This print-out should have 30 questions. Multiple-choice questions may continue on the next column or page – find all choices before making your selection. The due time is Central time.

PLEASE remember to bubble in your name, student ID number, and version number on the scantron!

Msci 16 0102
16:01, general, multiple choice, > 1 min, fixed.

One of the reactions used commercially to produce hydrogen gas is

\[ \text{H}_2\text{O}(g) + \text{CO}(g) \rightarrow \text{H}_2(g) + \text{CO}_2(g). \]

A proper expression for the rate of this reaction could be

1. \[ -\frac{\Delta[\text{CO}_2]}{\Delta t}. \]
2. \[ -\frac{\Delta[\text{H}_2]}{\Delta t}. \]
3. \[ +\frac{\Delta[\text{CO}]}{\Delta t}. \]
4. \[ -\frac{\Delta[\text{H}_2\text{O}]}{\Delta t}. \text{ correct} \]

Explanation:
The rate of a chemical reaction can either be expressed as the rate of disappearance of the reactant (as in this case) or as the rate of the appearance of the product; however, this rate is multiplied by the inverse of the coefficient of the species in question. The negative sign here reminds us that as the reaction progresses, this species is consumed and goes down in concentration.

Msci 16 0301
16:03, general, multiple choice, > 1 min, fixed.

Consider the stoichiometric reaction

\[ 2 \text{A} + \text{B} \rightarrow \text{C} + \text{D}. \]

The reaction rates are measured with the following results:

<table>
<thead>
<tr>
<th>Initial rate</th>
<th>[A]_0</th>
<th>[B]_0</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

The order with respect to [B]_0 is

1. 0 \text{ correct}
2. 1
3. 1.5
4. 2
5. 3

Explanation:
Since we’re looking at the order of $[B]_0$, all we have to look at is where $[B]_0$ changes and where $[A]_0$ stays the same. $[B]_0$ doubles from the first row to the third row, but the rate doesn’t change, so the rate order is 0.

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**Mlib 05 7065**  
16:03, basic, multiple choice, > 1 min, fixed.  
004

Which of the following does not affect the rate of a reaction?

1. the value of $\Delta H$ **correct**
2. the value of $E_a$
3. the presence of a catalyst
4. the temperature of the reactants

**Explanation:**  
The presence of a catalyst increases reaction rate, as does increasing the temperature of the reactants. A large $E_a$ slows down a reaction.

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**Msci 16 0415**  
16:04, general, multiple choice, > 1 min, fixed.  
005

Consider the reaction  
$$2\text{NOCl(g)} \rightarrow 2\text{NO(g)} + \text{Cl}_2\text{(g)}$$  
with rate constant 0.0480 M$^{-1} \cdot $s$^{-1}$ when conducted at 200°C. The initial concentration of NOCl was 0.521 M.

What is the concentration of NOCl after 0.535 minutes and at 200°C?

1. 0.200 M **correct**
2. 0.289 M
3. 0.0239 M
4. 0.112 M
5. 0.508 M

**Explanation:**  
$$k = 0.0480 \text{ M}^{-1} \cdot \text{s}^{-1} \quad t = 0.535 \text{ min}$$  
$$[A]_0 = 0.521 \text{ M}$$

---

The units on $k$ indicates a second order reaction:

$$\frac{1}{[A]_t} - \frac{1}{[A]_0} = a k t$$

$$= \frac{1}{0.521 \text{ M}} + a k t$$

$$= \frac{1}{0.521 \text{ M}} + 2(0.0480 \text{ M}^{-1} \cdot \text{s}^{-1}) \times (0.535 \text{ min}) \times \frac{60.0 \text{ s}}{\text{min}}$$

$$[A]_t = 0.200 \text{ M}$$

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**Msci 16 0403**  
16:04, general, multiple choice, > 1 min, fixed.  
006

The first-order rate constant is $k = 3.4 \times 10^{-3}$ s$^{-1}$ for the decomposition of cyclobutane and the half-life is 204 seconds.

What fraction of a sample of cyclobutane remains after 612 seconds under the specified conditions?

