第一部份：單選題(共30題，每題3分，共90分)

(1) The experiments of what two scientists were instrumental in determining the mass and charge of the electron?

A) Rutherford and Curie　B) Millikan and Cannizzaro　C) Thompson and Millikan
D) Thompson and Rutherford　E) Lavoisier and Dalton

(2) Indium has atomic number 49 and atomic mass 114.8 g. Naturally occurring indium contains a mixture of indium-112 and indium-115 in an atomic ratio of approximately

A) 6/94.　B) 24/76.　C) 50/50.　D) 76/24.　E) 94/6.

(3) Caffeine consists of carbon, hydrogen, oxygen, and nitrogen. When 0.1920 g of caffeine is burned in an excess of oxygen, 0.3482 g of carbon dioxide and 0.0891 g water are formed. Caffeine is 28.84% nitrogen by mass. Its molar mass is between 190 and 200 g/mol. What is the formula for caffeine?

A) $C_4H_5N_2O$　B) $C_3H_2N_2O_2$　C) $C_6H_4N_4O_4$　D) $C_8H_{10}N_4O_2$　E) none of these

(4) Consider the following reaction:

$$4NH_3(g) + 7O_2(g) \rightarrow 4NO_2(g) + 6H_2O(l)$$

Consider an experiment in which you react ammonia and oxygen. At the end of the experiment, you find that you produced 27.0 g of water, and 8.52 g of ammonia is left over. Calculate the initial mass of ammonia. Assume the reaction went to completion.

A) 10.8 g　B) 17.0 g　C) 25.5 g　D) 34.1 g　E) 68.0 g

(5) 1.00 mL of a 3.50×10^{-4} *M* solution of oleic acid is diluted with 9.00 mL of petroleum ether, forming solution A. 2.00 mL of solution A is diluted with 8.00 mL of petroleum ether, forming solution B. How many grams of oleic acid are in 5.00 mL of solution B? (molar mass for oleic acid = 282 g/mol)

A) 4.94×10^{-4} g　B) 7.00×10^{-6} g　C) 4.94×10^{-5} g　D) 1.97×10^{-6} g　E) 9.87×10^{-6} g

(6) Which of the following is(are) oxidation-reduction reactions?

I. $PCl_3 + Cl_2 \rightarrow PCl_5$
II. $Cu + 2AgNO_3 \rightarrow Cu(NO_3)_2 + 2Ag$
III. $CO_2 + 2LiOH \rightarrow Li_2CO_3 + H_2O$
IV. $FeCl_2 + 2NaOH \rightarrow Fe(OH)_2 + 2NaCl$

A) III only　B) IV only　C) I and II only　D) I, II, and III only　E) I, II, III, and IV

(7) Consider three 1.0-L flasks at STP. Flask A contains Ar gas, flask B contains Kr gas, and flask C contains H_2 gas.

In which flask do the gas particles have the highest average velocity?

A) flask A　B) flask B　C) flask C
D) The gas particles in all the flasks have the same average velocity.
E) The gas particles in two of the flasks have the same average velocity.

(8) Which of the following statements is true?

A) When two opposing processes are proceeding at identical rates, the system is at equilibrium.
B) Catalysts are an effective means of changing the position of an equilibrium.
C) The concentration of the products equals that of the reactants and is constant at equilibrium.
D) An endothermic reaction shifts toward reactants when heat is added to the reaction.
E) None of the above statements is true.

(9) At a given temperature, the equilibrium constant K for the reaction

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

is 3.0×10^9. If 2.60 mol of SO_2 and 3.90 mol of O_2 are placed in a 1.78-L container and allowed to react to equilibrium at this temperature, what is the concentration of SO_3 at equilibrium?

A) 2.19 M　B) 1.46 M　C) 3.65 M　D) 0.730 M　E) 2.92 M

(10) Consider the following equilibrium:

$$H_2(g) + I_2(s) \rightleftharpoons 2HI(g) \qquad \Delta H = +68.0 \text{ kJ/mol}$$

Which of the following statements about the equilibrium is *false*?

