

This exam should have 20 questions. The point values are given with each question. Bubble in your answer choices on the bubble sheet provided. Your score is based on what you bubble on the bubble sheet and not what is circled on the exam. Below are some constants you might want to use.

Compound	K_{sp}	Compound	K_{sp}	Compound	K_{sp}
Ag_2SO_4	1.2×10^{-5}	$\text{Ca}(\text{OH})_2$	4.7×10^{-6}	PbCl_2	1.7×10^{-5}
BaCO_3	2.6×10^{-9}	CuCO_3	1.4×10^{-10}	PbI_2	9.8×10^{-9}
BaSO_4	1.1×10^{-10}	PbBr_2	6.6×10^{-6}	$\text{Y}(\text{OH})_3$	1.0×10^{-22}

- 1 The solubility of $\text{Cd}(\text{IO}_3)_2$ is 0.529 g/L at 25°C. What is K_{sp} for this compound? (5 points)
- A. 2.5×10^{-8}
- ✓ B. 6.2×10^{-9}
- C. 3.4×10^{-6}
- D. 3.6×10^{-3}
- E. 7.2×10^{-5}

Explanation: The molecular mass of cadmium iodate is 462.2 g/mol. $(0.529\text{g/L})/(462.2\text{g/mol}) = .00115\text{ M}$. $[\text{Cd}^{2+}] = 0.00115\text{ M}$, $[\text{IO}_3^-] = 0.00229\text{ M}$. $K_{sp} = [\text{Cd}^{2+}][\text{IO}_3^-]^2 = (0.00115)(0.00229)^2 = 6.0 \times 10^{-9}$. The closest choice is the 6.2×10^{-9} .

- 2 Which of the following compounds has the highest molar solubility in water? (5 points)
- A. $\text{Co}(\text{OH})_2$, $K_{sp} = 5.9 \times 10^{-15}$
- B. FeCO_3 , $K_{sp} = 2.1 \times 10^{-11}$
- ✓ C. $\text{Mg}_3(\text{AsO}_4)_2$, $K_{sp} = 2.0 \times 10^{-20}$
- D. CuI , $K_{sp} = 1.3 \times 10^{-12}$

Explanation: CuI and FeCO_3 both have $x = \sqrt{K_{sp}}$ the larger one is FeCO_3 and gives you $x = 4.6 \times 10^{-6}\text{ M}$. $\text{Co}(\text{OH})_2$ will have $x = (K_{sp}/4)^{1/3} = 1.1 \times 10^{-5}$. But $\text{Mg}_3(\text{AsO}_4)_2$ will have the formula $x = (K_{sp}/108)^{1/5} = 4.5 \times 10^{-5}$ which is the largest value of the four choices given.

- 3 **The Setup:** An aqueous solution is allowed to saturate with the salt MX(s) and it turns out that the resulting solution has a X^- concentration of 0.001 M. After sitting for 24 hours a 100 mL sample of this saturated solution is pipetted into another container. No solid on the bottom of the flask was transferred, only the solution part. Now a small portion (between 20 and 35 mL) of a 0.001 M solution of NaX is added to the pipetted solution. (5 points)

Question: What is the K_{sp} for MX and does more solid precipitate when this other solution is added?

- A. $K_{\text{sp}} = 1.0 \times 10^{-3}$ and no precipitate forms.
B. $K_{\text{sp}} = 1.0 \times 10^{-3}$ and a precipitate does form.
✓ C. $K_{\text{sp}} = 1.0 \times 10^{-6}$ and no precipitate forms.
D. $K_{\text{sp}} = 1.0 \times 10^{-6}$ and a precipitate does form.
E. $K_{\text{sp}} = 4.0 \times 10^{-9}$ and no precipitate forms.
F. $K_{\text{sp}} = 4.0 \times 10^{-9}$ and a precipitate does form.

Explanation: The K_{sp} is just the 0.001 squared $x^2 = (.001)^2 = 1.0 \times 10^{-6}$. There can be no precipitate because the X^- concentration never changes (both solutions are 0.001 M) and the M^+ concentration drops due to dilution which means the solution goes undersaturated and no precipitation occurs.

