Below each question is listed where the information could be found, i.e. from homework problems (HW), etc. This is based on the Chemistry Text by Ebbing and Gammon.

1. The rate of a reaction depends on ______. (1pt)
   A) concentration of the reactants
   B) temperature of the reactants
   C) catalyst used in the reaction
   *D) all the above
   Rate = k[A], and see #2 and #3 below.

2. The rate constant depends on ______. (1pt)
   A) reactant concentrations
   *B) temperature
   C) volume
   D) mass of products

3. A catalyst increases the rate of the reaction by ______. (1pt)
   A) increasing the activation energy
   *B) decreasing the activation energy
   C) decreasing the rate constant
   D) increasing the enthalpy of the reaction

4. For the rate law, rate = k[A]^2[B], what is the order of the overall reaction? (1 pts)
   A) 1
   B) 2
   *C) 3
   D) 4
   E) very organized

5. For the reaction: \( \text{N}_2(g) + 3\text{H}_2(g) \rightarrow 2\text{NH}_3(g) \), nitrogen gas is reacting at a rate of 0.10 M/s, at what rate is hydrogen gas reacting? (2 pts)
   A) 0.10 M/s
   B) 0.20 M/s
   *C) 0.30 M/s
   D) 0.010 M/s
   E) 0.040 M/s
   F) 0.033 M/s
6. For the reaction whose rate law is rate = k[X], a plot of which of the following is a straight line? (2 pts)
   A) [X] versus time
   *B) ln [X] versus time
   C) 1/[X] versus time
   D) [X] versus 1/time
   E) ln [X] versus 1/time

7. The reaction 2NO$_2$(g) $\rightarrow$ 2NO(g) + O$_2$(g) is suspected to be second order in NO$_2$. Which of the following kinetic plots would be the most useful to confirm whether or not the reaction is second order? (2 pts)
   *A) a plot of [NO$_2$]$^{-1}$ vs. t
   B) a plot of ln [NO$_2$] vs. t
   C) a plot of [NO$_2$] vs. t
   D) a plot of ln [NO$_2$]$^{-1}$ vs. t
   E) a plot of [NO$_2$]$^2$ vs. t

8. Use the following data to determine the rate law for the reaction. (4 pts)
   2NO + H$_2$ $\rightarrow$ N$_2$O + H$_2$O.

<table>
<thead>
<tr>
<th>Expt. #</th>
<th>[NO]$_0$</th>
<th>[H$_2$]$_0$</th>
<th>Initial rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.021</td>
<td>0.065</td>
<td>1.46 M/min</td>
</tr>
<tr>
<td>2</td>
<td>0.021</td>
<td>0.260</td>
<td>1.46 M/min</td>
</tr>
<tr>
<td>3</td>
<td>0.042</td>
<td>0.065</td>
<td>5.84 M/min</td>
</tr>
</tbody>
</table>

   A) rate = k[NO]
   *B) rate = k[NO]$^2$
   C) rate = k[NO][H$_2$]
   D) rate = k[NO]$^2$[H$_2$]
   E) rate = k[NO]$^2$[H$_2$]$^2$
9. Which of the following is equal for the forward and reverse reactions at equilibrium? (1pt)
   A) concentration
   *B) rates
   C) rate constants

10. An example of heterogeneous equilibrium is ______. (1 pt)
   *A) \( \text{H}_2(g) + \text{I}_2(s) \rightleftharpoons 2\text{HI}(g) \)
   B) \( \text{H}_2(g) + \text{Cl}_2(g) \rightleftharpoons 2\text{HCl}(g) \)
   C) Enzyme-catalyzed reactions

