

國立清華大學 101 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：(2301)普通化學 共 7 頁，第 1 頁 *請在【答案卷】作答

(I) Multiple Choices. Please choose the one alternative that best answers the question. (50%, 2% of each)

- Aluminum sulfate is used in sand paper, among other uses. How many g of aluminum oxide dihydrate will be needed to produce 500 g of aluminum sulfate by sulfuric acid?
(a) 1.46 (b) 40.0 (c) 202 (d) 342 (e) 500
- At what pH will an 0.0010 M of iron(III)nitrate ($K_{sp}(\text{Fe}(\text{OH})_3) = 4.0 \times 10^{-38}$) begin to precipitate?
(a) 2.55 (b) 4.22 (c) 5.55 (d) 7.41 (e) 9.03
- Urea is used as a source of nitrogen in fertilizer. The second step of the synthesis is heating the intermediate ammonium carbamate to produce urea shown in the equation below.
$$\text{NH}_2\text{CO}_2\text{NH}_4 \rightarrow \text{NH}_2(\text{CO})\text{NH}_2 + \text{H}_2\text{O}$$

The reaction proceeds in 60% yield, on average, and the product is mixed with unreacted starting materials, which are readily separated from the product. They can then be recycled and undergo the process again. If one starts with 1 kg of ammonium carbamate, how many times will it have to be cycled through this reaction to give at least a 90% yield?
(a) 2 (b) 3 (c) 4 (d) 5 (e) infinite number of times
- Which of the following is in the order of increasing ionization energy?
(a) I, P, Cl (b) I, Cl, P (c) P, Cl, I (d) Cl, P, I (e) None of the above
- What are the spectator ions in the reaction of barium carbonate with hydrochloric acid?
(a) CO_3^{2-} , Cl^- (b) OH^- , Ba^{2+} (c) Cl^- , Ba^{2+} (d) H^+ , CO_3^{2-} (e) None of the above
- From the following information derive an activity series for the metals Pt, Zn, and Fe.
 - $\text{Pt}^{2+} + \text{Fe}_{(s)} \rightarrow \text{Pt}_{(s)} + \text{Fe}^{2+}$
 - $\text{Pt}^{2+} + \text{Zn}_{(s)} \rightarrow \text{Pt}_{(s)} + \text{Zn}^{2+}$
 - $\text{Zn}_{(s)} + \text{Fe}^{2+} \rightarrow \text{Fe}_{(s)} + \text{Zn}^{2+}$(a) $\text{Pt} < \text{Zn} < \text{Fe}$ (b) $\text{Fe} < \text{Pt} < \text{Zn}$ (c) $\text{Pt} < \text{Fe} < \text{Zn}$ (d) $\text{Zn} < \text{Fe} < \text{Pt}$ (e) $\text{Zn} < \text{Pt} < \text{Fe}$
- In which of the following molecules will the bond angle be distorted from the ideal geometric values?
 SF_5^+ 2. ICl_3 3. BrF_5 4. $\text{Si}(\text{CH}_3)_4$ 5. PF_5
(a) 1, 2, and 3 (b) 3 and 5 (c) 2, 3, and 4 (d) 4 and 5 (e) 2 and 3
- CO_2 will be released from the soda in order to reach equilibrium after opening to the room where the pressure of $\text{CO}_2 = 3.25 \times 10^{-4}$ atm and the total pressure is 758 mm Hg ($K_H = 1.6 \times 10^{-2}$ M/atm)?
(a) 3.5 mL (b) 3.5 L (c) 35 mL (d) 0.35 L (e) 100 mL

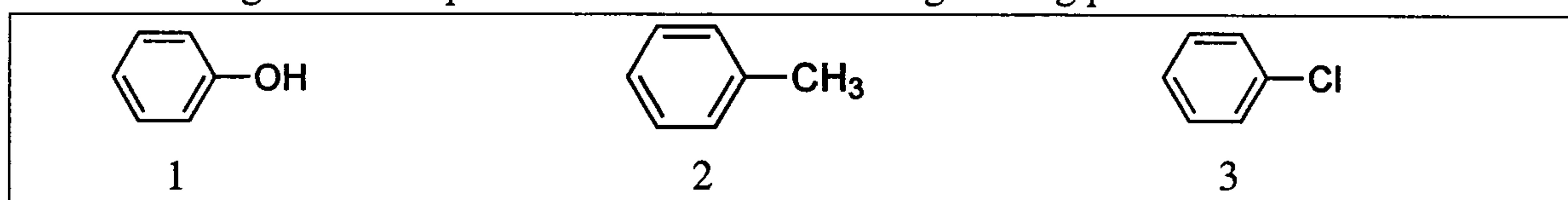
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考試科目：(2301)普通化學 共 7 頁，第 2 頁 *請在【答案卷】作答

