

科目：綜合化學(1001)

校系所組：中央大學化學學系

交通大學應用化學系(甲組)

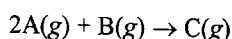
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清華大學材料科學工程學系(丙組)

每題 2 分

Fundamental Constants: Boltzmann's constant $k = 1.38 \times 10^{-23} \text{ J/K}$; Gas constant $R = 8.31 \text{ J/mol-K} = 0.082 \text{ L-atm/mol-K}$;
 Planck's constant $h = 6.62 \times 10^{-34} \text{ J-S}$; Faraday's constant $F = Ne = 9.64 \times 10^4 \text{ C/mol}$;
 Mass of electron = $9.10 \times 10^{-28} \text{ g}$

- The radius of the Earth is approximately 6370 km. If one could dig down straight towards the center of the Earth, one would find that the outermost 2890 km (the crust and the mantle) has an average density of about 4.5 g/cm^3 . Farther down is the core. If the average density of the Earth is 5.5 g/cm^3 , what is the average density of the Earth's core? (Recall that the volume of a sphere is given by $V = (4/3)\pi r^3$.)
 A) 11.0 g/cm^3 B) 5.7 g/cm^3 C) 6.2 g/cm^3 D) 1.9 g/cm^3 E) not enough data is provided
- The mineral hausmannite is a compound of manganese-55 and oxygen-16. If 72% of the mass of hausmannite is due to manganese, what is the empirical formula of hausmannite?
 A) MnO_2 B) Mn_3O C) Mn_3O_4 D) Mn_4O_3 E) MnO_3
- A copper wire has a diameter of 2.00 mm. What length of this wire contains exactly 1.00 mol of copper? ($\text{Cu} = 63.55$, density of $\text{Cu} = 8.92 \text{ g/cm}^3$)
 A) 0.178 m B) 0.678 m C) 60.1 m D) 45.1 m E) 2.27 m
- A 1.375 g sample of mannitol, a sugar found in seaweed, is burned completely in oxygen to give 1.993 g of carbon dioxide and 0.9519 g of water. The empirical formula of mannitol is ($\text{C} = 12$, $\text{H} = 1$, $\text{O} = 16$)
 A) CH_3O B) CH_7O_3 C) $\text{C}_2\text{H}_5\text{O}_2$ D) $\text{C}_3\text{H}_7\text{O}_3$ E) $\text{C}_3\text{H}_2\text{O}$
- A method for producing pure copper metal involves the reaction of copper(I) sulfide with oxygen gas to give copper metal and sulfur dioxide. Suppose the yield of this reaction is 87%. What mass of a copper ore consisting of 46% copper(I) sulfide must be mined in order to produce $1.0 \times 10^3 \text{ kg}$ of copper metal? ($\text{Cu} = 63.55$, $\text{S} = 32.07$, $\text{O} = 16$)
 A) $8.0 \times 10^3 \text{ kg}$ B) $3.1 \times 10^3 \text{ kg}$ C) $2.1 \times 10^3 \text{ kg}$ D) $1.5 \times 10^3 \text{ kg}$ E) $1.3 \times 10^3 \text{ kg}$
- When 20.0 mL of a 0.250 M $(\text{NH}_4)_2\text{S}$ solution is added to 150.0 mL of a solution of $\text{Cu}(\text{NO}_3)_2$, a CuS precipitate forms. The precipitate is then filtered from the solution, dried, and weighed. If the recovered CuS is found to have a mass of 0.3491 g, what was the concentration of copper ions in the original $\text{Cu}(\text{NO}_3)_2$ solution? ($\text{Cu} = 63.55$, $\text{S} = 32.07$)
 A) $2.65 \times 10^{-3} \text{ M}$ B) $1.32 \times 10^{-2} \text{ M}$ C) $3.33 \times 10^{-2} \text{ M}$ D) $4.87 \times 10^{-2} \text{ M}$ E) $2.43 \times 10^{-2} \text{ M}$
- A 350 mL sample of 0.276M HNO_3 is partially neutralized by 125 mL of 0.0120M $\text{Ca}(\text{OH})_2$. Find the concentration of nitric acid in the resulting solution.
 A) 0.210 M B) 0.0632 M C) 0.203 M D) 0.240 M E) 0.197 M
- Gas A and gas B are combined in a flask at initial pressures of 1.0 atm each. The flask is sealed and over time they react to completion to give gas C according to the following chemical equation:



Assuming the temperature stays constant, what will be the total pressure in the flask after the reaction goes to completion?