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- 4 Yttrium hydroxide is added to water to make a saturated solution at 25°C. What is the pH of this solution? (5 points)

- A. 8.74
B. 8.14
C. 8.26
D. 7.00
✓ E. 8.62
F. 6.94
G. 6.66
H. 7.81
I. 9.06
J. 7.28

Explanation: The ICE table for Y(OH)_3 leads to $K_{\text{sp}} = (x)(3x)^3$. Solving for x you get $x = (K_{\text{sp}}/27)^{1/4}$, where $x = (10^{-22}/27)^{1/4} = 1.39 \times 10^{-6}$. $[\text{OH}^-] = 3x = 4.16 \times 10^{-6}$ M. $\text{pOH} = 5.38$ and $\text{pH} = 8.62$

- 5 A large scoop of Ag_2SO_4 is added to a liter of water and stirred to make a saturated solution. What is the concentration of silver ion in this solution? (5 points)
- ✓ A. 0.0288 M
B. 0.0144 M
C. 0.0035 M
D. 0.0432 M
E. 0.0024 M

Explanation: $K_{\text{sp}} = [\text{Ag}^+]^2[\text{SO}_4^{2-}]$, $[\text{Ag}^+] = 2x$, $[\text{SO}_4^{2-}] = x$. Therefore $K_{\text{sp}} = 4x^3 = 1.2 \times 10^{-5}$. Solving for x you get 0.0144 M. $[\text{Ag}^+] = 2x = 0.0288$ M.

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- 6 If you mix 300 mL of a 0.05 M solution of $\text{Pb}(\text{NO}_3)_2$ solution with 200 mL of a 0.025 M solution of CaCl_2 , will you form a precipitate? and Why? (5 points)
- ✓ A. no, because $Q_{\text{sp}} < K_{\text{sp}}$
B. yes, because $Q_{\text{sp}} < K_{\text{sp}}$
C. no, because $Q_{\text{sp}} > K_{\text{sp}}$
D. yes, because $Q_{\text{sp}} > K_{\text{sp}}$
E. no, because $Q_{\text{sp}} = K_{\text{sp}}$
F. yes, because $Q_{\text{sp}} = K_{\text{sp}}$

Explanation: You need to compare Q_{sp} to K_{sp} . $Q_{\text{sp}} = [\text{Pb}^{2+}][\text{Cl}^-]^2$. You must first account for the diluting of adding 300mL to 200mL. $[\text{Pb}^{2+}] = (0.05\text{M})(300\text{mL}/500\text{mL}) = 0.03$ M. For the chloride ion, the concentration in the original solution is double that of the formula unit (0.05M), accounting for dilution, $[\text{Cl}^-] = (0.05\text{M})(200\text{mL}/500\text{mL}) = 0.02\text{M}$. $Q_{\text{sp}} = [\text{Pb}^{2+}][\text{Cl}^-]^2 = (0.03)(0.02)^2 = 1.2 \times 10^{-5}$ which is less than 1.7×10^{-5} . When $Q_{\text{sp}} < K_{\text{sp}}$ no precipitate is formed, solution is undersaturated.

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- 7 What is the molar solubility of lead(II) bromide in a solution of 0.255 M NaBr? (5 points)
- A. 1.2×10^{-2}
B. 6.5×10^{-6}
C. 2.5×10^{-5}
✓ D. 1.0×10^{-4}
E. 4.1×10^{-3}

Explanation: $K_{\text{sp}} = [\text{Pb}^{2+}][\text{Br}^-]^2$. The bromide ion conc is set via the NaBr to 0.255. So the amount that dissolves is the lead ion and $[\text{Pb}^{2+}] = K_{\text{sp}}/(0.255)^2 = 1.0 \times 10^{-4}$ M.

- 8 A solution contains both the anions sulfate and carbonate at concentrations of 0.0010 M each. Barium ion is introduced to this solution to selectively precipitate out the sulfate ion and leave the carbonate behind. What is the maximum percentage of the sulfate ion that can be precipitated with no interference from the carbonate ion? (5 points)

- A. 95.77%
B. 96.68%
C. 99.83%
D. 97.25%
E. 98.55%
F. 93.42%

Explanation: $[\text{Ba}^{2+}] = 2.6 \times 10^{-9} / (0.001) = 2.6 \times 10^{-6}$ (the carbonate precip onset). $[\text{SO}_4^{2-}] = 1.1 \times 10^{-10} / 2.6 \times 10^{-6} = 4.23 \times 10^{-5}$ M sulfate still in solution $4.23 \times 10^{-5} / 0.001 \times 100\% = 4.23\%$ still in solution which means that 95.77% has been precipitated.

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- 9 The reaction: $2\text{NO}(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow 2\text{NOCl}$ (5 points)
is first order in chlorine and second order in nitrogen monoxide.
What are the units for the rate constant?

