Thermo, electro, and aqueous equilibrium. No calculators on this part of the exam.

Pb2+(aq) + 2 e− → Pb(s) −0.13 volts

Zn2+ (aq) + 2 e− → Zn(s) −0.76 volts

Cu2+ (aq) + 2e− → Cu(s) +0.34 volts

Above are the standard reduction potentials for three metal ions. (questions 1 to 3)

1. Based on the half reactions above, one can conclude that

A) copper is a stronger reducing agent than lead

B) Pb2+ ion is a stronger oxidizing agent than Zn2+ ion

C) Zn2+ ion is a stronger oxidizing agent than H+ ion

D) Lead is a stronger reducing agent than zinc.

E) copper will react spontaneously with solutions containing Zn2+ ion

2. What is the standard potential of a chemical cell consisting of a Zn/Zn2+ half cell connected to a Pb?Pb2+ half cell? A) −0.63 volts B) + 0.63 volts

C) −.89 volts D) 0.89 volts E) 1.36 volts

3. The standard potential for a chemical cell that uses the reaction

Zn(s) + 2 Fe3+(aq) → Zn2+(aq) + 2 Fe2+ (aq) is 1.53 volts. Based on this information, and the potentials listed above, what is the standard reduction potential for the half reaction Fe3+ (aq) + e- → Fe2+ (aq)

4. In a half reaction in which the dichromate ion, Cr2O72− gains 6 moles of electrons per mole of dichromate in acidic media, a probable product of the reaction is

A) CrO42− (aq) B) Cr3+ (aq) C) Cr2+(aq) D) Cr(OH)3  E) Cr(s)

5. Aluminum metal can be prepared through the electrolysis of molten Al2O3 . How many grams of aluminum can be produced by the transfer of 1.00 moles of electrons? A) 9.00 B) 18.0 C) 27.0 D) 81.0 g E) 96.5 g

6. The standard potential for Zn(s) + 2 Ag+(aq) → Zn2+(aq) + 2 Ag is 1.56 volts.

Which change to a standard cell would cause the **largest** increase in voltage?

A) double the size of the zinc electrode.

B) decrease the Zn2+concentration to 0.50 M

C) decrease the Ag+ concentration to 0.50 M

D) increase the Ag+ concentration to 2.00 molar

E) increase the Zn2+ concentration to 3.00 molar

7. When the reaction in acidic media: IO3− + Fe2+ → I- + Fe3+ is balanced using the smallest possible whole number coefficients, the coefficient in front of the Fe2+ is

A) 2 B) 3 C) 4 D) 5 E) 6

8. 3 Cu(s) + 8 H+(aq) + 2 NO3−(aq) → 3 Cu2+ + 2 NO(g) + 4 H2O(l)

True statements about the reaction represented above include which of the following? I. Cu(s) acts as an oxidizing agent

II. The oxidation state of the nitrogen changes from +5 to +2.

III. Hydrogen ions are oxidized to form H2O

A) I only B) II only C) III only D) I and II E) II and III

9. The reaction 2 Al(s) + 3 Zn2+(aq) → 2 Al3+(aq) + 3 Zn(s) has a standard potential, E° of +0.90 volts. The expression that would produce the correct value of ΔG° for this reaction, in kilojoules is A) −2(96.5)(0.90) B) 2 (96.5)(0.90)

C) −6(96.5)(0.90) D) 6(96.5)(0.90) E) 6 (96500)0.90)

10. X(s) → X(ℓ)

Which of the following is true for any substance undergoing the process represented above **at its normal melting point**?

A) ΔS < 0 B) ΔH = 0 C) Δ H = T ΔG D) TΔS= 0 E) ΔH = TΔS

11. 3 C2H2(g) → C6H6(g)

What is the standard enthalpy change, ΔHo , for the reaction represented above?

( ΔHo*f*  of C2H2(g) is 230 kJ mol-1; ΔHo*f*  of C6H6(g) is 83 kJ mol-1 )

A) −607 kJ B) −147 kJ C) −19 kJ D) + 19 kJ E) + 773 kJ

A certain endothermic reaction is found to be spontaneous at 298 K.

12. Which must be true for this reaction at 298 K?

I. ΔH is + II. ΔS is + III. ΔG is +

A) I only B) II only C) I and II only D) I and III only

E) I, II and III.

13. The formation of ammonia, NH3 from its elements has a Kp of 6.9 x 105 at 298 K, and a Kp of 51 at 400. K. From this information we can conclude that the reaction at 298 K

I. has a positive entropy change. (ΔS>0) II. Has a Kp greater than 1

III. is endothermic.

A) I only B) II only C) I and II only D) II and III only

E) I, II and III.

