Worked Key

Chemistry 116 Final Exam Spring 2014 JDS part

1. Identify oxidation.
   A. loss of electrons
   B. decrease in oxidation number
   C. increase in oxidation number
   D. gain of electrons
   E. Both A and C.
   Answer: E

2. Identify the location of oxidation in an electrochemical cell.
   A. the cathode
   B. the anode
   C. the salt bridge
   D. the multimeter
   E. the battery
   Answer: B

3. How many electrons are transferred in the following reaction? The reaction is unbalanced.
   \[ \text{Cr}^{3+}(aq) + \text{Ni}(s) \rightarrow \text{Cr}(s) + \text{Ni}^{2+}(aq) \]
   A. 1
   B. 2
   C. 3
   D. 4
   E. 6
   Answer: E

4. Use the table of standard half cell potentials to calculate \( E^{\circ}_{\text{cell}} \) for the voltaic cell with this spontaneous reaction.
   \[ \text{Cl}_2(g) + \text{Pb}(s) \rightarrow \text{Pb}^{2+}(aq) + 2\text{Cl}^{-}(aq) \]
   A. +1.20V
   B. +1.23V
   C. -1.23V
   D. +1.49V
   E. -1.49V
   Answer: D
5. Which of the following is the strongest oxidizing agent?

A. MnO₄⁻(aq)  
B. Cl⁻(aq)  
C. Fe(s)  
D. Ni²⁺(aq)  
E. Mn(s)

Answer A

6. Determine the cell notation for the following voltaic cell reaction.

\[ \text{Sn(s)} + 2\text{Ag}^+(aq) \rightarrow \text{Sn}^{2+}(aq) + 2\text{Ag(s)} \]

A. Sn(s) \mid Ag(s) \mid Sn^{2+}(aq) \mid Ag^+(aq)  
B. Ag^+(aq) \mid Ag(s) \mid Sn(s) \mid Sn^{2+}(aq)  
C. Ag(s) \mid Ag^+(aq) \mid Sn^{2+}(aq) \mid Sn(s)  
D. Sn(s) \mid Sn^{2+}(aq) \mid Ag^+(aq) \mid Ag(s)  
E. Sn^{2+}(aq) \mid Sn(s) \mid Ag(s) \mid Ag^+(aq)

Answer D

7. Use the tabulated half-cell potentials to calculate \( \Delta G^\circ \) (in kJ/mole) for the following redox reaction.

\[ 2\text{Al}(s) + 3\text{Mg}^{2+}(aq) \rightarrow 2\text{Al}^{3+}(aq) + 3\text{Mg}(s) \]

A. +4.1 \times 10^2 \text{ kJ/mole}  
B. +1.4 \times 10^2 \text{ kJ/mole}  
C. -2.3 \times 10^2 \text{ kJ/mole}  
D. -7.8 \times 10^2 \text{ kJ/mole}  
E. +6.8 \times 10^2 \text{ kJ/mole}

Answer A

\[ \Delta G^\circ = -n \times F \times E_{\text{cell}} = -6 \times (-0.71) = 4.26 \text{ kJ/mole} \]
8. Given the following cell. Breaking our rule that the Anode is drawn on the left—In this case there is no significance to which electrode/solution combination is on the left or the right. The spontaneous reaction that occurs for this voltaic cell is given below.

\[ 2\text{Cr}^{2+}(aq) + \text{Fe}^{2+}(aq) \rightarrow 2\text{Cr}^{3+}(aq) + \text{Fe}(s) \]

**Oxidation** Anode: \[ 2\text{Cr}^{2+}(aq) \rightarrow 2\text{Cr}^{3+}(aq) + 2e^{-} \]

**Reduction** Cathode: \[ \text{Fe}^{2+}(aq) + 2e^{-} \rightarrow \text{Fe}(s) \]

NO3 migrates to the **Anode** to balance the increased charge.

Answer these questions:

a. Which electrode is the anode (Fe or Pt)?

b. Which way do the electrons flow? From Fe to Pt or from Pt to Fe?

c. If the salt bridge is filled with NaNO3(aq), which ion will tend to move toward the Pt electrode compartment?

<table>
<thead>
<tr>
<th>a</th>
<th>b</th>
<th>c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pt</td>
<td>Fe to Pt</td>
<td>Na⁺</td>
</tr>
<tr>
<td>Fe</td>
<td>Fe to Pt</td>
<td>Na⁺</td>
</tr>
<tr>
<td>Pt</td>
<td>Pt to Fe</td>
<td>Na⁺</td>
</tr>
<tr>
<td>Pt</td>
<td>Pt to Fe</td>
<td>NO₃⁻</td>
</tr>
<tr>
<td>E</td>
<td>Fe to Pt</td>
<td>NO₃⁻</td>
</tr>
</tbody>
</table>

Answer D

9. What is the \( E^o \) cell for the following reaction AS WRITTEN?

\[ \text{Ni}(s) + 2\text{Ag}^+(s) \rightarrow \text{Ni}^{2+}(aq) + 2\text{Ag}(s) \]

