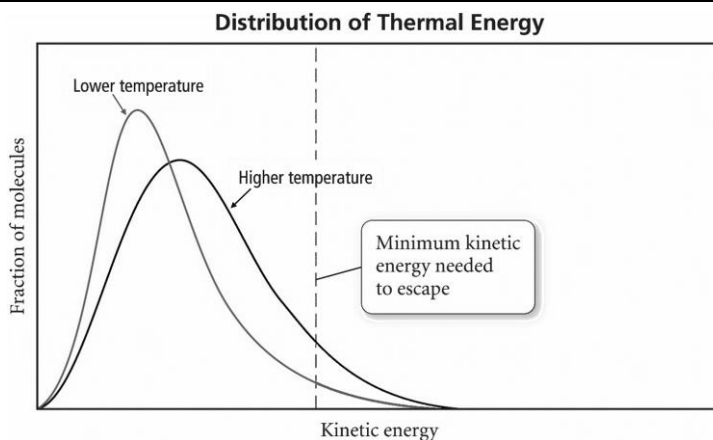

Questions 1 – 15 cover Exam 1 material

1. Which molecule **cannot** hydrogen bond to another molecule of itself?
- | | |
|-----------------------------|-----------------------------|
| A. CH_3OH | C. CH_3CH_3 |
| B. CH_3NH_2 | D. HF |
-
2. Concerning surface tension, which of the following is **incorrect**?
- A. A liquid comprised of hydrogen-bonding molecules has lower surface tension than a liquid without hydrogen bonds.
- B. A liquid comprised of polar molecules has higher surface tension than a liquid comprised of nonpolar molecules.
- C. Surface tension depends on temperature.
- D. Surface tension depends on molecular size.
-
3. A liquid is placed in a sealed flask. Which of the following explains the process of establishing the equilibrium vapor pressure?
- A. The rate of evaporation starts at zero and increases until it equals the rate of condensation.
- B. The rate of evaporation and the rate of condensation both increase together until they no longer change.
- C. The rate of evaporation begins high and decreases; the rate of condensation begins low and increases until it is the same as the rate of evaporation.
- D. The rate of condensation starts at zero and increases until it becomes constant and matches the constant rate of evaporation.
-

4. Using the figure at right, which statement is **correct** concerning vapor pressure?



- A. Vapor pressure is higher at lower temperatures because more molecules have enough energy to evaporate.
- B. Vapor pressure is lower at higher temperatures because more molecules have enough energy to evaporate.
- C. Vapor pressure is higher at higher temperatures because more molecules have enough energy to evaporate.
- D. Vapor pressure is temperature independent.

5. How much heat is **required** to vaporize 0.750 mol of $\text{Br}_2(l)$ at its boiling point of 58.8°C ?

$$\Delta H_{\text{vap}} = 29.96 \text{ kJ/mol}$$

- A. 22.5 kJ C. 18.6 kJ
- B. 30.0 kJ D. 39.8 kJ

6. Methanol (CH_3OH) has the following properties:

molar mass = 32.0 g/mol

melting point = $-98.0\text{ }^\circ\text{C}$

boiling point = $65.0\text{ }^\circ\text{C}$

$\Delta H_{\text{fus}} = 2.20\text{ kJ/mol}$

$\Delta H_{\text{vap}} = 35.2\text{ kJ/mol}$

C_s of $\text{CH}_3\text{OH}(s) = 3.28\text{ J/g}\cdot^\circ\text{C}$

C_s of $\text{CH}_3\text{OH}(l) = 2.54\text{ J/g}\cdot^\circ\text{C}$

C_s of $\text{CH}_3\text{OH}(g) = 1.50\text{ J/g}\cdot^\circ\text{C}$

How much energy is **required** to warm 320. g (10.0 mol) of $\text{CH}_3\text{OH}(l)$, initially at $-33.0\text{ }^\circ\text{C}$, to $\text{CH}_3\text{OH}(g)$ at $77.0\text{ }^\circ\text{C}$?

