Chemistry 1B, Spring 2004

Midterm 1

Feb 19, 2003

(90 min, closed book)

Name:___________________

SID:_____________________

TA Name:________________

- This exam has 43 multiple choice questions.
- Fill in the Scantron form AND circle your answer on the exam.
- Each question is worth 3.5 points.

Note:

- The questions on the exam may be answered in any order.
- All the questions are equally weighted. Answer those you can quickly and go back to those that require more thought.
- Some questions may seem obvious or too simple. They are. There are no ‘trick’ questions.
- Questions that contain ‘mark all that apply’ may require you to mark more than one answer to get credit for that question.

- Potentially useful relations:

$[A]_t = [A]_0 e^{-kt}$
$\ln[A]_t = \ln[A]_0 - kt$
$t_{1/2} = \ln2/k$
$1/[A]_t = 1/[A]_0 + kt$
$k = A\ e^{(-Ea/RT)}$
$\ln(k_1/k_2) = E_a/R\ (1/T_2 - 1/T_1)$
$t_{1/2} = 1/[A]_0 k$
$t_{1/2} = [A]_0/kt$

$PV = nRT$

$$E_{kin} = \frac{3}{2}RT$$

$$v_{rms} = \sqrt{\frac{3RT}{M}}$$

$\Delta E = q + w$

$w = -P_{ext}\Delta V$

$$\Delta E = \frac{3}{2}nR\Delta T$$

$N_0 = 6.02214 \times 10^{23}\ mol^{-1}$

$R_\infty = 2.179874 \times 10^{-18}$ J

$R_\infty = 3.28984 \times 10^{15}$ Hz

$k = 1.38066 \times 10^{-23}\ J\ K^{-1}$

$h = 6.62608 \times 10^{-34}$ J s

$m_e = 9.101939 \times 10^{-31}$ kg

$c = 2.99792 \times 10^{8}\ m\ s^{-1}$

Gas Constant:

$R = 8.31451\ J\ K^{-1}\ mol^{-1}$

$R = 8.20578 \times 10^{-2}\ L\ atm\ K^{-1}\ mol^{-1}$

T (K) = T (C) + 273.15

F = 96,485 C / mol

1 V = 1 J / C 1 nm = 10^{-9} m
1 kJ = 1000 J

$\Delta G° = \Delta H° - T\Delta S°$
$\Delta H° = \Sigma\ \Delta H°_f$ (products) $- \Sigma\ \Delta H°_f$ (reactants)
$\Delta S° = \Sigma\ S°$ (products) $- \Sigma\ S°$ (reactants)
$\Delta G° = \Sigma\ \Delta G°_f$ (products) $- \Sigma\ \Delta G°_f$ (reactants)
$S = k_B \ln W$

for $aA + bB \rightleftarrows cC + dD$

$$Q = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$ At equilibrium, Q = K

$\Delta G° = -RT\ln K$

$$\ln K = -\frac{\Delta H°}{R}\frac{1}{T} + \frac{\Delta S°}{R}$$

$\Delta G° = -nF\Delta Є°$
$\Delta Є = \Delta Є° - RT/nF \ln Q$
$\ln K = nF\Delta Є°/RT$

