Chem. 1B Exam 2
February 27, 2009

FORM A
First letter of your last name: 

Name: ____________________________________

Last Name

First Name

Perm # ____________________________________

There are a total of six pages (19 questions) on the exam. You must show your work on the exam. We can evaluate your exam only if you have shown work.

SCANTRON FORM:
1) Write your name
2) Bubble in FORM A
3) Bubble in your PERM number (7 digits only, no extra numbers)

INFORMATION PAGE: Remove the information page. No other notes or books are allowed.

INSTRUCTIONS: Turn in your Exam and Scantron form. No hats/hoods allowed. No sharing of calculators. Cell Phones, iPods, headsets, and any other electronic devices must be turned off and put away.

1. (6 pts) Given the data below, what is the rate law for the following reaction? A + B → C

<table>
<thead>
<tr>
<th>Experiment</th>
<th>[A] (M)</th>
<th>[B] (M)</th>
<th>Initial Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.012</td>
<td>0.035</td>
<td>0.10</td>
</tr>
<tr>
<td>2</td>
<td>0.024</td>
<td>0.070</td>
<td>0.80</td>
</tr>
<tr>
<td>3</td>
<td>0.024</td>
<td>0.035</td>
<td>0.10</td>
</tr>
<tr>
<td>4</td>
<td>0.012</td>
<td>0.070</td>
<td>0.80</td>
</tr>
</tbody>
</table>

ANSWERS are at the end of the exam

a) Rate = k [B]^4
b) Rate = k [B]^2
c) Rate = k [A]^2 [B]^2
d) Rate = k [A] [B]^3
e) Rate = k [B]^3
\[
\begin{array}{ccc}
\text{Au}^{3+} + 3 \text{e}^- & \rightarrow & \text{Au} (s) & 1.50 \\
\text{Cl}_2 + 2\text{e}^- & \rightarrow & 2 \text{Cl}^- & 1.36 \\
\text{O}_2 + 4\text{H}^+ + 2\text{e}^- & \rightarrow & 2 \text{H}_2\text{O} & 1.23 \\
\text{Fe}^{3+} + \text{e}^- & \rightarrow & \text{Fe}^{2+} & 0.77 \\
\text{I}_2 + 2 \text{e}^- & \rightarrow & 2 \text{I}^- & 0.54 \\
\text{Cu}^{2+} + 2 \text{e}^- & \rightarrow & \text{Cu} (s) & 0.34 \\
2 \text{H}^+ + 2 \text{e}^- & \rightarrow & \text{H}_2 & 0.00 \\
\text{Fe}^{3+} + 3 \text{e}^- & \rightarrow & \text{Fe} (s) & -0.036 \\
\text{Ni}^{2+} + 2 \text{e}^- & \rightarrow & \text{Ni} (s) & -0.23 \\
\text{Al}^{3+} + 2 \text{e}^- & \rightarrow & \text{Al} (s) & -1.66
\end{array}
\]

2. (6 pts) Using the above half reactions, which of the following species can be reduced by Fe(s)?

a) \(\text{Al}^{3+}\)
b) \(\text{Ni}\)
c) \(\text{I}_2\)
d) \(\text{Cu}\)
e) \(\text{I}^-\)

Questions 3 – 5: A galvanic cell is described by the following shorthand line notation

\[\text{Pt} | \text{H}_2 \ (g, 1.0 \ \text{atm}) | 0.1 \ \text{M} \ 	ext{H}^+ \ (aq) \ \parallel \ \text{Fe}^{3+} (1 \ \text{M}), \text{Fe}^{2+} (1 \ \text{M}) | \text{Pt}\]

3. (6 pts) The half reaction that occurs at the cathode of this cell is written as

a) \(\text{H}_2 (g, 1 \ \text{atm}) \rightarrow 2 \text{H}^+ (0.1 \ \text{M}) + 2\text{e}^-\)
b) \(2 \text{H}^+ (0.1 \ \text{M}) + 2\text{e}^- \rightarrow \text{H}_2 (g, 1 \ \text{atm})\)
c) \(\text{Pt} (s) + \text{Fe}^{3+} (1 \ \text{M}) \rightarrow \text{Pt}^{+} (aq) + \text{Fe}^{2+} (1 \ \text{M})\)
d) \(\text{Fe}^{2+} (1 \ \text{M}) \rightarrow \text{Fe}^{3+} (1 \ \text{M}) + \text{e}^-\)
e) \(\text{Fe}^{3+} (1 \ \text{M}) + \text{e}^- \rightarrow \text{Fe}^{2+} (1 \ \text{M})\)

4. (6 pts) The potential of this galvanic cell at 25 \(^\circ\)C is

a) \(0.77 \ \text{V}\)
b) greater than 0.77 \(\text{V}\)
c) less than 0.77 \(\text{V}\)
d) negative

c) \(0 \ \text{V}\)

5. (6 pts) When this cell is connected to an external circuit and its output is used to drive a fan motor, which of the following will occur?

a) Platinum will be reduced
b) Hydrogen gas will be formed
c) Platinum will be oxidized
d) Iron metal will plate out at the cathode
e) None of the above
Questions 6 – 7: An acidified solution was electrolyzed using copper electrodes. A constant current of 1.18 A caused the anode to lose 0.584 g after $1.52 \times 10^3$ sec. Hydrogen gas was produced at the cathode.

6. (6 pts) Calculate the value of Faraday’s constant from the experimental data given.
   a) $F > 96,485$ C/mol
   b) $F < 96,485$ C/mol
   c) $F = 96,485$ C/mol
   d) Faraday’s constant cannot be determined from the data given.

7. (6 pts) Use the data given above to determine the volume of hydrogen gas produced at 23 °C and 1 atm.
   a) 0.446 L
   b) 0.223 L
   c) 0.893 L
   d) 22.3 L
   e) none of the above

8. (6 pts) For the following galvanic cell, the standard free energy is $\Delta G^o = -89.3$ kJ.

   $\text{M(s)} \mid \text{M}^{2+} \text{(aq)} \parallel \text{Ag}^+ \text{(aq)} \mid \text{Ag(s)}$

   Calculate the standard cell potential $E^o$.
   a) +0.463 V
   b) -0.926 V
   c) -0.463V
   d) +0.926 V
   e) +0.231 V
9. (6 pts) The following two half-reactions take place in a galvanic cell. At standard conditions, what species are produced at each electrode?
\[ \text{Au}^{3+} + 3 \text{e}^- \rightarrow \text{Au} \text{ (s)} \quad 1.60 \]
\[ \text{Ag}^+ + \text{e}^- \rightarrow \text{Ag} \text{ (s)} \quad 0.70 \]

a) Ag is produced at the anode and \( \text{Au}^{3+} \) is produced at the cathode.
b) Au is produced at the cathode and \( \text{Ag}^+ \) is produced at the anode.
c) Au is produced at the anode and \( \text{Ag}^+ \) is produced at the cathode.
d) Ag is produced at the anode and Au is produced at the cathode.
e) Ag is produced at the cathode and \( \text{Au}^{3+} \) is produced at the anode.

10. (6 pts) For the reaction, \( A \rightarrow B \), the activation energy, \( E_a = 60 \text{ kJ/mol} \), and \( \Delta E = 25 \text{ kJ/mol} \). What is the activation energy for the reverse reaction, \( B \rightarrow A \)?

a) 85 kJ/mol
b) 60 kJ/mol
c) 35 kJ/mol
d) 25 kJ/mol
e) None of these

11. (6 pts) A particular first-order reaction, \( A \rightarrow \text{Products} \), is 55.0 % complete in 70 seconds. What is the concentration \([A]\) after 80 seconds, if the initial concentration \([A]_0 = 0.10 \text{ M}\)?

a) 0.01 M
b) 0.02 M
c) 0.04 M
d) 0.05 M
e) 0.06 M
Questions 12 – 15: (3 pts each) Consider the following mechanism.

\[
\begin{align*}
H_2O_2 & \rightarrow H_2O + O \\
O + CF_2Cl_2 & \rightarrow ClO + CF_2Cl \\
ClO + O_3 & \rightarrow Cl + 2 O_2 \\
CF_2Cl + Cl & \rightarrow CF_2Cl_2
\end{align*}
\]

Given the mechanism above, identify each of the following substances as a catalyst, intermediate or neither.

12. ClO  
   a) catalyst  
   b) intermediate  
   c) neither

13. CF_2Cl  
   a) catalyst  
   b) intermediate  
   c) neither

14. O_3  
   a) catalyst  
   b) intermediate  
   c) neither

15. CF_2Cl_2  
   a) catalyst  
   b) intermediate  
   c) neither

16. (6 pts) Consider the following mechanism.

\[
\begin{align*}
2 \text{NO} & \rightleftharpoons \text{N}_2\text{O}_2 \quad \text{fast equilibrium} \\
\text{N}_2\text{O}_2 + \text{H}_2 & \rightarrow \text{N}_2\text{O} + \text{H}_2\text{O} \quad \text{slow} \\
\text{N}_2\text{O} + \text{H}_2 & \rightarrow \text{N}_2 + \text{H}_2\text{O} \quad \text{fast}
\end{align*}
\]

What is the rate law for the mechanism given above? Eliminate all intermediates from the rate law.

a) Rate = k \frac{[N_2O_2] [H_2]}{[NO]^2} 

b) Rate = k \frac{[H_2]}{[NO]} 

c) Rate = k [NO] [H_2]^2 

d) Rate = k [NO]^2 [H_2]^2 

e) Rate = k [NO]^2 [H_2] 

More Problems
17. (6 pts) Consider the decomposition of hydrogen peroxide: \( 2 \text{H}_2\text{O}_2 \rightarrow \text{O}_2 + 2 \text{H}_2\text{O} \)

The activation energy for the uncatalyzed reaction is 42. kJ/mol. When the reaction is catalyzed by the enzyme catalase, the activation energy is 7.0 kJ/mol. Calculate the temperature at which the uncatalyzed reaction proceeds as rapidly as the catalyzed reaction proceeds at 20 °C. Assume the frequency factor \( A \) is the same in both cases.

a) \( 1.2 \times 10^3 \) K  
b) \( 1.8 \times 10^3 \) K  
c) \(< 1000 \) K  
d) \( > 2000 \) K  
e) 293 K

18. (6 pts) For which of the following transitions does the light emitted have the shortest wavelength?

a) \( n = 6 \) to \( n = 4 \)  
b) \( n = 4 \) to \( n = 6 \)  
c) \( n = 6 \) to \( n = 3 \)  
d) \( n = 3 \) to \( n = 6 \)

19. (4 pts) If a beam of green light (\( \lambda = 550 \) nm) can eject electrons from a metal surface, will red light (\( \lambda = 700 \) nm) be able to eject electrons from this metal surface?

a) Yes  
b) No


Partial Credit: 4 a (2 pts) 7 a (2 pts) 18 a (2 pts) 18 d (2 pts)
FORM A

There are a total of five pages (19 questions) on the exam. Show all your work on the exam and circle the answers. You will keep the exam so you can check your answers. The answers to the exam will be posted on our course web page. Carefully check all your answers on your Scantron form. Make sure you have indicated one answer for each question. There is only one answer for each question.

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Questions 1 – 3: (3 pts each) Light is absorbed when an electron in the \( n = 1 \) level of a hydrogen atom moves into the \( n = 3 \) level. Following the absorption of light, the H-atom emits a photon and the electron moves to the \( n = 2 \) level. Which of the following statements is true? Indicate true or false.

ANSWERS are given at the end of the exam

1. The net value of the change in energy, \( \Delta E \), for the two steps is positive.
   A) true     B) false

2. The emitted light has a shorter wavelength than the absorbed light.
   A) true     B) false

3. The frequency of the absorbed light is smaller than the frequency of the emitted light
   A) true     B) false

4. (6 pts) The energy required to remove one mole of electrons from the surface of Li (s) is 280 kJ/mol. When light composed of photons with a certain energy hits the surface of Li (s), the electrons leaving the surface have a kinetic energy of 29 kJ/mol. What is the energy of a mole of the photons used to irradiate Li (s)?
   A) 251 kJ/mol
   B) Less than 251 kJ/mol
   C) 309 kJ/mol
   D) More than 309 kJ/mol
   E) None of the above

5. (6 pts) For which of the following transitions does the light absorbed have the shortest wavelength?
   A) \( n = 6 \) to \( n = 4 \)     C) \( n = 6 \) to \( n = 3 \)
   B) \( n = 4 \) to \( n = 6 \)     D) \( n = 3 \) to \( n = 6 \)
6. (4 pts each) An electron is excited from the ground state to the \( n = 3 \) state in a hydrogen atom. Is the following statement true or false? The ionization energy (the energy required to remove the electron) from the \( n = 3 \) state is less than the ionization energy from the ground state.

A) true  
B) false  

7. (6 pts) Calculate the ionization energy for ground state He\(^+\)?

A) 328 kJ/mol  
B) 1312 kJ/mol  
C) 20,992 kJ/mol  
D) 656 kJ/mol  
E) 5248 kJ/mol  

Questions 8 – 10: (6 pts each) Consider the following galvanic cell.

\[
\begin{align*}
\text{Cd}^{2+} + 2e^- &\rightarrow \text{Cd} \text{ (s)} & \text{E}^0 &= -0.40 \text{ V} \\
\text{VO}_2^+ + 2H^+ + e^- &\rightarrow \text{VO}^{2+} + \text{H}_2\text{O} & \text{E}^0 &= 1.00 \text{ V}
\end{align*}
\]

8. (6 pts) What is the oxidizing agent for the spontaneous reaction that occurs when this is used as a galvanic cell?

A) \( \text{Cd}^{2+} \)  
B) \( \text{Cd} \text{ (s)} \)  
C) \( \text{VO}_2^+ \)  
D) \( \text{VO}^{2+} \)  
E) \( H^+ \)  

9. (6 pts) What is the value of the standard cell potential for the galvanic cell?

A) +0.60 V  
B) +1.40 V  
C) -1.40 V  
D) -0.60 V  
E) +2.40 V  

10. (6 pts) If the concentration of \( \text{Cd}^{2+} \) is reduced from 1.0 M to 0.01 M, and all other concentrations remain at their standard values, what happens to the potential of the cell?

A) The cell potential increases  
B) The cell potential decreases  
C) The cell potential remains the same  
D) The cell potential will be negative  
E) None of the above
11. (6 pts) A galvanic cell is described as follows. \[ \text{Cu(s) | Cu}^{2+} (1 \text{ M}) \ || \text{Fe}^{3+} (1 \text{ M}), \text{Fe}^{2+} (1 \text{ M}) | \text{Pt} \]
Which of the following will increase the cell voltage the most?

A) halve [Cu\(^{2+}\)]
B) halve [Fe\(^{2+}\)]
C) double [Cu\(^{2+}\)]
D) double [Fe\(^{2+}\)]
E) cut the Cu electrode in half

12. (6 pts) A galvanic cell is constructed with a copper electrode in a CuSO\(_4\) (aq) solution and the lead electrode in a Pb(NO\(_3\))\(_2\) (aq) solution at 25 °C. The standard reduction potentials are:
\[
\begin{align*}
\text{Pb}^{2+} + 2 \text{e}^- & \rightarrow \text{Pb} \quad E^0 = -0.13 \text{ V} \\
\text{Cu}^{2+} + 2 \text{e}^- & \rightarrow \text{Cu} \quad E^0 = +0.34 \text{ V}
\end{align*}
\]
When sulfuric acid is added to the Pb(NO\(_3\))\(_2\)(aq) solution, a PbSO\(_4\) (s) precipitate is formed. This will cause the cell potential to

A) increase
B) decrease
C) remain unchanged
D) more information is needed to determine the effect

13. (6 pts) Consider the following mechanism.
\[
\begin{align*}
\text{H}_2\text{S} & \rightleftharpoons \text{H}^+ + \text{HS}^- \quad \text{fast equilibrium} \\
\text{Cl}_2 + \text{HS}^- & \rightarrow \text{H}^+ + 2 \text{Cl}^- + \text{S} \quad \text{slow} \\
\text{Cl}_2 + \text{H}_2\text{S} & \rightarrow 2 \text{H}^+ + 2 \text{Cl}^- + \text{S}
\end{align*}
\]
In the rate law for the mechanism given above, what is the order with respect to H\(^+\)?

A) -1
B) -2
C) 1
D) 2
E) 1/2
14. (6 pts) For the reaction $A \rightarrow \text{products}$, the reaction times for successive half-lives are observed to be 10.0 minutes, 20.0 minutes, and 30.0 minutes for an experiment in which $[A]_0 = 0.20 \text{ M}$. What is the concentration of $A$ at 60 minutes?

A) 0.3 M  
B) 0.03 M  
C) 0.003 M  
D) 0.0003 M  
E) None of the above

15. (6 pts) Experimental data for the reaction $A \rightarrow 2 \text{B} + \text{C}$ have been plotted in the following three different ways (with concentration units in mol/L).

If the initial concentration is $[A]_0 = 0.1 \text{ M}$, what is the concentration of $A$ after 10.0 seconds?

A) 0.009 M  
B) 0.09 M  
C) 0.008 M  
D) 0.006 M  
E) None of the above

16. (3 pts) The reaction for decomposition of ozone is $2 \text{O}_3 (g) \rightarrow 3 \text{O}_2 (g)$. Which of the following chemical species has been shown to be a catalyst for the decomposition of ozone?

A) Cl•    B) Ar    C) C    D) O$_3$    E) H$_2$
17. (6 pts) For the reaction \( A + B + C \rightarrow D + E \), the initial reaction rate was measured for various initial concentrations of reactants. The following data were collected:

<table>
<thead>
<tr>
<th>Trial</th>
<th>([A]_0 (M))</th>
<th>([B]_0 (M))</th>
<th>([C]_0 (M))</th>
<th>Initial Rate ((M/s))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.10</td>
<td>0.10</td>
<td>0.10</td>
<td>(3.0 \times 10^{-5})</td>
</tr>
<tr>
<td>2</td>
<td>0.10</td>
<td>0.10</td>
<td>0.30</td>
<td>(9.0 \times 10^{-5})</td>
</tr>
<tr>
<td>3</td>
<td>0.20</td>
<td>0.10</td>
<td>0.10</td>
<td>(1.2 \times 10^{-4})</td>
</tr>
<tr>
<td>4</td>
<td>0.20</td>
<td>0.20</td>
<td>0.10</td>
<td>(1.2 \times 10^{-4})</td>
</tr>
</tbody>
</table>

What is the overall order for the reaction?
A) 1
B) 2
C) 3
D) 4
E) 5

18. (6 pts) Consider the reaction the following reaction. \(2\text{NO} (g) + 2\text{H}_2 (g) \rightarrow \text{N}_2(g) + 2\text{H}_2\text{O} (g)\)

<table>
<thead>
<tr>
<th>Trial</th>
<th>([\text{NO}]_0 (M))</th>
<th>([\text{H}_2]_0 (M))</th>
<th>Initial Rate ((M/s))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.16</td>
<td>0.32</td>
<td>0.0200</td>
</tr>
<tr>
<td>2</td>
<td>0.16</td>
<td>0.48</td>
<td>0.0300</td>
</tr>
<tr>
<td>3</td>
<td>0.32</td>
<td>0.32</td>
<td>0.0800</td>
</tr>
</tbody>
</table>

What is the numerical value of the rate constant?
A) 2.4
B) 7.6
C) 0.39
D) 1.2
E) 0.13

19. (6 pts) In a common car battery, six identical cells each carry out the following reaction:

\[ \text{Pb} + \text{PbO}_2 + 2\text{HSO}_4^- + 2\text{H}^+ \rightarrow 2\text{PbSO}_4 + 2\text{H}_2\text{O} \]

Suppose that to start a car on a cold morning, 136 amperes is drawn for 16.0 seconds from such a cell. How many grams of Pb are consumed? (The atomic mass of Pb is 207.19 g/mol.)
A) 9.35 g
B) 2.34 g
C) 4.67 g
D) 0.00913 g
E) 0.428 g


**Partial Credit:** 19 C (2 pts)  11 A (3 pts)
Chem. 1B Exam 2

Test Form A

Feb. 28, 2011

Name ___________________________ Last Name ___________________________ First Name ________________ Perm # ___________________________

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Answers are given at the end of the exam.