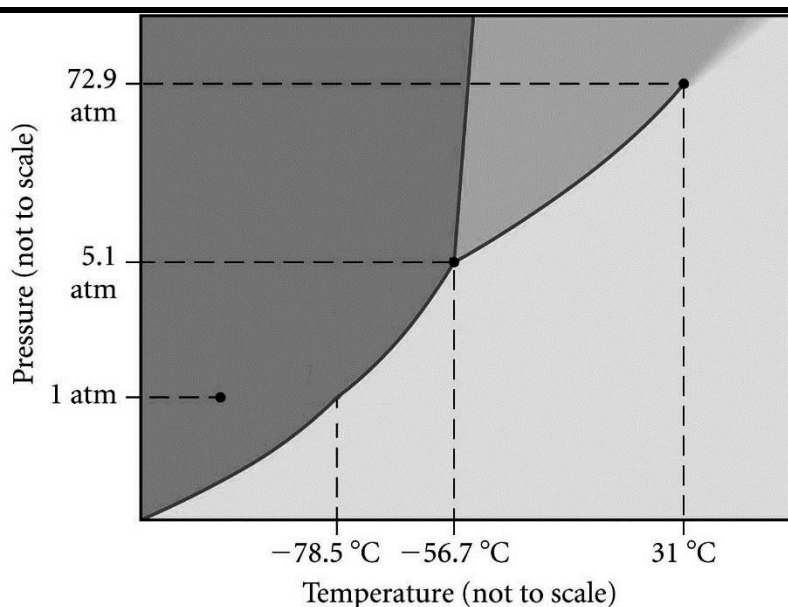
A. 675 kJ

C. 238 kJ

B. 437 kJ

D. 129 kJ

7. Using the phase diagram shown for CO_2 , what is the state of CO_2 at $-56.7\text{ }^\circ\text{C}$ and 1.0 atm?



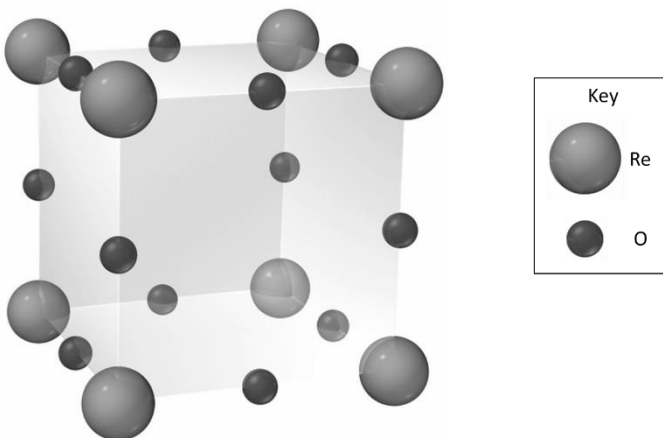
A. solid

C. gas

B. liquid

D. supercritical fluid

8. Determine the ionic formula of a rhenium oxide using the unit cell depicted at right. The oxygen ions (small dark gray spheres) are on each edge, and the rhenium ions (large light gray spheres) are at each corner.



