Chemistry 1B, Spring 2004

Midterm 3
April 22, 2004
(90 min, closed book)

Name:____________________

SID:______________________

TA Name:_________________

- This exam has 45 multiple choice questions.
- Fill in the Scantron form AND circle your answer on the exam.
- Each question is worth 4 points.

Note:

- The questions on the exam may be answered in any order.
- All the questions are equally weighted. Answer those you can quickly and go back to those that require more thought.
- Some questions may seem obvious or too simple. They are. There are no 'trick' questions.

- Potentially useful relations:

$[A]_t = [A]_0 e^{-kt}$
$\ln[A]_t = \ln[A]_0 - kt$
$t_{1/2} = \ln 2/k$
$1/[A]_t = 1/[A]_0 + kt$
$k = A\, e^{(-Ea/RT)}$
$\ln(k_1/k_2) = E_a/R\ (1/T_2 - 1/T_1)$
$t_{1/2} = 1/[A]_0 k$
$t_{1/2} = [A]_0/kt$

$PV = nRT$

$$E_{kin} = \frac{3}{2}RT$$

$\Delta E = q + w$

$w = -P_{ext}\Delta V$

$$\Delta E = \frac{3}{2}nR\Delta T$$

$N_0 = 6.02214 \times 10^{23}\ mol^{-1}$

$R_\infty = 2.179874 \times 10^{-18}\ J$

$R_\infty = 3.28984 \times 10^{15}\ Hz$

$k = 1.38066 \times 10^{-23}\ J\ K^{-1}$

$h = 6.62608 \times 10^{-34}\ J\ s$

$m_e = 9.101939 \times 10^{-31}\ kg$

$c = 2.99792 \times 10^{8}\ m\ s^{-1}$

Gas Constant:

$R = 8.31451\ J\ K^{-1}\ mol^{-1}$

$R = 8.20578 \times 10^{-2}\ L\ atm\ K^{-1}\ mol^{-1}$

T (K) = T (C) + 273.15

F = 96,485 C / mol

1 V = 1 J / C 1 nm = 10^{-9} m
1 kJ = 1000 J

$\Delta G° = \Delta H° - T\Delta S°$

$\Delta H° = \Sigma\ \Delta H°_f$ (products) $- \Sigma\ \Delta H°_f$ (reactants)

$\Delta S° = \Sigma\ S°$ (products) $- \Sigma\ S°$ (reactants)

$\Delta G° = \Sigma\ \Delta G°_f$ (products) $- \Sigma\ \Delta G°_f$ (reactants)
$S = k_B \ln W$
$\Delta T = i\ k_{b,f}\, m$
$\Pi = i\ RTc$

for $aA + bB \rightleftarrows cC + dD$

$$Q = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$ At equilibrium, Q = K

$\Delta G° = - RT\ln K$

$$\ln K = -\frac{\Delta H°}{R}\frac{1}{T} + \frac{\Delta S°}{R}$$

$\Delta G° = - nF\Delta Є^o$
$\Delta Є = \Delta Є^o - RT/nF \ln Q$
$\ln K = nF\Delta Є^o/RT$

$\Delta x\ \Delta p \sim h$
$p = h/\lambda$
Particle in a box:
$E_n = h^2n^2/8mL^2$; n = 1, 2, 3...
harmonic oscillator:
$E_v = (v + ½)\, hA/2\pi$; $A = (k/m)^{1/2}$; v = 0, 1, 2 .....
$m = m_a m_b/(m_a + m_b)$;
rotation:
$E_\ell = \ell(\ell+1)hB$; $B = h/8\pi^2 I$; $I = mr^2$; ℓ = 0, 1, 2, 3....
$m = m_a m_b/(m_a + m_b)$
H-Atom:
$E_n = -Z^2/n^2\ R$; n = 1, 2, 3...