1. (4 pts) Given the standard reduction potentials,

\[ \text{Cu}^{2+} + 2 \, \text{e}^- \rightarrow \text{Cu} \quad E^o = 0.34 \, \text{V} \]
\[ \text{IO}_3^- + 6 \, \text{H}^+ + 5 \, \text{e}^- \rightarrow \frac{1}{2} \text{I}_2 + 3 \, \text{H}_2\text{O} \quad E^o = 1.20 \, \text{V} \]

calculate the standard free energy for the following reaction.

\[ 2 \, \text{IO}_3^- + 12 \, \text{H}^+ + 5 \, \text{Cu} \rightarrow \text{I}_2 + 6 \, \text{H}_2\text{O} + 5 \, \text{Cu}^{2+} \]

A) \(-414.9 \, \text{kJ}\)
B) \(-675.4 \, \text{kJ}\)
C) \(-829.8 \, \text{kJ}\)
D) \(+675.4 \, \text{kJ}\)
E) \(+829.8 \, \text{kJ}\)

2. (4 pts) The following two half reactions take place in a galvanic cell. At standard conditions, what species are produced at each electrode?

\[ \text{Ag}^+ + \text{e}^- \rightarrow \text{Ag} \quad E^o = +0.80 \, \text{V} \]
\[ \text{Ni}^{2+} + 2 \, \text{e}^- \rightarrow \text{Ni} \quad E^o = -0.23 \, \text{V} \]

A) \(\text{Ag}^+\) is produced at the cathode and \(\text{Ni}^{2+}\) at the anode
B) \(\text{Ag}\) is produced at the cathode and \(\text{Ni}\) at the anode
C) \(\text{Ag}\) is produced at the cathode and \(\text{Ni}^{2+}\) at the anode
D) \(\text{Ag}^+\) is produced at the cathode and \(\text{Ni}\) at the anode
E) None of the above
3. (4 pts) For a reaction in a voltaic cell, both $\Delta H^\circ$ and $\Delta S^\circ$ are positive. Which of the following statements is true?
   A) $E^\circ_{cell}$ will not change with an increase in temperature.
   B) $E^\circ_{cell}$ will decrease with an increase in temperature.
   C) $E^\circ_{cell}$ will increase when the temperature increases.
   D) $\Delta G^\circ > 0$ for all temperatures.
   E) None of the above statements is true.

Questions 4 and 5: Consider the following galvanic cell.

$$
\begin{align*}
Zn^{2+} + 2 e^- & \rightarrow Zn (s) \quad E^\circ = -0.76 \text{ V} \\
VO_2^+ + 2H^+ + e^- & \rightarrow VO^{2+} + H_2O \quad E^\circ = 1.00 \text{ V}
\end{align*}
$$

**Left Side Concentrations**

$[Zn^{2+}] = 0.10 \text{ M}$

**Right Side Concentrations**

$[VO^{2+}] = 0.01 \text{ M}$

$[VO_2^+] = 2.0 \text{ M}$

$[H^+] = 0.50 \text{ M}$

4. (4 pts) What is the reducing agent for the spontaneous reaction that occurs when this is used as a galvanic cell?
   A) $Zn^{2+}$
   B) $VO_2^+$
   C) $H^+$
   D) $Zn (s)$
   E) $VO^{2+}$

5. (6 pts) What is the value of the cell potential, $E$, at $25 ^\circ C$, given the concentrations indicated above?
   A) 1.78 V
   B) 1.76 V
   C) 1.85 V
   D) 1.89 V
   E) 1.63 V
6. (6 pts) Nickel is electroplated from a NiSO₄ solution. A constant current of 5.00 A is applied by an external power supply. How long will it take to deposit 100 g of Ni metal? The atomic mass of Ni is 58.69 g/mol.

A) 18.3 hours  
B) 1.20 hours  
C) 63.1 minutes  
D) 56.7 seconds  
E) 9.1 hours

7. (6 pts) The following reaction was studied at 0°C by the method of initial rates:

\[ \text{H}_2\text{SeO}_3(aq) + 6\Gamma(aq) + 4\text{H}^+(aq) \rightarrow 2\text{I}_3^-(aq) + 3\text{H}_2\text{O}(l) + \text{Se(s)} \]

<table>
<thead>
<tr>
<th>[H₂SeO₃]₀</th>
<th>[H⁺]₀</th>
<th>[Γ]₀</th>
<th>Rate (mol/L • s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 × 10⁻⁴</td>
<td>2.0 × 10⁻²</td>
<td>2.0 × 10⁻²</td>
<td>1.66 × 10⁻⁷</td>
</tr>
<tr>
<td>2.0 × 10⁻⁴</td>
<td>2.0 × 10⁻²</td>
<td>2.0 × 10⁻²</td>
<td>3.33 × 10⁻⁷</td>
</tr>
<tr>
<td>3.0 × 10⁻⁴</td>
<td>2.0 × 10⁻²</td>
<td>2.0 × 10⁻²</td>
<td>4.99 × 10⁻⁷</td>
</tr>
<tr>
<td>1.0 × 10⁻⁴</td>
<td>4.0 × 10⁻²</td>
<td>2.0 × 10⁻²</td>
<td>6.66 × 10⁻⁷</td>
</tr>
<tr>
<td>1.0 × 10⁻⁴</td>
<td>1.0 × 10⁻²</td>
<td>2.0 × 10⁻²</td>
<td>0.42 × 10⁻⁷</td>
</tr>
<tr>
<td>1.0 × 10⁻⁴</td>
<td>2.0 × 10⁻²</td>
<td>4.0 × 10⁻²</td>
<td>13.4 × 10⁻⁷</td>
</tr>
<tr>
<td>1.0 × 10⁻⁴</td>
<td>1.0 × 10⁻²</td>
<td>4.0 × 10⁻²</td>
<td>3.36 × 10⁻⁷</td>
</tr>
</tbody>
</table>

What is the rate law?

A) Rate = k [H₂SeO₃] [H⁺] [Γ]  
B) Rate = k [H₂SeO₃] [H⁺]² [Γ]  
C) Rate = k [H₂SeO₃] [H⁺] [Γ]²  
D) Rate = k [H₂SeO₃]² [H⁺] [Γ]  
E) Rate = k [H₂SeO₃] [H⁺]² [Γ]³

8. (6 pts) At a particular temperature, N₂O₅ decomposes according to a first-order rate law with a half-life of 3.0 s. If the initial concentration of N₂O₅ is 1.0 × 10¹⁶ molecules/cm³, what will be the concentration in molecules/cm³ after 10.0 s?

A) 9.9 × 10¹⁴  
B) 1.8 × 10¹²  
C) 7.3 × 10⁹  
D) 6.3 × 10³  
E) 9.4 × 10²
9. (6 pts) A first-order reaction is 43\% complete at the end of 18 min. What is the value of the rate constant?

A) \(3.1 \times 10^{-2}\) min\(^{-1}\)
B) \(0.21\) min\(^{-1}\)
C) \(0.031\) min\(^{-1}\)
D) \(4.7 \times 10^{-2}\) min\(^{-1}\)
E) \(1.4 \times 10^{-2}\) min\(^{-1}\)

10. (6 pts) Consider the following reaction. \(2\text{N}_2\text{O}_5(g) \rightarrow \text{O}_2(g) + 4\text{NO}_2(g)\)

The reaction is first order in \(\text{N}_2\text{O}_5\). For this reaction at 45° C, the rate constant \(k = 1.0 \times 10^{-5}\) s\(^{-1}\), where the rate law is defined as

\[
\text{Rate} = -\frac{\Delta [\text{N}_2\text{O}_5]}{\Delta t} = k[\text{N}_2\text{O}_5]
\]

For a particular experiment, \([\text{N}_2\text{O}_5]_0 = 1.0 \times 10^{-3}\) M, calculate \([\text{N}_2\text{O}_5]\) after \(1.0 \times 10^5\) s.

A) \(5.0 \times 10^{-4}\) M
B) \(1.0 \times 10^{-3}\) M
C) \(3.7 \times 10^{-4}\) M
D) \(1.0 \times 10^{-5}\) M
E) 0

11. (6 pts) The mechanism for a chemical reaction includes the following elementary reactions:

\[
\begin{align*}
\text{N}_2\text{O}_5 & \iff \text{NO}_2 + \text{NO}_3 \quad \text{fast} \\
\text{NO}_3 & \rightarrow \text{NO}_2 + \text{NO} \quad \text{slow}
\end{align*}
\]

According to this rate law, what is the rate law?

A) Rate = \(k [\text{N}_2\text{O}_5]\)
B) Rate = \(k [\text{NO}_3]\)
C) Rate = \(k [\text{N}_2\text{O}_5] / [\text{NO}_2]\)
D) Rate = \(k [\text{NO}_3] / [\text{NO}_2]\)
E) Rate = \(k [\text{NO}_3]^2\)
12. (6 pts) For the reaction, A → B, the activation energy, $E_a = 65$ kJ/mol, and $\Delta E = 15$ kJ/mol. What is the activation energy for the reverse reaction, B → A?

A) 80 kJ/mol  
B) 40 kJ/mol  
C) 15 kJ/mol  
D) 50 kJ/mol  
E) 65 kJ/mol

13. (6 pts) The activation energy for the reaction $H_2(g) + I_2(g) \rightarrow 2HI(g)$ is changed from 184 kJ/mol to 59.0 kJ/mol at 600 K by the introduction of a Pt catalyst. Calculate the value of the ratio rate(catalyzed)/rate(uncatalyzed).

A) 1.00  
B) $7.62 \times 10^0$  
C) 1.38  
D) 0.321  
E) $1.31 \times 10^{-11}$

14. (6 pts) For which of the following transitions does the light emitted have the shortest wavelength?

A) $n = 5$ to $n = 2$  
B) $n = 2$ to $n = 5$  
C) $n = 5$ to $n = 3$  
D) $n = 3$ to $n = 5$

15. (6 pts) Light has a wavelength of 600 nm. What is the energy of a photon of this light? $1 \text{nm} = 1 \times 10^{-9} \text{m}$

A) $1.10 \times 10^{-19} \text{J}$  
B) $3.31 \times 10^{-19} \text{J}$  
C) $2.71 \times 10^{13} \text{J}$  
D) $3.68 \times 10^{-20} \text{J}$  
E) $1.33 \times 10^{-18} \text{J}$
Questions 16 – 19: (3 pts each) Indicate true or false for each of the following statements.

16. An electron is excited from the ground state to the \( n = 3 \) state in a hydrogen atom. The electron in the \( n = 3 \) state can return to its ground state by absorbing electromagnetic radiation.
   A) True     B) False

17. It takes more energy to ionize (remove) the electron from the \( n = 3 \) state of the hydrogen atom than from the ground state.
   A) True     B) False

18. The wavelength of light emitted for an electronic transition from \( n = 3 \) to \( n = 2 \) is shorter than the wavelength of light emitted for an electronic transition from \( n = 3 \) to \( n = 1 \).
   A) True     B) False

19. A photon of visible light (wavelength \( \approx 400 \text{ nm} \) to \( 700 \text{ nm} \)), has sufficient energy to excite an electron in a hydrogen atom to make the transition from \( n = 1 \) to \( n = 5 \)?
   A) True     B) False

20. (6 pts) The energy required to remove one mole of electrons from the surface of rubidium metal, \( \text{Ru (s)} \), is 208.4 \( \text{kJ/mol} \). If rubidium metal is irradiated with 254-nm light, what is the maximum kinetic energy the released electrons can have? \( 1\text{nm} = 1 \times 10^{-9} \text{m} \)
   A) \( 7.82 \times 10^{-19} \text{J} \)
   B) \( 1.13 \times 10^{-18} \text{J} \)
   C) \( 4.36 \times 10^{-19} \text{J} \)
   D) \( 3.46 \times 10^{-19} \text{J} \)
   E) None of the above


Partial Credit:  1 E (2 pts)  5 E (3 pts)
Chem. 1B Exam 2  
Test Form A  
First letter of your last name:  

March 5, 2012  

Name ___________________________________________  
Last Name  
First Name  
Perm # ___________________________________________  

There are a total of six pages (20 questions) on the exam. Each question is worth 5 points. Show all your work on the exam and circle the answers. You will keep the exam so you can check your answers. The answers to the exam will be posted on our course web page.

SCANTRON FORM:  
1) Write your name  
2) Bubble in FORM A  
3) Bubble in your PERM number (7 digits only, no extra numbers)

INFORMATION PAGE: Remove the information page. No other notes or books are allowed.

INSTRUCTIONS: No hats or hoods allowed. No sharing of calculators. Cell Phones, iPods, headsets, and any other electronic devices must be turned off and put away. REMAIN SEATED until 9:50 AM

It is to your benefit to show your work. Answers are given at the end of the exam.

Questions 1–3: Indicate true or false for each of the following statements.

1. The greater the frequency of the electromagnetic radiation, the greater the energy of the radiation.
   A) True  
   B) False

2. Visible light has a longer wavelength than ultraviolet light.
   A) True  
   B) False

3. In a vacuum, the speed of X-rays is faster than visible light rays.
   A) True  
   B) False

4. In the hydrogen spectrum, what is the wavelength of light associated with the $n = 2$ to $n = 1$ electron transition?
   $1 \text{ nm} = 1 \times 10^{-9} \text{ m}$
   A) $1.10 \text{ nm}$
   B) $365 \text{ nm}$
   C) $1.10 \times 10^{-11} \text{ m}$
   D) $9.12 \times 10^{-8} \text{ m}$
   E) $1.22 \times 10^{-7} \text{ m}$
Questions 5 – 8: Consider the following galvanic cell at 25 °C.

**Left Side Concentrations**
- \([\text{Mn}^{2+}] = 0.20 \text{ M}\)
- \([\text{MnO}_4^{-}] = 0.10 \text{ M}\)
- \([\text{H}^+] = 1.0 \text{ M}\)

**Right Side Concentrations**
- \([\text{Cr}^{3+}] = 0.40 \text{ M}\)
- \([\text{Cr}_2\text{O}_7^{2-}] = 0.30 \text{ M}\)
- \([\text{H}^+] = 1.0 \text{ M}\)

The standard reduction potentials are as follows:

\[
\begin{align*}
\text{MnO}_4^{-} + 8\text{H}^+ + 5\text{e}^- & \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O} & E^\circ = 1.51 \text{ V} \\
\text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ + 6\text{e}^- & \rightarrow 2 \text{Cr}^{3+} + 7\text{H}_2\text{O} & E^\circ = 1.33 \text{ V}
\end{align*}
\]

5. When current is allowed to flow, which species is oxidized?
A) \(\text{Cr}_2\text{O}_7^{2-}\)
B) \(\text{Cr}^{3+}\)
C) \(\text{MnO}_4^{-}\)
D) \(\text{Mn}^{2+}\)
E) \(\text{H}^+\)

6. When current is allowed to flow, which species is reduced?
A) \(\text{Cr}_2\text{O}_7^{2-}\)
B) \(\text{Cr}^{3+}\)
C) \(\text{MnO}_4^{-}\)
D) \(\text{Mn}^{2+}\)
E) \(\text{H}^+\)

7. What is the value of the cell potential, \(E\), at 25 °C, given the concentrations indicated?
\([\text{Mn}^{2+}] = 0.20 \text{ M}, \ [\text{MnO}_4^{-}] = 0.10 \text{ M}, \ [\text{H}^+] = 1.0 \text{ M}, \ [\text{Cr}^{3+}] = 0.40 \text{ M}, \ [\text{Cr}_2\text{O}_7^{2-}] = 0.30 \text{ M}\)

A) 0.174 V
B) 0.186 V
C) 0.143 V
D) 0.180 V
E) 0.149 V

8. In which direction do electrons flow in the external circuit?
A) left to right
B) right to left
C) No current flows; the cell is at equilibrium.
9. A concentration cell is constructed using two Ni electrodes with Ni$^{2+}$ concentrations of 1.64 M and 2.85 x 10$^{-4}$ M in the two half-cells.

Given the standard reduction potential: \[ \text{Ni}^{2+} + 2e^- \rightarrow \text{Ni} \quad \text{E}^o = -0.23 \text{ V} \]

Calculate the cell potential, E, at 25°C.

A) +0.341 V  
B) -0.222 V  
C) -0.256 V  
D) +0.111 V  
E) -0.0078 V

10. Copper is electroplated from an aqueous CuSO$_4$ solution. A constant current of 5.10 amps is applied by an external power supply. How long will it take to deposit 408. g of Cu? The atomic mass of copper is 63.546 g/mol.

A) 67.5 hr  
B) 33.7 hr  
C) 2.44 hr  
D) 135.0 hr  
E) 101.2 hr

11. Nitrogen monoxide can react with hydrogen gas to form water and nitrogen gas through the following overall reaction:

\[ 2 \text{H}_2 (g) + 2\text{NO}(g) \rightarrow 2 \text{H}_2\text{O}(g) + \text{N}_2 (g) \]

The following mechanism has been proposed for this reaction:

- $2\text{NO} \rightleftharpoons \text{N}_2\text{O}_2$ \hspace{1cm} fast equilibrium
- $\text{H}_2 + \text{N}_2\text{O}_2 \rightarrow \text{H}_2\text{O} + \text{N}_2\text{O}$ \hspace{1cm} slow
- $\text{N}_2\text{O} + \text{H}_2 \rightarrow \text{N}_2 + \text{H}_2\text{O}$ \hspace{1cm} fast

Derive a rate law for this reaction that is consistent with this mechanism.

A) rate = k [H$_2$] / [NO]$^2$  
B) rate = k [H$_2$]$^2$ [NO]  
C) rate = k [H$_2$]$^2$ [NO]$^2$  
D) rate = k [H$_2$] [NO]  
E) rate = k [H$_2$] [NO]$^2$
12. The mechanism for a reaction consists of the following two steps.

\[
\begin{align*}
\text{NO}_2 + \text{NO}_2 & \rightarrow \text{NO}_3 + \text{NO} \\
\text{NO}_3 + \text{CO} & \rightarrow \text{NO}_2 + \text{CO}_2
\end{align*}
\]

For this mechanism, which of the following statements is true?
A) \(\text{NO}_2\) is an intermediate
B) \(\text{NO}_2\) is a catalyst
C) \(\text{NO}_3\) is an intermediate
D) \(\text{NO}_3\) is a catalyst
E) Both (b) and (c) are true

**Questions 13 – 15:** Consider the following reaction in which HCl adds across the double bond of ethylene:

\[\text{HCl} + \text{H}_2\text{C}═\text{CH}_2 \rightarrow \text{H}_3\text{C}-\text{CH}_2\text{Cl}\]

The following mechanism, with the energy diagram shown below, has been suggested for this reaction:

- **Step 1** \(\text{HCl} + \text{H}_2\text{C}═\text{CH}_2 \rightarrow \text{H}_3\text{C}-\text{CH}_2^+ + \text{Cl}^-\)
- **Step 2** \(\text{H}_3\text{C}-\text{CH}_2^+ + \text{Cl}^- \rightarrow \text{H}_3\text{C}-\text{CH}_2\text{Cl}\)

13. Based on the potential energy diagram above, which step is rate limiting?
A) First Step
B) Second Step
C) More information is needed to answer this question.

14. What is the expected overall order of the reaction based on the proposed mechanism?
A) First order
B) Second order
C) Third order
D) More information is needed to answer this question.

15. How many transition states occur during this reaction?
A) 1
B) 2
C) 3
D) 4
E) 5
16. Consider the following reaction: \( 2 \text{NOBr} \rightarrow 2 \text{NO} + \text{Br}_2 \)

The rate law for this reaction is: \( \text{Rate} = - \frac{d[\text{NOBr}]}{dt} = k [\text{NOBr}]^2 \) where \( k = 1.00 \times 10^{-3} \text{ M}^{-1} \cdot \text{s}^{-1} \) at 25° C.

This reaction is run where the initial concentration of \([\text{NOBr}]_0 = 0.100 \text{ M}\).

Calculate the concentration of NO after 1.00 hour has passed.

A) 0.0529 M  
B) 0.0735 M  
C) 0.0306 M  
D) 0.0265 M  
E) none of these

**Questions 17–18:** A general reaction written as \(2 \text{A} + 2 \text{B} \rightarrow \text{C} + 2 \text{D}\) is studied and yields the following data.

<table>
<thead>
<tr>
<th>[A]₀</th>
<th>[B]₀</th>
<th>Initial rate ( \frac{d[\text{C}]}{dt} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.100 M</td>
<td>0.100 M</td>
<td>(4.00 \times 10^{-5}) mol/L • s</td>
</tr>
<tr>
<td>0.200 M</td>
<td>0.100 M</td>
<td>(4.00 \times 10^{-5}) mol/L • s</td>
</tr>
<tr>
<td>0.100 M</td>
<td>0.200 M</td>
<td>(8.00 \times 10^{-5}) mol/L • s</td>
</tr>
</tbody>
</table>

17. What is the overall order of the reaction?

A) 3  
B) 4  
C) 1  
D) 2  
E) 0

18. What are the proper units for the rate constant for the reaction?

A) \(\text{s}^{-1}\)  
B) \(\text{mol L}^{-1} \text{s}^{-1}\)  
C) \(\text{L mol}^{-1} \text{s}^{-1}\)  
D) \(\text{L}^2 \text{mol}^{-3} \text{s}^{-1}\)  
E) \(\text{L}^2 \text{mol}^{-2} \text{s}^{-1}\)
19. The reaction \(2\text{NO}_2 \rightarrow 2\text{NO} + \text{O}_2\) obeys the rate law
\[
\frac{d[\text{O}_2]}{dt} = 1.40 \times 10^{-2} \text{ M}^{-1} \text{s}^{-1} \ [\text{NO}_2]^2 \quad \text{at} \quad 500^\circ \text{K}
\]
If the initial concentration of \(\text{NO}_2\) is 1.00 \(M\), how long will it take for the \([\text{NO}_2]\) to decrease to 25.0\% of its initial value?
A) 49.5 s  
B) 71.4 s  
C) 214 s  
D) \(1.40 \times 10^{-2}\) s  
E) cannot be determined from these data

20. Consider the second-order reaction \(a\text{A} \rightarrow \text{products}\) (which has a first half-life of 22 s). If the concentration of \(\text{A}\) after 13.4 seconds is 0.46 \(M\), determine the initial concentration of \(\text{A}\).