1. fraction = $\frac{1}{2}$
2. fraction = $\frac{1}{3}$
3. fraction = $\frac{1}{6}$
4. fraction = $\frac{1}{8}$ **correct**
5. fraction = $\frac{1}{16}$

**Explanation:**
Make a chart.

<table>
<thead>
<tr>
<th>Time</th>
<th>Amount left (cyclobutane=C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>C</td>
</tr>
<tr>
<td>204</td>
<td>( \frac{2}{2} ) C</td>
</tr>
<tr>
<td>408</td>
<td>( \frac{4}{4} ) C</td>
</tr>
<tr>
<td>612</td>
<td>( \frac{6}{8} ) C</td>
</tr>
</tbody>
</table>

After 612 seconds, \( \frac{1}{8} \) of the original amount of cyclobutane is left.

**Alternate Solution:**

\[
\ln \frac{[A]_0}{[A]} = a k t
\]

\[
= (1)(3.4 \times 10^{-3}) \text{ sec}^{-1} \cdot (612 \text{ sec})
\]

\[
= 2.08
\]

\[
\frac{[A]_0}{[A]} = e^{2.08} = 8
\]

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**Msci 16 0908x**

16:07, general, multiple choice, > 1 min, fixed.

Consider the multistep reaction that has the overall reaction

\[2A + 2B \rightarrow C + D.\]

What is the rate law expression that would correspond to the following proposed mechanism?

1. Rate = \( k[A]^2[B] \)
2. Rate = \( k[I][B] \)
3. Rate = \( k[A]^2 \)
4. Rate = \( k[A][I][B] \)
5. Rate = \( k[A] \)
6. Rate = \( k[A][B] \)
7. Rate = \( k[A][B]^2 \text{ correct} \)
8. Rate = \( k[A]^2[B]^2 \)
9. Rate = \( k[B] \)

**Explanation:**
The slowest step is the rate determining step and is used to write the rate law.

\[ \text{Rate} = k[I][B] \]

The rate law must be in terms of reactants or products so the concentration must not appear in the rate law equation. The step that immediately precedes can be treated as an equilibrium system where

\[ \text{Rate}_{\text{forward}} = k_f[A][B] = k_r[I] = \text{Rate}_{\text{reverse}} \]

and \([I] = \frac{k_f}{k_r}[A][B]\) can be substituted to give the equation

\[ \text{Rate} = \frac{k_{f}^{\prime}}{k_{r}} [A][B]^{2} \text{ or Rate} = k[A][B]^{2} \]

**Msci 16 0004**
16:06, general, multiple choice, > 1 min, fixed.

Consider the potential energy diagram

for the one-step reaction

\[ X + Y \rightarrow Z + R \]

The arrow \(d\) represents the

1. net change in energy for the reaction. **correct**

2. energy content of products.

3. energy content of reactants.

4. activation energy for the forward reaction.

5. activation energy for the reverse reaction.

**Explanation:**

\(d\) is the net change in energy for the reaction.

**Msci 16 1008**
16:08, general, multiple choice, > 1 min, fixed.

Calculate the \(A\) in the Arrhenius equation, given that the second order reaction rate constant for a reaction is \(1.00 \times 10^3\) L/mol·s at 500°C and the activation energy \(E_a\) is 19.87 kcal/mole.

1. \(1.00 \times 10^7\)
2. \(2.4 \times 10^6\)
3. \(1.00 \times 10^8\)
4. \(4.55 \times 10^3\)
5. \(4.15 \times 10^8\) **correct**

**Explanation:**

\[ k = 1.0 \times 10^3 \frac{\text{L} \cdot \text{s}}{\text{mol}} \]

\[ T = (500 + 273) \text{ K} \]

\[ E_a = 19870 \frac{\text{cal}}{\text{mol}} \]

\[ k = A e^{-E_a/RT} \]

\[ A = k e^{E_a/RT} \]

\[ = (1 \times 10^3)^{19870 / (11.987)(773)} \]

\[ = 4.15 \times 10^8 \]

**Msci 16 1009**
16:06, general, multiple choice, > 1 min, fixed.

The reaction

\[ A + 3B \rightarrow C + 2D \]

has a rate constant \(k = 1.0 \times 10^{-5} \text{ s}^{-1}\) at 27°C.
If the activation energy for the reaction is 20,000 cal/mol, what is the value of the rate constant at 0°C?