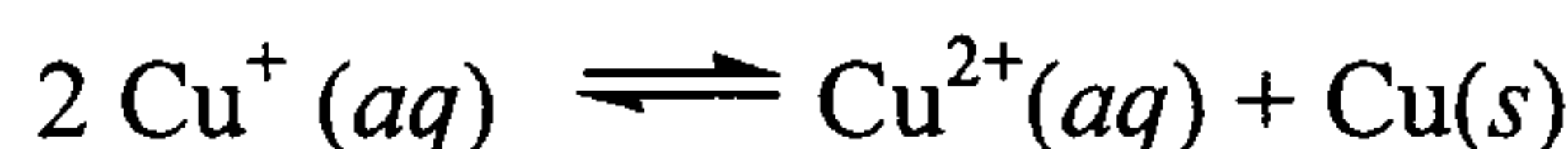
9. A flask is filled with hydrogen, oxygen and several mL of water. This flask is then connected to a flask containing oxygen gas consisting of only the ^{17}O isotope at the same pressure as the first flask. Which of the following will not occur?
- some water will evaporate
 - the $^{17}\text{O}_2$ will diffuse into the other flask
 - hydrogen and water vapor will diffuse into the second flask
 - ^{17}O will be incorporated into the water
 - none of the above

10. List the following three compounds in order of increasing boiling point:



- (a) 1, 2, 3 (b) 3, 2, 1 (c) 1, 3, 2 (d) 2, 1, 3 (e) 2, 3, 1

11. The copper(I) ion is a curious species. In aqueous solutions, there are a number of reactions that it can undergo; one is the reaction with other copper(I) ions:



	$\text{Cu}^+ (aq)$	$\text{Cu}^{2+}(aq)$	$\text{Cu}(s)$
$\Delta H^\circ_f(\text{kJ/mole})$	71.67	64.77	0
$S^\circ(\text{J/K})$	40.6	-99.6	33.15

Using the tabulated data, calculate the equilibrium constant for this reaction of $\text{Cu}^+ (aq)$ at 298 K and predict whether it will increase or decrease with increasing temperature. Choose from the following:

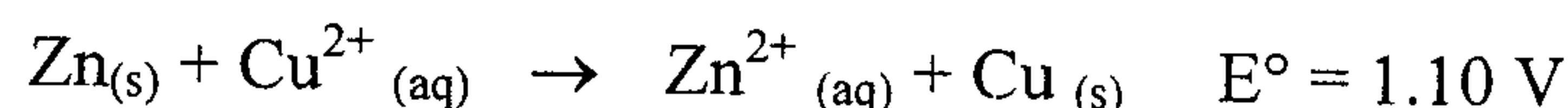
- (a) 3.5×10^4 ; increase (b) 1.2×10^6 ; decrease (c) 2.2×10^7 increase
 (d) 2.2×10^7 decrease (e) 3.5×10^4 decrease
12. A system containing nitrogen, ammonia, and hydrogen is at equilibrium. The exothermic reaction will shift to greater production of ammonia if:
- H_2 is added
 - NH_3 is added
 - Ar is added
 - A catalyst is added
 - The temperature is increased
13. In which solution will copper nitrate ($\text{Cu}(\text{NO}_3)_2$) be the least soluble?
- 0.1 M NaNO_3
 - 0.1 M NH_3
 - pure water
 - 0.1 M CuCl_2
 - 0.1 M NaOH

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14. Consider the Daniell cell where the cell reaction and standard potential are:

