001
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McCord CH302

unique: 49175 and 49190

Exam 3

Apr 17, 2019

Wednesday 7:30 - 9:00 PM

A-L in UTC 2.112A

M-Z In BUR 106

Remember to refer to the Periodic Table handout that is separate from this exam copy.

NOTE: Please keep this exam copy intact (all pages still stapled - including this cover page). You must turn in ALL the materials that were distributed. This means that you turn in your exam copy (name and signature included), bubble sheet, periodic table handout, and all scratch paper. Please also have your UT ID card ready to show as well.

This print-out should have 20 questions. Multiple-choice questions may continue on the next column or page – find all choices before answering.

001 5.0 points

Carbon-14 ($t_{1/2}$ = 5730 years) is useful for radioactive dating methods because we can estimate stable isotope ratios in organic samples. A fossil from the early Holocene Epoch originally contained 14.8 g ^{14}C. Today, the fossil contains 3.7 g. What is the approximate age of the fossil?

1. 5730 years

2. 22920 years

3. 24194 years

4. 11460 years **correct**

5. 17190 years

Explanation:

The fossil now has $\frac{1}{4}$ the original amount of isotope. $\frac{1}{2}$ remains after one half-life and $\frac{1}{4}$ after the second half-life, which represents

$$2\,(5730 \text{ years}) = 11460 \text{ years}\,.$$

002 5.0 points

What is the mass of the barium chromate precipitate resulting from the addition of 300 mL 0.025 M $Ba(OH)_2$ to 200 mL 0.040 M Na_2CrO_4?

1. 3.48 g

2. 2.03 g

3. 3.80 g

4. 2.52 g

5. 1.90 g **correct**

Explanation:

Start with the relevant net ionic formula based on what was provided in the question stem (Note: you can confirm that a precipitate will form using Q_{sp}):

$$Ba^{2+}(aq) + CrO_4^{2-}(aq) \longrightarrow BaCrO_4(s)$$

Here you should see that this is a limiting reagent problem. Because barium chromate has a very small K_{sp}, it is safe to assume the reaction goes approximately 100%. Solve for moles of each reagent:

$$Ba^{2+} : 0.0250\,\text{M} \times 0.300\,\text{L} = 0.00750\,\text{mol}$$

$$CrO_4^{2-} : 0.0400\,\text{M} \times 0.200\,\text{L} = 0.00800\,\text{mol}$$

This reaction is 1:1:1, so you can determine that the limiting reagent is the reactant with the fewest number of moles. This is also the number of moles of product formed. Convert to mass:

$$0.00750 \times 253.37\,\text{g/mol} = 1.90\,\text{g}$$

003 (part 1 of 2) 5.0 points

You run an experiment to determine the initial rates of the following generic reaction at various starting conditions:

$$A + X_2 \rightleftharpoons AX_2$$

	[A] M	[X_2] M	initial rate $M \cdot s^{-1}$
Trial 1	0.60	1.56	2.00×10^{-3}
Trial 2	0.60	3.12	8.00×10^{-3}
Trial 3	1.20	1.56	4.00×10^{-3}
Trial 4	0.90	2.40	7.10×10^{-3}

What is the correct rate law for the reaction?

1. Rate = (1.40)[A]

2. Rate = $(1.37 \times 10^{-3})[A][X_2]^2$ **correct**

3. Rate =$(1.37 \times 10^{-3})[A][X_2]$

4. Rate = $(3.84 \times 10^{-3})[A][X_2]^2$

5. Rate $= (3.84 \times 10^{-3})[\text{A}]^{-1}[\text{X}_2]^2$

Explanation:
Begin with the equation:

Rate $= k[\text{A}]^x[\text{B}]^y$

Compare trials to determine the value of x and y. Two good comparisons are trials 1 and 2 and trials 1 and 3.

Between trials 1 and 2, the concentration of X_2 doubles and the rate quadruples. Therefore, $y = 2$, meaning the reaction is second order in X_2.

Between trials 1 and 3, [A] doubles and the rate doubles. This means $x = 1$ and the reaction is first order in A.

Lastly, you can solve for k using any trial:

$2.00 \times 10^{-3} = (1.37 \times 10^{-3})(0.60)(1.56)^2$

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004 (part 2 of 2) 5.0 points

What are the units of the rate constant in the previous question?

