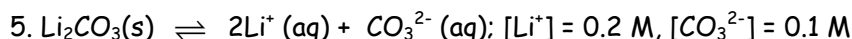
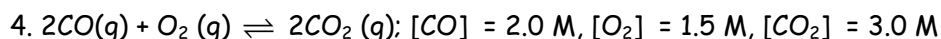
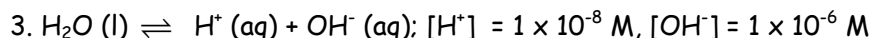
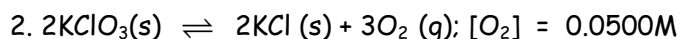
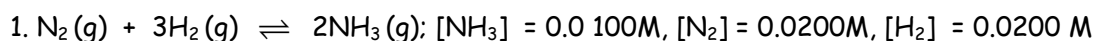


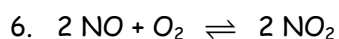
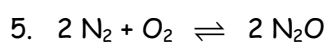
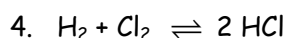
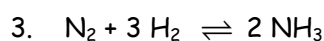
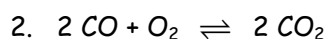
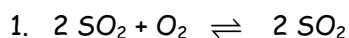
Ws 8.1: EQUILIBRIUM CONSTANT (K_{eq})

Write the expression for the equilibrium constant K_{eq} for the reactions below, using the equilibrium constant expressions you just determined, calculate the value of K_{eq} :

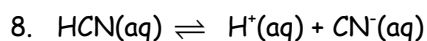
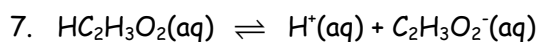


Ws 8.2: More Practice: Equilibria

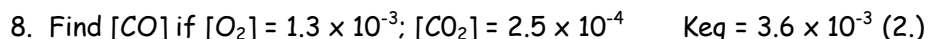
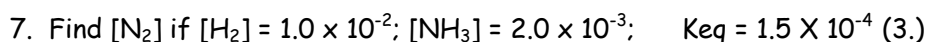
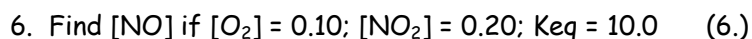
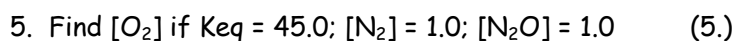
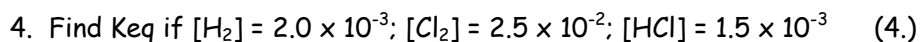
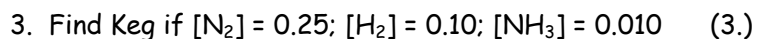
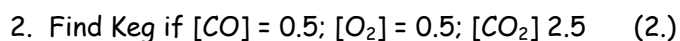
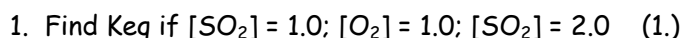
Part I. Write an equilibrium constant (K_{eq}) for each of the following 6 reactions. (All are gases)



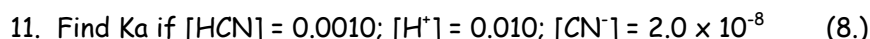
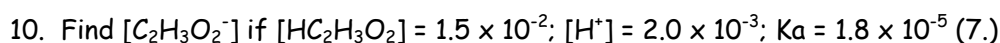
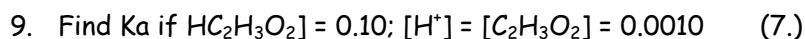
Write an ionization constant (K_a) for each of the following 2 reactions.



Part II. In each of the following, determine the unknown quantity from the information given. The number in parentheses refers to the corresponding reaction in Part I to which you should refer.



NOTE: K_a = ionization constant for acids. It is similar to K_{eq} for other reactions and the math works the same way.



