**Data and Observations**

Data Table 1: Observations for Chromate - Dichromate Equilibrium

|  |  |  |
| --- | --- | --- |
|  | Adding 1 M NaOH Solution | Adding 1 M HCl Solution |
| Potassium Chromate soln. (5 drops) | No visible reaction – remains yellow | Changes from yellow to orange (potassium dichromate color) |
| Potassium Dichromate soln. (5 drops) | Changes from orange to yellow (potassium chromate color) | No color change - remains orange |

Data Table 2: Observations for Equilibrium Between BaCrO4 and Its Ions

|  |  |  |
| --- | --- | --- |
|  | Adding 0.1 M Barium Nitrate soln. (2 Drops) | Adding 1 M HCl and then NaOH to existing soln. (unspecified amount) |
| 0.1 M Potassium Chromate soln. (5 drops) and 1 M NaOH soln. (1 drop) | White precipitate forms – milky yellow soln. | * Adding HCl: white precipitate dissolves, soln. turns solid orange * Adding NaOH afterwards: reverses the changes (white solid precipitates, soln. turns milky yellow) |
| 0.1 M Potassium Dichromate soln. (5 drops) and 1 M HCl soln. (1 drop) | No visible reaction – remains orange | * Adding NaOH: white precipitate forms, soln. turns milky yellow * Adding HCl afterwards: reverses the changes (white precipitate dissolves, soln. turns orange) |

Data Table 3: Observations for Additional Experiments on Chromate-Dichromate Equilibrium

|  |  |  |  |
| --- | --- | --- | --- |
|  | Adding 1 M Acetic Acid | Adding 1 M Ammonia | Adding 1 M Ethanol |
| Potassium Chromate soln. (5 drops) | Changes from yellow to orange (dichromate color) | No change (stays yellow) | No change (stays yellow) |
| Potassium Dichromate soln. (5 drops) | No change (stays orange) | Changes from orange to yellow (chromate color) | No change (stays orange) |

5. from procedure: BaCrO4 is less soluble than BaCr2O7 because, in step 3, there was a precipitate when K2CrO4 reacted with Ba(NO3)2 (implying that the solubility is not that high) but, in step 4, no precipitate formed when K2Cr2O7 reacted withBa(NO3)2 (implying that the solubility is relatively high so that everything that was added dissolved). Thus K2CrO4 is less soluble than K2Cr2O7.We may extrapolate this to BaCrO4 and BaCr2O7 because these molecules have the same form—containing metal and CrO4 or Cr2O7. Therefore BaCrO4 is less soluble than BaCr2O7.

