Chemistry 1A, Fall 2006

Midterm 2, Version A -KEY

Oct 17, 2006

(90 min, closed book)

Name:___________________

SID:_____________________

TA Name:________________

- There are 26 Multiple choice questions worth 3.0 points each.
- There are 6, multi-part short answer questions.
- For the multiple choice section, fill in the Scantron form AND circle your answer on the exam.
- Put your final answers in the boxes provided. Answers outside the boxes may not be considered in grading.
- The homework and chemquizzes that each question is based upon is listed after the question e.g. [HW 1.13, CQ 7.3]

Question	Page	Points	Score
Question 27	10	7	
Question 28	10	8	
Question 29	11	6	
Question 30	11	7	
Question 31	12	4	
Question 32	12	10	
Total		42	

Quantum:

$E = h\nu$

$\lambda\nu = c$ A)

$\lambda_{deBroglie} = h / p = h / mv$

E_{kin} (e-) $= h\nu - \Phi = h\nu - h\nu_0$

$E_n = -\frac{Z^2}{n^2} R_\infty$

$\Delta x \, \Delta p \sim h$

$p = mv$

Particle in a box (1-D Quantum):

$E_n = h^2 n^2 / 8mL^2$; n = 1, 2, 3...

Vibrational:

$E_v = (v + ½)\, hA/2\pi$; $A = (k/m)^{½}$

Rotational:

$E_n = n(n + 1)\, hB$; $B = h/8\pi^2 I$; $I = 2mr^2$

$m = m_A m_B/(m_A + m_B)$

Ideal Gas:

$PV = nRT$

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

$v_{rms} = \sqrt{\frac{3RT}{M}}$

Constants:

$N_0 = 6.02214 \times 10^{23}$ 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}

T (K) = T (C) + 273.15

F = 96,485 C / mol

1 V = 1 J / C

Gas Constant:

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

R = 8.20578×10^{-2} L atm K^{-1} mol^{-1}

1 nm = 10^{-9} m

1 kJ = 1000 J

1 atm = 760 mm Hg = 760 torr ≈ 1 bar

1 L atm ≈ 100 J

Thermodynamics:

$\Delta G° = \Delta H° - T\Delta S°$

$\Delta H° = \Sigma\, \Delta H°_f$ (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)

$S = k_B \ln W$

$\Delta S = q_{rev}/T$

$\Delta E = q + w$

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

for aA + bB $\rightleftarrows$ cC + dD

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

$\Delta G = \Delta G° + RT\ln Q$

$G = G° + RT\ln(a)$; a = activity = $\gamma P/P°$ or $\gamma[A]/[A]°$

$\Delta G° = -RT\ln K$

$\Delta G° = -nF\Delta Є°$

$\Delta Є = \Delta Є° - (RT/nF) \ln Q$

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

$\Delta T = ik_{b,f}\, m$

$\Pi = iMRT$

$P_{total} = P_A + P_B = X_A P_A° + X_B P_B°$

Acid Base:

$pH = -\log[H_3O^+]$

$pX = -\log X$

$pH = pK_a + \log\frac{[A^-]}{[HA]}$

Kinetics:

$[A]_t = [A]_0 e^{-kt}$

$\ln[A]_t = \ln[A]_0 - kt$

$t_{1/2} = \ln 2/k$

$1/[A]_t = 1/[A]_0 + kt$

$k = A\, e^{(-Ea/RT)}$

$\ln(k_1/k_2) = E_a/R\, (1/T_2 - 1/T_1)$

$t_{1/2} = 1/[A]_0 k$

$t_{1/2} = [A]_0/kt$

Section 1: Periodic Properties

1.) Which is the proper ordering of the following elements from smallest atomic radius to largest? [HW 1.82 CQ 11.2]

A) Na, Mg, Si, S, Ar
B) Ar, Na, Si, S, Mg
C) $\boxed{\text{Ar, S, Si, Mg, Na}}$
D) Mg, Na, Si, Ar, S
E) Si, S, Ar, Na, Mg

