

General Chemistry II Jasperse
Chemical equilibria. Extra Practice Problems

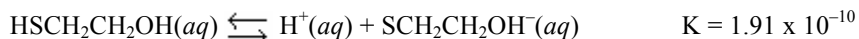
General Types/Groups of problems:

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Big-Picture Introductory Conceptual Questions

- Which of the following is true for a chemical reaction at equilibrium?
 - only the forward reaction stops
 - only the reverse reaction stops
 - both the forward and reverse reactions stop
 - the rate constants for the forward and reverse reactions are equal
 - the rates of the forward and reverse reactions are equal
- Which of the following is true regarding the **concentration of products**, for a chemical reaction **that is already at equilibrium**, assuming no disruptions to the equilibrium?
 - The concentrations of products will not change because there are no more reactants.
 - The concentrations of products will not change because the limiting reagent is gone.
 - The concentrations of products will not change because the forward and reverse rates are equal.
 - The concentrations of products will change continually because of reversibility.
- Which of the following are equal for a chemical system at equilibrium? If all are equal, answer E.
 - the **concentrations** of reactant and products are equal
 - the **rate constants** for the forward and reverse reactions are equal
 - the **time** that a particular atom or molecule spends as a reactant and product are equal
 - the **rate** of the forward and reverse reaction
 - all** of the above are equal
- A chemical equilibrium may be established by starting a reaction with _____
 - reactants only.
 - products only.
 - equal quantities of reactants and products.
 - any quantities of reactants and products.
 - all the above
- An equilibrium that strongly favors products has _____
 - a value of $K \ll 1$.
 - a value of $K \gg 1$.
 - a value of $Q \gg 1$.
 - a value of $Q \ll 1$.
 - $K = Q$.

6. The equilibrium constant for the acid ionization of mercaptoethanol ($\text{HSCH}_2\text{CH}_2\text{OH}$) is 1.91×10^{-10} .

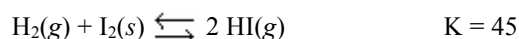


Which of the following statements is true regarding this equilibrium?

- I. The reaction is product favored.
- II. The reaction is reactant favored.
- III. Equilibrium lies far to the right.
- IV. Equilibrium lies far to the left.

- a. I and III
- b. I and IV
- c. II and III
- d. II and IV
- e. None are true, as the concentrations of reactants and products are comparable.

7. The equilibrium constant for the formation of hydrogen iodide from hydrogen and iodine is 45 at a certain temperature.



Which of the following is true regarding this equilibrium?

- I. The reaction is product favored.
- II. The reaction is reactant favored.
- III. Equilibrium lies to the right.
- IV. Equilibrium lies to the left.

- a. I and III
- b. I and IV
- c. II and III
- d. II and IV
- e. None are true, as the concentrations of reactants and products are essentially the same.

8. If the reaction quotient Q has a **smaller value** than the related equilibrium constant, K , _____

- a. the reaction is at equilibrium.
- b. the reaction is not at equilibrium, and will make more products at the expense of reactants.
- c. the reaction is not at equilibrium, and will make more reactants at the expense of products.
- d. the value of K will decrease until it is equal to Q .

9. If the reaction quotient Q has a **larger value** than the related equilibrium constant, K , _____

- a. the reaction is at equilibrium.
- b. the reaction is not at equilibrium, and will make more products at the expense of reactants.
- c. the reaction is not at equilibrium, and will make more reactants at the expense of products.
- d. the value of K will increase until it is equal to Q .

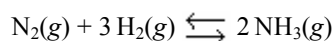
10. If the equilibrium is established by initially adding 0.10 mol each of A and B to a 1L container, then which of the following must be true once the mixture achieves equilibrium?



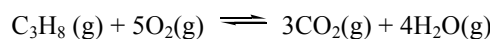
- a. $[\text{A}] = [\text{B}]$
- b. $[\text{A}] = [\text{B}] = [\text{C}]$
- c. $[\text{B}] = 2[\text{C}]$
- d. $[\text{A}] > [\text{B}]$
- e. $[\text{A}] < [\text{B}]$

Writing the Equilibrium Constant.**Reminder: solutes (aq) or gases (g) appear; solvents (l) or solids (s) do not.**

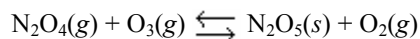
11. Write an expression for the equilibrium constant for the formation of two moles of ammonia gas (NH₃) from nitrogen and hydrogen in their standard states.