- A. ReO
B. ReO_3
C. Re_2O_6
D. Re_4O_6
9. The liquids CCl_4 and C_6H_{14}
- A. are miscible because they are both polar molecules.
B. are not miscible because there are no hydrogen bonds.
C. are miscible because intermolecular interactions in the liquids are of similar type and magnitude.
D. are not miscible because they are not identical, so the intermolecular interactions in the liquids are not of similar type and magnitude.
10. In a **saturated** solution of $\text{K}_2\text{Cr}_2\text{O}_7$ in water,
- A. dissolved $\text{K}_2\text{Cr}_2\text{O}_7$ is precipitating more rapidly than solid $\text{K}_2\text{Cr}_2\text{O}_7$ is dissolving.
B. solid $\text{K}_2\text{Cr}_2\text{O}_7$ is dissolving more rapidly than dissolved $\text{K}_2\text{Cr}_2\text{O}_7$ is precipitating.
C. dynamic equilibrium has been reached and the rates of dissolution and precipitation are equal.
D. the solution is unstable and the addition of a slight excess of solid $\text{K}_2\text{Cr}_2\text{O}_7$ triggers rapid crystallization.
11. A solution is prepared by mixing 167 g NaOCl (74.4 g/mol) with 750. g of water (density 1.00 g/mL) at 25.0 °C. What is the **molality** of NaOCl ?
- A. 3.18 *m*
B. 2.99 *m*
C. 0.178 *m*
D. 4.21 *m*

12. The maximum amount of 1,2-dichlorobenzene ($C_6H_4Cl_2$) allowed in water by the EPA is 600. ppb by mass. What mass of solution at this concentration contains 2.500 mg of 1,2-dichlorobenzene?

A. 4167 g

C. 1492 g

B. 3661 g

D. 568.0 g

13. What is the **molality** of a 0.260 M aqueous solution of $KClO_3$ (123 g/mol) with a density of 1.135 g/mL at 10 °C?

A. 0.236 *m*

C. 0.217 *m*

B. 0.302 *m*

D. 0.289 *m*

14. A solution contains 21.2 g of ethylene glycol ($C_2H_6O_2$, 62.07 g/mol) in 0.100 kg of water. Determine the freezing point for the solution. $K_f(H_2O) = 1.86\text{ }^\circ\text{C}/m$. Assume a density of water of 1.00 g/mL.

A. $-15.1\text{ }^\circ\text{C}$

C. $-4.99\text{ }^\circ\text{C}$

B. $-6.35\text{ }^\circ\text{C}$

D. $3.39\text{ }^\circ\text{C}$

15. Select the aqueous solution with the **lowest** vapor pressure.

A. 0.10 M sucrose

C. 0.10 M magnesium sulfate

B. 0.10 M sodium chloride

D. 0.10 M potassium phosphate

Questions 16 – 30 cover Exam 2 material

16. For the reaction $\text{CHCl}_3(g) + \text{Cl}_2(g) \rightarrow \text{CCl}_4(g) + \text{HCl}(g)$, use the table below to determine the **order of reaction** with respect to CHCl_3 .

[CHCl ₃] (M)	[Cl ₂] (M)	Initial Rate (M/s)
0.010	0.010	0.0035
0.020	0.010	0.0069
0.020	0.020	0.0098
0.040	0.040	0.027

- A. 0 C. 2
 B. 1 D. 3
-
17. The decomposition of $\text{N}_2\text{O}_5(g)$ is a first-order reaction with $k = 7.0 \times 10^{-2} \cdot \text{s}^{-1}$. If the initial concentration of $\text{N}_2\text{O}_5(g)$ is 1.5 M, what is the concentration of N_2O_5 after 92 seconds?
- A. $1.5 \times 10^{-4} \text{ M}$ C. $1.8 \times 10^{-2} \text{ M}$
 B. $2.4 \times 10^{-3} \text{ M}$ D. $9.3 \times 10^{-3} \text{ M}$

-
18. Consider the Arrhenius equation

$$k = A e^{-\frac{E_a}{RT}}$$

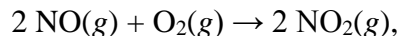
The frequency factor A

- A. is a high-energy transition state that molecules must go through to convert from reactants to products.
 B. represents the fraction of molecules that have enough energy to make it over the activation barrier on a given approach.
 C. is the energy barrier that must be surmounted for reactants to be transformed to products.
 D. is the number of times that the reactants approach the activation barrier per unit time.
-

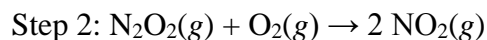
19. As described by the Arrhenius equation, reaction rate is **slowest** when the _____ is high.