A. 1.03 V
B. 0.57 V
C. -0.57 V
D. -1.03 V
E. 1.26 V

\( E^o_{\text{cell}} = E^o_{\text{cat}} - E^o_{\text{anode}} \)

\[ E^o_{\text{cell}} = +0.80V - (+0.23V) = +1.03V \]

as written
10. Calculate the cell potential for the following reaction that takes place in an electrochemical cell at 298K.

\[
\text{Cu}(s) \mid \text{Cu}^{2+}(aq, 0.0032M) \parallel \text{Cu}^{2+}(aq, 4.48M) \mid \text{Cu}(s)
\]

(A) 0.093V
\[
E_{\text{cell}} = E_{\text{cell}}^0 - \frac{0.0592 \log Q}{2} \quad E_{\text{cell}}^0 = +0.34V
\]
B. +0.000V
C. +0.054V
D. -0.093V
E. +0.186V
Answer A

\[
E_{\text{cell}} = E_{\text{cell}}^0 - \frac{0.0592 \log Q}{2} \quad E_{\text{cell}}^0 = +0.34V
\]

11. Use the table of half-cell potentials to calculate the equilibrium constant, K, for the following balanced redox reaction at 298K.

\[
2\text{Al}(s) + 3\text{Mg}^{2+}(aq) \rightarrow 2\text{Al}^{3+}(aq) + 3\text{Mg}(s)
\]

A. \(1.1 \times 10^{-24}\)
B. \(1.1 \times 10^{72}\)
C. \(9.5 \times 10^{35}\)
D. \(1.0 \times 10^{12}\)
E. \(1.1 \times 10^{-72}\)
Answer E

\[
E_{\text{cell}}^0 = -2.37V - (-1.66V) = -0.71V \
K = 10^{\frac{-0.71V}{0.0592}} = 10^{1.998 \times 10^{-72}} \Rightarrow \log K = -71.959
\]

12. Assuming the following reaction proceeds in the forward direction (as written):

\[
\text{Ni}^{2+}(aq) + \text{Cr}(s) \rightarrow \text{Ni}(s) + 2\text{Cr}^{2+}(aq)
\]

A. \(\text{Ni}^{2+}(aq)\) is oxidized and \(\text{Cr}(s)\) is reduced
B. \(\text{Ni}^{2+}(aq)\) is oxidized and \(\text{Ni}(s)\) is reduced
C. \(\text{Ni}(s)\) is oxidized and \(\text{Ni}^{2+}(aq)\) is reduced
D. \(\text{Cr}(s)\) is oxidized and \(\text{Ni}^{2+}(aq)\) is reduced
E. \(\text{Cr}(s)\) is oxidized and \(\text{Cr}^{2+}(aq)\) is reduced

\[
\text{Ni}^{2+} + 2e^- \rightarrow \text{Ni}(s) \quad \text{Redn} \\ 
\text{Cr}_3^+ \rightarrow \text{Cr}^{3+} + 3e^- \quad \text{OxidN}
\]

Answer D
13. Which of the following pairs of reactants will result in a spontaneous reaction at 298K?

A. Pb\(^{2+}\)(aq) + Cu(s)  
B. Fe\(^{3+}\)(aq) + Ni(s)  
C. Li\(^+\)(aq) + Al(s)  
D. Ag\(^+\)(aq) + Br\(^-\)(aq)  
E. None of the above pairs will react.

Answer B

14. Nickel can be plated from an aqueous solution according to the following half-reaction. How long would it take (in minutes) to plate 29.6 g of nickel at a current of 4.7 Amp. ?

A. 1.7 x 10\(^2\) min  
B. 5.9 x 10\(^2\) min  
C. 3.5 x 10\(^2\) min  
D. 4.8 x 10\(^2\) min  
E. 6.2 x 10\(^2\) min

Answer C

15. Consider the following half reactions and their potentials:

<table>
<thead>
<tr>
<th>Reaction</th>
<th>(E^0) (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cu(^{2+})(aq) + 2e(^-) → Cu(s)</td>
<td>+0.34</td>
</tr>
<tr>
<td>Sn(^{2+})(aq) + 2e(^-) → Sn(s)</td>
<td>-0.14</td>
</tr>
<tr>
<td>Fe(^{2+})(aq) + 2e(^-) → Fe(s)</td>
<td>-0.44</td>
</tr>
<tr>
<td>Al(^{3+})(aq) + 3e(^-) → Al(s)</td>
<td>-1.66</td>
</tr>
<tr>
<td>Mg(^{2+})(aq) + 2e(^-) → Mg(s)</td>
<td>-2.37</td>
</tr>
</tbody>
</table>

Which of the above metals or metal ions will reduce Fe\(^{2+}\)(aq)

A. Al(s) and Mg(s)  
B. Al\(^{3+}\)(aq) and Mg\(^{2+}\)(aq)  
C. Cu\(^{2+}\)(aq) and Sn\(^{2+}\)(aq)  
D. Sn(s) and Al\(^{3+}\)(aq)  
E. Cu(s) and Sn(s)