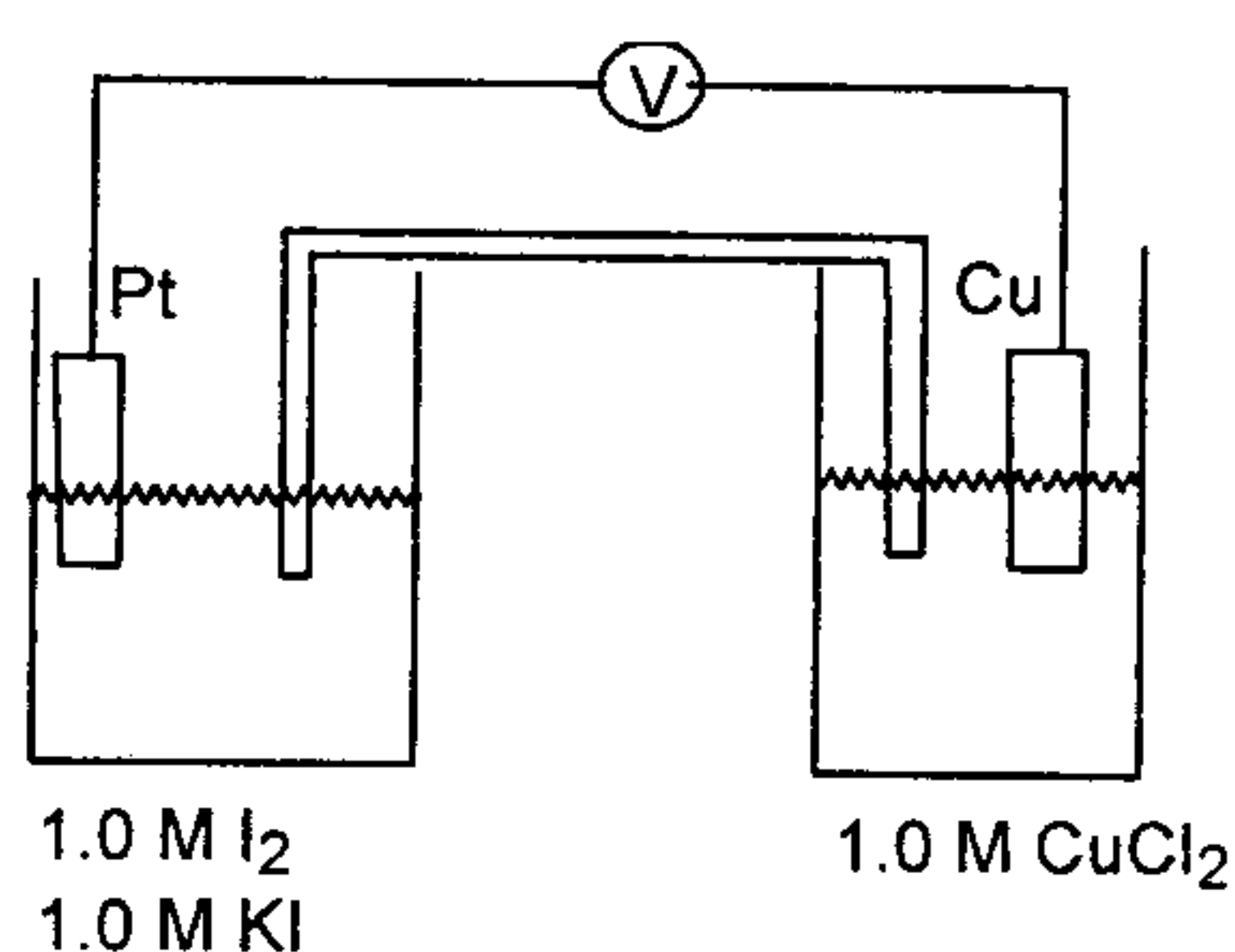


If the cell is initially at standard conditions ($[\text{Cu}^{2+}] = [\text{Zn}^{2+}] = 1.00 \text{ M}$), what are the concentrations of Cu^{2+} and Zn^{2+} when the cell potential has fallen to 1.06 V?