Ws 8.4 Practice Problems: K_{eq} and Q

1. At 740°C , $K_{eq} = 0.0060$ for the decomposition of calcium carbonate (CaCO_3) which is described by the equation: $\text{CaCO}_3(s) \rightleftharpoons \text{CaO}(s) + \text{CO}_2(g)$. Find Q and predict how the reaction will proceed if $[\text{CO}_2] = 0.0004 \text{ M}$.
2. For the reaction: $\text{CO}(g) + \text{H}_2\text{O}(g) \rightleftharpoons \text{H}_2(g) + \text{CO}_2(g)$. $K_{eq} = 5.10$ at 527°C . If $[\text{CO}] = 0.15 \text{ M}$, $[\text{H}_2\text{O}] = 0.25 \text{ M}$, $[\text{H}_2] = 0.42 \text{ M}$, and $[\text{CO}_2] = 0.37 \text{ M}$, calculate Q and determine how the reaction will proceed.
3. At 340°C , for the reaction: $\text{Fe}_2\text{O}_3(s) + 3\text{H}_2(g) \rightleftharpoons 2\text{Fe}(s) + 3\text{H}_2\text{O}(g)$, $K_{eq} = 0.064$. Given that $[\text{H}_2] = 0.45 \text{ M}$ and $[\text{H}_2\text{O}] = 0.37 \text{ M}$, find Q and predict how the reaction will proceed.
4. At 2130°C , $K_{eq} = 0.0025$ for the reaction: $\text{N}_2(g) + \text{O}_2(g) \rightleftharpoons 2\text{NO}(g)$. If $[\text{N}_2] = 0.81 \text{ M}$, $[\text{O}_2] = 0.75 \text{ M}$, and $[\text{NO}] = 0.030 \text{ M}$, find Q and determine the direction in which the reaction will proceed.
5. Ammonia is synthesized from nitrogen and hydrogen in the reaction: $\text{N}_2(g) + 3\text{H}_2(g) \rightleftharpoons 2\text{NH}_3(g)$. At 500°C , the equilibrium constant for this reaction is 0.080 . Given that $[\text{NH}_3] = 0.0596 \text{ M}$, $[\text{N}_2] = 0.600 \text{ M}$, and $[\text{H}_2] = 0.420 \text{ M}$, find Q and predict how the reaction will proceed.
6. The decomposition of antimony pentachloride (SbCl_5) is described by the equation: $\text{SbCl}_5(g) \rightleftharpoons \text{SbCl}_3(g) + \text{Cl}_2(g)$. At 448°C , the equilibrium constant for this reaction is 0.0251 . What is the value of Q if $[\text{SbCl}_5] = 0.095 \text{ M}$, $[\text{SbCl}_3] = 0.020 \text{ M}$, and $[\text{Cl}_2] = 0.050 \text{ M}$? How will this reaction proceed?
7. At 1000°C , $K_{eq} = 1.0 \times 10^{-13}$ for the decomposition of hydrofluoric acid (HF), as described in the reaction: $2\text{HF}(g) \rightleftharpoons \text{H}_2(g) + \text{F}_2(g)$. If $[\text{HF}] = 23.0 \text{ M}$, $[\text{H}_2] = 0.540 \text{ M}$, and $[\text{F}_2] = 0.380 \text{ M}$, determine the value of Q and predict how the reaction will proceed.
8. At 1227°C , $K_{eq} = 0.15$ for the reaction: $2\text{SO}_2(g) + \text{O}_2(g) \rightleftharpoons 2\text{SO}_3(g)$. If $[\text{SO}_2] = 0.344 \text{ M}$, $[\text{O}_2] = 0.172 \text{ M}$, and $[\text{SO}_3] = 0.056 \text{ M}$, find Q and determine how the reaction will proceed.

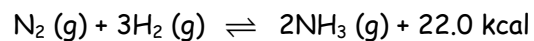
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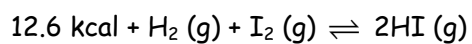
Ws 8.5 LE CHATELIER'S PRINCIPLE

Le Chatelier's Principle states that when a system at equilibrium is subjected to a stress, the system will shift its equilibrium point in order to relieve the stress.

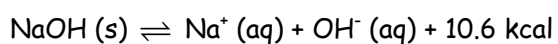
Complete the following chart by writing **left**, **right** or **none** for equilibrium shift, and **decreases**, **increases** or **remains the same** for the concentrations of reactants and products, and for the value of K_{eq} .