Answer A
16. What is the missing particle in each of the following reactions?

i. $^{226}_{88}Ra \rightarrow ^{222}_{86}Rn + \overset{2+}{4}{\rm He}$

ii. $^{234}_{90}{\rm Th} \rightarrow ^{234}_{91}Rn + \overset{0}{0}{\rm e}$

iii. $^{11}_{6}{\rm C} \rightarrow ^{11}_{5}{\rm B} + \overset{0}{0}{\rm e}$

A. $^4_2{\rm He}$ $^0_1{\rm e}$ $^0_1{\rm e}$
B. $^0_1{\rm e}$ $^0_1{\rm e}$ $^0_1{\rm e}$
C. $^4_2{\rm He}$ $^0_1{\rm e}$ $^0_1{\rm e}$
D. $^4_2{\rm He}$ $^0_1{\rm e}$ $^0_1{\rm e}$
E. $^0_1{\rm e}$ $^0_1{\rm e}$ $^0_1{\rm e}$

Answer C

17. The half-life of tritium, $^3_1{\rm H}$, is 12.3 years. How much tritium is left from a 32.0 g sample after 49.2 years?

$$\ln \left( \frac{N_t}{N_0} \right) = -kt$$

$$k = \frac{0.693}{12.3 \text{yr}^{-1}} = 0.0563 \text{yr}^{-1}$$

$$t = 49.2 \text{yr}$$

A. 0.0 g
B. 4.0 g
C. 1.0 g
D. 8.0 g
E. 2.0 g

Answer E

18. A sample of natural-fiber rope from an archaeological site has a $^{14}_6{\rm C}$ activity of 7.0 disintegrations per minute per gram (dpm-g$^{-1}$) of carbon. In current living material the carbon activity is 15.3 dpm-g$^{-1}$. How old is the rope, in years?

For $^{14}_6{\rm C}$

$$t = \frac{t_{1/2}^{(14}_6)}{t} \frac{N_{c}}{N_{t}}$$

$$t_{1/2}^{(14}_6{\rm C}) = 5730 \text{yr}^{-1}$$

$$t = \frac{2.8 \times 10^3}{15.3 \text{dpm-g}^{-1}}$$

A. $2.8 \times 10^3$
B. $6.5 \times 10^3$
C. $5.1 \times 10^3$
D. $1.1 \times 10^4$
E. $2.6 \times 10^3$

Answer B
19. What is the half-life of an isotope if 2.0 mg of the isotope decays to 1.8 mg in 1.0 minute?

A. 0.11 minutes
B. 15 minutes
C. 0.046 minutes
D. 6.6 minutes
E. 9.5 minutes

Answer D

20. Determine the binding energy per nucleon in kJ/nucleon for $^{114}_{48}$Cd, which has a specific mass of 113.903358 g/mole.

Use: \( l_{pi} = 1.007825 \text{ g/mole}; \quad l_{on} = 1.008665, c = 3.00 \times 10^8 \text{ m/s} \)

A. 8.2419 x 10^8
B. 9.3971 x 10^8
C. 7.3200 x 10^8
D. 8.1226 x 10^8
E. 9.2598 x 10^8

Answer A

\[ \Delta G = -9.397198 \times 10^{13} \text{ kJ/mole} \]

21. $^{225}_{88}$Ra has a half-life of 14.9 days and decays by two different mode simultaneously, $\alpha$ or $\beta^-$. What is the major product observed from each radioactive decay?

A. $^{221}_{86}$Rn
B. $^{221}_{86}$Rn
C. $^{221}_{86}$Rn
D. $^{221}_{86}$Rn
E. $^{221}_{86}$Rn

Answer A

22. What is the daughter nuclide resulting from the positron emission of $^{11}_6$C?

A. $^{11}_7$N
B. $^{11}_5$B
C. $^{10}_5$B
D. $^{12}_7$N
E. $^{12}_5$C

Answer B
23. The following reaction represents what nuclear process?

\[ ^2{}_1H + ^3{}_2He \rightarrow ^4{}_2He + ^1{}_1H \]

A. \( \alpha \) emission
B. \( \beta^- \) emission
C. \( \beta^+ \) emission
D. Nuclear fusion
E. Nuclear fission

Answer D

24. Determine how many neutrons are produced in the neutron-induced fission of \(^{239}_{94}\)Pu to form \(^{89}_{36}\)Kr and \(^{149}_{58}\)Ce.

\[
\begin{align*}
^{
239}_
{94}
Pu + ^{1}\alpha
\rightarrow & ^{89}_
{36}
Kn + ^{149}_
{58}
Ce \\
\text{sums: m+p: 240} & \quad \text{239} & \quad \text{238} & \quad \Delta = 2 \text{ neutrons}
\end{align*}
\]

