

國立清華大學 103 學年度碩士班考試入學試題

系所班組別：生醫工程與環境科學系 乙組（環境分子科學組）

考試科目：(2401)普通化學 共 7 頁，第 1 頁 *請在【答案卷、卡】作答

(I) Multiple Choices. Please choose the one alternative that best answers the question. (40%, 2% of each)
請在答案卡作答區內作答

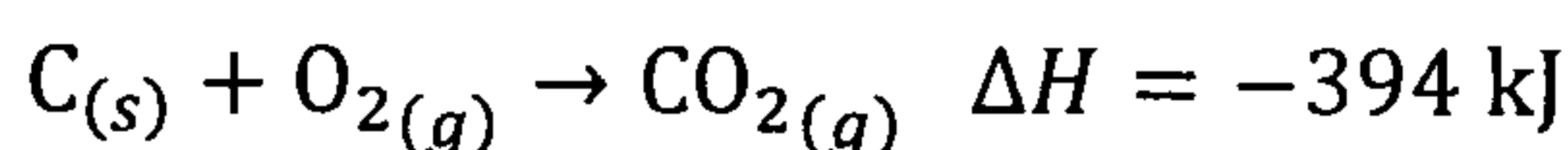
1. Dimethyl hydrazine, $(\text{CH}_3)_2\text{N}-\text{NH}_2$, is a liquid at room temperature. How many atoms in this molecule have trigonal pyramidal geometry?

- (A) 1 (B) 2 (C) 3 (D) 4 (E) 5

2. Which type of solid is the most densely packed?

- (A) Simple cubic (B) Face centered cubic (C) Body centered cubic
(D) Amorphous solid (E) None, they all have the same density

3. Assume that coal is essentially all carbon and has a density of 1.5 g/mL. (a) How much heat is produced if a piece of coal 7 cm \times 5 cm \times 6 cm undergoes complete combustion by the following reaction:

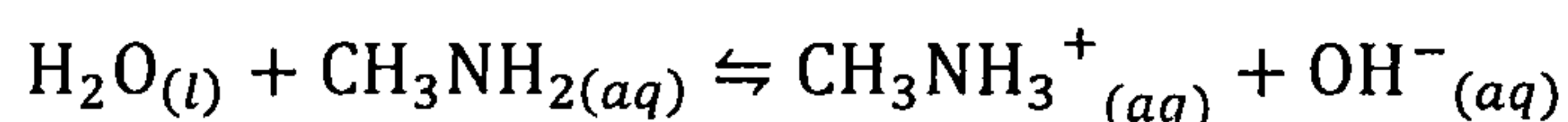


(b) What mass of water could be heated from 25 °C to 100 °C with this amount of heat?

(The specific heat of water is 4.184 J/g)

- (A) -1.0×10^4 kJ, 3.3×10^4 g of H_2O (B) $+1.0 \times 10^4$ kJ, 33 g of H_2O
(C) $+5.0 \times 10^3$ kJ, 33 g of H_2O (D) -5.0×10^3 kJ, 3,300 g of H_2O
(E) none of the above

4. When 0.1 mole of methylamine is dissolved in 500 mL of water, the following hydrolysis reaction occurs:



The hydroxide concentration is found to be 8.6×10^{-3} M when equilibrium is reached. What is the value of the equilibrium constant for this reaction?

- (A) 4.3×10^{-2} (B) 7.4×10^{-4} (C) 7.4×10^{-5}
(D) 3.9×10^{-4} (E) 7.4×10^{-3}

5. If the dissolution of CaCl_2 is endothermic, will any of the following increase the amount of CaCl_2 that will dissolve in water?

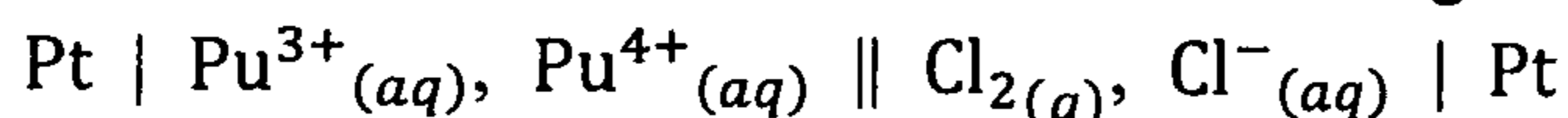
- (A) Addition of NaCl (B) Addition of $\text{Ca}(\text{NO}_3)_2$ (C) Addition of HCl
(D) Increase in temperature (E) Decrease in temperature

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6. Consider an electrochemical cell based on the following cell diagram:



Given that the standard cell emf is 0.35 V and that the standard reduction potential of chlorine is 1.36 V, what is the standard reduction potential $E^\circ(\text{Pu}^{4+}/\text{Pu}^{3+})$?