1. $\frac{1}{\text{M}^4 \cdot \text{s}}$

2. $\frac{1}{\text{M} \cdot \text{s}}$

3. $\frac{\text{M}}{\text{s}}$

4. $\frac{1}{\text{M}^2 \cdot \text{s}}$ **correct**

5. $\frac{1}{\text{M}^3 \cdot \text{s}}$

Explanation:
The rate constant has units that cancel out the concentrations in the rate law to give a rate in M/s. The rate constant has units of $\frac{1}{\text{M}^2 \cdot \text{s}}$

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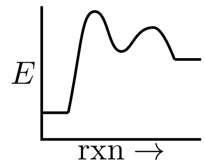
005 5.0 points

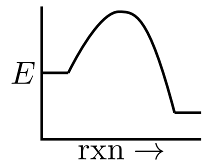
The chlorination of methane is an exothermic reaction with a two-step mechanism shown below:

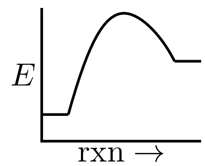
Step 1: $CH_4 + Cl_2 \longrightarrow CH_3 + HCl$ (slow)

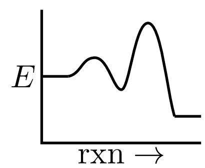
Step 2: $CH_3 + Cl_2 \longrightarrow CH_3Cl + Cl^-$ (fast)

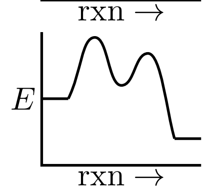
Which of the following reaction coordinate diagrams best fits this data?

1. 

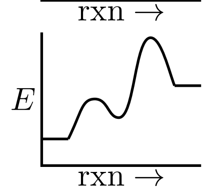
2. 

3. 

4. 

5. 

correct

6. 

Explanation:
The reaction coordinate diagram should match the mechanism and thermodynamics of the reaction. The reaction profile is exothermic, has two humps, and the first hump should be the largest (rate-determining step).

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006 5.0 points

A salt with the generic formula $M(OH)_3$ is stirred into a container of pure water at 25 °C until the solution becomes saturated. The pH is then measured and found to be 10.85. What is the value of K_{sp} for $M(OH)_3$?

1. 3.1×10^{-14}

2. 6.8×10^{-12}

3. 5.7×10^{-13}

4. 8.4×10^{-14} **correct**

5. 2.3×10^{-12}

6. 9.2×10^{-13}

Explanation:

$M(OH)_3(s) \rightleftharpoons M^{3+} + 3OH^-(aq)$

pOH = 14 - 10.85 = 3.15

$[OH^-] = 10^{-3.15} = 7.08 \times 10^{-4}$

$[M^{3+}] = [OH^-]/3 = 2.36 \times 10^{-4}$

$K_{sp} = [M^{3+}][OH^-]^3$

$K_{sp} = (2.36 \times 10^{-4})(7.08 \times 10^{-4})^3$

$K_{sp} = 8.37 \times 10^{-14}$

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007 5.0 points

The solubility of mercury(II) thiocyanate, $Hg(SCN)_2$, is 0.0683 g per 100 mL. What is the K_{sp} for this salt?

1. 2.6×10^{-10}

2. 3.2×10^{-20}

3. 4.0×10^{-8} **correct**

4. 5.3×10^{-12}

5. 4.6×10^{-6}

Explanation:

Convert to molar solubility, x, and then to K_{sp}:

0.0683 g per 100 mL is 0.683g/L

Divide by MWt (316.77) to get 0.00216 M

1:2 salt, $K_{sp} = 4x^3$

$4(.00216)^3 = 4.0 \times 10^{-8}$

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008 5.0 points

Identify the missing isotope in the nuclear reaction.

$$^{226}_{88}\text{Ra} \rightarrow \underline{\quad ? \quad} + ^{4}_{2}\alpha$$

1. $^{230}_{86}$Th

2. $^{226}_{86}$Rn

3. $^{222}_{90}$Rn

4. $^{222}_{86}$Rn **correct**

5. $^{230}_{90}$Th

Explanation:

$$^{226}_{88}\text{Ra} \rightarrow ^{222}_{86}\text{Rn} + ^{4}_{2}\alpha$$

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009 5.0 points

$^{99}_{42}$Mo undergoes radioactive decay by emitting a single beta particle. Which of the following reactions corresponds to this process?

1. $^{99}_{42}\text{Mo} \longrightarrow ^{99}_{44}\text{Ru} + ^{0}_{-1}\beta$

2. $^{99}_{42}\text{Mo} + ^{0}_{-1}\beta \longrightarrow ^{99}_{41}\text{Nb}$

3. $^{99}_{42}\text{Mo} \longrightarrow ^{98}_{42}\text{Tc} + ^{1}_{0}n$

4. $^{99}_{42}\text{Mo} \longrightarrow ^{99}_{43}\text{Tc} + ^{0}_{-1}\beta$ **correct**

5. $^{99}_{42}\text{Mo} + ^{0}_{-1}\beta \longrightarrow ^{99}_{43}\text{Tc}$

Explanation:

Write the balanced reaction involving the emission of a $^{0}_{-1}\beta$ particle.

