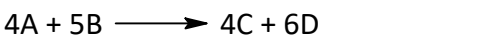
Chemistry 1210 Spring 2023 Test 1

Wednesday, February 1, 2023 Time: 1 hour 50 minutes

Name: _____ Student #: _____

*This test consists of **nine** pages of questions, the formula sheet, and a periodic table. Please ensure that you have a complete test and, if you do not, obtain one from me **immediately**. There are **45.5** marks available. Good luck!*

1) **[6.5 marks total]** The following initial rate data were collected for the reaction:



Run	[A] (M)	[B] (M)	$\frac{\Delta[A]}{\Delta t}(\frac{M}{s})$
1	0.50	0.64	-0.0800
2	0.80	0.64	-0.2048
3	0.40	0.16	-0.0256

a) **[2 marks]** Determine the rate law for the reaction kinetics followed by the reaction.

b) **[2 marks]** Determine the rate constant. Include units.

c) **[0.5 marks]** What is the overall order of the reaction kinetics?

d) **[1 mark]** What is the value of $\frac{\Delta[D]}{\Delta t}$ for run 1?

e) **[1 mark]** The reaction above does not occur in a single step. Give two reasons why this is so.

2) **[9 marks total]** Michaelis and Menten have proposed the following mechanism for an enzyme (E) acting on a substrate (S) to produce a product (P) after production of the compound ES:

$$E + S \underset{k_2}{\overset{k_1}{\rightleftharpoons}} ES \qquad \text{(fast)}$$

$$ES \xrightarrow{k_3} E + P \qquad \text{(slow)}$$

a) **[1 mark]** What is the overall reaction?

b) **[1 mark]** Which, if any, are the catalysts in the mechanism above?

c) **[1 mark]** Which, if any, are the reactive intermediates in the mechanism above?

d) **[1 mark]** Which, if any, are the termolecular steps in the mechanism above?

e) **[2 marks]** Derive the rate law predicted by the mechanism.

f) **[3 marks total]** Sketch the energy diagram for the mechanism. On it, be sure to:

i) **[0.5 marks]** Include proper labels and units for your axes.
ii) **[0.5 marks]** Indicate the forward activation energies for each of the two steps above.
iii) **[1.5 marks]** Include the appropriate number energy barriers with the appropriate relative heights.
iv) **[0.5 marks]** The appropriate relative energies for all products and reactants. You may assume that both steps in the reaction, and the reaction as a whole, are exothermic.

3) **[4 marks total]** It was found that the rate constant for a certain reaction followed the equation $lnk = 23.7 - \frac{12027}{T}$.

a) **[1 mark]** What is the pre-exponential factor (A)?

b) **[1 mark]** What is the energy of activation for the reaction? Give your answer in kJ/mol.

c) **[2 marks]** At what temperature will the rate constant be 1? (Give your answer in °C.)

4) **[2 marks]** If the rate of a reaction doubles when the temperature is increased from 6.85°C to 16.85°C, then the energy of activation for that reaction is:

a) 0.67 J/mol b) 46.8 kJ/mol c) 66.5 J/mol d) 468 J/mol

5) **[4 marks]** Suppose the way Pat's cat Jimmy eats his food follows first-order kinetics. Further suppose the half-life of a meal of his is 150 seconds. If, after 200 seconds, he has eaten 44 grams of food, how much was his total serving?

6) **[2 marks]** Given the following data:

[A] (M)	t (s)
	0
1	20
0.5	30
0.25	40

What was $[A]_o$? How do you know? (No marks for guessing. 😊)

7) **[4 marks]** Given the following equilibrium:

$H_2(g) + Cl_2(g) \rightleftharpoons 2HCl(g)$ $\Delta H° < 0$ (exothermic)

Predict the effect that each of the changes given below would have on the value of K and on the moles of Cl_2 present in a fresh system initially at equilibrium. Your choices are **I**ncrease from the starting value, **D**ecrease from the starting value, or **N**ot **C**hange from the starting value. You may assume that, unless explicitly stated otherwise, the changes were carried out at constant temperature.

	Effect on:					
	K_p			Cl_2		
Adding some H_2	I	D	NC	I	D	NC
Cooling the reaction mixture	I	D	NC	I	D	NC
compressing the reaction mixture	I	D	NC	I	D	NC
Adding some He(g)	I	D	NC	I	D	NC

8) **[8 marks]** Given the equilibrium:

$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(l)$ $\Delta H° = -1170.06$ kJ $K_p = 5.4 \times 10^{78}$ at 300°C

a) The value of K_p for

$2NO(g) + 3H_2O(l) \rightleftharpoons 2NH_3(g) + 2.5O_2(g)$

at 300°C should be:

i) 3.7×10^{-79}
ii) 4.3×10^{-40}
iii) -2.3×10^{39}
iv) -2.7×10^{78}

b) The value of K_c for the reaction

$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(l)$ $\Delta H° = -1170.06$ kJ $K_p = 5.4 \times 10^{78}$ at 300°C

at 300°C should be:

i) 2.2×10^{60}
ii) 2.2×10^{70}
iii) 1.1×10^{75}
iv) 1.1×10^{77}
v) 2.6×10^{80}
vi) 2.6×10^{82}
vii) 1.3×10^{87}
viii) 1.3×10^{97}

c) The value of K_p for the reaction

$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(l)$ $\Delta H° = -1170.06$ kJ $K_p = 5.4 \times 10^{78}$ at 300°C

at 400°C should be:

i) 6.3×10^{27}
ii) 7.8×10^{62}
iii) 4.8×10^{78}
iv) 5.2×10^{78}

d) Given the additional reaction:

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ $K_p = 0.01$ at 300°C

Calculate K_p (at 300°C) for the reaction:

$2N_2(g) + 6H_2(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(l)$

9) **[2 marks]** Ethanol has a vapour pressure of 58.9 torr at 25°C and a normal boiling point of 78.4°C. Its enthalpy of vaporization (in kJ/mol) should be:

a) 7.8 J/mol
b) 417 J/mol
c) 780 J/mol
d) 41.7 kJ/mol

10) **[4 marks total]** A flask was charged with 0.1 bar of H_2O, 0.1 bar of Cl_2O, and 0.2 bar of HOCl, and the equilibrium

$H_2O(g) + Cl_2O(g) \rightleftharpoons 2HOCl(g)$ $K = 2.25$ at 252.7°C

established.

a) **[1 mark]** In which direction did the reaction proceed to establish equilibrium? How do you know? (No marks for guessing. 😊)

b) **[3 marks]** Calculate the equilibrium partial pressures of all species.