14. The standard enthalpy of formation, ΔHo*f*, of HI(g) is +26 kJ mol−1 Which of the following is the approximate mass of HI(g) that must decompose into H2(g) and I2(s) to release 500 kJ of energy?

A) 250 g B) 650 g C) 1300 g D) 2500 g E) 13,000 g

15. For which of the following processes does entropy decrease (ΔS<0) ?

A) H2O(s) → H2O (ℓ) B) Br2(ℓ) → Br2(g)

C) Crystallization of I2(s) from an ethanol solution

D) Thermal expansion of a balloon filled with CO2(g)

E) Mixing of equal volumes of H2O(ℓ) and CH3OH(ℓ)

16. A certain reaction is spontaneous at temperatures below 400. K but is not spontaneous at temperatures above 400. K. If ΔH° for the reaction is

−20. kJ mol−1 and it is assumed that ΔH° and ΔS° do not change appreciably with temperature, then the value of ΔS° for the reaction is

A) −50. J mol−1K−1 B) −20. J mol−1K−1 C) −0.050 J mol−1K−1

D) 20. J mol−1K−1 E) 8000 J mol−1K−1

17. At 25oC, aqueous solutions with a pH of 8 have a hydroxide ion concentration, [OH−] of A) 1 x 10−14 M B) 1 x 10−8 M

C) 1 x 10−6 M D) 1 M E) 8 M

18. How can 100. mL of sodium hydroxide solution with a pH of 13.00 be converted to a sodium hydroxide solution with a pH of 12.00?

A) By diluting the solution with distilled water to a total volume of 108 mL

B) By diluting the solution with distilled water to a total volume of 200. mL

C)By diluting the solution with distilled water to a total volume of 1.00 L

D) By adding 100 mL of 0.10 M HCl E) By adding 100 mL of 0.10 M NaOH

19. Mixtures that would be considered buffers include which of the following?

I. 0.10 M HCl + 0.10 M NaCl II. 0.10 M HF +0.10 M NaF

III. 0.10 M HBr + 0.10 M NaBr

A) I only B) II only C) III only D) I and II E) II and III

20. Ascorbic acid, H2C6H6O6(s) is a diprotic acid with K1 = 7.9 x 10−5 and

K2 = 1.6 x 10−12. In a 0.005 M aqueous solution of ascorbic acid, which of the following species is present in the lowest concentration?

A) H2O B) H3O+ C) H2C6H6O6(aq) D) HC6H6O6− (aq) E) C6H6O62−(aq)

21. In a saturated solution of Zn(OH)2 at 25°C, the value of [OH−] is 2.0 x 10−6 M. What is the value of the solubility-product constant, Ksp, for Zn(OH)2 at 25°C ?

A) 4.0 x 10−18 B) 8.0 x 10−18 C) 1.6 x 10−17 D) 4.0 x 10−12 E) 2.0 x 10−6

22. The value of the acid-dissociation constant, Ka, for a weak monoprotic acid HA is 2.5 x 10−6 . The pH of 0.40 M HA is closest to

A) 2.0 B) 3.0 C) 4.0 D) 6.0 E) 8.0

23. The Ka of HC2H3O2 is 1.8 x 10−5 at 298 K. Which of the following solutions would have an [H+] of 9.0 x 10−6 ?

A) 2.0 mol of HC2H3O2 and 1.00 mol of NaC2H3O2 in a volume of 2.0 liters

B) 50.0 mL of 2.0 M HC2H3O2  mixed with 100 mL of 1.0 M NaC2H3O2

C) 50.0 ml o f 1.0 M HC2H3O2 mixed with 50.0 mL of 2.0 M NaC2H3O2

D) 50.0 mL of 1.0 M HC2H3O2 mixed with 50.0 mL of 1.0 M NaOH

E) 50.0 mL of 1.0 M HC2H3O2 mixed with 50.0 mL of 0.50 M HCl

24. Which acid-base titration would have an equivalence point at a pH of 7.0?

A) HCl with NH3 B) HClO with KOH C) HNO3 with NaOH

D) HC2H3O2 with Ba(OH)2 E) HF with KOH

H2PO4–(aq) + HC2O4– ⇄ HPO42–(aq) + H2C2O4 (aq)

25. If K < 1 for the reaction represented above, which of the following is the strongest base?

A) H2O B) H2PO4–(aq) C) HPO42–(aq) D) H2C2O4(aq) E) HC2O4–(aq)

26. Which of the following substances will dissolve in water to form the most strongly basic solution? (assume that they are all highly soluble)

A) SO2 B) BaO C) KNO3 D) MnCl2 E) CaSO4

Free Response Items. You may use calculators for this part of the test.