- (A) 2.37 V (B) 1.01 V (C) -1.71 V
(D) -1.01 V (E) 1.71 V

7. The reaction $2\text{NO}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}_2(\text{g})$ exhibits the rate law:

$$\text{Rate} = k[\text{NO}]^2[\text{O}_2]$$

Which of the following mechanisms is consistent with this rate law?

- (A) $\text{NO} + \text{O}_2 \rightarrow \text{NO}_2 + \text{O}$ Slow
 $\text{O} + \text{NO} \rightarrow \text{NO}_2$ Fast
(B) $\text{NO} + \text{O}_2 \rightleftharpoons \text{NO}_3$ Fast equilibrium
 $\text{NO}_3 + \text{NO} \rightarrow 2\text{NO}_2$ Slow
(C) $2\text{NO} \rightarrow \text{N}_2\text{O}_2$ Slow
 $\text{N}_2\text{O}_2 + \text{O}_2 \rightarrow \text{N}_2\text{O}_4$ Fast
 $\text{N}_2\text{O}_4 \rightarrow 2\text{NO}_2$ Fast
(D) $2\text{NO} \rightleftharpoons \text{N}_2\text{O}_2$ Fast equilibrium
 $\text{N}_2\text{O}_2 \rightarrow \text{NO}_2 + \text{O}$ Slow
 $\text{O} + \text{NO} \rightarrow \text{NO}_2$ Fast

8. Calculate the concentration of chromate ion (CrO_4^{2-}) in a 0.450 M solution of chromic acid (H_2CrO_4).

(For chromic acid, $K_{a1} = 0.18$, $K_{a2} = 3.2 \times 10^{-7}$)

- (A) 3.2×10^{-7} M (B) 1.5×10^{-6} M (C) 0.081 M
(D) 1.1×10^{-6} M (E) 0.21 M

9. Arrange the acids HOBr , HBrO_3 , and HBrO_2 in order of increasing acid strength.

- (A) $\text{HOBr} < \text{HBrO}_3 < \text{HBrO}_2$ (B) $\text{HOBr} < \text{HBrO}_2 < \text{HBrO}_3$ (C) $\text{HBrO}_2 < \text{HOBr} < \text{HBrO}_3$
(D) $\text{HBrO}_3 < \text{HOBr} < \text{HBrO}_2$ (E) $\text{HBrO}_3 < \text{HBrO}_2 < \text{HOBr}$

10. Which of the following sulfur species has the greatest delocalization as judged by the number of resonance structures?