A) 0.69 \(M\)  
B) 0.18 \(M\)  
C) 0.36 \(M\)  
D) 0.26 \(M\)  
E) 0.74 \(M\)


* Question 18, full credit (5 Pts) for any answer (because this answer depends on your answer to question 17).

**Partial Credit:** 7B (3 pts)  9A (2 pts)  10 B (2 pts)  12 E (2 pts)  16 B (2 pts)
Before doing anything, fill in the following on your ParSCORE form:

1) Write your name
2) Bubble in FORM A
3) Bubble in your PERM number (7 digits only—no extra numbers)

Instructions: No hats or hoods allowed. No books or notes allowed. No sharing of calculators. Cell phones, iPods, headsets/headphones, and any other electronic devices must be turned off and put away.

There are a total of 7 pages (18 questions) on the exam. Not every question is worth the same number of points—point values are indicated for each question. You may work out the problems and write your answers on this exam; however, you must completely fill in the appropriate bubble(s) on your ParSCORE form. When you are finished, turn in the ParSCORE form ONLY. You may keep your exam. The answers to the exam will be posted on our course web page.

1. (5 pts) Consider the following reaction: \( \text{N}_2\text{O}_4 \rightarrow 2 \text{NO}_2 \)
   A plot of \(1/\text{[N}_2\text{O}_4]\) versus time yielded a straight line. What is the rate law for this reaction?
   a) rate = \(k[\text{N}_2\text{O}_4]\)
   b) rate = \(k\)
   c) rate = \(k[\text{N}_2\text{O}_4]^{-1}\)
   d) rate = \(k[\text{N}_2\text{O}_4]^2\)
   e) none of these

2. (5 pts) A carbon atom and a \(\text{CO}_2\) molecule are traveling at the same velocity. Which has the smaller de Broglie wavelength?
   a) \(\text{C}\)
   b) \(\text{CO}_2\)
   c) Both have the same de Broglie wavelength

3. (5 pts) How many electrons are transferred in the following reaction? \(\text{N}_2 + \text{O}_2 \rightarrow \text{N}_2\text{O}_2\)
   a) 16
   b) 6
   c) 4
   d) 2
   e) 8
4. (5 pts) An electrochemical cell is described by the following line notation: \( \text{Al} | \text{Al}^{3+} | \text{Zn}^{2+} | \text{Zn} \)
   into which half-cell do electrons flow?
   a) Into the half-cell containing Zn and Zn\(^{2+}\)
   b) Into the half-cell containing Al and Al\(^{3+}\)

5. (5 pts) Consider the reaction \( 2 \text{Cu}^{+} + \text{Cd} \rightarrow \text{Cd}^{2+} + 2 \text{Cu} \)
   Which of the following will decrease the cell potential by the largest amount?
   a) Double \([\text{Cu}^{+}]\)
   b) Double \([\text{Cd}^{2+}]\)
   c) Halve \([\text{Cd}^{2+}]\)
   d) Halve \([\text{Cu}^{+}]\)
   e) More than one of these will decrease cell potential by the largest amount

6. (5 pts) Which of the following mechanisms contains a catalyst?
   a) \( \text{A} + \text{B} \rightarrow \text{C} \) (slow)
      \( \text{B} + \text{C} \rightarrow \text{D} \) (fast)
   b) \( \text{A} + \text{B} \rightleftharpoons \text{C} \) (fast)
      \( \text{A} + \text{C} \rightarrow \text{D} \) (slow)
   c) \( \text{A} + 2\text{B} \rightleftharpoons \text{C} \) (fast)
      \( \text{C} + \text{D} \rightarrow \text{E} + \text{B} \) (slow)
   d) more than one of these contains a catalyst
   e) none of these contains a catalyst
7. (5 pts) Light is absorbed when an electron in the n=1 level of the hydrogen atom moves to the n=3 level. Following the absorption of light, the H-atom emits a photon and the electron moves to the n=2 level. The emitted light has ______________ wavelength than the absorbed light.

a) longer
b) shorter
c) the same

Questions 8-9. Consider the following information:

\[
E^\circ (V) \\
\begin{align*}
    \text{Au}^{3+} + 3 \text{e}^- & \rightarrow \text{Au} & 1.50 \\
    \text{Ag}^{+} + \text{e}^- & \rightarrow \text{Ag} & 0.80 \\
    \text{I}_2 + 2 \text{e}^- & \rightarrow 2 \text{I}^- & 0.53 \\
    \text{Cu}^{2+} + 2 \text{e}^- & \rightarrow \text{Cu} & 0.34 \\
    \text{Pb}^{2+} + 2 \text{e}^- & \rightarrow \text{Pb} & -0.13 \\
    \text{Zn}^{2+} + 2 \text{e}^- & \rightarrow \text{Zn} & -0.76
\end{align*}
\]

8. (5 pts) Use the information above to determine which of the following statements is true.

a) Ag is capable of reducing I\(_2\) to I\(^-\) but not capable of reducing Au\(^{3+}\) to Au
b) Ag is capable of both reducing Au\(^{3+}\) to Au and reducing I\(_2\) to I\(^-\)
c) Ag is capable of reducing Au\(^{3+}\) to Au but not capable of reducing I\(_2\) to I\(^-\)
d) None of these statements is true

9. (6 pts) Use the information above to answer the following question: At 298K, a Galvanic cell is constructed using a Cu (s) electrode immersed in a 0.16 M solution of Cu\(^{2+}\) and an Au (s) electrode immersed in a 1.3 M solution of Au\(^{3+}\). Calculate \(\Delta G\) for the reaction under these conditions.

a) \(-672\) kJ
b) \(-686\) kJ
c) \(-677\) kJ
d) \(-657\) kJ
e) \(-698\) kJ
10. (5 pts) Determine the overall order for the reaction occurring via the following mechanism:

\[ \text{N}_2\text{O}_5 \rightleftharpoons \text{NO}_2 + \text{NO}_3 \quad \text{fast} \]
\[ 2 \text{NO}_3 \rightarrow \text{NO}_2 + \text{NO} \quad \text{slow} \]

a) 1
b) 1/2
c) 1
d) 2
e) 0

11. (6 pts) Consider the following reaction: \[ \text{A} \rightarrow \text{B} \quad \Delta E = -53 \text{ kJ/mol} \]

If the activation energy of the forward reaction is 34 kJ/mol, what is the activation energy for the reverse reaction?

a) −19 kJ/mol
b) 34 kJ/mol
c) −87 kJ/mol
d) 87 kJ/mol
e) 19 kJ/mol

12. (6 pts) The minimum frequency of light capable of removing electrons from a particular metal surface is \(7.4 \times 10^{14} \text{ s}^{-1}\).

Is light with a wavelength of 432 nm capable of removing electrons from the same metal surface?

a) Yes
b) No
13. (6 pts) The kinetics of the following reaction were studied: \[ 2 \text{A} + 2 \text{B} \rightarrow \text{C} + 2 \text{D} \]

The following data were collected:

<table>
<thead>
<tr>
<th>Exp.</th>
<th>[A] (M)</th>
<th>[B] (M)</th>
<th>Initial Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.100</td>
<td>0.100</td>
<td>4.00 \times 10^{-5}</td>
</tr>
<tr>
<td>2</td>
<td>0.200</td>
<td>0.100</td>
<td>4.00 \times 10^{-5}</td>
</tr>
<tr>
<td>3</td>
<td>0.100</td>
<td>0.200</td>
<td>8.00 \times 10^{-5}</td>
</tr>
</tbody>
</table>

What are the units of the rate constant (k) for this reaction?

a) M s^{-2}
b) M^{-1} s^{-1}
c) s^{-1}
d) M^{-2} s^{-1}
e) M^{-2} s^{-1}

14. (6 pts) For the first-order reaction \[ \text{A} \rightarrow \text{B} \]

The half-life is 31 s. How long will it take for [A] to be depleted to 44% of its initial value?

a) 37 s
b) 26 s
c) 18 s
d) 11 s
e) The initial concentration of A must be known
15. (6 pts) The ground-state ionization energy of the one-electron ion $X^{m+}$ is $3.28 \times 10^6$ kJ/mol. What is the value of “m” in $X^{m+}$?

a) 6  
b) 1  
c) 5  
d) 3  
e) 4

16. (6 pts) An aqueous solution of Cr$^{x+}$, where X is unknown, is electrolyzed to plate out solid Cr. If 36.4 grams of solid Cr is plated out using a constant current of 37 A for 122 minutes, what is the value of X?

a) 1  
b) 2  
c) 3  
d) 4  
e) 6

2 more questions on the last page --->
17. (6 pts) Ozone (O₃) absorbs ultraviolet light from the sun, causing the following reaction to occur:

\[ \text{O}_3 + \text{light} \rightarrow \text{O}_2 + \text{O} \]

If the ΔE for this reaction is 445 kJ/mol, then what is the maximum wavelength of light that will allow this reaction to occur?

a) 2.69x10⁻⁷ m
b) 4.47x10⁻³¹ m
c) 4.47x10⁻²⁸ m
d) 6.74x10⁻⁷ m
e) 9.67x10⁻⁸ m

18. (6 pts) The half life for a first order reaction is 40 sec at 273K and 18 sec at 298K. What is the activation energy for the reaction in kJ/mol?

a) −22 kJ/mol
b) 32 kJ/mol
c) 22 kJ/mol
d) −32 kJ/mol
e) 43 kJ/mol

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There are a total of 7 pages (18 questions) on the exam. Not every question is worth the same number of points—point values are indicated for each question. You may work out the problems and write your answers on this exam; however, you must completely fill in the appropriate bubble(s) on your ParSCORE form. When you are finished, turn in the ParSCORE form ONLY. You may keep your exam. The answers to the exam will be posted on our course web page.

1. (5 pts) To ionize Li\(^{2+}\) from the ground state, one must use photons with \__________\ wavelength than those required to ionize He\(^+\) from the ground state.
   a) shorter
   b) longer
   c) the same

2. (5 pts) In a vacuum, which of the following photons travels at the greatest speed?
   a) Red (\(\lambda = 700\) nm)
   b) Green (\(\lambda = 500\) nm)
   c) Both photons travel at the same speed

3. (5 pts) Consider the reaction \(A \rightarrow B\)
   The activation energy of the forward reaction \(A \rightarrow B\) is 35 kJ/mol
   The activation energy of the reverse reaction \(B \rightarrow A\) is 65 kJ/mol
   The reaction \(A \rightarrow B\) is \__________\n   a) Exothermic
   b) Endothermic
   c) Neither exothermic nor endothermic
4. (5 pts) Which of the following will a catalyst affect?

a) The reaction mechanism
b) The ΔH of the reaction
c) The rate of reaction
d) Only (a) and (c) will be affected by a catalyst
e) (a), (b), and (c) will be affected by a catalyst

Questions 5-6. Consider the following information:

<table>
<thead>
<tr>
<th>Reaction</th>
<th>ΔE° (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl₂ + 2 e⁻ → 2 Cl⁻</td>
<td>1.36</td>
</tr>
<tr>
<td>Br₂ + 2 e⁻ → 2 Br⁻</td>
<td>1.09</td>
</tr>
<tr>
<td>Ag⁺ + e⁻ → Ag</td>
<td>0.80</td>
</tr>
<tr>
<td>Cd²⁺ + 2 e⁻ → Cd</td>
<td>-0.40</td>
</tr>
<tr>
<td>Cr³⁺ + 3 e⁻ → Cr</td>
<td>-0.73</td>
</tr>
<tr>
<td>Al³⁺ + 3 e⁻ → Al</td>
<td>-1.66</td>
</tr>
</tbody>
</table>

5. (5 pts) Use the information above to determine which of the following is capable of oxidizing Cr but not Br⁻?

a) Cd
b) Cl₂
c) Ag⁺
d) Al³⁺
e) More than one of these

6. (5 pts) Use the information above to answer the following question: At 298K, a Galvanic cell is constructed using a Cd (s) electrode immersed in a 1.0 M solution of Cd²⁺ and an Al (s) electrode immersed in a 1.0 M solution of Al³⁺. Predict the change in cell potential if NaOH is added to the half-cell containing Al and Al³⁺, causing solid Al(OH)₃ to precipitate out.

a) cell potential will decrease
b) cell potential will increase
c) cell potential will not change
7. (5 pts) How many electrons are transferred in the following reaction? \[ \text{N}_2 + 2 \text{O}_2 \rightarrow 2 \text{NO}_2 \]

a) 4  
b) 6  
c) 2  
d) 16  
e) 8

8. (5 pts) A concentration cell is constructed using an Ag (s) electrode immersed in a 1.0 M Ag⁺ solution and an Ag (s) electrode immersed in a 2.0 M Ag⁺ solution. A KNO₃ salt bridge is used. Into which half-cell do NO₃⁻ ions flow?

a) Into the half-cell containing 1.0 M Ag⁺  
b) Into the half-cell containing 2.0 M Ag⁺

9. (5 pts) A reaction is believed to proceed by the following mechanism:

\[
\begin{align*}
\text{N}_2\text{O}_5 & \rightleftharpoons \text{NO}_2 + \text{NO}_3 & \text{fast} \\
\text{NO}_3 & \rightarrow \text{NO}_2 + \text{NO} & \text{slow}
\end{align*}
\]

According to this mechanism, what is the rate law?

a) rate = k [N₂O₅]  
b) rate = k [NO₃]  
c) rate = k [NO₃][NO₂]⁻¹  
d) rate = k [N₂O₅][NO₂]⁻¹  
e) rate = k [NO₃]²
10. (6 pts) A solution of Cu$^{2+}$ is electrolyzed to plate out solid Cu (molar mass = 63.55 g/mol). If 11 grams of solid Cu was plated out in 15 minutes, how many amps of current were used? Note 1 minute = 60 seconds.

a) 19 A  
b) 2227 A  
c) 37 A  
d) 74 A  
e) 9.3 A

11. (6 pts) The kinetics of the following reaction were studied: A $\rightarrow$ B

A plot of 1/[A] versus time yielded a straight line described by the equation y = 0.035*x + 1.29. Calculate the first half life for this reaction.

a) 0.035 sec  
b) 19.8 sec  
c) 0.014 sec  
d) 18.4 sec  
e) 36.9 sec

12. (6 pts) At what velocity will a sulfur atom have the same de Broglie wavelength as a helium atom traveling at 50 m/s?

a) 0.0062 m/s  
b) 0.40 m/s  
c) 400 m/s  
d) 0.16 m/s  
e) 6.2 m/s
13. (6 pts) The kinetics of the following reaction were studied: \[ 2 \text{A} + 2 \text{B} \rightarrow \text{C} + 2 \text{D} \]

The following data were collected:

<table>
<thead>
<tr>
<th>Exp.</th>
<th>[A] (M)</th>
<th>[B] (M)</th>
<th>Initial Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.100</td>
<td>0.100</td>
<td>4.00 \times 10^{-5}</td>
</tr>
<tr>
<td>2</td>
<td>0.200</td>
<td>0.100</td>
<td>4.00 \times 10^{-5}</td>
</tr>
<tr>
<td>3</td>
<td>0.100</td>
<td>0.200</td>
<td>8.00 \times 10^{-5}</td>
</tr>
</tbody>
</table>

Determine the initial rate when [A] = 0.380 M and [B] = 0.620 M

a) 9.40 \times 10^{-5}
b) 2.48 \times 10^{-4}
c) 1.54 \times 10^{-4}
d) 2.20 \times 10^{-5}
e) 2.22 \times 10^{-2}

14. (6 pts) The energy required to remove electrons from the surface of a metal is 275 kJ/mol. When the metal is irradiated with a light source, each ejected electron has a kinetic energy of 4.8 \times 10^{-19} J. What is the wavelength of light used for this experiment?

a) 8.5 \times 10^{-6} \text{ m}
b) 4.1 \times 10^{-7} \text{ m}
c) 1.2 \times 10^{-7} \text{ m}
d) 2.1 \times 10^{-7} \text{ m}
e) 7.2 \times 10^{-31} \text{ m}
15. (6 pts) At 298K, the rate constant for a reaction is increased to 11 times its value when a catalyst is added. If the activation energy for the uncatalyzed reaction is 44 kJ/mol, then what is the activation energy for the catalyzed reaction? Assume that the pre-exponential factor (A) is the same for the catalyzed and uncatalyzed reactions.

a) 44 kJ/mol  
b) 38 kJ/mol  
c) 50 kJ/mol  
d) 26 kJ/mol  
e) 31 kJ/mol

16. (6 pts) Consider a first-order reaction \[ \text{A} \rightarrow \text{Products} \]
The initial concentration of A is \([A_0]\). After 56 seconds, 85% of \([A_0]\) remains. At what time will 22% of \([A_0]\) remain?

a) 291 s  
b) 522 s  
c) 7.3 s  
d) 39 s  
e) 887 s

2 more questions on the last page ---
17. (6 pts) When an electron in the one-electron ion $X^{m+}$ transitions from $n=7$ to $n=3$, an emission line is observed at 27.9 nm. What is the value of “m” in $X^{m+}$?

a) 36
b) 35
c) 5
d) 6
e) 1

18. (6 pts) Consider the following reaction at 298K: $\text{PbS (s)} \rightleftharpoons \text{Pb}^{2+} + \text{S}^{2-}$ $K = 8.0 \times 10^{-28}$

Using this information, determine the standard reduction potential for the following reaction:

$\text{PbS (s)} + 2 \text{e}^- \rightarrow \text{Pb} (s) + \text{S}^{2-}$ $E^0 = ???$

Note: You may find the following standard reduction potential useful:

$\text{Pb}^{2+} + 2 \text{e}^- \rightarrow \text{Pb} (s)$ $E^0 = -0.13 \text{ V}$

a) $-0.80 \text{ V}$
b) $-0.67 \text{ V}$
c) $0.67 \text{ V}$
d) $-0.93 \text{ V}$
e) $0.48 \text{ V}$
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There are a total of 6 pages (18 questions) on the exam. Not every question is worth the same number of points—point values are indicated for each question. You may work out the problems and write your answers on this exam; however, you must completely fill in the appropriate bubble(s) on your ParSCORE form. When you are finished, turn in the ParSCORE form ONLY. You may keep your exam. The answers to the exam will be posted on our course web page.

1. (6 pts) Consider the reaction  \( \text{A} \rightarrow \text{B} \). For this reaction, \( \Delta E = -52 \text{ kJ/mol} \) and \( E_a = 24 \text{ kJ/mol} \). Calculate the activation energy \( (E_a) \) for the reverse reaction  \( \text{B} \rightarrow \text{A} \).
   
   a) \(-28 \text{ kJ/mol}\)
   b) \(76 \text{ kJ/mol}\)
   c) \(28 \text{ kJ/mol}\)
   d) \(24 \text{ kJ/mol}\)
   e) \(-52 \text{ kJ/mol}\)

2. (6 pts) The kinetics of the following reaction were studied by the initial rate method:

   \[ 2 \text{NO} + 2 \text{H}_2 \rightarrow \text{N}_2 + 2 \text{H}_2\text{O} \]

<table>
<thead>
<tr>
<th>[NO] (M)</th>
<th>[H\textsubscript{2}] (M)</th>
<th>Initial Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.15</td>
<td>0.30</td>
<td>0.0200</td>
</tr>
<tr>
<td>0.15</td>
<td>0.60</td>
<td>0.0400</td>
</tr>
<tr>
<td>0.30</td>
<td>0.30</td>
<td>0.0800</td>
</tr>
</tbody>
</table>

Excluding units, what is the value of the rate constant?

a) \(1.5\)
   b) \(9.9\)
   c) \(3.0\)
   d) \(0.13\)
   e) \(0.44\)
3. (6 pts) The overall reaction $A + 2B \rightarrow C$ is believed to take place by the following two-step mechanism:

$$A + 2B \rightleftharpoons I \quad \text{(fast)}$$
$$I + B \rightarrow C + B \quad \text{(slow)}$$

Based on this mechanism, what is the order of the overall reaction with respect to the concentration of B?

a) -2  
b) 0  
c) 1  
d) 2  
e) 3

4. (5 pts) Which of the following photons will have the lowest energy?

a) red ($\lambda = 650$ nm)  
b) green ($\lambda = 550$ nm)  
c) orange ($\lambda = 600$ nm)  
d) all of these photons have the same energy

5. (5 pts) Which of the following photons travels at the highest speed?

a) red ($\lambda = 650$ nm)  
b) green ($\lambda = 550$ nm)  
c) orange ($\lambda = 600$ nm)  
d) all of these photons travel at the same speed

6. (5 pts) Consider the following standard reduction potentials:

$$\text{Cl}_2 (l) + 2 \text{e}^- \rightarrow 2 \text{Cl}^- \quad E^\circ = 1.36 \text{ V}$$
$$\text{Pb}^{2+} + 2 \text{e}^- \rightarrow \text{Pb} (s) \quad E^\circ = -0.14 \text{ V}$$
$$\text{Zn}^{2+} + 2 \text{e}^- \rightarrow \text{Zn} (s) \quad E^\circ = -0.76 \text{ V}$$
$$\text{Al}^{3+} + 3 \text{e}^- \rightarrow \text{Al} (s) \quad E^\circ = -1.66 \text{ V}$$

Which of the following is the strongest oxidizing agent?

a) Zn (s)  
b) Pb$^{2+}$  
c) Al$^{3+}$  
d) Cl$^-$  
e) Al (s)
Questions 7-9. (4 pts each) Consider the following reaction mechanism:

\[
\begin{align*}
\text{Hg} + \text{H}_2 & \rightarrow \text{Hg} + 2 \text{H} \\
\text{H} + \text{C}_2\text{H}_4 & \rightarrow \text{C}_2\text{H}_6 \\
\text{C}_2\text{H}_5 + \text{H}_2 & \rightarrow \text{C}_2\text{H}_6 + \text{H} \\
\text{H} + \text{H} & \rightarrow \text{H}_2
\end{align*}
\]

Given the mechanism above, identify the following as a catalyst, intermediate, or neither.

