

※注意：請於試卷上「非選擇題作答區」標明題號並依序作答。

*請在答案卷上標明題號依序作答

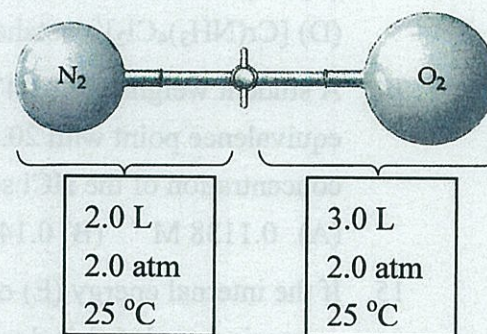
$$C = 3.00 \times 10^8 \text{ m/s}; h = 6.63 \times 10^{-34} \text{ J-s}; R_H = 1.096776 \times 10^7 \text{ m}^{-1}; F = 96500 \text{ C/mol}$$

$$\text{Gas constant: } R = 8.314 \text{ J/mol-K} = 0.0821 \text{ L-atm/mol-K}$$

$$\text{Na} = 23.00, \text{H} = 1.01, \text{C} = 12.01, \text{O} = 16.00, \text{N} = 14.01, \text{P} = 30.97$$

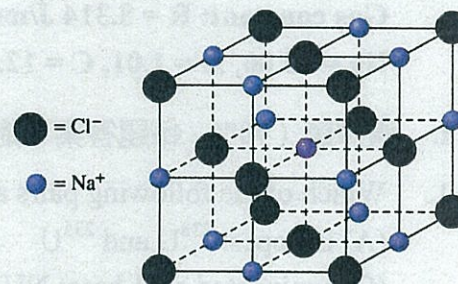
I. 選擇題 (90%, 每題答案可能 1 至多個, 全部選對始得題分 3 分)

- Which of the following pairs are the correct illustrations?
 (A) isotopes: ^{238}U and ^{235}U (B) allotrope: graphite, C_{60}
 (C) conjugated acid-base: NH_3 , NH_2^- (D) isomers: CH_3OCH_3 , $\text{CH}_3\text{CH}_2\text{OH}$
- Common commercial nitric acid is 70% by mass and has density 1.42 g/cm^3 . Calculate the molarity (mol/L) of the acid.
 (A) 11 M (B) 12 M (C) 16 M (D) 23 M (E) none of the above
- Which of the following reagent can be used to separate the cation Mg^{2+} from Pb^{2+} ?
 (A) NaOH(aq) (B) Na_2CO_3 (C) H_2SO_4 (D) HCl(aq)
- One mole of CH_4 and one mole of SO_2 gas are placed in a container. Choose the correct statements.
 (A) The ratio of partial pressure, $P_{\text{CH}_4} : P_{\text{SO}_2} = 1:1$
 (B) The ratio of average kinetic energy, $\overline{KE}_{\text{CH}_4} : \overline{KE}_{\text{SO}_2} = 1:1$
 (C) The ratio of root-mean-square speed, $u_{\text{CH}_4} : u_{\text{SO}_2} = 4:1$
 (D) The ratio of effusion rate, $r_{\text{CH}_4} : r_{\text{SO}_2} = 4:1$
- Consider the apparatus shown in the drawing, when the stopcock between the two containers is opened and the gases allowed to mix. Which of the following statement is true?
 (A) The volume occupied by the N_2 gas changes from 2.0 L to 5.0 L.
 (B) The partial pressure of the N_2 gas is kept 2.0 atm.
 (C) The partial pressure of the O_2 gas is 1.2 atm.
 (D) The total pressure of gas mixture is 4.0 atm.
- Chlorophyll *a*, one of several leaf pigments, absorbs red light with wavelength 600 nm.
 (A) Chlorophyll *a* appears red.
 (B) The energy of the red light is greater than UV light.
 (C) The frequency of the red light is greater than IR.
 (D) The energy of the photon is $3.31 \times 10^{-19} \text{ J}$
- For the following orbital diagram, choose the correct ground-state electron configurations.
 (A) $[\text{He}] \begin{array}{|c|} \hline \uparrow \\ \hline \end{array} \begin{array}{|c|} \hline \uparrow \\ \hline \end{array} \begin{array}{|c|} \hline \uparrow \\ \hline \end{array} \begin{array}{|c|} \hline \uparrow \\ \hline \end{array}$
 2s 2p
 (B) $[\text{He}] \begin{array}{|c|} \hline \uparrow\downarrow \\ \hline \end{array} \begin{array}{|c|} \hline \downarrow \\ \hline \end{array} \begin{array}{|c|} \hline \downarrow \\ \hline \end{array} \begin{array}{|c|} \hline \downarrow \\ \hline \end{array}$
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 (C) $[\text{He}] \begin{array}{|c|} \hline \uparrow\downarrow \\ \hline \end{array} \begin{array}{|c|} \hline \uparrow\downarrow \\ \hline \end{array} \begin{array}{|c|} \hline \downarrow\downarrow \\ \hline \end{array} \begin{array}{|c|} \hline \downarrow\downarrow \\ \hline \end{array}$
 2s 2p
 (D) $[\text{He}] \begin{array}{|c|} \hline \uparrow\downarrow \\ \hline \end{array} \begin{array}{|c|} \hline \uparrow \\ \hline \end{array} \begin{array}{|c|} \hline \downarrow \\ \hline \end{array} \begin{array}{|c|} \hline \uparrow \\ \hline \end{array}$
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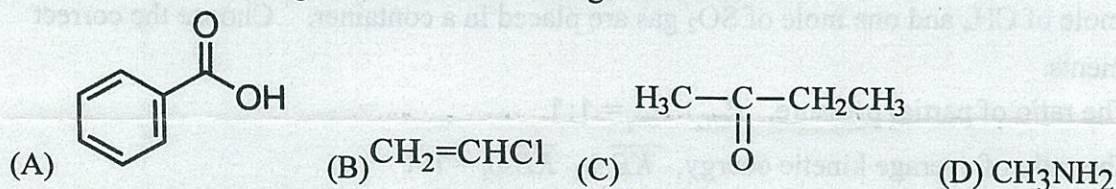


