請依序作答於答案卷上，並清楚註明題號

一、選擇題(單選，每題 2%，共 50%)

1. Which of the experiments listed below did *not* provide the information stated about the nature of the atom?
   A) The Rutherford experiment proved that the Thomson "plum pudding" model of the atom was essentially correct.
   B) The Rutherford experiment determined the charge on the nucleus.
   C) The cathode-ray tube proved that electrons have a negative charge.
   D) Millikan's oil-drop experiment showed that the charge on any particle was a simple multiple of the charge on the electron.
   E) none of these

2. The limiting reactant in a reaction
   A) is the reactant for which you have the least number of moles.
   B) has the lowest coefficient in a balanced equation.
   C) has the lowest ratio of coefficient in the balanced equation to moles available.
   D) has the lowest ratio of moles available to coefficient in the balanced equation.
   E) none of these

3. A solution contains the ions Ag^+, Pb^{2+}, and Ni^{2+}. Dilute solutions of NaCl, Na_2SO_4, and Na_2S are available to separate the positive ions from each other. In order to effect separation, the solutions should be added in which order?
   A) Na_2S, NaCl, Na_2SO_4　　　B) Na_2SO_4, NaCl, Na_2S　　　C) Na_2SO_4, Na_2S, NaCl
   D) NaCl, Na_2S, Na_2SO_4　　　E) NaCl, Na_2SO_4, Na_2S

4. Consider three 1-L flasks at the same temperature and pressure. Flask A contains CO gas, flask B contains N_2 gas, and flask C contains O_2 gas.
   In which flask do the molecules have the greatest momentum per impact?
   A) The molecules in all the flasks have the same momentum per impact.
   B) The molecules in two of the flasks have the same momentum per impact.
   C) flask C　　　D) flask A　　　E) flask B

5. Consider the following equilibrium:
$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$
   with $K = 2.3 \times 10^{-6}$. 1.00 mol each of all reactants and products is placed in a 1.00-L container.

   Which way will the reaction initially proceed?
   A) To the right.　　　B) We need to know the temperature.　　　C) The system is at equilibrium.
   D) To the left.　　　E) none of these

6. As water is heated, its pH decreases. This means that
   A) $[OH^-] > [H^+]$.　　　B) $[H^+] > [OH^-]$.　　　C) the water is no longer neutral.
   D) Two of these are correct.　　　E) None of these is correct.

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7. The reaction $Cr(s) + NO_3^-(aq) \rightarrow Cr^{3+}(aq) + NO(g)$ takes place in acidic solution.
 What is the coefficient of $H_2O(l)$ in the balanced equation?
 A) 3 　　　　 B) 5 　　　　 C) 4 　　　　 D) 2 　　　　 E) 1

8. For a particular process $q = -10$ kJ and $w = 25$ kJ. Which of the following statements is true?
 A) The system does work on the surroundings.
 B) Heat flows from the surroundings to the system
 C) $\Delta E = -35$ kJ 　　　　 D) All of these are true. 　　　　 E) None of these is true.

9. For the reaction $H_2O(l) \rightarrow H_2O(g)$ at 298 K, 1.0 atm, ΔH is more positive than ΔE by 2.5 kJ/mol.
 This quantity of energy can be considered to be
 A) the heat flow required to maintain a constant temperature.
 B) the work done in pushing back the atmosphere.
 C) the difference in the H—O bond energy in $H_2O(l)$ compared to $H_2O(g)$
 D) the value of ΔH itself. 　　　　 E) none of these

10. Choose the correct statement.
 A) A reaction that exhibits a negative value of ΔS cannot be spontaneous.
 B) Exothermic reactions are always spontaneous.
 C) Free energy is independent of temperature.
 D) At constant pressure and temperature, a decrease in free energy ensures an increase in the entropy of the system
 E) none of these