7. \(\text{C}_2\text{H}_5\)  
   a) catalyst  
   b) intermediate  
   c) neither

8. \(\text{Hg}\)  
   a) catalyst  
   b) intermediate  
   c) neither

9. \(\text{C}_2\text{H}_4\)  
   a) catalyst  
   b) intermediate  
   c) neither

10. (6 pts) How much energy is required to ionize 3.8 moles of hydrogen atoms?

   a) \(8.28 \times 10^{-19} \text{ J}\)  
   b) \(1.38 \times 10^{-21} \text{ J}\)  
   c) \(1.31 \times 10^6 \text{ J}\)  
   d) \(4.99 \times 10^6 \text{ J}\)  
   e) \(3.45 \times 10^5 \text{ J}\)

11. (6 pts) 530 mL of a 2.1 M \(\text{Fe}_2(\text{SO}_4)_3\) solution is electrolyzed using a current of 35 A. How long will it take to plate out all of the \(\text{Fe}^{3+}\) ions from this solution?

   a) 5.1 hour  
   b) 2.6 hour  
   c) 1.7 hour  
   d) 0.85 hour  
   e) 2600 hour
Questions 12-13 (4 pts each) Consider a Galvanic cell based on the following half reactions:

\[
Pb^{2+} + 2e^- \rightarrow Pb (s) \quad E^o = -0.13 \, V
\]
\[
Cr^{3+} + 3e^- \rightarrow Cr (s) \quad E^o = -0.73 \, V
\]

Initially, [Pb^{2+}] = 1.0 \, M and [Cr^{3+}] = 1.0 \, M. Will the cell potential (E) increase, decrease, or stay the same under the following conditions:

12. (4 pts) Water is added to both half-cell compartments until the volume of each solution is doubled.
   a) increase
   b) decrease
   c) stay the same

13. (4 pts) Sodium hydroxide is added to the chromium half-cell compartment. Note: OH⁻ ions react with Cr^{3+} to produce the insoluble compound Cr(OH)₃.
   a) increase
   b) decrease
   c) stay the same

14. (7 pts) A concentration cell is constructed using two copper electrodes each immersed in solutions of Cu^{2+}. In the cathode compartment, [Cu^{2+}] = 0.84 \, M. What must be the [Cu^{2+}] in the other compartment in order to achieve a cell potential of 22 \, mV at 298 \, K?
   a) 4.66 M
   b) 0.15 M
   c) 0.36 M
   d) 1.98 M
   e) 0.27 M
15. (7 pts) For an uncatalyzed reaction, $E_a = 83 \text{ kJ/mol}$. When a catalyst is used for the same reaction, $E_a = 28 \text{ kJ/mol}$. At what temperature will the rate constant of the catalyzed reaction be equal to the rate constant of the uncatalyzed reaction at $41^\circ C$?

Assume that the preexponential factor (A) is the same for the catalyzed and uncatalyzed reactions.

a) 14°C  
b) −167°C  
c) 106°C  
d) 658°C  
e) −54°C

16. (7 pts) The energy required to remove electrons from the surface of a metal is 252 kJ/mol. If the metal is irradiated with a light source of unknown wavelength, and each ejected electron has a kinetic energy of $4.6 \times 10^{-19} \text{ J}$, then what is the wavelength of the incident light?

a) $4.8 \times 10^{-6} \text{ m}$  
b) $7.9 \times 10^{-11} \text{ m}$  
c) $4.3 \times 10^{-7} \text{ m}$  
d) $2.3 \times 10^{-7} \text{ m}$  
e) $6.2 \times 10^{-6} \text{ m}$
17. (7 pts) Calculate the equilibrium constant (K) for the following reaction at 298K: 3 Fe^{2+} \rightarrow Fe (s) + 2 Fe^{3+}

**NOTE:** You may not need to use all of the reduction potentials listed below.

<table>
<thead>
<tr>
<th>Reaction</th>
<th>Reduction Potential (E°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe^{3+} + e^- \rightarrow Fe^{2+}</td>
<td>E° = 0.77 V</td>
</tr>
<tr>
<td>Fe^{3+} + 3 e^- \rightarrow Fe (s)</td>
<td>E° = -0.036 V</td>
</tr>
<tr>
<td>Fe^{2+} + 2 e^- \rightarrow Fe (s)</td>
<td>E° = -0.44 V</td>
</tr>
</tbody>
</table>

a) 3.4 \times 10^{-21}

b) 4.0 \times 10^{-62}

c) 5.5 \times 10^{-28}

d) 1.6 \times 10^{-123}

e) 1.2 \times 10^{-41}

18. (7 pts) Consider two reaction vessels, one containing A and the other containing B, with equal concentrations at t = 0. Both substances react by second order kinetics where:

\[
k_B = 0.55 \text{ M}^{-1} \text{s}^{-1}
\]

After 1.9 seconds, [A] = 0.55 and [B] = 0.85. What is the rate constant k_A?

a) 1.38 M^{-1} s^{-1}

b) 0.65 M^{-1} s^{-1}

c) 0.36 M^{-1} s^{-1}

d) 0.89 M^{-1} s^{-1}

e) 0.55 M^{-1} s^{-1}

**Answers:**

1) B  
2) C  
3) E  
4) A  
5) D  
6) B  
7) B  
8) A (C was also accepted)  
9) C  
10) D  
11) A  
12) B  
13) A  
14) B  
15) B (See Zumdahl #15.92)  
16) D  
17) E (See Zumdahl #11.45)  
18) D (See Zumdahl #15.48)
Before doing anything, fill in the following on your ParSCORE form:

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1. (5 pts) Consider the hydrogen atom spectrum. For which of the following transitions is the wavelength of emitted light the longest?
   
   a) n = 4 ---> n = 5
   b) n = 6 ---> n = 4
   c) n = 4 ---> n = 6
   d) n = 5 ---> n = 4
   e) more than one of these

2. (5 pts) How many electrons are transferred in the following reaction:

   \[ 2 \text{CO}(g) \rightarrow \text{C}(s) + \text{CO}_2(g) \]

   a) 2
   b) 0
   c) 4
   d) 8
   e) 1

3. (6 pts) Consider the following reaction: \( A \rightarrow B \)

   If \( \Delta E = 78.3 \text{ kJ/mol} \) and \( E_a = 106.9 \text{ kJ/mol} \), what is the activation energy for the reverse reaction: \( B \rightarrow A \)

   a) 185.2 kJ/mol
   b) 28.6 kJ/mol
   c) 106.9 kJ/mol
   d) -28.6 kJ/mol
   e) -106.9 kJ/mol
4. (5 pts) The kinetics of the reaction \( [A] \rightarrow \text{Products} \) were studied, and the following three plots were generated.

What is the order of the reaction with respect to \([A]\)?

a) Zero  
b) First  
c) Second  
d) None of these  
e) Reaction order can not be determined from the given information

**Questions 5 & 6**

Consider the following reaction in an electrochemical cell:

\[
\text{Cu}^{2+} + 2 \text{Fe}^{3+} \rightarrow 2 \text{Fe}^{2+} + \text{Cu (s)} \quad E^0_{\text{cell}} = 0.43 \text{ V}
\]

Initially \([\text{Cu}^{2+}] = 1.0 \text{ M}, [\text{Fe}^{3+}] = 1.0 \text{ M}, \) and \([\text{Fe}^{2+}] = 1.0 \text{ M}.\) Predict how the cell potential will change under the following conditions:

5. (4 pts) The Cu (s) electrode is doubled in size

a) cell potential increases  
b) cell potential decreases  
c) cell potential stays the same

6. (4 pts) Water is added to the half cell containing \( \text{Fe}^{3+} \) and \( \text{Fe}^{2+} \) until \([\text{Fe}^{3+}] = 0.5 \text{ M} \) and \([\text{Fe}^{2+}] = 0.5 \text{ M}\)

a) cell potential increases  
b) cell potential decreases  
c) cell potential stays the same
7. (6 pts) Which of the following aqueous solutions is capable of oxidizing Bi (s) to Bi^{3+} (aq)?

\[
\begin{align*}
\text{Cl}_2 + 2 \text{e}^- &\rightarrow 2 \text{Cl}^- & E^o = 1.36 \text{ V} \\
\text{Br}_2 + 2 \text{e}^- &\rightarrow 2 \text{Br}^- & E^o = 1.09 \text{ V} \\
\text{NO}_3^- + 4 \text{H}^+ + 3 \text{e}^- &\rightarrow \text{NO} + 2 \text{H}_2\text{O} & E^o = 0.96 \text{ V} \\
\text{Bi}^{3+} + 3 \text{e}^- &\rightarrow \text{Bi} (s) & E^o = 0.31 \text{ V} \\
2 \text{H}^+ + 2 \text{e}^- &\rightarrow \text{H}_2 & E^o = 0.00 \text{ V}
\end{align*}
\]

a) HCl only  
b) HBr only  
c) HNO_3 only  
d) HCl, HBr, and HNO_3  
e) None of these

8. (6 pts) Consider the following reaction mechanism:

\[
\begin{align*}
\text{F}_2 &\rightleftharpoons 2 \text{F} \quad \text{fast} \\
\text{F} + \text{CHF}_3 &\rightarrow \text{HF} + \text{CF}_3 \quad \text{slow} \\
\text{F} + \text{CF}_3 &\rightarrow \text{CF}_4 \quad \text{fast}
\end{align*}
\]

What is the rate law for this reaction mechanism?

a) \( \text{rate} = k [\text{F}_2][\text{CHF}_3] \)  
b) \( \text{rate} = k [\text{F}_2]^{\frac{1}{2}}[\text{CHF}_3] \)  
c) \( \text{rate} = k [\text{F}] [\text{CHF}_3] \)  
d) \( \text{rate} = k [\text{F}_2][\text{CHF}_3][\text{HF}]^{\frac{1}{2}}[\text{CF}_4]^{-\frac{1}{2}} \)  
e) \( \text{rate} = k [\text{F}_2]^{\frac{1}{2}}[\text{CHF}_3] \)
9. (6 pts) Consider the following elementary (single-step) equilibrium reaction: \[ A \rightleftharpoons B \]

The rate constant for the forward reaction is 139 s\(^{-1}\). The rate constant for the reverse reaction is 40 s\(^{-1}\). What is the equilibrium constant (K) for this reaction?

a) 99  
b) 3.5  
c) 5.8  
d) 0.29  
e) 0.81

10. (6 pts) The energy required to break C-S bonds is 272 kJ/mol.

Calculate the maximum wavelength of light for which a single C-S bond could be broken by absorbing a single photon.

a) \(4.40 \times 10^{-7}\) m  
b) \(7.31 \times 10^{-11}\) m  
c) \(6.87 \times 10^{-7}\) m  
d) \(9.61 \times 10^{-7}\) m  
e) \(6.82 \times 10^{14}\) m
11. (5 pts) Be\(^{3+}\) is a one-electron species. Calculate the frequency of light required to ionize a Be\(^{3+}\) ion if the electron is initially in its ground state.

a) \(3.29 \times 10^{15}\) s\(^{-1}\)  
b) \(5.26 \times 10^{16}\) s\(^{-1}\)  
c) \(1.32 \times 10^{16}\) s\(^{-1}\)  
d) \(2.96 \times 10^{16}\) s\(^{-1}\)  
e) \(5.39 \times 10^{-3}\) s\(^{-1}\) 

12. (6 pts) The energy required to remove electrons from the surface of a metal is 302 kJ/mol. What is the maximum wavelength of light required to remove electrons from this metal?

a) \(6.18 \times 10^{-4}\) m  
b) \(6.58 \times 10^{-31}\) m  
c) \(6.18 \times 10^{-7}\) m  
d) \(1.09 \times 10^{-54}\) m  
e) \(3.96 \times 10^{-7}\) m
13. (6 pts) The molar mass of element X was determined by electrolyzing a solution of \( X^{2+} \) ions. It took 64 minutes for a current of 15 A to plate out 27 grams of solid X. What is the molar mass of X? Note: 1 minute = 60 seconds.

a) 47 g/mol  
b) 23 g/mol  
c) 138 g/mol  
d) 91 g/mol  
e) 123 g/mol

14. (7 pts) Consider the reaction: \( A \rightarrow \text{Products} \)

The first, second, and third half lives for this reaction are 60 sec, 30 sec, and 15 sec, respectively. If the initial concentration of A is 3.4 M, what will be \([A]\) after 97 seconds have elapsed?

a) 1.3 M  
b) 1.1 M  
c) 0.72 M  
d) 0.49 M  
e) 0.65 M
15. (7 pts) Consider the Galvanic cell at 25°C described as follows: \( X | X^{2+} || Y^{3+} | Y \)

Where \( X \) and \( Y \) are unknown metals. Given the standard reduction potential for \( Y^{3+} \)

\[
Y^{3+} + 3 \text{e}^- \rightarrow Y \quad \quad \quad E^0 = 1.5 \text{ V}
\]

and that \( K \) for the overall reaction in this Galvanic cell is \( 1.2 \times 10^{20} \), what is the standard reduction potential of \( X^{2+} \)?

a) \(-1.7 \text{ V}\)
b) \(1.7 \text{ V}\)
c) \(2.1 \text{ V}\)
d) \(1.3 \text{ V}\)
e) \(-1.3 \text{ V}\)

16. (7 pts) Consider two reaction vessels, one containing \( A \) and the other containing \( B \), with equal concentrations at \( t = 0 \). If both substances decompose by first order kinetics where:

\[
k_A = 0.412 \text{ s}^{-1} \quad \text{and} \quad k_B = 0.603 \text{ s}^{-1}
\]

At what time will \([A] = 3.7[B]\)?

a) never
b) 211.8 s
c) 16.03 s
d) 6.85 s
e) 2.87 s

One more question on the back ---->
17. (7 pts) Consider the following electrochemical cell:

\[
\text{Al} \ | \ \text{Al}^{3+} (0.74 \text{ M}) \ | \ | \ \text{Cu}^{2+} (2.10 \text{ M}) \ | \ \text{Cu}
\]

Calculate the cell potential after 5.8 A of current has flowed through the cell for 19 hours (note 1 hour = 3600 seconds). Assume each half cell contains 1.00 L of solution.

\[
\begin{align*}
\text{Cu}^{2+} + 2e^- & \rightarrow \text{Cu} \text{ (s)} \quad E^0 = 0.34 \text{ V} \\
\text{Al}^{3+} + 3e^- & \rightarrow \text{Al} \text{ (s)} \quad E^0 = -1.66 \text{ V}
\end{align*}
\]

a) 2.00 V  
b) 1.95 V  
c) 1.98 V  
d) 0.71 V  
e) 1.86 V

(1 point) Make sure you mark your PERM AND TEST FORM on your Parscore. You will get one point for correctly marking these on your ParScore.

Answers: 1) D  2) A  3) B  4) A  5) C  6) C  7) C  
13) D (Zumdahl #11.78)  14) E (Zumdahl #15.46)  15) D  16) D (Zumdahl #15.48)  
17) B (Zumdahl #11.105)
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1. (5 pts) Consider a Galvanic cell described by the following half reactions:

   \[ \text{Ag}^+ + e^- \rightarrow \text{Ag} (s) \quad E^\circ = 0.80 \text{ V} \]
   \[ \text{Zn}^{2+} + 2 e^- \rightarrow \text{Zn} (s) \quad E^\circ = -0.76 \text{ V} \]

   Which of the following occurs at the anode?

   a) Ag is oxidized to Ag^+
   b) Ag^+ is reduced to Ag
   c) Zn is oxidized to Zn^{2+}
   d) Zn^{2+} is reduced to Zn

2. (4 pts) The frequency of light emitted for an electronic transition from \( n = 5 \) to \( n = 3 \) is higher than the frequency of light emitted for an electronic transition from \( n = 6 \) to \( n = 3 \).

   a) True
   b) False

3. (4 pts) Light of any wavelength can remove electrons from a metal surface, provided that the light source is sufficiently intense.

   a) True
   b) False
4. (5 pts) A cobalt atom and a helium atom have the same de Broglie wavelength. Which atom is traveling faster?

a) Helium  

b) Cobalt  

c) Both atoms are traveling at the same speed

5. (5 pts) Fill in the blank: The ground-state ionization energy of He⁺ is _________ than the ground-state ionization energy of H

a) two times larger  

b) two times smaller  

c) four times larger  

d) four times smaller

Questions 6-7 deal with the following mechanism:

\[
\begin{align*}
2 B & \rightarrow B_2 & \text{fast} \\
B_2 + A & \rightarrow E + D & \text{slow} \\
E + A & \rightarrow C + D & \text{fast}
\end{align*}
\]

6. (6 pts) Based on the mechanism above, what is the overall order for this reaction? Make sure there are no intermediates in your rate law expression.

a) 2  

b) 4  

c) 3/2  

d) 3  

e) 1/2

7. (5 pts) Consider the mechanism above. Do any catalysts appear in this mechanism?

a) Yes, B is a catalyst  

b) Yes, B₂ is a catalyst  

c) Yes, B₂ and E are both catalysts  

d) Yes, E is a catalyst  

e) There are no catalysts in this mechanism
8. (5 pts) How many electrons are transferred in the following reaction:

\[ 2 \text{HBrO}_2 \rightarrow \text{HBrO} + \text{HBrO}_3 \]

a) 1  
b) 2  
c) 4  
d) 8  
e) This is not a redox reaction

9. (5 pts) Consider a Galvanic cell in which the following reaction occurs:  \[ 2 \text{B} + \text{A}^{2+} \rightarrow 2 \text{B}^+ + \text{A} \]

Which of the following will increase the cell potential by the largest amount?

a) Double [A^{2+}]  
b) Double [B^+]  
c) Halve [A^{2+}]  
d) Halve [B^+]  
e) More than one of these will increase the cell potential by the largest amount

10. (6 pts) The kinetics of the following reaction were studied:  \[ \text{A} \rightarrow \text{B} \]

A plot of [A] vs. time yielded a straight line described by the equation \[ y = -0.051x + 2.89 \]
Calculate the first half life for this reaction under these conditions.

a) 0.051 sec  
b) 13.6 sec  
c) 56.7 sec  
d) 0.009 sec  
e) 28.3 sec
Questions 11-12 use the following table of reduction potentials

<table>
<thead>
<tr>
<th>Reactants</th>
<th>E° (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Au^{3+} + 3 e^- → Au</td>
<td>+1.50</td>
</tr>
<tr>
<td>NO_3^- + 4 H^+ + 3 e^- → NO + 2 H_2O</td>
<td>+0.96</td>
</tr>
<tr>
<td>Ag^{-} + e^- → Ag</td>
<td>+0.80</td>
</tr>
<tr>
<td>Cu^{2+} + 2 e^- → Cu</td>
<td>+0.34</td>
</tr>
<tr>
<td>2 H^+ + 2 e^- → H_2</td>
<td>0.00</td>
</tr>
<tr>
<td>Co^{2+} + 2 e^- → Co</td>
<td>−0.28</td>
</tr>
<tr>
<td>Fe^{2+} + 2 e^- → Fe</td>
<td>−0.44</td>
</tr>
<tr>
<td>Al^{3+} + 3 e^- → Al</td>
<td>−1.66</td>
</tr>
</tbody>
</table>

11. (5 pts) Consider the table of reduction potentials above. Which of the following will reduce Cu^{3+} but not Fe^{3+}?

a) H^+
b) Au^{3+}
c) Co
d) Al
e) More than one of these

12. (6 pts) Consider the table of reduction potentials above.