SECTION 1: QUANTUM MECHANICS

1.) Calculate the velocity of an oxygen molecule if it has a de Broglie wavelength of 0.0140 nm.

this question tossed

A) 890. $m \cdot s^{-1}$
B) 3.00×10^8 $m \cdot s^{-1}$
C) 1780 $m \cdot s^{-1}$
D) 445 $m \cdot s^{-1}$
E) 8.90 $m \cdot s^{-1}$

2.) Which of the following experiments most directly supports de Broglie's hypothesis of the wave nature of matter?

this question tossed

A) blackbody radiation
B) the photoelectric effect
C) alpha-particle scattering by a metal foil
D) electron diffraction by a crystal
E) the emission spectrum of the hydrogen atom

3.) In a one-dimensional particle in a box, for n = 6, how many wavelengths equals the size of the box?

A) 0
B) 3
C) 1
D) 12
E) 6

4.) In a one-dimensional particle in a box, for Ψ_4, how many nodes are predicted?

A) 1
B) 3
C) 0
D) 2
E) 4

5.) In a one-dimensional particle in a box, the *zero-point energy* corresponds to

A) a node.
B) n = 0.
C) n = 1.
D) a quantum state where the Uncertainty Principle is not valid.
E) $\Psi^2 = 0$.

6.) Which one of the following statements is incorrect?

A) For a one-dimensional particle in a box, as the mass of the particle becomes larger the separation between neighboring energy levels increases.
B) For a one-dimensional particle in a box, the separation between neighboring energy levels decreases as the length of the container increases.
C) For a one-dimensional particle in a box, the separation between neighboring energy levels becomes zero when the walls of the box are infinitely far apart.
D) Argon atoms in a cylinder can be treated as though their translational energy were not quantized.
E) A billiard ball on a table has a completely negligible *zero-point energy*.

7.) The total number of orbitals in a shell with principal quantum number 5 is

A) 32
B) 50
C) 25
D) 40
E) 5

8.) Which set of quantum numbers could correspond to a 4d orbital?

A) $n = 3, l = 2, m_l = 0$
B) $n = 3, l = 2, m_l = +1$
C) $n = 4, l = 3, m_l = +2$
D) $n = 4, l = 2, m_l = -2$
E) $n = 4, l = 2, m_l = +3$

9.) Which set of quantum numbers could correspond to a 4f orbital?

A) $n = 4, l = 4, m_l = +3$
B) $n = 4, l = 3, m_l = +4$
C) $n = 4, l = 3, m_l = -3$
D) $n = 3, l = 2, m_l = +1$
E) $n = 3, l = 2, m_l = 0$

10.) How many total nodal planes are present in the 3d orbitals?

A) 15
B) 0
C) 5
D) 20
E) 10

11.) How many *nodal planes (angular nodes)* are present in an f orbital?

A) 2
B) 3
C) 7
D) 4
E) 5

12.) Which is the ground-state electron configuration of a chromium atom?

this question tossed

A) $[Ar]4s^2 3d^4$
B) $[Ar]4s^1 3d^5$
C) $[Ar]3d^5 4s^1$
D) $[Ar]3d^6$
E) $[Ar]3d^4 4s^2$

13.) All of the following can have the ground-state electron configuration $[Xe]4f^{14}5d^{10}$ except

A) Pb^{4+}
B) Hg^{2+}
C) Bi^{5+}
D) Tl^{+}
E) Au^{+}

14.) Which of the following orbital groups cannot exist in an atom?

A) 4d
B) 5g
C) 5f
D) 4f
E) 3f

15.) Which of the following has bond angles slightly less than 109°?

A) NH_4^+
B) ClO_4^-
C) BrO_3^-
D) PO_4^{3-}
E) BH_4^-

16.) How many σ- and π-bonds, respectively, are there in acrolein, CH_2=CHCHO?

A) 4 and 2
B) 7 and 2
C) 5 and 2
D) 5 and 4
E) 7 and 1

17.) Identify the hybrid orbitals used by the underlined atom in acetone, $CH_3\underline{C}OCH_3$.

