Chem 1A, Fall 2016, Midterm Exam 1. Version A
September 20, 2016
(Prof. Head-Gordon)^2

Name: _ ________________

Student ID:___ _ TA: ___ ___ ________________

Contents: 9 pages

A. Multiple choice (7 points)
B. Stoichiometry (9 points)
C. Electron diffraction (8 points)
D. Particle-in-a-box (6 points)
E. Atomic orbitals (6 points)
F. Ionic bonding (6 points)
G. Covalent bonding (10 points)

Total Points: 50 points + 2 bonus

Instructions: Closed book exam. Basic scientific calculators are OK. Set brains in high gear and go! It is usually a good idea to do the questions you find easy first. OK

Some possibly useful facts and figures:

$R = 8.3145$ J mol^{-1} K^{-1}	molar volume at STP = 22.4 L
$h = 6.6261\times 10^{-34}$ J s	$\hbar = h/2\pi$
$c = 2.9979 \times 10^{8}$ m s^{-1}	1 eV = 1.60×10^{-19} J
$m_e = 9.1094 \times 10^{-31}$ kg	$\boxed{m_n = 1.6726 \times 10^{-27}\text{ kg}}$
$N_0 = 6.0221 \times 10^{23}$ mol^{-1}	

Some possibly relevant equations:

Planck relation:	$E = h\nu$	
de Broglie relation:	$p = h/\lambda$	
wave equation:	$c = \nu\lambda$	
uncertainty principle	$\Delta p\Delta x \geq \hbar/2$	
particle-in-a-box	$E_n = \dfrac{n^2\pi^2\hbar^2}{2ma^2}$	$\Psi_n = \sqrt{\dfrac{2}{a}}\sin\dfrac{n\pi x}{a}$
hydrogen atom	$E_n = -\dfrac{Z^2}{n^2}R_\infty$	$R_\infty = 2.18 \times 10^{-18} J$
linear momentum	$p = mv$	
kinetic energy	$T = \frac{1}{2}mv^2$	
photoelectric effect	$E_{kin}(e\text{-}) = h\nu - \Phi = h\nu - h\nu_0$	

Multiple choice (7 points): ***there may be one or more correct solutions, so circle all that apply***

1. Which of the following pairs of molecules have the same empirical formula?

(a) acetylene (C_2H_2), benzene (C_6H_6)
(b) nitrogen dioxide (NO_2), dinitrogen tetroxide (N_2O_4)
(c) ethane (C_2H_6), butane (C_4H_{10})
(d) diphenyl ether ($C_{12}H_{10}O$), phenol (C_6H_5OH)

2. Which of the following set of quantum numbers are not allowed i the hydrogen a

(a) n=3, l=2, m_l= 2
(b) n=0, l=0, m_l=0
(c) n=4, l=3, m_l= 4
(d) n=2, l=-1, m_l= 1

3. An electron's wave-particle duality is captured by

(a) the Schrodinger equation, $\hat{H}\,\psi_n(x) = E_n\psi_n(x)$ ✓
(b) Heisenberg uncertainty, $(\Delta p)(\Delta x) \geq h/4\pi$
(c) the wave equation, $v = \lambda\nu$
(d) the De Broglie relation, $p = h/\lambda$

4. In a photoelectric effect experiment, green light is observed to lead to electron emissio from a metal surface. Which other colors should lead to electron emission?

(a) red
(b) purple
(c) blue
(d) none of the above

5. The Bohr model is valid for which atoms?

(a) H_2
(b) Li^{2+}
(c) Be^{2+}
(d) He^{+}

6. An atomic orbital of the hydrogen atom

(a) has (**n**-1) total nodes
(b) determines the energy of the electron
(c) has **l** angular nodes
(d) when squared gives the probability density

7. Some plant fertilizer compounds are $(NH_4)_2SO_4$, $Ca_3(PO_4)_2$, K_2O, P_2O_5, and KCl. Which pairs contains molecules that both have a mixture of ionic and covalent bonds?

(a) $(NH_4)_2SO_4$ and KCl ✗
(b) K_2O and P_2O_5
(c) $(NH_4)_2SO_4$ and $Ca_3(PO_4)_2$
(d) P_2O_5 and KCl

--Work Space--

B. (9 points) Stoichiometry and DDT

DDT is an insecticide that has been proven to be harmful to fish, birds and humans. It is produced by the following reaction

$$C_6H_5Cl \text{ (chlorobenzene)} + C_2HOCl_3 \text{ (chloral)} \text{----->} C_{14}H_9Cl_5 \text{ (DDT)} + H_2O.$$

(a) (2 points) Write a balanced equation for this reaction.

