

Chem 6 sample final exam (200 points total)

- @ This is a closed book exam to which the Honor Principle applies.
- @ The last 3 pages contain equations, physical constants, and the periodic table. You can detach them for easy reference.
- @ Please write clearly and **SHOW YOUR WORK**. If you need to write on the back of the exam paper, please indicate this clearly.
- @ Some questions are more challenging than others. Allot your time accordingly, and try to answer **EVERY** question.
- @ Time is limited, so keep your answers brief and to the point.
- @ Please put your name both on this page and on p. 2.

NAME (please print) _____

1. (20 pts) An unknown compound, which contains Mn and NCS^- , could be either (1) tetrahedral $[\text{Mn}(\text{NCS})_4]^{2-}$ or (2) octahedral $[\text{Mn}(\text{NCS})_6]^{4-}$. Would measuring the magnetic susceptibility of this sample be useful in identifying it? Why or why not?

2. (20 pts) (a, 8 pts) Match the complex with its color:

$[\text{Cu}(\text{NH}_3)_4]^+$ colorless

$[\text{Cu}(\text{NH}_3)_4]^{2+}$ blue

Briefly **explain** your answer.

(b, 12 pts) For each of the complexes (1) FeBr_6^{3-} and (2) $[\text{FeCl}_4]^{2-}$ (this is tetrahedral)

(i) give the number of unpaired electrons and state whether the complex is paramagnetic or diamagnetic

(ii) give the crystal field stabilization energy

3. (20 pts) Use a Born-Haber cycle for the formation of MgO to find the **electron affinity of O⁻**. Many physical constants useful for this problem are given on page 14. [Note--you should not simply manipulate these numbers. You must also explicitly write down the Born-Haber cycle you use.]

4. (20 pts) An electron in an organic molecule which contains C=C double bonds behaves like a **particle in a one-dimensional box** whose length is proportional to the number of carbon atoms, N . The ground state of the electron has quantum number $n = N/2$.

(a, 12 pts) Find the wavelength of the light absorbed in a transition from the ground state to the first excited state in ethylene (C_2H_4). Assume that the length of the box is 1.32 \AA .

(b, 8 pts) As the number (N) of carbon atoms in the molecule (and therefore the length of the box) increases, will the wavelength of the transition described above increase or decrease? Briefly **explain** your answer.

5. (20 pts) At 25 °C, the rate of a given reaction is increased by a factor of 100 in the presence of a catalyst, and the activation energy for this **catalyzed** reaction is 10 kJ/mol.

Without the catalyst, at which **temperature** do you need to do the reaction to make it go as fast as the catalyzed reaction described above?

6. (20 pts) Consider the diatomic molecules NO, C₂, and N₂. State which one(s) would be stabilized by **removing** an electron, **and** which one(s) would be stabilized by **adding** an electron. Briefly **explain** your answer using MO theory.

7. (20 points) Light with wavelength 5 nm hits a ground-state Li^{2+} ion, ejecting an electron. Find the **velocity** of the ejected electron.

8. (20 pts, 4 each) For each of the following, give the **idealized molecular geometry**, any **deviations** from the ideal angles expected, and the **hybridization** of the central atom.

(a) CH_2

(b) NCN^{2-} [atom connectivity is N-C-N]

(c) XeO_3

(d) SCl_3^+

(e) PF_6^-

9. (20 pts) True or False? **Briefly explain** your answers.

(a, 7 pts) The boiling points of the noble gases follow the order $\text{He} < \text{Ne} < \text{Ar}$.

(b, 6 pts) AsH_3 has a higher boiling point than NH_3 .

(c, 7 pts) The melting point of MgO is higher than that of NaF .

10. (20 pts, 4 each) Multiple choice. **Circle** your answers.

(a) Pick the **true** statement(s) about activation energy.

- (i) Some elementary reactions have a negative activation energy.
- (ii) The activation energy is the difference in energy between the reactants and the products.
- (iii) A catalyst increases reaction rate by decreasing the activation energy.
- (iv) The rate of a reaction depends linearly on the activation energy.

