Due Thursday December 11. Show all work to receive credit.

1. Given the following table of thermodynamic data,

substance	$\Delta H_f°$	$S°$
PCl_3 (g)	-288.07 kJ/mol	311.7 J/mol-K
PCl_3 (l)	-319.6	217

determine the normal boiling point (in °C) of PCl_3.

2. $\Delta S°$ will be positive for the reaction _____ .
a) $2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$
b) $2NO_2(g) \rightarrow N_2O_4(g)$
c) $H^+(aq) + F^-(aq) \rightarrow HF(aq)$
d) $BaF_2(s) \rightarrow Ba^{2+}(aq) + 2F^-(aq)$
e) $2Hg(l) + O_2(g) \rightarrow 2HgO(s)$
Explain your answer.

3. The process of _____ causes a decrease in the entropy of the system.
a) boiling water to form steam
b) dissolution of solid KCl in water
c) mixing of two gases into one container
d) freezing water to form ice
e) melting ice to form water
Explain your answer.

4. Which one of the following reactions would have a <u>positive</u> value for $\Delta S°$?
a) $Ba(OH)_2(s) + CO_2(g) \rightarrow BaCO_3(s) + H_2O(l)$
b) $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$
c) $2SO_3(g) \rightarrow 2SO_2(g) + O_2(g)$
d) $AgNO_3(aq) + HCl(aq) \rightarrow AgCl(s) + HNO_3(aq)$
e) freezing water to form ice
Explain your answer.

5. Look up the K_{sp} of $Mg(OH)_2$ and then determine the pH of a 1.0×10^{-3} M $Mg(OH)_2$ solution. Show work to justify your answer.

6. Which molecule below should have the highest gas-phase absolute entropy at 25°C?

a) H_2 b) C_2H_6 c) C_2H_2 d) CH_4 e) C_2H_2

Explain your answer.

7. The solubility product for CrF3 is $Ksp = 6.6 \times 10^{-11}$. What is the molar solubility of CrF_3? Show work to justify your answer.

8. Consider the following table of thermodynamic data. All values are tabulated for 25°C.

Substance	ΔG°_f (kJ/mol)	S° (J/mol·K)
C_2H_2 (g)	209	201
C_2H_4 (g)	68	219
C_2H_6 (g)	-33	230
H_2 (g)	0	131
H_2O (g)	-229	189
C_2H_5OH (l)	-175	161

What is the value of ΔH° (in kJ) for the reaction described below? Assume the reaction is performed at 25°C.

$$C_2H_2 (g) + 2H_2 (g) \rightarrow C_2H_6 (g)$$
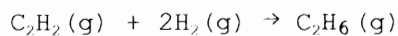
9. **A precipitate forms when 250 mL of 0.33 M Na_2CrO_4 are added to 250 mL of 0.12 M $AgNO_3$. $Ksp(Ag_2CrO_4) = 1.1 \times 10^{-12}$. What is the concentration of the Ag^+ ion remaining in solution? Show work to justify your answer.**

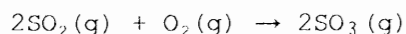10. Consider the reaction: $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$

Given the following table of thermodynamic data,

substance	ΔH_f°	S°
$Ag^+(aq)$	105.90 kJ/mol	73.93 J/mol-K
$Cl^-(aq)$	-167.2	56.5
$AgCl(s)$	-127.0	96.11

determine the temperature (in °C) above which the reaction is nonspontaneous.

11. Calculate the equilibrium constant of the reaction below at 25°C.

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

.Substance	ΔH°_f (kJ/mol)	S° (J/mol·K)
$SO_2(g)$	-297	249
$O_2(g)$	0	205
$SO_3(g)$	-395	256

12. The equilibrium constant for a reaction is 0.48 at 25°C. What is the value of ΔG° (kJ) at this temperature? (R = 8.314 J/K·mol)

13. The molar solubility of tin(II) iodide is 1.28 x 10^{-2} mol/L. What is Ksp for this compound? Show work to justify your answer.

14. The Ksp for $PbCl_2$ is 2.4 x 10^{-4}, will a precipitate of $PbCl_2$ form when 0.10 L of 3.0 x 10^{-2} M $Pb(NO_3)_2$ is added to 400 mL of 9.0 x 10^{-2} M NaCl? Show work to justify your answer.

