Chemistry 4A
Professor Pines

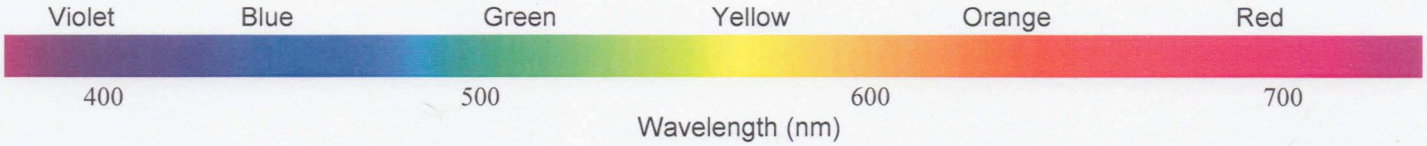
Midterm Exam 1 Version A
Closed Book, 45 minutes, 100 points

September 22, 2008
4 pages total

Student Name: KEY Student ID#: _____

GSI Name: _____ Lab Section Day/Time: _____

Potentially Useful Information



Light: $\lambda\nu = c$, $E_{photon} = h\nu$, c = 2.99792 x 10^{8} m s^{-1}

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

Matter: $p = mv$, $E_{kin} = \frac{mv^2}{2} = \frac{p^2}{2m}$

Wave/Matter: $\lambda_{deBroglie} = \frac{h}{p}$

Particle 1D box: $E_n = \frac{h^2 n^2}{8mL^2}$; n = 1, 2, 3...

H atom, 1-electron ion: $E_n = -\left(\frac{Z^2}{n^2}\right)R_\infty$; n = 1,2,3…

Orbital Nodes: Total = n – 1, Angular = ℓ, Radial = n – 1 – ℓ

N_A = 6.02214 x 10^{23} mol^{-1}

h = 6.62608 x 10^{-34} J s

$\mathcal{R}$ = 3.28984 x 10^{15} Hz

$R_\infty = h\mathcal{R}$ = 2.17987 x 10^{-18} J

R_∞/mole = 1312 kJ/mol

m_e = 9.10938 x 10^{-31} kg

	H	Na	K	Rb	Cl	Br	I
Ionization Energy [IE] (kJ/Mole)	1312	496	419	403	1251	1140	1008
Electron Affinity [EA] (kJ/Mole)	73	53	48	47	349	325	295

You may verify that the IE of atomic H corresponds to UV light with a photon wavelength of 91 nm.

Leave this section blank for grading

Multiple Choice Questions: 32

Short Answer Question #1: 30

Short Answer Question #2: 38

TOTAL: 100

Multiple Choice Questions 8 questions; **circle one answer** for each question (4 points each, 32 points total).

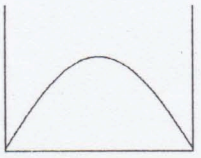
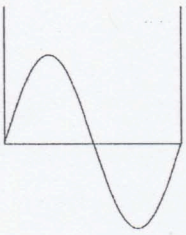
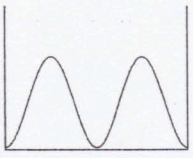
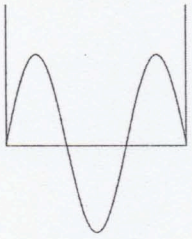
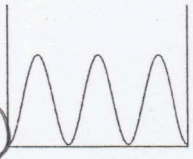
1) Green light does not eject electrons from a metal X. Light of which color will eject electrons?

A) Red (**R**) **B)** Yellow (**Y**) **C)** Blue (**B**) **D)** None of **R, Y, B** **E)** Can't tell

2) Which atom or ion can have the electronic configuration $[Ne]3s^1 3p^6$?

A) Ar+ **B)** Ar **C)** K **D)** K^+ **E)** Cl^-

3) Which corresponds to Ψ^2 for a particle in a 1D box with n = 3?

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

4) For a particle in a 1D box, which combination of quantum number n and box length has the lowest energy?

A) n = 1, L **B)** n = 1, 2L **C)** n = 2, L **D)** n = 2, 2L **E)** n = 2, 3L

5) Through a filter with which absorption range (nm) will a yellow solution look yellow?

A) 400 - 500 **B)** 500 - 600 **C)** 400 - 600 **D)** 500 - 700 **E)** None of **A, B, C, D**

6) Which is the smallest (has the lowest atomic or ionic radius)?

A) Cl **B)** Cl^- **C)** K **D)** K^+ **E)** Ca^{2+}

7) Which atom has a de Broglie wavelength two times smaller than ^{16}O at the same speed?

A) ^{32}S **B)** ^{24}Mg **C)** ^{20}Ne **D)** ^{8}B **E)** ^{4}He

8) Which compound has the lowest mass percentage of fluorine (F)?