- A) 0.25 atm B) 0.50 atm C) 0.67 atm D) 0.75 atm E) 1.0 atm

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9. 9.45 g of liquid hexane (C_6H_{14} , M.W. = 86.18) is introduced into a 10.0 L vessel containing 13.15 atm of oxygen gas at $21^\circ C$ and ignited, yielding carbon dioxide and water. If the vessel is then cooled to $-10^\circ C$, what will be the gas pressure inside the vessel?
A) 13.15 atm B) 12.6 atm C) 10.9 atm D) 3.09 atm E) 1.42 atm
10. A 2.50-L flask contains a mixture of methane (CH_4) and propane (C_3H_8) at a pressure of 1.45 atm and $20^\circ C$. When this gas mixture is then burned in excess oxygen, 8.60 g of carbon dioxide (M.W. = 44.0) is formed. (The other product is water.) What is the mole fraction of methane in the original gas mixture?
A) 0.965 B) 0.855 C) 0.659 D) 0.341 E) 0.145
11. Ethanol undergoes combustion in oxygen to produce carbon dioxide gas and liquid water. The standard heat of combustion of ethanol, $C_2H_5OH(l)$, is -1366.8 kJ/mol. Given that $\Delta H_f^\circ[CO_2(g)] = -393.5$ kJ/mol and $\Delta H_f^\circ[H_2O(l)] = -285.8$ kJ/mol, what is the standard enthalpy of formation of ethanol?
A) 3,010 kJ/mol B) 1,367 kJ/mol C) 687.6 kJ/mol D) -277.6 kJ/mol E) -687.6 kJ/mol
12. Pentaborane $B_5H_9(s)$ burns vigorously in O_2 to give $B_2O_3(s)$ and $H_2O(l)$. Calculate ΔH_{rxn}° for the combustion of 1 mol of B_5H_9 .
 $\Delta H_f^\circ[B_2O_3(s)] = -1,273.5$ kJ/mol, $\Delta H_f^\circ[B_5H_9(s)] = 73.2$ kJ/mol, $\Delta H_f^\circ[H_2O(l)] = -285.8$ kJ/mol
A) $-18,170$ kJ/mol B) $-1,2735$ kJ/mol C) $-9,086$ kJ/mol D) $-8,448$ kJ/mol E) $-4,543$ kJ/mol
13. The enthalpy change when a strong acid is neutralized by strong base is -56.1 kJ/mol. If 135 mL of 0.450 M HI at $23.15^\circ C$ is mixed with 145 mL of 0.500 M NaOH, also at $23.15^\circ C$, what will the maximum temperature reached by the resulting solution? (Assume that there is no heat loss to the container, that the specific heat of the final solution is 4.18 J/g $^\circ C$, and that the density of the final solution is that of water.)
A) $20.24^\circ C$ B) $26.06^\circ C$ C) $29.19^\circ C$ D) $32.35^\circ C$ E) $36.57^\circ C$
14. A photon is roughly 1800 times more massive than an electron. If a proton and an electron have the same kinetic energy,
A) The wavelength of the photon will be about $\sqrt{1800}$ times longer than the wavelength of the electron.
B) The wavelength of the photon will be about 1800 times longer than the wavelength of the electron.
C) The wavelength of the photon will be roughly equal to the wavelength of the electron.
D) The wavelength of the electron will be about 1800 times longer than the wavelength of the photon.
E) The wavelength of the electron will be about $\sqrt{1800}$ times longer than the wavelength of the photon.
15. A common way of initiating certain chemical reactions with light involves the generation of free halogen atoms in solution. If ΔH for the reaction $Cl_2(g) \rightarrow 2Cl(g)$ is 242.8 kJ/mol, what is the longest wavelength of light that will produce free chlorine atoms in solution? (Planck's constant $k = 6.626 \times 10^{-34}$ J \cdot s)
A) 698.6 nm B) 492.6 nm C) 465.2 nm D) 349.3 nm E) 246.3 nm

