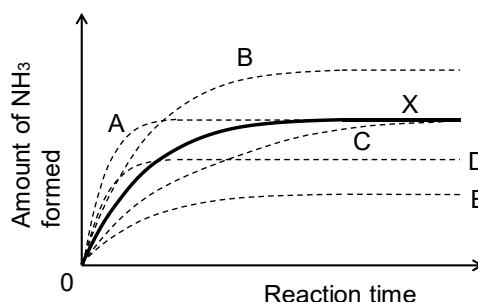
(2) Calculate the amount of heat generated by the reaction.

(3) Calculate the volume of the mixed gas after the reaction to two significant figures.

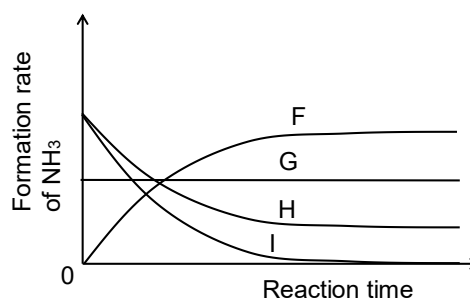
(4) Calculate the equilibrium constant to two significant figures.

(5) Line X in the figure on the right shows the time course of the amount of NH_3 formation. When the reaction conditions are changed as below, which of lines A – E will be obtained, if

- 1) a catalyst with higher activity is added.
- 2) the temperature is raised.



(6) The figure on the right shows the time course of the apparent rate of NH_3 formation under the same reaction conditions that give Line X above. Which of lines F–I is correct?



V Answer the following questions about organic compounds. Use the following values if necessary; the atomic weights of C, O, and H are 12.0, 16.0, and 1.00, respectively.

There is compound **A**, which is made up of carbon, hydrogen, and oxygen atoms. When 50.5 mg of compound **A** was combusted completely with dry oxygen, 110 mg of CO_2 and 40.5 mg of H_2O were obtained. A complete hydrolysis of compound **A** gave compounds **B** and **C** at a 2:1 molar ratio. Compound **B** reacted with sodium to give hydrogen gas. When compound **B** was oxidized, compound **D**, which gives a positive Tollens' test (silver mirror test), was formed. Further oxidation of compound **D** produced compound **E**. Each of compounds **B** and **E** produced a yellow precipitate by the treatment with I_2 and NaOH_{aq} . Compound **C** is the starting material for nylon 6,6.

(1) Write the appropriate values for x , y , and z in the molecular formula $\text{C}_x\text{H}_y\text{O}_z$ of compound **A**. The molecular weight of compound **A** does not exceed 300.

(2) Chose the appropriate structural formulas for compounds **B**, **C**, **D**, and **E** from options 1) to 20).

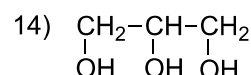
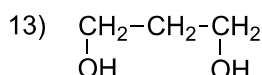
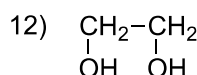
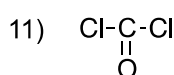
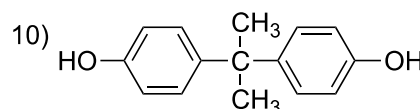
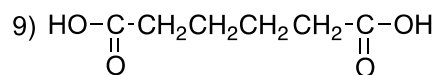
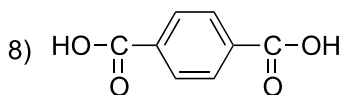
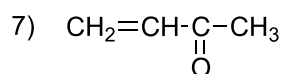
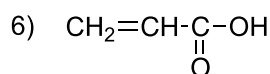
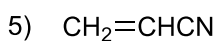
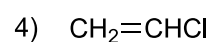
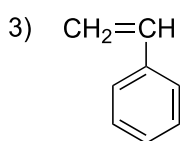
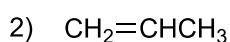
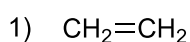
- 1) $\text{CH}_3\text{CH}_2\text{CH}_3$ 2) CH_3CH_3 3) $\text{CH}_3\text{CH}_2\text{OH}$ 4) $\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3$ 5) $\text{HOCH}_2\text{CH}_2\text{OH}$
 6) CH_3CHO 7) CH_3COOH 8) $\text{CH}_2=\text{CHCH}_2\text{CH}_3$ 9) $\text{CH}_3\text{CH}=\text{CHCH}_3$ 10) HCHO
 11) $\text{CH}_3\text{CH}_2\text{COOH}$ 12) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$ 13) $\text{CH}_3-\underset{\text{Cl}}{\text{CH}}-\text{CH}_2\text{CH}_3$ 14) $\text{CH}_3-\overset{\text{O}}{\underset{\text{O}}{\text{C}}}-\text{CH}_2\text{CH}_3$
 15) $\text{CH}_3-\underset{\text{OH}}{\text{CH}}-\text{CH}_2\text{CH}_3$ 16) $\text{HO}-\overset{\text{O}}{\underset{\text{O}}{\text{C}}}-\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2-\overset{\text{O}}{\underset{\text{O}}{\text{C}}}-\text{OH}$ 17) $\text{HO}-\overset{\text{O}}{\underset{\text{O}}{\text{C}}}-\text{CH}_2\text{CH}_2\text{CH}_2-\overset{\text{O}}{\underset{\text{O}}{\text{C}}}-\text{OH}$
 18) $\text{HO}-\overset{\text{O}}{\underset{\text{O}}{\text{C}}}-\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}_2-\overset{\text{O}}{\underset{\text{O}}{\text{C}}}-\text{OH}$ 19) $\text{HO}-\overset{\text{O}}{\underset{\text{O}}{\text{C}}}-\text{CH}_2\text{CH}=\text{CH}-\text{CH}_2-\overset{\text{O}}{\underset{\text{O}}{\text{C}}}-\text{OH}$ 20) CO_2

(3) Compound **F**, which has nitrogen atom(s), is used as another starting material with compound **C** for the synthesis of nylon 6,6. Write the appropriate values for a , b , and c in the molecular formula $\text{C}_a\text{H}_b\text{N}_c$ of Compound **F**.

VI Answer the following questions about polymers. Use the following values if necessary; the atomic weights of C, O, and H are 12.0, 16.0, and 1.00, respectively.

(1) Choose the appropriate structural formulas for constituent monomer units of synthetic polymers a) to c) from options 1) to 14).

a) Polystyrene b) Polyvinyl chloride c) Polypropylene



(2) Choose the appropriate structural formulas for the two constituent monomer units of polyethylene terephthalate from options 1) to 14) that are shown in question (1).

(3) For a polyethylene terephthalate with an average molecular weight of 2.00×10^4 , calculate the average degrees of polymerization to three significant figures.

(4) How many molecules of glucose ($\text{C}_6\text{H}_{12}\text{O}_6$) react in a dehydration reaction to produce a molecule of amylose with a molecular weight of 2.70×10^5 ? Calculate the value to three significant figures.

(5) Iodine test is positive for amylose, but is negative for cellulose. Chose the appropriate reason for this difference from options 1) to 4).

- 1) Cellulose has a helical structure, while amylose does not.
- 2) Amylose has a helical structure, while cellulose does not.
- 3) Amylose is stable, while cellulose is not.
- 4) Cellulose is stable, while amylose is not.