Problem Set #2, November 2019

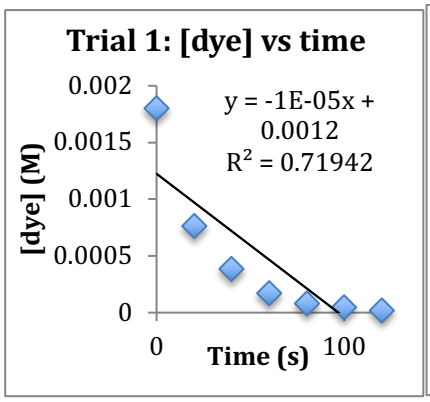
Questions 21 to 26 pertain to information below:

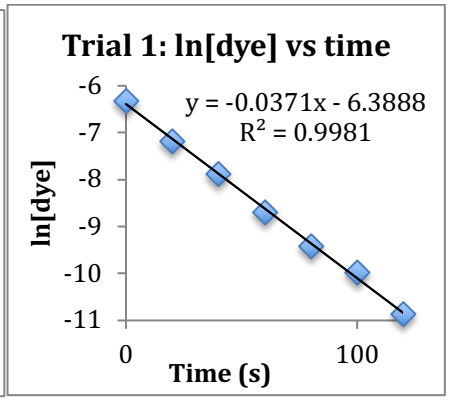
At the University of Toronto, first year life science students perform an experiment to learn about the kinetics of the reaction between dye and bleach. The reaction between the active component of bleach, the hypochlorite ion (OCl^-), and the dye (D) can be shown as:

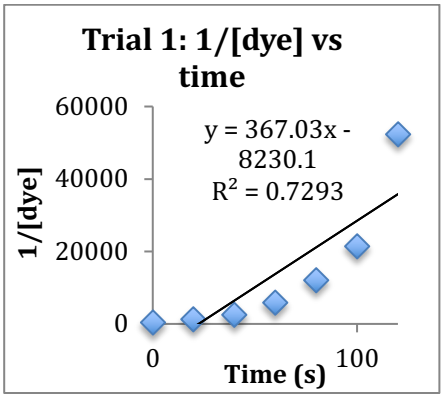
$$OCl^- + D \longrightarrow Cl^- + DO$$

where D is the coloured dye and DO is the colourless, oxidized form of the dye. In all of the plots below the concentration of the dye (D) was measured as a function of time after the addition of bleach. Assume all trials began with the same initial dye concentration.