$pX = -\log X$

$$pH = pK_a + \log\frac{[A^-]}{[HA]}$$

TABLE 12.2 Standard Potentials at 25°C*

Species†	Reduction half-reaction	$E°$, V
Oxidized form is strongly oxidizing		
F_2/F^-	$F_2(g) + 2\ e^- \longrightarrow 2\ F^-(aq)$	+2.87
Au^+/Au	$Au^+(aq) + e^- \longrightarrow Au(s)$	+1.69
Ce^{4+}/Ce^{3+}	$Ce^{4+}(aq) + e^- \longrightarrow Ce^{3+}(aq)$	+1.61
$MnO_4^-, H^+/Mn^{2+}, H_2O$	$MnO_4^-(aq) + 8\ H^+(aq) + 5\ e^- \longrightarrow Mn^{2+}(aq) + 4\ H_2O(l)$	+1.51
Cl_2/Cl^-	$Cl_2(g) + 2\ e^- \longrightarrow 2\ Cl^-(aq)$	+1.36
$Cr_2O_7^{2-}, H^+/Cr^{3+}, H_2O$	$Cr_2O_7^{2-} + 14\ H^+(aq) + 6\ e^- \longrightarrow 2\ Cr^{3+}(aq) + 7\ H_2O(l)$	+1.33
$O_2, H^+/H_2O$	$O_2(g) + 4\ H^+(aq) + 4\ e^- \longrightarrow 2\ H_2O(l)$	+1.23; +0.82 at pH = 7
Br_2/Br^-	$Br_2(l) + 2\ e^- \longrightarrow 2\ Br^-(aq)$	+1.09
$NO_3^-, H^+/NO, H_2O$	$NO_3^-(aq) + 4\ H^+(aq) + 3\ e^- \longrightarrow NO(g) + 2\ H_2O(l)$	+0.96
Ag^+/Ag	$Ag^+(aq) + e^- \longrightarrow Ag(s)$	+0.80
Fe^{3+}/Fe^{2+}	$Fe^{3+}(aq) + e^- \longrightarrow Fe^{2+}(aq)$	+0.77
I_2/I^-	$I_2(s) + 2\ e^- \longrightarrow 2\ I^-(aq)$	+0.54
$O_2, H_2O/OH^-$	$O_2(g) + 2\ H_2O(l) + 4\ e^- \longrightarrow 4\ OH^-(aq)$	+0.40; +0.82 at pH = 7
Cu^{2+}/Cu	$Cu^{2+}(aq) + 2\ e^- \longrightarrow Cu(s)$	+0.34
$AgCl/Ag, Cl^-$	$AgCl(s) + e^- \longrightarrow Ag(s) + Cl^-(aq)$	+0.22
H^+/H_2	$2\ H^+(aq) + 2\ e^- \longrightarrow H_2(g)$	0, by definition
Fe^{3+}/Fe	$Fe^{3+}(aq) + 3\ e^- \longrightarrow Fe(s)$	−0.04
$O_2, H_2O/HO_2^-, OH^-$	$O_2(g) + H_2O(l) + 2\ e^- \longrightarrow HO_2^-(aq) + OH^-(aq)$	−0.08
Pb^{2+}/Pb	$Pb^{2+}(aq) + 2\ e^- \longrightarrow Pb(s)$	−0.13
Sn^{2+}/Sn	$Sn^{2+}(aq) + 2\ e^- \longrightarrow Sn(s)$	−0.14
Fe^{2+}/Fe	$Fe^{2+}(aq) + 2\ e^- \longrightarrow Fe(s)$	−0.44
Zn^{2+}/Zn	$Zn^{2+}(aq) + 2\ e^- \longrightarrow Zn(s)$	−0.76
$H_2O/H_2, OH^-$	$2\ H_2O(l) + 2\ e^- \longrightarrow H_2(g) + 2\ OH^-(aq)$	−0.83; −0.42 at pH = 7
Al^{3+}/Al	$Al^{3+}(aq) + 3\ e^- \longrightarrow Al(s)$	−1.66
Mg^{2+}/Mg	$Mg^{2+}(aq) + 2\ e^- \longrightarrow Mg(s)$	−2.36
Na^+/Na	$Na^+(aq) + e^- \longrightarrow Na(s)$	−2.71
K^+/K	$K^+(aq) + e^- \longrightarrow K(s)$	−2.93
Li^+/Li	$Li^+(aq) + e^- \longrightarrow Li(s)$	−3.05
Reduced form is strongly reducing		

* For a more extensive table, see Appendix 2B.
† In the notation X/Y, X is the oxidized species (the reactant, the oxidizing agent) and Y is the reduced species (the product, the reducing agent) in the half-reaction.

SECTION 1: KINETICS

Consider the following reaction and the data below collected at 298 K for the following nine questions (M = moles/L):

$$NO_2\,(g) + O_3\,(g) \rightarrow NO_3\,(g) + O_2\,(g)$$

Exp.	Initial Concentration (M) $[NO_2]_0$	$[O_3]_0$	Initial Rate (Ms^{-1})
1	0.42	1.40	12.6
2	0.42	2.80	25.0
3	0.76	1.40	22.8
4	1.32	0.36	

1.) What is the value of 'x' in the rate law Rate = k $[NO_2]^x[O_3]^y$?

A) -1/2 B) -1 C) 0 $\boxed{\text{D) 1}}$ E) 2

2.) What is the value of 'y' in the rate law Rate = k $[NO_2]^x[O_3]^y$?

A) -1/2 B) -1 C) 0 $\boxed{\text{D) 1}}$ E) 2

3.) What is the numerical value of 'k' in the rate law Rate = k $[NO_2]^x[O_3]^y$?

$\boxed{\text{A) 21.4}}$ B) 0.42 C) 12.6 D) 1.54 E) 53

4.) What are appropriate units for k?

A) s^{-1} B) M $\boxed{\text{C) } M^{-1}s^{-1}}$ D) Ms^{-2} E) $M^{-2}s^{-2}$

5.) What is true of the reaction if the ratio of $E_{a\,F} / E_{a\,R} > 1$?

$\boxed{\text{A) endothermic}}$
B) exothermic
C) isothermic
D) can't tell

6.) What is the effect of an increase in temperature if $E_{a\,F} / E_{a\,R} > 1$?

A) favor products
B) favor reactants
C) increased ΔH
D) decreased ΔH
E) can't tell

7.) What is the forward activation energy (kJ) if when experiment 1 is run at 308 K the initial rate is 25.2 Ms^{-1}.