- (a) $[\text{Cu}^{2+}] = 8.5 \times 10^{-2} \text{ M}$; $[\text{Zn}^{2+}] = 1.91 \text{ M}$ (b) $[\text{Cu}^{2+}] = 0.94 \text{ M}$; $[\text{Zn}^{2+}] = 1.06 \text{ M}$
 (c) $[\text{Cu}^{2+}] = 1.91 \text{ M}$; $[\text{Zn}^{2+}] = 8.5 \times 10^{-2} \text{ M}$ (d) $[\text{Cu}^{2+}] = 0.50 \text{ M}$; $[\text{Zn}^{2+}] = 1.50 \text{ M}$
 (e) $[\text{Cu}^{2+}] = 0.90 \text{ M}$; $[\text{Zn}^{2+}] = 1.10 \text{ M}$

15. For the working galvanic cell shown at standard conditions, how would you increase the cell potential?

- (a) make the Pt electrode larger
 (b) make the Copper electrode larger
 (c) increase the concentration of KI
 (d) increase the concentration of I_2
 (e) none of these

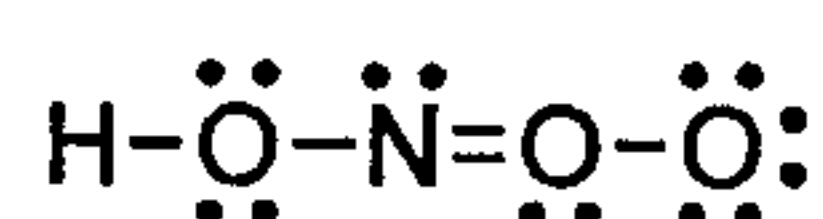


16. An electron in an H atom is excited to an energy of $-8.72 \times 10^{-20} \text{ J}$ which corresponds to a primary level

5. What is the largest value of m_l possible for this energy level? ($E_n = \frac{-2.18 \times 10^{-18} \text{ J}}{n^2}$)

- (a) 3 (b) 4 (c) 5 (d) 6 (e) none of the above

17. What are the formal charges on the atoms in the following Lewis structure for HNO_3 ?



Choice	Formal charges on H;O:N:O:O, respectively
(a)	1; 0; 0; 0; -1
(b)	0; 0; 1; 0; -1
(c)	1; 0; 1; 0; -2
(d)	0; 0; 0; 0; 0
(e)	0; 0; 0; 1; -1

18. The complex $\text{Fe}(\text{C}_2\text{O}_4)_3^{3-}$ has one unpaired electron. What is the electron configuration of this complex?

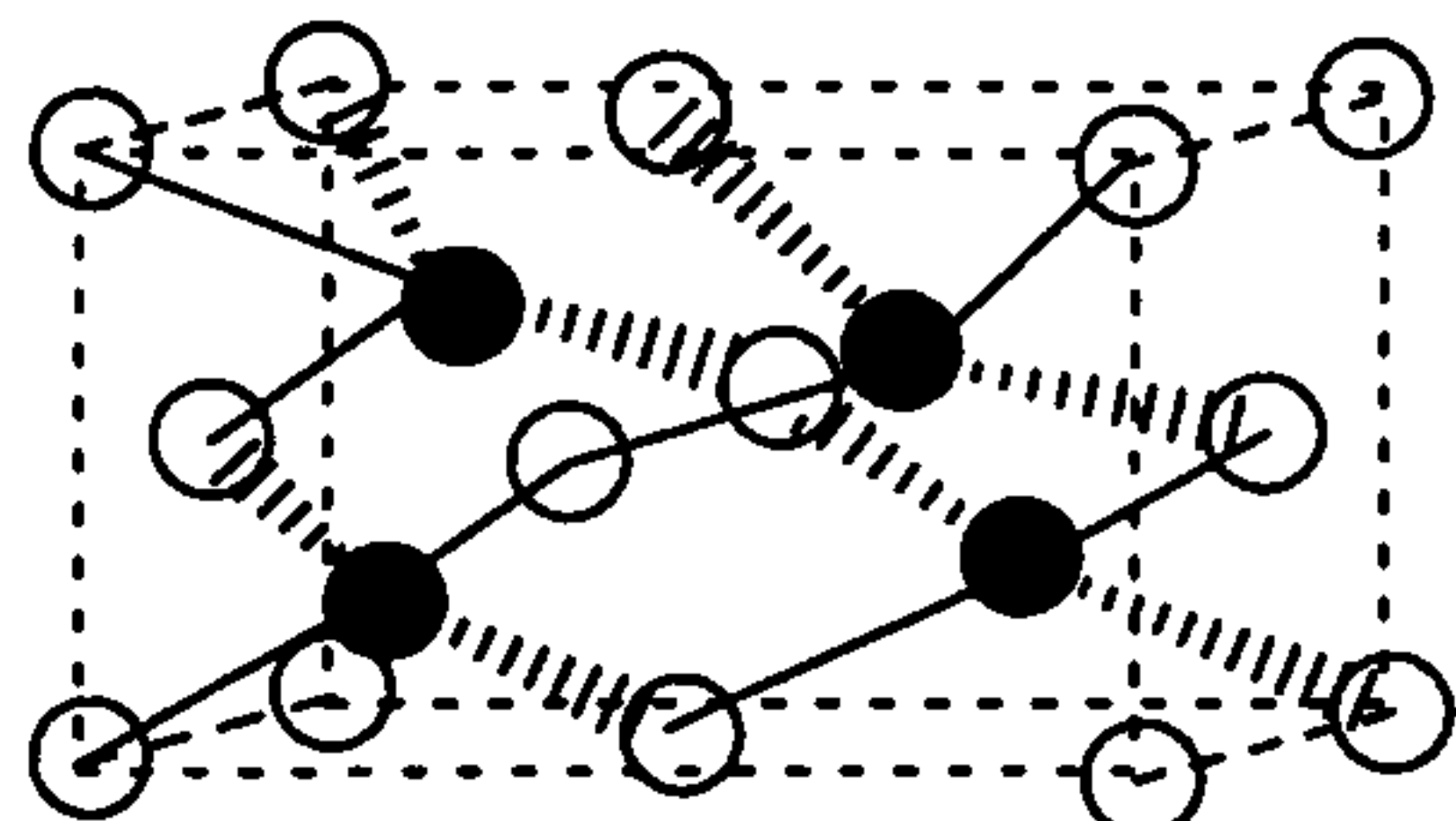
- (a) $t_{2g}^4 e_g^1$ (b) $t_{2g}^5 e_g^1$ (c) t_{2g}^5 (d) $t_{2g}^4 e_g^2$ (e) none of the above

