IMPORTANT: On the scantron (answer sheet), you MUST clearly fill your name, your student number, section number, and test form (white cover = test form A; yellow cover = test form B). Use a #2 pencil.

There are 40 questions on this exam. Check that you have done all of the problems and filled in the first 40 bubbles on the scantron BEFORE TIME IS CALLED. The maximum score on this exam is 40 points. Your score will be reported in percent (max 100%).

Exam policy
- Calculators with text-programmable memory are not allowed.
- Relevant data and formulas, including the periodic table, are attached at the end of this exam.
- Your grade will be based only on what is on the scantron form.
- The answer key will be posted on the web after the exam (on the Exam Schedule page).
- You must turn in your cover sheet with your scantron answer form.

Hints
- As you read the question, underline or circle key words to highlight them for yourself. Avoid errors from "mis-reading" the question.
- Pay attention to units and magnitudes (decimal places) of numbers obtained from calculations.
- There is no penalty for guessing.
1. The graduate students working on the new element Nittinium (Nt) are back for a final project! As previously discovered, in its pure form Nt is a metal. However, they have synthesized a new material by making nittinium nitrate! Its structure is ultimately unknown, but the solid is hard and brittle, has a high melting point, and has poor electrical conduction in the solid state. What can it be classified as?

A. Molecular solid  
B. Network Covalent solid  
C. Ionic solid  
D. Metallic solid  
E. Atomic solid

2. Which of the following ligands can be classified as bi-dentate?

i. \(\text{H}-\text{N}-\text{H}\)  
ii. \(\text{H}_2\text{N}-\text{NH}_2\)  
iii. \(\text{C}=\text{O}\)  
iv.  
v.  

A. i only  
B. iv only  
C. ii and iii  
D. ii, iii, iv  
E. ii and v

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Chemistry 112 Final Exam  
Form A  
December 17, 2014

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3. The polymer PVC is pictured below. What monomer unit is used to make this addition polymer?

\[
\begin{array}{c}
\text{PVC, poly vinyl chloride} \\
\end{array}
\]

A. \[
\begin{array}{c}
\text{H} \\
\text{C=Cl} \\
\text{H} \\
\end{array}
\]

B. \[
\begin{array}{c}
\text{H} \\
\text{C=Cl} \\
\text{H} \\
\text{H} \\
\end{array}
\]

C. \[
\begin{array}{c}
\text{H} \\
\text{C=Cl} \\
\text{H} \\
\end{array}
\]

D. \[
\begin{array}{c}
\text{Cl} \\
\text{C=Cl} \\
\text{H} \\
\end{array}
\]

E. \[
\begin{array}{c}
\text{Cl} \\
\text{C=Cl} \\
\text{Cl} \\
\end{array}
\]

4. Graphite is an allotrope of carbon. This material is classified as which type of solid?

A. Molecular  
B. Network Covalent  
C. Ionic  
D. Metallic  
E. Atomic
5. The porphyrin ligand is very important in biological systems. It is an integral part of both chlorophyll and hemoglobin, shown below.

![Hemoglobin and Chlorophyll a](image)

The porphyrin ligand has an overall charge of:

A. 0  
B. –1  
C. –2  
D. –3  
E. –4

6. Using the spectrochemical series below, which one of the following complexes would be expected to absorb light of the shortest wavelength?

$I^- < Br^- < Cl^- < SCN^- < F^- < OH^- < H_2O < NH_3 < en < NO_2^- < CN^- < CO$

A. $[CrI_6]^{3-}$  
B. $[Cr(CN)_6]^{3-}$  
C. $[Cr(SCN)_6]^{3-}$  
D. $[Cr(en)_3]^{3+}$  
E. $[Cr(H_2O)_6]^{3+}$
7. Using the molecular orbital diagram with the large 2s-2p interactions, what is the bond order of NO⁺ (nitrosonium ion)?

A. 0  
B. 1  
C. 2  
D. 2.5  
E. 3

8. What is the pH of a solution that is 0.55 M in CH₃COOH and 0.20 M in CH₃COONa at 25°C? (Kₐ of CH₃COOH = 1.8 x 10⁻⁵)

A. 4.30  
B. 5.20  
C. 0.45  
D. 2.60  
E. 2.80

9. Which of the following is an n-type semi-conductor?

A. Si-doped with B  
B. Ge-doped with Si  
C. GaAs  
D. AlAs  
E. Si-doped with As

10. Which type(s) of radioactive decay result(s) in a product with a greater atomic number than the parent isotope?

A. alpha decay  
B. beta decay  
C. electron capture  
D. positron emission  
E. electron capture and positron emission
11. The two monomers pictured below are utilized to make Dacron polyester, which is a common material used in clothing. What is the structure of the polymer?