A Galvanic cell at 298K is described by the following line notation: Co | Co^{2+} (1.0M) || Ag^- (? M) | Ag

Calculate the concentration of Ag^- required to achieve a cell potential (E_cell) of 1.04 V.

a) 0.21 M
b) 4.7 M
c) 2.4 M
d) 0.044 M
e) 0.14 M
13. (6 pts) The kinetics of the following reaction were studied:  \( A + B \rightarrow \text{Products} \)

The following data were collected:

<table>
<thead>
<tr>
<th>[A] (M)</th>
<th>[B] (M)</th>
<th>Initial Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.4</td>
<td>3.6</td>
<td>1.79</td>
</tr>
<tr>
<td>8.8</td>
<td>3.6</td>
<td>3.58</td>
</tr>
<tr>
<td>4.4</td>
<td>7.2</td>
<td>7.16</td>
</tr>
</tbody>
</table>

What is the order of this reaction with respect to [A]?

a) 1  
b) 2  
c) 3  
d) 4  
e) 0

14. (6 pts) Consider the Galvanic cell at 298K that uses the following two half reactions:

\[
\begin{align*}
\text{Cu}^+ + e^- & \rightarrow \text{Cu} \ (s) \quad E^0 = 0.52 \text{ V} \\
\text{Fe}^{3+} + 3 \ e^- & \rightarrow \text{Fe} \ (s) \quad E^0 = -0.036 \text{ V}
\end{align*}
\]

Initially, \([\text{Fe}^{3+}] = 1.27 \text{ M} \) and \([\text{Cu}^+] = 1.27 \text{ M}. \) Calculate the cell potential after the reaction has operated long enough for \([\text{Fe}^{3+}] \) to change by 0.41 M.

a) 0.65 V  
b) 0.56 V  
c) 0.29 V  
d) 0.52 V  
e) 0.47 V
15. (6 pts) Calculate the total energy of 2.9 moles of red photons (λ = 650 nm)
   a) 8.87x10^{-19} J
   b) 1.84x10^5 J
   c) 1.47x10^{-42} J
   d) 1.84x10^{-4} J
   e) 5.34x10^5 J

16. (6 pts) Consider the following first order reaction: \( \text{N}_2\text{O}_4 \rightarrow 2 \text{NO}_2 \) \( k = 0.0071 \text{ s}^{-1} \)
   
The reaction is run where the initial concentration \([\text{N}_2\text{O}_4]_0 = 1.6 \text{ M}\). Calculate the concentration of \(\text{NO}_2\) after 36 seconds have passed.
   a) 1.2 M
   b) 0.72 M
   c) 0.36 M
   d) 2.5 M
   e) 3.2 M

2 more questions on the last page ---->
17. (7 pts) When an electron in a hydrogen atom relaxes from an initial state of \( n = 7 \), a photon with a wavelength of \( 4.65 \times 10^{-6} \) m is emitted. What is the final state of the electron?

a) \( n = 8 \)
b) \( n = 3 \)
c) \( n = 6 \)
d) \( n = 5 \)
e) \( n = 10 \)

18. (7 pts) A certain reaction has an activation energy of 82 kJ/mol. As the temperature is increased from 25°C to a higher temperature, the rate constant \( (k) \) increases by a factor of 4. Calculate the higher temperature.

a) 38°C
b) 55°C
c) 81°C
d) 13°C
e) 311°C

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1. (4 pts) It takes less energy to ionize an electron from the n=5 state of the hydrogen atom than from the ground state.
   a) True  
   b) False

2. (4 pts) In a Galvanic cell, a salt bridge balances charge by supplying positive ions to the anode.
   a) True  
   b) False

3. (5 pts) Which of the following will increase the value of the rate constant (k) for a reaction?
   a) Decreasing temperature  
   b) Increasing temperature  
   c) Increasing the concentration of the reactants at a constant temperature  
   d) Answers (b) and (c) will both increase the value of the rate constant  
   e) None of these will increase the value of the rate constant
4. (5 pts) Consider a Galvanic cell described by the following half reactions:

$$\text{Ag}^+ + e^- \rightarrow \text{Ag (s)} \quad \text{E}^0 = 0.80 \text{ V}$$
$$\text{Zn}^{2+} + e^- \rightarrow \text{Zn (s)} \quad \text{E}^0 = -0.76 \text{ V}$$

Will the mass of the Zn (s) electrode increase, decrease, or remain the same when current is allowed to flow through this Galvanic cell?

a) The Zn (s) electrode will decrease in mass
b) The Zn (s) electrode will increase in mass
c) The mass of the Zn (s) electrode will remain constant

5. (5 pts) Fill in the blank: The activation energy of a reaction performed without a catalyst is ______ the activation energy of the same reaction performed with a catalyst.

a) greater than
b) less than
c) equal to

6. (5 pts) For which of these transitions in the hydrogen atom spectrum is the wavelength of absorbed light longest?

a) n = 2 \rightarrow n = 4
b) n = 5 \rightarrow n = 2
c) n = 6 \rightarrow n = 2
d) n = 3 \rightarrow n = 4

7. (6 pts) Consider the reaction $A \rightarrow B$.

If the rate constant (k) for this reaction is $2.6 \text{ M}^{0.7} \text{s}^{-1}$, What is the overall order of this reaction?

a) 0.7
b) -0.7
c) 1.7
d) -0.3
e) 1
Questions 8-9 use the following table of reduction potentials

<table>
<thead>
<tr>
<th>Reaction</th>
<th>E° (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{Au}^{3+} + 3 \text{e}^- \rightarrow \text{Au} )</td>
<td>+1.50</td>
</tr>
<tr>
<td>( \text{NO}_3^- + 4 \text{H}^+ + 3 \text{e}^- \rightarrow \text{NO} + 2 \text{H}_2\text{O} )</td>
<td>+0.96</td>
</tr>
<tr>
<td>( \text{Ag}^+ + \text{e}^- \rightarrow \text{Ag} )</td>
<td>+0.80</td>
</tr>
<tr>
<td>( \text{Cu}^{2+} + 2 \text{e}^- \rightarrow \text{Cu} )</td>
<td>+0.34</td>
</tr>
<tr>
<td>( 2 \text{H}^+ + 2 \text{e}^- \rightarrow \text{H}_2 )</td>
<td>0.00</td>
</tr>
<tr>
<td>( \text{Co}^{2+} + 2 \text{e}^- \rightarrow \text{Co} )</td>
<td>−0.28</td>
</tr>
<tr>
<td>( \text{Fe}^{3+} + 2 \text{e}^- \rightarrow \text{Fe} )</td>
<td>−0.44</td>
</tr>
<tr>
<td>( \text{Al}^{3+} + 3 \text{e}^- \rightarrow \text{Al} )</td>
<td>−1.66</td>
</tr>
</tbody>
</table>

8. (5 pts) Consider the table of reduction potentials above.

Which of the following metals will dissolve in a solution of \( \text{HNO}_3 \)?

a) \( \text{Fe} \) only  
b) \( \text{Au} \) only  
c) \( \text{Cu} \) only  
d) \( \text{Fe} \) and \( \text{Cu} \) only  
e) \( \text{Fe}, \text{Cu}, \) and \( \text{Au} \)

9. (6 pts) Consider the table of reduction potentials above.

A Galvanic cell at 298K is described by the following line notation:  \( \text{Co} | \text{Co}^{2+} \ (2.4 \text{ M}) \ | \ | \text{Ag}^+ \ (0.028 \text{ M}) \ | \text{Ag} \)

Calculate the cell potential \( (E_{\text{cell}}) \).

a) 1.02 V  
b) 1.14 V  
c) 1.08 V  
d) 1.18 V  
e) 0.98 V
10. (5 pts) The decomposition of ozone (O₃) can be catalyzed by nitrogen monoxide (NO), which is a component in automobile exhaust. This reaction is believed to occur according to the following mechanism:

\[
\begin{align*}
O_3 & \rightleftharpoons O_2 + O \quad \text{fast} \\
NO + O_3 & \rightarrow NO_2 + O_2 \quad \text{slow} \\
NO_2 + O & \rightarrow NO + O_2 \quad \text{fast}
\end{align*}
\]

What is the rate law for this mechanism?

a) \( k[NO]^2[O_2]^2[NO_2]^{-1} \)

b) \( k[NO][O_2][O] \)

c) \( k[NO][O_3] \)

d) \( k[O_3][NO_2][O][O_3]^{-1} \)

e) \( k[O_3]^2[NO_2] \)

11. (5 pts) Which of the following energy diagrams represents an endothermic reaction that takes place according to the following mechanism:

\[
\begin{align*}
W + X & \rightleftharpoons Y \quad \text{fast} \\
Y & \rightarrow Z \quad \text{slow}
\end{align*}
\]

a)  

b)  

c)  

d)  
12. (6 pts) Calculate the de Broglie wavelength of a marble (3.76 grams) traveling at 5.4 m/s.
   a) $3.3 \times 10^{-35}$ m
   b) $3.3 \times 10^{-38}$ m
   c) $3.3 \times 10^{-27}$ m
   d) $3.3 \times 10^{-32}$ m
   e) $3.3 \times 10^{-30}$ m

13. (6 pts) The kinetics of the following reaction were studied: $A \rightarrow B$

   A plot of $1/[A]$ vs. time yielded a straight line described by the equation $y = 0.42x + 19.0$

   Calculate the first half life for this reaction under these conditions.
   a) 0.13 sec
   b) 1.7 sec
   c) 0.026 sec
   d) 45 sec
   e) 23 sec

14. (6 pts) A concentration cell is constructed using two zinc electrodes each immersed in solutions of Zn$^{2+}$. In the anode compartment, $[Zn^{2+}] = 0.48$ M. What must be the $[Zn^{2+}]$ in the other compartment in order to achieve a cell potential of 0.025V at 298K?
   a) 0.068 M
   b) 1.3 M
   c) 3.4 M
   d) 0.18 M
   e) 5.7 M
15. (6 pts) Consider the following first order reaction: \[ \text{N}_2\text{O}_4 \rightarrow 2 \text{NO}_2 \quad k = 0.0077 \text{ s}^{-1} \]

The reaction is run where the initial concentration \( [\text{N}_2\text{O}_4]_0 = 1.7 \text{ M} \). Calculate the concentration of \( \text{NO}_2 \) after 24 seconds have passed.

a) \( 1.4 \text{ M} \)
b) \( 0.29 \text{ M} \)
c) \( 2.8 \text{ M} \)
d) \( 3.4 \text{ M} \)
e) \( 0.57 \text{ M} \)

16. (6 pts) When a photon with a wavelength of 468 nm strikes the surface of a metal, an electron is ejected with a kinetic energy of \( 2.4 \times 10^{-19} \text{ J} \). What is the binding energy of the metal, in units of kJ/mol?

a) \( 1.8 \times 10^{-22} \text{ kJ/mol} \)
b) \( 3.1 \times 10^{-26} \text{ kJ/mol} \)
c) \( 256 \text{ kJ/mol} \)
d) \( 144 \text{ kJ/mol} \)
e) \( 111 \text{ kJ/mol} \)
17. (7 pts) A certain reaction has an activation energy of 79 kJ/mol. At a temperature of 29°C, the rate constant (k) is 100 s⁻¹. At what temperature will the rate constant equal 711 s⁻¹?

a) 98°C  
b) 70°C  
c) 49°C  
d) 11°C  
e) 322°C

18. (7 pts) The emission spectrum of an unknown one-electron ion Xᵐ⁺ was studied. When the electron transitions from n=6 to n=3, a photon with a wavelength of 17.1 nm is emitted. What is the value of “m” in Xᵐ⁺?

a) 6  
b) 7  
c) 5  
d) 8  
e) 1

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Questions 1-2: Consider the following information:

\[
\begin{align*}
\text{Cl}_2 (g) + 2 \text{e}^- & \rightarrow 2 \text{Cl}^- & E^0 = 1.36 \text{ V} \\
2 \text{H}^+ + 2 \text{e}^- & \rightarrow \text{H}_2 (g) & E^0 = 0.00 \text{ V} \\
Pb^{2+} + 2 \text{e}^- & \rightarrow \text{Pb} (s) & E^0 = -0.14 \text{ V} \\
\text{Ni}^{2+} + 2 \text{e}^- & \rightarrow \text{Ni} (s) & E^0 = -0.23 \text{ V} \\
\text{Cd}^{2+} + 2 \text{e}^- & \rightarrow \text{Cd} (s) & E^0 = -0.40 \text{ V} \\
\text{Zn}^{2+} + 2 \text{e}^- & \rightarrow \text{Zn} (s) & E^0 = -0.76 \text{ V} \\
\text{Al}^{3+} + 3 \text{e}^- & \rightarrow \text{Al} (s) & E^0 = -1.66 \text{ V}
\end{align*}
\]

1. (5 pts) Which of the following can be reduced by Zn but not H_2?

a) Cd
b) Cl_2
c) Ni
d) Pb^{2+}
e) More than one of these

2. (5 pts) A Galvanic cell is constructed using a Ni (s) electrode immersed in a 1.0 M Ni^{2+} solution and an Al (s) electrode immersed in a 1.0 M Al^{3+} solution. How will the cell potential \(E_{cell}\) be affected when sodium hydroxide is added to the Al^{3+} solution? Hint: Al(OH)_3 is insoluble in water. Standard reduction potentials are listed above.

a) \(E_{cell}\) will increase
b) \(E_{cell}\) will decrease
c) \(E_{cell}\) will not change
3. (5 pts) What color of light is most likely to produce the photoelectric effect?
   
   a) Red ($\lambda = 650$ nm)
   b) Green ($\lambda = 550$ nm)
   c) Blue ($\lambda = 450$ nm)
   d) All of these are equally likely to produce the photoelectric effect

4. (5 pts) A particular reaction has the rate law: $\text{rate} = k[A]^{0.3}[B]^{-1}[C]^2$
   
   Determine the units of the rate constant $k$
   
   a) $M^{1.3} s^{-1}$
   b) $M^{-1.3} s^{-1}$
   c) $M^{0.7} s^{-1}$
   d) $M^{0.3} s^{-1}$
   e) $M^{-0.3} s^{-1}$

5. (5 pts) Consider the following energy diagram for an atom that has four possible energy levels.

   ![Energy Diagram]

   How many total lines are in the absorption line spectrum for this atom?
   
   a) 3
   b) 9
   c) 16
   d) 4
   e) 6

6. (5 pts) For an exothermic reaction, the activation energy of the forward reaction is _________ the activation energy of the reverse reaction.

   a) greater than
   b) equal to
   c) less than
7. (5 pts) A Galvanic concentration cell is constructed using Ag (s) electrodes and Ag⁺ solutions. In one half-cell, [Ag⁺] = 0.5 M. In the other half-cell, [Ag⁺] = 0.1 M. Write the line notation for this cell.

a) \( \text{Ag} \_|\_ \text{Ag}^+ (0.1 \text{ M}) \_|\_ \text{Ag} \)

b) \( \text{Ag}^+ (0.1 \text{ M}) \_|\_ \text{Ag} \_|\_ \text{Ag} \_|\_ \text{Ag}^+ (0.1 \text{ M}) \)

c) \( \text{Ag} \_|\_ \text{Ag}^+ (0.5 \text{ M}) \_|\_ \text{Ag}^+ (0.1 \text{ M}) \_|\_ \text{Ag} \)

d) \( \text{Ag}^+ (0.5 \text{ M}) \_|\_ \text{Ag} \_|\_ \text{Ag} \_|\_ \text{Ag}^+ (0.1 \text{ M}) \)

e) \( \text{Ag}^+ (0.1 \text{ M}) \_|\_ \text{Ag} \_|\_ \text{Ag}^+ (0.5 \text{ M}) \_|\_ \text{Ag} \)

8. (5 pts) For the reaction \( A \rightarrow B \) the first three half-lives are 100 seconds, 50 seconds, and 25 seconds, respectively. What is the rate law for this reaction?

a) \( \text{rate} = k[A] \)

b) \( \text{rate} = k[A]^{-1} \)

c) \( \text{rate} = k[A]^2 \)

d) \( \text{rate} = k[A][B]^{-1} \)

e) \( \text{rate} = k \)

9. (5 pts) Which of the following is ranked in order of decreasing ground-state ionization energy?

a) \( \text{Na}^{10+} > \text{B}^{4+} > \text{Li}^{2+} \)

b) \( \text{Li}^{2+} > \text{B}^{4+} > \text{Na}^{10+} \)

c) \( \text{B}^{4+} > \text{Li}^{2+} > \text{Na}^{10+} \)

d) \( \text{Li}^{2+} > \text{Na}^{10+} > \text{B}^{4+} \)

e) \( \text{Li}^{2+}, \text{B}^{4+}, \text{and} \text{Na}^{10+} \text{ all have the same ground-state ionization energy} \)

10. (6 pts) Under standard conditions, what will spontaneously occur when Cl₂ (g) is bubbled through a solution of sodium iodide (NaI)?

\[
\begin{align*}
\text{Cl}_2 (g) + 2 \text{ e}^- & \rightarrow 2 \text{ Cl}^- & E^0 &= 1.36 \text{ V} \\
\text{I}_2 (s) + 2 \text{ e}^- & \rightarrow 2 \text{ I}^- & E^0 &= 0.54 \text{ V} \\
\text{Na}^+ + \text{ e}^- & \rightarrow \text{Na} (s) & E^0 &= -2.71 \text{ V}
\end{align*}
\]

a) \( \text{I}_2 (s) \text{ will be formed} \)

b) \( \text{Cl}^- \text{ will be formed} \)

c) \( \text{Na} (s) \text{ will be formed} \)

d) \( \text{More than one of these will spontaneously occur} \)

e) \( \text{None of these will spontaneously occur} \)
11. (6 pts) Consider the following reaction: \[ 2 \text{NO} + 2\text{H}_2 \rightarrow \text{N}_2 + 2\text{H}_2\text{O} \]

The kinetics of this reaction were studied, and the following data were obtained:

<table>
<thead>
<tr>
<th>Exp.</th>
<th>[NO]₀ (M)</th>
<th>[H₂]₀ (M)</th>
<th>Initial Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.16</td>
<td>0.32</td>
<td>0.020</td>
</tr>
<tr>
<td>2</td>
<td>0.16</td>
<td>0.48</td>
<td>0.030</td>
</tr>
<tr>
<td>3</td>
<td>0.32</td>
<td>0.32</td>
<td>0.080</td>
</tr>
</tbody>
</table>

What is the overall order of this reaction?

a) 1  
b) 2  
c) 3  
d) 4  
e) 2.5

12. (6 pts) Consider the following reaction: \[ 2\text{SO}_2 + \text{O}_2 + 2\text{H}_2\text{O} \rightarrow 2\text{H}_2\text{SO}_4 \quad \Delta G^\circ = -305.4 \text{ kJ} \]

Calculate the standard cell potential \(E^\circ_{\text{cell}}\) for this reaction:

a) 0.79 V  
b) 3.17 V  
c) 1.58 V  
d) 0.40 V  
e) -1.58 V

13. (6 pts) We have three separate solutions: one contains Mo³⁺, one contains Sr²⁺, and one contains K⁺. These solutions are electrolyzed to plate out solid metals. If the solutions are electrolyzed using the same current for the same amount of time, which solid metal will be produced in the largest amount (by mass)?

a) Mo  
b) Sr  
c) K  
d) Equal masses of all three solid metals will be produced
14. (6 pts) Determine the rate law for a reaction that occurs according to the following mechanism. Make sure there are no intermediates in your rate law.

\[
\begin{align*}
A & \rightleftharpoons B + C & \text{fast} \\
B + D & \rightleftharpoons E & \text{fast} \\
E + D & \rightarrow F + G & \text{slow}
\end{align*}
\]

a) rate = k[E][D]  

b) rate = k[B][D]  

c) rate = k[A][D][C]^{-1}  

d) rate = k[A][D]^2[C]^{-1}  

e) rate = k[A][D]^2[C]^{-1}[F]^{-1}[G]^{-1}

15. (6 pts) An atom of element M travelling at a velocity of 6.36x10^6 m/s has a de Broglie wavelength of 8.36x10^{-18} m. What is the molar mass of element M?

a) 1.2x10^{-25} g/mol  

b) 61 g/mol  

c) 41 g/mol  

d) 75 g/mol  

e) 0.08 g/mol
16. (6 pts) In the emission spectrum for Li$^{2+}$, an emission line is observed at a wavelength of 121.6 nm. If this line corresponds to an electron transitioning from an unknown initial state to a final state of $n = 3$, what was the initial state?

a) 2  
b) 3  
c) 5  
d) 7  
e) 6

17. (6 pts) For an uncatalyzed reaction, $E_a = 68$ kJ/mol. When a catalyst is used for the same reaction, $E_a = 41$ kJ/mol. At what temperature will the rate constant of the catalyzed reaction be equal to the rate constant of the uncatalyzed reaction at 50$^\circ$C?

Assume that the frequency factor, $A$, is the same for the catalyzed and uncatalyzed reactions.

a) 226K  
b) 195K  
c) 535K  
d) 30K  
e) 96K
18. (6 pts) Consider the following first order reaction:  \( A \rightarrow \text{Products} \)

The rate constant for this reaction at 397K is 501 s\(^{-1}\), and the activation energy is 78.1 kJ/mol.

How long will it take for [A] to be depleted to 42\% of its initial value at 265K?

1) 228 s  
2) 981 s  
3) 1621 s  
4) 0.0017 s  
5) \(1.32\times10^{-8}\) s

**Answers:**  
1) D  
2) A  
3) C  
4) E  
5) E  
6) C  
7) A  
8) E  
9) A  
10) D  
11) C  
12) A  
13) B  
14) D  
15) D  
16) E  
17) B  
18) A
Before doing anything, fill in the following on your ParSCORE form:
1) Write your name
2) Bubble in FORM A
3) Bubble in your PERM number (7 digits only—no extra numbers)

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There are a total of 7 pages (18 questions) on the exam. Not every question is worth the same number of points—point values are indicated for each question. You may work out the problems and write your answers on this exam; however, you must completely fill in the appropriate bubble(s) on your ParSCORE form. When you are finished, turn in the ParSCORE form ONLY. You may keep your exam. The answers to the exam will be posted on our course web page.