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8. Which of the following molecule are polar molecules?
 (A) BCl_3 (B) SO_3 (C) PH_3 (D) ClF_3
9. For the followings molecules, choose the one with the smallest bond angle?
 (A) CCl_4 (B) H_2CO (C) NH_3 (D) XeF_4
10. The unit cell of sodium chloride is shown as figure. What is the coordination number of chloride ion?
 (A) 4 (B) 6 (C) 8 (D) 12 (E) 13 (F) 14

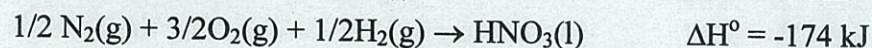
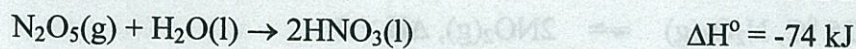


11. Which of the following ranking is correct?
 (A) Boiling point: *n*-pentane < 2-methylbutane < 2,2-dimethylpropane
 (B) Solubility in water: $\text{CO}_2(\text{g})$ < $\text{O}_2(\text{g})$ < $\text{He}(\text{g})$
 (C) pH value: 0.1 M CCl_3COOH < 0.1 M CH_3COOH < 0.1 M CH_3COONa
 (D) Boiling point: 0.10 m glucose < 0.10 m acetic acid < 0.10 m H_2SO_4 < 0.10 m CaCl_2
12. Which of the following molecules will undergo addition reaction?