- A. activation energy
B. temperature
C. collision frequency
D. reactant concentration
-

20. For the reaction



the following mechanism has been proposed.



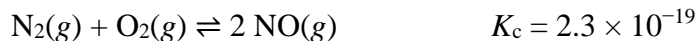
If the rate law is

$$\text{rate} = k[\text{NO}]^2[\text{O}_2]$$

which is the rate-determining step in the proposed mechanism?

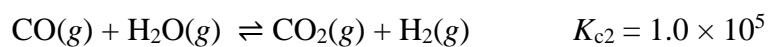
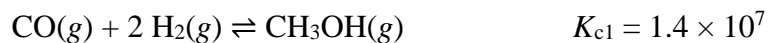
- A. Step 1 is the rate-determining step.
B. Step 2 is the rate-determining step.
C. Step 1 and Step 2 both determine the rate.
D. The rate-determining step cannot be identified from the information given.
-

21. Initially, 0.800 M each of N_2 and O_2 are present in a reaction vessel. Given the balanced chemical equation and K_c , what is true about the **equilibrium** concentrations of reactants and products?

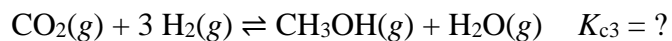


- A. The equilibrium favors neither reactants nor products, so appreciable amounts of N_2 , O_2 and NO will all be present at equilibrium.
B. The equilibrium lies far to the right and the concentration of NO will be significantly higher than the concentrations of N_2 and O_2 .
C. The equilibrium lies far to the right and the concentration of NO will be significantly lower than the concentrations of N_2 and O_2 .
D. The equilibrium lies far to the left and the concentration of NO will be significantly lower than the concentrations of N_2 and O_2 .
-

22. Given the reactions



calculate K_{c3} for the reaction



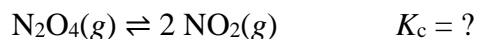
A. 1.4×10^{12}

C. 31

B. 140

D. 7.1×10^{-3}

23. $\text{N}_2\text{O}_4(g)$ and $\text{NO}_2(g)$ are in equilibrium according to this equation.



$\text{N}_2\text{O}_4(g)$ at an initial concentration of 0.0400 M produces a 0.0026 M equilibrium concentration of $\text{N}_2\text{O}_4(g)$ at 500. K. Determine K_c at 500. K.

A. 45.8

C. 2.15

B. 9.64

D. 0.502

24. Consider the reaction



In a reaction at equilibrium, the partial pressure of SO_2 is 137 torr and that of Cl_2 is 285 torr. What is the partial pressure of SO_2Cl_2 in this mixture?

- A. 2.3×10^{-5} torr
B. 1.8×10^{-2} torr
C. 13 torr
D. 4.6 torr

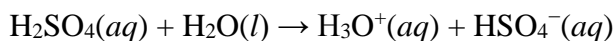
25. For the reaction,



at equilibrium at a fixed temperature, which of the following is **correct**?

- A. Increasing the volume causes the reaction to shift to the right (products).
B. Increasing the volume causes the reaction to shift to the left (reactants).
C. Decreasing the volume causes the reaction to shift to the right (products).
D. Changing the volume has no effect on the composition of the equilibrium system.

26. Consider the reaction



Identify whether each reactant is a Brønsted-Lowry acid or base.

- A. H_2SO_4 and H_2O are both Brønsted-Lowry acids.
B. H_2SO_4 and H_2O are both Brønsted-Lowry bases.
C. H_2O is a Brønsted-Lowry acid while H_2SO_4 is a base.
D. H_2SO_4 is a Brønsted-Lowry acid while H_2O is a base.
-

27. Select the true statement about a pure water sample at 50 °C. $K_w = 5.48 \times 10^{-14}$ at 50 °C

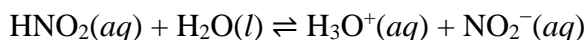
A. pH = 7.369, pOH = 6.631

C. pH = 6.631, pOH = 7.369

B. pH = 7.000, pOH = 7.000

D. pH = 6.631, pOH = 6.631

28. Consider the reaction



For a 2.5 M HNO₂ solution, the percent ionization is 1.4%. Determine the pH.

