Chemistry 331
Physical Chemistry
Practice Final Exam

Section _____ Name _____

1. A researcher has a laser that has a 250 nm wavelength. Which of the metals in the table below can be used to generate electrons? What is the highest energy electron that can be generated?

Metal	Electron Work Function
Al	4.28 eV
Au	5.10 eV
Cu	4.65 eV
In	4.12 eV
Mo	4.60 eV
Ni	5.15 eV
Pt	5.65 eV
Ti	4.33 eV
W	4.55 eV
Zn	4.33 eV

Energy of a 250 nm photon = _____.

Appropriate metals that satisy criterion = _____.

Highest energy photon that can be generated = _____.

2. A white dwarf collapses and then explodes into a supernova. The peak of the blackbody emission is observed to shift from 400 nm to 300 nm. A. What is the change in temperature of the surface of star as it becomes a supernova? B. What is the relative increase in radiative emitted power?

A. T at 300 nm = _____.
B. T at 400 nm = _____.
C. Relative increase in radiative power = _____.

3. Estimate the electron transition energy and wavelength of dodecene using the particle-in-a-box model. Assume that dodecene is a box of length 17.34 Å that contains 12 electrons.

Transition energy = _____.
Transition wavelength = _____.

4. A. The molecule Integrafor has a fluorescence quantum yield of 0.75 and an observed decay lifetime of 50 ns. Please determine the fluorescence rate constant (k_f) and the internal conversion (or non-radiative decay) rate constant (k_{IC}).

k_f = _____ k_{IC} = _____

B. A scientist synthesizes the molecule bromo-Integrafor with a fluorescence quantum yield of 0.1. The bromine causes a spin transition (singlet → triplet) because of the heavy atom effect. Assuming that k_f and k_{IC} are unchanged and that the origin of this effect is a third process is a rate constant for intersystem crossing k_{ISC}. Calculate the expected observed fluorescence lifetime for bromo-Integrafor. Please calculate the phosphorescence quantum yield (i.e. the quantum yield for emission from the triplet state Φ_{ISC}).

τ_{obs} = _____ .
Φ_{ISC} = _____.

5. An enzyme that follows Michaelis-Menten kinetics has a K_m of 100 µM. The initial velocity is 0.1 µM min^{-1} at a substrate concentration of 100 µM. What is the initial velocity when [S] is equal to (a) 1 µM or (b) 1 mM?

V = _____. [S] = 1 µM
V = _____. [S] = 1 mM

6. The binding constant of a drug at 310 K is 10^4 M^{-1} and at 330 K it is 5 x 10^3 M^{-1}. Calculate the standard enthalpy and entropy change for the binding process.

ΔH^o =_____.
ΔS^o =_____.

7. A. Calculate the energy of the transition series 6p → 2s, 5p → 2s, 4p → 2s in the hydrogen atom. B. Calculate the wavelength of light emitted for the 6p → 2s, 5p → 2s and 4p → 2s emission processes. C. What part of the electromagnetic spectrum is emitted by hydrogen in this series?

ΔE (6p → 2s) = _____ .
ΔE (5p → 2s) = _____.
ΔE (4p → 2s) = _____.
λ (6p → 2s) = _____.
λ (5p → 2s) = _____.
λ (4p → 2s) = _____.
Part of electromagnetic spectrum _____.

8. Please provide the following descriptions regarding vibrational and rotational energy levels and transitions.

   A. Sketch the potential energy function and first two wavefunctions for the vibrational solutions of the Schrödinger equation for N_2.

   B. Write a formula for the energy levels of vibration. Discuss the significance of the lowest vibrational level. What does the harmonic oscillator tell us about the motion of atoms at T = 0 K?

   C. Please write down the equation describes the rotational energy levels of N_2. Estimate the spacing of rotational lines in the microwave spectrum of N_2. In other words, derive the rotational constant (in units of Joules) from the difference in the energy levels.

9. The rotational constant of $H^{79}Br$ is 8.46 cm^{-1}. Calculate the bond length of the molecule.

10. The fundamental vibrational frequency of $H^{79}Br$ is 2649 cm^{-1}. Calculate the force constant of stretching vibration of this diatomic molecule in Newtons per meter.

11. Draw a diagram to describe the occupancy of the electrons in diatomic O_2 (Z=8).

A. What is the spin multiplicity of the ground state?

B. Assign the lowest energy transition in diatomic oxygen using the molecular orbitals in the diagram.

C. Give the bond order in the ground state.

D. Give the bond order of O_2^-.

13. The catabolism (break-down) of glucose is an important source of energy for all cells. It begins with the following transformation which is the first step of the glycolytic pathway:

Glucose → Glucose-6-Phosphate

Theoretically, the cell could phosphorylate glucose directly with inorganic phosphate (Pi) like so:

Glucose + Pi → Glucose-6-Phosphate + H_2O ΔG^o = + 3.3 kcal/mol I

a) Calculate the equilibrium constant for this reaction (include correct units).

b) Is it favorable under standard conditions? Why or why not?

c) In a typical cell, glucose and phosphate are maintained at 4.8 mM each. (1 mM = 10^{-3} M) What would be the equilibrium concentration of Glucose-6-Phosphate if the cells used the reaction as written above to make it?

d) Does this direct phosphorylation of glucose represent a reasonable route for the catabolism of glucose? Explain briefly.

The cell actually accomplishes the phosphorylation of glucose by coupling it to the hydrolysis of ATP in a reaction catalyzed by the enzyme hexokinase:

ATP + H_2O → ADP + Pi ΔG^o = -7.3 kcal/mol II

e) Write a balanced equation for the coupled reactions showing the ΔG^o for the net reaction.

14. A. Calculate the molar entropy change for a **reversible** expansion of an ideal gas from 1 L to 10 L to achieve a final pressure of 1 atm at 298 K.

B. Calculate the molar entropy change for an **irreversible** expansion of an ideal gas from 1 L to 10 L against an external pressure of 1 atm at 298 K.

15. If the xylem in a tree has an effective diameter of 0.1 mm calculate the height to which water can be transported by capillary action alone.

16. An engineer is asked to design a novel cylinder for an engine. What advice would you give the engineer regarding the paths for expansion and compression in the cylinder? Please write down formulae that justify your argument.

17. Use as many formulae as possible to justify the following statement. “Trees over 10 meters tall must use osmotic pressure and capillary action to facilitate transport of water from the roots to the top of the tree.”

18. It takes longer to cook soup at high elevation. Please provide the correct formula to justify your answer.