2.) Which species has the highest ionization energy ? [HW 1.77 CQ 11.3]

A) K B) Ti C) Cu D) Ge $\boxed{\text{E) Br}}$

3.) Which pair would form an ionic bond? [HW 2.63 CQ 11.4]

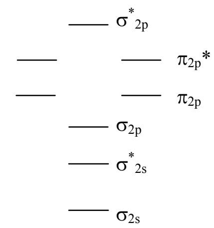
A) C and H
B) N and H
C) $\boxed{\text{Na and Cl}}$
D) O and Cl
E) C and Cl

4.) Which pair would form a bond that has a dipole moment? [HW 2.63]

A) C and H
B) N and H
C) C and Cl
D) O and Cl
E) $\boxed{\text{all of these}}$

Section 2: Molecular Structure

For questions 5-7 assume the molecular orbital energy diagram shown can be used for all molecules mentioned.



5.) How many unpaired electrons are in O_2^{+2}?[HW 3.47, CQ 15.2]

$\boxed{\text{A) 0}}$ B) 1 C) 2 D) 3 E) 4

6.) What is the bond order of NO? [HW 3.49, CQ 15.3]

A) 0.5 B) 1 C) 1.5 D) 2 $\boxed{\text{E) 2.5}}$

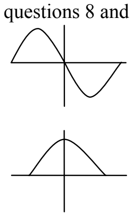
7.) Which of the following is not paramagnetic? [HW 3.47, CQ 15.2 ,15.4]

A) O_2^{-1} B) OF C) NO $\boxed{\text{D) OF}^-}$ E) CO^+

For questions 8 and 9 refer to the two functions plotted in the diagram below.

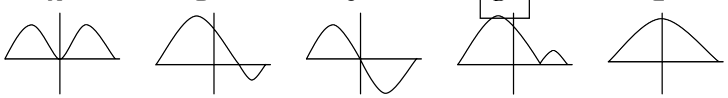
I

II



8.) What is the result of adding function I and function II shown in the diagram and squaring the result (i.e. $(I + II)^2$) ?

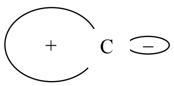
A B C $\boxed{\text{D}}$ E



9.) The process of calculating the new function $(I + II)^2$ is most analogous to the formation of which hybrid atomic orbital?

A) π^* B) sp^3 C) sp^2 D) σ^* $\boxed{\text{E) sp}}$

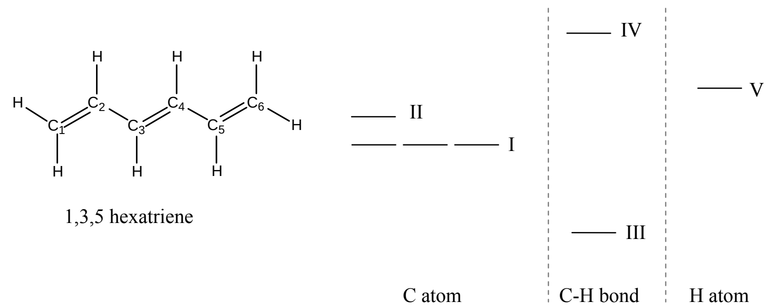
10.) What do the '+' and '–' signs designate in the following picture of a carbon hybrid atomic orbital?



A) Charge of the electrons.
B) Charge in the region of space.
C) The electric field in the region of space.
D) $\boxed{\text{The mathematical sign of the wavefunction.}}$
E) The sign of the probability function.

Use the diagrams below for 1,3,5-hexatriene to answer questions 11 - 17. The left side of the diagram shows the Lewis structure for the molecule. The right side shows the orbital energy level diagram for the C-H bonding at carbon C_2 in the molecule. On the right, the orbital energy levels are labeled I-V.

