Chem 1A, Fall 2015, Midterm Exam 1. Version A

September 21, 2015

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Name: ______________________________________

Student ID:__________________________________ TA: ______________________________

Contents: 9 pages

A. Multiple choice (7 points)
B. Stoichiometry (10 points)
C. Photoelectric effect (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: 53 points

Instructions: Closed book exam. Basic scientific calculators are OK. Set brains in high gear and go!

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

$N_0 = 6.0221 \times 10^{23}$ 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-) = $h\nu - \Phi = h\nu - h\nu_0$

Periodic Table of the Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H Hydrogen 1.008																	2 He Helium 4.003
3 Li Lithium 6.941	4 Be Beryllium 9.012											5 B Boron 10.811	6 C Carbon 12.011	7 N Nitrogen 14.007	8 O Oxygen 15.999	9 F Fluorine 18.998	10 Ne Neon 20.180
11 Na Sodium 22.990	12 Mg Magnesium 24.305											13 Al Aluminum 26.982	14 Si Silicon 28.086	15 P Phosphorus 30.974	16 S Sulfur 32.066	17 Cl Chlorine 35.453	18 Ar Argon 39.948
19 K Potassium 39.098	20 Ca Calcium 40.078	21 Sc Scandium 44.956	22 Ti Titanium 47.867	23 V Vanadium 50.942	24 Cr Chromium 51.996	25 Mn Manganese 54.938	26 Fe Iron 55.845	27 Co Cobalt 58.933	28 Ni Nickel 58.693	29 Cu Copper 63.546	30 Zn Zinc 65.38	31 Ga Gallium 69.723	32 Ge Germanium 72.631	33 As Arsenic 74.922	34 Se Selenium 78.971	35 Br Bromine 79.904	36 Kr Krypton 84.798
37 Rb Rubidium 84.468	38 Sr Strontium 87.62	39 Y Yttrium 88.906	40 Zr Zirconium 91.224	41 Nb Niobium 92.906	42 Mo Molybdenum 95.95	43 Tc Technetium 98.907	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.906	46 Pd Palladium 106.42	47 Ag Silver 107.868	48 Cd Cadmium 112.414	49 In Indium 114.818	50 Sn Tin 118.711	51 Sb Antimony 121.760	52 Te Tellurium 127.6	53 I Iodine 126.904	54 Xe Xenon 131.294
55 Cs Cesium 132.905	56 Ba Barium 137.328	57-71 Lanthanides	72 Hf Hafnium 178.49	73 Ta Tantalum 180.948	74 W Tungsten 183.84	75 Re Rhenium 186.207	76 Os Osmium 190.23	77 Ir Iridium 192.217	78 Pt Platinum 195.085	79 Au Gold 196.967	80 Hg Mercury 200.592	81 Tl Thallium 204.383	82 Pb Lead 207.2	83 Bi Bismuth 208.980	84 Po Polonium [208.982]	85 At Astatine 209.987	86 Rn Radon 222.018
87 Fr Francium 223.020	88 Ra Radium 226.025	89-103 Actinides	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [268]	110 Ds Darmstadtium [269]	111 Rg Roentgenium [272]	112 Cn Copernicium [277]	113 Uut Ununtrium unknown	114 Fl Flerovium [289]	115 Uup Ununpentium unknown	116 Lv Livermorium [298]	117 Uus Ununseptium unknown	118 Uuo Ununoctium unknown

57 La Lanthanum 138.905	58 Ce Cerium 140.116	59 Pr Praseodymium 140.908	60 Nd Neodymium 144.243	61 Pm Promethium 144.913	62 Sm Samarium 150.36	63 Eu Europium 151.964	64 Gd Gadolinium 157.25	65 Tb Terbium 158.925	66 Dy Dysprosium 162.500	67 Ho Holmium 164.930	68 Er Erbium 167.259	69 Tm Thulium 168.934	70 Yb Ytterbium 173.055	71 Lu Lutetium 174.967
89 Ac Actinium 227.028	90 Th Thorium 232.038	91 Pa Protactinium 231.036	92 U Uranium 238.029	93 Np Neptunium 237.048	94 Pu Plutonium 244.064	95 Am Americium 243.061	96 Cm Curium 247.070	97 Bk Berkelium 247.070	98 Cf Californium 251.080	99 Es Einsteinium [254]	100 Fm Fermium 257.095	101 Md Mendelevium 258.1	102 No Nobelium 259.101	103 Lr Lawrencium [262]

Alkali Metal	Alkaline Earth	Transition Metal	Basic Metal	Semimetal	Nonmetal	Halogen	Noble Gas	Lanthanide	Actinide

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

1. What is the order of heavy to light of 55 mol of the following substances

(a) $CH_4 > CO_2 > CO > HF$
(b) $CO_2 > CO > HF > CH_4$
(c) $CH_4 > HF > CO > CO_2$
(d) $HF > CO_2 > CO > CH_4$

2. The following statements are true about the blackbody radiation curve

(a) As T decreases, the peak moves to longer λ
(b) As T increases, there is an ultraviolet catastrophe
(c) As T increases, the peak intensity is higher
(d) none of the above

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 De Broglie relation, $p = h/\lambda$
(d) all of the above

4. Which transition in Li^{2+} occurs at the same energy as the $4 \rightarrow 2$ transition in He^{+}?

(a) $36 \rightarrow 9$
(b) $16 \rightarrow 1$
(c) $25 \rightarrow 4$
(d) none of the above

5. The wave function for the hydrogen atom

(a) defines the exact position of the electron
(b) depends only on the principal quantum number
(c) always has both radial and angular nodes
(d) when squared gives the probability density

6. The way(s) in which many-electron atoms differ from one-electron atoms

(a) s, p, and d sub-shells are no longer degenerate
(b) nuclear charge seen by e- in outer shell are reduced
(c) filled shells are stable due to lower screening
(d) Two paired electrons must occupy each AO

7. The periodic trends for ionization energy of an atom depends on

(a) Z-number
(b) Number of e-s between outer e- and nucleus
(c) electron distance from nucleus
(d) its electron configuration

--Work Space--

B. (10 points) Stoichiometry and acid etching

(a) (2 points) Hydrofluoric acid, HF, can be used to etch glass by reaction with solid SiO_2 (i.e. glass) to form silicon tetrafluoride (SiF_4) and water. Write a balanced equation for this reaction.

