2025-26 Division C
OSS Chemistry Lab Test

Test Structure:

- 50 MCQs, 4 FRQ parts, 1 Lab

Scoring:

- Stoichiometry (67 points), Kinetics (55 points), Lab (28 points) extra;) (6 points)

If you have any questions about this exam, feel free to contact:

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I hereby declare that the following responses are our own work without the assistance of outside or disallowed resources as per the 2025-26 National Science Olympiad rules

Names:_____

Team:_____

Score:________/150 points

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Reviewed by: Yifan Ren

GOOD LUCK

PERIODIC TABLE OF THE ELEMENTS

1 1A	2 2A	[illegible]	4 4B	[illegible]	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 H 1.008																	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	[illegible] 44.96	22 Ti 47.88	23 V [illegible]	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.97	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	[illegible] 88.91	40 Zr 91.22	41 [illegible]	42 Mo 95.95	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
55 Cs 132.9	56 Ba 137.3	[illegible] 138.9	72 Hf 178.5	73 Ta [illegible]	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac (227)	104 Rf (261)	[illegible] (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 Ds (281)	111 Rg (272)	112 Cn (285)	113 Nh (286)	114 Fl (289)	115 Mc (289)	116 Lv (293)	117 Ts (294)	118 Og (294)

58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

Written Portion

Stoichiometry Portion - 67 pts

MCQs - 25 pts

1. (1 point) 50 kg of ethylene(C_2H_4) are combusted in 60 kg oxygen. How many kg of H_2O are produced?
    a. 35.7 kg
    b. 33.75 kg
    c. 50 kg
    d. 22.5 kg
    e. NOTA

2. (1 point) When the reaction equation for the combustion of butane (C_4H_{10}) is balanced, what is the sum of the coefficients?
    a. 18
    b. 33
    c. 10
    d. 32
    e. NOTA

3. (1 point) How many oxygen atoms are in three molecules of Iron(II) Nitrate?
    a. 6
    b. 9
    c. 12
    d. 18
    e. NOTA

4. (1 point) Bob is hosting a backyard barbecue and decides to light a propane grill. He uses 20 g of propane (C_3H_8). If the propane burns completely in excess oxygen, how many grams of CO_2 are produced?
    a. 44 g
    b. 88 g
    c. 156 g
    d. 176 g
    e. NOTA (132 g)

5. (1 point) Abu, who is very thirsty, chugs down 1 L of pure water. This of course can lead to overhydration, but of course he disregards this. Yet, Abu wants to know, approximately how many molecules of dihydrogen monoxide did Abu consume?
    a. 3.34×10^{25} molecules
    b. 5.55×10^{23} molecules
    c. 2.67×10^{23} molecules :))
    d. 4.68×10^{25} molecules
    e. NOTA

6. (1 point) Abu, after being heavily hydrated, now begins swinging over to his friend Vallab's house. Right as he knocks on the door, his leg muscle begins to spasm. His brilliant biology mind thought that he might be cramping up from the water, but of course the reason was due to tropomyosin dysfunction (Usually a genetic condition).
    The major amino acid in tropomyosin has a chemical formula $C_aH_bNO_d$. Combustion of a 1.780 g sample of this amino acid produces 2.689 g of CO_2 and 1.104 g of H_2O. If oxygen makes up 31% of the mass of the

amino acid, what is the value of d? (Hint: This amino acid has one of the simplest chiral groups and is non-polar)

a. 1
b. 2
c. 3
d. 4
e. NOTA

7. (1 point) Vallab is a very bright minded student and is working in a lab. He needs to dilute 500 mL of 3 M HCl into a 1M solution. However, he accidentally spills 50 mL of a 1M solution of NaOH in the HCl, reacting with it. If we disregard acid-base equilibrium, how much water must be added to obtain a 1M concentration of HCl?
   a. 900 mL
   b. 1000 mL
   c. 950 mL
   d. 500 mL
   e. NOTA