A) If the system is heated, the right side is favored.
B) This is a heterogeneous equilibrium.
C) If the pressure on the system is increased by changing the volume, the left side is favored.
D) Adding more $H_2(g)$ increases the equilibrium constant.
E) Removing HI as it forms forces the equilibrium to the right.

(11) The strong acid HA is added to water. Which of the following is the strongest base in the system?

A) HA　B) H_2O　C) H_3O^+　D) A^-　E) H_2A^-

(12) What is the $[H_3O^+]$ of a 0.13 M solution of NH_4Cl in H_2O at 25°C? (K_b for $NH_3 = 1.8 \times 10^{-5}$)

A) 1.5×10^{-3} M　B) 2.3×10^{-6} M　C) 8.5×10^{-6} M　D) 1.2×10^{-9} M　E) 7.2×10^{-9} M

(13) How many moles of $Fe(OH)_2$ [$K_{sp} = 1.8 \times 10^{-15}$] will dissolve in 1 L of water buffered at pH = 12.00?

A) 1.8×10^{-11} mol　B) 1.8×10^{-9} mol　C) 8.0×10^{-6} mol　D) 5.0×10^{-12} mol　E) 4.0×10^{-8} mol

(14) Using the following data, calculate the standard heat of formation of ICl(*g*) in kJ/mol.

	$\Delta H°$ (kJ/mol)
$Cl_2(g) \rightarrow 2Cl(g)$	242.3
$I_2(g) \rightarrow 2I(g)$	151.0
$ICl(g) \rightarrow I(g) + Cl(g)$	211.3
$I_2(s) \rightarrow I_2(g)$	62.8

A) –211 kJ/mol　B) –14.6 kJ/mol　C) 16.8 kJ/mol　D) 245 kJ/mol　E) 439 kJ/mol

(15) For the reaction $Cl_2O(g) + (3/2)O_2(g) \rightarrow 2ClO_2(g)$, $\Delta H° = 126.4$ kJ/mol and $\Delta S° = -74.9$ J/(K • mol). What is $\Delta G°$ at 377°C?

A) 98.3 kJ/mol　B) 77.8 kJ/mol　C) 175.1 kJ/mol　D) 51.5 kJ/mol　E) none of these

(16) When the equation for the following reaction in basic solution is balanced, what is the sum of the coefficients?

$$MnO_4^-(aq) + CN^-(aq) \rightarrow MnO_2(s) + CNO^-(aq)$$

A) 13　B) 8　C) 10　D) 20　E) 11

(17) Estimate the solubility product of silver iodide at 25°C, given the following data: (RT/F = 0.0591)

	$E°$ (V)
$AgI(s) + e^- \rightarrow Ag(s) + I^-$	–0.15
$I_2(s) + 2e^- \rightarrow 2I^-$	+0.54
$Ag^+ + e^- \rightarrow Ag(s)$	+0.80

A) 2.9×10^{-3}　B) 1.9×10^{-4}　C) 2.1×10^{-12}　D) 8.4×10^{-17}　E) 3.5×10^{-20}

(18) What is the electron configuration of Cr^{3+}?

A) [Ar] $4s^2 3d^1$　B) [Ar] $4s^1 3d^2$　C) [Ar] $3d^3$　D) [Ar] $4s^2 3d^4$　E) none of these

(19) Which of the following statements is true of second ionization energies?

A) That of Al is higher than that of Mg because Mg wants to lose the second electron, so it is easier to take the second electron away.

B) That of Al is higher than that of Mg because the electrons are taken from the same energy level, but the Al atom has one more proton.

C) That of Al is lower than that of Mg because Mg wants to lose the second electron, so the energy change is greater.

D) That of Al is lower than that of Mg because the second electron taken from Al is in a p orbital, so it is easier to take away.

E) The second ionization energies are equal for Al and Mg.

