1. [1 point each]

For each question, circle the letter of the one correct answer and enter the answer on the TEST SCORING SHEET **in pencil**. The TEST SCORING SHEET will be considered final no matter what you marked on the examination paper.

1. Given $Zn(OH)_4^{2-}(aq) \rightarrow Zn(s)$ in basic solution.

The number of electrons in the balanced half-reaction is:

A) 2 **B)** 6 **C)** 4 **D)** 1 **E)** 0

2. Given:

$MnO_4^-(aq) + I^-(aq) + H_2O(l) \rightarrow MnO_2(s) + I_2(s) + OH^-(aq)$

If the coefficient of MnO_4^- in the balanced equation is 2, what are the coefficients of I^- and OH^- respectively ?

A) 6 and 8 **B)** 3 and 12 **C)** 6 and 6 **D)** 6 and 12
E) 3 and 4

3. For the cell diagram: $Pt \mid Br^-(aq) \mid Br_2(l) \mid\mid Cl_2(g), Cl^-(aq) \mid Pt$

The reaction which occurs at the cathode is

A) $Br_2(l) + 2e^- \rightarrow 2Br^-(aq)$

B) $Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$

C) $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$

D) $2Br^-(aq) \rightarrow Br_2(l) + 2e^-$

E) $Cl_2(g) + 2Br^-(aq) \rightarrow Br_2(l) + 2Cl^-(aq)$

4. When the $AgBr(s) \mid Ag(s) \mid Br^-(aq)$ electrode is the cathode, the half reaction is

A) $Ag^+(aq) + e^- \rightarrow Ag(s)$

B) $AgBr(s) + e^- \rightarrow Ag(s) + Br^-(aq)$

C) $2\,AgBr(s) + 2e^- \rightarrow 2\,Ag^+(aq) + Br_2(l)$

D) $Ag(s) + Br^-(aq) \rightarrow AgBr(s) + e^-$

E) $Ag(s) \rightarrow Ag^+(aq) + e^-$

5. Which species will reduce $Ag^+(aq)$ but not $Fe^{2+}(aq)$?

A) Au(s) **B)** $H_2(g)$ **C)** Cr(s)
D) V(s) **E)** Pt(s)

6. The standard potential of the cell

$$Zn(s) \mid Zn^{2+}(aq) \mid\mid Cu^{2+}(aq) \mid Cu(s)$$

is + 1.10 V at 25 °C.
The value of the equilibrium constant K at 25 °C for the cell reaction is:

A) 3.9×10^{18} **B)** 6.7×10^{-38} **C)** 1.5×10^{37} **D)** 2.5×10^{-19}
E) 1.6×10^{76}

7. Consider the following cell:

$$Ag(s) \mid Ag^{+}(aq, 1.000 \times 10^{-1} M) \mid\mid Ag^{+}(aq, 1.000 M) \mid Ag(s)$$

The voltage of this cell is
A) + 0.296 V **B)** + 0.0118 V **C)** + 0.0592 V **D)** - 0.0592 V
E) - 0.296 V

$Ag(s) \longrightarrow Ag^{+} + e$
$Ag^{+} + e \longrightarrow Ag(s)$

8. One cell diagram for a nickel-cadmium or nicad battery is written as:

$$Cd(s) \mid Cd(OH)_2(s) \mid KOH(aq) \mid Ni(OH)_3(s) \mid Ni(OH)_2(s) \mid Ni(s)$$

When this nicad battery is recharged:

A) Cd (s) is used up. **B)** $K^{+}(aq)$ is consumed.
C) $Ni(OH)_2$ (s) is produced. **D)** $Ni(OH)_3(s)$ is used up.
E) $Cd(OH)_2$ (s) is used up.

