

Surname : \_\_\_\_\_ Given name : \_\_\_\_\_

Student number: \_\_\_\_\_

Lab Section: \_\_\_\_\_ Lab TA: \_\_\_\_\_

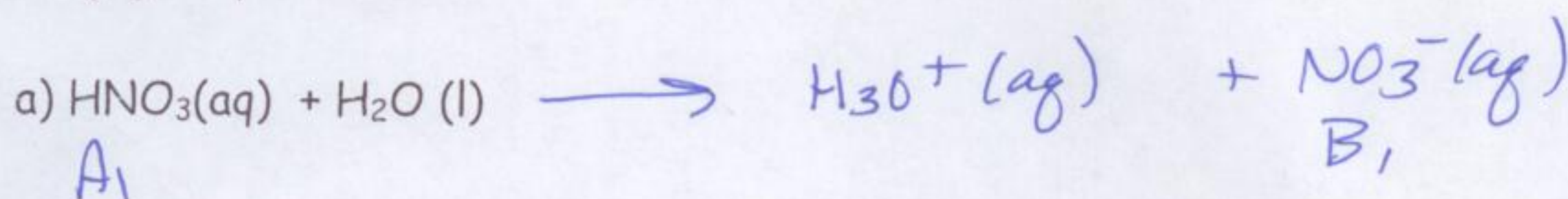
# Chemistry 1311D

## Test 2 V1

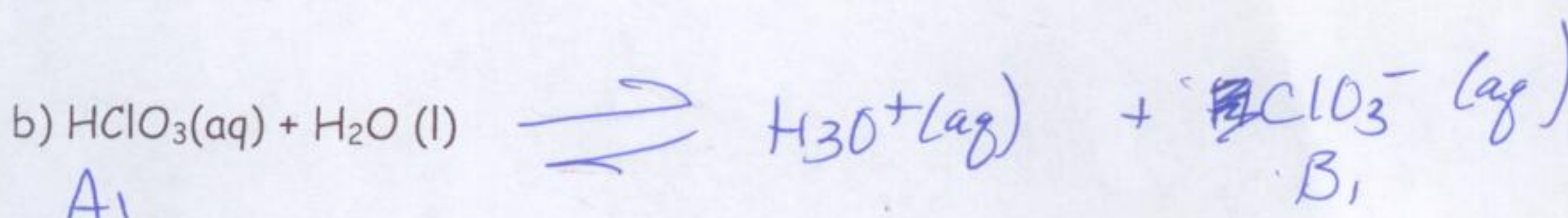
November 22, 2012

80 minutes You may remove last 2 pages

1. (3 points) Complete the following acid/base reactions (paying particular attention to the arrow used and states of products) and, where appropriate, identify acid/base conjugate pairs:



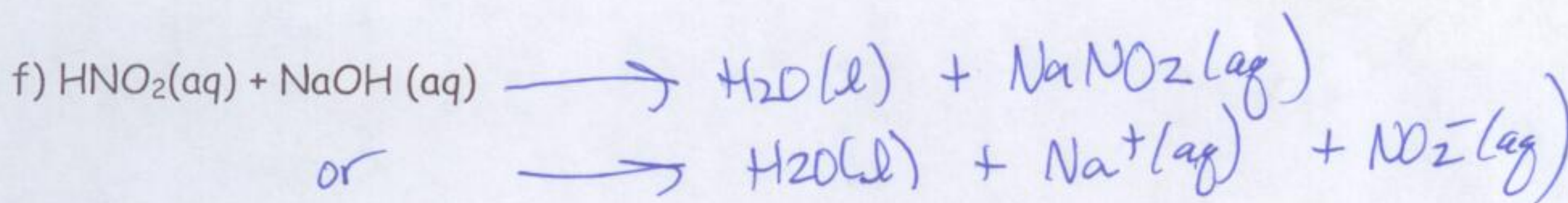
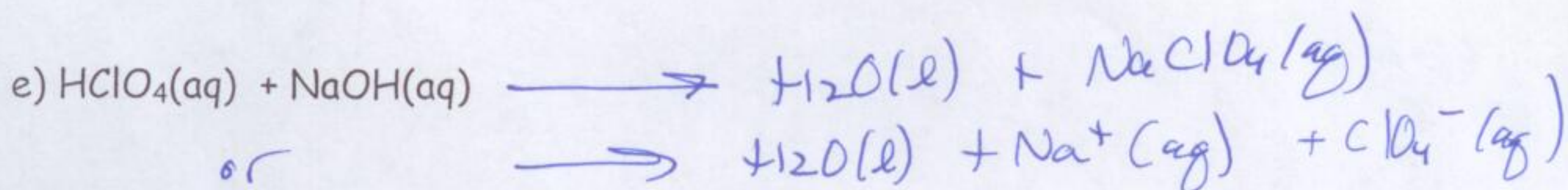
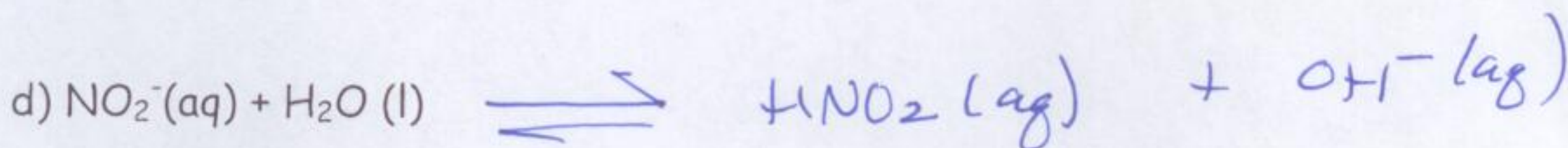
0.5 per rxn



-0.5 for no labelling



-0.1 error in arrow



# Version 1

2. A particular chemical reaction was studied and the half-life, found to be independent of concentration, was 25.7 s at 227 °C. At 277 °C the reactant concentration dropped from 1.5 M to 0.45 M in 5s.

a) (1 point) What is the order of the reaction?

*1<sup>st</sup> order because  $t_{1/2}$  independent of conc.*

b) (1 point) What is the rate constant at 227 °C?

$$t_{1/2} = \frac{\ln 2}{k}; \quad k = \frac{\ln 2}{25.7 \text{ s}} = 2.697 \times 10^{-2} \text{ s}^{-1} \approx 2.70 \times 10^{-2} \text{ s}^{-1}$$

c) (2 points) What is the rate constant at 277 °C?

$$\ln A = \ln A_0 - kt$$

$$\ln 0.45 = \ln 1.5 - k(5 \text{ s})$$

$$k = 2.41 \times 10^{-1} \text{ s}^{-1}$$

d) (3 points) What is the activation energy associated with this process?

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

$$k_1 = 2.70 \times 10^{-2} \text{ s}^{-1} \text{ @ } 500 \text{ K}$$

$$k_2 = 2.41 \times 10^{-1} \text{ s}^{-1} \text{ @ } 550 \text{ K}$$

$$\ln \frac{2.7 \times 10^{-2}}{2.41 \times 10^{-1}} = \frac{E_a}{8.314} \left( \frac{1}{550} - \frac{1}{500} \right)$$

$$18.201 = E_a (7.81818 \times 10^{-4})$$

$$E_a = 100.1 \text{ kJ}$$

e) (3 points) At what temperature will the rate of the reaction be twice that of 277 °C?

$$k_2 = 2.41 \times 10^{-1} \text{ s}^{-1} \text{ @ } 550$$

$$k_1 = 2(2.41 \times 10^{-1}) \text{ s}^{-1} = 4.82 \times 10^{-1} \text{ s}^{-1} \text{ @ } T?$$

$$\ln(2) = \frac{100.1 \times 10^3}{8.314} \left( \frac{1}{550} - \frac{1}{T_1} \right)$$