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19. Below is the structure for zinc sulfide. If the zinc atoms (zinc) are contained within the unit cell and the sulfur atoms (clear) form a face centered cubic structure, how many sulfur atoms must be contained within the unit cell to balance the charge?

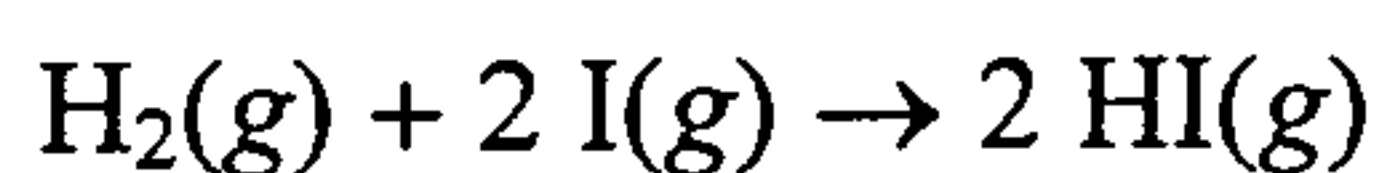


- (a) 1 (b) 2 (c) 3 (d) 4 (e) 5

20. Which of the following samples of substances has the smallest entropy change for fusion at its melting point, T_f ?

	substance	Sample size, (g)	MM (g/mole)	ΔH_f (J/mole)	T_f (K)
(a)	CO ₂	50	44.011	7949.6	195
(b)	H ₂ O	25	18.01594	6010	273.15
(c)	C ₆ H ₆	80	78.11	9951	278.68
(d)	CH ₃ OH	50	32.04	3177	175.25
(e)	C ₃ H ₈ O ₃ (glycerol)	95	92.09	8475	291.17

21. Hydrogen and iodine react to form HI. One possible mechanism is shown below:



Consider the following statements in light of this mechanism.

1. the rate law overall is second order
2. the iodine atom is an intermediate
3. the first step is the rate determining step
4. the second step is the fast step
5. the second step is rate determining

Which of the above statements are true?

- (a) 2, 3 and 4 (b) 2 and 5 (c) all except 5 (d) 1 and 2 only (e) 1, 2 and 5

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22. It is determined that the charcoal in a fire pit used as an ancient hearth has lost about 42.3% of the initial ^{14}C . How old was the fire pit if ^{14}C has a half life of 5730 years?