#	Stress	Equilibrium Shift	[N ₂]	[H ₂]	[NH ₃]	K _{eq}
1	Add N ₂	right	-----	decreases	increases	remains the same
2	Add H ₂			-----		
3	Add NH ₃				-----	
4	Remove N ₂		-----			
5	Remove H ₂			-----		
6	Remove NH ₃				-----	
7	Increase Temperature					
8	Decrease Temperature					
9	Increase Pressure					
10	Decrease Pressure					



#	Stress	Equilibrium Shift	[H ₂]	[I ₂]	[HI]	Keq
11	Add H ₂	right	-----	decreases	increases	remains the same
12	Add I ₂			-----		
13	Add HI				-----	
14	Remove H ₂		-----			
15	Remove I ₂			-----		
16	Remove HI				-----	
17	Increase Temperature					
18	Decrease Temperature					
19	Increase Pressure					
20	Decrease Pressure					



(Remember that pure solids and liquids do NOT affect equilibrium values.)

#	Stress	Equilibrium Shift	Amount of NaOH (s)	[Na ⁺]	[OH ⁻]	Keq
21	Add NaOH (s)		-----			
22	Add NaCl (adds Na ⁺)			-----		
23	Add KOH (adds OH ⁻)				-----	
24	Add H ⁺ (removes OH ⁻)				-----	
25	Increase Temperature					
26	Decrease Temperature					
27	Increase Pressure					
28	Decrease Pressure					

16-2 Practice Problems: Keq and Q

19. At 740°C, $K_{eq} = 0.0060$ for the decomposition of calcium carbonate (CaCO_3) which is described by the equation: $\text{CaCO}_3 (s) \rightleftharpoons \text{CaO} (s) + \text{CO}_2 (g)$. Find Q and predict how the reaction will proceed if $[\text{CO}_2] = 0.0004 \text{ M}$.
20. For the reaction: $\text{CO} (g) + \text{H}_2\text{O} (g) \rightleftharpoons \text{H}_2 (g) + \text{CO}_2 (g)$.
 $K_{eq} = 5.10$ at 527°C. If $[\text{CO}] = 0.15 \text{ M}$, $[\text{H}_2\text{O}] = 0.25 \text{ M}$, $[\text{H}_2] = 0.42 \text{ M}$, and $[\text{CO}_2] = 0.37 \text{ M}$, calculate Q and determine how the reaction will proceed.
21. At 340°C, for the reaction: $\text{Fe}_2\text{O}_3 (s) + 3\text{H}_2 (g) \rightleftharpoons 2\text{Fe} (s) + 3\text{H}_2\text{O} (g)$, $K_{eq} = 0.064$. Given that $[\text{H}_2] = 0.45 \text{ M}$ and $[\text{H}_2\text{O}] = 0.37 \text{ M}$, find Q and predict how the reaction will proceed.
22. At 2130°C, $K_{eq} = 0.0025$ for the reaction: $\text{N}_2 (g) + \text{O}_2 (g) \rightleftharpoons 2\text{NO} (g)$.
If $[\text{N}_2] = 0.81 \text{ M}$, $[\text{O}_2] = 0.75 \text{ M}$, and $[\text{NO}] = 0.030 \text{ M}$, find Q and determine the direction in which the reaction will proceed.
23. Ammonia is synthesized from nitrogen and hydrogen in the reaction:
 $\text{N}_2 (g) + 3\text{H}_2 (g) \rightleftharpoons 2\text{NH}_3 (g)$. At 500°C, the equilibrium constant for this reaction is 0.080. Given that $[\text{NH}_3] = 0.0596 \text{ M}$, $[\text{N}_2] = 0.600 \text{ M}$, and $[\text{H}_2] = 0.420 \text{ M}$, find Q and predict how the reaction will proceed.
24. The decomposition of antimony pentachloride (SbCl_5) is described by the equation:
 $\text{SbCl}_5 (g) \rightleftharpoons \text{SbCl}_3 (g) + \text{Cl}_2 (g)$. At 448°C, the equilibrium constant for this reaction is 0.0251. What is the value of Q if $[\text{SbCl}_5] = 0.095 \text{ M}$, $[\text{SbCl}_3] = 0.020 \text{ M}$, and $[\text{Cl}_2] = 0.050 \text{ M}$? How will this reaction proceed?
25. At 1000°C, $K_{eq} = 1.0 \times 10^{-13}$ for the decomposition of hydrofluoric acid (HF), as described in the reaction: $2\text{HF} (g) \rightleftharpoons \text{H}_2 (g) + \text{F}_2 (g)$. If $[\text{HF}] = 23.0 \text{ M}$, $[\text{H}_2] = 0.540 \text{ M}$, and $[\text{F}_2] = 0.380 \text{ M}$, determine the value of Q and predict how the reaction will proceed.
26. At 1227°C, $K_{eq} = 0.15$ for the reaction: $2\text{SO}_2 (g) + \text{O}_2 (g) \rightleftharpoons 2\text{SO}_3 (g)$. If $[\text{SO}_2] = 0.344 \text{ M}$, $[\text{O}_2] = 0.172 \text{ M}$, and $[\text{SO}_3] = 0.056 \text{ M}$, find Q and determine how the reaction will proceed.