Orbital diagrams for $C_2 - H$ bond



11.) What is the hybridization of the carbon labeled C_2 in 1,3,5 hexatriene? [HW 3.33 3.38, CQ16.1]

A) sp
B) $\boxed{sp^2}$
C) sp^3
D) dsp^2
E) cannot be determined

12.) What is the C-C-H bond angle on the carbon C_3 in 1,3,5 hexatriene? [HW 3.9, CQ16.3]

A) 60
B) 90
C) 109
D) $\boxed{120}$
E) 180

13.) What is the best label for the orbitals at energy level I on the right side of the diagram? [HW 3.49, CQ 15.2, 16.4]

A) s B) p C) sp $\boxed{\text{D) } sp^2}$ E) σ

14.) What is the best label for the orbitals at energy level IV on the right side of the diagram? [HW 3.49 CQ15.2]

A) s $\boxed{\text{B) } \sigma^*}$ C) π D) σ E) π^*

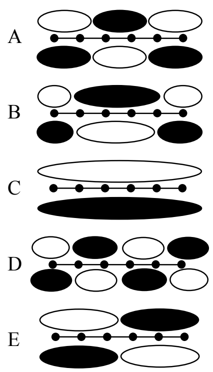
15.) How many p atomic orbitals can be used to form π molecular orbitals in 1,3,5 hexatriene? [HW 3.85, CQ 17.2]

A) 4
B) $\boxed{6}$
C) 8
D) 10
E) 12

16.) How many π molecular orbitals are formed in 1,3,5 hexatriene? [HW 3.85, CQ17.3]

A) 4
B) $\boxed{6}$
C) 8
D) 10
E) 12

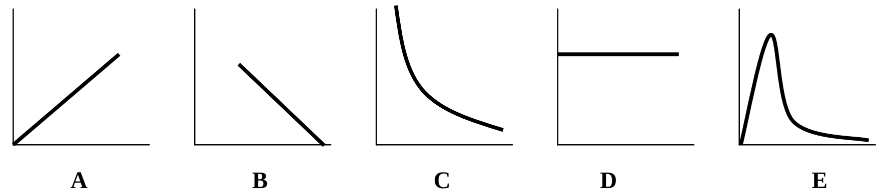
17.) Rank the following five possible π MOs in 1,3,5 hexatriene from highest to lowest energy. [HW 3.85, CQ17.3]



A) A, B, C, D, E
B) C, A~D, E, B
C) D, E, A, B, C
D) C, A, D~E, B
E) $\boxed{\text{D, A}\sim\text{B, E, C}}$

SECTION 3: PROPERTIES OF IDEAL GASES

For questions 18 – 22, choose the plot below that best demonstrates the relationship between the variables described (assume variables not listed are constant).



18.) Pressure vs. volume for an ideal gas. [HW 4.9, 4.10]

A) A B) B $\boxed{\text{C) C}}$ D) D E) E

19.) Volume vs. temperature for an ideal gas. [HW 4.9, 4.10]

$\boxed{\text{A) A}}$ B) B C) C D) D E) E

20.) Particle count (at each velocity) vs. the velocity of a gas. [HW 4.72]

A) A B) B C) C D) D $\boxed{\text{E) E}}$

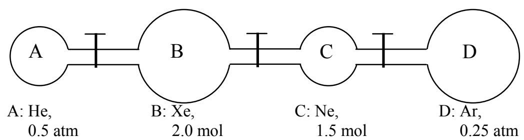
21.) PV/RT vs. P for a fixed amount of ideal gas.

A) A B) B C) C $\boxed{\text{D) D}}$ E) E

22.) Kinetic energy of a mole of ideal gas vs. temperature. [HW 4.65]

$\boxed{\text{A) A}}$ B) B C) C D) D E) E

For questions 23 - 26, consider the following system at 273 K and assume that the volume of the tubes connecting the flasks is negligible in any calculation. The smaller flasks have volume 11 L and the larger 22 L. Initially, the gas in each flask is separated from the others by closed valves between each flask.



