University of Kentucky Department of Chemistry

Lab 8
Using Properties of Potassium Permanganate Redox Reactions to distinguish DNA Nucleotides

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1 Introduction

The purpose of this experiment is to determine using redox chemical reactions, how a set of nucleotides are **reduced** by their reaction with potassium permanganate $KMnO_4$. By noting the solution's perceived color, the oxidation state of the manganate may be dedudced.

From this a proper control for the experiment may be established (by identifying a known oxidation state with a known color), and the errors are reduced in the experimental setup. A subgoal of this experiment asks:

The standard deviation SD is given by

$$SD = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}|\bar{x} - x_i|^2}$$

where $\bar{x}$ is the average.

Species	Reaction	Oxidation State of Mn	Color
No DNA (Control)	$KMNO_4(aq) \longrightarrow K^+(aq) + MnO_4{}^-$	-	Magenta
AMP	$KMnO_4\,(aq) + AMP\,(aq) \longrightarrow K^+(aq) + MnO_4{}^-(aq) + AMP^+(aq)$	-	-
	$K^+(aq) + MnO_4{}^-(aq) + AMP^+(aq) \longrightarrow K^+(aq) + Mn^{V}O_4{}^{2-}(aq) + AMP^+(aq)$	VI	Green
TMP	$KMnO_3\,(aq) + TMP(aq)\,2\,H_2O\,(l) \longrightarrow K^+(aq) + MnO_4{}^-(aq) + e^- + AMP^+(aq)$	-	-
	$K^+(aq) + MnO_4{}^-(aq) + e^- + AMP^+(aq) \longrightarrow K^+(aq) + Mn^{IV}O_2(aq) + TMP^{3+}(aq) + 4\,OH^-\,(aq)$	IV	Yellow
CMP	$KMnO_4(aq) + CMP\,(aq) + 8\,H^+(aq) \longrightarrow K^+(aq) + MnO_4{}^- + 4\,e^- + CMP^{4+}(aq) + 8\,H^+(aq)$	-	-
	$K^+(aq) + MnO_4{}^- + 4\,e^- + CMP^{4+}(aq) + 8\,H^+(aq) \longrightarrow K^+(aq) + Mn^{3+} + CMP^{4+}(aq) + 4\,H_2O\,(l)$	III	Pink
GMP	$KMnO_4(aq) + GMP\,(aq) + 8\,H^+(aq) \longrightarrow K^+(aq) + MnO_4{}^-(aq) + 5\,e^- + GMP^{5+}(aq) + 8\,H^+(aq)$	-	-
	$K^+(aq) + MnO_4{}^-(aq) + 5\,e^- + GMP^{5+}(aq) + 8\,H^+(aq) \longrightarrow K^+(aq) + Mn^{2+}(aq) + GMP^{5+}(aq) + 4\,H_2O\,(l)$	II	Clear
Knife	-	-	Clear

Table 1.1: **DNA and their (i) Ionic and (ii) Reduction Equations.** The (i) ionic equations are unhighlighted; the (ii) redox equations are highlighted. The Knife undergoes the same redution as the GMP nucleotide (the incident wavelength = colors are both the same, i.e. clear), hence the perp is id'd as Gary

2 Methods

This is experiment 8 in the CHE 111 lab manual. It can be found on pages 105 to 110. The procedure for this experiment can be found on pages 110.

3 Discussion

The purpose of the control test tube is to introduce control to the experiment, in order to minimize error. By having a **control solution** of $KMnO_4{}^-$ and knowing a priori that the solution color (magenta), the solution is of potassium permanangate is known to be uncontaminated. This tells us that reduction reactions and their colors are correct.

For each of the six reactions, the obverved colors are listed in the following table at the 20-minute time point. The most likely oxidation state of manganese is also listed for each of the six reactions

Species	Color	Oxidation State of Manganese	Oxidation state of redox species	What is being oxidized?	What is the reducing agent?	What is the oxidizing agent?
Control	Magenta					
AMP	Green					
TMP	Yellow					
CMP	Pink					
GMP	Clear					
Knife	Clear					

Table 3.1: **DNA and their (i) Ionic and (ii) Reduction Equations.** The (i) ionic equations are unhighlighted; the (ii) redox equations are highlighted. The Knife undergoes the same redution as the GMP nucleotide (the incident wavelength = colors are both the same, i.e. clear), hence the perp is id'd as Gary

From the table we see that the DNA nucleotide that is the strongest reducing agent is (???), and the nucleotide that is the weakest reducing agent is (???). This is because ???
The most likely murderer from this forensic analysis is Gary.
We predict the results in the following hypothetical situation: we suppose that Cindy sample is inadvertently contaminated with the Tina sample.

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Discussion Questions

1. What is the purpose of the control test tube? What does is tell you about the experiment in general?
2. For each of the six reactions, what color did you observe at the 20-minute time point? At the 20-minute time point, what is the most likely oxidation state of manganese in each of the 6 reactions?
3. In each reaction (see Figure 8.3), what is the oxidation state of the redox species in each reaction? What is being oxidized?
4. In each reaction, what is the reducing agent, and what is the oxidizing agent?
5. Which DNA nucleotide is the strongest reducing agent, and which is the weakest? Justify your answer.
6. Who is most likely the murderer in your forensic analysis?
7. Predict the results you would get if your Cindy sample was inadvertently contaminated with the Tina sample. How could you experimentally confirm your prediction?

Restatement of Purpose. In this lab it was successfully confirmed that

4 Conclusion

5 Citations

1. French April N., Allison Soult, Stephen Testa, Pauline Stratman, M. Meral Savas, Francois Botha, Carolyn Brock, Charles Griffith, Darla Hood, Robert Kiser, Penny O'Connor, William Plucknett, Donald Sands, Diene Vance, and William Wagner. "Experiment 8: Solving a Murder Mystery Using Transition Metals and DNA", CHE 111 General Chemistry Laboratory Manual. Plymouth: Hayden-McNeil, 2018. Print.