Chemistry 2500 Final Exam

Calculations must be shown to get credit. Five points will be deducted if a pen is used.

\[ h = 6.626 \times 10^{-34} \text{ J} \cdot \text{s} \]
\[ c = 2.998 \times 10^8 \text{ m/s} \]
\[ e = 1.602 \times 10^{-19} \text{ C} \]
\[ m_e = 9.109 \times 10^{-31} \text{ kg} \]
\[ N = 6.022 \times 10^{23} \text{ /mol} \]
\[ R = 8.3145 \text{ J/K} \cdot \text{mol} \]

1. (20 points) Complete and balance each reaction shown below. Use smallest integer values possible for coefficients. Product phases need not be specified.

\[ \text{Li}_3\text{N(s) + H}_2\text{O(l) } \rightarrow \]

\[ \text{Na(s) + NH}_3\text{(l) } \rightarrow \]

\[ \text{NaHCO}_3\text{(aq) + HC}_2\text{H}_3\text{O}_2\text{(aq) } \rightarrow \]

\[ \text{Mg(s) + TiCl}_4\text{(l) } \xrightarrow{\Delta} \]

\[ \text{CaCO}_3\text{(s) } \xrightarrow{\Delta} \]

\[ \text{CaO(s) + H}_2\text{O(l) } \rightarrow \]

\[ \text{B}_2\text{H}_6\text{(g) + H}_2\text{O(l) } \rightarrow \]

\[ \text{Al(s) + Cl}_2\text{(g) } \rightarrow \]

\[ \text{CH}_4\text{(g) + H}_2\text{O(l) } \xrightarrow{\Delta} \]

\[ \text{ClCN(g) } \xrightarrow{\Delta} \]
2. (12 points) The activation energy of a certain reaction is 76.7 kJ/mol. How many times faster will the reaction occur at 50 °C than at 0 °C?

3. (12 points) Name three polar, aprotic solvents; name three polar, protic solvents.

    Polar, aprotic
    Polar, protic
4. (12 points) Use a molecular-orbital diagram to explain the bond order in the dicarbide anion.

5. (16 points) For each element, write its common oxidation states other than zero.

   - nickel
   - gold

   - thallium
   - lead

   - titanium
   - niobium

   - molybdenum
   - manganese
6. (16 points) Draw the Lewis structure and predict the molecular geometries of the following molecules or polyatomic ions.

a) PCl$_3$  

b) XeF$_3^+$  

c) SF$_4$  

d) ICl$_2^-$

7. (12 points) Draw the cesium chloride structure and the rhenium oxide structure below; use small, closed spheres for cations and large, open spheres for anions.
8. (12 points) Write the chemical formula for each of the following metal complexes.

   a) sodium tetrahydroxocuprate(II)

   b) potassium tetrachloroferrate(III)

   c) hexaaquaaluminum(III) phosphate

   d) tetracarbonylnickel(0)

9. (10 points) Explain the chelate effect. Give an example of a chelating ligand.
10. (10 points) Consider the following equilibrium.

\[ [\text{AlCl}_4]^- (aq) + 4 \text{F}^- (aq) \rightleftharpoons [\text{AlF}_4]^- (aq) + 4 \text{Cl}^- (aq) \]

Do you expect the equilibrium constant to be greater than one or less than one? I.e., are the products or reactants favored? Briefly explain why.

11. (8 points) Write the electronic configuration for each element or monatomic ion. Use the noble-gas shorthand.

a) Cr  

b) Cu$^{2+}$

c) Mn$^{4+}$

d) W$^{6+}$

12. (12 points) Calculate the LFSE of the metal complex $[\text{Ni(CN)}_6]^{4-}$ in terms of $\Delta_0$ and $P$. 
13. (10 points) Complete and balance the following redox equation. A net ionic equation is both sufficient and preferred.

\[ \text{H}_2\text{O}_2(\text{aq}) + \text{I}_2(\text{s}) \rightarrow \text{H}_2\text{O}(\text{l}) + \text{HIO}_3(\text{aq}) \quad \text{acidic solution} \]

14. (4 points) Draw two-dimensional depictions of the orbitals listed below. Label axes used.

a) \(3d_{xy}\)  

b) \(3d_{xz}\)

15. (8 points) For each set of unit-cell parameters listed below, specify its basic cell type.

a)  
a = 7.663 Å  
b = 7.663 Å  
c = 4.002 Å  
\(\alpha = 90^\circ\)  
\(\beta = 90^\circ\)  
\(\gamma = 90^\circ\)  
b)  
a = 4.089 Å  
b = 9.343 Å  
c = 7.780 Å  
\(\alpha = 90^\circ\)  
\(\beta = 99.02^\circ\)  
\(\gamma = 90^\circ\)
16. (16 points) Cesium bromide has the cesium chloride structure, cell parameter $a = 4.295 \text{ Å}$, and a Born exponent of 11.0; the structure has a Madelung constant of 1.76267. Using this information, calculate its lattice energy in kJ/mol.

17. (6 points) For each pair of cations, circle the one that is more acidic.

   a) $\text{Fe}^{2+}$ or $\text{Fe}^{3+}$  
   b) $\text{Al}^{3+}$ or $\text{Ga}^{3+}$  
   c) $\text{Ti}^{4+}$ or $\text{K}^+$

18. (4 points) What produces paramagnetism?