17—1 Practice Problems: K_{sp}

1. Write the expression for the solubility product constant for SrSO₄.
2. Write the expression for the solubility product constant for MgCl₂.
3. Write the expression for the solubility product constant for FeSO₄.
4. Write the expression for the solubility product constant for Al₂(SO₄)₃.
5. Write the expression for the solubility product constant for Ba(NO₃)₂.
6. Write the expression for the solubility product constant for PbCl₂.
7. Write the expression for the solubility product constant for Zn(OH)₂.
8. Write the expression for the solubility product constant for AgI.
9. Write the expression for the solubility product constant for Cu(OH)₂.
10. Write the expression for the solubility product constant for Ni(OH)₂.
11. A sample of SrCO₃ (s) is added to pure water and allowed to come to equilibrium at 25°C. The concentration of Sr²⁺ is 4.0 × 10⁻⁵ M at equilibrium. What is the value of K_{sp} for SrCO₃?
12. At 18°C, the concentration of Pb²⁺ ions in a saturated solution of lead oxalate (PbC₂O₄) is 5.23 × 10⁻⁶ M. What is the value of K_{sp} for PbC₂O₄?
13. A sample of BaSO₄ (s) is added to pure water and allowed to come to equilibrium at 25°C. The concentration of Ba²⁺ is 1.05 × 10⁻⁵ M at equilibrium. What is the value of K_{sp} for BaSO₄?
14. At 25°C, the concentration of Ag⁺ ions in a saturated solution of AgBr is 7.07 × 10⁻⁷. What is the value of K_{sp} for AgBr?
15. A sample of MgCO₃ (s) is added to pure water and allowed to come to equilibrium at 25°C. The concentration of Mg²⁺ is 6.3 × 10⁻³ M at equilibrium. What is the value of K_{sp} for MgCO₃?
16. At 25°C, the concentration of Ca²⁺ ions in a saturated solution of CaSO₄ is 4.9 × 10⁻³ M. What is the value of K_{sp} for CaSO₄.
17. A sample of MgF₂ (s) is added to pure water and allowed to come to equilibrium at 25°C. The concentration of Mg²⁺ is 1.17 × 10⁻³ M at equilibrium. What is the value of K_{sp} for MgF₂.
18. At 25°C, the concentration of Sr²⁺ ions in a saturated solution of Sr(OH)₂ is 4.31 × 10⁻² M. What is the value of K_{sp} for Sr(OH)₂?
19. A sample of Ag₂CO₃ is added to pure water and allowed to come to equilibrium at 25°C. The concentration of Ag⁺ is 2.53 × 10⁻⁴ M at equilibrium. What is the value of K_{sp} for Ag₂CO₃?
20. At 25°C, the concentration of Ba²⁺ ions in a saturated solution of BaF₂ is 7.52 × 10⁻³ M. What is the value of K_{sp} for BaF₂?
21. What are the equilibrium concentrations of the ions in a saturated solution of Fe(OH)₂ at 25°C? (K_{sp} = 1.8 × 10⁻¹⁵)
22. What are the concentrations of the ions in a saturated solution of Ag₂SO₄ at 25°C? (K_{sp} = 1.2 × 10⁻⁵)
23. What are the concentrations of the ions in a saturated solution of Al(OH)₃ at 25°C? (K_{sp} = 2 × 10⁻³²)
24. What are the concentrations of the ions in a saturated solution of Ba₃(PO₄)₂ at 25°C? (K_{sp} = 1.3 × 10⁻²³)
25. What are the concentrations of Pb²⁺ and S²⁻ in a saturated solution of PbS at 25°C? (K_{sp} = 7.0 × 10⁻²⁹)
26. What are the concentrations of the ions in a saturated solution of Ca(OH)₂ at 25°C? (K_{sp} = 1.3 × 10⁻⁶)
27. What are the concentrations of the ions in a saturated solution of Ca₃(PO₄)₂ at 25°C? (K_{sp} = 2 × 10⁻²⁹)
28. What are the concentrations of the ions in a saturated solution of CaCO₃ at 25°C? (K_{sp} = 8.7 × 10⁻⁹)
29. What are the concentrations of Ag⁺ and SCN⁻ in a saturated solution of silver thiocyanate (AgSCN) at 25°C? (K_{sp} = 1.16 × 10⁻¹²)
30. What are the concentrations of the ions in a saturated solution of BaCO₃ at 16°C? (K_{sp} = 7.0 × 10⁻⁹)

