CHM 1311: General Chemistry 1, Fall 2004
Exam #2, October 6, 2004

Name (print) ___________ Answer Key ___________ SSN ___________

Pledge: I have neither given nor received aid on this exam: ___________.

Signature

For ALL problems: SHOW ALL WORK TO GET FULL CREDIT

Useful equations and constants

\[ KE = \frac{1}{2}mv^2 \quad c = \lambda \nu \quad E = h\nu \quad \lambda = \frac{h}{mv} \]

Rydberg Equation:
\[
\frac{1}{\lambda} = R_H \left( \frac{1}{n_1^2} - \frac{1}{n_2^2} \right)
\]

Bohr model of H atom:
\[
E = -\frac{2\pi^2 m_e e^4}{n^2 h^2} = -\frac{b}{n^2}
\]

electron: mass \((m_e) = 9.1093897e-28 \text{ g}\) charge \((e) = -1.60e-19 \text{ C}\)
proton: mass = 1.673e-24 g
neutron: mass = 1.675e-24 g
c = 3.00e8 m s\(^{-1}\) 1 amu = 1.66054e-24 g
h = 6.63e-34 J s 1 mole = 6.022e23

DO NOT WRITE IN THESE BLANKS

1. (4) ___________ 10. (2) ___________ 19. (2) ___________
2. (2) ___________ 11. (2) ___________ 20. (3) ___________
3. (4) ___________ 12. (2) ___________ 21. (6) ___________
4. (2) ___________ 13. (6) ___________ 22. (3) ___________
5. (3) ___________ 14. (2) ___________ 23. (2) ___________
6. (2) ___________ 15. (4) ___________ 24. (10) ___________
7. (4) ___________ 16. (14) ___________ 25. (2) ___________
8. (2) ___________ 17. (2) ___________ 26. (2) ___________
9. (5) ___________ 18. (2) ___________ 27. (6) ___________

TOTAL (100) ___________
1. (4 pts) Using the Bohr model, calculate the frequency of light emitted by a hydrogen atom during a transition of its electron from the energy level with \( n = 4 \) to the level with \( n = 1 \).

\[
\Delta E = -\hbar \left( \frac{1}{4^2} - \frac{1}{1^2} \right) = 0.9375 \times \hbar
\]

\[
\Delta E = 0.9375 \times 2.18 \times 10^{-18} \text{ J}
\]

\[
\Delta E = 2.04 \times 10^{-18} \text{ J}
\]

\[
\nu = \frac{\Delta E}{\hbar} = \frac{2.04 \times 10^{-18}}{6.63 \times 10^{-34}} = 3.09 \times 10^{15} \text{ s}^{-1}
\]

(a) 1.028 \times 10^7 \text{ s}^{-1}

(b) 1.215 \times 10^{-7} \text{ s}^{-1}

(c) 2.467 \times 10^{15} \text{ s}^{-1}

(d) 3.083 \times 10^{15} \text{ s}^{-1}

(e) 8.228 \times 10^6 \text{ s}^{-1}

(2 pts if well set up)

2. (2 pts) Given the following Lewis structures, which molecule is nonpolar?

a) \( \overset{\circ}{S} \equiv \overset{\circ}{O} \)

b) \( H \overset{\circ}{O} \equiv H \)

c) \( H \overset{\circ}{C} \equiv N \)

d) \( F \equiv Be \equiv F \)

e) \( H \equiv F \equiv F \)

3. (4 pts) Give the symbol of the element of lowest atomic number which has:

- five unpaired \( d \) electrons
- three \( 3p \) electrons

Cr

P

4. (2 pts) If the octet rule were firmly obeyed by arsenic atoms, which one of the following ions of arsenic could be found in arsenic compounds?

a. \( \text{As}^- \)

b. \( \text{As}^{2-} \)

c. \( \text{As}^{3-} \)

(d) \( \text{As}^{4-} \)

e. \( \text{As}^{5-} \)
5. (3 pts) Consider the aluminum atom. For how many electrons in this atom does:

\[
m_i = 1 \quad 2 \text{ or } 3 \\
m_s = +1/2 \quad 6 \text{ or } 7 \\
m_i = 1 \text{ and } m_s = +1/2 \\
\]

depends on whether the 3p electron is \( m_s = +1/2 \) or \(-1/2\).