12. Write the correct K_c expression for the following reaction?



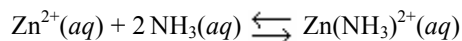
13. Write an expression for the equilibrium constant for this reaction.



14. For the reaction $2\text{A} + \text{B} \rightarrow 2\text{C}$ the appropriate form for the equilibrium constant expression is:

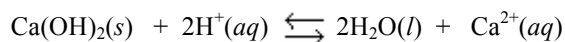
- $[\text{A}][\text{B}]^2/[\text{C}]$
- $[\text{A}]^2[\text{B}]/[\text{C}]^2$
- $[\text{C}]^2/[\text{A}]^2[\text{B}]$
- $[\text{A}][\text{B}]^2[\text{C}]$
- none of the above

15. Write the equilibrium expression for the reaction

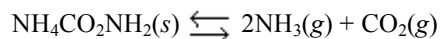


- | | |
|--|--|
| a. $K = [\text{Zn}^{2+}] + 2[\text{NH}_3] + [\text{Zn}(\text{NH}_3)_2^{2+}]$ | d. $K = \frac{[\text{Zn}(\text{NH}_3)_2^{2+}]}{[\text{Zn}^{2+}][\text{NH}_3]^2}$ |
| b. $K = \frac{[\text{Zn}^{2+}] + 2[\text{NH}_3]}{[\text{Zn}(\text{NH}_3)_2^{2+}]}$ | e. $K = [\text{Zn}(\text{NH}_3)_2^{2+}] - [\text{Zn}^{2+}] - 2[\text{NH}_3]$ |
| c. $K = \frac{[\text{Zn}^{2+}][\text{NH}_3]^2}{[\text{Zn}(\text{NH}_3)_2^{2+}]}$ | |

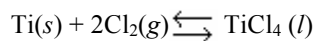
16. Write an expression for the equilibrium constant for this reaction.



17. Write an expression for the equilibrium constant for this reaction.

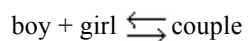


18. Write an expression for the equilibrium constant for this reaction.



Dumb and Silly ones! ☺

19. Identify the equilibrium expression for the following reaction:



a. $k = \frac{[\text{boy}][\text{girl}]}{[\text{couple}]}$

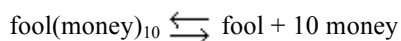
d. $k = \frac{[\text{couple}]}{[\text{boy}][\text{girl}]}$

b. $k = \frac{[\text{boy}] + [\text{girl}]}{[\text{couple}]}$

e. $k = [\text{couple}] - [\text{boy}] - [\text{girl}]$

c. $k = [\text{boy}][\text{girl}][\text{couple}]$

20. Write the equilibrium expression for the following reaction, assuming homogeneity:



a. $k = \frac{[\text{fool}(\text{money})_{10}][\text{fool}][\text{money}]}{[\text{fool}][\text{money}]^{10}}$

d. $k = \frac{[\text{fool}(\text{money})_{10}]^{10}}{[\text{fool}][\text{money}]}$

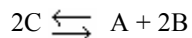
b. $k = \frac{[\text{fool}][\text{money}]^{10}}{[\text{fool}(\text{money})_{10}]}$

e. $k = [\text{fool}] + 10[\text{money}] - [\text{fool}(\text{money})_{10}]$

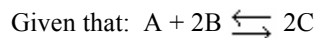
c. $k = \frac{[\text{fool}(\text{money})_{10}][\text{fool}][\text{money}]^{10}}{[\text{fool}][\text{money}]}$

Manipulations of K: Reversing or Multiplying or Both

21. For the chemical equilibrium $A + 2B \rightleftharpoons 2C$, the value of the equilibrium constant, K , is 10. What is the value of the equilibrium constant for the reaction written in reverse?