A) sp^3d
B) sp^2
C) Pure p_z orbitals are used in sigma bonding.
D) sp^3
E) sp

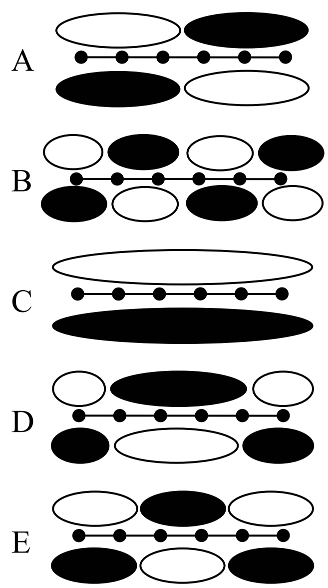
18.) The experimental observation that B_2 has two unpaired electrons indicates that, in molecular orbital ideas,

A) the $2p_\pi$ orbitals lie above the $2p_\sigma$ orbital in energy.
B) the $2p_\pi$ orbitals lie below the $2p_\sigma$ orbital in energy.
C) the $2p_\pi$* orbitals lie below the $2p_\sigma$* orbital in energy.
D) the $2p_\pi$ orbitals are nonbonding.
E) the $2p_\pi$* orbitals lie above the $2p_\sigma$* orbital in energy.

19.) How many π molecular orbitals are formed in 1,3,5 hexatriene; CH_2=CH–CH=CH–CH=CH_2 ?

A) 4
B) 6
C) 8
D) 10
E) 12

20.) Rank the possibilities for π MOs in 1,3,5 hexatriene from lowest to highest energy.



A) A, B, C, D, E
B) C, A~D, E, B
C) D, A, B~E, C
D) C, A, D~E, B
E) B, D, E, D, A

Consider the following ions trapped in a tiny box H^+, He^+, Li^{+2}, Be^{+3} so that each displays quantum particle in a box behavior for the next three questions.

21.) Which has the lowest ground state energy?

A) H^+
B) He^+
C) Li^{+2}
D) Be^{+3}
E) all are equal

22.) Which has the lowest translational n=1 to n = 2 transition energy?

A) H^+
B) He^+
C) Li^{+2}
D) Be^{+3}
E) all are equal

23.) Which has the highest n=1 to n=2 electronic transition energy?

A) H^+
B) He^+
C) Li^{+2}
D) Be^{+3}
E) all are equal

Continue with the next question:

Match the following molecular phenomenon with the appropriate regions of the electromagnetic spectrum in the next three questions.

24.) Rotation

A) radio waves
B) microwaves
C) infra red
D) visible
E) none of these

25.) Vibration

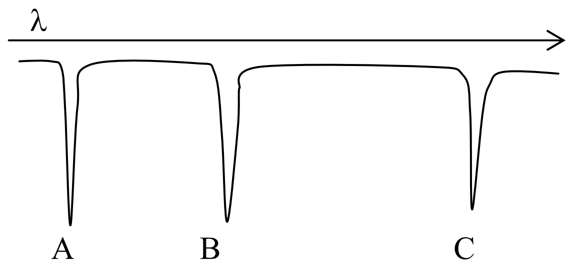
A) radio waves
B) microwaves
C) infra red
D) visible
E) none of these

26.) Electronic transitions

A) radio waves
B) microwaves
C) infra red
D) visible

Continue with the next question:

Each absorbance in the following spectrum is produced by a C-O stretching mode in A) CH_3OH, B) CO, or C) CO_2. Assign each peak in the next three questions.



27.) Absorbance A

A) CH_3OH
B) CO
C) CO_2

28.) Absorbance B

A) CH_3OH
B) CO
C) CO_2

29.) Absorbance C

A) CH_3OH
B) CO
C) CO_2

Continue with the next question:

SECTION 2: THERMODYNAMICS

30.) Consider the following reaction $NO(g) + \frac{1}{2}O_2(g) \rightarrow NO_2(g)$. If $\Delta H° = -56.52$ kJ and $\Delta S° = -72.60\ J{\cdot}K^{-1}$ at 298 K, calculate the equilibrium constant for the reaction at 298 K.

A) 1.31×10^{6}
B) 7.63×10^{-7}
C) 660
D) 1.22×10^{14}
E) 8.08×10^{9}

31.) Given: $C(s) + CO_2(g) \rightarrow 2CO(g)$. At equilibrium at a certain temperature, the partial pressures of CO (g) and CO_2 (g) are 1.22 atm and 0.780 atm, respectively. Calculate the value of K for this reaction.