- (A) H_3SO_4^+ (B) H_2SO_4 (C) HSO_4^-
(D) SO_4^{2-} (E) None of the above

11. If 12% of a certain radioisotope decays in 5.2 years, what is the half-life of this isotope?

- (A) 0.59 yr (B) 1.7 yr (C) 22 yr (D) 28 yr (E) 32 yr

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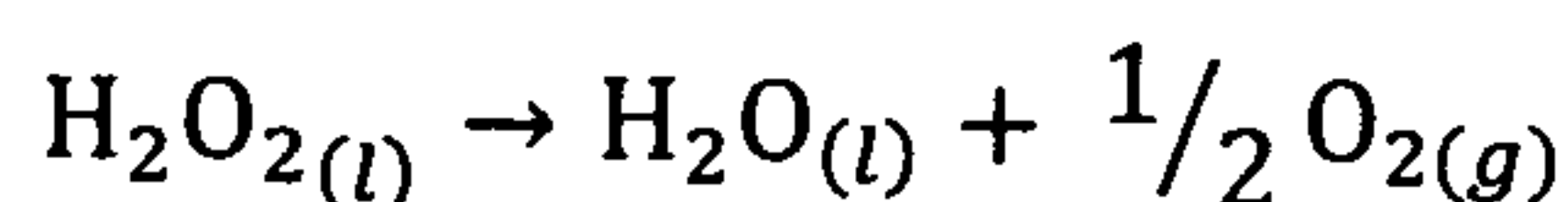
12. Arrange the following in order of vapor pressure at room temperature.
1. CH_3OCH_3 2. $\text{CH}_3\text{CH}_2\text{OCH}_2\text{CH}_3$ 3. $\text{CH}_3\text{C}(\text{O})\text{CH}_3$ 4. $\text{CH}_3\text{CH}_2\text{OH}$
(A) $2 < 3 < 1 < 4$ (B) $1 < 4 < 3 < 2$ (C) $4 < 3 < 2 < 1$
(D) $3 < 4 < 1 < 2$ (E) $4 < 1 < 2 < 3$
13. In which solution will copper nitrate ($\text{Cu}(\text{NO}_3)_2$) be the least soluble?
(A) 0.1 M NaNO_3 (B) 0.1 M NH_3 (C) pure water
(D) 0.1 M CuCl_2 (E) 0.1 M NaOH
14. The maximum number of electrons that can occupy an energy level described by the principal quantum number, n , is
(A) n (B) $n + 1$ (C) $2n$ (D) $2n^2$ (E) n^2
15. 10.0 g of gaseous ammonia and 6.50 g of oxygen gas are introduced into a previously evacuated 5.50 L vessel. If the ammonia and oxygen then react to yield NO gas and water vapor, what is the final density of the gas mixture inside the vessel at 23°C ?
(A) 1.68 g/L (B) 3.00 g/L (C) 1.32 g/L
(D) 2.20 g/L (E) 16.5 g/L
16. You have 500.0 mL of a buffer solution containing 0.20 M acetic acid (CH_3COOH) and 0.30 M sodium acetate (CH_3COONa). What will the pH of this solution be after the addition of 20.0 mL of 1.00 M NaOH solution? ($K_a = 1.8 \times 10^{-5}$)
(A) 4.41 (B) 4.74 (C) 4.56 (D) 4.92 (E) 5.07
17. Arrange the following in order of increasing boiling point: RbCl , CH_3Cl , CH_3OH , CH_4 .
(A) $\text{CH}_3\text{OH} < \text{CH}_3\text{Cl} < \text{RbCl} < \text{CH}_4$ (B) $\text{CH}_3\text{OH} < \text{CH}_4 < \text{CH}_3\text{Cl} < \text{RbCl}$
(C) $\text{RbCl} < \text{CH}_3\text{Cl} < \text{CH}_3\text{OH} < \text{CH}_4$ (D) $\text{CH}_4 < \text{CH}_3\text{OH} < \text{CH}_3\text{Cl} < \text{RbCl}$
(E) $\text{CH}_4 < \text{CH}_3\text{Cl} < \text{CH}_3\text{OH} < \text{RbCl}$
18. A gaseous compound is 30.4% nitrogen and 69.6% oxygen by mass. A 5.25-g sample of the gas occupies a volume of 1.00 L and exerts a pressure of 1.26 atm at -4.0°C . Which of the following is its molecular formula?
(A) NO (B) NO_2 (C) N_3O_6 (D) N_2O_4 (E) N_2O_5

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19. Hydrogen peroxide (H_2O_2) decomposes according to the equation:



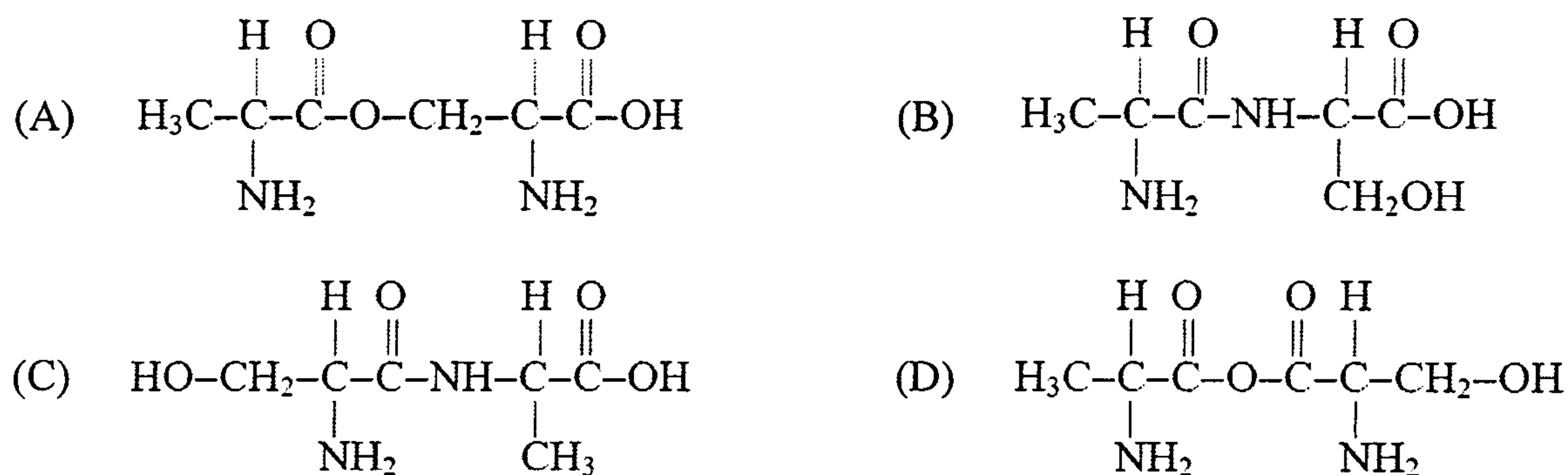
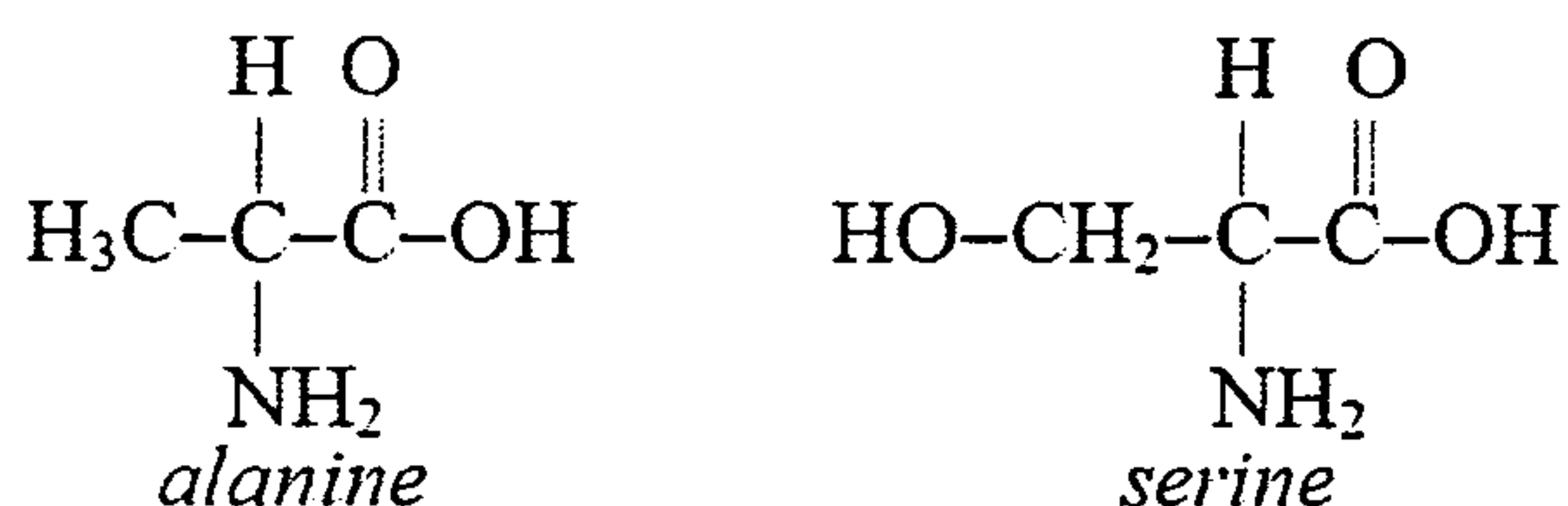
Calculate the equilibrium constant K_p for this reaction at 25°C .

($\Delta H^\circ = -98.2 \text{ kJ/mol}$, $\Delta S^\circ = 70.1 \text{ J/K}\cdot\text{mol}$).