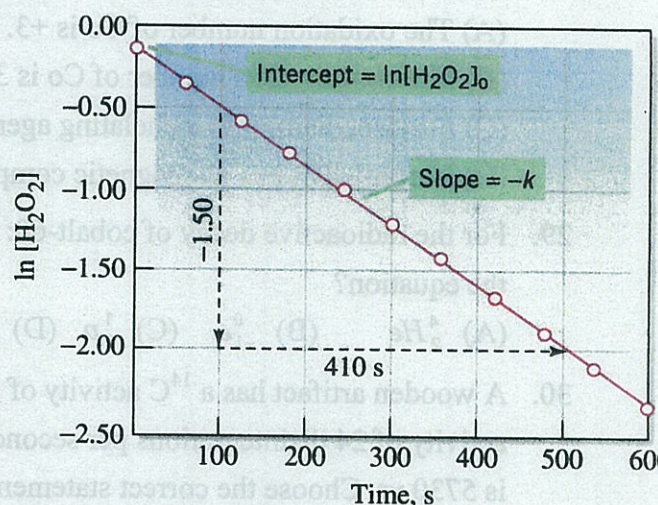
13. Which of the following species has geometric isomers?
 (A) $\text{CH}_3\text{CH}=\text{CHCH}_3$ (B) $\text{CH}_3\text{CH}(\text{NH}_2)\text{COOH}$ (C) $[\text{PtCl}_2(\text{NH}_3)_2]$ (square planar)
 (D) $[\text{Cr}(\text{NH}_3)_4\text{Cl}_2]^+$ (octahedral)
14. A student weighs out 0.2470 g of sodium carbonate as primary standard and titrates to the equivalence point with 20.48 mL of an unknown concentration of HCl solution. What is the concentration of the HCl solution?
 (A) 0.1138 M (B) 0.1453 M (C) 0.2276 M (D) 0.2906 M (E) None of the above
15. If the internal energy (E) of a thermodynamic system is increased by 258 J while 43 J of expansion work (w) is done to surroundings, then
 (A) $\Delta E = +258 \text{ J}$ (B) $w = +43 \text{ J}$ (C) $q = 215 \text{ J}$
 (D) the heat is transferred from surroundings into the system.
16. After 50.0 mL of 1.00 M $\text{Ba}(\text{OH})_2$ and the same volume and concentration of acetic acid react in a constant-pressure calorimeter of negligible heat capacity. The initial temperature of both solutions is the same at 20.5 °C, and the final temperature of the solution is 36.5 °C. Calculate the molar heat of neutralization in kJ/mol. Assume the density and specific heat capacity of aqueous solution is same as water (1.00 g/mL and 4.184 J/g·°C, respectively).
 (A) -50.2 (B) -25.1 (C) +25.1 (D) +50.2 (E) None of the above
17. For the Haber process, $\text{N}_2(\text{g}) + 3\text{H}_2(\text{g}) \rightleftharpoons 2\text{NH}_3(\text{g})$, $\Delta H^\circ = -92 \text{ kJ}$, $\Delta S^\circ = -198 \text{ J/K}$, and $\Delta G^\circ = -33 \text{ kJ}$ at 25°C. Calculate equilibrium constant, K, at 800 K.
 (A) 6.1×10^5 (B) 143 (C) 0.10 (D) 4.6×10^{-5} (E) None of the above

18. At 25°C and 1 atm, calculate ΔH_f° of $N_2O_5(g)$ in kJ/mol, according to the following thermochemical equations:



- (A) 12 (B) 186 (C) 298 (D) 472 (E) None of the above
19. For the reaction: $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$ at 298 K, $\Delta H^\circ = 178 \text{ kJ}$, $\Delta S^\circ = 160 \text{ J/K}$. Choose the correct statements.
- (A) This is an endothermic reaction.
(B) The entropy of the system is increased.
(C) At standard states and 298 K, $\Delta G^\circ = -2804 \text{ kJ/mol}$.
(D) When the reaction reaches equilibrium $\Delta G = 0$.
20. The vapor pressures of pure benzene (C_6H_6) and toluene ($C_6H_5CH_3$) at 20°C are 76 mmHg and 24 mmHg, respectively. Consider a mixture containing 1.0 mol of benzene and 1.0 mol of toluene in a closed system at 20°C, calculate the mole fraction of toluene in the vapor phase. Assume ideal solution.
- (A) 0.24 (B) 0.32 (C) 0.50 (D) 0.76 (E) None of the above

21. For the decomposition reaction of H_2O_2
 $H_2O_2(aq) \rightarrow H_2O(l) + 1/2 O_2(g)$, we got a plot of $\ln[H_2O_2]$ versus time shown as figure.