15. Balance the following redox reaction in acidic solution.
    $HClO_2$ + MnO_2 → Cl_2 + MnO_4
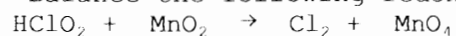
16. Balance the following redox reaction in basic solution.
    BrO + $Fe(OH)_2$ → Br + $Fe(OH)_3$ (basic solution)
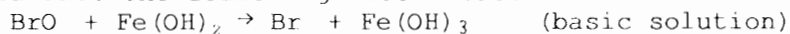
17. The half-reaction occurring at the anode in the voltaic reaction $3MnO_4$ (aq) + $24H^+$(aq) + 5Fe(s) → $3Mn^{2+}$(aq) + $5Fe^{3+}$(aq) + $12H_2O$(l) is

a) MnO_4 (aq) + $8H^+$(aq) + 5e → Mn^{2+}(aq) + $4H_2O$(l)
b) $2MnO_4$ (aq) + $12H^+$(aq) + 6e → $2Mn^{2+}$(aq) + $3H_2O$(l)
c) Fe(s) → Fe^{3+}(aq) + 3e
d) Fe(s) → Fe^{2+}(aq) + 2e
e) Fe^{2+}(aq) → Fe^{3+}(aq) + e

18. What is the purpose of the salt bridge in an electrochemical cell?

19. For the reaction, $Fe^{3+} + e \rightarrow Fe^{2+}$, $E^\circ = 0.77V$. What is the value of the standard reduction potential for the reaction, $49Fe^{3+} + 49e \rightarrow 49Fe^{2+}$?

20. The two electrodes $Cr(s)/Cr^{3+}(aq)$ and $Fe(s)/Fe^{2+}(aq)$ are combined to afford a spontaneous electrochemical reaction. The standard reduction potentials in V for $Cr^{3+}(aq)$ and $Fe^{2+}(aq)$ are -0.74 and -0.44, respectively. Calculate E° for the cell (in V).

21. Which one of the following types of elements is most likely to be good oxidizing agents?
a) alkali metals
b) lanthanides
c) alkaline earth elements
d) transition elements
e) halogens
Explain your answer.

22. Bromine can oxidize each of the metals below except

Substance	E° (v)
Br2	1.09
Ag	0.80
Pt	1.20
Cu	0.34
Pd	0.83
Li	-3.05

a) Ag   b) Pt   c) Cu   d) Pd   e) Li
Explain your answer.

23. Given the following information

Half-reaction E°_{red}

Sn^{4+} (aq) + 2e $\rightarrow$ Sn^{2+} (aq)   +0.154 V
Fe^{2+} (aq) + 2e $\rightarrow$ Fe (s)   -0.440
Fe^{3+} (aq) + e $\rightarrow$ Fe^{2+} (s)   +0.771
Cr^{3+} (aq) + 3e $\rightarrow$ Cr (s)   -0.74

determine the standard potential (in V) of a cell based on the reaction:

Sn^{2+} (aq) + 2 Fe^{3+} (aq) $\rightarrow$ 2 Fe^{2+} (aq) + Sn^{4+} (aq)

24. What is meant by cathodic protection?

25. Given the following information

Half-reaction εred°

Sn^{4+} (aq) + 2e $\rightarrow$ Sn^{2+} (aq)   +0.154 V
Fe^{2+} (aq) + 2e $\rightarrow$ Fe (s)   -0.440
Fe^{3+} (aq) + e $\rightarrow$ Fe^{2+} (s)   +0.771
Cr^{3+} (aq) + 3e $\rightarrow$ Cr (s)   -0.74

which of the following reactions will occur spontaneously as written?

a) Sn^{4+} (aq) + Fe^{3+} (aq) $\rightarrow$ Sn^{2+} (aq) + Fe^{2+} (aq)
b) 3Fe (s) + 2Cr^{3+} (aq) $\rightarrow$ 2Cr (s) + 3Fe^{2+} (aq)
c) Sn^{4+} (aq) + Fe^{2+} (aq) $\rightarrow$ Sn^{2+} (aq) + Fe (s)
d) 3Sn^{4+} (aq) + 2Cr (s) $\rightarrow$ 2Cr^{3+} (aq) + 3Sn^{2+} (aq)
e) Fe (s) + 2Fe^{3+} (aq) $\rightarrow$ 3Fe^{2+} (aq)

Justify your answer.