A) 3.13
B) 2.00
C) 1.91
D) 1.56
E) 0.640

32.) Write the equilibrium constant for $2NaBr(aq) + Pb(ClO_4)_2(aq) \rightarrow PbBr_2(s) + 2NaClO_4(aq)$.

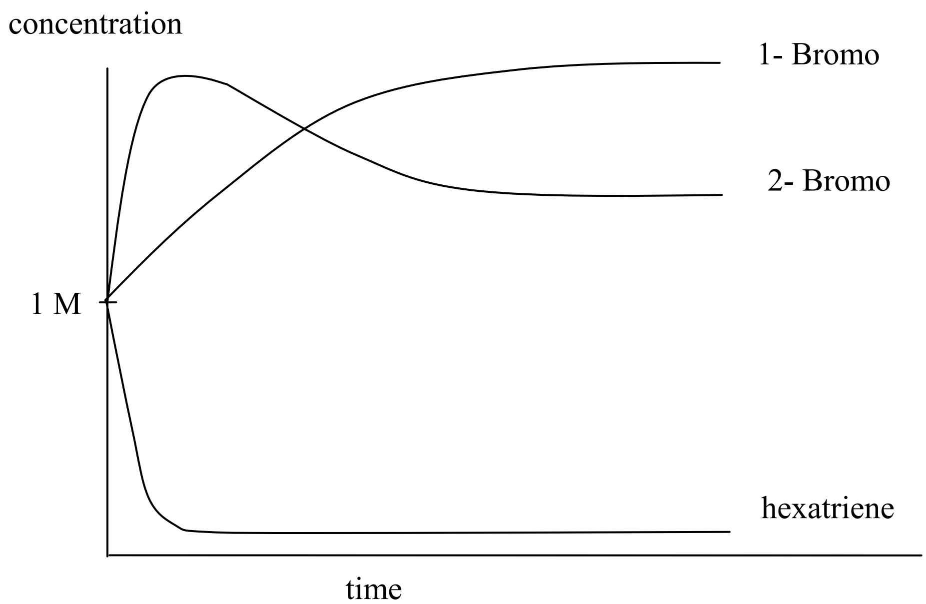
A) $K = [Pb^{2+}][Br^-]^2$
B) $K = 1/([Pb^{2+}][Br^-]^2)$
C) $K = [NaClO_4]^2/([NaBr]^2[Pb(ClO_4)_2]$
D) $K = [PbBr_2]/([Pb^{2+}][Br^-]^2)$
E) $K = 1/([Pb(ClO_4)_2][NaBr]^2)$

33.) Consider the reaction: $4NH_3(g) + 3O_2(g) \rightarrow 2N_2(g) + 6H_2O(g)$, $K = 10^{80}$ at a certain temperature. Initially, all reactants and products have concentrations equal to 12 M. At equilibrium, the approximate concentration of oxygen is

A) 6 M.
B) 0 M.
C) 3 M.
D) 12 M.
E) 18 M.

Continue with the next question:

Consider the following for the next five questions: Two products are formed in the reaction of 1,3,5-hexatriene with HBr, 2-Bromohexadiene with K = 10 and 1-Bromohexadiene with K = 35. The following plot of concentration vs. time is obtained starting with 1 M of each reactant and product.



34.) Which is the correct ranking of the components in terms of free energy of formation?

A	B	C	D	E
hexatriene	hexatriene	1-Bromo	2-Bromo	1-Bromo
1-Bromo	2-Bromo	hexatriene	1-Bromo	2-Bromo
2-Bromo	1-Bromo	2-Bromo	hexatriene	hexatriene

35.) Which of the following is true of this reaction?