A) 21.4 B) 0.42 C) 12.6 D) 1.54 E) 53

8.) What initial rate would be expected in for reaction 1 in the presence of a catalyst?

A) 2.1 B) 0.52 C) 12.6 D) 33.2 E) 0.11

9.) Which is true in the presence of a catalyst if in the unanalyzed reaction $E_{a\,F} / E_{a\,R} > 1$?

A) endothermic
B) exothermic
C) isothermic
D) can't tell

Continue with the next question:

Consider the rate constants for an elementary reaction $A + A \rightarrow C$ are $k_f = 0.34\ M^{-1}s^{-1}$ and $k_r = 0.0023\ s^{-1}$ for the next two questions

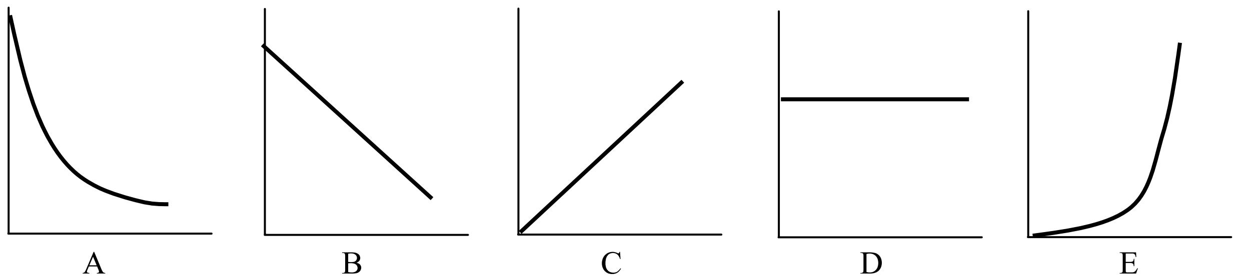
10.) What is the equilibrium constant for the reaction?

A) 0.072 B) 13.2 C) 45.1 D) 103 E) 150

11.) What initial rate for $[A]_0 = 0.46$ M?

A) 0.072 B) 13.2 C) 45.1 D) 103 E) 150

For the next 10 questions, choose the plot below that best describes the relationship between the pair of variables.



12.) [A] vs. time for first order reaction A $\rightarrow$ B + C. $\boxed{\text{A}}$

13.) [A] vs. time for zero order reaction A $\rightarrow$ B + C. $\boxed{\text{B}}$

14.) [A] vs. time for the elementary reaction A + B $\rightarrow$ C + D when $[A]_0 = [B]_0$. $\boxed{\text{A}}$

15.) ln[A] vs. time for the elementary reaction A + B $\rightarrow$ C + D when $[A]_0 << [B]_0$. $\boxed{\text{B}}$

16.) ln[A] vs. time for the second order reaction A $\rightarrow$ B + C. $\boxed{\text{A}}$

17.) ln[A] vs. time for first order reaction A $\rightarrow$ B + C. $\boxed{\text{B}}$

18.) $[A]^{-1}$ vs. time for the second order reaction A $\rightarrow$ B + C. $\boxed{\text{C}}$

19.) The half life vs. $[A]^{-1}$ for the second order reaction A + B $\rightarrow$ C $\boxed{\text{C}}$

20.) The half life vs. $[A]^{-1}$ for the first order reaction A $\rightarrow$ B $\rightarrow$ C. $\boxed{\text{D}}$

21.) lnk vs. 1/T (k = rate constant, T=Temperature). $\boxed{\text{B}}$

Continue with the next question:

Continue with the next question:

Consider the following reaction mechanism for the oxidation of iodide (I^-) by hypochlorite (ClO^-) for the following two questions.

Step 1: $ClO^- + H_2O \rightarrow HClO + OH^-$ (and reverse, both fast)

Step 2: $I^- + HClO \rightarrow HIO + Cl^-$ (slow)

Step 3: $HIO + OH^- \rightarrow IO^- + H_2O$ (fast)

22.) Which rate law is consistent with the reaction mechanism?

A) rate = k $[I^-][ClO^-]$
B) rate = k $[I^-][HClO]$
C) rate = k $[I^-][Cl^-]^{-1}$
D) $\boxed{\text{rate} = k [I^-][ClO^-][OH^-]^{-1}}$
E) can't tell

23.) What is the effect of an increased forward rate in step 1?

A) overall rate doubles
B) overall rate halves
C) overall rate increases by $2^{1/2}$
D) no effect
E) can't tell

Continue with the next question:

24.) What is the ratio of rate at pH 13 to pH 14 for the following elementary reaction?

$$CH_3OH + OH^- \rightarrow CH_3O^- + H_2O$$

$\boxed{\text{A) } 0.1}$ B) 1 C) 10 D) 100 E) 1000

25.) A sample of radioactive material decomposes from 35 mCi (millicurries) to 17 mCi in 1 month. What is the total time (months) for the activity to drop from 35 mCi to 8.5 mCi (assume first order behavior)?