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16. Imagine a universe in which the four quantum numbers can have the same possible values as in our universe except that the angular-momentum quantum number ℓ can have integral values of $0, 1, 2, \dots, n$ (instead of $0, 1, 2, \dots, n-1$). What would be the atomic number of the fifth element in the second row?
A) 7 B) 11 C) 13 D) 21 E) 23
17. For phosphorus atoms, which ionization energy will show an exceptionally large increase over the previous ionization energy?
A) 3rd B) 4th C) 5th D) 6th E) 7th
18. In the best Lewis structure for the fulminate ion, CNO^- , what is the formal charge on the central nitrogen atom?
A) -2 B) -1 C) 0 D) +1 E) +2
19. Use the given average bond dissociation energies D to estimate ΔH for the reaction of methane with fluorine according to the equation:
- $$\text{CH}_4(\text{g}) + 2 \text{F}_2(\text{g}) \rightarrow \text{CF}_4(\text{g}) + 2 \text{H}_2(\text{g}).$$
- | Bond | D , kJ/mol |
|------|--------------|
| C-F | 450 |
| C-H | 410 |
| F-F | 158 |
| H-H | 436 |
- A) +716 kJ B) +318 kJ C) -318 kJ D) -438 kJ E) -716 kJ
20. Consider the species Cl_2^+ , Cl_2 , and Cl_2^- . Which of these species will be paramagnetic?
A) only Cl_2 B) Cl_2 and Cl_2^- C) Cl_2^+ and Cl_2 D) Cl_2^+ and Cl_2^- E) all three are paramagnetic
21. In which of the following would the bonding be *strengthened* with the addition of an electron to form the negative molecular ion?
A) F_2 B) O_2 C) N_2 D) all of these E) none of these
22. Rhodium has a face-centered cubic structure and has a density of 12.4 g/cm^3 . What is its atomic radius? ($R_h = 102.9$)
A) 135 pm B) 190 pm C) 269 pm D) 381 pm E) 1070 pm
23. The molar enthalpy of vaporization of hexane (C_6H_{14}) is 28.9 kJ/mol , and its normal boiling point is 68.73°C . What is the vapor pressure of hexane at 25°C ?
A) 337 torr B) 171 torr C) 117 torr D) 75.9 torr E) 4.44 torr

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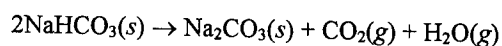
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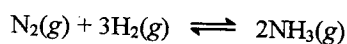
24. A solution of chloroform, CHCl_3 , and acetone, $(\text{CH}_3)_2\text{CO}$, exhibits a negative deviation from Raoult's law. This result implies that
- Chloroform-chloroform interactions are stronger than chloroform-acetone interactions.
 - Chloroform-chloroform interactions are weaker than chloroform-acetone interactions.
 - Acetone-acetone interactions are weaker than chloroform-acetone interactions.
 - Both B and C.
 - Both A and C.
25. An aqueous fructose solution having a density of 1.049 g/cm^3 is found to have an osmotic pressure of 17.0 atm at 25°C . Find the temperature at which this solution freezes. [Given: for water $K_f = 1.86^\circ\text{C/m}$; molecular mass of fructose = 180.16 g/mol]
- -1.69°C
 - -1.57°C
 - -1.52°C
 - -1.41°C
 - -1.30°C

26. Sodium carbonate can be made by heating sodium bicarbonate:



Given that $\Delta H^\circ = 128.9 \text{ kJ/mol}$ and $\Delta G^\circ = 33.1 \text{ kJ/mol}$ at 25°C , above what minimum temperature will the reaction become spontaneous under standard state conditions?