1. $3.6 \times 10^{-7}$ correct
2. $3.0 \times 10^{-6}$
3. $3.3 \times 10^{-5}$
4. $2.8 \times 10^{-4}$
5. None of these

**Explanation:**

$k = 1.0 \times 10^{-5} \text{ s}^{-1}$  
$E_a = 20,000 \text{ cal/mol}$

$T_1 = 27^\circ C = 300 \text{ K}$  
$T_2 = 0^\circ C = 273 \text{ K}$

Use the combined Arrhenius equation,

$$\ln \frac{k_2}{k_1} = \left( \frac{E_a}{R} \right) \left( \frac{1}{T_1} - \frac{1}{T_2} \right)$$

$$\frac{k_2}{k_1} = e^{(E_a/R)(1/T_1-1/T_2)}$$

$$k_2 = k_1 e^{(E_a/R)(1/T_1-1/T_2)}$$

$$k_2 = 10^{-5} \exp \left[ \left( \frac{20,000}{1.987} \right) \left( \frac{1}{300 \text{ K}} - \frac{1}{273 \text{ K}} \right) \right]$$

$$= 3.6 \times 10^{-7}$$

**Alternate Solution:**

$$\ln \frac{k_2}{k_1} = \frac{E_a}{R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right)$$

$$\ln k_2 - \ln k_1 = \frac{E_a}{R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right)$$

$$\ln k_2 = \frac{E_a}{R} \left( \frac{1}{T_1} - \frac{1}{T_2} \right) + \ln k_1$$

$$= \left( \frac{20000 \text{ cal/mol}}{1.987 \text{ cal/mol} \cdot \text{K}} \right) \times \left( \frac{1}{300 \text{ K}} - \frac{1}{273 \text{ K}} \right)$$

$$+ \ln (1.0 \times 10^{-5})$$

$$\ln k_2 = -3.32 + (-11.5) = -14.82$$

$$k_2 = 3.6 \times 10^{-7}$$
Explanation:

Mlib 05 7037
16:08, basic, multiple choice, > 1 min, fixed.
014
Generally, reaction rates increase when the temperature of the system is raised because

1. the activation barrier decreases as the temperature increases.

2. the concentration of reactants increases as the temperature increases.

3. the bond energy of the reactants decreases as the temperature increases.

4. the kinetic energy (and thus the speed) of the reactants increases as the temperature increases. correct

5. the bond energy of the products decreases as the temperature increases.

Explanation:
Higher KE means more collisions and more properly oriented collisions, therefore a faster rate of reaction.

Msci 17 0104
17:01, general, multiple choice, > 1 min, fixed.
015
When a reaction reaches equilibrium,

1. the rate of the forward reaction and the rate of the reverse reaction are equal to zero.

2. all reaction stops.

3. the rate of the forward reaction is zero.

4. the rate of the reverse reaction is zero.

5. the forward and reverse reaction rates are equal. correct

Explanation:
For the reaction
\[ aA + bB \rightarrow cC + dD \]
The rate of the forward reaction is \( K_r[A][B] \).
The rate of the reverse reaction is \( K_r[C][D] \).
At equilibrium, these rates are equal, not zero.

Mlib 08 0071
21:06, basic, multiple choice, > 1 min, fixed.
016
How many moles of sodium can be produced from the electrolysis of \( \text{Na}_2\text{SO}_4 \) if 1 Faraday of electricity is passed?

1. one half
2. one correct
3. two
4. four

Explanation:

Msci 21 0600
21:06, general, multiple choice, > 1 min, fixed.
017
How many grams of Cu metal (63.55 g/mol) will be plated out of a \( \text{Cu(NO}_3\text{)}_2 \) solution by passing a current of 3.00 amperes for 11 minutes? (1 Faraday = 96,485 Coulombs)

1. 0.652 g correct
2. 2.608 g
3. 1.304 g
4. 0.0721 g
5. No other answer is within 2 percent