**Interpretations and Conclusions**

1. First of all, we must realize that the behavior of Potassium Chromate and Potassium Dichromate is directly related to the equilibrium of Chromate and Dichromate ions in solution, because the formula units will simply dissociate in solution. Therefore we may discuss Chromate and Dichromate alone from this point. Increasing the concentration of hydrogen ions (H+) favors the formation of Dichromate (Cr2O72-) for a chromate-dichromate equilibrium. This is evident when we recognize from observation that high concentrations of Chromate (CrO42-) in solution are yellow in color; high concentrations of Dichromate in solution are orange in color. When HCl is added to each respective solution, it acts as an acid and dissociates—contributing H+ to the solution. For Chromate in solution, Data Table 1 shows that it changes color from yellow to orange. It should be noted that orange is the color of Dichromate in solution as mentioned above. This means that the concentration of Dichromate increases as a result of adding HCl and the color of Dichromate in solution becomes the dominant color. For Dichromate, adding HCl makes the solution remain orange. Concentration of Dichromate also increases in this case but because the solution is already orange, it does not change color but remains orange. In both solutions, formation of Dichromate is favored. This evidence, coupled with the assumption that Chromate and Dichromate establish equilibrium in solution, the hypothesis that increasing H+ concentration favors formation of Dichromate is obvious.
2. 2CrO42- (aq) + 2H+ (aq) ↔ Cr2O72- (aq) + H2O (l)
3. Citing the logic from question 1, we know that adding H+ ions (in this case by adding HCl) favors the formation of Dichromate. This can be explained using Le Chatelier’s principle by observing the equation from question 2. We observe that hydrogen ions (H+) are reactants in the equilibrium (as it is written/in terms of the forward reaction). Therefore, increasing their concentration (in this case by adding HCl) will shift the equilibrium to the right (as it is written/in terms of the forward reaction). In other words, Le Chatelier’s principle implies that increasing the concentration of H+ ions will shift the equilibrium to favor the formation of Cr2O72- and H2O (Dichromate and Water). Thus the observations in question 1 are precisely the same as when applying Le Chatelier’s principle, ignoring the formation of H2O.
4. Increasing the concentration of hydroxide ions (OH-) favors the formation of Chromate (CrO42-) for a chromate-dichromate equilibrium. Here, we cite the colors of Chromate (yellow) and Dichromate (orange) in solution as mentioned in question 1. When NaOH is added to the solution, it acts as a base and dissociates—contributing OH- to the solution. Data Table 1 shows that for the Dichromate solution, adding NaOH changes the color from orange to yellow. It should be noted that yellow is the color of high concentrations of Chromate in solution. This means that the concentration of Chromate increases as a result of adding NaOH and the color of Chromate in solution becomes the dominant color. For Chromate, the color remains yellow (it is already yellow so the increased concentration of Chromate will not result in a visible color change). In both solutions, formation of Chromate is favored when NaOH is added, i.e. when the concentration of OH- increases.
5. Cr2O72- (aq) + 2OH- (aq) ↔ 2CrO42- (aq) + H2O (l)
6. Citing the logic from question 4, we know that adding hydroxide ions (OH-), in this case by adding NaOH, favors the formation of Chromate. Observing the equation from question 5, we can explain this in terms of Le Chatelier’s principle. Observe that hydroxide ions (OH-) are reactants in the equation (as it is written/in terms of the forward reaction). This means that increasing their concentration will shift the equilibrium to the right (as it is written/in terms of the forward reaction). This means that doing so will increase the concentrations of CrO42- and H2O (Chromate and Water). Thus the conclusion in question 4 are precisely the same as when applying Le Chatelier’s principle, ignoring the formation of H2O.
7. BaCrO4 (s) ↔ Ba+2 (aq) + CrO42- (aq)
8. In step 6, HCl is added to a solution with K2CrO4, NaOH, and Ba(NO3)2. The Ba(NO3)2 and K2CrO4 yields BaCrO4 as one of the products. Citing the equation in question 7 above, this will result in both Ba+2 and CrO42- ions forming. Once HCl has been added and, i.e., H+ has been introduced into solution, we may refer to the Chromate-Dichromate equilibrium: this will increase the reactants in the equilibrium described by the equation 2CrO42- (aq) + 2H+ (aq) ↔ Cr2O72- (aq) + H2O (l). Since the amount of Chromate and Hydrogen ions has increased, Le Chatelier’s principle dictates that the equilibrium will shift to favor the formation of Cr2O72- and H2O (l) (shifts right when written in this way). This will result in Dichromate forming. The first part of this lab and Data Table 1 shows that more Dichromate in solution results in an orange color. This explains why the the solution turns orange, as per Data Table 2. In step 7, NaOH is added to a solution with K2Cr2O7, HCl, and Ba(NO3)2. The K2Cr2O7 and the Ba(NO3)2 yield BaCr2O7 as one of the products. This BaCr2O7 will dissociate and yield Dichromate ions. Once NaOH has been introduced to the system, i.e. adding OH- ions, this will increase the reactants of the equilibrium equation Cr2O72- (aq) + 2OH- (aq) ↔ 2CrO42- (aq) + H2O (l). Since the concentration of the reactants has increased, Le Chatelier’s principle dictates that the equilibrium position will shift to the right. This will result in the favorable formation of Chromate. This explains the solution in this step turns yellow as per Data Table 2—because Chromate in solution in high enough concentration is yellow in color as per Data Table 1 and initial observations.
9. We can conclude that: Acetic Acid is, indeed, an acid; Ammonia is a base; Ethanol is neutral. Observe from Data Table 1 that increasing HCl (an acid) concentration shifted the Chromate-Dichromate in favor of the formation of Dichromate. We also see that increasing NaOH (a base) concentration had no visible changes for Chromate, because it favors the formation of Chromate which is already prevalent in the solution. For Dichromate, adding NaOH resulted in a color change as a result of equilibrium favoring Chromate formation while adding HCl favored further Dichromate concentration. So, an acid in this case yields a yellow to orange color change for the Chromate solution by shifting the equilibrium in favor of Dichromate formation; however, an acid must also yield no visible change when added to the Dichromate solution. From Data Table 3, this would immediately allow us to conclude that Acetic Acid is an acid (it is in the name, after all). Then we look at the bases: adding NaOH to the Chromate solution should yield no visible change but must yield an orange to yellow color change when added to the Dichromate solution. This holds only for Ammonia; therefore, Ammonia is a base. For Ethanol, neither of these conclusions hold because no change occurs when added to either the Chromate or Dichromate solution. Therefore, Ethanol is neither an acid nor a base—it is effectively neutral.