11. Which is the correct equilibrium constant expression for the following reaction?
    \[
    \text{Fe}_2\text{O}_3(s) + 3\text{H}_2(g) \rightleftharpoons 2\text{Fe}(s) + 3\text{H}_2\text{O}(g)
    \] (1 pts)
    A) \( K_c = [\text{Fe}_2\text{O}_3][\text{H}_2]^3/[\text{Fe}]^2[\text{H}_2\text{O}]^3 \)
    B) \( K_c = [\text{H}_2]/[\text{H}_2\text{O}] \)
    *C) \( K_c = [\text{H}_2\text{O}]^3/[\text{H}_2]^3 \)
    D) \( K_c = [\text{Fe}]^2[\text{H}_2\text{O}]^3/[\text{Fe}_2\text{O}_3][\text{H}_2]^3 \)
    E) \( K_c = [\text{Fe}][\text{H}_2\text{O}]/[\text{Fe}_2\text{O}_3][\text{H}_2] \)

12. For the following reactions the equilibrium constants are defined as follows:
    \[
    \text{A} + 2\text{B} \rightleftharpoons \text{C} \quad K_1
    \text{C} \rightleftharpoons \text{D} + \text{E} \quad K_2
    \]
    For the reaction \( \text{A} + 2\text{B} \rightleftharpoons \text{D} + \text{E} \), having equilibrium constant \( K_c \), (2pts)
    A) \( K_c = K_1 + K_2 \)
    B) \( K_c = K_1/K_2 \)
    C) \( K_c = K_1 - K_2 \)
    *D) \( K_c = (K_1)(K_2) \)
    E) \( K_c = K_2/K_1 \)

13. The expression for \( K_p \) for the reaction
    \[
    2\text{NaHCO}_3(s) \rightleftharpoons \text{Na}_2\text{CO}_3(s) + \text{CO}_2(g) + \text{H}_2\text{O}(g)
    \] is ______. (1 pts)
    A) \( P_{\text{CO}_2} \)
    B) \( P_{\text{H}_2\text{O}} \)
    C) \( P_{\text{CO}_2}/P_{\text{H}_2\text{O}} \)
    *D) \( (P_{\text{CO}_2})(P_{\text{H}_2\text{O}}) \)
    E) \( 1 \)
    \[
    (P_{\text{CO}_2})(P_{\text{H}_2\text{O}})
    \]
14. The equilibrium constant for the reaction
   \[2\text{HCl}(g) \rightleftharpoons \text{H}_2(g) + \text{Cl}_2(g)\]
   is \(4.17 \times 10^{-31}\). The equilibrium constant for the reaction
   \[\text{H}_2(g) + \text{Cl}_2(g) \rightleftharpoons 2\text{HCl}(g)\]
   is (2 pts)
   A) \(-4.17 \times 10^{-31}\)
   B) \(4.17 \times 10^{-31}\)
   *C) \(2.40 \times 10^{30}\)
   D) \(2.40 \times 10^{33}\)

   See Quiz on 3/15 #2.

15. \(K_p = K_c\) for the reaction ______. (2 pts)
   A) \(\text{CaCO}_3(s) \rightleftharpoons \text{CaO}(s) + \text{CO}_2(g)\)
   B) \(\text{H}_2(g) + \text{I}_2(s) \rightleftharpoons 2\text{HI}(g)\)
   C) \(\text{N}_2(g) + 3\text{H}_2(g) \rightleftharpoons 2\text{NH}_3(g)\)
   *D) \(\text{H}_2(g) + \text{Cl}_2(g) \rightleftharpoons 2\text{HCl}(g)\)

16. The equilibrium constant in terms of rate constants for the forward reaction, \(k_f\), and the
   reverse reaction, \(k_r\), is given as ______. (2 pts)
   A) \(K = \frac{k_r}{k_f}\)
   B) \(K = k_f + k_r\)
   *C) \(K = \frac{k_f}{k_r}\)
   D) \(K = k_f \cdot k_r\)

17. Which can alter the value of the equilibrium constant? (2 pts)
   A) Catalyst
   B) Concentration
   C) Pressure
   *D) Temperature