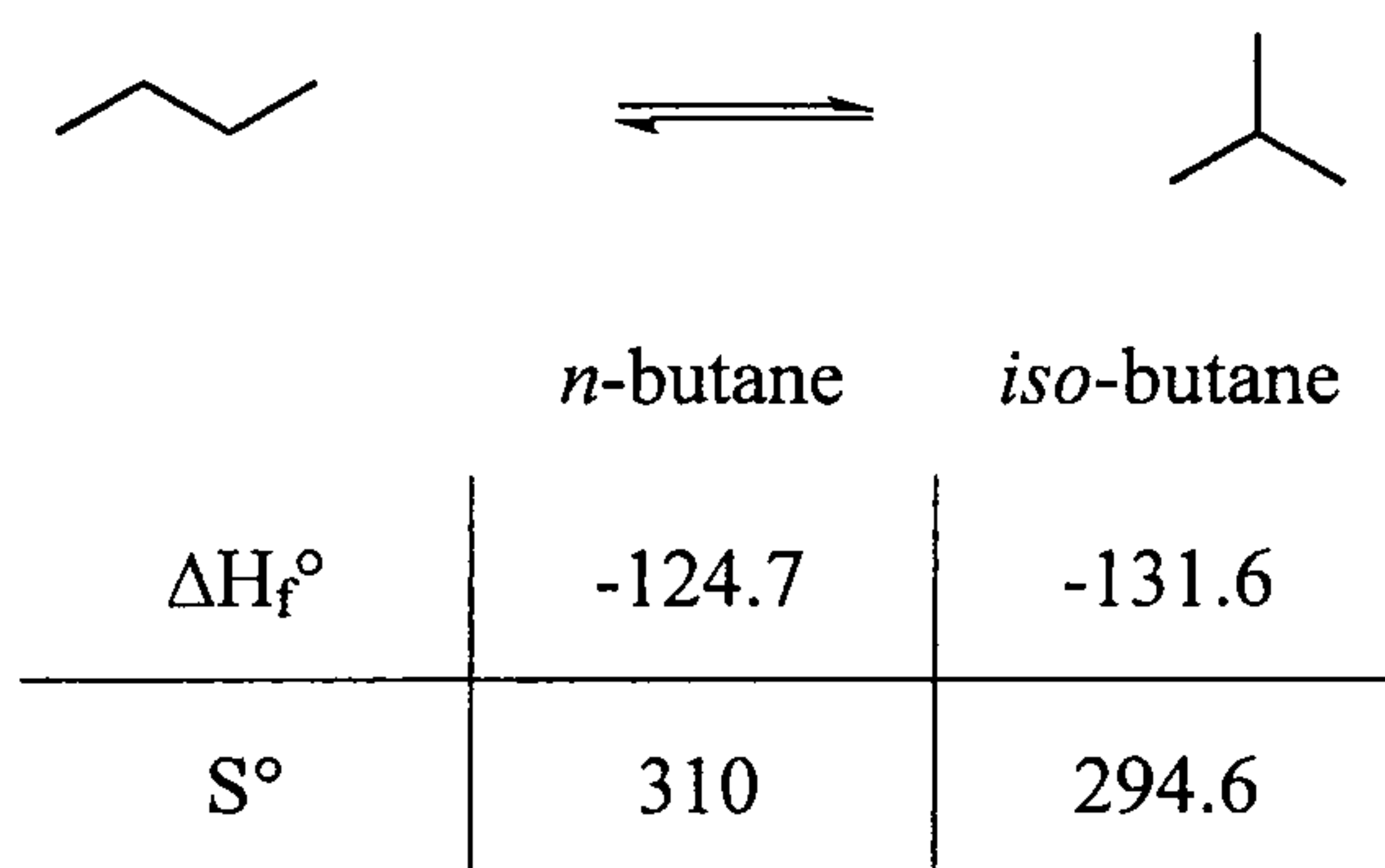
- (a) 2210 yrs (b) 4430 yrs (c) 4550 yrs (d) 5250 yrs (e) 7750 yrs

23. Which of the following 5 complexes are paramagnetic with 2 unpaired electrons?

1.	2.	3.	4.	5.
$\text{Mn}(\text{H}_2\text{O})_6^{2+}$	WCl_6^{4-}	$\text{Cr}(\text{H}_2\text{O})_6^{2+}$	ZrCl_6^{4-}	$\text{Cr}(\text{CN})_6^{4-}$

(a) 1 and 2 (b) 2, 4 and 5 (c) 3 (d) 4 and 5 (e) 1 and 3

24. Isomerization of hydrocarbons is important in the refining of petroleum. A simple example is that of butane, which has only two isomers:



Which of the following statements is most correct?