A) LiF **B)** NaF **C)** KF **D)** RbF **E)** CsF

Short Answer Question #1 [30 points]

Write your answers and show your work in the boxes provided. Nothing outside the boxes will be graded.

a) [10 points] A hydrocarbon of molecular mass 26 has 92.3% C by mass. Write the empirical and molecular formulae.

Empirical Formula

CH

Molecular Formula

C_2H_2

Show your work and provide an explanation

Consider 100 g sample:

$(92.3\text{ g C})\left(\frac{\text{mol C}}{12\text{ g C}}\right) = 7.7\text{ mol C}$

$(7.7\text{ g H})\left(\frac{\text{mol H}}{1\text{ g H}}\right) = 7.7\text{ mol H}$

C:H = 1:1

$CH = 13\text{ g/mol}$

$C_2H_2 = 26\text{ g/mol}$

b) [10 points] What is the minimal quantity (mass and moles) of molecular oxygen required to fully combust 26 grams (1 mole) of the hydrocarbon?

Mass O_2 (include units)

80 g

Moles of O_2

2.5

Show your work, including balancing of relevant chemical equations

$C_2H_2 + \frac{5}{2}O_2 \longrightarrow 2CO_2 + H_2O$

(or $2C_2H_2 + 5O_2 \longrightarrow 4CO_2 + 2H_2O$)

$(2.5\text{ mol } O_2)\left(\frac{32\text{ g}}{\text{mol } O_2}\right) = 80\text{ g}$

c) [10 points] 52 grams (2 moles) of the hydrocarbon are combusted with 224 grams (7 moles) of molecular oxygen. What are the components of the resulting gas mixture, and in what quantities (moles)?

Components of the mixture, including quantities (moles)

4 mol CO_2

2 mol H_2O

2 mol O_2

Show your work

$2C_2H_2 + 7O_2 \longrightarrow 4CO_2 + 2H_2O + 2O_2$

Short Answer Question #2 [38 points]

Write your answers and show your work in the boxes provided. Nothing outside the boxes will be graded.

a) [15 points] Which pair is more stable (lower energy) at infinite distance, **K .... Cl** or **K^+ .... Cl^-**, and by how much?

K ... Cl or **K^+ ... Cl^-**

K ... Cl

By how much? (kJ/mol)

70 kJ/mol

Show your work

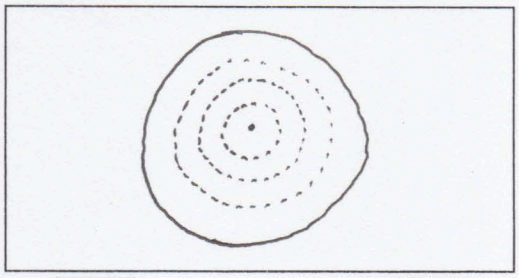
$K \rightarrow K^+ + e^-$ ionization energy K

$Cl + e^- \rightarrow Cl^-$ electron affinity Cl

$IE_K - EA_{Cl} = 419 \frac{kJ}{mol} - 349 \frac{kJ}{mol} = 70 \frac{kJ}{mol}$

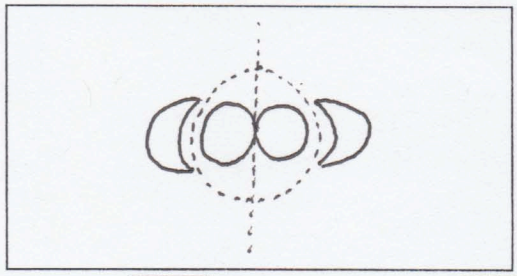
b) [8 points] Sketch the highest-energy occupied orbital of K and K^+ in the ground state and indicate the number of nodes. (In your sketches, indicate nodes with a dashed line.)

K



Radial nodes: 3 **Angular nodes:** 0

K^+



Radial nodes: 1 **Angular nodes:** 1

c) [15 points] Atoms of K are ionized with 91 nm light. What is the kinetic energy of the ejected electrons?

Answer (incl. units)

893 kJ/mol

Show your work

Ver. A 91 nm $E = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34}\ J s)(2.99792 \times 10^{8}\ m\ s^{-1})}{(91 \times 10^{-9}\ m)} = 2.183 \times 10^{-18}\ J = \frac{1314\ kJ}{mol}$

$IE_K = 419 \frac{kJ}{mol}$ excess energy $= E_{light} - IE_K = 1314 \frac{kJ}{mol} - 419 \frac{kJ}{mol} = \boxed{895 \frac{kJ}{mol}}$

Ver. B From hint on front page, 91 nm = IE_H = 1312 kJ/mol

$1312\ kJ/mol - 419\ kJ/mol = \boxed{893 \frac{kJ}{mol}}$ (difference comes from rounding 91 nm for IE_H)