- 0.4 K
 - 3.9 K
 - 321 K
 - 401 K
 - 525 K
27. Which of the following statements concerning equilibrium is *not* true?
- A system that is disturbed from an equilibrium condition responds in such a way as to restore equilibrium.
 - Equilibrium in molecular systems is dynamic, with two opposing processes balancing one another.
 - The value of the equilibrium constant for a given reaction mixture is the same regardless of the direction from which equilibrium is attained.
 - A system moves spontaneously toward a state of equilibrium.
 - The equilibrium constant is independent of temperature.
28. Ammonia is prepared industrially by the following reaction



For the reaction, $\Delta H^\circ = -92.2 \text{ kJ}$ and K (at 25°C) = 4.0×10^8 . When the temperature of the reaction is increased to 500°C , which of the following statements is true?

- K for the reaction will be larger at 500°C than at 25°C .
- At equilibrium, more NH_3 is present at 500°C than at 25°C .
- Product formation (at equilibrium) is not favored as the temperature is raised.
- The reaction of N_2 with H_2 to form ammonia is endothermic.
- None of these is true.

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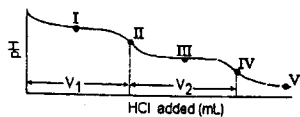
29. At -75°C , K for the reaction



is 4.66×10^{-8} . We introduce 0.036 mol of N_2O_4 into a 2.1-L vessel at -75°C and let equilibrium be established. The total pressure in the system at equilibrium will be

- A) 0.23 atm. B) 0.28 atm. C) 0.11 atm. D) 0.56 atm. E) 4.66×10^{-8} atm.
30. Calculate the $[\text{H}^+]$ in a $2.0 \times 10^{-6} \text{ M}$ solution of $\text{NaC}_2\text{H}_3\text{O}_2$. (K_a for $\text{HC}_2\text{H}_3\text{O}_2 = 1.8 \times 10^{-5}$)
- A) $1.1 \times 10^{-7} \text{ M}$ B) $6.0 \times 10^{-6} \text{ M}$ C) $3.4 \times 10^{-8} \text{ M}$ D) $1.7 \times 10^{-9} \text{ M}$ E) $9.6 \times 10^{-8} \text{ M}$
31. Calculate the percentage of pyridine ($\text{C}_5\text{H}_5\text{N}$) that forms pyridinium ion, $\text{C}_5\text{H}_5\text{NH}^+$, in a 0.10 M aqueous solution of pyridine ($K_b = 1.7 \times 10^{-9}$).
- A) 0.013% B) 1.6% C) 0.77% D) 0.060% E) 0.0060%
32. In deciding which of two acids is the stronger, one must know
- A) The concentration of each acid solution only.
- B) The pH of each acid solution only.
- C) The equilibrium constant of each acid only.
- D) All of the these.
- E) Both the concentration and the equilibrium constant of each acid
33. Consider the following information about the diprotic acid ascorbic acid (H_2As for short, molar mass = 176.0).
- | | K_{a1} | $\text{p}K_a$ |
|--|-----------------------|---------------|
| $\text{H}_2\text{As} \rightleftharpoons \text{H}^+ + \text{HAS}^-$ | 7.9×10^{-5} | 4.10 |
| $\text{HAS} \rightleftharpoons \text{H}^+ + \text{As}^{2-}$ | 1.6×10^{-12} | 11.79 |

The titration curve for disodium ascorbate, Na_2As , with standard HCl is shown below:



What is the pH at point I ($V_1/2$ HCl added)?