18. Calculate \(K_c\) for the reaction \(2\text{HI}(g) \rightleftharpoons \text{H}_2(g) + \text{I}_2(g)\) given that the concentrations of
   each species at equilibrium are as follows:
   \([\text{HI}] = 0.85 \text{ mol/L}, [\text{I}_2] = 0.60 \text{ mol/L}, [\text{H}_2] = 0.27 \text{ mol/L}\). (3 pts)
   A) 5.25
   *B) 0.22
   C) 4.5
   D) 0.19
   E) \(1.6 \times 10^2\)

   See Quiz on 3/15 #1.
19. At 700 K, the reaction \( 2\text{SO}_2(g) + \text{O}_2(g) \rightleftharpoons 2\text{SO}_3(g) \) has the equilibrium constant \( K_c = 4.3 \times 10^6 \), and the following concentrations are present: \([\text{SO}_2] = 0.10 \text{ M}; [\text{SO}_3] = 10. \text{ M}; [\text{O}_2] = 0.10 \text{ M}\).

Is the mixture at equilibrium? If not at equilibrium, in which direction (as the equation is written), \textit{left to right} or \textit{right to left}, will the reaction proceed to reach equilibrium? (3 pts)
A) Yes, the mixture is at equilibrium.
*B) No, \textit{left to right}
C) No, \textit{right to left}
D) There is not enough information to be able to predict the direction.

20. Which of the following will result if some \( \text{CH}_4(g) \) is removed from the reaction \( \text{CO}(g) + 3\text{H}_2(g) \rightleftharpoons \text{CH}_4(g) + \text{H}_2\text{O}(g) \) at equilibrium? (2 pts)
A) \( \text{H}_2\text{O} \) will be consumed.
*B) More \( \text{CH}_4 \) and \( \text{H}_2\text{O} \) will be produced.
C) \( K_p \) will decrease.
D) More \( \text{CO} \) will be produced.
E) No change will occur.

21. Consider the following reaction at equilibrium:
\[
2\text{SO}_2(g) + \text{O}_2(g) \rightleftharpoons 2\text{SO}_3(g), \quad \Delta H_{\text{rxn}}^\circ = -198 \text{ kJ/mol} \text{ (for the forward reaction)}
\]

If the volume of the system is decreased at constant temperature, what change will occur in the position of the equilibrium? (2 pts)
A) A shift to produce more \( \text{O}_2 \)
B) No change
*C) A shift to produce more \( \text{SO}_3 \)

22. Consider the following reaction at equilibrium:
\[
2\text{SO}_2(g) + \text{O}_2(g) \rightleftharpoons 2\text{SO}_3(g), \quad \Delta H_{\text{rxn}}^\circ = -198 \text{ kJ/mol} \text{ (for the forward reaction)}
\]

If the temperature of the system is increased, what change will occur in the position of the equilibrium? (2 pts)
*A) A shift to produce more \( \text{O}_2 \)
B) No change
C) A shift to produce more \( \text{SO}_3 \)
23. The electron configuration of a Mn atom is (1 pts)
   *A) [Ar]4s^23d^5.
   B) 1s^22s^22p^63s^23p^63d^7.
   C) [Ne]3s^23p^6.
   D) [Ar]4s^13d^6.
   E) [Ar]4s^24d^5.
   See Chem1, Quiz on Ch.22 #1.

24. The electron configuration of an Fe^{2+} ion is (2pts)
   A) [Ar]4s^24d^4.
   B) [Ar]4s^23d^6.
   C) [Ar]3d^5.
   D) [Ar]3d^6.
   *E) [Ar]3d^7.
   See Quiz on Ch.22 #2.

25. How many 3d electrons does a Mn^{2+} ion have? (2pts)
   A) 1
   B) 2
   C) 3
   D) 4
   *E) 5
   See Quiz on Ch.22 #2.

26. In the complex ion [Fe(CN)_6]^{4-}, the oxidation number of Fe is (2 pts)
   A) +1.
   *B) +2.
   C) +3.
   D) −4.
   E) +6.
   See Quiz on Ch.22 #3.