(20) Draw the Lewis structures of the molecules below, and use them to answer the following questions.
I. BH_3 II. NO_2 III. SF_6 IV. O_3 V. PCl_5

How many of the molecules have no dipole moment?
A) 1 B) 2 C) 3 D) 4 E) They are all polar.

(21) Select the correct molecular structure for SF_5^+.
A) pyramidal B) tetrahedral C) square planar D) octahedral E) none of these

(22) Which of the following statements is *false*?
A) Atoms or molecules with an even number of electrons are diamagnetic.
B) Atoms or molecules with an odd number of electrons are paramagnetic.
C) Paramagnetism cannot be deduced from the Lewis structure of a molecule alone.
D) Paramagnetic molecules are attracted toward a magnetic field.
E) N_2 molecules are diamagnetic.

(23) The reaction $2NO_2 \rightarrow 2NO + O_2$ obeys the rate law
$\frac{\Delta[O_2]}{\Delta t} = 1.40 \times 10^{-2}\,[NO_2]^2$ at 500° K.

If the initial concentration of NO_2 is 1.00 *M*, how long will it take for the $[NO_2]$ to decrease to 25.0% of its initial value?
A) 49.5 s B) 71.4 s C) 107 s D) 214 s E) cannot be determined from these data

(24) A metal crystallizes in a body-centered unit cell with an edge length of 2.18×10^2 pm. Assume the atoms in the cell touch along the cube diagonal. What will be the percentage of empty volume in the unit cell? ($\sqrt{2} = 1.414, \sqrt{3} = 1.732$)
A) 0.00% B) 26.0% C) 32.0% D) 68.0% E) 75.5%

(25) The osmotic pressure of a 0.0100 *M* solution of NaCl in water at 25°C is found to be different from 372 torr because
A) osmotic pressures are hard to measure. B) Na^+ and Cl^- ions are strongly hydrated.
C) NaCl does not dissociate in water. D) Na^+ and Cl^- ions can form ion pairs.
E) none of these

(26) Superoxides have the general formula
A) MO_2 B) M_2O_2 C) M_2O D) M_2O_3 E) MO

(27) Which of the following complexes would be diamagnetic?
A) $[Mn(CN)_6]^{4-}$ B) $[V(CN)_6]^{3-}$ C) $[Co(CN)_6]^{3-}$ D) $[Cr(CN)_6]^{3-}$

(28) Oxygen is stored in mammalian tissue in which type of molecule?
A) hemoglobin　B) myoglobin　C) chlorophyll　D) cytochrome　E) prophyrin

(29) The rate constant for the beta decay of a particular radioactive element is 2.70×10^{-2}/day. What is the half-life of this nuclide? ($ln2 = 0.693$, $ln3 = 1.099$)
A) 3.90×10^{-1} days　B) 1.85×10^{1} days　C) 3.70×10^{1} days
D) 2.57×10^{1} days　E) 7.41×10^{2} days

(30) When heat is added to proteins, the hydrogen bonding in the secondary structure breaks apart. What are the algebraic signs of ΔH and ΔS for the denaturation process?
A) Both ΔH and ΔS are positive.　B) Both ΔH and ΔS are negative.
C) ΔH is positive and ΔS is negative.　D) ΔH is negative and ΔS is positive.
E) ΔH is positive and ΔS is 0.

第二部份：簡答題(共兩題，每題5分，共10分。請寫出計算推導過程)

(1) For the reaction

$2A + B \rightarrow$ products

the following mechanism is proposed:

$$A + B \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} M$$

$$A + M \xrightarrow{k_2} \text{products}$$

Using the steady-state approximation, determine the rate law.

(2) Arsenic acid (H_3AsO_4) is a triprotic acid with $K_{a1} = 5 \times 10^{-3}$, $K_{a2} = 8 \times 10^{-8}$, and $K_{a3} = 6 \times 10^{-10}$. Calculate $[AsO_4^{3-}]$ in a 0.20 M arsenic acid solution.