- (a) At standard temperatures, *n*-butane is the preferred isomer
 (b) At temperatures less than 450, *n*-butane is the preferred isomer
 (c) At temperatures greater than 450 K, *n*-butane is the preferred isomer
 (d) At ambient temperatures, a sample of *n*-butane and *so*-butene which was at equilibrium would contain barely any butane
 (e) A 1:1 mixture of *n*-butane and *iso*-butane is at equilibrium at room temperature.

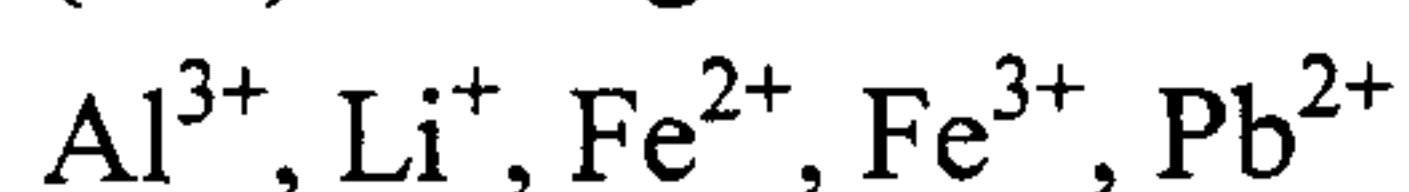
25. Which of the following are Lewis bases?

1.	2.	3.	4.	5.
Cl^-	SO_3	NH_3	PCl_5	Cr_2O_3

(a) 1, 2 and 3 (b) 1, 3, and 5 (c) 2, 4, and 5 (d) 1, 3, and 4 (e) all of the above

(II) Short Answer Questions (50%)

1. (3%) Arrange the following elements in order of hardness from softest to hardest.

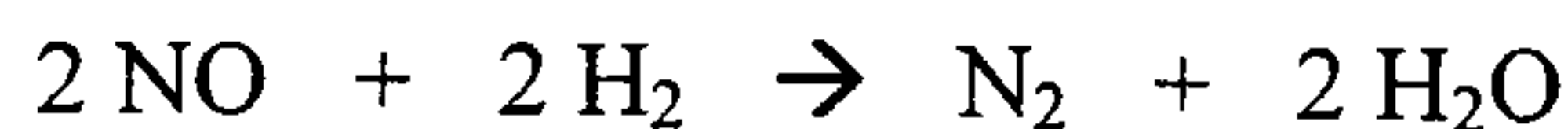


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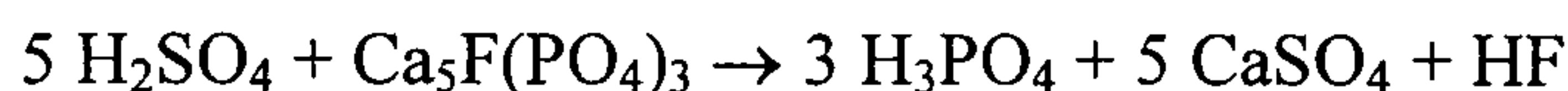
2. (4%) The following are initial rate data for:



Experiment	Initial [NO]	Initial [H ₂]	Initial Rate
1	0.20	0.12	0.066
2	0.20	0.24	0.13
3	0.20	0.36	0.20
4	0.40	0.12	0.26
5	0.60	0.12	0.59

Determine the rate constant using the data from experiment 2.

3. (3%) Millions of tons of phosphoric acid are manufactured by the treatment of $\text{Ca}_5\text{F}(\text{PO}_4)_3$ with 55% by mass H_2SO_4 in water (density = 1.993 g/mL). How many L of this sulfuric acid solution are required to synthesize 1.0×10^6 kg of H_3PO_4 by the following reaction?



4. (5%) The dehydration of benzyl alcohol to benzaldehyde is shown below:



The equilibrium constant for this process is 0.558 at 525 K. 0.2 moles of benzyl alcohol is placed in a 2L flask with 0.15 moles benzaldehyde and 1.0 moles of H_2 gas. Determine Q for this mixture and which direction the reaction will shift to reach equilibrium.