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

Answer A

25. Initial refining of uranium ore is to produce a form suitable for isotope enrichment. That form is:

A. \( \text{UCI}_5 \)
B. \( \text{UO}_2 \) ("yellow cake")
C. \( \text{U}_2\text{O}_3 \)
D. \( \text{UF}_6 \) ("hex")
E. \( \text{U}_3\text{O}_8 \)

Answer D

26. In order to use uranium in reactors and weapons it must be "isotopically enriched". This process is achieved using gas diffusion centrifuges. In an isotopically enriched sample the percentage of (1) \( \text{U-235} \) increases, whereas the percentages of (2) \( \text{U-234} \) and (3) \( \text{U-238} \) decreases.

\[
\begin{array}{ccc}
(1) & (2) & (3) \\
A. & U-238 & U-235 & U-234 \\
B. & U-234 & U-238 & U-235 \\
C. & U-235 & U-238 & U-234 \\
D. & U-235 & U-236 & U-232 \\
E. & U-232 & U-238 & U-234 \\
\end{array}
\]

235 Fissionable Isotope

\( 234, 235, 238 \) principal naturally occurring isotopes

Answer C
27. Which emission or particle listed below has the highest penetrating power?
A. $\alpha$
B. $\beta^-$
C. $\beta^+$
D. $\gamma$
E. $n$
Answer D

28. Describe what changes occur during gamma ray emission.
A. The mass number and atomic number both decrease.
B. The mass number and atomic number both increase.
C. The mass number is unchanged and the atomic number increases.
D. The mass number is unchanged and the atomic number decreases.
E. The mass number and atomic number do not change.
Answer E

29. Determine the identity of the parent nuclide, if $^{32}_{16}S$ is the daughter produced from $\beta^-$ decay.
A. $^{33}_{15}P$
B. $^{32}_{15}P$
C. $^{33}_{16}S$
D. $^{32}_{14}Si$
E. $^{28}_{13}Al$
Answer B

30. $^{232}_{90}Th$ undergoes the following decay series: $\alpha, \beta^-, \beta^-$. What is the identity of the daughter nuclide at the end of this series?
A. $^{232}_{90}Th$
B. $^{228}_{89}Ac$
C. $^{228}_{90}Th$
D. $^{232}_{87}Fr$
E. $^{232}_{92}U$
Answer C
31. Which of the following changes when temperature changes?

A. rate
B. rate law
C. rate constant
D. B and C
E. A and C

Answer E

32. The first-order decomposition of dinitrogen pentoxide \( \text{N}_2\text{O}_5(\text{g}) \) is represented by:
\[ 2 \text{N}_2\text{O}_5(\text{g}) \rightarrow 4\text{NO}_2(\text{g}) + \text{O}_2(\text{g}) \]

The concentration vs time data for this reaction are:

<table>
<thead>
<tr>
<th>T(s)</th>
<th>[N\textsubscript{2}O\textsubscript{5}(g)], M</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.91</td>
</tr>
<tr>
<td>300</td>
<td>0.75</td>
</tr>
<tr>
<td>600</td>
<td>0.64</td>
</tr>
<tr>
<td>1300</td>
<td>0.44</td>
</tr>
<tr>
<td>3000</td>
<td>0.16</td>
</tr>
</tbody>
</table>

What is the rate constant for this decomposition reaction?

A. \(9.0 \times 10^{-4} \text{ s}^{-1}\)
B. \(4.6 \times 10^{-4} \text{ s}^{-1}\)
C. \(6.1 \times 10^{-4} \text{ s}^{-1}\)
D. \(5.8 \times 10^{-3} \text{ s}^{-1}\)
E. \(1.2 \times 10^{-3} \text{ s}^{-1}\)

Answer D

33. For the hypothetical general reaction between reactants A and Product B:
\[ a\text{A} + b\text{B} \rightarrow c\text{C} + d\text{D} \]
Use the data in the table to determine the rate law.

<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>0.10</td>
<td>0.015</td>
<td>(2.1 \times 10^{-4})</td>
</tr>
<tr>
<td>2</td>
<td>0.20</td>
<td>0.015</td>
<td>(4.2 \times 10^{-4})</td>
</tr>
<tr>
<td>3</td>
<td>0.10</td>
<td>0.030</td>
<td>(8.4 \times 10^{-4})</td>
</tr>
</tbody>
</table>

A. \(R = k[A][B]\)
B. \(R = k[A]^2\)
C. \(R = k[A][B]^2\)
D. \(R = k[B]\)
E. \(R = k[A]^2B\)

Answer C
34. Calculate the rate constant for Problem 33.
A. $0.14 \text{ M}^{-1}\text{s}^{-1}$
B. $0.0105 \text{ M}^{-1}\text{s}^{-1}$
C. $9.33 \text{ M}^{-2}\text{s}^{-1}$
D. $0.028 \text{ s}^{-1}$
E. $0.70 \text{ M}^{-2}\text{s}^{-1}$
Answer C

35. Which of the following expressions a)-e) are correct for the rate of the reaction:

$$\text{F}_2(\text{g}) + 2\text{ClO}_2(\text{g}) \rightarrow 2\text{FClO}_2(\text{g})$$