(b) (2 points) 500 mL of an 0.5M solution of HF is prepared. How many moles of HF does the solution contain?

(c) (3 points) A piece of glass weighing 10.00g is placed in the HF solution. How many moles of Si atoms does the glass sample contain?

(d) (3 points) After waiting long enough for the reaction to complete, predict the mass of SiF_4 produced. Answering this question requires your equation from (a) – skip if you could not do (a).

__________ grams SiO_2

C. (8 points) Photoelectric effect and wave-particle duality. The photoelectric effect involves observing the way in which (i) the number of electrons emitted from a surface, and (ii) their kinetic energy (KE) depends on the radiation directed at the surface. For a particular metal surface, radiation of intensity 1.0 W cm^{-2} and wavelength 300 nm yields electrons of kinetic energy 40 kJ mol^{-1}.

(a) (3 points) Predict the effect of increasing the intensity from 1.0 W cm^{-2} to 2.0 W cm^{-2} on the KE of the emitted electrons. (Circle your answer and explain your choice.)

KE of e- greater KE of e- lesser no difference in KE of e-

(b) (3 points) The work function of a material is the energy required to remove an electron. Calculate the work function (eV) of the metal surface used in this experiment.

(c) (2 points) If the experiment is repeated with a new material, and no emitted electrons can be detected with radiation of intensity 1.0 W cm^{-2} and wavelength 300 nm, what can you conclude? (Circle your answer and explain your choice.)

Φ metal 1 > Φ metal 2 Φ metal 1 = Φ metal 2 Φ metal 1 < Φ metal 2

--Work Space--

D. (6 points) Wavefunctions and nodes of the particle in a box. An experiment is performed in which an electron in a confined potential (i.e. like the particle in a box) is promoted from the n=1 energy level to the n=2 energy level with radiation of 400 nm.

(a) (2 points) How many nodes are there in the wavefunction of the n=1 state and the n=2 state of the particle in a box? (Complete the table provided.)

	# nodes
n=1	
n=2	

(b) (2 points) Predict the effect (on the electron) of changing the wavelength to 300 nm on the experiment giving a reason for your prediction.

(c) (2 points) For the original experiment of 400 nm light, calculate the length of the box.

---Work Space---

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

(a) (2 points) Ionization is the process of removing an electron from an atom or a molecule. Does this process give off energy or require energy? Explain your answer carefully.

(b) (2 points) Calculate the energy change associated with removing a 1s electron from He^+.

(c) (2 points) Would you expect the ionization energy of the first 1s electron from He to be larger or smaller than the answer you obtained in (b)? (Circle your choice and explain.)

ionization energy of a 1s in He^+ > ionization of a 1s in He	ionization energy of a 1s in He^+ < ionization of a 1s in He

---Work Space--

F. (6 points) Ionic bonding

(a) (2 points) A pure substance does not conduct electricity in the solid state but it does dissolve in water and the resulting solution conducts electricity. The substance has a fairly high melting point. Is the substance an ionic compound or a covalent compound? State your reason.

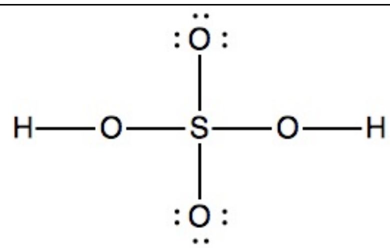
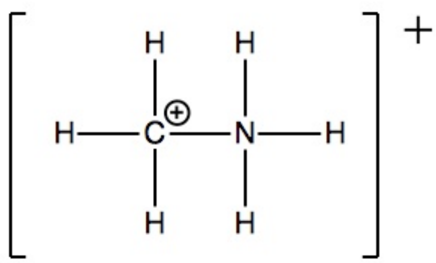
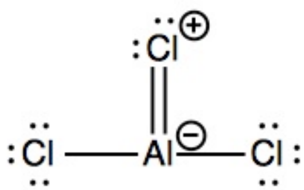
(b) (2 points) Which of the following alkali metals: Na, K, and Rb, will have the shortest critical distance for electron transfer to occur with a fluorine atom, and why?

(c) (2 points) Given the following alkali metal halides: LiCl, KBr, and CsI, what is the order of their lattice energies (energy relative to the isolated ions) from largest to smallest? State the reason for your answer.

---Work Space---

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

(a) (4 points) Which of the following Lewis structures are correct (and good) Lewis structures and which are incorrect (or are correct but poor)? Explain what is wrong with the incorrect ones.

Structure	OK? (Yes/No)	Correction if no
		
		
		

(b) (3 points) The NO_2 molecule is partly responsible for brown color associated with photochemical smog. Draw a Lewis structures for this molecule including all relevant resonance forms and showing any formal charges.

(c) (3 points) Under some conditions of pressure and temperature, two NO_2 molecules can combine to form N_2O_4 molecules. Draw Lewis structures for N_2O_4