



Carleton
UNIVERSITY

CHEM 1006 A
Winter 2018

Midterm #2: Deferred

Test duration: 80 minutes

Instructor: Alyssa Nause

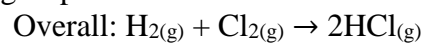
Student Name: _____

Student Number: _____

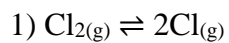
Answer the questions on the exam paper.

If more space is needed, use reverse of exam pages.

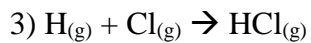
3. The following overall reaction has part of a potential mechanism listed below. Predict the missing step of the mechanism.



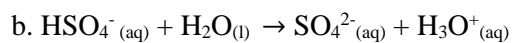
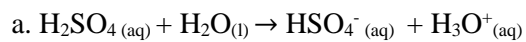
Mechanism:



2) Unknown



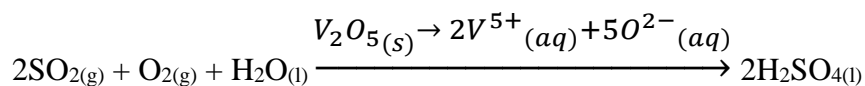
4. Some acids, like H_2SO_4 (sulfuric acid) can lose more than one proton in an acid-base reaction. Identify the conjugate acid-base pairs of each of the reactions below:



Part B: Long Answer Problems (10 marks each)

5. One of the industrial methods used to form concentrated sulfuric acid ($\text{H}_2\text{SO}_{4(l)}$) is the “Contact Process” which utilizes vanadium oxide (V_2O_5) as a catalyst. The major steps of this process are shown below. The overall reaction has an energy change of -212 kJ/mol.
- Sketch an energy profile for the overall reaction and its catalyzed mechanism (sketch both on the same plot).
 - On your sketched energy profile, include arrows to indicate each activation energy and the energy change of the reaction.
 - Note each non-catalyst species in the catalyzed mechanism in its appropriate location on the energy profile.

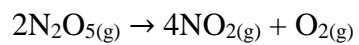
Overall: $E_{a,\text{overall}} = 315$ kJ/mol



Catalyzed Mechanism:

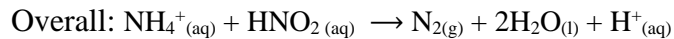
- | | |
|--|-----------------------|
| 1) $2\text{SO}_{2(g)} + 4\text{V}^{5+}_{(aq)} + 2\text{O}^{2-}_{(aq)} \rightarrow 2\text{SO}_{3(g)} + 4\text{V}^{4+}_{(aq)}$ | $E_{a,1} = 95$ kJ/mol |
| 2) $4\text{V}^{4+}_{(aq)} + \text{O}_{2(g)} \rightarrow 4\text{V}^{5+}_{(aq)} + 2\text{O}^{2-}_{(aq)}$ | $E_{a,2} = 44$ kJ/mol |
| 3) $2\text{H}_2\text{SO}_{4(l)} + 2\text{SO}_{3(g)} \rightarrow 2\text{H}_2\text{S}_2\text{O}_7(l)$ | $E_{a,3} = 65$ kJ/mol |
| 4) $2\text{H}_2\text{S}_2\text{O}_7(l) + 2\text{H}_2\text{O}_{(l)} \rightarrow 4\text{H}_2\text{SO}_{4(l)}$ | $E_{a,4} = 53$ kJ/mol |

6. For the following reaction and experimental data:
- Determine the activation energy.
 - Determine the rate constant at 100.0°C, and comment on the effect this lower temperature has on the reaction progress.

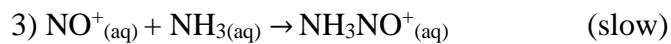
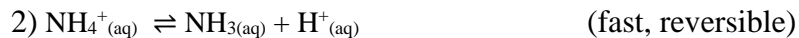


Experimental rate constant ($\text{M}^{-1} \text{s}^{-1}$)	Temperature ($^{\circ}\text{C}$)
6.67×10^{-8}	673
2.70×10^{-5}	452

7. Determine the rate law for the following given mechanism. If possible, substitute any invalid compounds in the predicted rate law to determine the corrected predicted rate law.



Mechanism:



Equations and Constants:

$$R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$$

$$1/[A] = 2kt + 1/[A]_0$$

$$N_{Av} = 6.022 \times 10^{23} \text{ mol}^{-1}$$

$$\text{Rate} = k[A]^x[B]^y$$

$$n = m/M$$

$$k_1[A_2] = k_{-1}[A]^2$$

$$c = n/V$$

$$k = Ae^{-E_a/RT}$$

$$\rho = m/V$$

$$\ln(k) = \ln(A) - E_a/RT$$

$$b = n/m$$

$$\ln\left(\frac{k_2}{k_1}\right) = \left(\frac{E_a}{R}\right)\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$X_C = n_C/n_{\text{total}}$$

$$t_{1/2} = \ln 2 / ak$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$t_{1/2} = 1 / 2k[A]_0$$

$$0 = ax^2 + bx + c$$

$$\ln[A] = -akt + \ln[A]_0$$

$$1 \text{ atm} = 1.01325 \times 10^5 \text{ Pa} = 760 \text{ Torr} = 1.01325 \text{ bar}$$

$$T(\text{K}) = T(^{\circ}\text{C}) + 273.15$$

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18																																																																																																																																																																																																																																																																																																																																																																																								
Hydrogen 1 H 1.008	Beryllium 4 Be 9.0122	Lithium 3 Li 6.94	Sodium 11 Na 22.990	Magnesium 12 Mg 24.305	Calcium 20 Ca 40.078(4)	Potassium 19 K 39.098	Rubidium 37 Rb 85.468	Cesium 55 Cs 132.91	Francium 87 Fr [223.02]	Scandium 21 Sc 44.956	Yttrium 39 Y 88.906	Lanthanum 57 La 138.91	Actinium 89 Ac [227.03]	Titanium 22 Ti 47.867	Zirconium 40 Zr 91.224(2)	Hafnium 72 Hf 178.49(2)	Rutherfordium 104 Rf [261.12]	Lawrencium 103 Lr [262.11]	Vanadium 23 V 50.942	Niobium 41 Nb 92.906(2)	Tantalum 73 Ta 180.95	Dubnium 105 Db [268.13]	Praseodymium 59 Pr 140.91	Protactinium 91 Pa 231.04	Caesium 58 Ce 140.12	Thorium 90 Th 232.04	Neodymium 60 Nd 144.24	Uranium 92 U 238.03	Plutonium 94 Pu [244.06]	Samarium 62 Sm 150.36(2)	Einsteinium 95 Es [285.17]	Europium 63 Eu 151.96	Americium 95 Am [243.06]	Gadolinium 64 Gd 157.25(3)	Curium 96 Cm [247.07]	Terbium 65 Tb 158.93	Berkelium 97 Bk [247.07]	Dysprosium 66 Dy 162.50	Californium 98 Cf [251.08]	Ytterbium 70 Yb 173.05	Nobelium 102 No [259.10]	Fluorine 9 F 18.998	Oxygen 8 O 15.999	Nitrogen 7 N 14.007	Carbon 6 C 12.011	Boron 5 B 10.81	Helium 2 He 4.0026																																																																																																																																																																																																																																																																																																																																																										
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