6. (2 pts) Give a set of 4 quantum numbers for one of the unpaired electrons in the +2 ion of palladium (if there are no unpaired electrons, then answer “no unpaired electrons”):

\[
\begin{align*}
\ell & = 2 \\
\ell & = -2, -1, 0, 1, 2 \\
\alpha & = +1/2 \text{ or } -1/2
\end{align*}
\]

7. (4 pts) Write the electron configuration for each of the following species:

- Co\(^{2+}\): \([\text{Ar}] \ 3d^7\) (use shorthand notation)
- Sb: \([\text{Kr}] 5s^2 4p^6 4d^{10} 5s^2\) (use full notation)
- Mo\(^+\): \([\text{Kr}] 4d^4\) or \([\text{Kr}] 4d^5\) (use shorthand notation)
- Bromide ion: \([\text{Ar}] 4s^2 3d^{10} 4p^6\) or \([\text{Kr}]\) (use shorthand notation)

8. (2 pts) Which one of the following bonds is the most polar?

a. H—C
b. H—Cl
c. H—P
d. H—S
e. H—Se

9. (5 pts) Sodium chloride, like most salts, is a stable compound as a crystal but not in the gas phase. Explain this being as specific as possible.

The electron affinity of the chlorine atom is not enough to overcome the ionization energy of the sodium atom in the gas phase. However, in the crystal, the lattice energy (attraction of nearest neighbor oppositely charged ions) is very strong and is more than enough to stabilize the compound.
Questions 10 to 12 refer to the molecule which has the Lewis structure given below.

10. (2 pts) What is the hybridization on the C atom labeled "b"?
   a. $sp$
   b. $sp^2$
   c. $sp^3$
   d. $dsp^3$
   e. $d^2sp^3$

11. (2 pts) What is the approximate bond angle denoted as "a"?
   a. 90°
   b. 109.5°
   c. 120°
   d. 180°
   e. none of the above

12. (2 pts) How many pi ($\pi$) bonds are present in the structure?
   a. 2
   b. 3
   c. 4
   d. 9
   e. 13
13. (6 pts) Draw the best Lewis structure for hydrogen peroxide ($\text{H}_2\text{O}_2$).

![Lewis structure of $\text{H}_2\text{O}_2$]

14. (2 pts) Given the following Lewis structure, what is/are the approximate F-Br-F bond angle(s) in the $\text{BrF}_2^-$ ion?

- $\text{BrF}_2^-$ structure

a. $180^\circ$
b. $109.5^\circ$
c. $120^\circ$
d. $90^\circ$
e. one is $90^\circ$, one is $120^\circ$

15. (4 pts) Complete the best Lewis structure for $\text{H}_2\text{SeO}_3$ from the skeletal template presented below by filling in the bonds and the remaining valence electrons (those which are not in the bonds).

- Full credit
- Half credit
16. (a) (6 pts) Draw the best Lewis structure for NF₃.

(b) (4 pts) Sketch the correct molecular 3D structure (still include all electrons). Be sure to include any relevant bond angles.

(c) (2 pts) Give the correct name of the shape of the molecule. \textit{trigonal pyramid}

(d) (2 pts) Is NF₃ polar or nonpolar? \textit{polar}

17. (2 pts) Which one of the following reactions corresponds to the largest electron affinity?

a. Cl(g) + e⁻ \rightarrow Cl⁻(g)

b. He(g) + e⁻ \rightarrow He⁻(g)

c. Ar(g) + e⁻ \rightarrow Ar⁻(g)

d. O⁻(g) + e⁻ \rightarrow O²⁻(g)

e. N²⁻(g) + e⁻ \rightarrow N³⁻(g)
18. (2 pts) What is the sum of all the formal charges in the H₂SeO₄ molecule?
   a. 0
   b. 1
   c. 2
   d. 3
   e. 4