8. (1 point) When iron rusts it reacts with oxygen gas in the presence of moisture to form iron(III) oxide, the main component of rust. What is the balanced chemical reaction for this?
   a. $Fe(s) + O_2(g) \rightarrow FeO_2(s)$
   b. $Fe(s) + O(g) \rightarrow FeO(s)$
   c. $4Fe(s) + 3O_2(s) \rightarrow 2Fe_2O_3(s)$
   d. $Fe(s) + O_2(g) \rightarrow Fe_2O_3$
   e. NOTA ($4Fe(s) + 3O2(g) \rightarrow 2Fe2O3(s)$)

9. (1 point) What is the molar mass of ethanol (CH_3CH_2OH)?
   a. 46 g/mol
   b. 45 g/mol
   c. 40 g/mol
   d. 15 g/mol
   e. NOTA

10. (1 point) Ammonia reacts with oxygen to form Nitric Oxide and water vapor. If 12 g of NH_3 and 20 g of O_2 are used, which statement is correct?
    a. Oxygen is limiting; 17.9 g NO are formed.
    b. Ammonia is limiting; 14.2 g NO are formed.
    c. Oxygen is limiting; 14.2 g NO are formed.
    d. Ammonia is limiting; 17.9 g NO are formed.
    e. NOTA

11. (1 point) An 18.75 g sample of $KClO_3$ decomposes into KCl and oxygen. What is the theoretical yield of oxygen gas in grams?
    a. 4.80 g
    b. 6.70 g ;))
    c. 6.90 g ;))
    d. 8.00 g
    e. NOTA

12. (1 point) Alien is running a reaction in the lab between Zn and HCl, he is finally using proper PPE. Zinc and HCl react in the following reaction: $Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$. Alien reacts 1.250 g of Zn with 50.00 mL of 1.00 M HCl. Alien loves to do math, and so he reports that he collected hydrogen that occupies 1.00 L at 25 °C and 0.950 atm. What is the percent yield of H_2 collected by Alien?
    a. 74%
    b. 81%
    c. 85%
    d. 95%
    e. NOTA

13. (1 point) Alien is now attempting to create water. He is working in a controlled room. At STP, he adds 22.4 L of hydrogen gas that reacts with excess oxygen gas to form water vapor. How many grams of water are produced?
    a. 9.00 g
    b. 12.0 g
    c. 36.0 g
    d. 72.0 g
    e. NOTA (18.0 g)

14. (1 point) True or False: The coefficient number in front of the formula of a molecule represents the number of molecules needed stoichiometrically in the reaction.
    a. True
    b. False
15. (1 point) $Mg + 2\ HCl \rightarrow MgCl_2 + H_2$. 1.50 g Mg reacts; 0.75 g H_2 collected. Percent yield:
    a. 95%
    b. 97%
    c. 100%
    d. 92%
    e. NOTA

Use the following for Questions **16-19**: Brodok is trying to impress his students with a chemistry demonstration. He decides to generate oxygen gas from the decomposition of potassium chlorate, but he accidentally adds a bit too much manganese dioxide as a catalyst. He carefully measures out 20.0 g of $KClO_3$ and adds it to a reaction flask. As the reaction occurs, oxygen gas is released according to the reaction: $2\ KClO_3\ (s) \rightarrow 2\ KCl\ (s) + 3\ O_2\ (g)$.

16. (1 point) How much O_2 is theoretically made from the decomposition of 20.0 g of $KClO_3$?
    a. 7.8 g
    b. 8.2 g
    c. 9.6 g
    d. 10.0 g
    e. NOTA

17. (1 point) If he collects oxygen at STP in a 5.00 L container, what is the pressure of O_2?
    a. 1.50 atm
    b. 2.12 atm
    c. 2.50 atm
    d. 3.12 atm
    e. NOTA

18. (1 point) Later, Brodok wants to use some of the oxygen to combust 12.0 g of propane. Assuming he uses all the O_2 produced from the previous reaction, how many grams of CO_2 can be produced?
    a. 10.3 g
    b. 14.5 g
    c. 21.6 g
    d. 24.0 g
    e. NOTA

19. (1 point) Brodok decides to dissolve the leftover KCl in water to make a 0.50 M solution. If he originally produced 20.0 g of KCl, what volume of solution (in liters) would he need to achieve this concentration?
    a. 0.25 L
    b. 0.50 L
    c. 0.75 L
    d. 1.00 L
    e. NOTA