27. In the complex ion [Co(en)_2Br_2]^+, the oxidation number of Co is (2 pts)
   A) +1.
   B) +2.
   *C) +3.
   D) −2.
   E) −1.
   See Quiz on Ch.22 #3.

28. In the complex ion [Co(NH_3)_4Cl_2]^+, the coordination number is (2 pts)
   A) 1
   B) 2
   C) 3
   D) 4
   *E) 6
29. A bidentate ligand always (1pt)
   A) forms bonds to two metal ions.
   B) has a charge of 2+ or 2−.
   C) forms complex ions with a charge of 2+ or 2−.
   *D) has two donor atoms.
   E) has medical uses.

30. Which of the following ligands produces the strongest crystal field? (1pt)
   A) Cl−
   B) H2O
   C) NH3
   D) en
   *E) CN−

31. In the compound K₄[Fe(CN)₆], the ligand is ____. (1pt)
   A) Fe²⁺
   *B) CN−
   C) Fe³⁺
   D) K⁺

32. Optical isomers differ from one another in ____. (1pt)
   A) reactivity
   B) bond distances
   *C) their effect on plane polarized light
   D) their spectra

33. Geometrical isomers are identical in their ____. (1pt)
   A) dipole moments
   B) reactivity
   C) absorption spectra
   *D) molar masses

34. The correct formula for the dichlorobis(ethylenediamine)chromium(III) ion is (2pts)
   A) [Cr(en)₂Cl₂]³⁺.
   B) [Cr(en)Cl]²⁺.
   C) [Cr(en)₂Cl₂]²⁺.
   *D) [Cr(en)₂Cl₂]⁺.
   E) [Cr(en)₃Cl₂]⁺.

See Quiz on Ch.22 #4 & 5.
35. The best name for $[\text{Ru(NH}_32\text{)(en)}\text{]}(\text{NO}_3\text{)}_2$ is (2pts)
   A) (ethylenediamine)diammineruthenium(II) nitrate.
   B) diamminebis(ethylenediamine)ruthenium(III) nitrate.
   *C) diammine(ethylenediamine)ruthenium(II) nitrate.
   D) diammine(ethylenediamine)nitratoruthenium(III).
   E) bis(ethylene)diamminenitratoruthenate(II).

   See Quiz on Ch.22 #4-5.

# 36-38. Use the following Crystal Field splitting diagrams for the next three questions:

Diagram A:

- $d_{x^2-y^2}$
- $d_{xy}$
- $d_{z^2}$
- $d_{yz}$

Diagram B:

- $d_{x^2-y^2}$
- $d_{xy}$
- $d_{xz}$
- $d_{yz}$

Diagram C:

- $d_{x^2-y^2}$
- $d_{xy}$
- $d_{xz}$
- $d_{yz}$

36. Using the Crystal Field splitting diagrams above, which describes the splitting in an octahedral complex? (2pts)
   A) A
   B) B
   *C) C

37. Using the Crystal Field splitting diagrams above, which describes the splitting in a tetrahedral complex? (2pts)
   A) A
   B) B
   C) C

38. Using the Crystal Field splitting diagrams above, which describes the splitting in a square planar complex? (2pts)
   A) A
   B) B
   C) C
39. How many unpaired electrons are there in the complex ion \([\text{Mn(CN)}_6]^{3-}\) ? (4 pts)
   A) 0
   B) 1
   *C) 2
   D) 3
   E) 4
   See Quiz on Ch.22 #6.

40. If a complex ion absorbs light at a wavelength of 450 nm, what color is the complex? (2 pts)
   A) red
   B) orange
   *C) yellow
   D) green
   E) blue
   F) purple
   See Quiz on Ch.22 #7.