11. Consider a solution consisting of the following two buffer systems:
 $$H_2CO_3 \rightleftharpoons HCO_3^- + H^+ \quad pK_a = 6.4 \;;\; H_2PO_4^- \rightleftharpoons HPO_4^{2-} + H^+ \quad pK_a = 7.2$$
 At pH 6.4, which one of the following is true of the relative amounts of acid and conjugate base present?
 A) $[H_2CO_3] > [HCO_3^-]$ and $[H_2PO_4^-] > [HPO_4^{2-}]$
 B) $[HCO_3^-] > [H_2CO_3]$ and $[HPO_4^{2-}] > [H_2PO_4^-]$
 C) $[H_2CO_3] > [HCO_3^-]$ and $[HPO_4^{2-}] > [H_2PO_4^-]$
 D) $[H_2CO_3] = [HCO_3^-]$ and $[HPO_4^{2-}] > [H_2PO_4^-]$
 E) $[H_2CO_3] = [HCO_3^-]$ and $[H_2PO_4^-] > [HPO_4^{2-}]$

12. What is the probability of finding a particle in a one-dimensional box in energy level $n = 4$ between $x = L/4$ and $x = L/2$? (L is the length of the box.)
 A) 50% 　　　 B) 12.5% 　　　 C) 33% 　　　 D) 25% 　　　 E) 37.5%

13. According to the VSEPR model, the electron pairs around NH_3 and those around CH_4 are arranged
 A) differently, because in each case there are a different number of atoms around the central atom.
 B) the same, because both nitrogen and carbon are in the second period.
 C) differently, because in each case there are a different number of electron pairs around the central atom.
 D) differently or the same, depending on the conditions leading to maximum repulsion.
 E) the same, because in each case there are the same number of electron pairs around the central atom.

14. Which statement about the thiocyanate ion, SCN^-, is true?
   A) Only one correct resonance structure can be drawn.
   B) Its Lewis structure contains an unpaired electron.
   C) Its shape is bent like that of H_2O.
   D) There are more than two σ bonds in the ion.
   E) none of these

15. Initial rate data have been determined at a certain temperature for the gaseous reaction

$$2NO + 2H_2 \rightarrow N_2 + 2H_2O$$

$[NO]_0$ (M)	$[H_2]_0$ (M)	Initial Rate (M/s)
0.15	0.30	0.0200
0.15	0.45	0.0300
0.30	0.30	0.0800

What is the numerical value of the rate constant?
   A) 1.5　　　　B) 9.9　　　　C) 3.0　　　　D) 0.13　　　　E) 0.44

16. The reaction $A \rightarrow B + C$ is known to be zero order in A with a rate constant of 5.0×10^{-2} mol/L · s at 25° C. An experiment was run at 25°C where $[A]_0 = 1.0 \times 10^{-3}$ M. What is the integrated rate law?
   A) $[A] = kt$　　　　　　B) $[A]_0 - [A] = kt$　　　　　C) $[A] - [A]_0 = kt$
   D) $\dfrac{[A]}{[A]_0} = kt$　　　　　E) $\ln \dfrac{[A]}{[A]_0} = kt$

17. A p-type semiconductor
   A) is made by doping host atoms with atoms having more valence electrons than the host.
   B) has electrons that lie close in energy to the conduction bands.
   C) is made by doping host atoms with atoms having fewer valence electrons than the host
   D) two of these　　　　　E) none of these

18. A liquid-liquid solution is called an ideal solution if
   I.　　it obeys $PV = nRT$;　　　II.　　it obeys Raoult's law.
   III.　solute-solute, solvent-solvent, and solute-solvent interactions are very similar.
   IV.　solute-solute, solvent-solvent, and solute-solvent interactions are quite different.
   A) II, IV　　　　B) II, III　　　　C) I, II　　　　D) I, II, III　　　　E) I, II, IV

19. 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 abilities to form strong pi bonds.
   C) There are large differences in their ionization energies.
   D) There are large differences in their electronegativities.
   E) none of these

20. Which of the following is diamagnetic?
   A) F_2^+　　　　B) C_2^+　　　　C) H_2^+　　　　D) N_2　　　　E) N_2^+

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21. The U-238 nucleus decays to form Pb-206 by α and β decays.
    Calculate the number of α decays.
    A) 2　　　　　B) 4　　　　　C) 6　　　　　D) 8　　　　　E) none of these

22. In lecture, the professor named a molecule 2-ethyl-4-tertiary-butylpentane. An alert student pointed out that although the correct structure could be drawn from this name, the name did not follow systematic rules. What is the correct systematic name for the molecule?
    A) 3,5,6,6-tetramethylheptane　　　B) 2-ethyl-4,5,5-trimethylhexane　　　C) undecane
    D) 2,2,3,5-tetramethylheptane　　　E) 2-*t*-butyl-5-methylhexane

23. Which of the following is optically active (that is, chiral)?
    A) 3-chloropentane　　　B) 1-bromopentane　　　C) 2-chloropentane
    D) dichloromethane　　　E) dimethylamine

24. For a reaction in a voltaic cell, both $\Delta H°$ and $\Delta S°$ 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) $\Delta G° > 0$ for all temperatures.
    E) None of the above statements is true.