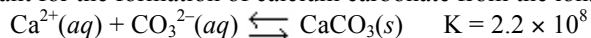


$$K = ???$$

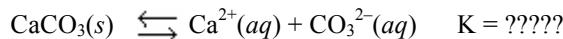


$$K = 10$$

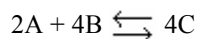
- a. 0.10
b. 10
c. 1
- d. 100
e. -10
22. The equilibrium constant for the formation of calcium carbonate from the ions in solution is 2.2×10^8 according to the reaction:



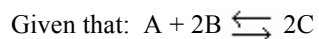
What is the value of the equilibrium constant for the reverse of this reaction?



- a. the same, 2.2×10^8
b. -2.2×10^8
c. 2.2×10^{-8}
- d. 4.5×10^{-9}
e. 4.5×10^9
23. For the chemical equilibrium $A + 2B \rightleftharpoons 2C$, the value of the equilibrium constant, K , is 10. What is the value of the equilibrium constant for the following reaction?

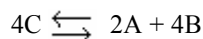


$$K = ???$$

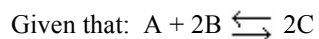


$$K = 10$$

- a. 0.10
b. 0.20
c. 40
- d. 400
e. 100
24. For the chemical equilibrium $A + 2B \rightleftharpoons 2C$, the value of the equilibrium constant, K , is 10. What is the value of the equilibrium constant for the following reaction?

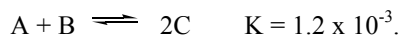


$$K = ???$$



$$K = 10$$

- a. 0.10
b. 0.20
c. 0.010
- d. 20
e. 100
25. Given:



What is K for the reaction

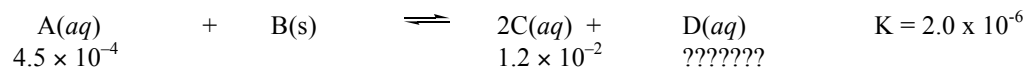


K Calculations: Solving for an Equilibrium Concentration when K and all Other Equilibrium Concentrations are Given

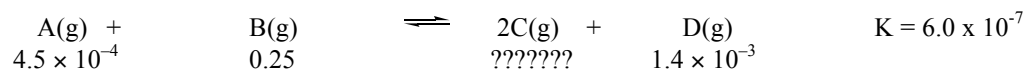
30. What is the equilibrium concentration of Br₂ if [HBr] = 0.35 M and [H₂] = 0.22 M at equilibrium?



31. What is the equilibrium concentration of D?

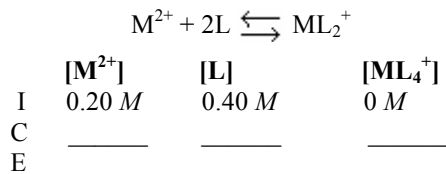


32. What is the equilibrium concentration of C?



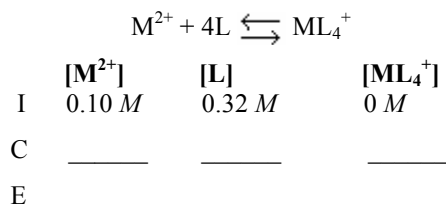
Using Ice: Generic, Then Real But Simple Numbers

33. In the ICE table started for calculating equilibrium concentrations of the reaction shown, the three terms in the "change" row are _____



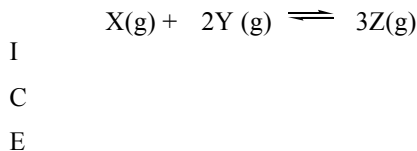
- a. $-x, -x, +x$
 b. $+x, +x, -x$
 c. $-x, -2x, +x$
 d. $+x, +2x, +x$
 e. $+x, +4x, -x$

34. In the ICE table started for calculating equilibrium concentrations of the reaction shown, the three terms in the "change" row are _____