A) 0.5 B) 1 $\boxed{\text{C) } 2}$ D) 4 E) can't tell

26.) In a second order reaction $H_2 + I_2 \rightarrow 2\ HI$, the partial pressure of I_2 gas falls from 3.0 atm to 1.5 atm in 30 seconds. How much additional time (seconds) will it take for the pressure to drop to 0.75 atm?

A)15 B) 30 $\boxed{\text{C) } 60}$ D) 90 E) can't tell

SECTION 2: ELECTROCHEMISTRY

Consider a fuel cell with the overall reaction $2\ H_2\ (g) + O_2\ (g) \rightarrow 2\ H_2O\ (l)$ for the next six questions.

27.) How many electrons are transferred in this reaction?

A) 0 B) 1 C) 2 D) 3 $\boxed{\text{E) 4}}$

28.) Which compound is oxidized?

$\boxed{\text{A) } H_2}$ B) O_2 C) H_2O D) OH^- E) H^+

29.) Which compound is reduced?

A) H_2 $\boxed{\text{B) } O_2}$ C) H_2O D) OH^- E) H^+

30.) What is the standard potential (V) for the reaction?

A) 0 $\boxed{\text{B) 1.23}}$ C) 2.33 D) -1.43 E) -0.87

31.) What is the standard free energy change (kJ) for the reaction?

A) 0 B) 103 C) 225 $\boxed{\text{D) -475}}$ E) -618

32.) How much current (Amp) could be produced when 1 kg of H_2 is consumed in 1.0 hour?

A) 25 B) 110 C) 2300 D) 11000 $\boxed{\text{E) 27000}}$

Continue with the next question:

Consider the reaction below for the following five questions:
$Cl_2O_7\ (g) + H_2O_2\ (aq) \rightarrow ClO_2^-\ (aq) + O_2\ (g)$?

33.) Which compound is oxidized (mark all that apply)?

A) Cl_2O_7 $\boxed{\text{B) } H_2O_2}$ C) ClO_2^- D) O_2 E) can't tell

34.) Which compound is reduced (mark all that apply)?

$\boxed{\text{A) } Cl_2O_7}$ B) H_2O_2 C) ClO_2^- D) O_2 E) can't tell

35.) What is the coefficient of H_2O_2 in the balanced equation in acid solution?

A) 1/2 B) 1 C) 2 D) 3 $\boxed{\text{E) 4}}$

36.) How many electrons are transferred?

A) 1 B) 2 C) 4 $\boxed{\text{D) 8}}$ E) 10

37.) Which is the appropriate rate law for the reaction?

A) rate = k $[H_2O_2][ClO_2^-]$
B) rate = k $[H_2O_2][Cl_2O_7]$
C) rate = k $[H_2O_2]^4[Cl_2O_7]$
D) rate = k $[H_2O_2][ClO^-]^{-1}[Cl_2O_7]$
$\boxed{\text{E) can't tell}}$

Continue with the next question:

38.) Which will oxidize Br^-?

$\boxed{\text{A) } F_2}$ B) H^+ C) I_2 D) Ag^{+1} E) none of these

39.) Which will reduce Fe^{+3} but not Cu^{+2} ?

A) F_2 B) H^+ $\boxed{\text{C) } I^-}$ D) Ag^{+1} E) none of these

Consider the cell below for the following four questions:
$Zn\ (s)\ |\ Zn^{+2}\ (aq)\ ||\ Cu^{+2}\ (aq)\ |\ Cu\ (s)$

40.) Which voltage (V) would be sufficient to plate (reduce) zinc ions (mark all that apply)?

A) 0.5 B) 0.75 C) 1.0 D) 1.1 $\boxed{\text{E) 1.5}}$

41.) Under which conditions would you expect the voltage of the cell to be 0.5V (mark all that apply)?

A) $[Zn^{+2}] = [Cu^{+2}]$
$\boxed{\text{B) } [Zn^{+2}] > [Cu^{+2}]}$
C) $[Zn^{+2}] < [Cu^{+2}]$
D) $[Zn^{+2}] = [Cu^{+2}] = 1.00$
E) $[Zn^{+2}] = [Cu^{+2}] = 0.50$

42.) What is the equilibrium constant for the cell reaction at 298K?

A) 1.43e-14
B) 9.63e23
C) 1.62e37
D) 3.10e-5
E) 8.77e10

43.) What is the voltage (V) of the cell when the $[Zn^{+2}]$ = 0.3 M and $[Cu^{+2}]$ = 0.1 M?

A) 0.190 B) 0.34 C) 0.89 D) 1.09 E) 2.11