$^{99}_{42}\text{Mo} \longrightarrow ^{99}_{43}\text{Tc} + ^{0}_{-1}\beta$

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010 5.0 points

How does a catalyst affect the rate of a chemical reaction?

1. A catalyst decreases the rate constant by lowering the activation energy

2. A catalyst increases the energy of the transition state such that a larger number of particles have sufficient energy to overcome the activation energy

3. A catalyst increases the rate constant by increasing the activation energy

4. A catalyst increases the rate constant by providing an alternate mechanism with a lower activation energy **correct**

Explanation:
A catalyst increases the rate constant by providing an alternate mechanism with a lower activation energy

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011 5.0 points

You mix 0.02 mmol $Sr(NO_3)_2$ solution and 0.05 mmol NaF solution to form a 100 mL solution. What precipitate (if any) forms?

1. SrF_2

2. No precipitate forms **correct**

3. $NaNO_3$

4. NaF

5. $Sr(NO_3)_2$

Explanation:
First, come up with the double-displacement equation for this problem to show that SrF_2 is the solid product. However, this product will only be formed if $Q > K$. Therefore, you must solve for Q_{sp} at the instant of mixing:

$$Q_{sp} = [Sr^{2+}][F^-]^2$$

$$Q_{sp} = (.0002)(0.0005)^2 = 5.11 \times 10^{-11}$$

Compare to K_{sp}, which is 4.3×10^{-9}. Because Q is less than K, the solution is understaturated and no precipitate forms.

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012 5.0 points

Consider the elementary reaction shown below at 645 K:

$2HI(g) \rightleftharpoons H_2(g) + I_2(g)$

$k = 1.44 \times 10^{-4}\,M^{-1}s^{-1}$

If 2.00 moles of HI are placed into a 5.00 L container, how many hours will pass after two half-lives?

1. 86.8 hours

2. 14.5 hours **correct**

3. 0.965 hours

4. 1.93 hours

5. 2.95 hours

6. 0.482 hours

Explanation:
Second order reactions have a half life that is dependent on concentration. Simply solve for the total time using this equation for both half-lives:

half-life $= \frac{1}{k[HI]_0}$

52083 seconds $= \frac{1}{k(0.4\,M)} + \frac{1}{k(0.2\,M)}$

$= 14.5$ hours

Alternatively, you can use the integrated rate law to solve for the time it takes to reduce [HI] to a quarter of its original value.

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013 5.0 points

Consider the following reaction:

$$2C_2H_6(g) + 7O_2(g) \longrightarrow 4CO_2(g) + 6H_2O(\ell)$$

Oxygen is being consumed at a rate equal to 1.24 M/s. What is the initial rate at which carbon dioxide is forming?

1. 0.709 M/s **correct**

2. 2.17 M/s

3. 4.96 M/s

4. 1.24 M/s

5. 8.68 M/s

Explanation:
The stoichiometric ration between carbon dioxide and oxygen is 4:7. This means that carbon dioxide is being formed at $\frac{4}{7}$ the initial rate of oxygen.

$$1.24\,M/s \times \frac{4\,CO_2}{7\,O_2} = 0.709\,M/s$$

014 5.0 points

Consider the fission reaction of the plutonium-239 isotope, used for nuclear power:

$${}^{1}_{0}n + {}^{239}\text{Pu} \longrightarrow {}^{134}\text{Xe} + {}^{103}\text{Zr} + 3\,{}^{1}_{0}n$$

$$\text{Rate} = k[{}^{1}_{0}n][{}^{239}\text{Pu}]$$

Based on the information above, which of the following statements should be a concern regarding the use of plutonium-239 as a thermal fuel?

1. Exposure to radioactive steam is common in areas surrounding nuclear power plants

2. The rate of the reaction rapidly diminishes as neutrons are consumed in the nuclear chain reaction

3. The fission of the plutonium-239 nucleus is highly endothermic, creating a violent energy output

4. The rate of the reaction can rapidly increase in the first few minutes if this process is not carefully controlled **correct**

Explanation:
Based on the information provided in the question, it should be observed that the rate will rapidly increase at the start of the reaction because 1 neutron reactant becomes 3 neutron products. This will lead to exponential rate growth in the first few minutes of the process if the nuclear chain reaction is not carefully controlled.

015 5.0 points

Which of the following salts is the most soluble in pure water?