20. (1 point) A hydrocarbon is burned, producing 44.0 g CO_2 and 18.0 g H_2O from 10.0 g of hydrocarbon. Its empirical formula is:
    a. CH4
    b. C2H6
    c. C3H8
    d. C2H4
    e. NOTA

21. (1 point) The synthesis of octane (C_8H_{18}) can be represented by the following two-step process: butene (C_4H_8) is dimerized to an intermediate, octene C_8H_{16}, with a 75.0% yield. ($2C_4H_8$ (g)$\rightarrow$ C_8H_{16}(g)). The octene is then hydrogenated to form octane with a 92.0% yield. (C_8H_{16} (g) + H_2(g) $\rightarrow$ C_8H_{18}(g)). If a chemist starts with 1.00 kg of butene, what is the maximum mass of isooctane (in grams) that can be produced?
    a. 655.5 g
    b. 676.7 g
    c. 702.3 g
    d. 755.2 g

e. NOTA

Use the following for questions 22-23. A mixture of Mg and Zn with a combined mass of 1.500 g is reacted with excess hydrochloric acid, producing hydrogen gas at STP. The balanced equations are: Mg(s) + 2HCl (aq) $\rightarrow MgCl_2(aq) + H_2(g)$ and Zn(s) + 2HCl (aq) $\rightarrow ZnCl_2(aq) + H_2(g)$. The hydrogen gas produced is collected and has a volume of 1.200 L at STP.

22. (1 point) Calculate the mass of Zn(s) in the mixture.
    a. 0.316 g
    b. 0.756 g
    c. 1.356 g
    d. 1.500 g
    e. NOTA

23. (1 point) Calculate the mass percent of Magnesium in the mixture.
    a. 21.1%
    b. 24.6%
    c. 78.9%
    d. 75.4%
    e. NOTA

24. (1 point) Alien is back and this time he wants to do more math. Unfortunately, he wasn't able to use Calculus as some people may not be able to solve it. So, he decides to add 500 g of Calcium Phosphate to 500 mL of water. He asks, what is the concentration of the solution in **ppm (Parts per Million)**?
    a. 3.2
    b. 1000
    c. 3200
    d. 5000
    e. NOTA (1,000,000)

25. (1 point) A 5.00 g sample of $CuSO_4 \cdot xH_2O$ is heated, leaving 3.20 g of anhydrous $CuSO_4$. Percent water in the hydrate is:
    a. 28%
    b. 36%
    c. 42%
    d. 50%
    e. NOTA

FRQs - 2 Parts (42 points)

Reaction Balancing - 10 pts

Balancing the following chemical equations and write the type of reaction it is next to it (Multiple types of reactions can happen) (1 pt for balance and 1pt for reaction type, all or nothing in each part):

1. _2_NaOH + _1_H_2SO_4 → _1_Na_2SO_4 + _2_H_2O _Neutralization, Double Displacement (Metathesis)_
2. _2_C_2H_6 + _7_O_2→ _4_CO_2 + _6_H_2O _Combustion, Redox_
3. _4_ Fe + _3 O_2 → _2 Fe_2O_3 _Synthesis, Combination, Redox_
4. _1 Cu + _2 $AgNO_3$ → _ 1$Cu(NO_3)_2$ + _2 Ag _Single Replacement, Redox
5. _1$Pb(NO_3)_2$ + _1Na_2SO_4 → _1$PbSO_4$ + _2$NaNO_3$ _Double Displacement (Metathesis), Precipitation

Reaction Predicting - 32 pts

Vaibhav is in a lab and wants to complete some reactions. Write the full equation of the following reactions that are described. Make sure to include phases and proper stoichiometry. You don't need to address heat in reactions, but you do need to address particles in nuclear reactions. **Don't write net ionic equations unless redox is told. Also make sure to keep water in reactions that produce it.** (2pt each; all or nothing)