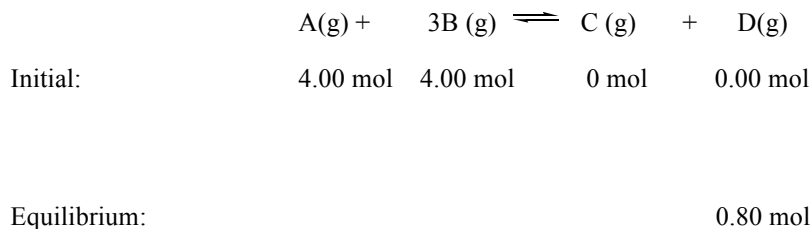
- a. $-x, -x, +x$
 b. $+x, +x, -x$
 c. $-x, -4x, +x$
 d. $+x, +4x, +x$
 e. $+x, +4x, -x$

35. A reaction $X + 2Y \rightarrow 3Z$ is started with 1.0 M Z and no X or Y. To calculate the equilibrium concentrations of all species using an ICE table, which of the following would you enter in the Z column for the C row?



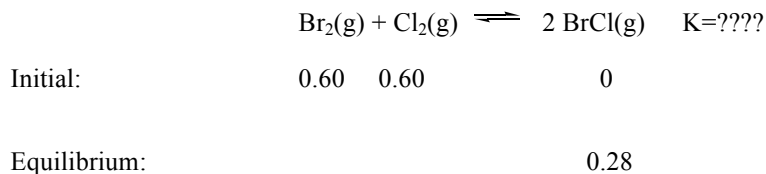
- a. 1.0 M
 b. $1.0 M - x$
 c. $1.0 M - 3x$
 d. $1.0 M + 3x$
 e. $-3x$

36. When 4.00 mol of A and 4.00 mol of B are placed in a container and allowed to come to equilibrium, the resulting mixture is found to contain 0.80 mol of D. **What are the amounts of A, B, and C at equilibrium?**

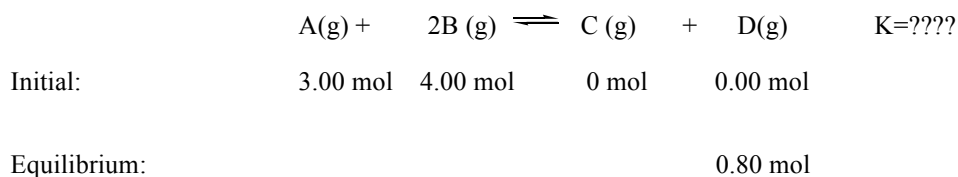


Using Ice: Solving for K given Initial Concentrations and at Least one Equilibrium Concentration

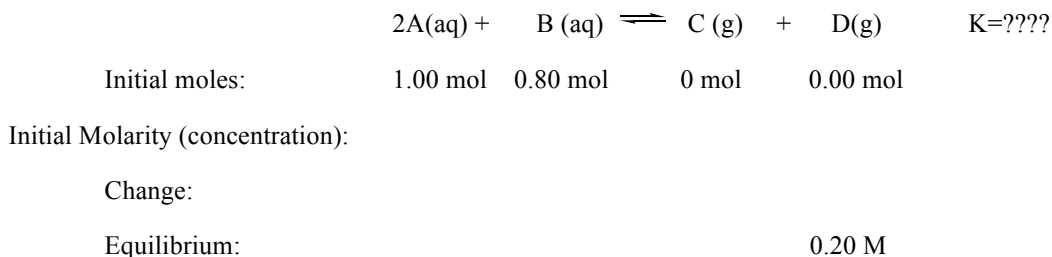
37. 0.60 mol of Br₂ and 0.60 mol of Cl₂ are placed in a 1.00 L flask and allowed to reach equilibrium. (There is no BrCl at first.) After reaching equilibrium, the flask is found to contain 0.28 mol of BrCl. **What is the value of K for this reaction?**



38. When 3.00 mol of A and 4.00 mol of B are placed in a container and allowed to come to equilibrium, the resulting mixture is found to contain 0.80 mol of D. **What is the value of K at equilibrium?**

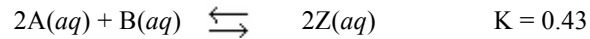


39. When 1.00 mol of A and 0.800 mol of B are placed **in a 2.00 L container** and allowed to come to equilibrium, the resulting mixture is found to be 0.20M in D. What is the value of K at equilibrium? (This problem requires extra step of using quantity and volume to convert to molarity. Here I'm giving you moles; in lab you might instead be starting with grams, and needing to convert grams to moles, then moles to molarity.)

