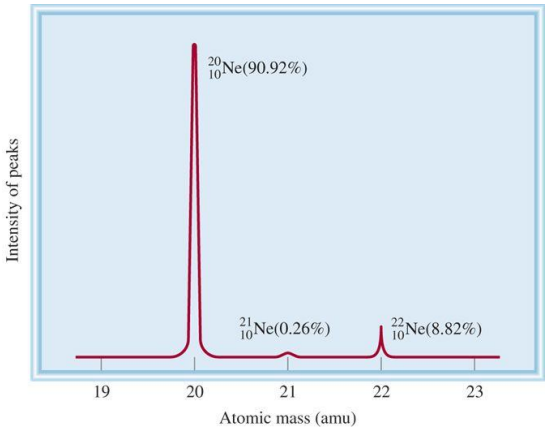
NAME_____ **STAMP**_____ **PERIOD**____

PICTURES & GRAPHS

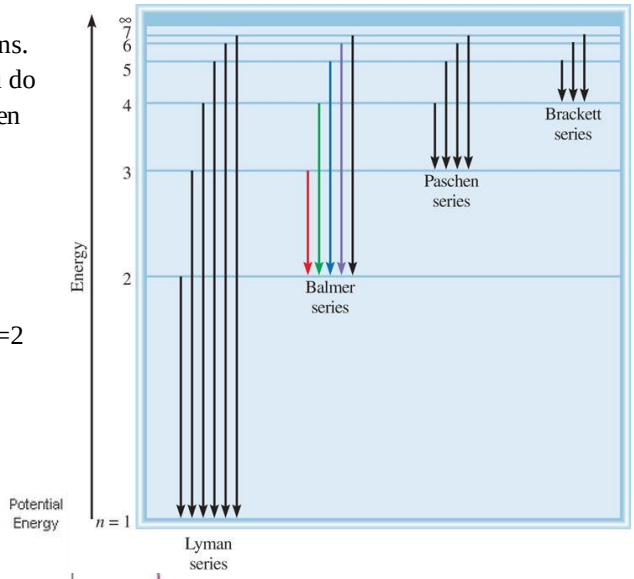
A. The Atom

1. Calculate the average atomic mass using the spectrum below.



2. Answer the questions regarding the energy level diagram shown.

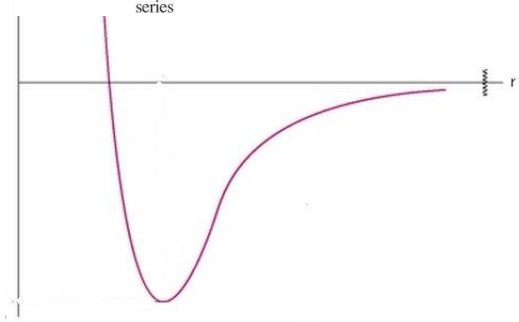
a) The emission lines for the series above are in the IR, Vis and UV regions. Match the series with the region and justify your choice (FYI – AP you do not need to memorize the names of the series. IB will need to know then for next year).



b) Would the wavelength of light be longer or shorter for lithium for an n=2 to n=1 transition than it would be for hydrogen? Justify your answer.

B. Bonding/IMFs

1. Answer the following questions regarding potential energy curves.
   a) One side of the curve represents increases in attractive forces and the other increases in repulsive forces. Label the two sides.
   b) Label the point on the curve that represents the average bond distance between two atoms. Why is this distance called the "average" bond distance? What part of the electromagnetic spectrum would be used to study this?



   c) Draw and label a curve that shows what would change if the bond is a triple bond as opposed to a single bond.

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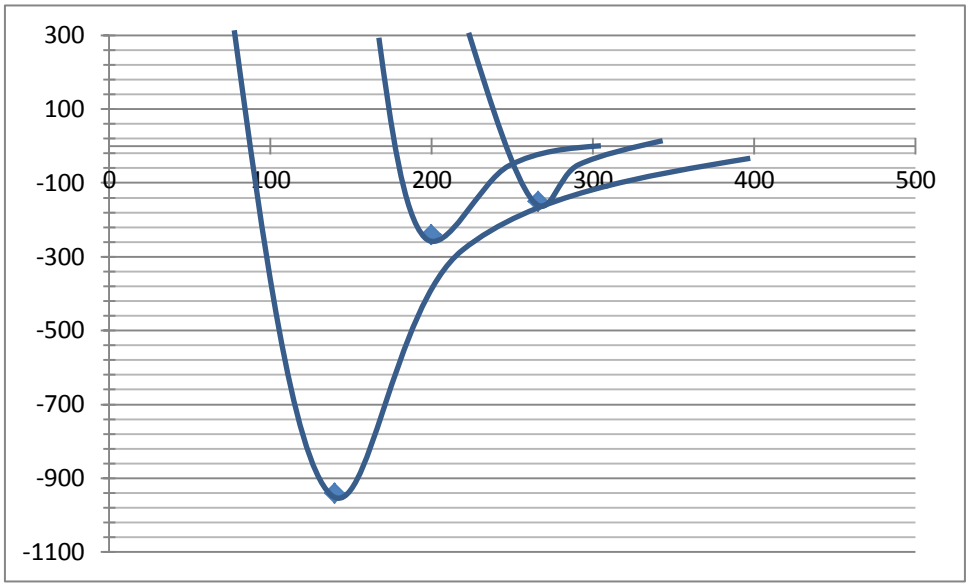
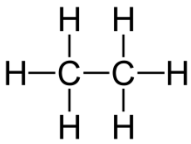
2. Answer the following questions regarding the potential energy curves for Cl_2, N_2, and I_2, as shown below.
   a) Label the axis. Potential energy is in KJ/mol and bond length is in picometers.
   b) Label the curves for Cl_2, N_2, and I_2. Justify your choice.

