請將答案寫在答案卷上，並清楚標明題號。

一、選擇題(50%；每題 2%)

1. Which one of the following combinations of names and formulas is incorrect?
   - A.　H_3PO_4 phosphoric acid
   - B.　HNO_3 nitric acid
   - C.　$NaHCO_3$ sodium carbonate
   - D.　H_2CO_3 carbonic acid
   - E.　KOH potassium hydroxide

2. Magnesium (used in the manufacture of light alloys) reacts with iron(III) chloride to form magnesium chloride and iron.

   $3Mg(s) + 2FeCl_3(s) \rightarrow 3MgCl_2(s) + 2Fe(s)$
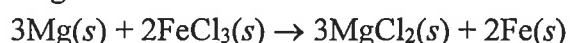
   A mixture of 41.0 g of magnesium (M = 24.31 g/mol) and 175 g of iron(III) chloride (M = 162.2 g/mol) is allowed to react. Identify the limiting reactant and determine the mass of the excess reactant present in the vessel when the reaction is complete.
   - A.　Limiting reactant is Mg; 67 g of $FeCl_3$ remain.
   - B.　Limiting reactant is Mg; 134 g of $FeCl_3$ remain.
   - C.　Limiting reactant is Mg; 104 g of $FeCl_3$ remain.
   - D.　Limiting reactant is $FeCl_3$; 2 g of Mg remain.
   - E.　Limiting reactant is $FeCl_3$; 87 g of Mg remain.

3. Which one of the following is a redox reaction?
   - A.　$2Na(g) + Cl_2(g) \rightarrow 2NaCl(s)$
   - B.　$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$
   - C.　$K_2Cr_2O_7(aq) + 2KOH(aq) \rightarrow 2K_2CrO_4(aq) + H_2O(l)$
   - D.　$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$
   - E.　$H_2O(l) \rightarrow H^+(aq) + OH^-(aq)$

4. Select the statement which does NOT apply to an ideal gas.
   - A.　There are no attractive forces between the gas molecules.
   - B.　There are strong repulsive forces between the gas molecules.
   - C.　The volume occupied by the molecules is negligible compared to the container volume.
   - D.　The gas behaves according to the ideal gas equation.
   - E.　The average kinetic energy of the molecules is proportional to the absolute temperature

5. Interference of light waves
   - A.　separates light into its component colors.
   - B.　creates a pattern of light and dark regions.
   - C.　focuses a broad beam of light into a point.
   - D.　bends light as it passes the edge of an object.
   - E.　creates a laser beam.

6. Which of the lines on the figure below is the best representation of the relationship between the volume of a gas and its Celsius temperature, other factors remaining constant?
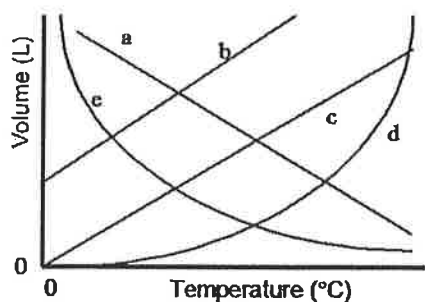
   A. a   B. b   C. c   D. d   E. e

7. In which of the following processes is $\Delta H = \Delta E$?
   A. Two moles of ammonia gas are cooled from 325°C to 300°C at 1.2 atm.
   B. One gram of water is vaporized at 100°C and 1 atm.
   C. Two moles of hydrogen iodide gas react to form hydrogen gas and iodine gas in a 40-L container.
   D. Calcium carbonate is heated to form calcium oxide and carbon dioxide in a container with variable volume.
   E. One mole of solid carbon dioxide sublimes to the gas phase.

8. Atomic orbitals developed using quantum mechanics
   A. describe regions of space in which one is most likely to find an electron.
   B. describe exact paths for electron motion.
   C. give a description of the atomic structure which is essentially the same as the Bohr model.
   D. allow scientists to calculate an exact volume for the hydrogen atom.
   E. are in conflict with the Heisenberg Uncertainty Principle.

9. Which of the following is a correct set of quantum numbers for an electron in a $5f$ orbital?
   A. $n = 5, l = 3, m_l = +1$ B. $n = 5, l = 2, m_l = +3$
   C. $n = 4, l = 3, m_l = 0$ D. $n = 4, l = 2, m_l = +1$
   E. $n = 5, l = 4, m_l = 3$

10. What is the correct order of decreasing size of the following ions?
    A. $P^{3-} > Cl^- > K^+ > Ca^{2+}$ B. $Ca^{2+} > K^+ > Cl^- > P^{3-}$
    C. $K^+ > Cl^- > Ca^{2+} > P^{3-}$ D. $K^+ > Cl^- > P^{3-} > Ca^{2+}$
    E. None of these choices is correct.

