Name: KEY

Chemistry 111
Test 1
October 4, 2004

Instructions before starting the test:

1. Write your name in the space above and on the backs of the other pages.
2. This exam is closed-everything.
3. Your exam booklet should have **six** pages total, with questions on pages 2-5, and a periodic table and other information on p. 6. Check to see you have six pages now. If you do not, ask for another copy of the exam.
4. You may use programmable calculators, but chemical data should not be stored in them.
5. To receive full credit for a mathematical problem, you must show the method by which you obtained the final answer, including dimensional analysis.
6. You have **60 minutes** to work on this exam. Do not start until you are instructed to.

Page (Possible Points)	Your Score
Page 2 (20)	
Page 3 (29)	
Page 4 (24)	
Page 5 (27)	
Total (100)	

mean 69
see histogram for score/grade distribution

1. (12 points total) Circle the best answer to each of the following questions. Your answers need not be justified, and no partial credit will be awarded.

A. Which of the following sets of quantum numbers is allowed?

(a) $n = 2, l = 2, m_l = 1, m_s = +1/2$

(b) $n = 3, l = 1, m_l = 2, m_s = -1/2$

(c) $n = 16, l = 8, m_l = -8, m_s = -1/2$

(d) $n = 3, l = 2, m_l = 1, m_s = 0$

(e) None of choices (a), (b), (c), and (d) is allowed.

B. Which set of species is given in order of increasing radius?

(a) Cr, Cr^{2+}, Cr^{3+}

(b) S^{2-}, Cl^-, K^+

(c) Mg^{2+}, Na^+, F^-

(d) I^-, Br^-, Cl^-

(e) None of choices (a), (b), (c), and (d) is given in order of increasing radius.

C. Which of the following statements is true?

(a) The most electronegative elements are in Period 6 of the periodic table.

(b) The wavelength of a standing wave increases with increasing number of nodes.

(c) Solid SrO requires less energy to dissolve than solid BaO.

(d) Potassium reacts violently with water due to K's high ionization energy.

(e) Statements (a), (b), (c), and (d) are all false.

2. (8 points total) Predict how many unpaired electrons there are in the ground state of Ni^{2+}. Justify your answer with some representation of the ion's electronic structure.

Ni: $[Ar]4s^2 3d^8 \Rightarrow Ni^{2+}: [Ar]3d^8$

(remove 4s e⁻'s before 3d e⁻'s)

↑↓ ↑↓ ↑↓ ↑ ↑

3d

2 unpaired e⁻'s

(-4) if you didn't remove 4s e⁻'s (ie you said 4 unpaired e⁻'s)

(-4) if you added 2 e⁻'s

(-4) for a misinterpretation of $[Ar]3d^8$ configuration

(-5) for a very inaccurate e⁻ configuration (eg filling 4p subshell or saying 3p is valence)

-7 something

3. (29 points total) For each of the following molecules or ions, do the following:

   (i) Name the species (except for (c)).

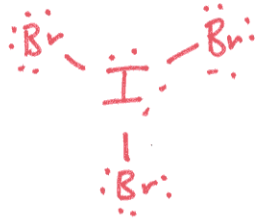
   (ii) Draw the best (that is, lowest-energy) Lewis structure, including any non-zero formal charges. It is fine if you draw higher-energy Lewis structures as part of your reasoning process, but be sure to label clearly what the best structure is.