9. The products of the electrolysis of NaF (aq) with inert electrodes are

A) H_2 (g) and F_2 (g) **B)** H_2 (g) and O_2(g)
C) F_2(g), H_2 (g) and OH^{-} (aq) **D)** Na(s) and F_2 (g) **E)** Na(s) and O_2 (g)

10. Molten magnesium chloride is electrolyzed using inert electrodes. The reactions involved are:

$$2Cl^{-} \rightarrow Cl_2(g) + 2e^{-}$$

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

Which of the following statements is true ?
A) Oxidation occurs at the cathode.
B) Mg^{2+} ions are reduced at the anode.
C) Electrons pass through the circuit from Mg^{2+} ions to Cl^{-} ions.
D) Cl^{-} ions are reducing agents.
E) The anions in the electrolyte undergo reduction.

11. Consider the reaction

$2\ Cr^{+3}(aq) + 3\ IO_4^-(aq) + 10\ OH^-(aq) \rightarrow 2\ CrO_4^{2-}(aq) + 3\ IO_3^-(aq) + 5\ H_2O(l)$

For a given set of conditions the rate of appearance of $IO_3^-(aq)$ is 3.17×10^{-4} mol L^{-1} s^{-1}. The rate of disappearance of $OH^-(aq)$ is:

A) 3.17×10^{-4} mol L^{-1} s^{-1} **B)** 3.17×10^{-5} mol L^{-1} s^{-1}
C) 1.06×10^{-3} mol L^{-1} s^{-1} **D)** 1.06×10^{-4} mol L^{-1} s^{-1}
E) 9.51×10^{-3} mol L^{-1} s^{-1}

12. The rate of a reaction increases by a factor of approximately 1.75 when the concentration of a reactant is tripled. The order of the reaction with respect to this reactant is approximately:

A) 1.5 **B)** 1.0 **C)** 0.5 **D)** 2.0 **E)** 3.0

13. Consider the reaction: $2A + B \rightarrow$ products

The following initial rate data were measured:

[A] , mol L^{-1}	[B] , mol L^{-1}	Initial Rate , mol L^{-1} s^{-1}
0.102	0.101	0.020
0.203	0.101	0.080
0.305	0.101	0.18
0.203	0.203	0.080

The overall order for this reaction is

A) 1 **B)** 2 **C)** 3
D) 1.5 **E)** 0.5

14. A reaction that has a very low activation energy:

A) must be first-order. **B)** must be second order.
C) has a rate that changes greatly with temperature.
D) has a rate that is not very sensitive to temperature..
E) must be zeroth order.

15. Consider the reaction: $2\ A \rightarrow A_2$ with: rate $= k[A]^2$

When the initial concentration of A is 2.0 M, it requires 1.0 hours for 60 % of A to react. The rate constant is:

A) $1.6 \times 10^{-4}\ M^{-1} \cdot s^{-1}$ **B)** $5.6 \times 10^{-4}\ M^{-1} \cdot s^{-1}$ **C)** $9.3 \times 10^{-5}\ M^{-1} \cdot s^{-1}$

D) $2.1 \times 10^{-4}\ M^{-1} \cdot s^{-1}$ **E)** $2.5 \times 10^{-4}\ M^{-1} \cdot s^{-1}$

16. The rate of decay of a sample containing I-131 is 2.15×10^5 disintegrations per minute initially and 6.43×10^4 disintegrations per minute after 2 weeks. The half life of I-131 is:

A) 8.04 days **B)** 9.70 days **C)** 18.5 days **D)** 14.0 days **E)** 4.02 days

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17. A reaction has a rate constant $k = 2.80\ L\ mol^{-1}\ s^{-1}$. The initial reactant concentration is 1.00 mol L^{-1}. The time required for 90 % reaction is:

A) 0.036 s **B)** 0.040 s **C)** 3.6 s **D)** 0.40 s **E)** 3.2 s

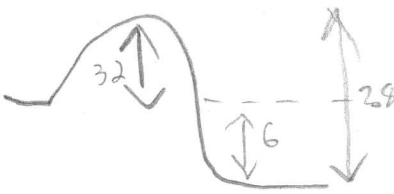
18. The activation energy of a reaction is given by:

A) - R ÷ (slope of a plot of ln k vs. 1/T)
B) + (slope of a plot of ln k vs. 1/T) ÷ R
C) - (slope of a plot of ln k vs. 1/T) x R
D) - (slope of a plot of ln k vs. 1/T) ÷ R
E) + (slope of a plot of ln k vs. 1/T) x R

slope = $-E_a/R$

19. An elementary process has an activation energy of 32 kJ/mol. The activation energy of the reverse process is 38 kJ/mol. The enthalpy change for the reverse reaction is:

A) - 6 kJ/mol **B)** 32 kJ/mol **C)** - 32 kJ/mol **D)** - 38 kJ/mol
E) 6 kJ/mol



20. Consider the reaction:

$2\ NO_2(g) + F_2(g) \rightarrow 2\ NO_2F(g)$ rate = $k\ [NO_2][F_2]$

Which of the following must be true ?:

A) The overall order of the reaction is 1.
B) The reaction occurs in one step as indicated by the equation.
C) The order of the reaction with respect to NO_2 is 2.
D) The overall order of the reaction is 3.
E) The reaction occurs in more than one elementary step.

21. The standard molar enthalpies of formation of C(s, diamond) and CO_2 (g) are +1.895 and - 393.51 kJ./mol respectively. Calculate the standard molar enthalpy of combustion of diamond.

A) - 393.51 kJ/mol **B)** - 395.41 kJ/mol **C)** - 391.61 kJ/mol **D)** - 397.1 kJ/mol
E) - 1.895 kJ/mol

$C_{(s)} + O_2 \rightarrow CO_2(g)$

22. The enthalpy of fusion of water at its normal melting point is 6.00 kJ/mol.

ΔS° for melting 1 mole of water at this temperature is:

sol -> liquid $\Delta S > 0$

A) - 22.0 $J \cdot K^{-1}$
B) + 6.00 x 10^3 $J \cdot K^{-1}$
C) + 22.0 $J \cdot K^{-1}$
D) - 6.00 x 10^3 $J \cdot K^{-1}$
E) + 23.0 $J \cdot K^{-1}$

23. For the exothermic reaction 2 CuO (s) + C(s) → 2 Cu(s) + CO_2 (g)

$\Delta S > 0$
$\Delta H < 0$

Under standard conditions, this reaction is:

A) spontaneous at all temperatures.
B) spontaneous only at high temperatures.
C) not spontaneous at high temperature.
D) disfavored by the enthalpy change..
E) not spontaneous at low temperature.

24. Consider the equilibrium: $NH_3(aq) + H_2O(l) \rightleftarrows NH_4^+(aq) + OH^-(aq)$

K is 1.75 x 10^{-5} at 25°C.

$\triangle G^0$ for this reaction at 25°C is:

A) -27.1 kJ **B)** - 2.27 kJ **C)** 2.27 kJ **D)** 6.47 kJ **E)** 27.1 kJ

$-RT \ln K$

25. Which of the following statements regarding free energy is true ?

A) $\triangle G$ is never equal to $\triangle G^\circ$.
B) $\triangle G$ always equals $\triangle G^\circ$ at equilibrium.
C) $\triangle G$ does not depend on the temperature.
D) $\triangle G$ changes as a reaction proceeds.
E) $\triangle G$ is always greater than zero if the equilibrium constant K is less than one.

2. [7 points]

(a)A 1 M $CuSO_4$ (aq) neutral solution was electrolyzed using inert electrodes.
Write the anode reaction. Write the cathode reaction.

$H_2SO_{3(aq)} + H_2O_{(l)} \rightarrow SO_4^{2-}{}_{(aq)} + 4H^+_{(aq)} + 2e^-$ $\quad Cu^{2+}_{(aq)} + 2e^- \rightarrow Cu_{(s)}$

Assuming no overpotential effects, what is the minimum potential that must be supplied to the cell for the onset of electrolysis ?