- (A) This is a first-order reaction.
(B) This is a second-order reaction.
(C) The value of rate constant (k) is -3.66×10^{-3} .
(D) The half-life of the reaction is 189 s.
22. In a study of nitrosyl halides, a chemist proposes the following mechanism for the synthesis of nitrosyl bromide:
- Step 1: $NO(g) + Br_2(g) \rightleftharpoons NOBr_2(g)$ [fast]
Step 2: $NOBr_2(g) + NO(g) \rightarrow 2NOBr(g)$ [slow]
- (A) $NOBr_2$ is the intermediate.
(B) Step 1 is a bimolecular reaction.
(C) Step 2 is the rate determining step.
(D) The rate law deduced from the mechanism is: $rate = k[NO][Br_2]$.
23. Consider the titration of 20.0 mL of 0.10 M unknown acid (HX with $K_a = 1.0 \times 10^{-5}$) by 0.10 M sodium hydroxide solution.
- (A) Before titration, the initial pH of 0.10 M HX(aq) is 3.00.
(B) After adding 10.0 mL of 0.10 M NaOH to the acid, the pH of the solution is 5.00.
(C) At equivalence point, the pH of the solution is 7.00.
(D) Phenolphthalein ($pK_a = 8$) is an appropriate indicator for the titration.

24. How many moles of NH_4Cl must be added to 1.0 L of 0.10 M NH_3 to form a buffer whose pH is 9.00? K_b of NH_3 is 1.8×10^{-5} .
 (A) 0.055 mol (B) 0.10 mol (C) 0.18 mol (D) None of the above
25. For the reaction at 25 °C, $\text{N}_2\text{O}_4(\text{g}) \rightleftharpoons 2\text{NO}_2(\text{g})$, $\Delta H > 0$
 (A) $\Delta S > 0$
 (B) Increasing the temperature will increase the equilibrium constant.
 (C) Decrease the volume of the closed system at constant temperature will shift the equilibrium position to the right
 (D) Add certain catalyst to the system could increase the value of equilibrium constant.
26. According to the cell diagram: $\text{Pt}(\text{s}) \mid \text{H}_2(\text{g}) \mid \text{H}^+(\text{aq}) \parallel \text{Ag}^+(\text{aq}) \mid \text{Ag}(\text{s})$
 (A) $\text{Pt}(\text{s})$ is the reducing agent. (B) $\text{Ag}(\text{s})$ is the anode.
 (C) $\text{Pt}(\text{s})$ is the negative electrode. (D) Ag^+ is reduced.
27. Calculate the standard cell potential, E°_{cell} , of a galvanic cell bases on the following half-reactions at 25°C.
 $\text{Al}^{3+} + 3\text{e}^- \rightarrow \text{Al} \quad E^\circ = -1.66 \text{ V}$
 $\text{Mg}^{2+} + 2\text{e}^- \rightarrow \text{Mg} \quad E^\circ = -2.37 \text{ V}$
 (A) -0.71 V (B) +0.71 V (C) +3.79 (D) 4.03 (E) None of the above
28. For the coordination compound $[\text{Co}(\text{en})_3]\text{Cl}_3$, which of the following statement is true?
 The "en" stands for ethylenediamine that is a strong field ligand.
 (A) The oxidation number of Co is +3.
 (B) The coordination number of Co is 3.
 (C) Ethylenediamine is a chelating agent.
 (D) $[\text{Co}(\text{en})_3]\text{Cl}_3$ is a diamagnetic complex.
29. For the radioactive decay of cobalt-60: ${}^{60}_{27}\text{Co} \rightarrow \boxed{?} + {}^{60}_{28}\text{Ni}$, what is the missing particle in the equation?
 (A) ${}^4_2\text{He}$ (B) ${}^0_{-1}\text{e}$ (C) ${}^1_1\text{p}$ (D) ${}^1_0\text{n}$
30. A wooden artifact has a ${}^{14}\text{C}$ activity of 12 disintegrations per second as compared with an activity of 24 disintegrations per second for a standard of zero age. The half-life for ${}^{14}\text{C}$ decay is 5730 yr. Choose the correct statements.
 (A) The radioactive decay of ${}^{14}\text{C}$ is a first order reaction.
 (B) The decay constant (k) for the process is $1.2 \times 10^{-4} \text{ yr}^{-1}$.
 (C) The age of the sample is 11460 yr.
 (D) We could shorten the half-life of ${}^{14}\text{C}$ by increasing the temperature.

II. 計算問答題 (10%)

31. Base on molecular orbital theory, (a) draw the molecular orbitals energy-level diagrams.
 (b) Determine the bond orders.
 (c) Indicate the magnetic property (diamagnetic or paramagnetic) of the O_2 molecule.
 (d) Is the bond length of O_2 longer or shorter than O_2^{2-} ?