(a) $\text{rate} = -\frac{\Delta[\text{F}_2]}{\Delta t}$
(b) $\text{rate} = -\frac{\Delta[\text{ClO}_2]}{2\Delta t}$
(c) $\text{rate} = -\frac{1}{2}\frac{\Delta[\text{F}_2]}{\Delta t}$
(d) $\text{rate} = -\frac{1}{2}\frac{\Delta[\text{ClO}_2]}{\Delta t}$
(e) $\text{rate} = \frac{\Delta[\text{FClO}_2]}{\Delta t}$

A. a), b) and e)
B. c) and b)
C. b) and d)
D. a), b) and c)
E. a) and d)
Answer E

The following pages are the answer Key for Dr. McHale’s Part
1. For which of the following reactions is $K_P = K_c$?

A. $C(s) + H_2O(g) \rightleftharpoons CO(g) + H_2(g)$

B. $N_2O_3(g) \rightleftharpoons N_2O_2(g) + O_2(g)$

* C. $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$  

No change in the number of moles of gas

D. $C_6H_{12}O_6(s) + 6O_2(g) \rightleftharpoons 6CO_2(g) + 6H_2O(g)$

E. $2NO(g) + Cl_2(g) \rightleftharpoons 2NOCl(g)$

2. Which of the following expressions is the correct $K_c$ for the reaction $NH_4HS(s) \rightleftharpoons NH_3(g) + H_2S(g)$?

* A. $[NH_3][H_2S]$  

Solids & pure liquids don't appear in $K_c$

B. $\frac{[NH_3][H_2S]}{[NH_4HS]}$

C. $P_{NH_3}P_{H_2S}$

D. $\frac{P_{NH_3}P_{H_2S}}{P_{NH_4HS}}$

E. $\frac{[NH_4HS]}{[NH_3][H_2S]}$

3. Consider the reaction $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ at 500 K. At equilibrium, the concentrations are $[N_2] = 0.12$ M, $[H_2] = 0.11$ M, and $[NH_3] = 0.44$ M. Find $K_c$ at this temperature.

A. 47

$K_c = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{(0.44)^2}{(0.12)(0.11)^3}$

B. 4.7

C. 33

D. 0.030

* E. 1200
4. The reaction \( \text{CO(g)} + \text{H}_2\text{O(g)} \rightleftharpoons \text{CO}_2(g) + \text{H}_2(g) \) has \( K_p = 0.0611 \) at 2000 K. If the initial partial pressures are \( P_{\text{CO}} = P_{\text{H}_2\text{O}} = 5.00 \text{ atm} \), and \( P_{\text{CO}_2} = P_{\text{H}_2} = 0 \), find the partial pressures of all the reagents at equilibrium.

A. \( P_{\text{CO}} = P_{\text{H}_2\text{O}} = 4.91 \text{ atm} \), and \( P_{\text{CO}_2} = P_{\text{H}_2} = 0.061 \text{ atm} \)

*B. \( P_{\text{CO}} = P_{\text{H}_2\text{O}} = 4.01 \text{ atm} \), and \( P_{\text{CO}_2} = P_{\text{H}_2} = 0.991 \text{ atm} \)

C. \( P_{\text{CO}} = P_{\text{H}_2\text{O}} = 3.57 \text{ atm} \), and \( P_{\text{CO}_2} = P_{\text{H}_2} = 1.43 \text{ atm} \)

D. \( P_{\text{CO}} = P_{\text{H}_2\text{O}} = 2.76 \text{ atm} \), and \( P_{\text{CO}_2} = P_{\text{H}_2} = 2.24 \text{ atm} \)

E. \( P_{\text{CO}} = P_{\text{H}_2\text{O}} = 4.01 \text{ atm} \), and \( P_{\text{CO}_2} = P_{\text{H}_2} = 6.01 \text{ atm} \)

5. The pH of a \( 10^{-9} \text{ M} \) solution of NaOH is

A. Slightly less than 7

*B. Slightly greater than 7

C. 9

D. 5

E. -1

6. In the reaction \( \text{C}_3\text{H}_5\text{N(aq)} + \text{H}_2\text{O(l)} \rightleftharpoons \text{C}_3\text{H}_5\text{NH}^+(aq) + \text{OH}^-(aq) \)

A. \( \text{OH}^- \) is acting as a base and \( \text{C}_3\text{H}_5\text{N} \) is the conjugate acid.

B. \( \text{C}_3\text{H}_5\text{N} \) is acting an acid and \( \text{C}_3\text{H}_5\text{NH}^+ \) is the conjugate base.

C. \( \text{H}_2\text{O} \) is acting as a base and \( \text{C}_3\text{H}_5\text{NH}^+ \) is the conjugate acid.

*D. \( \text{C}_3\text{H}_5\text{N} \) is acting a base and \( \text{C}_3\text{H}_5\text{NH}^+ \) is the conjugate acid.