19. (2 pts) Which statement below is true about the spectrum of hydrogen obtained in gas discharge tubes experiments?
   a. a photon is absorbed as the electron goes from a state with a higher energy to one with a lower energy
   b. a photon is absorbed as the electron goes from a state with a lower energy to one with a higher energy
   c. a photon is emitted as the electron goes from a state with a higher energy to one with a lower energy
   d. a photon is emitted as the electron goes from a state with a lower energy to one with a higher energy
   e. an electron is emitted as the photon goes from a state with a higher energy to one with a lower energy

20. (3 pts) How many lone pair (non-bonding valence electrons) are there around the nitrogen atom in the nitrate ion?
   a. 0
   b. 2
   c. 4
   d. 6
   e. 8
21. (6 pts) For each species below, fill in the diagram to show the ground state configuration of all electrons beyond the noble gas core electron configuration. Use ↑ and ↓ to indicate different spin states of each electron. Indicate below the orbitals which shell they are located in. One example is shown filled out for you:

\[ \text{B} \]
\[ \begin{array}{c}
\uparrow \downarrow \\
2s \\
\end{array} \]  
\[ \begin{array}{cccc}
\uparrow \downarrow \\
\downarrow \downarrow \\
\end{array} \]  
\[ \begin{array}{c}
\uparrow \downarrow \\
\uparrow \downarrow \\
\uparrow \downarrow \\
\end{array} \]  
\[ \begin{array}{c}
\uparrow \downarrow \\
\uparrow \downarrow \\
\end{array} \]  
\[ \begin{array}{c}
\uparrow \downarrow \\
\uparrow \downarrow \\
\end{array} \]  
\[ \begin{array}{c}
\uparrow \downarrow \\
\uparrow \downarrow \\
\end{array} \]  

Each subshell 1 point

22. (3 pts) For all 3 species in the previous problem, which are diamagnetic and which are paramagnetic (based on your answers in the previous question)?

Diamagnetic  \[ \text{I}^- \]
Paramagnetic  \[ \text{B}, \text{Ru}^{2+} \]

23. (2 pts) Consider the following orderings:

I.  \[ \text{Al} < \text{Si} < \text{P} < \text{S} \]
II.  \[ \text{Be} < \text{Mg} < \text{Ca} < \text{Sr} \]
III.  \[ \text{Na}^+ < \text{Mg}^{2+} < \text{Al}^{3+} < \text{Si}^{4+} \]

Which of these give(s) a correct trend in size?

a. I
b. II
b. II

Which of these give(s) a correct trend in size?
24. Given the following Lewis structure for TeCl₄

(a) (2 pts) What is the electron pair geometry around Te? Trigonal Bipyramidal

(b) (4 pts) Sketch the correct molecular 3D structure (still including all electrons). Be sure to include any relevant bond angles.

(d) (2 pts) What is the hybridization of the Te atom? sp⁢³⁹

(e) (2 pts) Is TeCl₄ polar or nonpolar? Polar

25. (2 pts) For which one of the processes below is the ionization energy the largest in magnitude:

a. Li(g) → Li⁺(g) + e⁻
b. B(g) → B⁺(g) + e⁻
c. B²⁺(g) → B³⁺ + e⁻
d. B³⁺(g) → B⁴⁺(g) + e⁻
e. Be⁺(g) → Be²⁺(g) + e⁻
26. (2 pts) Sketch the following atomic orbitals.

- a 2p orbital

- a 3d orbital

27. A Lewis structure for nitromethane, CH₃NO₂, is shown below.

(a) (3 pts) In terms of bond order, describe the bonding between nitrogen and oxygen:

There are two resonance structures. Each N–O bond is single in one and double in the other. The bond order is between 1 and 2. (actually 1.5)

(b) (3 pts) Calculate the formal charge on the nitrogen:

\[ \text{N}: \text{group 5} - 4 \text{ bonds} - 0 \text{ electrons in lone pairs} \]

\[ = +1 \]