A. 

B. 

C. 

D. 

E. None of the above.
12. What is $K_{eq}$ for the following reaction?

$$[\text{Ni(NH}_3\text{)}_6]^{2+}(\text{aq}) + 3 \text{en (aq)} \rightleftharpoons [\text{Ni(en)}_3]^{2+}(\text{aq}) + 6 \text{NH}_3(\text{aq})$$

$K_f[\text{Ni(NH}_3\text{)}_6]^{2+} = 1.2 \times 10^9$

$K_f[\text{Ni(en)}_3]^{2+} = 6.8 \times 10^{17}$

A. $8.2 \times 10^{26}$
B. $5.7 \times 10^8$
C. $2.0 \times 10^{-9}$
D. $6.8 \times 10^{17}$
E. Cannot be determined with the given info.

13. Both semiconductors and insulators have a band gap energy, $E_g$, specific to that material. When energy equal to $E_g$ is provided to these materials, which statement is true?

A. An insulator acts like a metal when energy is applied, and the band gap disappears.
B. A semiconductor and an insulator will both conduct electricity when energy is applied.
C. A semiconductor becomes an insulator when energy is applied.
D. Doping occurs when energy is applied to a semiconductor.
E. The band gap energy of an insulator is on the same order of magnitude as the bond dissociation energy, and the material breaks apart when energy equal to $E_g$ is applied.

14. Which of the following 2p molecular orbitals are classified as bonding MOs?

A. i, ii, iv only
B. i and iii only
C. ii and iv only
D. iii only only
E. All of the MOs depicted are considered to be bonding.
15. It requires 200 seconds for a first-order reaction to go 25% of the way to completion. What is the half-life of the reaction?

A. 400 s  
B. 464 s  
C. 482 s  
D. 512 s  
E. 550 s

16. The species HPO$_4^{2-}$ (aq) can BEST be described as:

A. An acid only  
B. A base only  
C. An amphoteric species  
D. A spectator ion  
E. A salt

17. Which one of the following compounds is diamagnetic and will NOT interact with a magnetic field?

A. [Co(CN)$_6$]$^{4-}$ (low spin)  
B. [CoF$_6$]$^{3-}$ (high spin)  
C. [Fe(CO)$_6$] (low spin)  
D. [Fe(OH)$_6$]$^{3-}$ (high spin)  
E. [CuBr$_6$]$^{4-}$ (high spin)
18. Photosynthesis is an important biosynthetic pathway used by plants to store energy in the form of sugar as shown below:

\[
6 \text{CO}_2 \text{(g)} + 6 \text{H}_2\text{O (ℓ)} + \text{Energy} \rightarrow \text{C}_6\text{H}_12\text{O}_6 \text{(s)} + 6 \text{O}_2 \text{(g)}
\]

Which of the following is / are TRUE about this pathway?

I. The activation energy for the reverse reaction is lower than the forward reaction.
II. Catalysts increase the production of \(\text{C}_6\text{H}_12\text{O}_6\) by increasing \(K_{eq}\).
III. This reaction cannot proceed in the forward direction without a catalyst.
IV. A catalyst won’t change the free energy of the products.

A. I & III only
B. I, II, & IV only
C. I & IV only
D. I & II only
E. All of the above are true.

19. If the coordination compound \(K_2[\text{Ni(en)}(\text{CN})_4]\) existed, what would be the charge on the complex ion, the coordination number on the central metal atom, and the oxidation state of the metal atom?

<table>
<thead>
<tr>
<th></th>
<th>Charge on Complex Ion</th>
<th>Coordination number on metal atom</th>
<th>Oxidation state of metal atom</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0</td>
<td>5</td>
<td>+2</td>
</tr>
<tr>
<td>B</td>
<td>−2</td>
<td>5</td>
<td>−2</td>
</tr>
<tr>
<td>C</td>
<td>+2</td>
<td>6</td>
<td>+3</td>
</tr>
<tr>
<td>D</td>
<td>−2</td>
<td>6</td>
<td>+2</td>
</tr>
<tr>
<td>E</td>
<td>0</td>
<td>7</td>
<td>+3</td>
</tr>
</tbody>
</table>
The Haber Process has been used for the conversion of atmospheric nitrogen to ammonia:

\[ \text{N}_2 (g) + 3 \text{H}_2 (g) \rightleftharpoons 2 \text{NH}_3 (g) \]