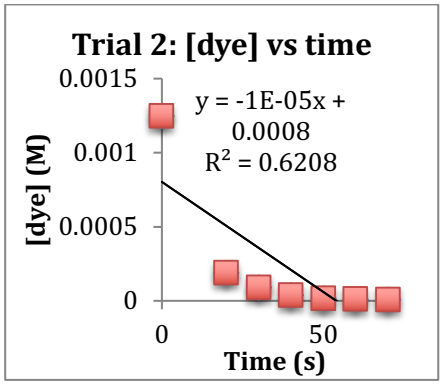
Trial 1: $[OCl^-]$ = 0.117 M, T = 298 K

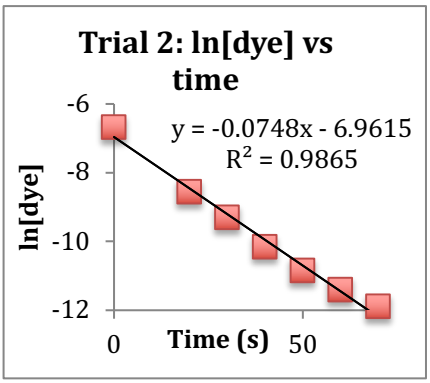


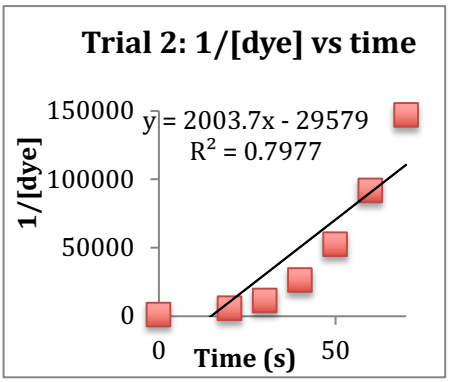




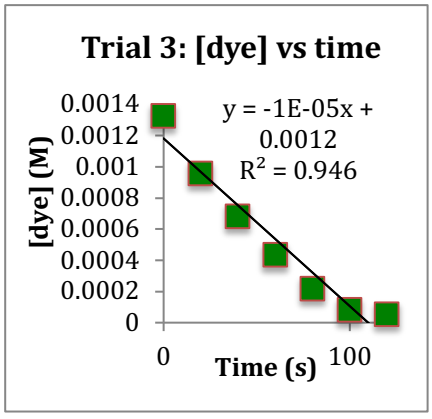
Trial 2: $[OCl^-]$ = 0.243 M, T = 298 K

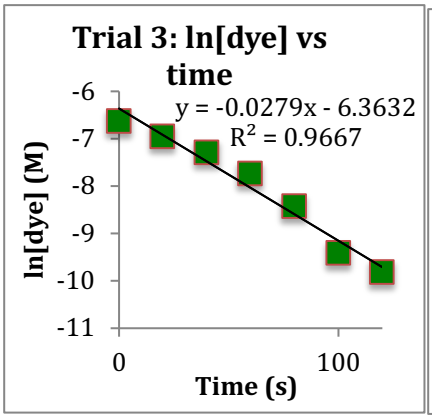


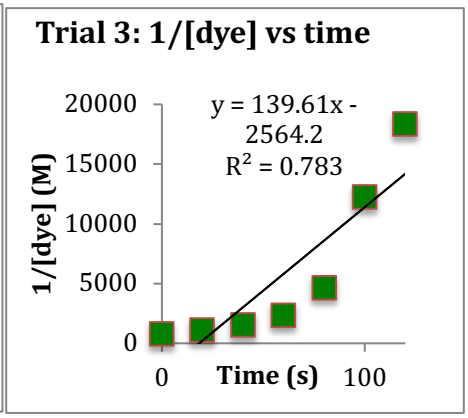




Trial 3: $[OCl^-]$ = 0.117 M, T = 285.45 K







21. A large excess of bleach is used in the experiment. Which of the following statement is FALSE?

a) Since there is a large excess of bleach, the reaction order with respect to bleach is zero.
b) The bleach concentration can be considered essentially constant.
c) The large excess of bleach allows the rate law to be simplified from rate = k[dye][bleach] to rate = k'[dye] where $k'=k[OCl^-]^m$.
d) The amount of bleach that reacts with the dye is small compared to the total concentration of bleach.
e) The concentration of bleach affects the rate of reaction.

22. What is the reaction order with respect to the dye?

a) 0 b) 1 c) 2 d) 3 e) cannot determine with information given

23. What is the reaction order with respect to bleach?

a) 0 b) 1 c) 2 d) 3 e) cannot determine with information given

24. Given that the rate law is rate = $k[bleach]^m[dye]^n$, what is the rate constant, k, at 25 ˚C?

a) $-0.317\ M^{-1}s^{-1}$ b) $0.317\ s^{-1}$ c) $0.317\ M^{-1}s^{-1}$ d) $0.0371\ s^{-1}$ e) $0.0371\ M^{-1}s^{-1}$

25. What is the activation energy for this reaction? (Hint: You need similar concentrations, but different temperatures)

a) 5.6 kJ/mol b) 16 kJ/mol c) 21 kJ/mol d) 98 kJ/mol
e) Cannot be determine with information given

26. A new experiment is performed with an initial dye concentration of 0.0015 M and an initial bleach concentration of 0.15 M. What is the initial rate of this reaction at 25 ˚C?

a) 8.3×10^{-6} M/s b) 4.1×10^{-5} M/s c) 6.8×10^{-4} M/s d) 1.7×10^{-5} M/s e) 7.1×10^{-5} M/s

27. For a Haber process taking place in an enclosed vessel,

$N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g) \qquad \Delta H = -92.4\ kJ \cdot mol^{-1}$

which of the following will not result in an increase in net production of NH_3?

a) Adding more N_2
b) Increasing the pressure of the vessel
c) Decreasing the volume of the vessel
d) Adding an iron catalyst
e) Decreasing the temperature

28. Which of the following statements are true for the reaction below?

$2H_2(g) + O_{2(}g) \longrightarrow 2H_2O(g)$ $\Delta H = -241.818\ kJ{\cdot}mol^{-1}$

a) The rate of this reaction is higher at lower temperatures
b) If $T_1 > T_2$ then $K_1 > K_2$
c) K_{eq} is the same at all temperatures
d) The change in entropy for the reaction is positive.
e) None of the above

29. 20.00 mL of 0.1000 M weak acid, HA, is titrated with 0.2500 M NaOH. The pH of the solution is 4.83 after 5.00 mL of NaOH is added. What is the pKa of the weak acid?

a) 2.32 b) 3.56 c) 4.60 d) 4.83 e) 5.10

30. A flask containing only NO_2 is heated to 375 °C and reacts as follows:

$2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$

At equilibrium, the density of the gas mixture is 0.735 g/L and the total pressure is 0.890 atm. What is K_p for the reaction at 375 °C?