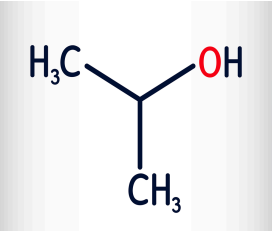
1. Combustion of liquid propanol.
    a. $2C_3H_8O(l) + 9O_2 \rightarrow 6CO2(g) + 4H2O(g)$
2. Reaction of Magnesium metal in Zinc(II) Nitrate solution.
    a. $Mg(s) + Zn(NO3)2(aq) \rightarrow Mg(NO3)2(aq) + Zn(s)$
3. Reaction of Formic Acid with Potassium Hydroxide.
    a. $HCOOH(aq) + KOH(aq) \rightarrow H_2O(l) + KCOOH(aq)$
4. Combustion of Magnesium metal in atmosphere.
    a. $2Mg(s) + O2(g) \rightarrow 2MgO(s)$
5. Permanganate oxidizes iron(II) to iron(III) in acidic solution (You may write net ionic here)
    a. $MnO4^-(aq)+5Fe2+(aq)+8H+(aq)\rightarrow Mn2+(aq)+5Fe3+(aq)+4H2O(l)$
6. Hypochlorite oxidizes iodide to iodine in a basic solution (You may write net ionic here).
    a. $ClO^-(aq)+2I^-(aq)+H2O(l)\rightarrow Cl^-(aq)+I2(s)+2OH^-(aq)$

7. In acidic solution, dichromate ion oxidizes iron(II) to iron(III). (You may write net ionic).
    a. $Cr2O7^{2-}(aq) + 14\ H+(aq) + 6\ Fe2+(aq) \rightarrow 2\ Cr3+(aq) + 7\ H2O(l) + 6\ Fe3+(aq)$
8. Andrew is planning on making TNT for his devious master plans in Chemistry (He thinks he's him). He treats liquid toluene ($C_6H_5CH_3$) with a mixture of nitric acid and sulfuric acid (as a catalyst) under heated conditions to produce his solid weapon. (You don't need to address the catalyst in equation)
    a. $C_6H_5CH_3\ (l) + 3\ HNO3\ (aq) \rightarrow C6H2(NO2)3CH3\ (s) + 3\ H2O\ (l)$

9. Andrew is still displeased with the power of TNT and begins looking for more powerful options. He begins pulling ties and manages to find pieces of plutonium-239 from the "Fat Man". He allows plutonium-239 to undergo alpha decay. (Make sure to write the particles and atomic number with mass number with it)

$$Pu_{94}^{239} \xrightarrow[24{,}000\ years]{} U_{92}^{235} + \underbrace{He_2^4}_{\text{(alpha particle)}}$$

    a. (They don't have to write years and can replace Helium with alpha symbol)
10. Ammonium Hydroxide **REACTS** with Calcium Acetate in a solution together.
    a. $2NH4OH(aq) + Ca(C2H3O2)2(aq) \rightarrow 2NH_4C_2H_3O_2(aq) + Ca(OH)_2(aq)$
11. Potassium Carbonate **REACTS** with solid Strontium(II) Sulfate.
    a. $K_2CO_3(aq) + SrSO_4(s) \rightarrow SrCO_3(s) + K_2SO_4(aq)$
12. Lithium Hydride in water. (Hint: It is highly reactive).
    a. $LiH(s) + H_2O(l) \rightarrow LiOH(aq) + H_2(g)$
13. Salt in water. (You don't need to write net ionic ;))
    a. $NaCl(s) + H_2O(l) \rightarrow NaCl(aq) + H_2O(l)$ or
    b. $NaCl(s) \rightarrow NaCl(aq)$
14. The classic haloform reaction is where a methyl ketone, or alcohol oxidized to a ketone, reacts with bleach (NaOCl) to produce chloroform (CHCl3), which is a very toxic gas. Write the balanced equation for the reaction of liquid isopropyl alcohol with liquid bleach.
    a. $CH_3CHOHCH_3\ (l) + 3\ NaOCl\ (l) \rightarrow CHCl_3(g) + NaCH_3COO(aq) + 2\ H_2O(l)$
15. Equilibrium of Ozone and Oxygen gas in the atmosphere.
    (You can write a single arrow if you want)
    a. $2O_3\ (g) \rightarrow 3O_2\ (g)$
    b. $2O_3(g) \leftrightarrow 3O_2(g)$
16. Solid Baking Soda and Liquid Vinegar added together (Their main components).
    a. $NaHCO_3(s) + HC_2H_3O_2\ (l \text{ or } aq) \rightarrow NaC_2H_3O_2(aq) + CO_2(g) + H_2O(l)$