11. Combustion of a fat will release more energy than combustion of an equal mass of carbohydrate because
    A. fats contain more bonds to oxygen than carbohydrates.
    B. fats contain fewer bonds to oxygen than carbohydrates.
    C. the total energy of the carbon-carbon and carbon-hydrogen bonds in fats is greater than the energy content of the carbon-oxygen and oxygen-hydrogen bonds in the reaction products (carbon dioxide and water).
    D. the total energy of the carbon-carbon and carbon-hydrogen bonds in fats is greater than the energy content of the bonds in carbohydrates.
    E. fats have higher molar masses than carbohydrates.

12. In the $COCl_2$ molecule, carbon is the central atom. Based on the best Lewis structure for $COCl_2$, what is the formal charge on carbon?

    A.   0   B. +1   C. -1   D. +2   E. -2

13. Which of the following statements relating to molecular orbital (MO) theory is incorrect?

    A.   Combination of two atomic orbitals produces one bonding and one antibonding MO.

    B.   A bonding MO is lower in energy than the two atomic orbitals from which it is formed.

    C.   Combination of two $2p$ orbitals may result in either σ or π MOs.

    D.   A species with a bond order of zero will not be stable.

    E.   In a stable molecule having an even number of electrons, all electrons must be paired.

14. Which of the following statements describes the correct method of preparation of 1.00 L of a 2.0 M urea solution? M $_{urea}$ = 60.06 g/mol

    A.   Dissolve 120 g of urea in 1.00 kg of distilled water.

    B.   Dissolve 120 g of urea in 880 g of distilled water.

    C.   Dissolve 120 g of urea in enough distilled water to produce 1.00 L of solution.

    D.   Dissolve 120 g of urea in 1.00 liter of distilled water.

    E.   The density of urea is needed in order to do this calculation.

15. The basic character of the binary oxides X_mO_n

    A.   is greatest when X has a low atomic number.

    B.   is greatest when X is a nonmetal.

    C.   increases as the oxidation number of X increases.

    D.   increases as the oxidation number of X decreases.

    E.   is unaffected by the oxidation number of X.

16. Consider the following phase diagram and identify the process occurring as one goes from point C to point D.
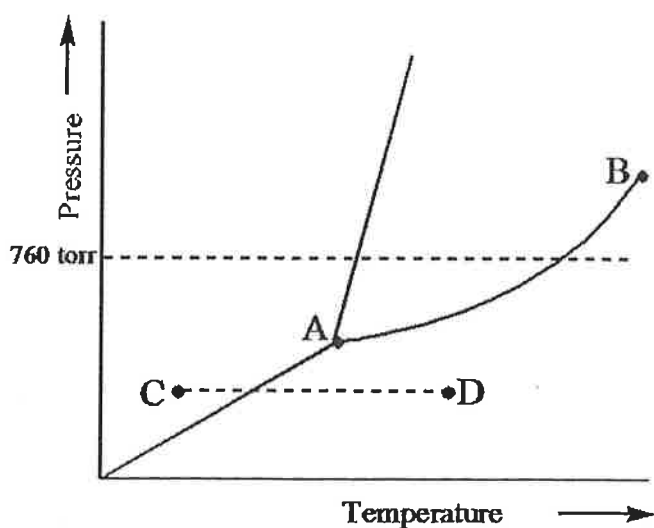
    A.   increasing temperature with a phase change from solid to liquid

    B.   increasing temperature with a phase change from solid to vapor

    C.   increasing temperature with a phase change from liquid to vapor

    D.   increasing temperature with no phase change

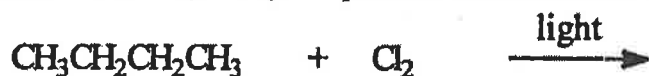   E.   increasing temperature beyond the critical point

17. Identify the principal organic product of the reaction between butane and chlorine.

$$CH_3CH_2CH_2CH_3 \quad + \quad Cl_2 \quad \xrightarrow{\text{light}}$$

   A. CH_3Cl B. $CH_3CH_2CHClCH_3$ C. $CH_3CHClCH_3$

   D. CH_3CH_2Cl · E.   None of these choices is a major product of the reaction.

18. The gas-phase reaction $CH_3NC \rightarrow CH_3CN$ has been studied in a closed vessel, and the rate equation was found to be: Rate = $-\Delta[CH_3NC]/\Delta t = k[CH_3NC]$. Which one of the following actions is least likely to cause a change in the rate of the reaction?

   A.   lowering the temperature   B.   adding a catalyst

   C.   using a larger initial amount of CH_3NC in the same vessel

   D.   using a bigger vessel, but the same initial amount of CH_3NC

   E.   continuously removing CH_3CN as it is formed

19. Which of the following has an effect on the magnitude of the equilibrium constant?

   A.   adding a catalyst   B.   adding more of a reactant

   C.   removing products as they are formed

   D.   increasing the pressure, in a gas-phase reaction

   E.   change in temperature

20. Select the correct relationship among the concentrations of species present in a 1.0 M aqueous solution of the weak acid represented by HA.