E. \( \text{OH}^- \) is acting as a base and \( \text{C}_3\text{H}_5\text{NH}^+ \) is the conjugate acid.
7. Benzoic acid $C_6H_5COOH$ has $K_a = 6.5 \times 10^{-5}$. The pH of a 1.5 M solution of benzoic acid is

$$K_a = 6.5 \times 10^{-5} = \frac{[H^+][A^-]}{[HA]} = \frac{x^2}{1.5 - x}$$

Solve $x = [H^+] = 0.00984$

$$pH = -\log(0.00984)$$

A. 1.19
B. 1.71
C. 2.01
D. 4.56
E. 6.87

$pK_a = -\log(1.5 \times 10^{-5}) = 3.337$

8. Nitrous acid $HNO_2$ has $K_a = 4.6 \times 10^{-4}$. Find the pH of a solution that contains 0.50 M $HNO_2$ and 0.75 M $NaNO_2$.

$$K_a = \frac{[H^+][NO_2^-]}{[HNO_2]}$$

$$-\log K_a = -\log [H^+] - \log \frac{[NO_2^-]}{[HNO_2]}$$

A. 3.51
B. 1.82
C. 12.18
D. 3.16
E. 8.84

9. Which of the following statements is true about $NH_3$?

A. It is both a Bronsted-Lowry acid and a Lewis acid.
B. It is Bronsted-Lowry base and but not a Lewis base.
C. It is a Lewis base but not a Bronsted-Lowry base.
D. It is a Lewis acid and a Bronsted-Lowry base.
E. It is both a Bronsted-Lowry base and a Lewis base.

10. The percent ionization of an acid HA is 4.55 %. The $K_a$ of this acid is

A. $5.48 \times 10^{-5}$
B. $2.17 \times 10^{-3}$
C. $4.67 \times 10^{-7}$
D. $2.45 \times 10^{-2}$

Let $[HA]_{initial} = 1.00 M$

At equilibrium $[H^+] = [A^-] = 0.0455 M$

$[HA] = 1 - 0.0455 = 0.9545 M$

$$K_a = \frac{[H^+][A^-]}{[HA]} = \frac{(0.0455)^2}{0.9545} = 2.17 \times 10^{-3}$$
11. The enthalpy of vaporization $\Delta H_{\text{vap}}$ of chloroform, CHCl$_3$ is 31.4 kJ/mol and the normal boiling point is 61.3 °C. The entropy of vaporization $\Delta S_{\text{vap}}$ of chloroform is

- A. 1920 J/(mol K)
- B. 512 J/(mol K)
- C. 0.512 J/(mol K)
- D. 93.9 kJ/(mol K)
- E. 83.4 J/(mol K)

\[ \Delta S = \frac{q}{T} \text{ isothermal process} \]
\[ q = \Delta H \text{ constant pressure} \]
\[ \Delta S_{\text{vap}} = \frac{\Delta H_{\text{vap}}}{T} = \frac{31,400 \text{ J/mol}}{(61.3 + 273.15) \text{ K}} \]

12. Use the tabulated data to find $\Delta G^\circ$ for the reaction

\[ 2\text{CH}_4(\text{g}) \rightleftharpoons \text{C}_2\text{H}_6(\text{g}) + \text{H}_2(\text{g}) \]

and state whether the reaction is spontaneous.

- A. $\Delta G^\circ = 69.0 \text{ kJ/mol}$, the reaction is spontaneous
- *B. $\Delta G^\circ = 69.0 \text{ kJ/mol}$, the reaction is not spontaneous
- C. $\Delta G^\circ = -69.0 \text{ kJ/mol}$, the reaction is spontaneous
- D. $\Delta G^\circ = -69.0 \text{ kJ/mol}$, the reaction is not spontaneous
- E. $\Delta G^\circ = 18.5 \text{ kJ/mol}$, the reaction is not spontaneous

\[
\Delta G^\circ = -32.0 - 2(-50.5) = 69.0 \text{ kJ/mol} > 0
\]

13. The reaction $\text{I}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightleftharpoons 2\text{ICl}(\text{g})$ has $K_p = 81.9$ at 298 K. Find $\Delta G^\circ$.

- A. $-10.9 \text{ kJ/mol}$
- B. $-4.74 \text{ kJ/mol}$
- C. $108 \text{ kJ/mol}$
- D. $1.78 \text{ kJ/mol}$
- E. $-108 \text{ kJ/mol}$

\[
\Delta G^\circ = -RT \ln K_p = -(8.314 \text{ J/mol K})(298 \text{ K}) \ln 81.9
\]
\[
= -109.14 \text{ J/mol}
\]
14. A spontaneous process obeys the following inequalities:

\[ T \Delta S_{\text{univ}} = -\Delta G \]

- A. \( \Delta S_{\text{univ}} > 0, \Delta G < 0 \)
- B. \( \Delta S_{\text{univ}} > 0, \Delta G > 0 \)
- C. \( \Delta S_{\text{univ}} < 0, \Delta G < 0 \)
- D. \( \Delta S_{\text{univ}} < 0, \Delta G > 0 \)
- E. \( \Delta S_{\text{univ}} = 0, \Delta G < 0 \)