23.) What is the pressure (atm) in flask C [HW 4.13]?

A) 0.5 B) 1.0 C) 2.0 D) 3.0 E) 3.5

24.) If the valve between flask C and D is opened, what is the partial pressure (atm) of Ne in the combined volume of the two flasks? [HW 4.53, CQ MT2.7]

A) 0.17 B) 1.0 C) 1.3 D) 1.7 E) 2.6

25.) Which molecules have the highest rms velocity? [HW 4.67 4.69]

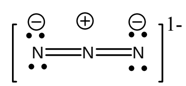
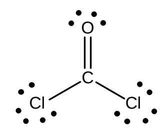
A) He B) Xe C) Ne D) Ar E) all are the same

26.) Which molecules have the highest average kinetic energy? [CQ 19.1]

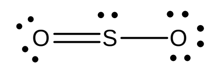
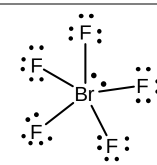
A) He B) Xe C) Ne D) Ar E) all are the same

SECTION 4: SHORT ANSWER

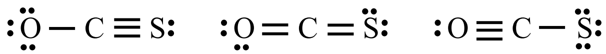
27.) For the following molecules, draw the best Lewis structure showing all bonds and lone pairs of electrons (include resonance if needed). [HW 2.33, 2.36, CQ12.2, 12.3]

N_3^-	$COCl_2$ (C is the central atom)
	

28.) Complete the following table based on the Lewis structures. [HW 3.1, 3.7, 3.17, 3.33, CQ12.2, 12.3, 14.1-4]

		
Polar? (yes/no)	yes	yes
Electronic Structure about the central atom	trigonal planar	octahedral
Molecular Structure	bent or angular	square pyramidal
Hybridization of the central atom	sp^2	sp^3d^2

29.) Three resonance structures of carbonyl sulfide are shown. Fill in the boxes for formal charge on each atom and explain which is the best structure in 20 words or less. [HW 2.43 2.45 CQ 13.1, 13.3]



Formal Charge	-1	0	+1	0	0	0	+1	0	-1

Explanation:
O=C=S is the best structure because formal charge is minimized

30.) Data show that the boiling points of NH_3 and PH_3 are the reverse of what would be expected based on their molar masses. Explain the relationship between the boiling points by completing the following: [HW 5.12, CQ 20.2]

What is the strongest intermolecular force in NH_3 liquid?

hydrogen bonding

What is the strongest intermolecular force in PH_3 liquid?

dipole-dipole

Circle the compound with the higher boiling point: NH_3 PH_3

Explain your reasoning in 20 words or less.

Explanation:
NH_3 has stronger intermolecular forces than PH_3. This will make NH_3 harder to boil.

31.) Two solutions, one red, the other blue are examined with a UV-Vis spectrophotometer. [Laboratory]
Circle the solution with the higher extinction coefficient at 650 nm: Red Blue
Explain your reasoning in 20 words or less.

Explanation:
The blue solution absorbs red light. 650nm is red light, so ϵ is high at 650nm for the blue solution.

32.) Assign the ionization energies 495 kJ/mol and 4560 kJ/mol to Na or Na^+ in the table below and write the corresponding chemical reaction: [Discussion, CQ MT2.1]

Species	Reaction	Ionization Energy
Na	$Na(g) \rightarrow Na^+(g) + 1e-$	495 kJ/mol
Na^+	$Na^+(g) \rightarrow Na^{2+}(g) + 1e-$	4560 kJ/mol

Write the electronic configurations for the three species below: [HW 2.11]

Na	$1s^2 2s^2 2p^6 3s^1$
Na^+	$1s^2 2s^2 2p^6$
Na^{2+}	$1s^2 2s^2 2p^5$

Explain the large difference in ionization energies between Na and Na^+ in terms of the electronic configurations in 20 words or less.

Explanation:
The first IE removes a valence electron. The second IE removes a core electron, which takes a lot more energy.