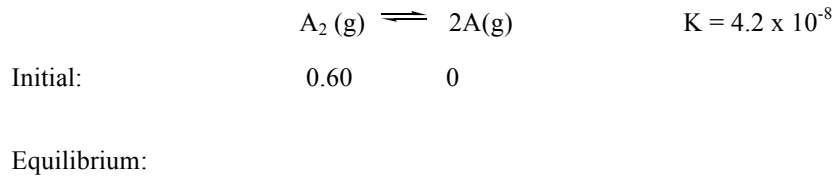


Solving for Equilibrium Concentrations Using Ice, Given K

40. Concept Question: Given a K value of 0.43 for the following aqueous equilibrium, suppose sample Z is placed into water such that its original concentration is 0.033 M. Assume there was zero initial concentration of either A(aq) or B(aq). Once equilibrium has occurred, what will be the equilibrium concentration of Z?



- a. more than 0.033 M
 b. less than 0.033 M
 c. 0.033 M exactly
 d. there is no way to tell
41. What are the **final concentrations** of A and A₂ **at equilibrium** if the initial [A₂] concentration is 0.60M?



42. Find final equilibrium concentrations for HA, H⁺, and A⁻:



Initial Concentrations 0.60 0 0

43. Find final equilibrium concentrations for HA, H⁺, and A⁻:



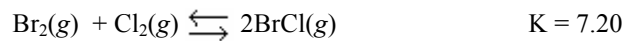
Initial Concentrations 0.30 0 0

44. Find final equilibrium concentrations for HA, H⁺, and A⁻:

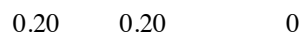


Initial Concentrations 0.30 0 0

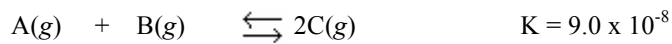
45. The reaction of bromine gas with chlorine gas, shown here, has a K_c value of 7.20 at 200°C. If a closed vessel was charged with the two reactants, each at an initial concentration of 0.200 M, but with no initial concentration of BrCl, what would be the equilibrium concentration of BrCl(g)?



Initial Concentrations



46. Given the initial concentrations shown below, find the equilibrium concentrations for A, B, and C.



Initial Concentrations



LeChatelier's Principle: When a System at Equilibrium has something happen that disrupts the equilibrium. How will the concentrations respond to reestablish equilibrium?

- **3 Types of disruptions:**
 - 1. Change in Concentration**
 - 2. Change in Temperature**
 - 3. Change in Volume or Pressure**

Concepts involving Q

- **When a System may not Actually be at Equilibrium to Start with**
- **Or after a LeChatelier's Principle Disruption**

47. Which of the following occurs when **reactants are added** to a chemical reaction in solution or the gas phase at equilibrium?
- a. Q increases, so the equilibrium shifts to produce more products.
 - b. Q increases, so the equilibrium shifts to produce more reactants.
 - c. Q decreases, so the equilibrium shifts to produce more products.
 - d. Q decreases, so the equilibrium shifts to produce more reactants.
 - e. Q is unchanged by the addition of reactants.
48. Which of the following occurs when **products are added** to a chemical reaction in solution or the gas phase at equilibrium?
- a. Q increases, so the equilibrium shifts to produce more products.
 - b. Q increases, so the equilibrium shifts to produce more reactants.
 - c. Q decreases, so the equilibrium shifts to produce more products.
 - d. Q decreases, so the equilibrium shifts to produce more reactants.
49. Which of the following occurs when **products are removed** from a chemical reaction in solution or the gas phase at equilibrium?
- a. Q increases, so the equilibrium shifts to produce more products.
 - b. Q increases, so the equilibrium shifts to produce more reactants.
 - c. Q decreases, so the equilibrium shifts to produce more products.
 - d. Q decreases, so the equilibrium shifts to produce more reactants.
50. Which of the following occurs when **reactants are removed** from a chemical reaction in solution or the gas phase at equilibrium?
- a. Q increases, so the equilibrium shifts to produce more products.
 - b. Q increases, so the equilibrium shifts to produce more reactants.
 - c. Q decreases, so the equilibrium shifts to produce more products.
 - d. Q decreases, so the equilibrium shifts to produce more reactants.
51. Increasing the temperature of an **exothermic** reaction results in _____
- a. more products and fewer reactants.
 - b. more reactants and fewer products.
 - c. more reactants and products.
 - d. fewer reactants and products.
 - e. no change in the quantities of reactants and products.