15. If a reaction is spontaneous at high temperature but not at low temperature then the following must be true:

- A. \( \Delta H > 0, \Delta S = 0 \)
- B. \( \Delta H > 0, \Delta S < 0 \)
- C. \( \Delta H < 0, \Delta S > 0 \)
- D. \( \Delta H < 0, \Delta S < 0 \)
- E. \( \Delta H > 0, \Delta S > 0 \)

\[ \Delta G = \Delta H - T \Delta S < 0 \quad \text{for spontaneous} \]

\[ \Delta G \rightarrow \Delta H \quad \text{as} \ T \rightarrow 0 \quad \text{not spont at low} \ T \]

\[ \therefore \Delta H > 0 \]

\[ \Delta G \rightarrow -T \Delta S \quad \text{at high} \ T \quad \text{spontaneous} \]

\[ \therefore \Delta S > 0 \]
Physical and Chemical Constants

Avogadro constant \( N_A = 6.022 141 99 \times 10^{23} \text{ mol}^{-1} \)

Neutron mass \( m_n = 1.008665 \text{ g/mole} \)

 Electron mass \( m_e = 9.109 381 88 \times 10^{-31} \text{ kg} \)

Pil \( \sigma = 3.141 592 654 \)

Electronic charge \( e = 1.602 176 662 \times 10^{-19} \text{ C} \)

Planck constant \( b = 6.626 068 76 \times 10^{-34} \text{ J s} \)

Proton mass \( m_p = 1.007825 \text{ g/mole} \)

Faraday constant \( F = 96 485.3415 \text{ C/mol} \)

Gas constant \( R = 8.314 \text{ J} \text{ mol}^{-1} \text{ K}^{-1} \)

Speed of light \( c = 2.997 924 58 \times 10^8 \text{ m/s} \)

\( \text{in a vacuum} \)

Use \( c = 3.00 \times 10^8 \text{ m/s} \)

for this exam

\[
\text{Rate} = -\frac{1}{a} \frac{\Delta [A]}{\Delta t} = -\frac{1}{b} \frac{\Delta [B]}{\Delta t} = \frac{1}{c} \frac{\Delta [C]}{\Delta t} = \frac{1}{d} \frac{\Delta [D]}{\Delta t}
\]

**Rate Equations**

**Integrated Rate Law**

**half-life Equations**

\[
k[A]^0 = k \quad [A]_t = -kt + [A]_0
\]

\[
k[A] \quad \ln[A]_t = -kt + \ln[A]_0
\]

\[
\ln \frac{A_t}{A_0} = -kt \quad t_{1/2} = \frac{-\ln 2}{k} = 0.693
\]

\[
k[A]^2 \quad \frac{1}{[A]_t} = kt + \frac{1}{[A]_0}
\]

\[
t_{1/2} = \frac{1}{k[A]_0}
\]

\[
k = Ae^{-}\frac{E_r}{RT} \quad \ln(k) = \ln(A) + \ln(e^{-}\frac{E_r}{RT}) = \ln(A) + (-\frac{E_r}{RT})
\]

\[
\ln \frac{k_2}{k_1} = \frac{-E_a}{R} \left[ \frac{1}{T_2} - \frac{1}{T_1} \right] \quad \ln(k) = -\left( \frac{E_a}{R} \times \frac{1}{T_f} \right) + \ln(A)
\]

\[
\Delta E = (\Delta m)c^2 \quad E_b = -\Delta E \quad \ln \frac{A_t}{A_0} = -kt
\]

\[
\Delta G^\circ = -nFE_{\text{cell}}^\circ \quad F = 96,485 \text{ C/mol e}^{-}
\]

\[
E_{\text{cell}}^\circ = \frac{0.0592 \text{ V}}{n} \log K
\]

\[
E_{\text{cell}} = E_{\text{cell}}^\circ - \frac{0.0592 \text{ V}}{n} \log Q
\]

\[
2 \text{H}^+(aq) + 2 \text{e}^- \rightarrow \text{H}_2(g) \quad E^\circ = 0.00 \text{ V}
\]

\[
E_{\text{cell}}^\circ = E_{\text{cathode}}^\circ - E_{\text{anode}}^\circ
\]

\[
1 \text{ A} = 1 \text{ C/s} \quad 1 \text{ V} = 1 \text{ J/C}
\]