41. _____ is an example of a low-spin complex. (2 pts)
   A) \([\text{FeBr}_6]^{3-}\)
   *B) \([\text{Fe(CN)}_6]^{3-}\)
   C) \([\text{CoF}_6]^{3-}\)
   D) \([\text{Co(H}_2\text{O)}_6]^{2+}\)

42. An example of a high-spin complex is _____ . (2 pts)
   A) \([\text{Co(NH}_3)_6]^{3+}\)
   B) \([\text{Co(CN)}_6]^{3-}\)
   *C) \([\text{CoCl}_6]^{3+}\)
   D) \([\text{Fe(CO)}_6]^{3-}\)

43. The electron configuration that forms a colorless cation is ____. (2 pts)
   A) \(3d^6\)
   B) \(3d^8\)
   C) \(3d^9\)
   *D) \(3d^{10}\)
CALCULATIONS OR OTHER (Partial Credit Available)
For Calculations, must show correct units and significant figures for answers. Please circle answers. Partial credit available for work shown.

44. In the following pair of complex ions, choose the one that absorbs light at a longer wavelength. (4 pts)
   *(a) [Co(H₂O)₆]²⁺ or (b) [Co(NH₃)₆]²⁺

NH₃ is a stronger field ligand than H₂O, therefore, it has a larger crystal field splitting (ΔE).

   Since, \( \Delta E = \frac{hc}{\lambda} \), a larger ΔE will have a smaller \( \lambda \). So the NH₃ ligand has a shorter \( \lambda \), thus the H₂O ligand has the longer wavelength (\( \lambda \)).

See Quiz on Ch.22 #7.

45. At 25°C the rate constant for the first-order decomposition of a pesticide solution is \( 6.40 \times 10^{-3} \text{ min}^{-1} \). If the starting concentration of pesticide is 0.0314 M, what concentration will remain after 62.0 min at 25°C? (5 pts)

For 1st order reactions: \( \ln[A]_t = -kt + \ln[A]_0 \)

\[
\ln[A]_t = -(6.40 \times 10^{-3} \text{ min}^{-1})(62.0 \text{ min}) + \ln(0.0314)
\]

\[\ln[A]_t = -3.8577\]

\[ [A]_t = e^{-3.8577}\]

\[ [A]_t = 0.0211 \text{ M} \]
46. In a lab, the rate constant in units of (s\(^{-1}\)) was measured at different temperatures for a particular reaction. The data was used to make the plot below. Calculate the Activation Energy for this reaction. (4 pts)

Using the Arrhenius Equation: \( \ln k = \frac{-E_A}{RT} + \ln A \), if \( \ln k \) is plotted on the y-axis, and \( \frac{1}{T} \) is plotted on the x-axis, then the slope of the line, \( m = -E_A/R \). From the equation of the best fit line on the graph, \( y = -19077x + 30.577 \), the slope \( m = -19077 \).

Solving for \( E_A \), \( E_A = -mR = -(\text{-}19077 \text{ K})(8.314 \text{ J/molK})(1 \text{ kJ/1000 J}) = 159 \text{ kJ/mol} \)

47. For the rxn: \( A + B \rightarrow C + D \), the rate law is found to be: rate = \( k[A] \). Calculate the rate constant for this reaction using the following data: (3 pts)

<table>
<thead>
<tr>
<th>[A] (M)</th>
<th>[B] (M)</th>
<th>Rate (M/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.50</td>
<td>2.50</td>
<td>0.320</td>
</tr>
<tr>
<td>3.00</td>
<td>1.50</td>
<td>0.640</td>
</tr>
</tbody>
</table>

Given: Rate = \( k[A] \). You could use the data from either experiment #1 or #2 that is given.