52. Increasing the temperature of an **endothermic** reaction results in _____

- more products and fewer reactants.
- more reactants and fewer products.
- more reactants and products.
- fewer reactants and products.
- no change in the quantities of reactants and products.

53. For the following reaction, write how each of the changes will affect the indicated quantity, assuming a container of fixed size. Write “increase”, “decrease”, or “no change”. (Or use an “up” arrow to indicate “increase”, and a “down” arrow to indicate “decrease”.) (For a chemical added, write how it would respond AFTER the addition.)



Change	[H ₂]	[Br ₂]	[HBr]	K value
1. Some H ₂ added				
2. Some HBr added				
3. Some H ₂ removed				
4. Some HBr removed				
5. The temperature is increased				
6. The temperature is decreased				
7. Pressure is increased and the container volume decreased				

54. For the following reaction, write how each of the changes will affect the indicated quantity, assuming a container of fixed size. Write “increase”, “decrease”, or “no change”. (Or use an “up” arrow to indicate “increase”, and a “down” arrow to indicate “decrease”.) (For a chemical added, write how it would respond AFTER the addition.)



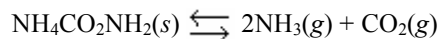
Change	[NO ₂]	[NO]	[O ₂]	K value
1. Some NO ₂ added				
2. Some O ₂ added				
3. Some NO ₂ removed				
4. Some O ₂ removed				
5. The temperature is increased				
6. The temperature is decreased				
7. Pressure is increased (and the container volume decreased)				
8. Pressure is decreased (so the container volume increases)				

55. Given: $2\text{A}(\text{g}) \rightleftharpoons \text{B}(\text{g}) + \text{C}(\text{g}) \quad \Delta H^\circ = +27\text{ kJ} \quad K = 3.2 \times 10^{-4}$

Which of the following would be true if the temperature were increased from 25°C to 100°C?

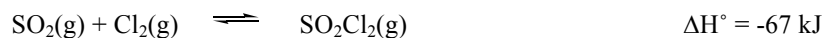
- The value of K would be smaller.
 - The concentration of A(g) would be increased.
 - The concentration of B(g) would increase.
- 1 only
 - 2 only
 - 3 only
 - 1 and 2 only
 - 2 and 3 only

56. Which of the listed perturbations will change the position of equilibrium for the following reaction? List those that do as a sequence of letters, e.g., ACE. (There is more than one.)



- A. Increasing the quantity of $\text{NH}_4\text{CO}_2\text{NH}_2(s)$
- B. Removing $\text{CO}_2(g)$
- C. Increasing the total pressure
- D. Increasing the volume of the container

57. Given the following reaction at equilibrium, which of the following alterations will increase the amount (in moles) of SO_2Cl_2 : (there is only one correct answer)



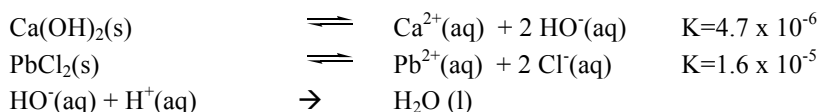
- a. adding heat to the system
- b. adding Cl_2 to the system.
- c. removing Cl_2 from the system.
- d. increasing the volume of the reaction vessel.

58. Given: $\text{A}(s) + \text{B}(l) \rightleftharpoons \text{C}(g) + \text{D}(g) \quad \Delta H^\circ = 84.3 \text{ kJ}$

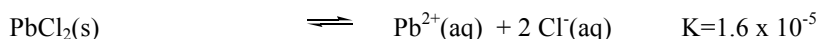
If the above reactants and products are contained in a closed vessel and the reaction system is at equilibrium, the number of moles of C can be decreased by which of the following? (Note that the reactants are solid and liquid.)