- A) 10 B) 7.95 C) 11.79 D) 12.39 E) none of these
34. Which of the following solutions will be the best buffer at a pH of 4.74? (K_a for $\text{HC}_2\text{H}_3\text{O}_2$ is 1.8×10^{-5} ; K_b for NH_3 is 1.8×10^{-5} .)
- A) 0.10 M $\text{HC}_2\text{H}_3\text{O}_2$ and 0.10 M $\text{NaC}_2\text{H}_3\text{O}_2$ B) 5.0 M $\text{HC}_2\text{H}_3\text{O}_2$ and 5.0 M NH_4Cl C) 0.10 M NH_3 and 0.10 M NH_4Cl
- D) 5.0 M $\text{HC}_2\text{H}_3\text{O}_2$ and 5.0 M $\text{NaC}_2\text{H}_3\text{O}_2$ E) 5.0 M $\text{HC}_2\text{H}_3\text{O}_2$ and 5.0 M NH_3

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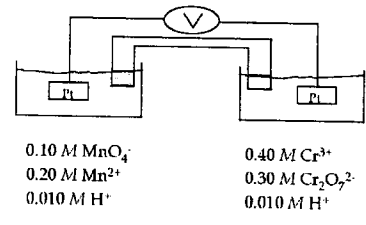
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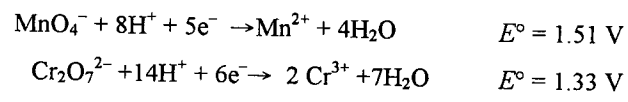
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35. Calculate the solubility of $\text{Ca}_3(\text{PO}_4)_2(\text{s})$ ($K_{\text{sp}} = 1.3 \times 10^{-32}$) in a $1.0 \times 10^{-2} \text{ M Ca}(\text{NO}_3)_2$ solution.
 A) $5.7 \times 10^{-14} \text{ mol/L}$ B) $6.2 \times 10^{-7} \text{ mol/L}$ C) $1.6 \times 10^{-14} \text{ mol/L}$ D) $3.16 \times 10^{-12} \text{ mol/L}$ E) none of these
36. For a reaction in a voltaic cell, both ΔH° and ΔS° are positive. Which of the following statements is true?
 A) E°_{cell} will increase with an increase in temperature.
 B) E°_{cell} will decrease with an increase in temperature.
 C) E°_{cell} will not change when the temperature increases.
 D) $\Delta G^\circ > 0$ for all temperatures.
 E) None of the above statements is true.

37. Refer to the galvanic cell below (the contents of each half-cell are written beneath each compartment).



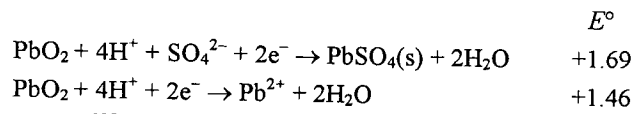
The standard reduction potentials are as follows:



What is the value of Q , the reaction quotient, for this cell reaction?

- A) 6.7×10^{40} B) 1.5×10^{-41} C) 1.5×10^{-4} D) 6.7×10^3 E) None of above

38. Use the following data to calculate the K_{sp} value at 25°C for $\text{PbSO}_4(\text{s})$.



- A) 2.57×10^{105} B) 3.89×10^{-105} C) 5.9×10^7 D) 1.7×10^{-8} E) 2.0×10^{-5}

39. Why is aluminum protected from corrosion? (The standard reduction potential for Al^{3+} is -1.66 V .)

- A) Aluminum forms a protective oxide coating.
 B) The oxidation of aluminum is not a favored process, as seen by the standard reduction potential for Al^{3+} .
 C) Oxygen and aluminum have no affinity for one another.
 D) At least two of these are correct.
 E) Aluminum is not protected from corrosion.

40. The reaction $\text{A} \rightarrow \text{B} + \text{C}$ is known to be first order in A with a rate constant of $5.0 \times 10^{-2} \text{ mol/L} \cdot \text{s}$ at 25°C . An experiment was run at 25°C where $[\text{A}]_0 = 1.0 \times 10^{-3} \text{ M}$. What is the integrated rate law?