- (A) 1.3×10^{-21} (B) 20.9 (C) 3.46×10^{17}
 (D) 7.5×10^{20} (E) 8.6×10^4

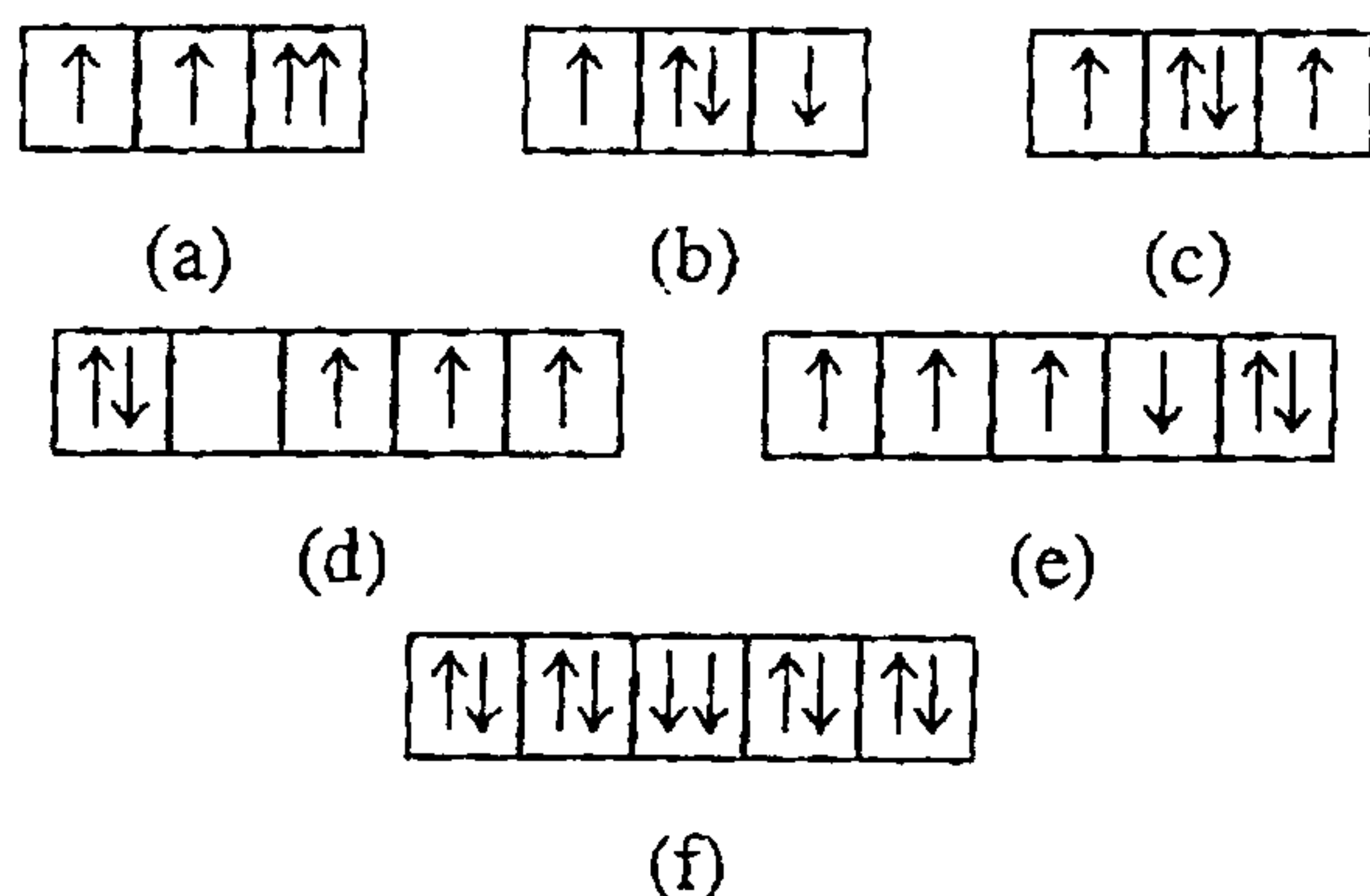
20. Which of the structures below corresponds to the dipeptide alanylserine?

Note the following structures:



(II) Short Answer Questions (60%) 請在答案卷作答區內作答

1. (5%) Shown below are portions of orbital diagrams representing the ground-state electron configurations of certain elements. Which of them violate the Pauli exclusion principle? Hund's rule?



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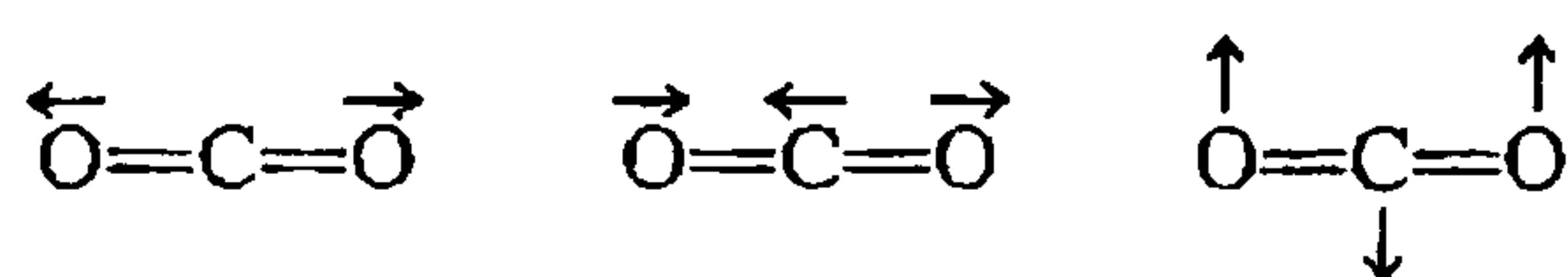
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2. (3%) Fahrenheit developed his temperature scale where he set zero degrees as the freezing point for a salt-water solution. What is the concentration of this salt solution in molality (assume NaCl in water)?