Current (C/s) x Time (s) = Charge (C)
<table>
<thead>
<tr>
<th>Reduction reaction</th>
<th>$E^\circ$ (volts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F_2(g) + 2e^-$</td>
<td>2.87</td>
</tr>
<tr>
<td>$H_2O_2(aq) + 2H^+(aq) + 2e^-$</td>
<td>1.78</td>
</tr>
<tr>
<td>$PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^-$</td>
<td>1.69</td>
</tr>
<tr>
<td>$MnO_4^- (aq) + 4H^+(aq) + 3e^-$</td>
<td>1.68</td>
</tr>
<tr>
<td>$MnO_4^- (aq) + 8H^+(aq) + 5e^-$</td>
<td>1.51</td>
</tr>
<tr>
<td>$Au^{3+}(aq) + 3e^-$</td>
<td>1.50</td>
</tr>
<tr>
<td>$PbO_2(s) + 4H^+(aq) + 2e^-$</td>
<td>1.46</td>
</tr>
<tr>
<td>$Cl_2(g) + 2e^-$</td>
<td>1.36</td>
</tr>
<tr>
<td>$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^-$</td>
<td>1.33</td>
</tr>
<tr>
<td>$O_2(g) + 4H^+(aq) + 4e^-$</td>
<td>1.23</td>
</tr>
<tr>
<td>$MnO_2(s) + 4H^+(aq) + 2e^-$</td>
<td>1.21</td>
</tr>
<tr>
<td>$IO_3^-(aq) + 6H^+(aq) + 5e^-$</td>
<td>1.20</td>
</tr>
<tr>
<td>$Br_2(l) + 2e^-$</td>
<td>1.09</td>
</tr>
<tr>
<td>$VO_2^{2+}(aq) + 2H^+(aq) + e^-$</td>
<td>1.00</td>
</tr>
<tr>
<td>$NO_3^-(aq) + 4H^+(aq) + 3e^-$</td>
<td>0.96</td>
</tr>
<tr>
<td>$ClO_2(g) + e^-$</td>
<td>0.95</td>
</tr>
<tr>
<td>$Ag^+(aq) + e^-$</td>
<td>0.80</td>
</tr>
<tr>
<td>$Fe^{3+}(aq) + e^-$</td>
<td>0.77</td>
</tr>
<tr>
<td>$O_2(g) + 2H^+(aq) + 2e^-$</td>
<td>0.70</td>
</tr>
<tr>
<td>$MnO_4^-(aq) + e^-$</td>
<td>0.56</td>
</tr>
<tr>
<td>$I_2(s) + 2e^-$</td>
<td>0.54</td>
</tr>
<tr>
<td>$Cu^+(aq) + e^-$</td>
<td>0.52</td>
</tr>
<tr>
<td>$O_2(g) + 2H_2O(l) + 4e^-$</td>
<td>0.40</td>
</tr>
<tr>
<td>$Cu^{2+}(aq) + 2e^-$</td>
<td>0.34</td>
</tr>
<tr>
<td>$SO_4^{2-}(aq) + 4H^+(aq) + 2e^-$</td>
<td>0.20</td>
</tr>
<tr>
<td>$Cu^{2+}(aq) + e^-$</td>
<td>0.16</td>
</tr>
<tr>
<td>$Sn^{4+}(aq) + 2e^-$</td>
<td>0.15</td>
</tr>
<tr>
<td>$2H^+(aq) + 2e^-$</td>
<td>0</td>
</tr>
<tr>
<td>$Fe^{3+}(aq) + 3e^-$</td>
<td>-0.036</td>
</tr>
<tr>
<td>$Pb^{2+}(aq) + 2e^-$</td>
<td>-0.13</td>
</tr>
<tr>
<td>$Sn^{2+}(aq) + 2e^-$</td>
<td>-0.14</td>
</tr>
<tr>
<td>$Ni^{2+}(aq) + 2e^-$</td>
<td>-0.23</td>
</tr>
<tr>
<td>$Cd^{2+}(aq) + 2e^-$</td>
<td>-0.40</td>
</tr>
<tr>
<td>$Fe^{2+}(aq) + 2e^-$</td>
<td>-0.45</td>
</tr>
<tr>
<td>$Cr^{3+}(aq) + e^-$</td>
<td>-0.50</td>
</tr>
<tr>
<td>$Cr^{3+}(aq) + 3e^-$</td>
<td>-0.73</td>
</tr>
<tr>
<td>$Zn^{2+}(aq) + 2e^-$</td>
<td>-0.76</td>
</tr>
<tr>
<td>$2H_2O(l) + 2e^-$</td>
<td>-0.83</td>
</tr>
<tr>
<td>$Mn^{2+}(aq) + 2e^-$</td>
<td>-1.18</td>
</tr>
<tr>
<td>$Al^{3+}(aq) + 3e^-$</td>
<td>-1.66</td>
</tr>
<tr>
<td>$Mg^{2+}(aq) + 2e^-$</td>
<td>-2.37</td>
</tr>
<tr>
<td>$Na^{+}(aq) + e^-$</td>
<td>-2.71</td>
</tr>
<tr>
<td>$Ca^{2+}(aq) + 2e^-$</td>
<td>-2.76</td>
</tr>
<tr>
<td>$Ba^{2+}(aq) + 2e^-$</td>
<td>-2.90</td>
</tr>
<tr>
<td>$K^+(aq) + e^-$</td>
<td>-2.92</td>
</tr>
<tr>
<td>$Li^+(aq) + e^-$</td>
<td>-3.04</td>
</tr>
</tbody>
</table>