17-2 Practice Problems: K_{sp}

For all the problems, you may assume that a negligible change in volume occurs during the operations (temperature changes).

1. A solution is prepared by dissolving 0.957 mol of SrF₂ in 1000 L of hot water. Will a precipitate form if the solution is cooled to 18°C? (K_{sp} = 2.8 × 10⁻⁹ at 18°C)
2. A solution is prepared by dissolving 0.000 1 mol of Zn(OH)₂ in 50 L of hot water. Will a precipitate form if the solution is cooled to 25°C? (K_{sp} = 4.5 × 10⁻¹⁷ at 25°C)
3. A solution is prepared by dissolving 0.003 mol of ferrous oxalate (FeC₂O₄) in 5 L of hot water. FeC₂O₄ dissolves according to the equation:
$$\text{FeC}_2\text{O}_4 (\text{s}) \rightarrow \text{Fe}^{2+} (\text{aq}) + \text{C}_2\text{O}_4^{2-} (\text{aq})$$
Will a precipitate form if the solution is cooled to 25°C? (K_{sp} = 2.1 × 10⁻⁷ at 25°C)
4. A solution is prepared by dissolving 0.0001 mol of CuCO₃ in 5 L of hot water. Will a precipitate form if the solution is cooled to 25°C? (K_{sp} = 2.5 × 10⁻¹⁰ at 25°C)
5. A solution is prepared by dissolving 0.0003 mol of cuprous thiocyanate (CuSCN) in 100 L of hot water. CuSCN dissolves according to the equation
$$\text{CuSCN} (\text{s}) \rightarrow \text{Cu}^+ (\text{aq}) + \text{SCN}^- (\text{aq})$$
Will a precipitate form if the solution is cooled to 18°C? (K_{sp} = 1.6 × 10⁻¹¹ at 18°C)
6. A solution is prepared by dissolving 9 × 10⁻⁵ mol of lead(II) chromate (PbCrO₄) in 1000 L of hot water. Will a precipitate form if the solution is cooled to 18°C? (K_{sp} = 1.77 × 10⁻¹⁴ at 18°C)
7. A solution is prepared by dissolving 1.9 × 10⁻¹⁰ mol of cobalt(II) sulfide (CoS) in 1000 L of hot water. Will a precipitate form if the solution is cooled to 18°C? (K_{sp} = 3 × 10⁻²⁶ at 18°C)
8. A solution is prepared by dissolving 3.16 × 10⁻⁵ mol of barium chromate (BaCrO₄) in 2 L of hot water. Will a precipitate form if the solution is cooled to 28°C? (K_{sp} = 2.4 × 10⁻¹⁰ at 28°C)
9. A solution is prepared by dissolving 5.5 × 10⁻⁴ mol of AgOH in 5 L of hot water. Will a precipitate form if the solution is cooled to 20°C? (K_{sp} = 1.52 × 10⁻⁸ at 20°C)
10. A solution is prepared by dissolving 7 × 10⁻¹² mol of cadmium sulfide (CdS) in 1000 L of hot water. Will a precipitate form if the solution is cooled to 18°C? (K_{sp} = 3.6 × 10⁻²⁹ at 18°C)