5. (4%) What is the pH of a solution made by the addition of 0.34 mole of Na_2HPO_4 and 0.65 mole of NaH_2PO_4 and sufficient water to give a total volume of 1.2 L? The pK_a 's of the three acid-conjugate base pairs derived from phosphoric acid, H_3PO_4 , are 2.12, 7.21 and 12.32.
6. (3%) Use a Born-Haber analysis to estimate the energy released on forming KCl_2 from $\text{K}(\text{s})$ and Cl_2 where K has a 2+ charge (the lattice energy for KCl_2 is about 2200 kJ/mole; heat of vaporization (K) = 77.1 kJ/mole; $\text{IE}_1(\text{K}) = 419$ kJ/mole; $\text{IE}_2(\text{K}) = 3051$ kJ/mole; Cl_2 bond energy = 240 kJ/mole; $\text{EA}(\text{Cl}) = -348.8$ kJ).
7. (6%) Gold is mined by forming a solution containing the Au^{3+} ion and then displacing the gold ion with an active metal such as zinc. A 4.00×10^4 L pool of such a solution has a density of 1.08 g/mL and contains 0.0051% gold by mass. Treatment with zinc gives a 98% yield of the dissolved gold. (a) What is the stoichiometric mass of zinc (in kg) required to remove the gold in this solution? (b) What mass of gold will be recovered by this treatment?

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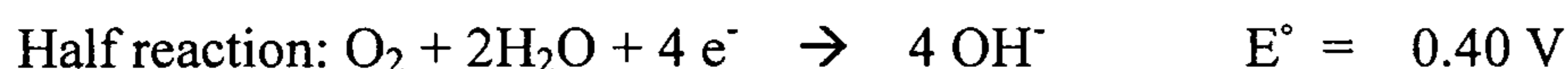
8. (8%) The water gas shift reaction is used to remove CO from the mixture of gases in ammonia production:



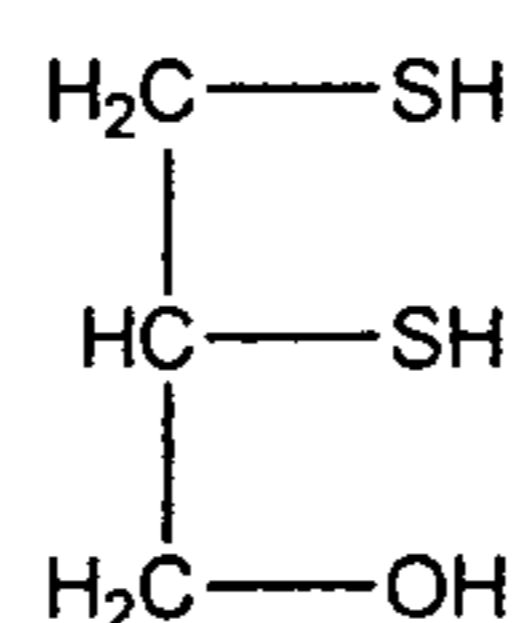
At 300 °C, the equilibrium constant for this reaction has $K = 36$. If a tank with a volume of 30.0 L is charged with 1.0 mole of CO and 2.2 moles of H₂O and the temperature brought to 300 °C, what are the equilibrium pressures of CO, H₂, H₂O and CO₂ in the tank?

9. (3%) The ruby laser contains chromium (III) ions in Al₂O₃. It is the Cr(III) ion that emits light of 627 nm under the laser emission conditions. If a ruby contains 0.0010% Cr by mass, what is the minimum mass of a ruby (in g) required to produce a single pulse with energy 1.5 J? ($h = 6.626 \times 10^{-34}$ J·s, $c = 3.0 \times 10^8$ m/s, $m_{e^-} = 9.11 \times 10^{-31}$ kg)

10. (5%) What is the maximum work that can be obtained from a hydrogen-oxygen fuel cell at standard conditions that produces 1.00 kg of water at 25°C? Why do we say that this is the maximum work that can be obtained?



11. (6%) BAL is a chelating agent used in treating heavy metal poisoning. It acts as a bidentate ligand. What types of linkage isomers are possible when BAL coordinates to a metal ion?



Note: The atomic masses of elements are as follows:

H = 1.0	C = 12.0	N = 14.0	O = 16.0	Al = 27.0	S = 32.1
Ca = 40.1	F = 19.0	P = 31.0	Na = 23.0	Zn = 65.4	Au = 197.0
Cr = 52.0					