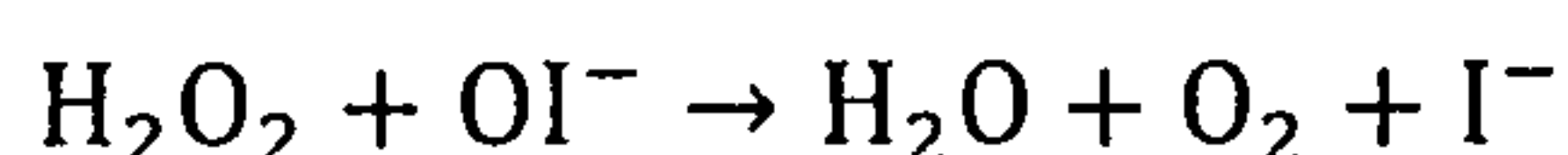
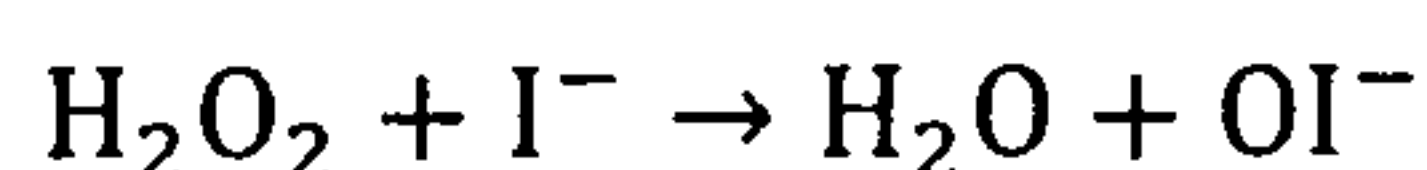
$$(T_f = 1.86 \text{ }^\circ\text{C} / m) \quad ([^\circ\text{F}] = [^\circ\text{C}] \times \frac{9}{5} + 32)$$

3. (5%) Greenhouse gases absorb (and trap) outgoing infrared radiation (heat) from Earth and contribute to global warming. The molecule of a greenhouse gas either possesses a permanent dipole moment or has a changing dipole moment during its vibrational motions. Consider three of the vibrational modes of carbon dioxide



where the arrows indicate the movement of the atoms. (During a complete cycle of vibration, the atoms move toward one extreme position and then reverse their direction to the other extreme position.) Which of the preceding vibrations are responsible for CO₂ to behave as a green house gas? Which of the following molecules can act as a greenhouse gas: N₂, O₂, CO, NO₂, and N₂O?

4. (3%) A flask contains a mixture of compounds A and B. Both compounds decompose by first-order kinetics. The half-lives are 50.0 min for A and 18.0 min for B. If the concentrations of A and B are equal initially, how long will it take for the concentration of A to be four times that of B.
5. (6%) Write the overall equation of reaction for the following mechanism and identify any reaction intermediates and any catalysts.