Explanation:
Remembering that
\[ 3.00 \text{ amperes} = 3.00 \text{ C/s} \]
the number of Coulombs (C) passed through solution is
\[ 3.00 \text{ C/s} (60 \text{ s/min}) (11 \text{ min}) = 1980 \text{ C} \]
The number of grams of Cu plated out is then
1980 C \left( \frac{1 \text{ mol } e^-}{96485 \text{ C}} \right) \left( \frac{1 \text{ mol } \text{Cu}}{2 \text{ mol } e^-} \right) \left( \frac{63.55 \text{ g}}{1 \text{ mol}} \right) = 0.652 \text{ g Cu}

Note: \( \text{Cu(NO}_3\text{)}_2 \) contains \( \text{Cu}^{2+} \)

\( \text{Cu}^{2+} + 2e^- \rightarrow \text{Cu} \)

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**DAL 03 0408**

21:99, general, multiple choice, < 1 min, fixed.

Using the standard potential tables, what is the largest approximate \( E^0 \) value that can be achieved when two half cell reactions are combined to form a battery?

1. 6 V correct
2. 3 V
3. −3 V
4. −6 V

**Explanation:**

\[ E_{\text{cell}} = E_{(\text{cathode})} - E_{(\text{anode})} \]
\[ = -0.76 - (-0.44) \]
\[ = -0.32 \]

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**Msci 21 1218**

21:15, general, multiple choice, > 1 min, fixed.

What is the \( E^0 \) for the following electrochemical cell where Zn is the cathode?

\( \text{Zn} | \text{Zn}^{2+} (1.0 \text{ M}) || \text{Fe}^{2+} (1.0 \text{ M}) | \text{Fe} \)

\( E^0(\text{Zn}) = -0.76 \quad E^0(\text{Fe}) = -0.44 \)

1. +0.32
2. −0.32 correct
3. +1.20
4. −1.20

**Explanation:**

The electrolysis of molten NaBr includes a reduction step:

\( \text{Na}^+ + 1e^- \rightarrow \text{Na} \)

and an oxidation step:

\( 2\text{Br}^- \rightarrow \text{Br}_2 + 2e^- \)

Reduction occurs at the cathode, so

\( \text{Na}^+ + 1e^- \rightarrow \text{Na} \)

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**Msci 21 0307**

21:03, general, multiple choice, > 1 min, fixed.

The half-reaction that occurs at the cathode during the electrolysis of molten sodium bromide is

1. \( 2\text{Br}^- \rightarrow \text{Br}_2 + 2e^- \)
2. \( \text{Br}_2 + 2e^- \rightarrow 2\text{Br}^- \)
3. \( \text{Na}^+ + 1e^- \rightarrow \text{Na} \) correct
4. \( \text{Na} \rightarrow \text{Na}^+ + 1e^- \)
5. \( 2\text{H}_2\text{O} + 2e^- \rightarrow 2\text{OH}^- + \text{H}_2 \)

**Explanation:**

**Mlib 50 8037**

21:08, basic, multiple choice, > 1 min, fixed.

A device that generates an electrical current by taking advantage of a difference in the spontaneous tendency of substances to lose and gain electrons is called

1. a voltaic cell. correct
2. an electrolysis cell.
3. an electroplating cell.
4. an electrolyte cell.

**Explanation:**
What takes place at the negatively charged terminal of an electrolytic cell?

1. oxidation
2. reduction correct
3. combustion
4. the net redox reaction
5. a very small fission explosion

Explanation:

A battery has two electrodes labeled anode and cathode.
Electrons flow from the ? to the ? through the external circuit and a(n) ? reaction occurs at the cathode.

1. anode; cathode; oxidation
2. anode; cathode; reduction correct
3. cathode; anode; oxidation
4. cathode; anode; reduction

Explanation:
A battery is a galvanic (spontaneous) cell. Reduction always takes place at the cathode, so eliminate the “anode, cathode, oxidation” and the “cathode, anode, reduction” options. Also, electrons always flow FROM the anode TO the cathode since this is where the reduction takes place.