A. 1.46

C. 3.14

B. 2.22

D. 6.78

29. What is the pH of a solution that contains 0.200 M HNO₃ and 0.400 M HBrO?

$$K_a(\text{HBrO}) = 2.8 \times 10^{-9}$$

A. 0.70

C. 3.16

B. 1.99

D. 6.32

30. The pK_a of ethylammonium ion ($\text{C}_2\text{H}_5\text{NH}_3^+$) is 10.75. What is K_b of ethylamine ($\text{C}_2\text{H}_5\text{NH}_2$)?

A. 3.27

C. 5.62×10^{-4}

B. 9.32×10^{-2}

D. 1.06×10^{-11}

Questions 31 – 45 cover Exam 3 material

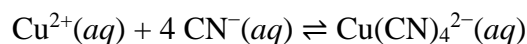
31. Which of the following 0.10 M solutions has $\text{pH} > 7.0$?

- | | |
|-----------------------------|---|
| A. NH_4NO_3 | C. $\text{KC}_2\text{H}_3\text{O}_2$ |
| B. NaBr | D. $\text{C}_6\text{H}_5\text{NH}_3\text{Cl}$ |

32. Which of the following lists acids in order of **increasing** acid strength?

- | | |
|--|--|
| A. $\text{HBr} < \text{HCl} < \text{HF}$ | C. $\text{H}_2\text{S} < \text{H}_2\text{Se}, < \text{HI}$ |
| B. $\text{H}_2\text{Se} < \text{H}_2\text{S} < \text{H}_2\text{O}$ | D. $\text{HF} < \text{H}_2\text{O} < \text{NH}_3$ |

33. Which statement is true for the reaction below?



- A. Cu^{2+} is a Lewis base; it is an electron pair donor.
- B. Cu^{2+} is a Lewis base; it is an electron pair acceptor.
- C. CN^{-} is a Lewis acid; it is an electron pair acceptor.
- D. CN^{-} is a Lewis base; it is an electron pair donor.

34. What is the ratio of base to acid ($[\text{base}] : [\text{acid}]$) in a buffer with a pH of 3.12 prepared from HNO_2 and NaNO_2 ? $\text{p}K_a(\text{HNO}_2) = 3.34$

- | | |
|------------|-------------|
| A. 3.2 : 1 | C. 0.60 : 1 |
| B. 1.6 : 1 | D. 0.82 : 1 |
-

35. A 1-L buffer solution is 0.150 M acetic acid ($\text{HC}_2\text{H}_3\text{O}_2$) and 0.150 M sodium acetate ($\text{NaC}_2\text{H}_3\text{O}_2$). What is the most likely pH range of the solution after the addition of 0.010 mol of KOH?

$$\text{p}K_{\text{a}} (\text{HC}_2\text{H}_3\text{O}_2) = 4.74$$

- A. $2.00 < \text{pH} < 4.74$ C. $4.74 < \text{pH} < 7.00$
B. $\text{pH} = 4.74$ D. $7.00 < \text{pH} < 12.00$

36. Which of the following is **true** concerning the effectiveness of buffers?

- A. Buffers are most effective when [base] and [acid] are both small.
B. Buffers are most effective when [base]:[acid] < 0.1
C. Buffers are most effective when [base]:[acid] = 1
D. Buffers are most effective when [base]:[acid] > 10

37. A 100-mL buffer solution contains 0.150 M formic acid (HCHO_2) and 0.125 M potassium formate (KCHO_2). What is the pH after 10.0 mL of 0.500 M KOH is added?