- A) $[\text{A}] = kt$ B) $[\text{A}] - [\text{A}]_0 = kt$ C) $\frac{[\text{A}]}{[\text{A}]_0} = kt$ D) $\ln \frac{[\text{A}]}{[\text{A}]_0} = -kt$ E) $[\text{A}]_0 - [\text{A}] = kt$

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41. The rate law for a reaction is found to be $\text{Rate} = k[\text{A}]^2[\text{B}]$. Which of the following mechanisms gives this rate law?
- I. $\text{A} + \text{B} \rightleftharpoons \text{E}$ (fast)
 $\text{E} + \text{B} \rightarrow \text{C} + \text{D}$ (slow)
- II. $\text{A} + \text{B} \rightleftharpoons \text{E}$ (fast)
 $\text{E} + \text{A} \rightarrow \text{C} + \text{D}$ (slow)
- III. $\text{A} + \text{A} \rightarrow \text{E}$ (slow)
 $\text{E} + \text{B} \rightarrow \text{C} + \text{D}$ (fast)
- A) I only B) II only C) III D) two of these E) none of these
42. The reaction $2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2$ has the following mechanism:
- $$\text{H}_2\text{O}_2 + \text{I}^- \rightarrow \text{H}_2\text{O} + \text{IO}^-$$
- $$\text{H}_2\text{O} + \text{IO}^- \rightarrow \text{H}_2\text{O} + \text{O}_2 + \text{I}^-$$
- What is the catalyst in the reaction?
- A) I^- B) H_2O C) H_2O_2 D) IO^- E) No catalyst
43. What reason is given for the stability of C-C, N-N, and O-O bonds, compared to the instability of Si-Si, P-P, and S-S bonds?
- A) Their metallic character varies greatly.
 B) There are large differences in their ionization energies.
 C) There are large differences in their electronegativities.
 D) There are large differences in their abilities to form strong pi bonds.
 E) none of these
44. Choose the correct molecular structure for XeO_2F_2 .
- A) Distorted tetrahedron
 B) Trigonal planar
 C) Tetrahedral
 D) Octahedral
 E) None of these
45. Which of the following statements is true of the crystal field model?
- A) The interaction between metal ion and ligand is treated as a Lewis acid-base interaction.
 B) The ligands are treated as negative point charges.
 C) The metal ion-ligand bonds are considered completely ionic.
 D) The electrons are assumed to be localized.
 E) None of these statements is true.
46. For which of the following metal ions would there be no distinction between low spin and high spin in octahedral complexes?
- A) Cr^{2+} B) V^{2+} C) Co^{3+} D) Mn^{2+} E) Ni^{3+}
47. The number of unpaired electrons are found in $[\text{MnCl}_6]^{3-}$ is A and the number of unpaired electrons are found in $\text{Fe}(\text{en})_3^{2+}$ (en = ethylenediamine) is B. What's the number of A-B (A minus B)?
- A) 1 B) 3 C) 4 D) 2 E) 5

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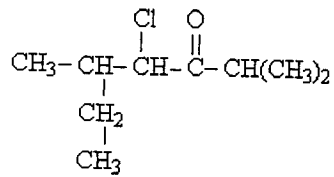
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48. A radioactive isotope of vanadium, ${}_{23}^{53}\text{V}$, decays by producing β particles and gamma rays. The nuclide formed has the atomic number

- A) 22 B) 21 C) 23 D) 24 E) 25

49. Name the following:



- A) 2-chloro-3-ethyl-1-isopropylbutanone
 B) isopropyl-chloro,methylbutyl ketone
 C) 4-chloro-2,5-dimethyl-3-heptanone
 D) 2-butyl,chloro,isobutanoyl methane
 E) 3-methyl-4-chloro-1-isopropylpentanone
50. What is the complementary nucleic acid sequence for the DNA sequence 5'-GAC TAC GTT AGC-3'?
- A) 5'-GAC TAC GTT AGC-3'
 B) 5'-TCA GCA TGG CTA-3'
 C) 3'-CTG ATG CAA TCG-5'
 D) 3'-CGA AAC GTA GTC-5'
 E) 3'-GCG AAA GGG TTA-5'