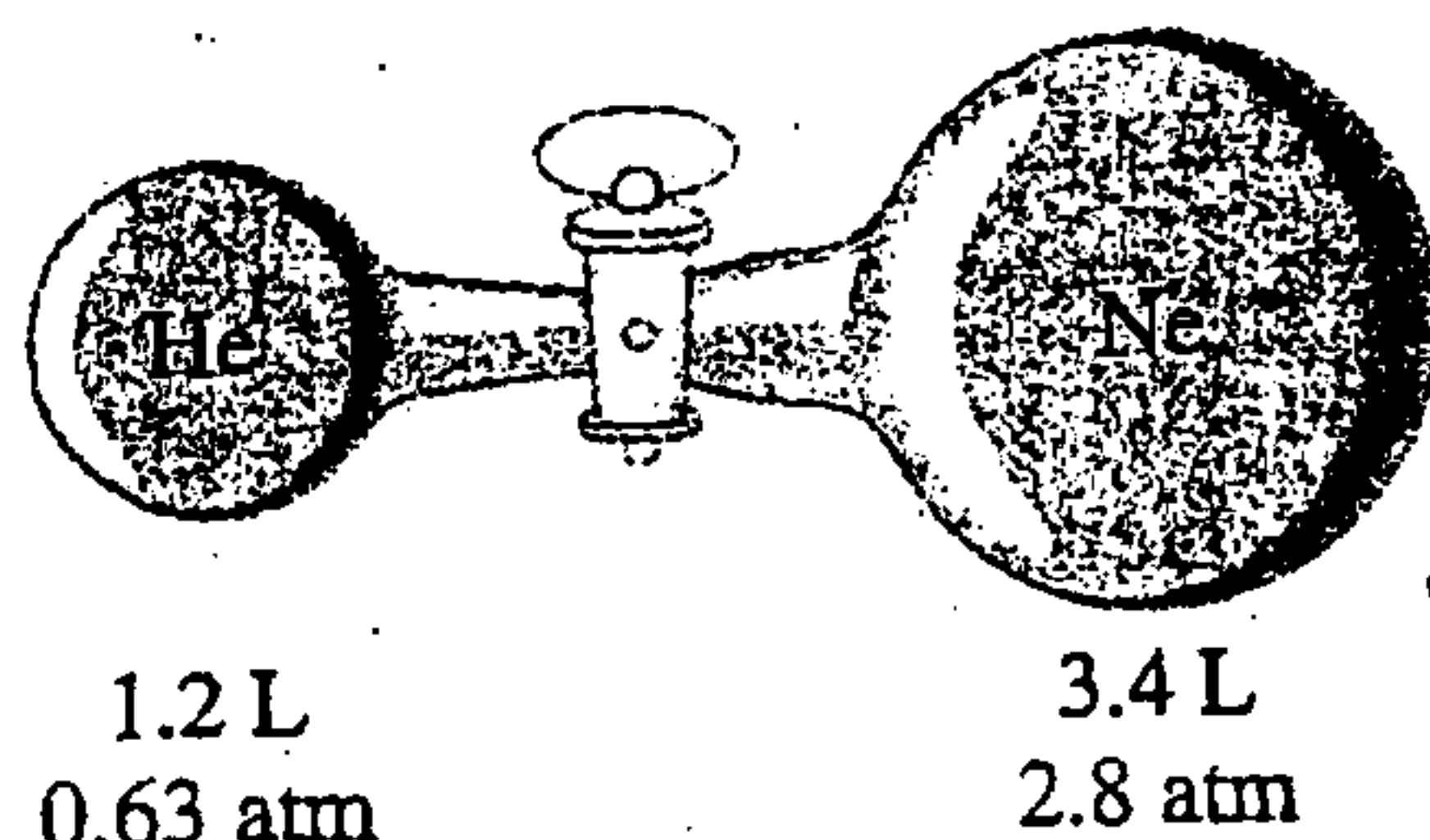
6. (5%) When 2.00 mol of SO_{2(g)} react completely with 1.00 mol of O_{2(g)} to form 2.00 mol of SO_{3(g)} at 25°C and a constant pressure of 1.00 atm, 198 kJ of energy are released as heat. Calculate ΔH and ΔE for this process.
7. (3%) Diethyl ether is a volatile, highly flammable organic liquid that is used mainly as a solvent. The vapor pressure of diethyl ether is 401 mmHg at 18°C. Calculate its vapor pressure at 32°C.
($\Delta H_{\text{vap}} = 26.0 \text{ kJ/mol}$)
8. (4%) Which of the complex ions CoCl₆⁴⁻ or CoCl₄²⁻ will absorb light with the longest wavelength? Explain. How many unpaired electrons are in each complex ion?

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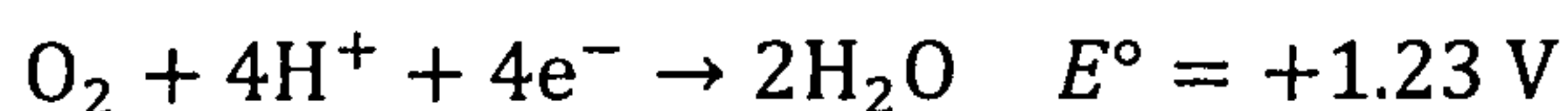
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9. (4%) Consider the following apparatus. Calculate the partial pressures of helium and neon after the stopcock is open. The temperature remains constant at 16°C.

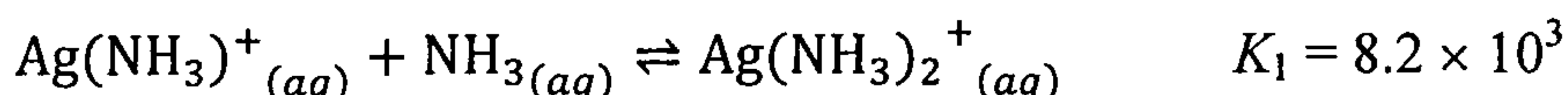
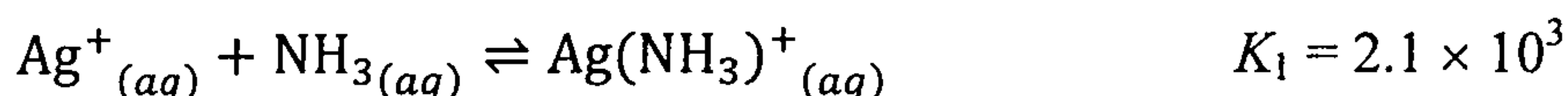