(b) Pick the **true** statement(s) about atomic radii.

- (i) The difference between the atomic radii of V and Nb is larger than the difference between the atomic radii of Nb and Ta.
- (ii) The atomic radius of F is greater than that of C.
- (iii) The atomic radius of Li is greater than that of K.
- (iv) The atomic radius of Ti is greater than that of Zr.

(c) Pick the **true** statement(s) about quantization.

- (i) In the Bohr model of the atom, angular momentum, distance of the electron from the nucleus, and energy are quantized.
- (ii) The experimental relationship between intensity and wavelength of blackbody radiation can be satisfactorily explained without postulating quantization of the energy.
- (iii) The energy of an electron in the hydrogen atom does not depend on the quantum numbers l and m_l .
- (iv) The energy of an electron in a multi-electron atom does not depend on the quantum numbers l and m_l .

(d) Pick the pair(s) of molecules which have the **same** idealized geometries.

- (i) XeF₂ and BeH₂
- (ii) CO₃²⁻ and SO₃
- (iii) CCl₄ and XeF₄
- (iv) PF₅ and ClF₅

(e) The first-order decomposition of N₂O₅ has rate constant $k = 1.72 \times 10^{-5} \text{ s}^{-1}$. 77.4% of the N₂O₅ will have decomposed after:

- (i) 1 second
- (ii) 1 minute
- (iii) 1 hour
- (iv) 1 day

$$\frac{dc}{dt} = -kc$$

USEFUL INFO

$$c = c_0 e^{-kt}$$

$$\frac{dc}{dt} = -2kc^2$$

$$\frac{1}{c} = \frac{1}{c_0} + 2kt$$

$$t_{1/2} = \frac{0.6931}{k}$$

$$T(^{\circ}C) + 273 = T(K)$$

$$t_{1/2} = \frac{1}{2kc_0}$$

$$k = Ae^{-E_a/RT}$$

$$\ln k = \ln A - \frac{E_a}{RT}$$

$$\frac{dP}{dt} = k_2[ES] = \frac{k_2[E]_0[S]}{[S] + K_M}$$

$$N_0 = 6.022 \times 10^{23} \text{ mole}^{-1}$$

$$R = 8.31451 \text{ J} \cdot \text{mole}^{-1} \text{ K}^{-1} = 0.0821 \text{ L} \cdot \text{atm} \cdot \text{mole}^{-1} \text{ K}^{-1}$$

$$\text{K.E.} = mv^2/2 = p^2/2m \quad \text{Total Energy} = \text{K.E.} + \text{P.E.}$$

$$\lambda = h/p$$

$$p = mv$$

$$mvr = nh/2\pi$$

$$r_n = (n^2/Z)a_0$$

$$E_n = -2.18 \times 10^{-18} \text{ J} (Z^2/n^2)$$

$$\Delta E = -2.18 \times 10^{-18} \text{ J} Z^2 (1/n_f^2 - 1/n_i^2)$$

$$v = 3.29 \times 10^{15} \text{ s}^{-1} Z^2 (1/n_f^2 - 1/n_i^2)$$

$$E = hv \quad c = v\lambda$$

$$c = 3 \times 10^8 \text{ m s}^{-1}$$

$$(1/2)mv^2 = hv - \phi$$

$$e = 1.60 \times 10^{-19} \text{ Coulombs}$$

$$h = 6.626 \times 10^{-34} \text{ J s}$$

$$1 \text{ \AA} = 10^{-10} \text{ m}$$

$$1 \text{ nm} = 10^{-9} \text{ m}$$

$$a_0 = 0.530 \text{ \AA}$$

$$\hbar = h/2\pi$$

$$E_n = n^2 h^2 / 8mL^2$$

$$\Psi_n = A \sin(n\pi x/L)$$

$$\Delta E = (2n+1)(h^2/8mL^2) \quad 1 \text{ J} = 1 \text{ kg m}^2 \text{ s}^{-2}$$