Conditions: 200 atm, 450°C, metal catalyst

This process has been used for about a century to produce fertilizers. However, despite its use in chemical industry, the mechanism was not clearly defined. Use this information to answer the following TWO questions:

20. A group of enthusiastic scientists discovered that a soluble iron complex, FeL₆, could act as a catalyst in the Haber process (L represents a certain ligand). The following mechanism was proposed:

\[
\begin{align*}
\text{N}_2(g) + \text{FeL}_6(aq) & \rightarrow \text{FeL}_5(\text{N}_2)(aq) + \text{L}(aq) \quad \text{(slow step)} \\
\text{H}_2(g) + \text{FeL}_6(aq) & \rightarrow \text{FeL}_5(\text{H}_2)(aq) + \text{L}(aq) \quad \text{(fast step)} \\
4 \text{L}(aq) + \text{FeL}_5(\text{N}_2)(aq) + 3 \text{FeL}_5(\text{H}_2)(aq) & \rightarrow 2 \text{NH}_3(g) + 4 \text{FeL}_6(aq) \quad \text{(fast step)}
\end{align*}
\]

What is the rate law based on this mechanism?
A. Rate = k[N₂][H₂][FeL₆]  
B. Rate = k[L]⁴[FeL₅(N₂)][FeL₅(H₂)]³  
C. Rate = k[N₂]  
D. Rate = k[FeL₆][H₂]  
E. Rate = k[N₂][FeL₆]

21. This initial proposed mechanism for the Haber process above was later modified by an additional study, wherein a competing group of scientists presented the following data:

<table>
<thead>
<tr>
<th>Experiment #</th>
<th>[N₂] (M)</th>
<th>[H₂] (M)</th>
<th>Initial Rate (M s⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.4 x 10⁻³</td>
<td>2.2 x 10⁻³</td>
<td>2.6 x 10⁻⁵</td>
</tr>
<tr>
<td>2</td>
<td>12.8 x 10⁻³</td>
<td>2.2 x 10⁻³</td>
<td>1.0 x 10⁻⁴</td>
</tr>
<tr>
<td>3</td>
<td>6.4 x 10⁻³</td>
<td>4.4 x 10⁻³</td>
<td>5.2 x 10⁻⁵</td>
</tr>
</tbody>
</table>

What is the rate law based on this data?
A. Rate = k[N₂][H₂]³  
B. Rate = k[H₂]³  
C. Rate = k[N₂]  
D. Rate = k[N₂][H₂]  
E. Rate = k[N₂]²[H₂]
22. The $^{14}\text{C}/^{12}\text{C}$ molar ratio found in an ancient wooden artifact is 1/12 of the $^{14}\text{C}/^{12}\text{C}$ molar ratio naturally found in the atmosphere. What is the approximate age of the artifact? (The half-life of $^{14}\text{C}$ is 5,700 years.)

A. 20,000 years  
B. 20,400 years  
C. 21,200 years  
D. 24,700 years  
E. 25,100 years

23. When $^{235}\text{U}$ is bombarded with one neutron, fission occurs. The products are three neutrons, $^{94}\text{Kr}$ and which other isotope?

A. $^{139}\text{Ba}$  
B. $^{141}\text{Ba}$  
C. $^{139}\text{Ce}$  
D. $^{139}\text{Xe}$  
E. $^{142}\text{I}$

24. Rick T. Cat, a famed hero, needs to forge iron claws for his next great adventure through the deserts of Caldeum. He does so using electrolysis, according to the reaction below:

$$\text{Fe}^{2+} (aq) + 2\text{e}^- \rightarrow \text{Fe} (s)$$

Rick needs to plate out 111.7 grams of solid iron on his claws to be adequately prepared for his quest. If he has 8 hours to plate out his iron, at what current should he run the electrolysis reaction?

A. 3.4 Amperes  
B. 5.2 Amperes  
C. 6.7 Amperes  
D. 10.4 Amperes  
E. 13.4 Amperes
25. What is the hydronium ion concentration of a $1.67 \times 10^{-5}$ M Sr(OH)$_2$ solution at 25°C?