$w = -nFE$

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(b) 15.0 milligrams of titanium was deposited when a titanium chloride solution was electrolyzed for 500.0 seconds with a 120.0 milliAmp current. What is the oxidation number of titanium in the titanium chloride compound ?

Charge = Current x time

$e\left(\frac{15.0 \div 1000}{47.88}\right)F = \left(\frac{120}{1000}\right)(500)$ $\quad e(mol)F = I \times t$

$\therefore e \doteq 2$

$\Rightarrow$ the oxidation number of titanium in the compound is 2

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3. [6 points]

(a) Determine the value of the equilibrium constant at 298 K and standard conditions for the reaction: $2\,Hg^{2+}(aq) + H_2(g) \rightarrow Hg_2^{2+}(aq) + 2\,H^+(aq)$

$2Hg^{2+}_{(aq)} + 2e^- \longrightarrow Hg_2^{2+}{}_{(aq)}$ $\quad E^\circ = 0.92\,V$

$H_{2(g)} \longrightarrow 2H^+ + 2e^-$ $\quad E^\circ = 0$

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

$\therefore \ln K = \frac{nFE^\circ}{RT} = \frac{2(F)(0.92)}{R(298)} = 71.7$

$K = 1.32 \times 10^{31}$

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(b) What is the value of the potential E for the above reaction at 298 K if the pH = 6.00 and all other species are present at standard concentrations or pressures ?

$E = E^\circ - \frac{RT}{nF}\ln Q$

$= 0.92 - \frac{R(298K)}{2F}\ln\left((1\times10^{-6})^2\right)$

$= 1.27\,V$

$pH = -\log[H^+]$

$-6 = \log[H^+]$

$\therefore [H^+] = 1 \times 10^{-6}$

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4. [5 points] A proposed mechanism for a reaction is:

$Br_2(g)$	$\overset{k_1}{\underset{k_{-1}}{\rightleftharpoons}}$	~~$2\,Br(g)$~~	K	Fast equilibrium
~~$Br(g)$~~ + $CHBr_3(g)$	$\rightarrow$	~~$CBr_3(g)$~~ + $HBr(g)$	k_2	Slow
~~$CBr_3(g)$~~ + ~~$Br(g)$~~	$\rightarrow$	$CBr_4(g)$	k_3	Fast

Write the chemical equation for the overall reaction.

$Br_2(g) + CHBr_3(g) \rightarrow CBr_4(g) + HBr(g)$ ✓

Derive an expression for the rate law for the proposed mechanism.

$rate = k_2[Br(g)][CHBr_3]$ ✓, but $Br(g)$ is an intermediate

$K = \dfrac{[Br(g)]^2}{[Br_2(g)]}$ ✓

$[Br(g)] = \sqrt{K[Br_2(g)]} = K^{1/2}[Br_2(g)]^{1/2}$ ✓

$\therefore rate = K^{1/2}k_2[Br_2(g)]^{1/2}[CHBr_3]$ ✓

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5. [7 points]

(a) Circle the correct response in the following statements.

(i) The rate of all chemical reactions change with time. Circle ***true*** or ***false*** ✗

(ii.)A catalyst decreases the rate of the reverse reaction. Circle ***true*** or ***false***. ✓

(iii)A catalyst changes the reaction path followed. Circle ***true*** or ***false***. ✓

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(b) The rate constant of a reaction increases by a factor of 2.50 when the temperature is increased from 35 °C to 55 °C. What is the activation energy in kJ mol^{-1} for this reaction ?

$\ln(2.50) = \left(\dfrac{Ea}{R}\right)\left(\dfrac{\Delta T}{T_1 T_2}\right)$ ✓

$= \left(\dfrac{Ea}{R}\right)\left(\dfrac{328K - 308K}{328K \cdot 308K}\right)$ ✓

$Ea = \left(\dfrac{\ln(2.50)(101024K)}{20K}\right) \cdot R$

$= 38.5\ kJ/mol$ ✓✓

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