$$5.757 \times 10^{-5} = \frac{1}{550} - \frac{1}{T_1}$$

$$1.7606 \times 10^{-3} = \frac{1}{T_1}$$

$$T_1 = 568 \text{ K}$$

$$295 \text{ °C}$$

## Version 1

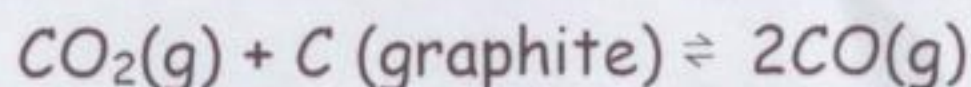
Jenna

3. a) (4 points) A container contains  $\text{CO}_2$  at  $p = 0.464$  bar. Graphite is added to the container and some  $\text{CO}_2$  is converted to  $\text{CO}$ ; at equilibrium the total pressure is 0.746 bar. Determine the equilibrium constant for the reaction:

$$P_i = 0.464 \text{ bar}$$

$$P_T = 0.746 \text{ bar}$$

$$P_T = P_{\text{CO}_2} + P_{\text{CO}}$$



i	0.464	—	—
c	-x		+2x
e	0.464-x		2x

$$P_T = 0.746 = \overset{P_{\text{CO}_2}}{(0.464 - x)} + \overset{P_{\text{CO}}}{2x} = 0.464 + x$$

$$x = 0.282 \text{ bar}$$

$$P_{\text{CO}_2} = 0.464 - 0.282 = 0.182 \text{ bar}$$

$$P_{\text{CO}} = 0.564 \text{ bar} = 2(0.282 \text{ bar})$$

$$K_p = \frac{P_{\text{CO}}^2}{P_{\text{CO}_2}} = \frac{(0.564)^2}{0.182} = 1.748$$

b) (1 point) The equilibrium system above is compressed to 1/3 its initial volume. Applying Le Chatelier's principle will reaction shift to left or right? Explain briefly.

Volume decreased, pressure increased, shifts to fewer moles of gas **LEFT**

c) (4 points) Find the new equilibrium pressure for the system.

Need starting non-equilibrium pressure following compression

$$P_1 V_1 = P_2 V_2$$

$$P_1 = 0.464 \quad V_f = V_i, \quad P_2 = ? \quad V_2 = \frac{1}{3} V_1$$

$$(0.464) V_i = \frac{1}{3} P_2 V_i; \quad P_2 = 1.392 \text{ bar}$$

	$\text{CO}_2 +$	c	$\rightleftharpoons$	2CO
i	1.392	—		—
c	-x			2x
e	1.392-x			2x

$$K_p = \frac{(2x)^2}{1.392-x} = 1.748$$

$$= \frac{4x^2}{1.392-x}$$



d) (1 point) A catalyst is added to the reaction mixture. What is the role of a catalyst and how will this effect the equilibrium concentrations?

Catalyst speeds up reaction.  
Catalyst does NOT effect equilibrium concentrations.

$$4x^2 = 2.433 - 1.748x$$

$$4x^2 + 1.748x - 2.433 = 0$$

$$x = \frac{-1.748 \pm \sqrt{1.748^2 - 4(4)(-2.433)}}{2(4)}$$

$$= \frac{-1.748 \pm 4.479}{8}$$

$$x = 0.592$$

$$P_{CO_2} = 1.392 - 0.591 = 0.801 \text{ bar}$$

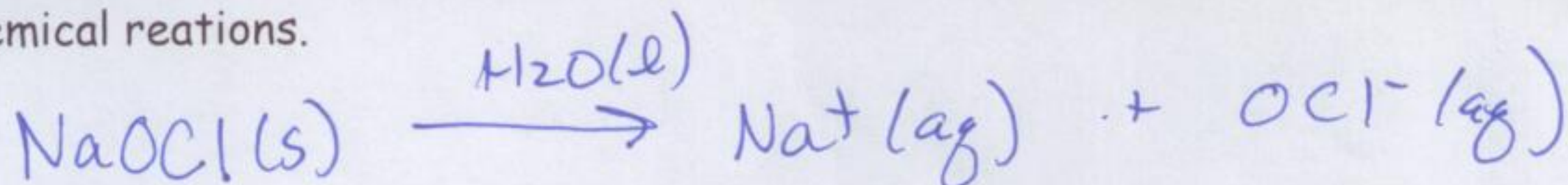
$$P_{CO} = 2(0.592) = 1.184$$

$$P_T = 1.985 \text{ bar}$$

# All vesions

4. Sodium hypochlorite, NaOCl, is the active ingredient in laundry bleach. Typical bleach solutions contain 0.64 M of NaOCl. Hypochlorous acid, HOCl, has a  $K_a$  of  $4.0 \times 10^{-8}$ .

a) (2 points) What happens when solid NaOCl is added to water? Write all relevant chemical reactions.



b) (4 points) Determine the equilibrium concentration of ALL species in an aqueous solution of 0.64 M NaOCl (there are five species, not including  $\text{H}_2\text{O}$ ).