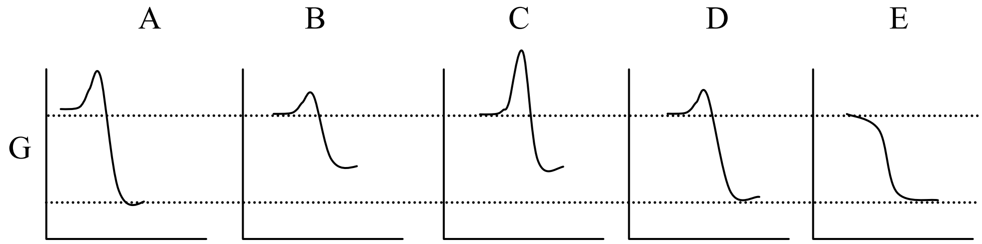
A) 1-Bromo is kinetically favored
B) 2-Bromo is kinetically favored
C) 2-Bromo is thermodynamically favored
D) 1-Bromo and 2-Bromo are thermodynamically similar
E) 1-Bromo and 2-Bromo are kinetically equivalent

36.) Which of the following is true of this reaction?

A) $\Delta G° = 0$ for the formation of hexatriene
B) $\Delta G° > 0$ for the formation of 2-Bromo
C) $\Delta G° < 0$ for the formation of 2-Bromo

D) $\Delta G° > 0$ for the formation of 1-Bromo
E) $\Delta G°$ is the same for 1-Bromo and 2-Bromo

Match the plots for the course of reaction to the appropriate product of the hexatriene reaction



37.) 1-Bromo

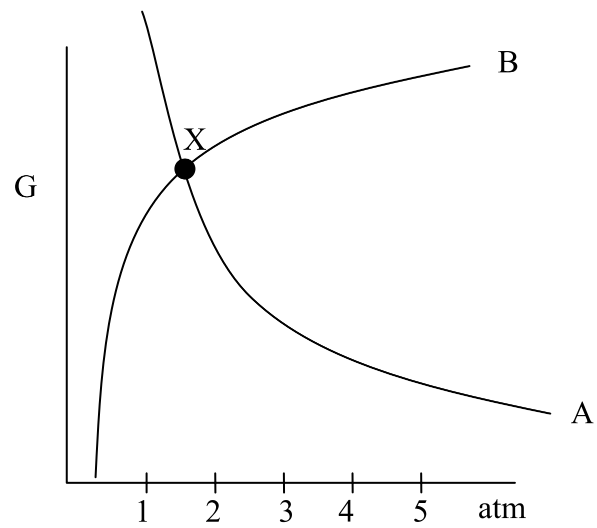
A) A
B) B
C) C
D) D
E) E

38.) 2- Bromo

A) A
B) B
C) C
D) D
E) E

Continue with the next question:

Consider the following plot of free energy vs. activity (P/P_0) for the gas phase reaction A (g) → B (g) for the following four questions.



39.) Which is true?

A) G° (A) = G° (B)
B) G° (A) > G° (B)
C) G° (A) < G° (B)
D) G° (A) = 0
E) G° (B) = 0

40.) Which is true at point X?

A) the forward reaction is favored
B) the reverse reaction is favored
C) the reaction is at equilibrium
D) G (A) = 0
E) G (B) = 0

41.) Which is true of the reaction A → B?

A) $\Delta G° = 0$
B) $\Delta G = 0$
C) $\Delta G = \Delta G°$
D) $\Delta G > 0$
E) $\Delta G° < 0$

42.) What is the partial pressure (atm) of gas A at equilibrium?

A) 1
B) 1.5
C) 2
D) 2.5
E) 3

43.) Which is true when A and B are placed in a container at partial pressures of 4 atm?

A) $\Delta G° > 0$
B) $\Delta G > 0$
C) $\Delta G = \Delta G°$
D) $\Delta G = 0$
E) $\Delta G < 0$

Continue with the next question:

44.) Pure liquids and solids

A) never appear as variables in an equilibrium constant
B) are always in the numerator of an equilibrium constant
C) are always in the denominator of an equilibrium constant
D) have activities that are sensitive to pressure
E) have activities that are sensitive to concentration

45.) At the triple point of a substance

A) the gas phase is the highest free energy
B) the liquid to gas transition is favored
C) the liquid to solid transition is favored
D) solid has the lowest free energy
E) all phases have equal free energy