Isopropyl alcohol

Kinetics Portion - 55 pts ;))

MCQs-25 Questions (25 Points)

1. (1 point) A student is experimenting with a reaction rate. He finds that the rate of a reaction doubles when the concentration of A is doubled, but remains unchanged when B is doubled. What is the rate law?
    a. rate = k[A][B]
    b. rate = $k[A]^2$

c. rate = k[A]
d. rate = k[B]²
e. NOTA

2. (1 point) A reaction has the rate law: rate = k[A][B]. If [A] is tripled and [B] is halved, what happens to the rate?
   a. Rate increases by 1.5×
   b. Rate increases by 3×
   c. Rate decreases by 1.5×
   d. Rate remains the same
   e. NOTA

3. (1 point) Itoshi is bored in class and notices that the half-life of a certain first-order decomposition is 20 minutes. How long will it take for 87.5% of the reactant to decompose?
   a. 40 min
   b. 60 min
   c. 80 min
   d. 100 min
   e. NOTA

4. (1 point) A student measures the rate constant for a reaction at two temperatures and plots ln(k) vs. 1/T. What is the slope of the line equal to? (Ea is Activation energy)
   a. –Ea
   b. –Ea/R
   c. Ea
   d. Ea/R
   e. NOTA

5. (1 point) Bob decides to measure a reaction and finds that it is zero-order with respect to A. Which of the following correctly describes the concentration of A over time?
   a. [A] decreases linearly with time
   b. [A] decreases exponentially with time
   c. [A] increases linearly with time
   d. [A] stays constant
   e. NOTA

6. (1 point) Which correctly matches the units of the rate constant for the type of rate?
   a. 0th order = 1/s, 1st order = M/s, 2nd order = 1/(M*s)
   b. 0th order = s, 1st order = M/s, 2nd order = 1/s
   c. 0th order = M/s, 1st order = 1/s, 2nd order = 1/(M*s)
   d. 0th order = 1/(M*s), 1st order = 1/s, 2nd order = M/s
   e. NOTA

7. (1 point) A unimolecular decomposition has a half-life of 200 s when [A] = 0.50 M. When [A] = 1.0 M, the half-life is 100 s. What is the order of the reaction?
   a. Zero-order
   b. First-order
   c. Second-order

d. Mixed-order
e. NOTA

8. (1 point) If a graph of Concentration vs Time produces a negative slope-linear constant graph, what is the order of the reaction?
   a. 0th order
   b. 1st order
   c. 2nd order
   d. Not enough information
   e. NOTA

9. (1 point) A mechanism is proposed:
   Step 1 (slow): $NO_2 + F_2 \rightarrow NO_2F + F$
   Step 2 (fast): $F + NO_2 \rightarrow NO_2F$
   Overall: $NO_2 + F_2 \rightarrow 2\ NO_2F$
   What is the rate law predicted by this mechanism?
   a. rate = $k[NO_2][F_2]$
   b. rate = $k[NO_2]^2$
   c. rate = $k[F_2]^2$
   d. rate = $k[NO_2F]$
   e. NOTA

   Use the following for questions **10-12:**
   The decomposition of H_2O_2 is catalyzed by iodide with mechanism:
   $H_2O_2 + I^- \rightarrow H_2O + IO^-$ (slow)
   $H_2O_2 + IO^- \rightarrow H_2O + O_2 + I^-$ (fast)

10. (1 point) What is the role of I^- in this mechanism?
    a. Catalyst
    b. Intermediate
    c. Product
    d. Inhibitor
    e. NOTA

11. (1 point) What is the role of IO^- in this mechanism?
    a. Catalyst
    b. Intermediate
    c. Reactant
    d. Product

e. NOTA

12. (1 point) Which best describes the overall rate law for this mechanism?
    a. It is a 0th order
    b. It is 1st order with respect to H_2O_2
    c. It is 2nd order with respect to H_2O_2
    d. It is 2nd order with respect to I^-
    e. NOTA