1. (5 pts) Consider an electrochemical cell described by the following line notation: \( \text{Al} | \text{Al}^{3+},1 | \text{Cu}^{2+} | \text{Cu} \)

Water is added to both half-cell compartments until the volumes of the \( \text{Al}^{3+} \) and \( \text{Cu}^{2+} \) solutions are doubled. How will the cell potential \( E_{\text{cell}} \) be affected?

a) \( E_{\text{cell}} \) will increase
b) \( E_{\text{cell}} \) will decrease
c) \( E_{\text{cell}} \) will not change

2. (5 pts) For the reaction \( A \rightarrow B \) the concentration of \( A \) was measured as a function of time. A plot of \( 1/[A] \) versus time resulted in a straight line. What is the rate law for this reaction?

a) rate = \( k \)
b) rate = \( k[A] \)
c) rate = \( k[A]^{-1} \)
d) rate = \( k[A]^{2} \)
e) rate = \( k[A][B]^{-1} \)

3. (5 pts) Which of the following will have a shorter de Broglie wavelength?

a) A proton (1.7x10\(^{-27}\) kg) traveling at 2x10\(^{5}\) m/s
b) An electron (9.1x10\(^{-31}\) kg) traveling at 2x10\(^{5}\) m/s
c) The proton and electron are traveling at the same velocity, so they will have the same de Broglie wavelength
4. (5 pts) In the hydrogen atom spectrum, which of the following transitions will result in the longest wavelength of absorbed light?

a) \( n = 1 \rightarrow n = 5 \)
b) \( n = 1 \rightarrow n = 3 \)
c) \( n = 2 \rightarrow n = 1 \)
d) \( n = 6 \rightarrow n = 1 \)
e) \( n = 2 \rightarrow n = 3 \)

5. (5 pts) The following two reactions take place in a Galvanic cell. Under standard conditions, what species are produced at each electrode?

\[
\begin{align*}
\text{Cu}^{2+} + 2 \text{e}^- & \rightarrow \text{Cu} \quad \text{E}^0 = 0.34 \text{ V} \\
\text{Mn}^{2+} + 2 \text{e}^- & \rightarrow \text{Mn} \quad \text{E}^0 = -1.18 \text{ V}
\end{align*}
\]

a) Mn is produced at the anode and Cu\(^{2+}\) is produced at the cathode
b) Cu is produced at the anode and Mn\(^{2+}\) is produced at the cathode
c) Mn is produced at the anode and Cu is produced at the cathode
d) Cu is produced at the cathode and Mn\(^{2+}\) is produced at the anode
e) Mn is produced at the cathode and Cu\(^{2+}\) is produced at the anode

6. (5 pts) How many electrons are transferred in the following reaction?

\[
2 \text{SO}_2 + \text{O}_2 + 2 \text{H}_2\text{O} \rightarrow 2 \text{H}_2\text{SO}_4
\]

a) 2
b) 4
c) 6
d) 8
e) 0

7. (5 pts) Calculate the ionization energy for Li\(^{2+}\) when the electron is initially in the \( n = 4 \) state.

a) \( 1.23 \times 10^{-18} \text{ J} \)
b) \( 1.36 \times 10^{-19} \text{ J} \)
c) \( 1.64 \times 10^{-19} \text{ J} \)
d) \( 1.96 \times 10^{-17} \text{ J} \)
e) \( 1.84 \times 10^{-17} \text{ J} \)
Questions 8-9 deal with the following reaction energy diagram:

![Reaction Energy Diagram]

8. (5 pts) Considering the energy diagram above, which of the following represents the activation energy of the reverse reaction?

a) A  

b) B  

c) C  

d) A/C  

e) C/A

9. (5 pts) Considering the energy diagram above, introducing a catalyst into this reaction will change:

a) A only  

b) B only  

c) C only  

d) A and C only  

e) A, B, and C

10. (6 pts) The energy required to remove electrons from the surface of a metal is 329 kJ/mol. What is the minimum frequency of light required to remove an electron from this metal?

a) 1.29 \times 10^{18} \text{ s}^{-1}  

b) 4.97 \times 10^{38} \text{ s}^{-1}  

c) 8.25 \times 10^{14} \text{ s}^{-1}  

b) 2.99 \times 10^{62} \text{ s}^{-1}  

e) 1.29 \times 10^{15} \text{ s}^{-1}
11. (6 pts) Consider the following reaction: \[ 2 \text{NO} + 2\text{H}_2 \rightarrow \text{N}_2 + 2\text{H}_2\text{O} \]

The kinetics of this reaction were studied, and the following data were obtained:

<table>
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<th>([\text{H}_2]_0 \text{ (M)})</th>
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Excluding units, what is the value of the rate constant for this reaction?

a) 1.2  
b) 7.6  
c) 2.4  
d) 0.13  
e) 0.39

12. (6 pts) Determine the rate law for a reaction that occurs according to the following mechanism. Make sure there are no intermediates in your rate law.

\[ \begin{align*}
2 \text{NO} & \rightleftharpoons \text{N}_2\text{O}_2 & \text{fast} \\
\text{N}_2\text{O}_2 + \text{H}_2 & \rightleftharpoons \text{N}_2\text{O} + \text{H}_2\text{O} & \text{fast} \\
\text{N}_2\text{O} + \text{H}_2 & \rightarrow \text{N}_2 + \text{H}_2\text{O} & \text{slow}
\end{align*} \]

a) \( \text{rate} = k[\text{NO}]^2[\text{H}_2][\text{H}_2\text{O}]^{-1} \)  
b) \( \text{rate} = k[\text{N}_2\text{O}][\text{H}_2] \)  
c) \( \text{rate} = k[\text{N}_2\text{O}_2][\text{H}_2][\text{H}_2\text{O}]^{-1} \)  
d) \( \text{rate} = k[\text{NO}][\text{H}_2]^2[\text{H}_2\text{O}]^{-1} \)  
e) \( \text{rate} = k[\text{NO}]^2[\text{H}_2]^2[\text{H}_2\text{O}]^{-1} \)
13. (6 pts) A carbon-fluorine bond in a certain molecule absorbs radiation that has a frequency of $1.2 \times 10^{15}$ s$^{-1}$. What is the energy of this radiation in units of kJ per mole of photons?

a) 479 kJ/mol  
b) 7.95 \times 10^{-22} \text{ kJ/mol}  
c) 1.32 \times 10^{-45} \text{ kJ/mol}  
d) 1.51 \times 10^{-17} \text{ kJ/mol}  
e) 751 \text{ kJ/mol}  

14. (6 pts) We have three separate solutions: one contains Al$^{3+}$, one contains Ca$^{2+}$, and one contains Rb$^+$. These solutions are electrolyzed using the same current to plate out solid metals. Which of the following will take the longest amount of time?

a) Plating 5 grams of solid Al from an Al$^{3+}$ solution  
b) Plating 15 grams of solid Ca from a Ca$^{2+}$ solution  
c) Plating 40 grams of solid Rb from a Rb$^+$ solution  
d) All three processes take the same amount of time  

15. (6 pts) Under standard conditions, what will spontaneously occur when crystals of I$_2$ (s) are added to a solution of NaCl?

\[
\begin{align*}
\text{Cl}_2 (g) + 2 \text{e}^- & \rightarrow 2 \text{Cl}^- & E^o &= 1.36 \text{ V} \\
\text{I}_2 (s) + 2 \text{e}^- & \rightarrow 2 \text{I}^- & E^o &= 0.54 \text{ V} \\
\text{Na}^+ + \text{e}^- & \rightarrow \text{Na (s)} & E^o &= -2.71 \text{ V}
\end{align*}
\]

a) I$^-$ will be formed  
b) Cl$_2$ (g) will be formed  
c) Na (s) will be formed  
d) More than one of these will spontaneously occur  
e) None of these will spontaneously occur
16. (6 pts) Consider an electrochemical cell described as follows: \[ \text{Al | Al}^{3+} || \text{Cd}^{2+} | \text{Cd} \]

Calculate $\Delta G$ for this reaction at 298K when $[\text{Al}^{3+}] = 0.034 \text{ M}$ and $[\text{Cd}^{2+}] = 3.2 \text{ M}$.

\[
\begin{align*}
\text{Cd}^{2+} + 2 \text{ e}^- & \rightarrow \text{Cd} \quad E^0 = -0.40 \text{ V} \\
\text{Al}^{3+} + 3 \text{ e}^- & \rightarrow \text{Al} \quad E^0 = -1.66 \text{ V}
\end{align*}
\]

a) $-741 \text{ kJ}$  
b) $-787 \text{ kJ}$  
c) $-846 \text{ kJ}$  
d) $-729 \text{ kJ}$  
e) $-755 \text{ kJ}$

17. (6 pts) Consider the following first-order reaction: \[ A \rightarrow \text{Products} \]

The half-life for this reaction is 500 s at 530 K. Calculate the half-life for this reaction at 680 K. The activation energy for the reaction is 120 kJ/mol.

a) $2.0 \times 10^3 \text{ s}$  
b) $1.23 \text{ s}$  
c) $0.56 \text{ s}$  
d) $500 \text{ s}$  
e) $0.17 \text{ s}$
18. (6 pts) Consider the second order reaction \[ \text{A} \rightarrow \text{products} \] (which has a first half-life of 32 s). If the concentration of A is 0.58 M after 14.2 seconds, determine the initial concentration of A.

a) 1.2 M  
b) 0.42 M  
c) 0.18 M  
d) 0.84 M  
e) 0.78 M

Answers:  
1) B  
2) D  
3) A  
4) E  
5) D  
6) B  
7) A  
8) C  
9) D  
10) C  
11) C  
12) E  
13) A  
14) B  
15) E  
16) E  
17) B  
18) D
Before doing anything, fill in the following on your ParSCORE form:

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2) Bubble in FORM B
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1. (5 pts) The light absorbed for the n=2 to n=4 transition in the H atom will have ________ wavelength than the light absorbed for the n=2 to n=4 transition in He⁺.

   a) longer
   b) shorter
   c) the same

2. (5 pts) A reaction is believed to occur according to the following mechanism:

   \[ 2 \text{NO} \rightleftharpoons \text{N}_2\text{O}_3 \quad \text{fast} \]
   \[ \text{N}_2\text{O}_2 + \text{H}_2 \rightarrow \text{N}_2\text{O} + \text{H}_2\text{O} \quad \text{slow} \]
   \[ \text{N}_2\text{O} + \text{H}_2 \rightleftharpoons \text{N}_2 + \text{H}_2\text{O} \quad \text{fast} \]

What are the units of the rate constant (k) for the overall reaction?

   a) \( \text{M}^{-3/2} \text{ s}^{-1} \)
   b) \( \text{M}^{-1} \text{ s}^{-1} \)
   c) \( \text{M} \text{ s}^{-1} \)
   d) \( \text{M}^{-3} \text{ s}^{-1} \)
   e) \( \text{M}^{-2} \text{ s}^{-1} \)
3. (5 pts) Rank Cd, H₂, and Cu⁺ in order of increasing reducing strength.

\[
\begin{align*}
\text{Cu}^+ + e^- &\rightarrow \text{Cu} (s) \quad E^0 = 0.52 \text{ V} \\
\text{Cu}^{2+} + e^- &\rightarrow \text{Cu}^+ \quad E^0 = 0.16 \text{ V} \\
2 \text{H}^+ + 2 e^- &\rightarrow \text{H}_2 (g) \quad E^0 = 0.00 \text{ V} \\
\text{Cd}^{2+} + 2 e^- &\rightarrow \text{Cd} (s) \quad E^0 = -0.40 \text{ V} \\
\text{H}_2 (g) + 2 e^- &\rightarrow 2 \text{H}^- \quad E^0 = -2.23 \text{ V}
\end{align*}
\]

a) Cd < Cu⁺ < H₂  
b) Cu⁺ < Cd < H₂  
c) Cu⁺ < H₂ < Cd  
d) H₂ < Cd < Cu⁺  
e) Cd < H₂ < Cu⁺

Questions 4-5: Consider the energy diagram shown below for the reaction A \(\rightarrow\) B

![Energy Diagram](image)

reaction progress

4. (5 pts) A catalyst is added that acts only on the second step of this reaction’s mechanism. What effect will this catalyst have on the overall rate of the reaction A \(\rightarrow\) B?

a) The overall rate of reaction will increase  
b) The overall rate of reaction will not change  
c) The overall rate of reaction will decrease

5. (5 pts) Based on the energy diagram above, the reaction A \(\rightarrow\) B is __________

a) Endothermic  
b) Exothermic  
c) Neither exothermic nor endothermic  
d) Both exothermic and endothermic
6. (5 pts) Fill in the blank: To increase the de Broglie wavelength of an object, one must _____________ its velocity.

a) increase  
b) the de Broglie wavelength will not change if velocity is changed  
c) decrease

7. (5 pts) You have been given a Galvanic cell: one half-cell consists of an Fe (s) electrode immersed in a 1.0 M solution of Fe\(^{2+}\). The substances used in the other half-cell are unknown. When an NaNO\(_3\) salt bridge connects the two half-cells, NO\(_3^-\) ions from the salt bridge flow into the half-cell containing Fe\(^{2+}\) and Fe (s). Which are more likely to the substances used in the unknown half-cell?

\[
\begin{align*}
\text{Ni}^{2+} + 2 \text{e}^- & \rightarrow \text{Ni} (s) \quad E^0 = -0.25 \text{ V} \\
\text{Fe}^{2+} + 2 \text{e}^- & \rightarrow \text{Fe} (s) \quad E^0 = -0.44 \text{ V} \\
\text{Zn}^{2+} + 2 \text{e}^- & \rightarrow \text{Zn} (s) \quad E^0 = -0.76 \text{ V}
\end{align*}
\]

a) A Ni (s) electrode immersed in a 1.0 M solution of Ni\(^{2+}\)  
b) A Zn (s) electrode immersed in a 1.0 M solution of Zn\(^{2+}\)

8. (5 pts) Determine the balanced reaction described by the line notation: \( \text{Pt} | \text{Cr}^{2+}, \text{Cr}^{3+} | || \text{Co}^{2+} | \text{Co} \)

a) \( \text{Pt} + 2 \text{Co}^{2+} \rightarrow \text{Cr}^{2+} + \text{Cr}^{3+} + \text{Co} \)  
b) \( 2 \text{Cr}^{2+} + \text{Co} \rightarrow \text{Co} + 2 \text{Cr}^{3+} \)  
c) \( \text{Pt} + \text{Cr}^{2+} + \text{Cr}^{3+} \rightarrow \text{Co}^{3+} + \text{Co} \)  
d) \( \text{Cr}^{2+} + \text{Cr}^{3+} \rightarrow \text{Co}^{2+} + \text{Co} \)  
e) \( 2 \text{Cr}^{3+} + \text{Co}^{2+} \rightarrow 2 \text{Cr}^{3+} + \text{Co} \)
9. (5 pts) For the reaction \(A \rightarrow \text{Products}\), a plot of \([A]\) vs. time yields a straight line if the reaction is ____________

a) Zero order  
b) First order  
c) Second order  
d) All of these  
e) None of these

10. (6 pts) Determine \(K\) for the following reaction at \(25^\circ\text{C}\):

\[
\text{Hg}_2\text{Cl}_2 (s) \rightleftharpoons \text{Hg}^{2+} (aq) + 2 \text{Cl}^- (aq)
\]

Using the following standard reduction potentials:

\[
\begin{align*}
\text{Cl}_2 (g) + 2 \text{e}^- & \rightarrow 2 \text{Cl}^- (aq) & E^0 = 1.36 \text{ V} \\
\text{Hg}^{2+} (aq) + 2 \text{e}^- & \rightarrow 2 \text{Hg} (l) & E^0 = 0.789 \text{ V} \\
\text{Hg}_2\text{Cl}_2 (s) + 2 \text{e}^- & \rightarrow 2 \text{Hg} (l) + 2 \text{Cl}^- (aq) & E^0 = 0.271 \text{ V}
\end{align*}
\]

Note: You may not need to use all of the reduction potentials provided here.

a) \(3.0 \times 10^{-18}\)  
b) \(4.5 \times 10^{-41}\)  
c) \(1.4 \times 10^{-36}\)  
d) \(9.0 \times 10^{-36}\)  
e) \(7.2 \times 10^{35}\)

11. (6 pts) Calculate the total energy of 3.1 moles of orange photons (\(\lambda = 550\ \text{nm}\))

a) \(7.03 \times 10^4\ \text{J}\)  
b) \(2.18 \times 10^5\ \text{J}\)  
c) \(1.12 \times 10^{-18}\ \text{J}\)  
d) \(2.18 \times 10^{-6}\ \text{J}\)  
e) \(6.74 \times 10^5\ \text{J}\)
12. (6 pts) The kinetics of the following reaction are studied: \( A + B \rightarrow \text{Products} \)

The following data were collected:

<table>
<thead>
<tr>
<th>A (M)</th>
<th>B (M)</th>
<th>Initial Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.35</td>
<td>2.4</td>
<td>1.48</td>
</tr>
<tr>
<td>0.70</td>
<td>2.4</td>
<td>5.92</td>
</tr>
<tr>
<td>0.35</td>
<td>4.8</td>
<td>5.92</td>
</tr>
</tbody>
</table>

What will be the initial rate if \([A] = 1.9 \text{ M}\) and \([B] = 2.1 \text{ M}\)?

a) 15.4 M/s
b) 2.31 M/s
c) 8.23 M/s
d) 32.3 M/s
e) 3.92 M/s

13. (6 pts) Consider the following second order reaction: \( A \rightarrow \text{Products} \)

It takes 241 seconds for the concentration of A to decrease to 25% of its initial value. What is the half life for this reaction?

a) 121 s
b) 482 s
c) 60 s
d) 80 s
e) 723 s

14. (6 pts) A certain first-order reaction has an activation energy of 85 kJ/mol. At a temperature of 84°C, the rate constant \((k)\) is 97 s\(^{-1}\). At what temperature (in degrees Celsius) will the rate constant equal 9700 s\(^{-1}\)?

a) 81°C
b) 35°C
c) 152°C
d) 308°C
e) 425°C
15. (6 pts) The energy required to remove electrons from the surface of a metal is \(222 \text{ kJ/mol}\). Calculate the maximum kinetic energy of an electron ejected from this metal when it is exposed to light with a wavelength of 304 nm.

a) \(3.69 \times 10^{-19} \text{ J}\)
b) \(2.85 \times 10^{-19} \text{ J}\)
c) \(1.34 \times 10^{-19} \text{ J}\)
d) \(2.22 \times 10^{5} \text{ J}\)
e) \(1.02 \times 10^{-18} \text{ J}\)

16. (6 pts) Consider the emission spectrum of the one-electron species \(X^{m+}\). If the electron transitions from an initial state of \(n=5\) to a final state of \(n=3\), photons are emitted with a wavelength of 142.5 nm.

If the electron transitions from an unknown initial state to a final state of \(n=3\), photons are emitted with a wavelength of 111.7 nm. What is the unknown initial state responsible for this wavelength of emitted light?

a) 4
b) 6
c) 8
d) 2
e) 7

2 more questions on the last page ——>
17. (5 pts) Consider the galvanic cell shown below:

Initially, the mass of the Al (s) electrode = 116 g, and the mass of the Zn (s) electrode = 150 g. Assuming the reaction goes to completion, calculate the final mass of the Al (s) electrode.

\[ \text{Zn}^{2+} + 2 \text{e}^- \rightarrow \text{Zn} \ (s) \quad E^0 = -0.76 \text{V} \]
\[ \text{Al}^{3+} + 3 \text{e}^- \rightarrow \text{Al} \ (s) \quad E^0 = -1.66 \text{V} \]

a) 125 g
b) 103 g
c) 8.8 g
d) 107 g
e) 13 g

18. (6 pts) The molar mass of element X was determined by electrolyzing a solution of X^{3+} ions. It took 48 minutes for a current of 12 A to plate out 29 grams of solid X. What is the molar mass of X? Note: 1 minute = 60 seconds.

a) 140 g/mol
b) 27 g/mol
c) 81 g/mol
d) 94 g/mol
e) 243 g/mol

Before doing anything, fill in the following on your ParSCORE form:

1) Write your name
2) Bubble in FORM B
3) Bubble in your PERM number (7 digits only—no extra numbers)

Instructions: No hats or hoods allowed. No books or notes allowed. No sharing of calculators. Cell phones, iPods, headsets/headphones, and any other electronic devices must be turned off and put away.

There are a total of 7 pages (18 questions) on the exam. Not every question is worth the same number of points—point values are indicated for each question. You may work out the problems and write your answers on this exam; however, you must completely fill in the appropriate bubble(s) on your ParSCORE form. When you are finished, turn in the ParSCORE form ONLY. You may keep your exam. The answers to the exam will be posted on our course web page.