- A. $\text{M}^{-1} \text{s}^{-1}$
B. $\text{M} \text{s}^{-1}$
C. M^{-1}
 D. $\text{M}^{-2} \text{s}^{-1}$
E. s^{-1}

Explanation: The reaction is third order overall. $\text{rate} = k[\text{NO}]^2[\text{Cl}_2]$
In order to get the desired M/s units for rate, k must have units of $\text{M}^{-2} \text{s}^{-1}$

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- 10 For the reaction: $2\text{HI}(\text{g}) \rightarrow \text{H}_2(\text{g}) + \text{I}_2(\text{g})$ (5 points)
the rate constant at 650 K was determined to be 2.15×10^{-8} . When the temperature was increased to 700 K, the rate constant was found to be 2.39×10^{-7} . What is the activation energy for this reaction?

- A. 182 kJ/mol
B. 1.79 kJ/mol
C. 63.2 kJ/mol
D. 203 kJ/mol
E. 20.3 kJ/mol

Explanation:

$$\ln \frac{2.39 \times 10^{-7}}{2.15 \times 10^{-8}} = \frac{E_a}{8.314} \left(\frac{1}{650} - \frac{1}{700} \right)$$

$$E_a = 182,344 \text{ J/mol} = 182 \text{ kJ/mol}$$

- 11 The overall reaction $3A + B \rightarrow 2C + 5D$ (5 points)
- is proceeding such that the rate of change in product D is +0.025 M/min. What is the corresponding rate of change in reactant A?
- A. -0.005 M/min
 - B. +0.005 M/min
 - C. -0.010 M/min
 - D. +0.010 M/min
 - ✓ E. -0.015 M/min
 - F. +0.015 M/min
 - G. -0.025 M/min
 - H. +0.025 M/min

Explanation: The reactant A is running at 3/5 that of D and opposite in sign.

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- 12 A decomposition reaction has the rate law $k[A]^2$ where the rate constant is $1.2 \times 10^{-4} \text{ M}^{-1} \text{ s}^{-1}$. About how long will it take for a 0.25 M sample of A to decompose down to 0.0010 M? (5 points)
- A. 13 hours
 - ✓ B. 96 days
 - C. 48 days
 - D. 35 minutes
 - E. 122 days
 - F. 21 hours

Explanation: use 2nd order integrated rate law: $t = (1/.001 - 1/.25)/0.00012 = 8.3\text{e}6$ seconds. $/60 /60 /24 = 96$ days.

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- 13 The decomposition of aqueous hydrogen peroxide to gaseous oxygen and water is a first-order reaction with a rate constant of $k = 0.1066 \text{ hr}^{-1}$. If it takes 6.5 hours for the concentration of H_2O_2 to decrease from 0.50M to 0.25M, how many hours are required for the concentration to decrease from 0.40M to 0.10M? (5 points)
- ✓ A. 13 hours
 - B. 6.5 hours
 - C. 3.25 hours
 - D. 30 hours
 - E. 9.75 hours
 - F. 19.5 hours

Explanation: There are two possible ways to solve this problem. In the general method, solve for time using the first-order integrated rate equation: $\frac{[A]_0}{[A]} = e^{-kt}$ which is equivalent to $\ln(A) = -kt + \ln(A_0)$. $\ln 0.10 = - (0.1066 \text{ hr}^{-1})(t) + \ln 0.40$, $-2.3026 = - (0.1066 \text{ hr}^{-1})(t) - 0.9163$, $-1.3863 = - (0.1066 \text{ hr}^{-1})(t)$, $t = 13 \text{ hr}$

Alternatively, one could recognize that a decrease from 0.50 to 0.25 represents one half-life. A decrease from 0.40 to 0.10 is two half-lives. Since we are informed that one half-life equals 6.5 hrs, the time to go from 0.40 to 0.10 must 13 hrs.

14 A table of initial rate data are shown for the reaction



Use the data in the table to determine the *overall* order for this reaction.

- A. zero
- B. first
- C. second
- D. third
- ✓ E. fourth
- F. fifth
- G. it is not possible to determine the order from this data

	[A] (M)	[B] (M)	rate (M/min)
1	0.1	0.1	0.03
2	0.1	0.2	0.24
3	0.2	0.2	0.48

(5 points)

Explanation: As [A] doubles, the rate doubles, indicating the reaction is first order in A ($2^1 = 2$). As [B] doubles, the rate goes up by a factor of 8, indicating it is third order in B. ($2^3 = 8$). First order in A and third order in B means that the reaction is fourth order overall.

15 Which of the following factors does not ultimately affect the reaction rate?

(5 points)

- A. temperature
- B. pressure of a reactant
- C. amount of catalyst
- ✓ D. magnitude of ΔG°
- E. size of reactant particles

Explanation: ΔG° does not affect reaction rates - it affects spontaneity and the equilibrium condition.