$$\text{p}K_{\text{a}} (\text{HCHO}_2) = 3.74$$

- A. 2.96 C. 4.62
B. 3.98 D. 5.34
-

38. What is the pH after titrating 20.0 mL of 0.150 M CH_3NH_2 with 32.5 mL of 0.120 M HCl?

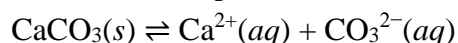
$$K_b(\text{CH}_3\text{NH}_2) = 4.4 \times 10^{-4}$$

- A. 1.77
B. 3.36
C. 9.23
D. 10.64

39. Determine the molar solubility of Ag_2S in pure water. $K_{sp}(\text{Ag}_2\text{S}) = 6.0 \times 10^{-51}$

- A. 3.0×10^{-23} M
B. 7.2×10^{-14} M
C. 8.3×10^{-6} M
D. 1.1×10^{-17} M

40. What happens when 0.50 moles CH_3COOH (acetic acid) is added to a 0.50 L saturated solution where the following equilibrium reaction is present?



- A. The solution becomes supersaturated.
B. The addition of acetic acid has no impact on the solubility of CaCO_3 .
C. Additional CaCO_3 precipitates as the equilibrium reaction is shifted to the left.
D. Additional CaCO_3 dissolves as the equilibrium reaction is shifted to the right.

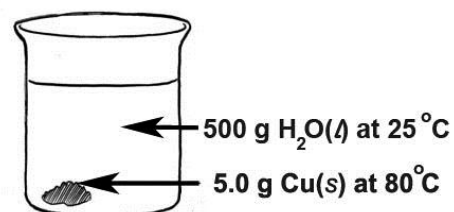
41. Will a precipitate of MnS form when two solutions are mixed such that the final concentrations are 2.0×10^{-6} M $\text{Mn}(\text{NO}_3)_2$ and 1.0×10^{-8} M Na_2S ?

$$K_{sp}(\text{MnS}) = 2.3 \times 10^{-13}$$

- A. Yes, because $Q > K_{sp}$
B. Yes, because $Q < K_{sp}$
C. No, because $Q = K_{sp}$
D. No, because $Q < K_{sp}$
-

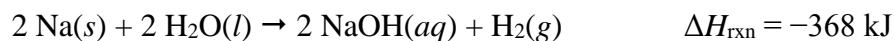
-
42. Which of the following statements is **true**?
- A. Spontaneous reactions can occur with different reaction rates, some fast and some slow.
 - B. A process that is spontaneous in one direction is also spontaneous in the reverse direction.
 - C. Nonspontaneous reactions can never occur.
 - D. Spontaneous reactions require outside intervention.

-
43. According to the Second Law of Thermodynamics, heat must flow from the copper to the water because



- A. there is more water than copper.
 - B. it results in more dispersal of heat, thereby increasing the entropy of the universe.
 - C. it results in more dispersal of heat, thereby decreasing the entropy of the universe.
 - D. it results in less dispersal of heat, thereby increasing the entropy of the universe.
-
44. Which of the following reactions **increase** the entropy of the system?
- A. $\text{CH}_3\text{OH}(g) \rightarrow \text{CH}_3\text{OH}(l)$
 - B. $\text{CH}_3\text{OH}(l) \rightarrow \text{CH}_3\text{OH}(s)$
 - C. $\text{CH}_3\text{OH}(g) \rightarrow \text{CH}_3\text{OH}(s)$
 - D. $\text{CH}_3\text{OH}(s) \rightarrow \text{CH}_3\text{OH}(l)$

-
45. Determine the entropy change in the **surroundings** for the following reaction at 27.00 °C, constant temperature and pressure.