1. (5 pts) Consider the following mechanism:

\[ \text{O}_3 (g) + \text{NO} (g) \rightarrow \text{NO}_2 (g) + \text{O}_2 (g) \]
\[ \text{NO}_2 (g) + \text{O} (g) \rightarrow \text{NO} (g) + \text{O}_2 (g) \]

Which of the following acts as a catalyst in this reaction?

a) \text{O}_3 \\
b) \text{O}_2 \\
c) \text{NO}_2 \\
d) \text{NO} \\
e) More than one of these

2. (5 pts) For the chemical reaction: \[ 2 \text{O}_3 (g) \rightarrow 3 \text{O}_2 (g) \]

The rate law was determined to be \( \text{rate} = k [\text{O}_3]^2 [\text{O}_2]^{-1} \)

What are the units of the rate constant \( k \) for this reaction?

a) \( \text{s}^{-1} \) \\
b) \( \text{M s}^{-1} \) \\
c) \( \text{M}^{-1} \text{s}^{-1} \) \\
d) \( \text{M}^{-2} \text{s}^{-1} \) \\
e) \( \text{M}^{3} \text{s}^{-1} \)
3. (6 pts) Consider the reaction: \[ A \rightleftharpoons B \]

The activation energy of the forward reaction is 25 kJ/mol. The activation energy of the reverse reaction is 42 kJ/mol. According to collision theory, what will happen to the position of equilibrium if temperature is increased?

a) The position of equilibrium shifts right
b) The position of equilibrium shifts left
c) The position of equilibrium does not shift

4. (5 pts) According to experiments concerned with the photoelectric effect, which of the following will increase the kinetic energy of an electron ejected from a metal surface?

I. Decreasing the wavelength of the light striking the surface
II. Decreasing the frequency of the light striking the surface
III. Increasing the intensity of light striking the surface

a) I. only
b) II. only
c) III. only
d) I. and II.
e) I. and III.

5. (5 pts) Will silver dissolve in a 1.0 M solution of CuBr₂?

\[ \begin{align*}
\text{Br}_2 (l) + 2 e^- &\rightarrow 2 \text{Br}^- (aq) & E^0 &= 1.08 \text{ V} \\
\text{Ag}^+ + e^- &\rightarrow \text{Ag} (s) & E^0 &= 0.80 \text{ V} \\
\text{Cu}^{2+} + 2 e^- &\rightarrow \text{Cu} (s) & E^0 &= 0.34 \text{ V}
\end{align*} \]

a) Yes
b) No
6. (5 pts) Consider a Galvanic cell described by the following two half reactions:

\[
\text{Sn}^{2+} + 2 \text{e}^- \rightarrow \text{Sn} (s) \quad E^\circ = -0.14 \text{ V} \\
\text{Fe}^{2+} + 2 \text{e}^- \rightarrow \text{Fe} (s) \quad E^\circ = -0.44 \text{ V}
\]

A NaNO\textsubscript{3} salt bridge is used in the construction of this Galvanic cell. Into which compartment will Na\textsuperscript{+} ions flow?

a) Into the compartment containing Fe\textsuperscript{2+} and Fe (s)
b) Into the compartment containing Sn\textsuperscript{2+} and Sn (s)
c) Into both compartments

7. (5 pts) Determine the frequency of the wave shown below:

![Graph of amplitude vs time](image)

a) 3 s\textsuperscript{-1} 
b) 6 s\textsuperscript{-1} 
c) 2 s\textsuperscript{-1} 
d) 12 s\textsuperscript{3} 
e) 4 s\textsuperscript{-1}

8. (5 pts) For the reaction \( \text{A} \rightarrow \text{Products} \), the half-lives remain constant over time if the reaction is ______

a) Second order 
b) Zero order 
c) First order 
d) All of these 
e) None of these
9. (5 pts) A reaction is believed to occur according to the following mechanism:

\[
\begin{align*}
2 \text{NO} & \rightleftharpoons \text{N}_2\text{O}_2 & \text{fast} \\
\text{N}_2\text{O}_2 + \text{H}_2 & \rightarrow \text{N}_2\text{O} + \text{H}_2\text{O} & \text{slow} \\
\text{N}_2\text{O} + \text{H}_2 & \rightleftharpoons \text{N}_2 + \text{H}_2\text{O} & \text{fast}
\end{align*}
\]

What is the rate law for this reaction?

a) \( k [\text{H}_2]^2 [\text{NO}]^2 \)

b) \( k [\text{H}_2] [\text{NO}]^{-1/2} \)

c) \( k [\text{N}_2\text{O}_2] [\text{H}_2] \)

d) \( k [\text{N}_2\text{O}_2] [\text{H}_2] [\text{N}_2\text{O}]^{-1} [\text{H}_2\text{O}]^{-1} \)

e) \( k [\text{H}_2] [\text{NO}]^2 \)

10. (6 pts) How much energy is required to ionize 0.87 moles of hydrogen atoms?

a) \( 1.90 \times 10^{-18} \text{ J} \)

b) \( 7.54 \times 10^5 \text{ J} \)

c) \( 3.15 \times 10^{-12} \text{ J} \)

d) \( 1.14 \times 10^5 \text{ J} \)

e) \( 1.31 \times 10^6 \text{ J} \)

11. (6 pts) 349 grams of molten Na\(_2\)O (62 g/mol) are electrolyzed using a current of 15 A. How long will it take to plate out all of the Na\(^+\) ions? Note: 1 hour = 3600 seconds.

a) 1.8 hour

b) 3.6 hour

c) 20 hour

d) 10 hour

e) 40 hour
12. (6 pts) Consider the following reaction: \[ 2 \text{Cr}^{3+} + \text{Co}^{2+} \rightarrow 2 \text{Cr}^{3+} + \text{Co} \] \( E^0 = 0.22 \text{ V} \)

Calculate the cell potential at 298K when \([\text{Cr}^{2+}] = 0.23 \text{ M}, [\text{Co}^{3+}] = 0.25 \text{ M}, \text{ and } [\text{Cr}^{3+}] = 2.4 \text{ M}.\)

a) 0.06 V
b) 0.19 V
c) 0.14 V
d) 0.17 V
e) 0.22 V

13. (6 pts) When an electron in Li\(^{2+}\) relaxes from an initial state of \( n = 7 \), a photon with a wavelength of 112 nm is emitted. What is the final state of the electron?

a) \( n = 2 \)
b) \( n = 10 \)
c) \( n = 6 \)
d) \( n = 4 \)
e) \( n = 3 \)

14. (6 pts) Calculate \( K \) for the following reaction at 298K: \[ 3 \text{Au}^+ \rightleftharpoons \text{Au}^{3+} + 2 \text{Au} (s) \]

Given the following standard reduction potentials:

\[
\text{Au}^+ + e^- \rightarrow \text{Au} (s) \quad E^0 = 1.69 \text{ V} \\
\text{Au}^{3+} + 3 e^- \rightarrow \text{Au} (s) \quad E^0 = 1.50 \text{ V} \\
\text{Au}^{3+} + 2 e^- \rightarrow \text{Au}^+ \quad E^0 = 1.26 \text{ V}
\]

Note: you may not need to use all of the reduction potentials provided here.

a) \( 1635 \)
b) \( 3.5 \times 10^{14} \)
c) \( 4.3 \times 10^{43} \)
d) \( 2.3 \times 10^{24} \)
e) \( 4.4 \times 10^{9} \)
15. (6 pts) The half-life for a first order reaction is 123 sec at 298K and 37 sec at 350K. What will be the half-life for this reaction at 533K?

a) 393 sec  
b) 3.5 sec  
c) 4346 sec  
d) 7.5 sec  
e) 14.3 sec

16. (6 pts) Consider the following elementary (single-step) reaction: \( 2 \text{NO}_2 \text{(g)} \rightarrow 2 \text{NO} \text{(g)} + \text{O}_2 \text{(g)} \)

The rate constant \(k\) for this reaction is 0.86 M\(^{-1}\) s\(^{-1}\) at 600K. Into a rigid, evacuated container, 2.50 atm of \(\text{NO}_2\) is added. Calculate the total pressure in the container at 600K after 20 seconds.

a) 3.75 atm  
b) 2.50 atm  
c) 1.33 atm  
d) 3.09 atm  
e) 1.76 atm
17. (6 pts) $C_60$ is a molecule containing 60 carbon atoms which adopts a soccer-ball shape. This shape can be assumed to be a sphere with a diameter of 0.70 nm. At what velocity will a $C_60$ molecule have a de Broglie wavelength equal to its diameter?

a) $1.3 \times 10^{-34}$ m/s  
b) 0.047 m/s  
c) 47 m/s  
d) 0.79 m/s  
e) $7.9 \times 10^{-4}$ m/s

18. (6 pts) Consider an electrochemical cell described as follows: $\text{Fe} | \text{Fe}^{2+} | \text{Cd}^{2+} | \text{Cd}$

The initial concentration of $\text{Cd}^{2+}$ is 1.00 M, and the initial concentration of $\text{Fe}^{2+}$ is 0.50 M. Calculate $[\text{Fe}^{2+}]$ when the reaction reaches equilibrium at 298K.

$$\text{Cd}^{2+} + 2 \text{e}^- \rightarrow \text{Cd} (s) \quad E^0 = -0.40 \text{ V}$$
$$\text{Fe}^{2+} + 2 \text{e}^- \rightarrow \text{Fe} (s) \quad E^0 = -0.44 \text{ V}$$

a) 1.44 M  
b) $1.6 \times 10^{-5}$ M  
c) 0.064 M  
d) 0.94 M  
e) 1.24 M

Answers: 1) D  
          2) A  
          3) B  
          4) A  
          5) B  
          6) B  
          7) C  
          8) C  
          9) E  
          10) D  
          11) C  
          12) C  
          13) E  
          14) B  
          15) B  
          16) D  
          17) D  
          18) A
Exam 2

Multiple Choice
Identify the choice that best completes the statement or answers the question.
Record the test form letter in the TEST FORM box on your ParSCORE form.
Record your name on the top of this exam and on the scantron form.
Be sure to fill out your perm ID# on your scantron correctly.
Record all of your answers on the scantron form.

1. (4 points) According to the Heisenberg uncertainty principle,
   a. the momentum of a particle cannot be measured precisely.
   b. neither the position nor the momentum of a particle can be measured precisely.
   c. the position and momentum of a particle can be measured precisely, but not at the same time.
   d. the position of a particle cannot be measured precisely.

2. (5 points) For the hypothetical reaction \( A + B^X \rightarrow A^X + B, \ E^o = 1.19 \ V = \text{and} \ \Delta G^o = -115 \ kJ \). For this reaction the value of \( x = \) __________.
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5

3. (4 points) The equilibrium constant \( K_p \) for the dissociation reaction of \( \text{Cl}_2 \)
   \[ \text{Cl}_2(g) \rightleftharpoons 2\text{Cl}(g) \]
   was measured as a function of temperature (in K). A graph of \( \ln K_p \) versus \( 1/T \) for this reaction gives a straight line with a slope of \(-1.352 \times 10^4\) and an intercept of 14.51. What is the value of \( \Delta S \) for this dissociation reaction?
   a. 26.81 J/K•mol
   b. 112.0 J/K•mol
   c. 53.14 J/K•mol
   d. 120.6 J/K•mol
   e. none of these
A mechanism for a naturally occurring reaction that destroys ozone is:

Step 1: \( \text{O}_3(g) + \text{HO}(g) \rightarrow \text{HO}_2(g) + \text{O}_2(g) \)

Step 2: \( \text{HO}_2(g) + \text{O}(g) \rightarrow \text{HO}(g) + \text{O}_2(g) \)

__4. (3 points) Which species is an intermediate?__

a. \( \text{HO} \)

b. \( \text{HO}_2 \)

c. \( \text{O} \)

d. \( \text{O}_3 \)

__5. (3 points) Which species is a catalyst?__

a. \( \text{HO} \)

b. \( \text{HO}_2 \)

c. \( \text{O} \)

d. \( \text{O}_3 \)

__6. (6 points) Hydrogen peroxide decomposes to water and oxygen according to the reaction below:__

\[ 2 \text{H}_2\text{O}_2(aq) \rightarrow 2 \text{H}_2\text{O}(l) + \text{O}_2(g) \]

What is the average rate of disappearance of \( \text{H}_2\text{O}_2(aq) \) in M/s in the first 45.0 seconds of the reaction if 1.00 L of \( \text{H}_2\text{O}_2 \) reacts at 25°C and 1.00 atm pressure?

<table>
<thead>
<tr>
<th>Time (s)</th>
<th>( \text{O}_2 ) Collected (mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>45.0</td>
<td>2</td>
</tr>
<tr>
<td>90.0</td>
<td>4</td>
</tr>
</tbody>
</table>

a. \( 1.64 \times 10^{-4} \) M/s
b. \( 4.33 \times 10^{-5} \) M/s
c. \( 3.63 \times 10^{-6} \) M/s
d. \( 9.09 \times 10^{-7} \) M/s
e. none of these
7. (6 points) How many grams of nickel metal are plated out when a constant current of 15.0 A is passed through aqueous NiCl₂ for 80.0 minutes?
   a. 48.4 g
   b. 43.8 g
   c. 21.9 g
   d. 14.7 g
   e. none of these

<table>
<thead>
<tr>
<th>Reaction</th>
<th>( E^0 ) (volts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{Na}^+ + e^- \rightarrow \text{Na} )</td>
<td>-2.71</td>
</tr>
<tr>
<td>( \text{Mg}^{2+} + 2e^- \rightarrow \text{Mg} )</td>
<td>-2.37</td>
</tr>
<tr>
<td>( \text{Al}^{3+} + 3e^- \rightarrow \text{Al} )</td>
<td>-1.66</td>
</tr>
<tr>
<td>( 2 \text{H}_2\text{O} + 2e^- \rightarrow \text{H}_2 + \text{OH}^- )</td>
<td>-0.83</td>
</tr>
<tr>
<td>( \text{Co}^{2+} + 2e^- \rightarrow \text{Co} )</td>
<td>-0.28</td>
</tr>
</tbody>
</table>

8. (5 points) Which will reduce water but not \( \text{Mg}^{2+} \)?
   a. \( \text{Co} \)
   b. \( \text{Al}^{3+} \)
   c. \( \text{Al} \)
   d. \( \text{Na} \)
   e. \( \text{Na}^+ \)

9. (6 points) For a particular first-order reaction, it takes 48 minutes for the concentration of the reactant to decrease to 25% of its initial value. What is the value for rate constant (in \( s^{-1} \)) for the reaction?
   a. \( 1.0 \times 10^{-4} \ s^{-1} \)
   b. \( 4.8 \times 10^{-4} \ s^{-1} \)
   c. \( 2.9 \times 10^{-2} \ s^{-1} \)
   d. \( 6.0 \times 10^{-3} \ s^{-1} \)
10. (5 points) Which cell involves a nonspontaneous redox reaction?
   a. electrolytic cell
   b. fuel cell
   c. galvanic cell
   d. concentration cell

11. (5 points) The greater the energy of a photon, the
   a. longer the wavelength and the higher the frequency.
   b. shorter the wavelength and the higher the frequency.
   c. shorter the wavelength and the lower the frequency.
   d. longer the wavelength and the lower the frequency.

12. (6 points) For a first order reaction, a plot of ln k vs 1/T was graphed and produced a straight line
described by the equation y = -9037x + 33.96. What is the activation energy for this reaction?
   a. -1087 J/mol
   b. 9037 J/mol
   c. 1087 J/mol
   d. 75130 J/mol
   e. 33.96 J/mol

13. (5 points) According to the Bohr model, when a hydrogen electron makes a transition from n=4 to n=2,
which of the following statements is true?
   I. Energy is emitted.
   II. Energy is absorbed.
   III. Electrons lose energy.
   IV. Electrons gain energy.
   a. I only
   b. I and III
   c. I and IV
   d. II and IV
   e. II and III
14. (7 points) The rate law for a reaction is found to be Rate = \( k[A]^2[B] \). Which of the following mechanisms gives this rate law?
   I. \( A + B \leftrightarrow E \) (fast)
      \( E + B \rightarrow C + D \) (slow)
   II. \( A + B \leftrightarrow E \) (fast)
        \( E + A \rightarrow C + D \) (slow)
   III. \( A + A \rightarrow E \) (slow)
        \( E + B \rightarrow C + D \) (fast)

   a. III
   b. II only
   c. I only
   d. two of these
   e. none of these

15. (5 points) What factor affects the rate of a chemical reaction?
   a. collision frequency
   b. fraction of collisions with sufficient energy
   c. orientation of molecules
   d. Only two of the above are factors
   e. a, b and c are all factors

16. (5 points) A galvanic cell consists of a \( \text{La}^{3+}/\text{La} \) half-cell and a standard hydrogen electrode. If the \( \text{La}^{3+}/\text{La} \) half-cell standard cell functions as the anode, and the standard cell potential is 2.52 V, what is the standard reduction potential for the \( \text{La}^{3+}/\text{La} \) half-cell?
   a. -0.84 V
   b. -2.52 V
   c. +2.52 V
   d. +0.84 V
17. (6 points) Which statement below regarding the half-life of a zeroth-order reaction is true?
   a. The half-life remains unchanged throughout the course of the reaction.
   b. Each half-life is half as long as the preceding half-life.
   c. Each half-life is four times as long as the preceding half-life.
   d. Each half-life is twice as long as the preceding half-life.
   e. none of these

18. (7 points) Consider the following cell at 25°C:
     \[ \text{Sn(s)} \mid \text{Sn}^{2+}(0.94 \text{ M}) \parallel \text{Ag}^+(0.94 \text{ M}) \mid \text{Ag(s)} \]
     Calculate the cell potential after the reaction has transpired long enough for [Ag^+] to change by 0.84 M.
     \[ \text{Ag}^+ + e^- \rightarrow \text{Ag} \quad E^o = 0.80 \text{ V} \]
     \[ \text{Sn}^{2+} + 2e^- \rightarrow \text{Sn} \quad E^o = -0.14 \text{ V} \]
   a. 0.88 V
   b. 0.94 V
   c. 0.83 V
   d. 0.98 V
   e. none of these
19. (7 points) The following set of data was obtained by the method of initial rates for the reaction:

\[ \text{S}_2\text{O}_8^{2-}(aq) + 3 \text{I}^-(aq) \rightarrow 2 \text{SO}_4^{2-}(aq) + \text{I}_3^-(aq) \]

What is the initial rate when \( \text{S}_2\text{O}_8^{2-} \) is 0.15 M and \( \text{I}^- \) is 0.15 M?