25. Which of the following coordination compounds will form a precipitate when treated with an aqueous solution of $AgNO_3$?
    A) $Na_3[CrCl_6]$　　　B) $[Cr(NH_3)_3Cl_3]$　　　C) $Na_3[Cr(CN)_6]$　　　D) $[Cr(NH_3)_6]Cl_3$　　　E) all of these

二、非選擇題 (50%)

1. Consider the following diagram
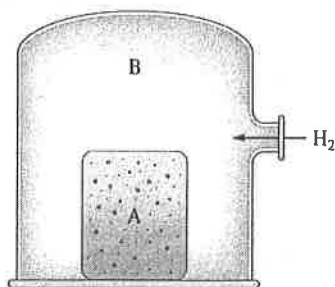
A porous container (A) , filled with air at STP, is contained in a large enclosed container (B), which is flushed with $H_2(g)$. What will happen to the pressure inside container A? Explain your answer. (4%)

2. Rank the following 0.1 M solutions in order of increasing pH. (6%)
   a. HI, HF, NaF, NaI
   b. NH_4Br, HBr, KBr, NH_3
   c. $C_6H_5NH_3NO_3$, $NaNO_3$, NaOH, HOC_6H_5, KOC_6H_5, $C_6H_5NH_2$, HNO_3

3. The following plot shows the pH curves for the titrations of various acids with 01 M NaOH (all the acids were 50.0 ml samples of 0.10 M concentration)
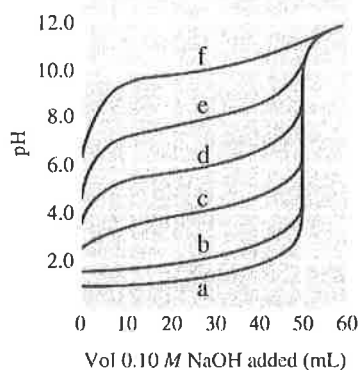
a. Which pH curve corresponds to the weakest and the strongest acid, respectively? Why? (3%)
b. Which point on the pH curve would you examine to see if this acid is a strong acid or weak acid (assuming you did not know the initial concentration of the acid)? Explain. (3%)
c. Which pH curve corresponds to an acid with Ka being around 1×10^{-6}? Explain (4%)

4. Which of the following processes are exothermic? Account for your answers. (6%)
a. $N_2(g) \rightarrow 2N(g)$　　　　b. $H_2O(l) \rightarrow H_2O(s)$　　　　c. $Cl_2(g) \rightarrow 2Cl(g)$
d. $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$　　e. $O_2(g) \rightarrow 2O(g)$

5. For the cell reaction
　　　　$2Al(s) + 3Mn^{2+}(aq) \rightarrow 2 Al^{3+}(aq) + 3Mn(s)$　$E° = 0.48$ V
Predict whether E will be larger or small than $E°$ for the following cases. Explain. (6%)
　a. $[Al^{3+}] = 2.0 M$, $[Mn^{2+}] = 1.0 M$
　b. $[Al^{3+}] = 1.0 M$, $[Mn^{2+}] = 3.0 M$

6. Which of the following sets of quantum numbers are not allowed in the hydrogen atoms? For the sets of quantum numbers that are incorrect, state what is wrong in each set. (6%)
　a. $n = 3, l = 2, m_l = 2$
　b. $n = 4, l = 3, m_l = 4$
　c. $n = 0, l = 0, m_l = 0$
　d. $n = 2, l = -1, m_l = 1$

7. Would the slope of a $\ln(k)$ versus $1/T$ (K) plot for a catalyzed reaction be more or less negative than the slope of a $\ln(k)$ versus $1/T$ (K) plot for the uncatalyzed reaction? Assume that both rate laws are first order. Explain. (4%)

8. The $Co(NH_3)_6^{3+}$ ion is diamagnetic, but $Fe(H_2O)_6^{2+}$ is paramagnetic. Explain. (8%)