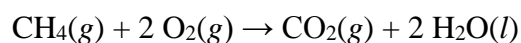


- A. -4.11 kJ/K
 - B. -8.28 kJ/K
 - C. +6.95 kJ/K
 - D. +1.23 kJ/K
-

Questions 46 – 60 cover material after Exam 3

46. When $\Delta H_{\text{rxn}} < 0$ and $\Delta S_{\text{rxn}} > 0$
- A. $\Delta G_{\text{rxn}} < 0$ and the reaction is spontaneous.
 - B. $\Delta G_{\text{rxn}} > 0$ and the reaction is spontaneous.
 - C. $\Delta G_{\text{rxn}} < 0$ and the reaction is non-spontaneous.
 - D. The temperature is needed to answer the question.

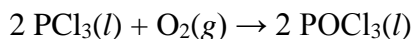
47. Given the data at right, calculate $\Delta G^{\circ}_{\text{rxn}}$ for



Substance	ΔG°_f (kJ/mol)
$\text{CH}_4(g)$	-50.5
$\text{CO}_2(g)$	-394.4
$\text{CO}_2(aq)$	-386.0
$\text{H}_2\text{O}(g)$	-228.6
$\text{H}_2\text{O}(l)$	-237.1

- A. -818 kJ
- B. -1020 kJ
- C. -652 kJ
- D. -401 kJ

48. Use the table of standard entropies to determine $\Delta S_{\text{rxn}}^{\circ}$ for the balanced chemical equation:



Substance	S° (J/mol·K)
$\text{POCl}_3(l)$	222
$\text{POCl}_3(g)$	326
$\text{PCl}_3(l)$	217
$\text{PCl}_3(g)$	312
$\text{O}_2(g)$	205

- A. -215 J/K
 - B. -195 J/K
 - C. -191 J/K
 - D. 10.0 J/K
-

49. Calculate ΔG_{rxn} at 298 K for the reaction



when $P(\text{H}_2) = 4.26 \text{ atm}$, $P(\text{I}_2) = 0.024 \text{ atm}$, and $P(\text{HI}) = 0.23 \text{ atm}$.

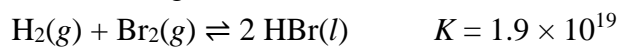
A. 2.38 kJ/mol

C. -1.44 kJ/mol

B. 0.97 kJ/mol

D. -2.71 kJ/mol

50. Determine ΔG° for the following reaction at 25 °C.



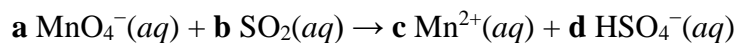
A. 86 kJ

C. -92 kJ

B. 23 kJ

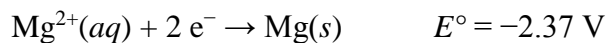
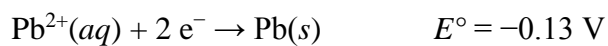
D. -110 kJ

-
51. What is the coefficient **b** when the reaction below is balanced with the lowest integral coefficients in acid solution?



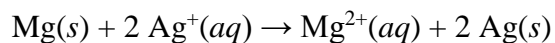
- A. 1
B. 2
C. 3
D. 5

-
52. Determine E°_{cell} for the spontaneous reaction.