a) 8.32×10^{-6} b) 7.45×10^{-5} c) 2.24×10^{-5} d) 3.78×10^{-4} e) 1.3×10^{-4}

31. The K_{sp} for silver chloride, AgCl (used in photography) is 2.8×10^{-10} at a given temperature. The solubility of AgCl in 0.010 M HCl solution, expressed as mole $litre^{-1}$, at this temperature will be

a) 2.8×10^{-12} b) 2.8×10^{-8} c) 5.6×10^{-8} d) 2.8×10^{-4} e) 5.6×10^{-4}

32. Which of the following indicators can best be used to indicate the half-equivalence point of a 25.00 mL solution of 0.1 M HF ($K_a = 3.5 \times 10^{-4}$) titrated with 0.247 M NaOH?

a) methyl red ($pK_{in} = 5.0$)
b) methyl orange ($pK_{in} = 3.4$)
c) thymol blue ($pK_{in} = 8.9$)
d) phenolphthalein ($pK_{in} = 9.4$)
e) bromothymol blue ($pK_{in} = 7.1$)

33. A solution has the following molar concentrations: $[Cl^-] = 1.5 \times 10^{-1}$, $[Br^-] = 5.0 \times 10^{-4}$, $[CrO_4^{2-}] = 1.9 \times 10^{-2}$. A solution of $AgNO_3$ (100% dissociated) is added to the above solution, drop by drop. Which silver salt will precipitate first?

Data: $K_{sp}(AgCl) = 1.5 \times 10^{-10}$; $K_{sp}(AgBr) = 5.0 \times 10^{-13}$; $K_{sp}(Ag_2CrO_4) = 1.9 \times 10^{-12}$

a) AgCl b) AgBr c) Ag_2CrO_4 d) AgCl and AgBr together
e) None of the above

34. What is the wavelength of the light photon emitted when an excited electron in a hydrogen atom falls from the $n = 5$ to $n = 2$ level?

a) 4.34×10^{-7} m
b) 5.12×10^{-7} m
c) 5.82×10^{-7} m
d) 6.50×10^{-7} m
e) None of these values

35. Which one of the following salts, when dissolved in water, produces the solution with the *highest* pH?

a) KI b) KBr c) KCl d) KF
e) All of the salts will produce a solution with the same pH.

36. Solution A has a pH of 8, and solution B has a pH of 12. How many times the concentration of hydroxide ions is higher in solution B?

a) 4 times b) 100 times c) 1000 times d) 10 000 times e) 100 000 times

37. The symbol $K_b(HS^-)$ is the equilibrium constant for the reaction:

a) $HS^-(aq) + H_2O \rightleftharpoons H_2S(aq) + HO^-(aq)$
b) $HS^-(aq) + HO^-(aq) \rightleftharpoons S^{2-}(aq) + H_2O$
c) $HS^-(aq) + H_2O \rightleftharpoons H_3O^+(aq) + S^{2-}(aq)$
d) $HS^-(aq) + CH_3COOH(aq) \rightleftharpoons H_2S(aq) + CH_3COO^-(aq)$
e) $HS^-(aq) + H_3O^+(aq) \rightleftharpoons H_2S(aq) + H_2O$

38. Which of the following statements is true regarding the following reaction?

$A + B \rightleftharpoons C + D$

I. The rate constant, $k_{reverse}$ of the reverse reaction increases when temperature is increased
II. The equilibrium constant, K_{eq}, increases when temperature is increased
III. The activation energy, E_a, of the reaction decreases when temperature is increased.

a) I only b) II only c) III only d) I and III only e) I, II, and III

39. 2.3 g of sodium acetate was dissolved to make 1 L of solution. 2 mL of 0.391 M HCl was then added to this solution. What is the final pH of the solution? $pKa_{CH3COOH} = 4.67$

a) 1.68 b) 4.67 c) 6.21 d) 7.65 e) 12.58

40. The following reaction mechanism has been proposed for the overall reaction between molecular hydrogen and bromide to yield hydrogen bromide $H_2 + Br_2 \longrightarrow 2HBr$:

$Br_2 \rightleftharpoons 2Br$ (fast, reversible) (k_1, k_{-1})
$Br + H_2 \longrightarrow HBr + H$ (slow) (k_2)
$H + Br_2 \longrightarrow HBr + Br$ (fast) (k_3)

What is the rate law? (Hint: steady-state approximation!)

a) $k[H_2][Br_2]$
b) $k[H_2][Br_2]/[HBr]^2$
c) $k[H_2][Br_2]^{(1/2)}$
d) $k[H_2]^{(1/2)}[Br_2]/[HBr]$
e) $k[H_2]^{(1/2)}[Br_2]^{(1/2)}$