13. (1 point) Use the Arrhenius equation to determine: For Ea = 50.0 kJ·mol^{-1}, how does k change when temperature increases from 300 K to 310 K? (R = 8.314 J·mol^{-1}·K^{-1})
    a. Increases by ~10%
    b. Increases by ~50%
    c. Doubles (≈1.9×)
    d. Triples
    e. NOTA

14. (1 point) A student plots ln[A] vs. time and obtains a straight line with slope −0.0030 s^{-1}. What is the half-life?
    a. 33 s
    b. 100 s
    c. 231 s
    d. 1000 s
    e. NOTA

15. (1 point) Here is a mechanism developed:
    Step 1: A + B ⇌ C (fast equilibrium, K = k_1/k_{-1}) (Where k_1 is forward and k_{-1} is backward)
    Step 2: C + A ⟶ D (slow, k_2)
    Derive rate law (pre-equilibrium).
    a. rate = $k_2[A][C]$
    b. rate = $(k_1 k_2 / k_{-1})[A]^2[B]$
    c. rate = $k_2[A][B]$
    d. rate = $(k_2/k_1)[A]^2$
    e. NOTA

16. (1 point) A reaction is 0th order for a unimolecular reaction with A as a reactant. Its rate constant is 0.020. If the initial concentration of A is 0.10 M, how long will it take for the concentration to drop to 0.02 M?
    a. 2.0 s
    b. 3.0 s
    c. 4.0 s
    d. 5.0 s
    e. NOTA

17. (1 point) Consider the reaction: A + B ⟶ Products
    The reaction is second order overall: first order in A and first order in B.
    Initially, [A] = [B] = 0.10 M and k = 0.50. What is the concentration of A after 10 seconds?
    a. 0.090 M
    b. 0.067 M ;))
    c. 0.050 M
    d. 0.033 M
    e. NOTA

Use the following for questions 18-22:
Yifan, literally the best chemist ever but opps on biochem, is studying the enzyme lactase which catalyzes the hydrolysis of lactose into glucose and galactose. The reaction follows Michaelis–Menten kinetics with the following parameters at 37°C:
V_{max} = 100μM min^{-1}, K_m = 5.0mM

Michaelis-Menten Equation

$$V_o = \frac{V_{max}\,S}{K_m + S}$$

18. (1 point) If the substrate concentration was 5mM, what is the initial reaction rate?
    a. 25 μM/min
    b. 50 μM/min
    c. 75 μM/min
    d. 100 μM/min
    e. NOTA

19. (1 point) At very high substrate concentrations, what does the reaction rate approach?
    a. 0
    b. Half of V_{max}
    c. V_{max}
    d. Infinity
    e. NOTA

20. (1 point) If a competitive inhibitor was added, which of the following changes occur?
    a. V_{max} decreases and K_m increases
    b. V_{max} stays the same and K_m decreases
    c. V_{max} and K_m decrease
    d. V_{max} stays the same and K_m increases
    e. NOTA

21. (1 point) Suppose a Lineweaver-Burk (double reciprocal) plot was made, which of the following is true?
    a. Slope equals $1/V_{max}$
    b. Y-intercept equals K_m/V_{max}
    c. X-intercept equals $-1/K_m$
    d. Slope equals $K_m/[S]$
    e. NOTA

22. (1 point) If substrate concentration was increased from 1mM to 50 mM, what is the best description of the rate change?

a. Rate increases linearly with [S]
b. Rate increases but levels off near V_{max}
c. Rate decreases with higher [S]
d. Rate becomes zero at high [S]
e. NOTA

23. (1 point) Consider the decomposition reaction: $2N_2O_5 \rightarrow 4NO_2 + O_2$. At a certain point in time, the rate of disappearance of N_2O_5 is 0.020 M/s. Which of the following is true?
    a. The rate of formation of NO_2 is 0.030 M/s
    b. The rate of formation of NO_2 is 0.020 M/s
    c. The rate of formation of O_2 is 0.030 M/s
    d. The rate of formation of O_2 is 0.020 M/s
    e. NOTA