   A. $[H_2O] > [A^-] \sim [H_3O^+] > [HA] > [OH^-]$

   B. $[H_2O] > [HA] > [A^-] > [H_3O^+] > [OH^-]$

   C. $[HA] > [H_2O] > [A^-] > [H_3O^+] > [OH^-]$

   D. $[H_2O] > [HA] > [A^-] \sim [H_3O^+] > [OH^-]$

   E. $[HA] > [H_2O] > [A^-] \sim [H_3O^+] > [OH^-]$

21. An acetate buffer has a pH of 4.40. Which of the following changes will cause the pH to decrease?

   A.   dissolving a small amount of solid sodium acetate

   B.   adding a small amount of dilute hydrochloric acid

   C.   adding a small amount of dilute sodium hydroxide

   D.   dissolving a small amount of solid sodium chloride

   E.   diluting the buffer solution with water

22. Which of the following values is based on the Third Law of Thermodynamics?

   A. $\Delta H^\circ_f = 0$ for Al(s) at 298 K

   B. $\Delta G^\circ_f = 0$ for H_2(g) at 298 K

   C. $S^\circ = 51.446$ J/(mol·K) for Na(s) at 298 K

   D. $q_{sys} < 0$ for H_2O(l) $\rightarrow$ H_2O(s) at 0°C

   E.   None of these choices is correct.

23. Which of the following statements about voltaic and electrolytic cells is correct?
    A. The anode will definitely gain weight in a voltaic cell.
    B. Oxidation occurs at the cathode of both cells.
    C. The free energy change, ΔG, is negative for the voltaic cell.
    D. The electrons in the external wire flow from cathode to anode in an electrolytic cell.
    E. None of these choices is correct.

24. Consider the following octahedral complex structures, each involving ethylene diamine and two different, unidentate ligands X and Y.
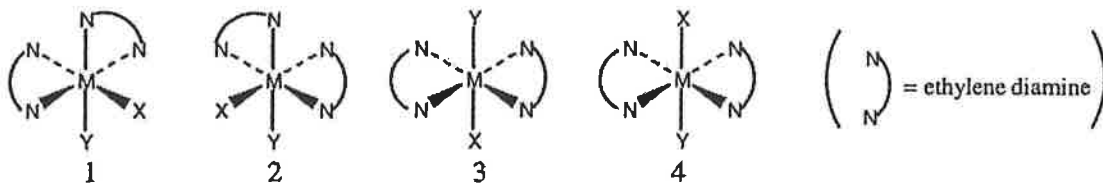
    Which one, if any, of the following is a pair of optical isomers?
    A. 1 and 2   B. 1 and 3   C. 1 and 4
    D. 3 and 4   E. None of these choices is correct.

25. The isotope $^{42}_{21}Sc$ is unstable. This is predictable because
    A. the number of neutrons is too large in relation to the number of protons.
    B. the number of neutrons is too small in relation to the number of protons.
    C. the atomic number is too large.
    D. the mass number is too large.
   E. Sc isotopes are all unstable

二、非選擇題(50%)

1. The density of pure gaseous compound was measured at 0.00 °C as a function of pressure to give the following results:

Density (g/L)	Pressure (atm)
0.17893	0.2500
0.35808	0.5000
0.53745	0.7500
0.71707	1.000

    Calculate the molar mass of this compound, corrected for any nonideal behavior of the gas. Assume the nonideal gas obeys the equation of $PV/nRT = 1 + \beta P$. (10%)
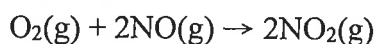
2. For the reaction
        $O_2(g) + 2NO(g) \rightarrow 2NO_2(g)$
    the observed rate law is
        Rate $= k\,[NO]^2\,[O_2]$
    Which of the changes listed below would affect the value of the rate constant k? Please account for your answer. (10%)

    a. increasing the partial pressure of O_2.
    b. change the temperature
    c. using an appropriate catalyst
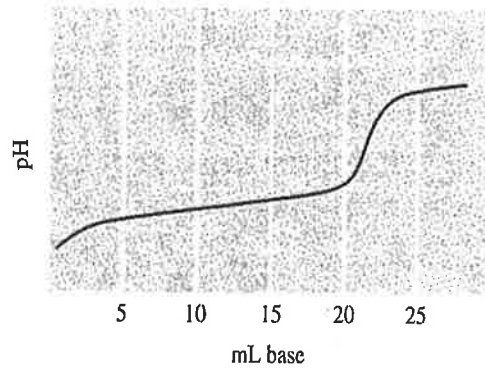
3. Consider the titration of a general weak acid HA with a strong base that gives the following titration curve. (10%)

Please indicate the points on the curve corresponding to the following.
 i) the equivalence point
 ii) the maximum buffering region
 iii) the pH = pKa
 iv) the pH depends only on [HA]
 v) the pH depends only on [A⁻] on the curve

4. For the species of O_2, O_2^+, and O_2^-, give the electron configuration and the bond order for each. Which has the strongest bond? (10%)

5. Determine the direction of electron flow, designate the anode and cathode, and calculate the potential at 25 °C for the cell represented in the following. (10%)