A. $5.99 \times 10^{-10}$ M  
B. $1.67 \times 10^{-5}$ M  
C. $2.99 \times 10^{-10}$ M  
D. $1.20 \times 10^{-9}$ M  
E. $3.65 \times 10^{-8}$ M 

26. Which one of the following will produce the most acidic aqueous solution at 25°C?

A. CuCl$_2$  
B. KF  
C. BaI$_2$  
D. Fe(NO$_3$)$_3$  
E. H$_2$O 

27. What is the molar solubility of Ca(OH)$_2$ (s) in water at 25°C? ($K_{sp}$ of Ca(OH)$_2$ = $5.5 \times 10^{-6}$)

A. $1.8 \times 10^{-2}$ M  
B. $1.11 \times 10^{-2}$ M  
C. $2.3 \times 10^{-3}$ M  
D. $2.2 \times 10^{-2}$ M  
E. $5.5 \times 10^{-6}$ M 

28. Which of the following isotopes is most likely to undergo alpha decay?

A. Helium-4  
B. Helium-6  
C. Iron-56  
D. Arsenic-75  
E. Uranium-238
29. Given the following values of $K_a$ and $K_b$ for aqueous solutions at 25°C, which choice is the strongest acid?

Pyridine, $C_5H_5N$ ($K_b = 1.7 \times 10^{-9}$)
Acetic acid, $CH_3COOH$ ($K_a = 1.8 \times 10^{-5}$)
Phenol, $C_6H_5OH$ ($K_a = 1.3 \times 10^{-10}$)
Hydrogen cyanide, HCN ($K_a = 4.9 \times 10^{-10}$)

A. $C_5H_5NH^+$
B. $CH_3COOH$
C. $C_6H_5O^-$
D. $C_6H_5OH$
E. HCN

30. Given the data in the table below, calculate the expected normal boiling point of mercury at 1 atm.

\[
Hg (l) \rightleftharpoons Hg (g)
\]

<table>
<thead>
<tr>
<th>Substance</th>
<th>$\Delta H^\circ_f$ (kJ mol$^{-1}$)</th>
<th>$\Delta G^\circ_f$ (kJ mol$^{-1}$)</th>
<th>$S^\circ$ (J K$^{-1}$ mol$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hg(g)</td>
<td>60.83</td>
<td>31.76</td>
<td>174.89</td>
</tr>
<tr>
<td>Hg(l)</td>
<td>0.0</td>
<td>0.0</td>
<td>77.4</td>
</tr>
<tr>
<td>O$_3$(g)</td>
<td>142.3</td>
<td>163.4</td>
<td>237.6</td>
</tr>
<tr>
<td>O$_2$(g)</td>
<td>0.0</td>
<td>0.0</td>
<td>205.0</td>
</tr>
<tr>
<td>O (g)</td>
<td>247.5</td>
<td>230.1</td>
<td>161.0</td>
</tr>
</tbody>
</table>

A. 0.624 K
B. 97.5 K
C. 60.8 K
D. 312 K
E. 624 K
A voltaic cell is constructed from the following materials:

Using this information, answer the following TWO questions:

31. What is $E^{\circ}_{\text{cell}}$ at 25°C?

A. +4.09 V  
B. −1.20 V  
C. +1.66 V  
D. +2.86 V  
E. −0.46 V

32. What is $E_{\text{cell}}$ in the cell above if the concentrations are equal to $[\text{Al}^{3+}] = 2.5 \text{ M}$ and $[\text{Pt}^{2+}] = 0.01 \text{ M}$ at 25°C?

A. 2.79 V  
B. 2.84 V  
C. 2.93 V  
D. 2.46 V  
E. 3.26 V
The following “Rocket Fuel” reaction was demonstrated in class:

\[
C_{12}H_{22}O_{11} (s) + 8 \text{ KClO}_3 (s) \rightarrow 12 \text{ CO}_2 (g) + 11 \text{ H}_2\text{O} (\ell) + 8 \text{ KCl} (s)
\]

<table>
<thead>
<tr>
<th>Substance</th>
<th>(\Delta G^\circ_f) (kJ mol(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>sucrose (C(<em>{12})H(</em>{22})O(_{11}), s)</td>
<td>−1544.3</td>
</tr>
<tr>
<td>KClO(_3), s</td>
<td>−289.9</td>
</tr>
<tr>
<td>CO(_2), g</td>
<td>−394.4</td>
</tr>
<tr>
<td>H(_2)O, (\ell)</td>
<td>−237.1</td>
</tr>
<tr>
<td>KCl, s</td>
<td>−408.3</td>
</tr>
</tbody>
</table>