24. (1 point) Which of the following best explains the collision theory in kinetics?
    a. Every collision forms a product.
    b. Only collisions with enough energy and correct orientation form the product.
    c. Only orientation matters.
    d. Rate depends only on concentration.
    e. NOTA
25. Which of the following best describes the role of a catalyst?
    a. Lowers activation energy by creating an alternative pathway for the reaction
    b. Changes the molecule for lower activation energy
    c. Reacts to produce the product
    d. Increases temperature of the reaction
    e. NOTA

FRQs - 2 Problems (30 pts)

1. (16 points total) A student is studying the decomposition of hydrogen peroxide catalyzed by iodide: $2H_2O_2\,(aq) \rightarrow 2H_2O(l) + O_2(g)$. The student measures the initial rates of reaction at different concentrations of H_2O_2 while keeping the iodide concentration constant. This is his data:

$[H_2O_2]$ (M)	**Initial Rate (M/s)**
0.10	2.0×10^{-4}
0.20	4.0×10^{-4}
0.30	6.0×10^{-4}

1a.) (2 points) Using the data above, determine the order of the reaction with respect to H_2O_2 and explain why.

Rate doubles when $[H_2O_2]$ doubles → first order. Make sure it's a proper explanation.
1 point for valid explanation and 1 point for correct order determined.

1b.) (4 points) Write the rate law for this reaction and find the value of the rate constant, k. Show your work and make sure the units are correct.

Rate = $k[H_2O_2]$. Make sure they solve for k properly where they use a value from the table to solve. k = 2.0 x 10^{-3} s^{-1}. 1 pt for correct rate law, 1pt for showing work, 1pt for correct k value, and 1 pt for units.

1c.) (2 points) If the initial concentration of H_2O_2 is 0.50 M, calculate the initial rate of reaction, show your work.

Initial rate = 1.0×10^{-3} M/s. 1pt for correct answer, 1 pt for showing work.

1d.) (2 points) Identify two factors that explain the overall decrease of rate over time in the reaction.

Fewer H_2O_2 molecules → fewer effective collisions per second. Rate is proportional to $[H_2O_2]$ (first-order reaction) → as $[H_2O_2]$ decreases, the rate decreases. 1pt per correct answer

1e.) (4 points) Explain two ways the iodide catalyst affects the rate of the reaction in terms of collision theory.

Lowers activation energy → increases the fraction of collisions with sufficient energy to react. Provides an alternative pathway → allows more collisions to be effective without changing orientation requirements or concentrations. (2pts per correct answer).

1f.) (2 points) A second student runs the reaction at the same $[H_2O_2]$ but without the catalyst. Compare the initial rate in the catalyzed to the uncatalyzed reaction and explain why.

Initial rate is slower without the catalyst. Without the catalyst, the fraction of collisions with energy. Activation energy is smaller, so fewer collisions are effective. The catalyzed reaction provides a lower-energy pathway → more collisions result in product formation.
1 point for correct comparison and 1 point for explanation.

2.) (14 points)

A student is studying the thermal decomposition of nitrogen dioxide, which proceeds via the following mechanism:

Rate Constant = k_1: $NO_2 \longrightarrow NO + O$ (slow)

Rate Constant = k_2: $O + NO_2 \longrightarrow NO + O_2$ (fast)

2a.(2 points) Identify the intermediate species and explain why it qualifies as an intermediate.

Intermediate = O. It is produced in one step and consumed in a subsequent step, never accumulating in large amounts. 1 pt for correct intermediate and 1 pt for explanation.

2b. (3 points) Write the overall rate of formation of O in terms of k_1, k_2, $[NO_2]$, [O].

$k_1[NO_2] - k_2[O][NO_2]$. Overall rate is Produced rate($k_1[NO_2]$) - Consumed rate($k_2[O][NO_2]$).

3 points if expression is right

2c. (3 points) Assuming steady-state approximation applies to O ($d[O]/dt \approx 0$), where rate of formation of O is almost 0, solve for [O] in terms of k_1, k_2, and $[NO_2]$.