1. CaF_2 $K_{sp} = 3.5 \times 10^{-11}$ **correct**

2. $BaSO_4$ $K_{sp} = 1.1 \times 10^{-10}$

3. CuBr $K_{sp} = 6.3 \times 10^{-9}$

4. All of these salts have the same solubility

Explanation:
Calculate the molar solubility, x, for each substance:

CaF_2: $K_{sp} = 3.5 \times 10^{-11} = 4x^3$

$x = 2.06 \times 10^{-4}$ (correct)

$BaSO_4$: $K_{sp} = 1.1 \times 10^{-10} = x^2$

$x = 1.05 \times 10^{-5}$

CuBr: $K_{sp} = 6.3 \times 10^{-9} = x^2$

$x = 7.94 \times 10^{-5}$

016 5.0 points

^{123}I is a radioactive isotope ($t_{1/2} = 13.22$ hours) useful for clinical imaging. How long will it take for a dose to diminish to 18.7% of its original value?

1. 87.9 hours

2. 34.2 hours

3. 38.7 hours

4. 70.7 hours

5. 557 hours

6. 22.2 hours

7. 32.0 hours **correct**

8. 29.7 hours

Explanation:
This is radioactive decay, meaning we must follow first-order kinetics:

$\ln\left(\frac{100}{18.7}\right) = kt$

Solve for k first:

$k = \frac{\ln(2)}{13.22\,\text{hours}}$

$k = 0.052431708\,\text{hours}^{-1}$

Now complete the equation up top to solve for t:

$\ln\left(\frac{100}{18.7}\right)/0.052431708\,\text{hours}^{-1} = t$

$t = 32.0$ hours

017 5.0 points

Barium fluoride (BaF_2) is most soluble in which of the following solutions?

1. 0.50 M NaF

2. The molar solubility of barium fluoride is the same in each of these solutions

3. 0.005 M $Ba(OH)_2$ **correct**

4. 0.18 M NaF

5. 0.15 M $Ba(OH)_2$

Explanation:
According to the common ion effect, solubility decreases as the effective concentration of a common ion increases. The smallest common ion concentration would be the 0.005 M $Ba(OH)_2$.

018 5.0 points

Consider the following reaction mechanism:

Step 1: $2NO \rightleftharpoons N_2O_2$ (k_1, fast, eq.)

Step 2: $O_2 + N_2O_2 \rightarrow 2NO_2$ (k_2, slow)

Which of the following will increase the rate of the reaction without affecting the activation energy of the overall reaction?

I. Increasing the O_2 concentration

II. Increasing the temperature

III. Introducing a catalyst

IV. Increasing the NO_2 concentration

1. I and II only **correct**

2. I only

3. I, II, and III only

4. II only

5. III and IV only

6. I and III only

Explanation:
All statements except for IV will increase the rate of the reaction. However, statement III will increase the rate by decreasing the activation energy of the reaction. Therefore, the only true statements are I and II.

019 5.0 points

A biological reaction has an activation energy of 16.7 kJ/mol and a rate constant equal to 0.012 s^{-1} at 25 °C. What is the value of the rate constant at 37 °C?

1. 0.0092 s^{-1}

2. 0.024 s^{-1}

3. 0.016 s^{-1} **correct**

4. 30.5 s^{-1}

5. 0.012 s^{-1}

Explanation:
Here we use the Arrhenius equation to solve for k_2:

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

$$\ln\left(\frac{k_2}{.012}\right) = \frac{16.7}{.008314}\left(\frac{1}{298.15} - \frac{1}{310.15}\right)$$

Rearrange to solve for k_2 and keep the original units = 0.015573499 s^{-1}

020 5.0 points

Consider the following overall reaction:

$$2\,A_2 + X \rightarrow B.$$

Using the overall reaction, determine the rate law for the following mechanism:

$A_2 + X \rightleftharpoons Z + Y$ (k_1, fast)

$Z + Y \rightarrow I$ (k_2, slow)

$I + A_2 \rightarrow B$ (k_3, fast)

1. Rate = k' [Z][Y]

2. Rate = k' [A_2] [Z] [X]

3. Rate = $k^{'}$ [A_2] [X] **correct**

4. Rate = $k^{'}$ [Z] [X]

5. Rate = $k^{'}$ $[A_2]^2$

6. Rate = $k^{'}$ $[A_2]^2$ [X]

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

$$\text{Rate} = k_2\,[\text{Z}]\,[\text{Y}]$$

For the final answer, we need the rate law in terms of only the reactants of the overall reaction. We need to substitute in for [Z] using the previous fast step in equilibrium:

$$k_1\,[\text{A}_2]\,[\text{X}] = k_{-1}\,[\text{Z}][\text{Y}]$$
$$[\text{Z}] = \frac{k_1}{k_{-1}}\frac{[\text{A}_2]\,[\text{X}]}{[\text{Y}]}$$

If you fit this into your original rate law, you will see that [Y] cancels out:

$$\text{Rate} = \frac{k_2 k_1}{k_{-1}}\frac{[\text{A}_2]\,[\text{X}]\,[\text{Y}]}{[\text{Y}]}$$

So our final answer is just:

$$\text{Rate} = k'[\text{A}_2]\,[\text{X}]$$