Answers

More Practice: Equilibria

Part I.	Part II.
1. $K_{eq} =$	1. 4.0
2. $K_{eq} =$	2. 50
3. $K_{eq} =$	3. 0.4
4. $K_{eq} =$	4. 0.045
5. $K_{eq} =$	5. 0.022 M
6. $K_{eq} =$	6. 0.2 M
7. $K_a =$	7. 2.67×10^4 M
8. $K_a =$	8. 0.116 M
	9. 1.0×10^{-5}
	10. 1.35×10^{-4} M
	11. 2×10^{-7}
	12. 1.44×10^{-5} M

16-2 Practice Problems: K_{eq} and Q

19. $Q = 0.0004$. The reaction will proceed to the right.
20. $Q = 4.1$. The reaction will proceed to the right.
21. $Q = 0.56$. The reaction will proceed to the left.
22. $Q = 0.0015$. The reaction will proceed to the right.
23. $Q = 0.080$. The reaction is at equilibrium.
24. $Q = 0.010$. The reaction will proceed to the right.
25. $Q = 3.88 \times 10^{-4}$. The reaction will proceed to the left.
26. $Q = 0.15$. The reaction is at equilibrium.

17-1 Practice Problems: K_{sp}

1. $K_{sp} = [Sr^{2+}][SO_4^{2-}]$	16. $K_{sp} = 2.4 \times 10^{-5}$ at $25^\circ C$
2. $K_{sp} = [Mg^{2+}][Cl^-]^2$	17. $K_{sp} = 6.4 \times 10^{-9}$ at $25^\circ C$
3. $K_{sp} = [Fe^{2+}][SO_4^{2-}]$	18. $K_{sp} = 3.20 \times 10^{-4}$ at $25^\circ C$
4. $K_{sp} = [Al^{3+}]^2 [SO_4^{2-}]^3$	19. $K_{sp} = 8.10 \times 10^{-12}$ at $25^\circ C$
5. $K_{sp} = [Ba^{2+}][NO_3^-]^2$	20. $K_{sp} = 1.70 \times 10^{-6}$ at $25^\circ C$
6. $K_{sp} = [Pb^{2+}][Cl^-]^2$	21. $[Fe^{2+}] = 7.7 \times 10^{-6}$ M, $[OH^-] = 1.5 \times 10^{-5}$ M
7. $K_{sp} = [Zn^{2+}][OH^-]^2$	22. $[Ag^+] = 2.9 \times 10^{-2}$ M, $[SO_4^{2-}] = 1.4 \times 10^{-2}$ M
8. $K_{sp} = [Ag^+][I^-]$	23. $[Al^{3+}] = 5 \times 10^{-9}$ M and $[OH^-] = 2 \times 10^{-8}$ M
9. $K_{sp} = [Cu^{2+}][OH^-]^2$	24. $[Ba^{2+}] = 3.1 \times 10^{-5}$ M, $[PO_4^{3-}] = 2.1 \times 10^{-5}$ M
10. $K_{sp} = [Ni^{2+}][OH^-]^2$	25. $[Pb^{2+}] = 8.4 \times 10^{-15}$ M, $[S^{2-}] = 8.4 \times 10^{-15}$ M
11. $K_{sp} = 1.6 \times 10^{-9}$ at $25^\circ C$	26. $[Ca^{2+}] = 6.9 \times 10^{-3}$ M and $[OH^-] = 1.4 \times 10^{-2}$ M
12. $K_{sp} = 2.74 \times 10^{-11}$ at $18^\circ C$	27. $[Ca^{2+}] = 2 \times 10^{-6}$ M and $[PO_4^{3-}] = 1 \times 10^{-6}$ M
13. $K_{sp} = 1.1 \times 10^{-10}$ at $25^\circ C$	28. $[Ca^{2+}] = 9.3 \times 10^{-5}$ M, $[CO_3^{2-}] = 9.3 \times 10^{-5}$ M
14. $K_{sp} = 5.00 \times 10^{-13}$ at $25^\circ C$	29. $[Ag^+] = 1.08 \times 10^{-6}$ M, $[SCN^-] = 1.08 \times 10^{-6}$ M
15. $K_{sp} = 4.0 \times 10^{-5}$ at $25^\circ C$	30. $[Ba^{2+}] = 8.4 \times 10^{-5}$ M, $[CO_3^{2-}] = 8.4 \times 10^{-5}$ M

17-2 Practice Problems: K_{sp} and Precipitation

1. Yes 2. No 3. Yes 4. Yes 5. No 6. No 7. Yes 8. Yes 9. No 10. Yes