I. In an electrolytic cell, a current of 0.250 ampere is passed through a solution of a chloride of iron, producing Fe*(s)* and Cl2*(g)*.

(a) Write the equation for the half-reaction that occurs at the anode.

(b) When the cell operates for 2.00 hours, 0.521 gram of iron is deposited at one electrode. Determine the formula of the chloride of iron in the original solution.

(c) Write the balanced equation for the overall reaction that occurs in the cell.

(d) How many liters of Cl2*(g)*, measured at 25C and 750 mm Hg, are produced when the cell operates as described in part (b) ?

(e) Calculate the current that would produce chlorine gas from the solution at a rate of 3.00 grams per hour.

2. NH3(aq) + H2O (ℓ) ⇄ NH4+(aq) + OH− (aq)

In aqueous solution, ammonia reacts as represented above. In 0.0180 M NH3(aq) at 25° C, the hydroxide ion concentration, [OH−], is 5.60 x 10−4 M. In answering the following, assume that the temperature is constant, and the volumes are additive.

a) Write the equilibrium-constant expression for the reaction indicated above

b) Determine the pH of 0.0180 M NH3(aq)

c) Determine the value of the ionization constant, Kb, for NH3(aq)

d) Determine the percent ionization of NH3 in0.0180 M NH3(aq)

e) In an experiment, a 20.0 mL sample of 0.0180 M NH3(aq) was placed in a flask and titrated to the equivalence point and beyond using 0.0120 M HCl(aq)

1) Determine the volume of 0.0120 M HCl that was added to reach the equivalence point.

ii) Determine the pH of the solution in the flask after a total of 15.0 mL of 0.0120 M HCl was added.

iii) Determine the pH of the solution in the flask after a total of 40.0 mL of 0.0120 M HCl was added.

3.

CO*(g)* + 2 H2*(g)* → CH3OH*(l)* *H* = -128.1 kJ

*Hf* *Gf* S

(kJ mol-1) (kJ mol-1) (J mol-1 K-1)

CO*(g)* -110.5 -137.3 +197.9

CH3OH*(l)* -238.6 -166.2 +126.8

The data in the table above were determined at 25C.

(a) Calculate *G* for the reaction above at 25C.

(b) Calculate Keq for the reaction above at 25C.

(c) Calculate *S* for the reaction above at 25C.

(d) In the table above, there are no data for H2. What are the values of *Hf*, *Gf*, and of the absolute entropy, S, for H2 at 25C?

4. Write the formulas to show the reactants and products in each of the laboratory situations described below. Assume that solutions are aqueous. Represent substances in solution as ions if the substances are extensively ionized. Omit formulas for ions or molecules that are unchanged by the reaction. Balance your equations using the smallest possible whole number coefficients.

A. Carbon dioxide gas is passed over hot, solid sodium oxide.

When the product of the reaction is dissolved in water, is it acidic, basic, or neutral?

B. 0.2 M barium nitrate solution is added to a 0.2 M potassium chromate solution.

What color is the product?

C. Strips of zinc metal are placed in a solution of copper(II) sulfate.

Over time, a color change is observed in the solution. Describe this change.

5. Ti3+ + HOBr → TiO2+ + Br- (in acid solution)

(a) Write the correctly balanced half-reactions and net ionic equation for the skeletal equation shown above.

(b) Identify the oxidizing agent and the reducing agent in this reaction.

(c) A galvanic cell is constructed that utilizes the reaction above. The concentration of each species is 0.10 molar. Compare the cell voltage that will be observed with the standard cell potential. Explain your reasoning.

(d) Give one example of a property of this reaction, other than the cell voltage, that can be calculated from the standard cell potential, *E*. State the relationship between *E* and the property you have specified.

6. NH4+ + OH– ↔NH3 + H2O

H2O + C2H5O– ↔ C2H5OH + OH–

The equations for two acid–base reactions are given above. Each of these reactions proceeds essentially to completion to the right when carried out in aqueous solution.

(a) Give the Brønsted–Lowry definition of an acid and a base.

(b) List each acid and its conjugate base for each of the reactions above.

(c) Which is the stronger base, ammonia or the ethoxide ion. C2H5O–? Explain your answer.

d) Based on the second of these two reactions, why are solutions of ethanol, C2H5OH essentially neutral ( pH ≈7) ?