(a) HS^- **Name is** hydrogen sulfide (ion) — 2 pts

(-2) Drew the radical H–S·
(-6) More than a duet on H
(-4) formal charge error

8 pts

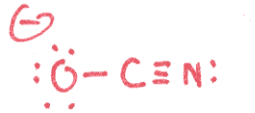
(b) IBr_3 **Name is** iodine tribromide — 2 pts



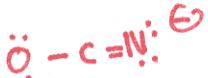
(-4) separated opposite charge
(-6) wrong # of e⁻'s
(-4) best structure not labeled
(-6) unpaired e⁻'s

9 pts

(c) Cyanate ion, OCN^- (C is the central atom)



best (⊖ on most electronegative atom)



full credit

(-5) more than 1 unpaired e⁻
(-5) wrong # of e⁻'s
(-2) thought OCN was a radical
(-6) more than an octet on an atom
(-6) less than an octet

(-5) mislabeled formal charge
(-4) separated opposite charge
(-4) best structure not labeled

8 pts

4. (24 points) Radiation in outer space leads to a variety of excited one-electron ions that are extremely difficult to form on earth. One such species is the C^{5+} ion in the $n = 8$ state.

(a) Calculate the longest wavelength of light (in nm) that can be emitted by this ion.

18 pts

$$\Delta E = -\mathcal{R} Z^2 \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = E_{photon} = -\frac{hc}{\lambda}$$

$$\Delta E = \left(-\frac{2.178\times10^{-18}\,J}{particle}\right) 6^2 \left(\frac{1}{7^2} - \frac{1}{8^2}\right) = -3.750_4 \times 10^{-19}\ J\ part^{-1}$$

longest wavelength ⇒ smallest ΔE ⇒ smallest change in n

$$\lambda = -\frac{hc}{E_{photon}} = +\left(\frac{particle}{3.750_4\times10^{-19}\,J}\right)\left(\frac{6.626\times10^{-34}\,J\,s}{particle}\right)\left(\frac{2.998\times10^{8}\,nm}{s}\right)$$

$$\times\left(\frac{10^9\,nm}{m}\right) = \boxed{529.6_7\ nm}$$

(-6) $n_f \neq 7$ ($n_f = 1 \Rightarrow \lambda = 2.574$ nm)

(-3) wrong value of Z

(-2) math error [in addition to n_f error]

(-9) $n_f = 0$ (not allowed by Bohr!)

(-12) wrong method

(-6) Left out c

(b) What is the frequency (in s^{-1}) corresponding to the wavelength you computed in part (a)?

6 pts

$$c = \lambda\upsilon \Rightarrow \upsilon = \frac{c}{\lambda} = \left(\frac{2.998\times10^{8}\,m}{s}\right)\left(\frac{1}{529.6_7\,nm}\right)\left(\frac{nm}{10^{-9}\,m}\right)$$

$$= \boxed{5.660\times10^{14}\,s^{-1}}$$

(if $\lambda = 2.574$ nm, $\upsilon = 1.165\times10^{17}$ Hz 100% credit for self-consistency)

(-2) math (if not already penalized above)

-4 wrong method

5. (27 points) **Choose <u>one</u> of the following essay questions (a <u>or</u> b):**

a. What controls (i) the kinetic energy of electrons and (ii) the rate of emission of electrons produced in the photoelectric effect? Contrast in detail what the wave model of light versus the photon model of light say about (i) and (ii).

b. Consider the following possible electron configurations for strontium (Sr):

Circle the ground state configuration of Sr, and explain your choice. You should give at least one stabilizing (*i.e.* energy-lowering) feature and one destabilizing (*i.e.* energy-raising) feature of both **I** and **II**. Your explanation must also incorporate and interpret plots of the radial probability distribution that show the correct number of radial nodes.

Grading rubrics for (a)

-6 saying that photon freq controls e⁻ emission rate
-6 saying that in the wave model, light freq controls KE
-12 no discussion of photon model
-10 some (incorrect) discussion of wave model
-6 vague (but correct) discussion of wave model
-10 some (incorrect) discussion of photon model
-3 vague on what controls photon E
-3 vague on KE
-3 no discussion of what controls e⁻ emission rate in wave model

Grading Rubrics for (b)

-3 one incorrect radial probability distribution
-5 two " " " "
-6 no mention of pairing penalty
-9 no plots (or discussion of plots)
-6 confused shielding + penetration
-6 confused which subshell penetrates better
-6 only discuss plots