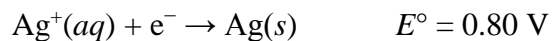


- A. 2.63 V
B. 2.50 V
C. 2.24 V
D. 2.11 V

-
53. Calculate ΔG° for the reaction

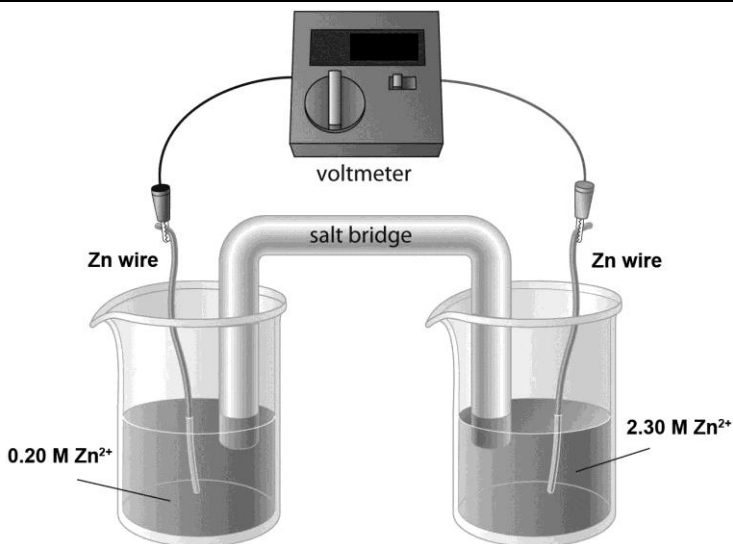
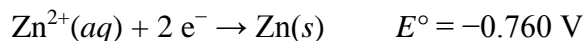


given

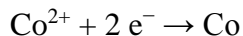


- A. -382 kJ
B. -476 kJ
C. -258 kJ
D. 139 kJ
-

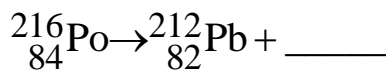
54. Determine the voltage of the cell at right at 298 K.



- A. 0.850 V
B. 0.031 V
C. -0.063 V
D. -0.790 V
55. What mass of cobalt (58.93 g/mol) can be plated out of a $\text{CoSO}_4(\text{l})$ solution by a $2.20 \times 10^4 \text{ s}$ flow of 10.0 A current?

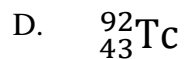
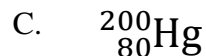
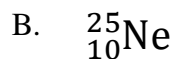
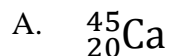


- A. 27.1 g
B. 152 g
C. 67.2 g
D. 78.3 g
56. What type of radioactive decay does Po-216 undergo, given the nuclear equation below?



- A. alpha (α) decay
B. beta (β) decay
C. gamma ray (γ) emission
D. positron (${}_{+1}^0\text{e}$) emission

57. Which one of the following isotopes has the highest nuclear stability?



58. In band theory, a material with a **small** energy gap between the valence band and conduction band is called

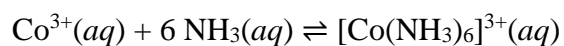
A. a metal.

B. a semiconductor.

C. an insulator.

D. a diode.

59. What concentration of Co^{3+} will remain in a solution that was initially $1.0 \times 10^{-3} \text{ M Co(NO}_3)_3$ and 0.20 M NH_3 ? K_f of $[\text{Co(NH}_3)_6]^{3+} = 2.3 \times 10^{33}$



A. $6.1 \times 10^{13} \text{ M}$

B. $1.0 \times 10^{-9} \text{ M}$

C. $2.3 \times 10^{-27} \text{ M}$

D. $8.2 \times 10^{-33} \text{ M}$

60. Hexacyanoferrate(III) is a complex ion with the chemical formula $[\text{Fe(CN)}_6]^{3-}$. What is the oxidation state (primary valence) of the central metal atom and coordination number (secondary valence) of the complex?

A. +3; 6

B. -3; 6

C. +6; 3

D. -6; 3

Answer Key:

1. C
2. A
3. D
4. C
5. A
6. B
7. C
8. B
9. C
10. C
11. B
12. A
13. A
14. B
15. D
16. B
17. B
18. D
19. A
20. B
21. D
22. B
23. C
24. B
25. A
26. D
27. D
28. A
29. ?
30. C
31. C
32. C
33. D
34. C
35. C
36. C
37. B
38. A
39. D

- 40. D
- 41. D
- 42. A
- 43. B
- 44. D
- 45. D
- 46. A
- 47. A
- 48. B
- 49. B
- 50. D
- 51. D
- 52. C
- 53. A
- 54. B
- 55. C
- 56. A
- 57. C
- 58. B
- 59. D
- 60. A