Consider the following standard reduction potentials.

\[
\begin{align*}
\text{Cu}^{2+} + 2e^- & \rightarrow \text{Cu} \quad E^0 = 0.337 \text{ V} \\
\text{Ag}^+ + e^- & \rightarrow \text{Ag} \quad E^0 = 0.7994 \text{ V} \\
\text{Au}^+ + e^- & \rightarrow \text{Au} \quad E^0 = 1.68 \text{ V}
\end{align*}
\]

Which of the following statements about the reducing strength of the Group IB metals is true?

1. Au is a stronger reducing agent than Ag.
2. Ag is a stronger reducing agent than Cu.
3. Au is a stronger reducing agent than Cu.
4. Nothing can be predicted about reducing strengths from a table of standard reduction potentials.
5. Cu is a stronger reducing agent than Au. correct

Explanation:
The bigger the \( E^0 \), the easier it is for the species to be reduced, or harder it is to be oxidized. Since Cu has a smaller \( E^0 \) than Au, it is harder to be reduced and also easier to be oxidized.

Consider the half-reactions

\[
\begin{align*}
\text{Mn}^{2+} + 2e^- & \rightarrow \text{Mn} \quad E^0 = -1.029 \text{ V} \\
\text{Ga}^{3+} + 3e^- & \rightarrow \text{Ga} \quad E^0 = -0.560 \text{ V} \\
\text{Fe}^{2+} + 2e^- & \rightarrow \text{Fe} \quad E^0 = -0.409 \text{ V} \\
\text{Sn}^{2+} + 2e^- & \rightarrow \text{Sn} \quad E^0 = -0.136 \text{ V}
\end{align*}
\]

Of the species listed, the strongest oxidizing agent is

1. \( \text{Sn}^{2+} \) correct
2. \( \text{Mn}^{2+} \)
3. Mn
4. Sn
5. \( \text{Ga}^{3+} \)

Explanation:
Oxidizing agents get reduced. As \( E_0 \) increases, the easier it is for the species to be reduced. Since \( \text{Sn}^{2+} \) has the biggest \( E_0 \), it is
reduced the easiest, making it the strongest oxidizing agent.

\[ 2 \text{H}^+ (aq) + 2e^- \rightleftharpoons \text{H}_2 (g) \quad E^0 = 0.000 \text{ V} \]

Assuming the pressure of the hydrogen gas is 1 atm, what is the pH of the cell if the reduction potential under non-standard concentration is \(-0.1775 \text{ V}\)?

1. 3.00 correct
2. 2.00
3. 6.00
4. 1.50
5. 2.67
6. 3.25

**Explanation:**

\[
\ln K = \frac{nFE}{RT} \\
= \frac{2 \text{ mol} \left( \frac{96485 \text{ J}}{\text{V} \cdot \text{mol}} \right) (-0.638 \text{ V})}{(8.314 \text{ J/mol} \cdot \text{K})(298 \text{ K})} \\
= -49.6917 \\
K = 2.625 \times 10^{-22}
\]

For a redox reaction to be SPONTANEOUS under standard conditions, the following is true

1. \(\Delta G > 0 \quad K < 1 \quad E_{\text{cell}} > 0\)
2. \(\Delta G < 0 \quad K < 1 \quad E_{\text{cell}} < 0\)
3. \(\Delta G > 0 \quad K > 1 \quad E_{\text{cell}} < 0\)
4. \(\Delta G < 0 \quad K > 1 \quad E_{\text{cell}} > 0\) correct

**Explanation:**

\(\Delta G\) is negative for a spontaneous reaction. \(K = \frac{[\text{products}]}{[\text{reactants}]}\), so when the equilibrium favors the products (making the reaction spontaneous), \(K > 1\). Also, \(E^0 = \frac{0.05916 \log K}{n}\). So when \(K > 1\), \(E^0\) is positive.

In the reaction, which species is reduced?

1. \(\text{Cu(NO}_3\text{)}_2\) correct
2. Zn
3. Cu
4. \(\text{Zn(NO}_3\text{)}_2\)

**Explanation:**

\[-nEF = -RT \ln K\]
Car battery
21:23, general, multiple choice, < 1 min, fixed.

030
What metal (in various oxidation states) is present at both the cathode and the anode in a typical car battery?

1. lead correct

2. nickel

3. cadmium

4. copper

5. iron

6. zinc

Explanation:
A car battery is also known as a lead storage battery.