- a. adding some A to the system.
- b. removing some D from the system.
- c. decreasing the size/volume of the reaction vessel.
- d. increasing the temperature of the reaction system.
- e. adding some B to the system.

59. Calcium hydroxide and lead chloride both have limited solubility in neutral water. When acid is added, the solubility of calcium hydroxide goes way up, but that of lead chloride doesn't change. Which statement explains the acid impact?



- a. Acid reacts with the calcium ions that are produced.
 - b. Acid increases the solubility of any slightly-soluble solid.
 - c. Acid reacts with the hydroxide that is produced from calcium hydroxide. By removing the hydroxide product, this has a LeChatelier-type impact and results in more calcium hydroxide dissolving to produce more calcium ions.
60. PbCl_2 has limited solubility in neutral water. But the amount of lead ions is reduced when sodium chloride is added to the water. Addition of sodium chloride has no impact on the solubility of Ca(OH)_2 . Which statement explains why?



- a. Sodium ions reacts with the lead ions that are produced.
- b. Addition of sodium ions reduces the solubility of any slightly-soluble solid.
- c. Adding sodium chloride effectively adds aqueous chloride ions. The addition of chloride ions has a LeChatelier-type impact, drives the PbCl_2 solubility to the left, and results in less PbCl_2 dissolving.

1. E
2. C
3. D
4. E
5. B
6. D
7. A
8. B
9. C
10. D
11. $K = [\text{NH}_3]^2 / [\text{N}_2][\text{H}_2]^3$
12. $K = [\text{H}_2\text{O}]^4 [\text{CO}_2]^3 / [\text{C}_3\text{H}_8][\text{O}_2]^5$
13. $K = [\text{O}_2] / [\text{N}_2\text{O}_4][\text{O}_3]$
14. C
15. D
16. $K = [\text{Ca}^{2+}] / [\text{H}^+]^2$
17. $K = [\text{NH}_3]^2 [\text{CO}_2]$
18. $K = 1 / [\text{Cl}_2]^2$
19. D
20. B
21. A
22. D
23. E
24. C
25. 8.3×10^2
26. 0.016
27. 5.6×10^{-4}
28. C
29. 49
30. 8.9×10^{-3}
31. 6.25×10^{-6}
32. 2.19×10^{-4}
33. C
34. C
35. E
36. 3.2 mol, 1.6 mol, 0.8 mol
37. 0.37
38. $K = 0.0505$
39. $K = 20$

40. B
41. 1.6×10^{-4}
42. $[\text{H}^+] = [\text{A}^-] = 3.5 \times 10^{-3}$, $[\text{HA}] = 0.60$
43. $[\text{H}^+] = [\text{A}^-] = 3.9 \times 10^{-5}$, $[\text{HA}] = 0.30$
44. $[\text{H}^+] = [\text{A}^-] = 0.165$, $[\text{HA}] = 0.135$
(quadratic required for 44)
45. $[\text{Br}_2] = [\text{Cl}_2] = 0.085$, $[\text{BrCl}] = 0.23$
46. $[\text{A}] = [\text{B}] = 0.500$, $[\text{C}] = 1.5 \times 10^{-4}$
47. C
48. B
49. C
50. B
51. B
52. A
- 53.

	$[\text{H}_2]$	$[\text{Br}_2]$	$[\text{HBr}]$	K
1	down	down	up	--
2	up	up	down	--
3	up	up	down	--
4	down	down	up	--
5	up	up	down	down
6	down	down	up	up
7	--	--	--	--

54.

	$[\text{NO}_2]$	$[\text{NO}]$	$[\text{O}_2]$	K
1	down	up	up	--
2	up	down	down	--
3	up	down	down	--
4	down	up	up	--
5	down	up	up	up
6	up	down	down	down
7	up	down	down	down
8	down	up	up	up

55. C
56. B,C,D
57. B
58. C
59. C
60. C