<table>
<thead>
<tr>
<th>([\text{S}_2\text{O}_8^{2-}] ) (M)</th>
<th>([\text{I}^-] ) (M)</th>
<th>Initial Rate (M s(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25</td>
<td>0.10</td>
<td>9.00 \times 10^{-3}</td>
</tr>
<tr>
<td>0.10</td>
<td>0.10</td>
<td>3.36 \times 10^{-3}</td>
</tr>
<tr>
<td>0.20</td>
<td>0.30</td>
<td>2.16 \times 10^{-2}</td>
</tr>
</tbody>
</table>

a. \( 8.10 \times 10^{-3} \) M s\(^{-1}\)  
b. \( 5.40 \times 10^{-2} \) M s\(^{-1}\)  
c. \( 4.10 \times 10^{-6} \) M s\(^{-1}\)  
d. \( 1.22 \times 10^{-2} \) M s\(^{-1}\)  
e. none of these
Exam 2
Answer Section

MULTIPLE CHOICE

1. ANS: C  PTS:  4
2. ANS: A  PTS:  5
3. ANS: D  PTS:  4
4. ANS: B  PTS:  3
5. ANS: A  PTS:  3
6. ANS: C  PTS:  6
7. ANS: C  PTS:  6
8. ANS: C  PTS:  5
9. ANS: B  PTS:  6
10. ANS: A  PTS:  5
11. ANS: B  PTS:  5
12. ANS: D  PTS:  6
13. ANS: B  PTS:  5
14. ANS: B  PTS:  7
15. ANS: E  PTS:  5
16. ANS: B  PTS:  5
17. ANS: B  PTS:  6
18. ANS: A  PTS:  7
19. ANS: A  PTS:  7
Exam 2

Multiple Choice
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1. (6 points) The reaction $A \rightarrow B$ follows first-order kinetics with a half-life of 14.3 days. If the concentration of $A$ is 0.024 M after 3.25 days, what is the initial concentration of $A$?
   a. 0.11 M
   b. 0.021 M
   c. 0.028 M
   d. 0.030 M
   e. 0.041 M

2. (4 points) Identify intermediates and/or catalysts:
   Step 1: $\text{NO}_2(g) + \text{O}_3(g) \rightarrow \text{NO}_2(g) + \text{O}_2(g)$
   Step 2: $\text{O}_2(g) + \text{NO}_2(g) \rightarrow \text{NO}_2(g) + \text{O}_2(g)$
   a. NO is a catalyst and NO$_2$ is an intermediate
   b. NO$_2$ is a catalyst and NO is an intermediate
   c. NO and NO$_2$ are both catalysts
   d. NO and NO$_2$ are both intermediates
   e. None of these are true

3. (6 points) Calculate $\Delta G^\circ$ for the disproportionation reaction of Cu$^+$ at 25 °C,
   $2 \text{Cu}^+(aq) \rightarrow \text{Cu}^{2+}(aq) + \text{Cu}(s)$
given the following thermodynamic information.
   $\text{Cu}^+(aq) + e^- \rightarrow \text{Cu}(s) \quad E^\circ = +0.518 \text{ V}$
   $\text{Cu}^{2+}(aq) + 2 e^- \rightarrow \text{Cu}(s) \quad E^\circ = +0.337 \text{ V}$
   a. $-165 \text{ kJ}$
   b. $-135 \text{ kJ}$
   c. $-34.9 \text{ kJ}$
   d. $+17.5 \text{ kJ}$
   e. $+135 \text{ kJ}$
4. (6 points) Cu\textsuperscript{2+} is reduced to Cu(s) at an electrode. If a current of 1.25 ampere is passed for 72 hours, what mass of copper is deposited at the electrode? Assume 100% current efficiency. The atomic weight of Cu is 63.546 g/mol.
   a. $1.1 \times 10^2$ g
   b. $3.0 \times 10^{-2}$ g
   c. $2.90 \times 10^2$ g
   d. $2.1 \times 10^2$ g
   e. $4.3 \times 10^2$ g

5. (6 points) Nitrogen dioxide reacts with carbon monoxide to produce nitrogen monoxide and carbon dioxide.
   \[ \text{NO}_2(g) + \text{CO}(g) \rightarrow \text{NO}(g) + \text{CO}_2(g) \]
   A proposed mechanism for this reaction is
   \[ 2 \text{NO}_2(g) \rightleftharpoons \text{NO}_3(g) + \text{NO}(g) \]  
   \[ \text{NO}_3(g) + \text{CO}(g) \rightarrow \text{NO}_2(g) + \text{CO}_2(g) \]
   (fast, equilibrium)  
   (slow)
   What is a rate law that is consistent with the proposed mechanism?
   a. rate = $k[\text{NO}_2]^2[\text{CO}][\text{NO}]^{-1}$
   b. rate = $k[\text{NO}_2]^2[\text{CO}]$
   c. rate = $k[\text{NO}_2][\text{CO}]$
   d. rate = $k[\text{NO}_3][\text{CO}]$
   e. rate = $k[\text{NO}_2]^2$

6. (4 points) In Bohr's atomic theory, when an electron moves from one energy level to another energy level more distant from the nucleus,
   a. energy is emitted.
   b. energy is absorbed.
   c. light is emitted.
   d. no change in energy occurs.
   e. none of these
7. (5 points) Calculate the activation energy, $E_a$, for

$$ \text{N}_2\text{O}_2(g) \rightarrow 2 \text{NO}_2(g) + \frac{1}{2} \text{O}_2(g) $$

given $k$ (at 45.0 °C) = $5.79 \times 10^{-4}$ s$^{-1}$ and $k$ (at 60.0 °C) = $3.83 \times 10^{-3}$ s$^{-1}$.

a. 0.256 kJ/mol
b. 2.83 kJ/mol
c. 31.1 kJ/mol
d. 111 kJ/mol
e. 389 kJ/mol

8. (4 points) For which of the following transitions would a hydrogen atom absorb a photon with the longest wavelength?

a. $n = 1$ to $n = 2$
b. $n = 2$ to $n = 4$
c. $n = 5$ to $n = 1$
d. $n = 7$ to $n = 6$
e. $n = 5$ to $n = 6$

9. (4 points) Use the standard reduction potentials below to determine which element or ion is the best oxidizing agent.

$$ \text{Hg}_2^{2+}(aq) + 2 \text{e}^- \rightarrow 2 \text{Hg(ℓ)} \quad E^o = +0.789 \text{ V} $$

$$ \text{I}_2(s) + 2 \text{e}^- \rightarrow 2 \text{I}^-(aq) \quad E^o = +0.535 \text{ V} $$

$$ \text{Ni}^{2+}(aq) + 2 \text{e}^- \rightarrow \text{Ni(s)} \quad E^o = -0.25 \text{ V} $$

a. $\text{I}_2(s)$
b. $\text{Hg}_2^{2+}(aq)$
c. $\text{I}^-(aq)$
d. $\text{Ni}^{2+}(aq)$
e. $\text{Hg(ℓ)}$
Refer to the galvanic cell below (the contents of each half-cell are written beneath each compartment).

\[
\text{Left Side Concentrations} \\
[Mn^{2+}] = 0.20 \text{ M} \\
[MnO}_4^- = 0.10 \text{ M} \\
[H^+] = 1.0 \text{ M}
\]

\[
\text{Right Side Concentrations} \\
[Cr^{3+}] = 0.40 \text{ M} \\
[Cr}_2O_7^{2-} = 0.30 \text{ M} \\
[H^+] = 1.0 \text{ M}
\]

The standard reduction potentials are as follows:

\[
\text{MnO}_4^- + 8H^+ + 5e^- \rightarrow \text{Mn}^{2+} + 4H_2O \quad E^o = 1.51 \text{ V}
\]

\[
\text{Cr}_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2 \text{ Cr}^{3+} + 7H_2O \quad E^o = 1.33 \text{ V}
\]

10. (3 points) How many electrons are transferred in the balanced reaction (that is, what will be the value of \( n \) in the Nernst equation)?
   a. 22
   b. 30
   c. 2
   d. 6
   e. 5

11. (3 points) When current is allowed to flow, which species is oxidized?
   a. \( \text{Mn}^{2+} \)
   b. \( \text{Cr}^{3+} \)
   c. \( \text{MnO}_4^- \)
   d. \( \text{Cr}_2O_7^{2-} \)
   e. \( H^+ \)

12. (3 points) When current is allowed to flow, which species is reduced?
   a. \( H^+ \)
   b. \( \text{MnO}_4^- \)
   c. \( \text{Cr}^{3+} \)
   d. \( \text{Mn}^{2+} \)
   e. \( \text{Cr}_2O_7^{2-} \)

13. (3 points) In which direction do electrons flow in the external circuit?
   a. right to left
   b. left to right
   c. No current flows; the cell is at equilibrium.
14. (4 points) For a second-order decomposition reaction,

\[ 2A \rightarrow B \]

rate = \( k[A]^2 \)

which of the following functions can be plotted versus time to give a straight line?

a. \([A]\)

b. \(\frac{k}{[A]^2}\)

c. \(\ln\left(\frac{1}{[A]}\right)\)

d. \(\ln[A]\)

e. \(\frac{1}{[A]}\)

15. (5 points) When ethyl chloride, \(\text{CH}_3\text{CH}_2\text{Cl}\), is dissolved in 1.0 \(M\) \(\text{NaOH}\), it is converted into ethanol, \(\text{CH}_3\text{CH}_2\text{OH}\), by the reaction

\[ \text{CH}_3\text{CH}_2\text{Cl} + \text{OH}^- \rightarrow \text{CH}_3\text{CH}_2\text{OH} + \text{Cl}^- \]

If the pre-exponential factor, \(A\), is \(3.4 \times 10^{14} \text{ s}^{-1}\) and the activation energy for the reaction is 100.0 kJ/mol, what will the rate constant be at 28\(^\circ\)C?

a. \(3.8 \times 10^{14} \text{ s}^{-1}\)

b. \(1.1 \times 10^{-3} \text{ s}^{-1}\)

c. \(8.9 \times 10^2 \text{ s}^{-1}\)

d. \(9.2 \times 10^{-3} \text{ s}^{-1}\)

e. \(1.5 \times 10^{-3} \text{ s}^{-1}\)

16. (4 points) Which of the following statements is/are CORRECT?

1. A lithium ion battery is an example of a rechargeable battery, often used in portable devices.

2. Hydrogen-oxygen fuel cells use the heat of combustion of hydrogen to recharge lead storage batteries.

3. Concentration cells create voltages that are typically very large.

a. 1 only

b. 2 only

c. 1 and 2

d. 1 and 3

e. 1, 2, and 3
17. (4 points) Which type of experiment demonstrates that an electron has the properties of a wave?
   a. nuclear fission
   b. electron diffraction
   c. light emission from atomic gases
   d. mass spectroscopy
   e. photoelectric effect

18. (6 points) Given the initial rate data for the reaction \( A + B \rightarrow C \), determine the rate expression for the reaction.

<table>
<thead>
<tr>
<th>[A], M</th>
<th>[B], M</th>
<th>( \frac{\Delta[C]}{\Delta t} ) (initial) M/s</th>
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</thead>
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<tr>
<td>0.0460</td>
<td>0.220</td>
<td>( 1.31 \times 10^{-4} )</td>
</tr>
<tr>
<td>0.0920</td>
<td>0.220</td>
<td>( 5.24 \times 10^{-4} )</td>
</tr>
<tr>
<td>0.0460</td>
<td>0.440</td>
<td>( 1.31 \times 10^{-4} )</td>
</tr>
</tbody>
</table>

   a. \( \frac{\Delta[C]}{\Delta t} = 1.29 \times 10^{-2} \text{ M}^{-2}\text{s}^{-1}[A][B] \)
   b. \( \frac{\Delta[C]}{\Delta t} = 2.81 \times 10^{-1} \text{ M}^{-2}\text{s}^{-1}[A]^2[B] \)
   c. \( \frac{\Delta[C]}{\Delta t} = 6.19 \times 10^{-2} \text{ M}^{-1}\text{s}^{-1}[A]^2 \)
   d. \( \frac{\Delta[C]}{\Delta t} = 5.88 \times 10^{-2} \text{ M}^{-2}\text{s}^{-1}[A][B]^2 \)
   e. \( \frac{\Delta[C]}{\Delta t} = 2.85 \times 10^{-3} \text{ s}^{-1}[A] \)

19. (3 points) What is the overall order of the reaction below
\[ 2 \text{ NO(g)} + \text{ O}_2(\text{g}) \rightarrow 2 \text{ NO}_2(\text{g}) \]
if it proceeds via the following rate expression?
\[ \frac{\Delta\text{[NO]}}{\Delta t} = k\text{[NO]}^2\text{[O}_2]\]

   a. zero-order
   b. first-order
   c. second-order
   d. third-order
   e. fourth-order
20. (6 points) Consider the following galvanic cell at 25°C.

\[ \text{Pt} \mid \text{Cr}^{2+}(0.42\ M), \text{Cr}^{3+}(3.4\ M) \parallel \text{Co}^{2+}(0.22\ M) \mid \text{Co} \]

The overall reaction and equilibrium constant value are given below. Calculate the cell potential, \( E \), for this galvanic cell.

\[ 2 \text{Cr}^{2+}(aq) + \text{Co}^{2+}(aq) \rightarrow 2 \text{Cr}^{3+}(aq) + \text{Co}(s) \quad K = 2.79 \times 10^7 \]

a. 0.220 V  
b. 0.174 V  
c. 0.293 V  
d. 0.147 V  
e. 0.267 V

21. (3 points) Why is aluminum protected from corrosion? (Note: The standard reduction potential for \( \text{Al}^{3+} \) is \(-1.66\ V\).)

a. Oxygen and aluminum have no affinity for one another.  
b. The oxidation of aluminum is not a favored process, as seen by the standard reduction potential for \( \text{Al}^{3+} \).  
c. Aluminum forms a protective oxide coating.  
d. At least two of these are correct.  
e. Aluminum is not protected from corrosion.

22. (4 points) According to collision theory, which condition(s) must be met in order for molecules to react?

1. The reacting molecules must collide with sufficient energy to initiate the process of breaking and forming bonds.  
2. A catalyst must be in contact with the reacting molecules for a reaction to occur.  
3. The reacting molecules must collide with an orientation that can lead to rearrangement of the atoms.

a. 1 only  
b. 2 only  
c. 3 only  
d. 1 and 2  
e. 1 and 3
23. (4 points) The ____ of a photon of light is ____ proportional to its frequency and ____ proportional to its wavelength.
   a. energy, directly, inversely
   b. energy, inversely, directly
   c. velocity, directly, inversely
   d. intensity, inversely, directly
   e. amplitude, directly, inversely
Exam 2
Answer Section

MULTIPLE CHOICE

1. ANS: C  PTS: 6
2. ANS: A  PTS: 4
3. ANS: C  PTS: 6
4. ANS: A  PTS: 6
5. ANS: A  PTS: 6
6. ANS: B  PTS: 4
7. ANS: D  PTS: 5
8. ANS: E  PTS: 4
9. ANS: B  PTS: 4
10. ANS: B PTS: 3
11. ANS: B PTS: 3
12. ANS: B PTS: 3
13. ANS: A PTS: 3
14. ANS: E PTS: 4
15. ANS: E PTS: 5
16. ANS: A PTS: 4
17. ANS: B PTS: 4
18. ANS: C PTS: 6
19. ANS: D PTS: 3
20. ANS: D PTS: 6
21. ANS: C PTS: 3
22. ANS: E PTS: 4
23. ANS: A PTS: 4
Exam 2

Multiple Choice
Identify the choice that best completes the statement or answers the question.
Record the test form letter in the TEST FORM box on your ParSCORE form.
Record your name on the top of this exam and on the scantron form.
Be sure to fill out your perm ID# on your scantron correctly.
Record all of your answers on the scantron form.

1. (6 points) According to collision theory, which condition(s) must be met in order for molecules to react?
   1. The reacting molecules must collide with sufficient energy to initiate the
      process of breaking and forming bonds.
   2. The reacting molecules must collide with an orientation that can lead to
      rearrangement of the atoms.
   3. A catalyst must be in contact with the reacting molecules for a reaction to
      occur.

   a. 1 only
   b. 2 only
   c. 3 only
   d. 1 and 2
   e. 1 and 3

2. (4 points) According to experiments concerned with the photoelectric effect, decreasing the wavelength of
   the light striking the surface will increase the kinetic energy of an electron ejected from a metal surface.
   a. True
   b. False

3. (4 points) In a typical lithium-ion battery, an ammonium chloride paste is used as a salt bridge to transfer
   negative ions.
   a. True
   b. False

4. (4 points) Concentration cells create voltages that are typically very large.
   a. True
   b. False
5. (6 points) The reaction $2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2$ has the following mechanism:
   
   $\text{H}_2\text{O}_2 + \text{I}^- \rightarrow \text{H}_2\text{O} + \text{IO}^-$
   
   $\text{H}_2\text{O} + \text{IO}^- \rightarrow \text{H}_2\text{O} + \text{O}_2 + \text{I}^-$
   
   What is the catalyst in the reaction?
   
   a. There is no catalyst.
   b. $\text{H}_2\text{O}_2$
   c. $\text{H}_2\text{O}$
   d. $\text{IO}^-$
   e. $\text{I}^-$

6. (6 points) If a constant current of 8.00 amperes is passed through a cell containing $\text{Zn}^{2+}$ for 2.00 hours, how many grams of zinc will plate out onto the cathode?
   
   a. 0.985 g
   b. 126 g
   c. $1.43 \times 10^3$ g
   d. 19.5 g
   e. 39.0 g

7. (7 points) For a given reaction, the rate constant triples when the temperature is increased from 32 °C to 71 °C. What is the activation energy for this reaction?
   
   a. 3.00 kJ/mol
   b. 24.6 kJ/mol
   c. 0.234 kJ/mol
   d. 0.532 kJ/mol
   e. 53.2 kJ/mol
8. (6 points) For the reaction \( A + 2B \rightarrow C \), the rate law is
\[
\frac{\Delta [C]}{\Delta t} = k[A]^0.
\]
What are the units of the rate constant where time is measured in seconds?

a. \( \frac{1}{s} \)

b. \( \frac{1}{M \cdot s} \)

c. \( \frac{M^2}{s} \)

d. \( \frac{M}{s} \)

e. \( \frac{1}{M^2 \cdot s} \)

9. (6 points) Consider the following half-reactions:

\[
\begin{align*}
F_2(g) + 2 e^- & \rightarrow 2 F^-(aq) & E^o &= +2.87 \text{ V} \\
Cu^{2+}(aq) + 2 e^- & \rightarrow Cu(s) & E^o &= +0.34 \text{ V} \\
Sn^{2+}(aq) + 2 e^- & \rightarrow Sn(s) & E^o &= -0.14 \text{ V} \\
Al^{3+}(aq) + 3 e^- & \rightarrow Al(s) & E^o &= -1.66 \text{ V} \\
Na^+(aq) + e^- & \rightarrow Na(s) & E^o &= -2.71 \text{ V}
\end{align*}
\]
Which of the above elements or ions will reduce \( Sn^{2+}(aq) \)?

a. \( F_2(g) \) and \( Cu^{2+}(aq) \)

b. \( F^-(aq) \) and \( Cu(s) \)

c. \( Al^{3+}(aq) \) and \( Na^+(aq) \)

d. \( Al(s) \) and \( Na(s) \)

e. \( Cu(s) \) and \( Al^{3+}(aq) \)

10. (6 points) What is the energy (in kJ) of 1.00 mole of photons of green light with a wavelength of 507 nm?

a. 4.24 kJ

b. 60.7 kJ

c. 91.6 kJ

d. 152 kJ

e. 236 kJ
11. (7 points) For the overall reaction
   \[ A + 2B \rightarrow C \]
   which of the following mechanisms yields the correct overall chemical equation and is consistent with the rate equation below?
   \[ \text{rate} = k[A][B] \]
   a. \( A + B \rightleftharpoons I \) (fast)
      \( I + A \rightarrow C \) (slow)
   b. \( A + B \rightarrow I \) (slow)
      \( I + B \rightarrow C \) (fast)
   c. \( A + 2B \rightleftharpoons I \) (fast)
      \( I + B \rightarrow C + B \) (slow)
   d. \( 2B \rightleftharpoons I \) (fast)
      \( I + A \rightarrow C \) (slow)
   c. \( 2B \rightarrow I \) (slow)
      \( A + I \rightarrow C \) (fast)

12. (7 points) Calculate the standard reduction potential for the following reaction at 25 °C,
   \[ \text{AuCl}_4^-(aq) + 3 \text{e}^- \rightarrow \text{Au(s)} + 4 \text{Cl}^- (aq) \]
given the following thermodynamic information.
   \[ \text{Au}^{3+}(aq) + 3 \text{e}^- \rightarrow \text{Au(s)} \quad E^\circ = +1.50 \text{ V} \]
   \[ \text{Au}^{2+}(aq) + 4 \text{Cl}^- (aq) \rightarrow \text{AuCl}_4^- (aq) \quad K_f = 2.3 \times 10^{25} \]
   a. -0.50 V
   b. -1.28 V
   c. +1.28 V
   d. +1.00 V
   e. +3.85 V

13. (6 points) For a second-order decomposition reaction,
   \[ 2A \rightarrow B \]
   which of the following functions can be plotted versus time to give a straight line?
   a. \([A]\)
   b. \(\frac{k}{[A]^2}\)
   c. \(\ln \frac{1}{[A]}\)
   d. \(\frac{1}{[A]}\)
   c. \(\ln[A]\)
14. (6 points) Calculate $E_{\text{cell}}$ for the following electrochemical cell at 25 °C

$\text{Cl}^-(\text{aq}, 0.20 \text{ M}) \mid \text{AgCl(s)} \mid \text{Ag(s)} \parallel \text{Pt(s)} \mid \text{Fe}^{3+}(\text{aq}, 0.25 \text{ M}), \text{Fe}^{2+}(\text{aq}, 0.25 \text{ M})$

given the following standard reduction potentials.

$\text{AgCl(s)} + e^- \rightarrow \text{Ag(s)} + \text{Cl}^-(\text{aq}) \quad E^o = +0.222 \text{ V}$

$\text{Fe}^{3+}(\text{aq}) + e^- \rightarrow \text{Fe}^{2+}(\text{aq}) \quad E^o = +0.771 \text{ V}$

a. +0.549 V  
b. +0.508 V  
c. +0.135 V  
d. +0.590 V  
e. −0.549 V

15. (7 points) The decomposition of phosphine, PH$_3$, follows first-order kinetics.

$4\ \text{PH}_3(\text{g}) \rightarrow \text{P}_4(\text{g}) + 6\ \text{H}_2(\text{g})$

The half-life for the reaction at 550 °C is 81.3 seconds. What percentage of phosphine remains after 275 seconds?

a. 30%  
b. 2.3%  
c. 9.6%  
d. 26%  
e. 74%
16. (6 points) Initial rate data have been determined at a certain temperature for the gaseous reaction

\[ 2\text{NO} + 2\text{H}_2 \rightarrow \text{N}_2 + 2\text{H}_2\text{O} \]

<table>
<thead>
<tr>
<th>[NO]₀ (M)</th>
<th>[H₂]₀ (M)</th>
<th>Initial Rate (M/s)</th>
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<td>0.15</td>
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<td>0.15</td>
<td>0.45</td>
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<td>0.30</td>
<td>0.30</td>
<td>0.0720</td>
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</tbody>
</table>

What is the numerical value of the rate constant?

a. 2.7  

b. 0.12  

c. 8.9  

d. 1.3  

e. 0.40  

17. (6 points) From the following list of observations, choose the one that most clearly supports the conclusion that electrons have wave properties.

a. diffraction  

b. the photoelectric effect  

c. the scattering of alpha particles by metal foil  

d. cathode "rays"  

e. the emission spectrum of hydrogen
Exam 2
Answer Section

MULTIPLE CHOICE

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