(b) (2 points) A sample of 1142 g of chlorobenzene is available. How many moles are in this sample? Provide the correct number of significant figures for full credit.

(c) (2 points) The chlorobenzene sample from (a) is reacted with 6.000 moles of chloral. Which reagent is is limiting and which reagent is in excess?

(d) (3 points) What mass of excess reactant is left over if the reaction goes to completion? Both show your work, and record your final answer in the lower right.

____ grams

C. (8 points) Electron diffraction and wave-particle duality. A beam of electrons can exhibit diffraction from an ordered metal surface under some conditions, something which not be expected to happen according to classical physics.

(a) (2 points) What is the magnitude of the momentum for an electron beam with kinetic energy of 49 eV? Give units for full credit.

(b) (2 points) Suppose an electron beam with momentum 3.0×10^{-24} kg m s^{-1} causes diffraction on a metal surface. What de Broglie wavelength do the electrons have? Give units for full credit.

(c) (2 points) Would a beam of neutrons (mass m_n) require different energy to exhibit diffraction? Explain why or why not.

(d) (2 points) Evaluate the kinetic energy (give units) of the neutrons that would give diffraction.

--Work Space--

D. (6 points) Wavefunctions and nodes of the particle in a box. An electron is trapped in a confining potential (like the particle in a box) which restricts its position in one dimension to a length of $\boxed{3.14 \text{ Å.}}$

(a)(2 points) The electron is described by a wavefunction that has the form sin(3x) where x is the electron position (in Å). Make a sketch of how this wavefunction de ends on x from 0 to 3.14 Å.

(b)(1 point) How many nodes do you observe in your wavefunction, and what quantum number does this correspond to?

Number of nodes?	Quantum number?

(c) (1.5 points) Would you expect that another particle in a box wavefunction of the form sin($4x$) would have a lower or higher energy than your wavefunction in (a). Give a reason

Lower or higher?	Reason?

(d)(1.5 points) If the box size were halved to 1.57 Å, which of sin($3x$) and sin($4x$) would remain an allowed wavefunction? Give a brief reason.

Which is allowed?	Reason?

---Work Space---

E. (6 points) Atomic orbitals and their energy levels.

(a)(2 points) Write the ground state electron configurations of the following atoms and ions.

Li:	F:
Ne:	Cr:

EA

(b) (2 points) Electron attachment is the process of adding an electron to an atom or a molecule. Does this process release heat or not for the F atom? Give a reason for your answer.

(c) (2 points) (2 points) Does electron attachment release heat or not for the C atom? Give a reason for your answer.

--Work Space--

F. (6 points) Ionic bonding

(a) (1.5 points) Give the expected charge of the ions of each of the following atoms.

Cl	Al	S

(b) (1 point) Predict the empirical formula of the ionic compound formed between aluminum and sulfur.

(c) (2 points) Suggest two factors that are important in comparing the lattice energy of LiF relative to the lattice energy of MgO (recall that the lattice energy is the difference between the ionic solid and the isolated gas phase ions).

1.	2.

(d) (1.5 points) Explain why you expect the lattice energy of LiF to be either smaller or bigger in magnitude than the lattice energy of MgO, based on the factors you identified above.

---Work Space---

G. (10 points) Covalent bonding and Lewis structures.

(a) (4 points) Draw Lewis ~~structures for the~~ following species, showing lone pairs, unpaired electrons, resonance structures and formal charges, as necessary.

H_2O	C_2H_4
CH_3O^-	C_6H_6

(b) (2 points) The CO_3^{2-} ion is often used in water softeners, and has 3 O atoms coordinated to the central C atom. Draw Lewis structures for this ion including all relevant resonance forms and showing any lone pairs and formal charges.

(c) (1 point) What is the bond order of the CO bond in the CO_3^{2-} ion?

(d) (2 points) The SO_4^{2-} ion has 4 O atoms coordinated to the central S atom. Draw Lewis structures for this ion including all relevant resonance forms and showing any lone pairs and formal charges.

(e) (1 point) Does each O atom satisfy the octet rule in your Lewis structures? If not, how many electrons do O have a share in? Then repeat for the S atom.

O:	S: