SOLUTIONS

Chem 1200b Midterm Test

Sunday, March 6, 2011 2 h 30 min

Multiple Choice Section

Section code 000 Exam code 000

Message from the Dean: All answer sheets are subject to a common data analysis which identifies anomalies of statistical significance in the selection of right and wrong answers by pairs of students. The course instructor is required to report all statistically significant results which suggest that cheating may have occurred. All such incidents will be subject to further investigation. All proven cases of cheating will be subject to severe academic penalties. If you are currently seated near someone with whom you studied, and you think you may choose many of the same answers as that person, please raise your hand now and ask a proctor to reseat you.

This test contains 25 multiple-choice questions, each worth one mark, and 6 short-answer questions, each worth two marks. Be sure you have a complete test paper. Scrap paper and a periodic table are attached, and they may be removed for use.

Place your student ID card on your desk.

The only permitted calculator is a Sharp EL-510R(B). No other electronic devices may be in your possession, even for timekeeping purposes. A molecular model kit is permitted, but the sharing of models or model pieces is strictly forbidden.

You are welcome to keep the question booklet and any scrap sheets.

Proctors and instructors will not interpret, translate, clarify, or explain questions, nor will they confirm, verify, or assist you with your answers or your thinking. Therefore, you are not permitted to ask any questions related to the content of the test.

There is no extra time allotted for filling in the Scantron. After the allotted time, everyone must put their pencils down. The Scantron, whether completed or not, will be collected. Under no circumstances will this booklet be used for marking purposes. The answers on your Scantron are considered to be your official answers, so please ensure that you complete your Scantron accurately, and prior to the end of the test. Answers that cannot be read by the Scantron computer will be marked as being incorrect.

If you do not leave before the last 15 minutes, you must stay in your seat until you are dismissed. NO TALKING IS ALLOWED AT ANY TIME.

Before starting the test, be sure that you have correctly entered:

- Your student number
- Section code 000
- Exam code 000

1. Consider the following equilibria at a given temperature:

1) $\frac{1}{2}N_2(g) + \frac{1}{2}O_2(g) \rightleftharpoons NO(g)$ $K = 6.45 \times 10^8$

2) $NO(g) + \frac{1}{2}Br_2(g) \rightleftharpoons NOBr(g)$ $K = 1.40$

Determine the value of the equilibrium constant for the following reaction at the same temperature:

3) $\frac{1}{2}N_2(g) + \frac{1}{2}O_2(g) + \frac{1}{2}Br_2(g) \rightleftharpoons NOBr(g)$

A) 9.03×10^8
B) 4.17×10^{17}
C) 6.45×10^8
D) 3.36×10^{-18}
E) 5.83×10^{17}

Add 1) + 2) $\Rightarrow$ 3)

$\therefore K_3 = K_1 \times K_2$

$= 6.45 \times 10^8 \times 1.40$

$= 9.03 \times 10^8$

2. Equal moles of $PCl_3(g)$ and $Cl_2(g)$ are placed in a cylinder fitted with a piston, and the system is allowed to reach equilibrium (Figure A). Which of the statements listed below are correct?

p1-14

$$PCl_3(g) + Cl_2(g) \rightleftharpoons PCl_5(g)$$

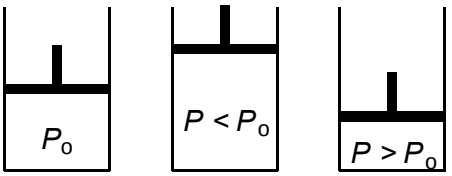

Figure A Figure B Figure C

1. At equilibrium, all three gases are present in the mixture.
2. When the mixture is compressed (Figure C), more PCl_5 will be formed. - fewer moles
3. When the mixture is expanded (Figure B), the total number of gas molecules will increase. - more moles

A) All statements are correct
B) 1 and 2 only
C) 2 and 3 only
D) 1 only
E) 1 and 3 only

3. Consider the following reaction:

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta G^\circ = -1.273 \times 10^4 \text{ J at } 25^\circ C$$

At some point during the reaction, the concentrations of the species are $[NO_2] = 0.015$ atm and $[N_2O_4] = 0.025$ atm. What must occur in order for the system to establish equilibrium?

Sec 1.1.6, p.1-16, 1-17

$\Delta G^\circ = -RT \ln K$

A) The reaction must proceed to the right.
B) Nothing, the system is already at equilibrium.
C) The volume of the system must increase.
D) The temperature of the system must decrease.
E) The pressure of the system must increase.

$-1.273 \times 10^4 = -8.314 \times 298 \ln K$

$\therefore K = 1.704 \times 10^2$

$Q = \frac{P_{N_2O_4}}{(P_{NO_2})^2} = \frac{0.025}{(0.015)^2} = 1.11 \times 10^2$

$Q < K$; rxn proceeds to right

$H_2O(l) \rightleftharpoons H_2O(g)$

4. At 25°C, the vapour pressure of water is 3.13×10^{-2} atm. If the ΔH° for the vapourization of water is 44 kJ mol^{-1}, calculate the vapour pressure of water, in atm, at 100°C.

At 25°: $K_p = 3.13 \times 10^{-2}$

$\Delta H^\circ = 44\ kJ\,mol^{-1} = 44000\ J\,mol^{-1}$

p. 1-18

$\ln \frac{K_2}{K_1} = \frac{\Delta H^\circ}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$

A) 1.11
B) 3.49×10^{155}
C) 0.125
D) 4.49×10^{-2}
E) 3.14×10^{-2}

$\ln \frac{K_2}{3.13 \times 10^{-2}} = \frac{44000}{8.314}\left(\frac{1}{298} - \frac{1}{373}\right)$

$K_2 = 1.11$

5. Which of the following will NOT change the solubility of AgCl?

1. Adding solid AgCl to a saturated solution of AgCl — no change
2. Adding NaCl to a saturated solution of AgCl — decrease solubility
3. Changing the temperature of a saturated solution of AgCl — inc. solubility

A) 1 and 3 only
B) 2 only only
C) 1 only
D) 2 and 3 only
E) All of 1, 2, and 3

6. A mixture consists of 0.01 M of each of Al^{3+}, Cd^{2+}, and Pb^{2+}. The K_{sp} values for the respective hydroxides, $M(OH)_n$, are 5.0×10^{-33}, 1.5×10^{-6}, and 4.2×10^{-15}. Which of these will form a precipitate of the metal hydroxide at pH 7?

p. 1-29

pH = 7 ; $[OH^-] = 1.0 \times 10^{-7}$

Ppte forms if $Q > K_{sp}$

A) Al^{3+} only
B) Pb^{2+} only
C) Cd^{2+} only
D) Al^{3+} and Pb^{2+} only
E) All of them will form a precipitate at pH 7

Al^{3+}: $Q = (0.01)(1 \times 10^{-7})^3 = 1.0 \times 10^{-23}$

Cd^{2+}, Pb^{2+}: $Q = (0.01)(1 \times 10^{-7})^2 = 1.0 \times 10^{-16}$

At first trace of ppt, $Q = K_{sp}$

7. HCl gas is bubbled through 100 mL of a solution of 0.005 M $AgNO_3$. Assuming that the volume of the solution remains constant, what mass of HCl has been dissolved in the solution when the first trace of a precipitate appears? The K_{sp} of AgCl is 1.7×10^{-10}.

p. 1-29

A) 1.24×10^{-7} g
B) 4.76×10^{-4} g
C) 4.76×10^{-6} g
D) 2.38×10^{-5} g
E) 9.52×10^{-5} g

$K_{sp} = [Ag^+][Cl^-]$

$1.7 \times 10^{-10} = (0.005)[Cl^-]$

$[Cl^-] = 3.40 \times 10^{-8}$

In 100 mL, mol $Cl^- = 3.4 \times 10^{-9}$

mass $HCl = 3.4 \times 10^{-9} \times 36.5$

$= 1.24 \times 10^{-7}$ g

8. Based on Brønsted-Lowry acid-base theory, which of the following are conjugate pairs?

Sec. 1.3.4
p. 1-46

X 1. H_3PO_4 and HPO_4^{2-}
✓ 2. NH_2^- and NH_3
X 3. HClO and ClO_2^-

A) 2 only
B) 2 and 3 only
C) 1 and 3 only
D) 1 only
E) All of 1, 2, and 3

9. Which of the following aqueous solutions are acidic?

1. Na_3PO_4 → PO_4^{3-}
2. Na_2HPO_4 → HPO_4^{2-}
3. KH_2PO_4 → $H_2PO_4^-$

Ex. 1.3.17 p.1-62

K_a values for H_3PO_4: $K_{a1} = 7.1 \times 10^{-3}$, $K_{a2} = 6.3 \times 10^{-8}$, $K_{a3} = 4.5 \times 10^{-13}$

A) 3 only
B) 2 and 3 only
C) 2 only
D) None of them
E) All of them

PO_4^{3-}: $K_b = 2.22 \times 10^{-2}$ Basic

HPO_4^{2-}: $K_a = 4.5 \times 10^{-13}$, $K_b = 1.59 \times 10^{-7}$ Basic

$H_2PO_4^-$: $K_a = 6.3 \times 10^{-8}$ Acidic, $K_b = 1.41 \times 10^{-12}$

10. What is the % ionization (% dissociation) of the NH_4^+ ion in a 0.100 M solution of $(NH_4)_2SO_4$? The K_b of NH_3 is 1.8×10^{-5}.

Q.12 p.1-64

A) 5.3×10^{-3}
B) 7.5×10^{-3}
C) 0.011
D) 0.95
E) 1.3

$[NH_4^+] = 0.200\ M$

$K_a(NH_4^+) = \frac{1.0 \times 10^{-14}}{1.8 \times 10^{-5}} = 5.56 \times 10^{-10}$

$5.56 \times 10^{-10} = \frac{x^2}{0.200 - x}$

$x = 1.05 \times 10^{-5}$

$\% = \frac{1.05 \times 10^{-5}}{0.200} \times 100 = 5.3 \times 10^{-3}\ \%$

11. How many of the following statements about H_2O are correct?

- It can act as a Lewis base.
- It can act as a Brønsted-Lowry acid.
- It can act as a Brønsted-Lowry base.
- Its conjugate acid is H_3O^+.

A) 4
B) 2
C) 1
D) 3
E) None of the statements are correct

12. Which of the following solutions are buffer solutions?

1. A solution formed by dissolving 0.1 mol of NaOH in 100 mL of 1.0 M acetic acid
2. A solution formed by mixing 50 mL of 0.05 M HCl with 5 mL of 1.0 M NH_3
3. A solution formed by dissolving 0.15 mol of NaOH in 100 mL of 1.0 M acetic acid

A) 2 only
B) 1 only
C) 3 only
D) 1 and 3 only
E) All of them

13. Rank the following processes in the order of the smallest to largest *change* in the pH of the bolded solution:

Sec 1.1.4 p. 1-76

1. Adding 100 mL of 0.05 M HCl to **100 mL of water** - acidic
2. Adding 100 mL of water to **100 mL of a solution containing 0.5 M of each of NH_3 and NH_4^+** - dilute buffer
3. Adding 100 mL of 0.05 M HCl to **100 mL of a solution containing 0.5 M of each of NH_3 and NH_4^+** - acid to buffer

A) 2 < 3 < 1
B) 2 < 1 < 3
C) 1 < 2 < 3
D) 3 < 2 < 1
E) 3 < 1 < 2

14. What is the pH of a solution formed by mixing 40.0 mL of 0.300 M CH_3COOH with 30.0 mL of 0.400 M KOH? The K_a of CH_3COOH is 1.8×10^{-5}.

Ex. 1.4.9 p. 1-79 Q. 10 p. 1-64

A) 8.99
B) 3.33
C) 8.41
D) 2.75
E) 7.00

mol CH_3COOH = .012
mol KOH = .012
} react to for 0.012 mol CH_3COO^-

$$[CH_3COO^-] = \frac{0.012\ mol}{0.070\ L} = 0.1714\ M$$

$$K_b(CH_3COO^-) = \frac{1.0 \times 10^{-14}}{1.8 \times 10^{-5}} = 5.56 \times 10^{-10}$$

$$5.56 \times 10^{-10} = \frac{x^2}{0.1714 - x}$$

$x = 9.76 \times 10^{-6} = [OH^-]$

$pOH = 5.01$

$pH = 8.99$

"HA"

15. 75 mL of a 0.0333 M weak monoprotic acid ($K_a = 1.90 \times 10^{-5}$) are titrated with 0.100 M NaOH. What is the pH of the solution after 12.5 mL of titrant have been added to the acid?

Ex. 1.4.5 p. 1-74

A) 4.72
B) 9.28
C) 4.28
D) 4.12
E) 9.88

mol HA = 2.5×10^{-3}
mol NaOH = 1.25×10^{-3}
∴ xs HA = 1.25×10^{-3} mol
A^- formed = 1.25×10^{-3} mol

$K_a = \frac{[H^+][A^-]}{[HA]} \Rightarrow 1.9 \times 10^{-5} = \frac{[H^+](.00125)}{.00125}$

$[H^+] = 1.9 \times 10^{-5}$ ∴ pH = 4.72

16. Which one of the following compounds contains hydrogen with an oxidation state that is different from hydrogen in the other compounds?

Sec 2.1.3 p. 2-4, 2-5

A) H_2SO_4 +1
B) $LiAlH_4$ −1
C) KH −1
D) CaH_2 −1
E) All of the compounds contain H with the same oxidation number

will cause

17. How many metals listed below can induce the precipitation of Cd metal when placed in a solution of 1 M Cd^{2+} at 25°C.

Ag Zn Ni Pb

- must be ox.

Similar to Ex. 2.2.7 p. 2-21

A) 1
B) 2
C) 3
D) 4
E) None of them

$Cd^{2+} + 2e^- \rightarrow Cd \quad \varepsilon^\circ = -0.40V$

$Ag \rightarrow Ag^+ + e^- \quad \varepsilon^\circ = -0.80$

* $Zn \rightarrow Zn^{2+} + 2e^- \quad \varepsilon^\circ = +0.76$

$Ni \rightarrow Ni^{2+} + 2e^- \quad \varepsilon^\circ = +0.25$

$Pb \rightarrow Pb^{2+} + 2e^- \quad \varepsilon^\circ = +0.13$

Only Zn combined with Cd^{2+} will produce a +ve ε°_{cell}.

18. When paired with the half-reaction

$$O_2(g) + 2H_2O + 4e^- \rightarrow 4OH^- \qquad E^\circ = +0.40\ V$$

which of the following half-reactions will act as the anode? – oxidation

Sec. 2.2.6 p. 2-20

1. $2H^+ + 2e^- \rightarrow H_2(g)$ $E^\circ = +0.00\ V$
2. $2H_2O + 2e^- \rightarrow H_2(g) + 2OH^-$ $E^\circ = -0.83\ V$
3. $Cu^{2+} + 2e^- \rightarrow Cu$ $E^\circ = +0.34\ V$

} all must change sign

A) All of them
B) 1 only
C) 2 only
D) 1 and 3 only
E) None of them

All result in a +ve E°_{cell}.

If the viewpoint that 1, 2 + 3 are also reduction reactions, the "None of Them" is acceptable

19. Silver metal can be electroplated via the electrolysis of an aqueous solution of $AgNO_3$. Which one of the following statements must be correct?

Ex. 2.2.3 p2-37

A) Silver metal is plated at the cathode.
B) A current of one ampere will plate out one mole of silver every second.
C) Silver metal is plated at the anode.
D) Ag^+ is oxidized at the anode.
E) One Coulomb of electrons is required for every mole of silver plated out.

Rxn: $Ag^+ + e^- \rightarrow Ag$

This is reduction, occurs at cathode.

$Cu^{2+} + 2e^- \rightarrow Cu$

20. Copper metal can be electroplated from a solution containing of Cu^{2+}. If 2.00 L of 0.500 M $CuCl_2$ is electrolyzed for 5.00 hours using a current of 1.50 A, what is the concentration of Cu^{2+} in the solution after this time?

Ex. 2.3.4 p. 2-37
Q. 4 p. 2-39

A) 0.430 M
B) 0.860 M
C) 0.140 M
D) 0.280 M
E) 0.560 M

mol Cu^{2+} initial = 1.00

$Q = 1.5 \times 5 \times 3600 = 2.7 \times 10^4$ C

$n_{e^-} = 0.279$

$\therefore n_{Cu^{2+}}$ used $= 0.140$

$n_{Cu^{2+}}$ xs $= 0.860$ mol

$[Cu^{2+}]_{xs} = \frac{0.860 \text{ mol}}{2.0 \text{ L}} = 0.430$ M

21. The mercury battery is used in watches, hearing aids, and other small devices.

$\overset{0}{Zn} + \overset{+2}{HgO} + H_2O \rightarrow \overset{+2}{Zn(OH)_2} + \overset{0}{Hg}$ $\quad n = 2$

Ex. 2.4.2 p. 2-43

If the battery contained 0.065 g of Zn, 0.43 g of HgO, and 0.50 g of H_2O, for how many hours can it deliver a current of 0.020 milliamps?

XD $n_{Zn} = .000994$ $\quad n_{HgO} = 1.98 \times 10^{-3}$

A) 5320
B) 2660
C) 13320
D) 26440
E) 107

$n_{e^-} = .001988$

$Q = .001988 \times 96485$

$= 191.8$

$191.8 = \frac{0.020}{1000} \times t$

$t = 959609$ sec $= 2664$ hr

22. When a lead-acid battery is recharged, the reactions are:

+2 0
$PbSO_4(s) + 2e^- \rightarrow Pb(s) + SO_4^{2-}(aq)$

+2 +4
$PbSO_4(s) + 2H_2O(l) \rightarrow PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^-$

Sec. 2.4.4. p. 2-45

Which one of the following statements best describes this process?

A) As a battery is recharged, a disproportion reaction occurs.
B) As the battery is recharged, the pH of the solution increases.
C) The voltage needed to recharge the battery decreases as the recharge is nearing completion.
D) As the battery is recharged, the density of the solution decreases.
E) The oxidation state of oxygen changes during the recharge process.

23. How many of the following ions will precipitate when added to a solution containing Ag^+?

✓ ✓ ✓ ✗
Cl^- Br^- I^- NO_3^-

A) 3
B) 2
C) 1
D) 4
E) None of them

all halides form a ppt with Ag^+
all NO_3^- cmpds are soluble

24. In the Equilibrium experiment, it was necessary to add deionized water to the standard samples. This was done to…

A) Ensure a constant total volume for all the samples
B) Ensure that all the solutions had the same concentration
C) Ensure that no shift in the position of the equilibrium could occur
D) Ensure that the solutions were sufficiently diluted so that they were safe
E) Ensure that solutions did not react until you were ready to take the measurements

25. In the Spectrophotometry experiment, why was it necessary to prepare so many buffer solutions?

A) To collect enough data to accurately determine pK_a from a graph
B) To see all of the indicator's possible colours
C) To obtain a large selection to visibly choose the best green colour
D) To provide extra practice in calculating the pH of buffers
E) To accurately determine the concentration of the indicator

R values

0.0821 L atm mol^{-1} K^{-1}

0.0831 L bar mol^{-1} K^{-1}

8.314 L kPa mol^{-1} K^{-1}

8.314 J mol^{-1} K^{-1}

8.314 kg m^2 s^{-2} mol^{-1} K^{-1}

1 atm = 101.3 kPa

1 L kPa = 1 J

1 L atm = 101.3 J

K = °C + 273.15

$N_A = 6.02 \times 10^{23}$

1 ampere = 1 C s^{-1}

$\Delta G° = -RT \ln K$

$K_w = 1.0 \times 10^{-14}$

Faraday = 96485 C mol^{-1}

$$\ln\frac{K_2}{K_1} = \frac{\Delta H°}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$E_{cell} = E^{o}_{cell} - \left(\frac{RT}{nF}\right)\ln Q$$

Scrap paper