Solve for \( k \), \( k = \frac{\text{rate}}{[A]} = \frac{0.320 \text{ M/s}}{1.50 \text{ M}} = 0.213 \text{ s}^{-1} \)
48. Consider the reaction \( \text{N}_2(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2\text{NO}(\text{g}) \), for which \( K_c = 0.10 \) at 2000ºC. Starting with initial concentrations of 0.040 M \( \text{N}_2 \) and 0.040 M \( \text{O}_2 \), determine the equilibrium concentration of \( \text{NO} \). (6 pts)

\[
\begin{align*}
\text{N}_2(\text{g}) & \quad + \quad \text{O}_2(\text{g}) & \rightleftharpoons & \quad 2\text{NO}(\text{g}) \\
\text{Initial:} & \quad 0.040 \text{ M} & \quad 0.040 \text{ M} & \quad 0 \\
\text{Change:} & \quad -x & \quad -x & \quad +2x \\
\text{Equilibrium:} & \quad 0.040 - x & \quad 0.040 - x & \quad 2x
\end{align*}
\]

\[
K_c = \frac{[\text{NO}]^2}{[\text{N}_2][\text{O}_2]} = 0.10, \quad \text{substitute Eq. values:} \quad 0.10 = \frac{(2x)^2}{(0.040 - x)^2}, \quad \text{take the square root of both sides to get:} \quad \sqrt{0.10} = \frac{2x}{(0.040 - x)}
\]

\[
(0.040 - x)(\sqrt{0.10}) = 2x \quad , \quad (0.040)(\sqrt{0.10}) - (\sqrt{0.10})x = 2x \quad ,
\]

\[
(0.040)(\sqrt{0.10}) = 2x + (\sqrt{0.10})x \quad , \quad (0.040)(\sqrt{0.10}) = (2 + \sqrt{0.10})x
\]

\[
x = \frac{(0.040)(\sqrt{0.10})}{(2 + \sqrt{0.10})} = 0.0055 \text{ M}
\]

At Equilibrium, \([\text{NO}] = 2x = 2(0.0055 \text{ M}) = 0.011 \text{ M}

See Quiz on 3/15 #4.

EXTRA CREDIT. For the following reaction, at 1000 K, the equilibrium constant \( K_c \) is \( 3.80 \times 10^{-5} \). If you start with 0.13 M of \( \text{I}_2 \) only, what are the concentrations of both gases at equilibrium? (4 pts)

\[
\begin{align*}
\text{I}_2(\text{g}) & \quad \rightleftharpoons & \quad 2\text{I}(\text{g}) \\
\text{Initial:} & \quad 0.13 \text{ M} & \quad 0 \\
\text{Change:} & \quad -x & \quad +2x \\
\text{Equilibrium:} & \quad 0.13 - x & \quad 2x
\end{align*}
\]

\[
K_c = \frac{[\text{I}]^2}{[\text{I}_2]}, \quad 3.80 \times 10^{-5} = \frac{(2x)^2}{(0.13 - x)}
\]

\[
(3.80 \times 10^{-5})(0.13) - (3.80 \times 10^{-5})x = 4x^2
\]
\[4x^2 + (3.80 \times 10^{-5})x - (3.80 \times 10^{-5})(0.13) = 0, \quad 4x^2 + (3.80 \times 10^{-5})x - 4.94 \times 10^{-6} = 0\]
a = 4, \ b = 3.80 \times 10^{-5}, \ c = -4.94 \times 10^{-6}\] for the quadratic equation:

\[x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-3.80 \times 10^{-5} \pm \sqrt{(3.80 \times 10^{-5})^2 - 4(4)(-4.94 \times 10^{-6})}}{2(4)}\]

\[x = \frac{-3.80 \times 10^{-5} \pm \sqrt{7.904 \times 10^{-5}}}{8} = -4.75 \times 10^{-6} \pm 0.011\]

\[x = -0.0011 \text{ or } x = 0.0011\]

\[\text{this negative } x \text{ does not make physical sense (the } [I]\text{ cannot } = -0.0022 \text{ M), so } x = 0.0011\]

At Equilibrium: \([I] = 2x = 2(0.0011 \text{ M}) = 0.0022 \text{ M},\]

\[\text{and } [I_2] = 0.13 - x = 0.13 - 0.0011 = 0.129 = 0.13 \text{ M}\]

See Quiz on 3/15 #4.