10. (3%) Lysozyme is an enzyme found in tears whose function is to break down bacterial cell walls thus killing the bacteria and protecting the eye from infection. A solution made which contains 0.100 g of lysozyme in 150 g of water ($\rho = 1.00 \text{ g/mL}$) at 25°C has an osmotic pressure of 8.9 torr. What is the molar mass of this enzyme?
11. (3%) Calculate the difference in free energy between 1.00 M HCl and 0.100 M HCl at 25°C.
12. (4%) An electrochemical cell is made by immersing a piece of Cd metal into a solution of 0.100 M CdSO_4 and a Zn electrode into a solution of 1.00 M ZnSO_4 and placing a salt bridge to allow ion flow between the two solutions. (a) What voltage will be produced by the cell and (b) what metal is the anode? ($\text{Cd}^{2+} + 2e^- \rightarrow \text{Cd} \quad E^\circ = -0.402 \text{ V}$, $\text{Zn}^{2+} + 2e^- \rightarrow \text{Zn} \quad E^\circ = -0.76 \text{ V}$)
13. (5%) Given the following standard reduction potentials in acid solution



write the formula of the (a) weakest reducing agent and (b) the strongest oxidizing agent.

14. (3%) Calculate the solubility of silver(I) bromide in a 0.200 M NH_3 solution.

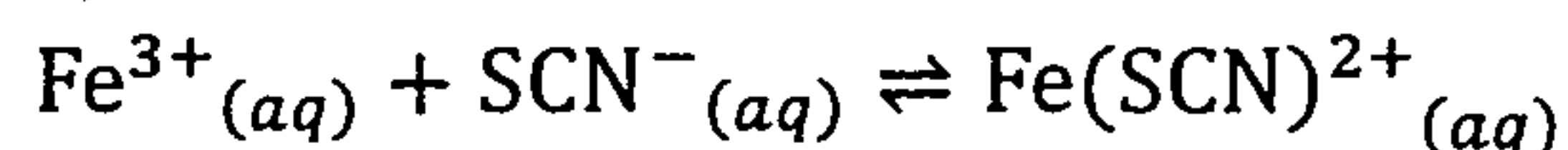


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15. (4%) Consider the reaction



How will the equilibrium position shift if

- Water is added, doubling the volume?
- $\text{AgNO}_3_{(aq)}$ is added? (AgSCN is insoluble.)
- $\text{NaOH}_{(aq)}$ is added? [$\text{Fe}(\text{OH})_3$ is insoluble.]
- $\text{Fe}(\text{NO}_3)_3_{(aq)}$ is added?

1. $R = 0.082 \text{ L}\cdot\text{atm}/\text{mol}\cdot\text{K}$

2. $R = 8.314 \text{ J}/\text{mol}\cdot\text{K}$

3. Periodic table

1 H 1.008																	2 He 4.0026
3 Li 6.94	4 Be 9.0122											5 B 10.81	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
11 Na 22.990	12 Mg 24.305											13 Al 26.982	14 Si 28.085	15 P 30.974	16 S 32.06	17 Cl 35.45	18 Ar 39.948
19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.867	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.693	29 Cu 63.546	30 Zn 65.38	31 Ga 69.723	32 Ge 72.63	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.798
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.96	43 Tc [97.91]	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	71 Lu 174.97	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.08	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [208.98]	85 At [209.99]	86 Rn [222.02]
87 Fr [223.02]	88 Ra [226.03]	103 Lr [262.11]	104 Rf [265.12]	105 Db [268.13]	106 Sg [271.13]	107 Bh [270]	108 Hs [277.15]	109 Mt [276.15]	110 Ds [281.16]	111 Rg [280.16]	112 Cn [285.17]	113 Uut [284.18]	114 Fl [289.19]	115 Uup [288.19]	116 Lv [293]	117 Uus [294]	118 Uuo [294]
anthanoids		57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm [144.91]	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.05		
*Actinoids		89 Ac [227.03]	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np [237.05]	94 Pu [244.06]	95 Am [243.06]	96 Cm [247.07]	97 Bk [247.07]	98 Cf [251.08]	99 Es [252.08]	100 Fm [257.10]	101 Md [258.10]	102 No [259.10]		