26. Explain the difference between the reaction quotient, Q, and the equilibrium
constant, K.

27. Calculate the equilibrium constant for the following reaction given that E°
for $Cr_2O_7^{2-}/Cr^{3+}$ is 1.36 V and for $S_2O_3^{2-}/S_4O_6^{2}$ is 0.17 V.
$Cr_2O_7^{2}$ + 6$S_2O^{2-}_3$ + 14H^+ $\rightarrow$ 2Cr^{3+} + 3$S_4O_6^{2}$ + 7H_2O

28. The standard reduction potentials in V for Zn^{2+} and Cu^{2+} are -0.76 and +0.34, respectively. What is the potential of the cell (in V) represented below?

$Zn \mid Zn^{2+}(1.00\ M) \parallel Cu^{2+}(0.100\ M) \mid Cu$

29. Given the following information

Half-reaction $\varepsilon_{red}°$

$Cu^{2+}\ (aq) + 2e \rightarrow Cu\ (s)$ +0.337 V
$Ni^{2+}\ (aq) + 2e \rightarrow Ni\ (s)$ -0.28 V

determine the potential (in V) of an electrochemical cell in which the concentration of nickel(II) ion is 0.155 M and the concentration of copper(II) ion is 0.352 M. (T = 298 K)

30. Given the following information

Half-reaction $E_{red}°$

$2\ H^+\ (aq) + 2e \rightarrow H_2\ (g)$ +0.00 V
$Sn^{2+}\ (aq) + 2e \rightarrow Sn\ (s)$ -0.136 V

Consider an electrochemical cell based on the reaction:

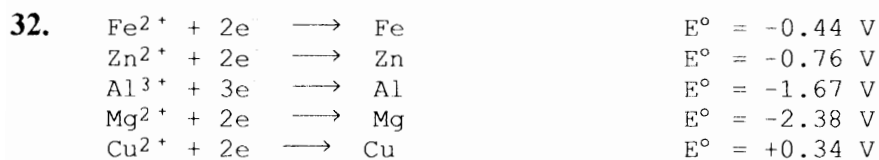$2\ H^+(aq) + Sn(s) \rightarrow Sn^{2+}(aq) + H_2(g)$
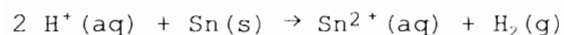
Determine which of the following actions would increase the measured cell potential.
a) increasing the pressure of hydrogen gas in the hydrogen cell
b) increasing the tin(II) ion concentration
c) lowering the pH in the cathode compartment
d) increasing the pH in the cathode compartment
e) any of these things will increase the measure cell potential
Explain your answer.

31. What mass of chromium could be deposited by electrolysis of an aqueous solution of $Cr_2(SO_4)_3$ for 60.0 minutes using a constant current of 10.0 amperes? (One Faraday = 96,500 coulombs.)

32.

$$Fe^{2+} + 2e \longrightarrow Fe \qquad\qquad E° = -0.44 \text{ V}$$
$$Zn^{2+} + 2e \longrightarrow Zn \qquad\qquad E° = -0.76 \text{ V}$$
$$Al^{3+} + 3e \longrightarrow Al \qquad\qquad E° = -1.67 \text{ V}$$
$$Mg^{2+} + 2e \longrightarrow Mg \qquad\qquad E° = -2.38 \text{ V}$$
$$Cu^{2+} + 2e \longrightarrow Cu \qquad\qquad E° = +0.34 \text{ V}$$

From a consideration of these data, determine which of the following species will oxidize Fe to Fe^{2+}.

a. Zn^{2+}
b. Al^{3+}
c. Mg^{2+}
d. Cu^{2+}
e. none of these

33. The standard reduction potentials in V for Ag^+ to Ag and Fe^{3+} to Fe^{2+} are +0.80 and +0.77, respectively. Calculate $\Delta G°$ (in kJ) for the following reaction. (F = 96,500 J/V·mol)
$Ag^+(aq) + Fe^{2+}(aq) \rightleftharpoons Ag(s) + Fe^{3+}(aq)$