	$\text{OCl}^-$	+	$\text{H}_2\text{O}$	$\rightleftharpoons$	$\text{HOCl}$	+	$\text{OH}^-$	$K_a = 4.0 \times 10^{-8}$
i	0.64		—		—		$10^{-7}$	$K_b = \frac{10^{-14}}{4 \times 10^{-8}}$
c	-x		—		x		+x	$= 2.5 \times 10^{-7}$
e	0.64-x		—		x		$10^{-7} + x$	

$$K_b = \frac{x(10^{-7} + x)}{0.64 - x} = \frac{x^2}{0.64 - x} \approx \frac{x^2}{0.64} = 2.5 \times 10^{-7}$$

$$x = 4.0 \times 10^{-4} = [\text{OH}^-]$$

$$[\text{OH}^-] = 4.0 \times 10^{-4} \text{ M}$$

$$[\text{Na}^+] = 0.64 \text{ M}$$

$$[\text{OCl}^-] = 0.64 - 4.0 \times 10^{-4} \approx 0.64 \text{ M}$$

$$[\text{HOCl}] = 4 \times 10^{-4} \text{ M}$$

$$[\text{H}_3\text{O}^+] = \frac{10^{-14}}{4 \times 10^{-4}} = 2.5 \times 10^{-11} \text{ M}$$

c) (1 point) What is the pH of this solution?

$$\text{pH} = -\log(2.5 \times 10^{-11}) = 10.4$$

D-VI

5. a) (4 points) What volumes of water and 1.06 M of ammonia  $[NH_3]$  should be used to prepare 2 L of buffer solution that contains 78.312 g of dissolved  $NH_4Cl$  and has pH 9.12.  $K_b$  of  $NH_3$  is  $1.8 \times 10^{-5}$ .

$NH_4Cl$  MM = ~~78.312~~ = 53.489      moles =  $\frac{78.312}{53.489 \text{ g/mol}} = 1.464$

$[NH_4^+] = 1.464 / 2L = 0.732 M$

pH = 9.12       $K_b = 1.8 \times 10^{-5}$        $K_a = K_w / K_b = 5.556 \times 10^{-10}$

$pH = pK_a + \log \frac{NH_3}{NH_4^+} = 9.12 = 9.26 + \log \frac{NH_3}{0.732}$

$9.12 = 9.26 + \log \frac{NH_3}{0.732}$

$-0.14 = \log NH_3 / 0.732$

$[NH_3] = 0.53 M$

$$\begin{aligned} V_{NH_3} [1.06] &= 2 [0.53] \\ V_{NH_3} &= 1 L \\ V_{H_2O} &= 1 L \end{aligned}$$

b) (1 point) Determine the resulting pH when 5 g of solid NaOH is added to 2 L of

water. MM NaOH = 40.0 g/mol ; 5g / 40g/mole = 0.125 moles

0.125 moles in 2L       $[OH^-] = 0.125 / 2L = 0.0625 M$

$pOH = -\log(0.0625) = 1.20$

$pH = 12.80$

c) (4 points) If 5 g of solid NaOH were added to you 2L buffer solution, what would the be resulting change in pH of the buffer solution?

5g = 0.125 moles = 0.0625 M base

$[NH_4^+] = 0.732 - 0.0625 = 0.6695$

$[NH_3] = 0.530 + 0.0625 = 0.5925$

$pH = 9.26 + \log \frac{0.5925}{0.6695}$   
= 9.21

pH increases from 9.12 to 9.21 or 0.09 pH units

d) (1 point) Is the buffer effective?

Yes!