$$m(\text{electron}) = 9.11 \times 10^{-31} \text{ kg}$$

$$\Delta x \Delta p \geq \{h/4\pi\}$$

PERIODIC TABLE

¹ H 1.0079																	² He 4.00260
³ Li 6.941	⁴ Be 9.01218											⁵ B 10.81	⁶ C 12.011	⁷ N 14.0067	⁸ O 15.9994	⁹ F 18.9984	¹⁰ Ne 20.179
¹¹ Na 22.9898	¹² Mg 24.305											¹³ Al 26.9815	¹⁴ Si 28.0855	¹⁵ P 30.9738	¹⁶ S 32.06	¹⁷ Cl 35.453	¹⁸ Ar 39.948
¹⁹ K 39.0983	²⁰ Ca 40.08	²¹ Sc 44.9559	²² Ti 47.88	²³ V 50.9415	²⁴ Cr 51.996	²⁵ Mn 54.9380	²⁶ Fe 55.847	²⁷ Co 58.9332	²⁸ Ni 58.69	²⁹ Cu 63.546	³⁰ Zn 65.39	³¹ Ga 69.72	³² Ge 72.59	³³ As 74.9216	³⁴ Se 78.96	³⁵ Br 79.904	³⁶ Kr 83.80
³⁷ Rb 85.4678	³⁸ Sr 87.62	³⁹ Y 88.9059	⁴⁰ Zr 91.224	⁴¹ Nb 92.9064	⁴² Mo 95.94	⁴³ Tc (98)	⁴⁴ Ru 101.07	⁴⁵ Rh 102.906	⁴⁶ Pd 106.42	⁴⁷ Ag 107.868	⁴⁸ Cd 112.41	⁴⁹ In 114.82	⁵⁰ Sn 118.71	⁵¹ Sb 121.75	⁵² Te 127.60	⁵³ I 126.905	⁵⁴ Xe 131.29
⁵⁵ Cs 132.905	⁵⁶ Ba 137.33	⁵⁷ La 138.906	⁷² Hf 178.49	⁷³ Ta 180.948	⁷⁴ W 183.85	⁷⁵ Re 186.207	⁷⁶ Os 190.2	⁷⁷ Ir 192.22	⁷⁸ Pt 195.08	⁷⁹ Au 196.967	⁸⁰ Hg 200.59	⁸¹ Tl 204.383	⁸² Pb 207.2	⁸³ Bi 208.980	⁸⁴ Po (209)	⁸⁵ At (210)	⁸⁶ Rn (222)
⁸⁷ Fr (223)	⁸⁸ Ra 226.025	⁸⁹ Ac 227.028	¹⁰⁴ Unq (261)	¹⁰⁵ Unp (262)	¹⁰⁶ Unh (263)	¹⁰⁷ Uns (262)	¹⁰⁸ Uno (265)	¹⁰⁹ Une (266)									

⁵⁸ Ce 140.12	⁵⁹ Pr 140.908	⁶⁰ Nd 144.24	⁶¹ Pm (145)	⁶² Sm 150.36	⁶³ Eu 151.96	⁶⁴ Gd 157.25	⁶⁵ Tb 158.925	⁶⁶ Dy 162.50	⁶⁷ Ho 164.930	⁶⁸ Er 167.26	⁶⁹ Tm 168.934	⁷⁰ Yb 173.04	⁷¹ Lu 174.967
⁹⁰ Th 232.038	⁹¹ Pa 231.036	⁹² U 238.029	⁹³ Np (237)	⁹⁴ Pu (244)	⁹⁵ Am (243)	⁹⁶ Cm (247)	⁹⁷ Bk (247)	⁹⁸ Cf (251)	⁹⁹ Es (252)	¹⁰⁰ Fm (257)	¹⁰¹ Md (258)	¹⁰² No (259)	¹⁰³ Lr (260)