In the demo, the solid reactants were placed in a small vial, which was kept in a beaker containing sand. A few drops of concentrated H\(_2\)SO\(_4\) were then added to the reactants and the reaction instantly began. As the reaction proceeded, a large flame and lots of smoke were generated. Use this information to answer the following TWO questions:

33. Which of the following sets of data accurately describes this reaction?

<table>
<thead>
<tr>
<th>(\Delta H)(_{rxn})</th>
<th>(\Delta S)(_{rxn})</th>
<th>Spontaneous at:</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. (−)   (+)</td>
<td></td>
<td>All Temperatures</td>
</tr>
<tr>
<td>B. (+)    (+)</td>
<td></td>
<td>Low Temperatures</td>
</tr>
<tr>
<td>C. (−)    (−)</td>
<td></td>
<td>Low Temperatures</td>
</tr>
<tr>
<td>D. (−)    (+)</td>
<td></td>
<td>High Temperatures</td>
</tr>
<tr>
<td>E. (+)    (+)</td>
<td></td>
<td>High Temperatures</td>
</tr>
</tbody>
</table>

34. What is the maximum amount of work that can be done by the Rocket Fuel system?

A. 14.5 x 10\(^3\) kJ
B. 6.7 x 10\(^3\) kJ
C. 2.3 x 10\(^3\) kJ
D. 8.0 x 10\(^2\) kJ
E. The system cannot do work, work must be done on this system.
35. Which one of the following will NOT change the solubility of CaF$_2$ when added to a saturated aqueous solution of CaF$_2$ at 25°C? (K$_{sp}$ = 3.9 x 10$^{-11}$)

A. HF  
B. NaOH  
C. Ca(NO$_3$)$_2$  
D. HCl  
E. KCl

36. When in an aqueous solution, the complex ion [FeF$_6$]$^{4-}$ appears blue to the eye. [Fe(CN)$_6$]$^{4-}$ appears orange to the eye in a separate aqueous solution. Given this information, which of the following statements is/are TRUE?

i. $\Delta_0$ is larger for [FeF$_6$]$^{4-}$

ii. [FeF$_6$]$^{4-}$ absorbs photons of $\lambda$ = 460 nm

iii. [Fe(CN)$_6$]$^{4-}$ absorbs photons of $\lambda$ = 600 nm

iv. $\Delta_0$ is larger for [Fe(CN)$_6$]$^{4-}$

A. i only  
B. iv only  
C. i and iii only  
D. ii and iv only  
E. ii, iii, and iv only

37. What is the pH of an aqueous solution of 0.28 M NaN$_3$ at 25°C? (For hydroazoic acid, HN$_3$, K$_a$ = 1.9 x 10$^{-5}$)

A. 2.6  
B. 9.1  
C. 4.9  
D. 11.4  
E. 8.95
38. A titration enthusiast titrates a 50 mL solution of 0.30 M HNO\textsubscript{2} (aq) (K\textsubscript{a} = 4.5 \times 10^{-4}) with 0.15 M NaOH until the \textit{equivalence point}. What is the pH of this solution at the equivalence point at 25°C?

A. 6.1  
B. 7.0  
C. 7.9  
D. 8.2  
E. 13.5

39. What will be the initial product formed at the CATHODE of an electrolytic cell containing aqueous 1.0 M PbCl\textsubscript{2}?

A. Pb (s)  
B. O\textsubscript{2} (g)  
C. H\textsubscript{2} (g)  
D. Cl\textsubscript{2} (g)  
E. Pb\textsuperscript{2+} (aq)

40. In class, we demonstrated that Ni\textsuperscript{2+} forms a complex ion with ethylenediamine, with a formula of [Ni(en)\textsubscript{3}]\textsuperscript{2+}. The magnitude of the octahedral crystal field splitting energy (Δ\textsubscript{o}) is 210 kJ mol\textsuperscript{-1}. What color does this complex appear to the eye?

A. Red  
B. Orange  
C. Green  
D. Blue  
E. Purple

END OF EXAM
Chem 112 Practice Exam 4B
Final Exam Answer Key

1. C
2. E
3. B
4. B
5. C
6. B
7. E
8. A
9. E
10. B
11. A
12. B
13. E
14. B
15. C
16. C
17. C
18. C
19. D
20. E
21. E
22. B
23. A
24. E
25. C
26. D
27. B
28. E
29. B
30. E
31. D
32. A
33. A
34. B
35. E
36. B
37. B
38. D
39. A
40. E