16 Balance the reaction: $?H_2S(g) + ?O_2(g) \rightarrow ?S(s) + ?H_2O(\ell)$

(5 points)

Now, after further inspection, which one of the following is the proper conclusion pertaining to the rate law?

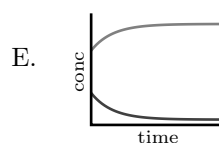
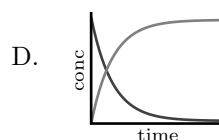
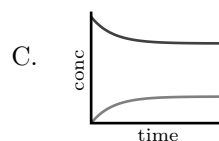
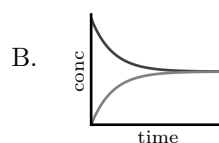
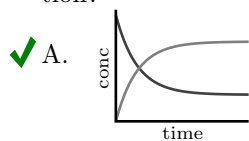
- A. The reaction is first order with respect to H_2S and second order with respect to O_2 .
- B. The reaction is fourth order overall.
- C. The rate law is: $rate = k[H_2S]^2[O_2]$.
- D. The reaction is catalyzed by the O_2 .
- ✓ E. The rate law cannot be determined from the information given.

Explanation: A rate law can only be determined experimentally.

17 Consider the simple reaction: $A \longrightarrow B$

(5 points)

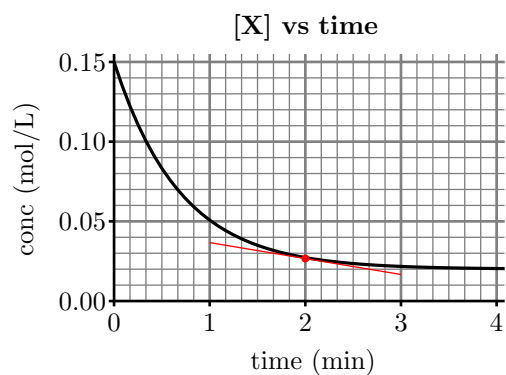
At 25°C, the forward reaction has a rate constant equal to 0.045 min^{-1} , while the reverse reaction has a rate constant equal to 0.015 min^{-1} . Which of the following plots is the correct one for this reaction?



Explanation: The ratio of the rate constants is 3 which is what the equilibrium constant, K , must equal. There is only one plot where the products finish at a 3:1 ratio more than the reactants.

18 Look at the concentration vs time plot to the right for a simple $X \rightarrow Y$ reaction scheme. What is the rate of the reaction at 120 seconds?

- A. $6.0 \times 10^{-2} \text{ M/min}$
 B. $9.0 \times 10^{-2} \text{ M/min}$
 C. $6.8 \times 10^{-4} \text{ M/min}$
 ✓ D. $1.0 \times 10^{-2} \text{ M/min}$
 E. $3.0 \times 10^{-3} \text{ M/min}$
 F. $3.0 \times 10^{-1} \text{ M/min}$



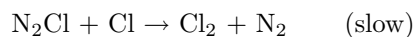
Explanation: The absolute value of the tangential slope at 2 minutes is $1.0 \times 10^{-2} \text{ M/min}$. Notice the red line shown over the graph.

19 How is it that a catalyst is able to speed up a reaction? (5 points)

- A. By participating in the reaction mechanism and lowering the activation energy.
- B. By physically shifting the reaction to the right (products).
- C. By lowering the enthalpy of the reaction, ΔH_{rxn} .
- D. This is a false statement. Catalysts do not speed up reactions.
- E. By increasing the enthalpy of the reaction, ΔH_{rxn} .
- F. By raising the activation energy via reactant-catalyst interaction.
- G. By changing the energies of all species in the reaction scheme.

Explanation: A catalyst alters the mechanism of a reaction by participating in the reaction mechanism and lowering the barrier of the rate limiting step which is the activation energy.

20 Consider the following 2-step mechanism for combining Cl atoms to make Cl_2 . (5 points)



Which of the following rate laws does this mechanism support?

- A. $\text{rate} = k[\text{N}_2\text{Cl}][\text{Cl}]$
- B. $\text{rate} = k[\text{Cl}]^2$
- C. $\text{rate} = k[\text{N}_2][\text{Cl}]^2$
- D. $\text{rate} = k \frac{[\text{Cl}]}{[\text{Cl}_2]}$
- E. $\text{rate} = k[\text{N}_2][\text{Cl}]$

Explanation: none

Remember to bubble in ALL your answers BEFORE time is called. Please SIGN your bubblesheet. Turn in your bubblesheet and KEEP your exam copy for reference.