$0 = k_1[NO_2] - k_2[O][NO_2]$, $k_2[O][NO_2] = k_1[NO_2]$. **$[O] = k_1 / k_2$.** 3 pts if right

2d. (2 points) Write an expression for the overall rate of formation of O_2 in terms of k_1, k_2, and $[NO_2]$.

Rate of $[O_2] = k_2[O][NO_2]$. Substitute $[O] = k_1/k_2$: Rate of $[O2] = k_2(k_1/k_2)[NO_2] =$ **$k_1[NO_2]$**

2 pts if right

2e. (2 points) Explain why the overall reaction appears first-order in NO_2 even though the mechanism involves two steps.

Any explanation works if it's valid; Step 1 (slow step) determines the rate. SSA shows the intermediate O reaches steady-state quickly ⟶ overall rate depends only on the slow step, which is first-order in NO_2. 2 points for explanation

2f. (2 points) If a third reaction is added: $O + O \longrightarrow O_2$ (fast), how would this affect the steady-state concentration of O?

Steady state concentration of O decreases. Additional consumption of O increases total rate of O removal: $d[O]/dt = k_1[NO_2] - k_2[O][NO_2] - k_3[O]^2$. Any valid explanation with reasoning that correctly explains this: 2pts.

Lab

Determining the Formula of a Hydrate

Objective: Determine the number of water molecules in a hydrated salt ($CuSO_4 \cdot xH_2O$) by heating on a hot plate and observing mass changes. Students will record observations, trends, and reflections related to chemical formulas.
MAKE SURE TO RECORD DATA AND MAKE OBSERVATIONS

Materials:

- Manganese (II) Chloride xhydrate ($MnCl_2 \cdot xH_2O$), ~5 g per trial
- Small heat-resistant glass container (e.g., beaker or watch glass)
- Hot plate
- Tongs or oven mitts
- Digital balance (0.01 g precision)
- Stopwatch
- Safety goggles and gloves

Safety Notes:

- Wear goggles and gloves at all times.
- Copper sulfate is toxic if ingested; do not touch or taste.
- Use tongs or oven mitts to handle hot containers.
- Work on a stable surface; hot plates remain hot after turning off.

Background:

Hydrated salts contain water molecules integrated into their crystal lattice. When heated, the water is removed as vapor, leaving behind the anhydrous salt:

$MnCl_2 \cdot xH_2O\ (s) \longrightarrow MnCl_2\ (s) + x\ H_2O\ (g)$

Procedure

1. Measure and record the mass of your container $\longrightarrow m_1$.
2. Add ~5 g of $MnCl_2 \cdot xH_2O$. Record mass of container + hydrate $\longrightarrow m_2$.
3. Place the container on a hot plate set to medium heat.
4. Heat until crystals appear dry or change color.
5. Allow to cool to room temperature; record mass of container + anhydrous salt $\longrightarrow m_3$.
6. Repeat heating if necessary until mass remains approximately constant.
7. Record observations during the process.
8. Complete as many trials as you need to.

Data Table (10 points)

At least 2 trials needed; 5pt per trials split based on data collected.

Trial	Mass container (g)	Mass container + hydrate (g)	Mass container + dry salt (g)
1			
2			
3			
4			

Observations (3 points)

1. Describe at least 2 changes you saw during the heating process.
   Describe color/texture/shape/smell/vapor/etc = 2pts (2 changes)

Analysis Questions (15 points)

1. (4 pts) How does color and texture indicate water loss?
   Mass of the salt decreases after heating, indicating water loss. Color consistently changes from pink to pale gray-white. Texture becomes drier and more powdery.

2. (3 pts) What is the importance of gradually heating it up?
   Prevents splashing or spattering of the salt. Reduces risk of decomposition of the anhydrous salt. Ensures controlled water loss for accurate mass measurements.

3. (3 points) List at least 3 possible sources of error during this experiment.

   Incomplete heating, Sample loss during handling, Scale precision, Uneven heating

   1pt per source.

4. What was the value of x in the hydrate?

   X = 4

Nice Job!

You've reached the End of the Exam

For 0.00000… points: How many semi colons are on this test?

Answer: 18

The combustion of Zinc in air has a second, less common reaction. What is it? (6 points)

Zn_3N_2 formation