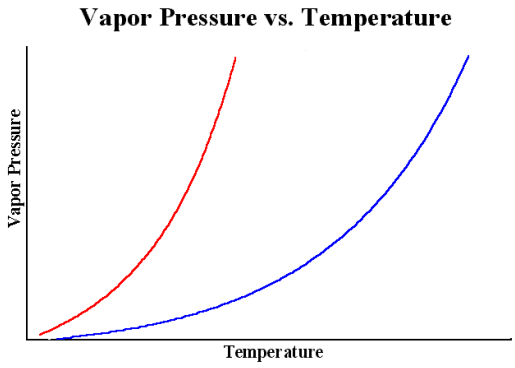


   c) Which requires energy: bond formation or bond breaking? Justify your answer.

   d) What is the bond energy in joules for one **molecule** of nitrogen?

3. The graph below shows the effect of changing temperature on the vapor pressure for two liquids, ethane (shown) and water.
   a) Explain why vapor pressure increases with increasing temperature.

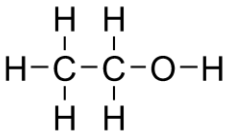




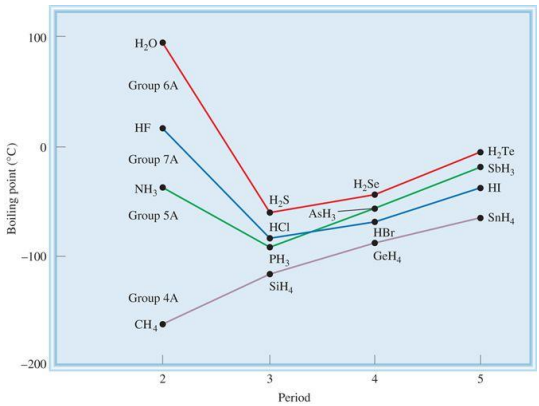
   b) Identify the intermolecular forces involved for each substance.

   c) Indicate which curve is likely water and which curve is ethane. Justify your answer using intermolecular forces

   d) Sketch the curve you would expect for ethanol (shown). Justify your sketch using intermolecular forces.



4. Answer the following question regarding the boiling point curves shown.
   a) Explain the general increasing trend in terms of intermolecular forces.



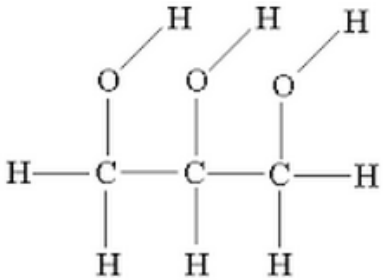
   b) Explain the anomalies seen with NH_3, H_2O, and HF in terms of intermolecular forces.

   c) Why doesn't CH_4 follow the same pattern as NH_3, H_2O, and HF?

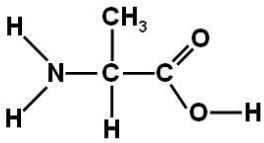
C. States of Matter & Solubility

1. Draw a picture showing the solvation/hydration of $MgCl_2$ in water.

2. Draw the lone pair electrons on the structure below. Show the dipole-dipole attractions between water and the glycerol molecule shown below. Make sure you show examples of the hydrogen and oxygen ends of water.

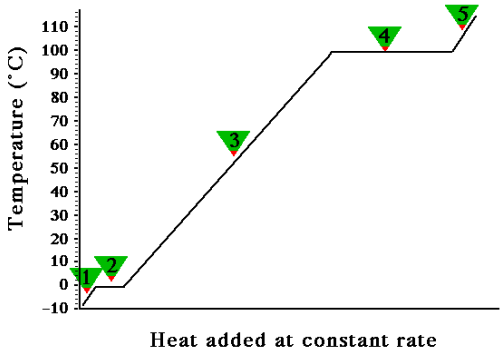


3. Draw the lone pair electrons on the structure below. Show the dipole-dipole attractions between water and the amino acid molecule shown below. Make sure to show water attracted to BOTH functional groups.



4. Use the heating curve to answer the following questions.

a) Identify (include the segment number) the phase changes that occur during the heating curve.



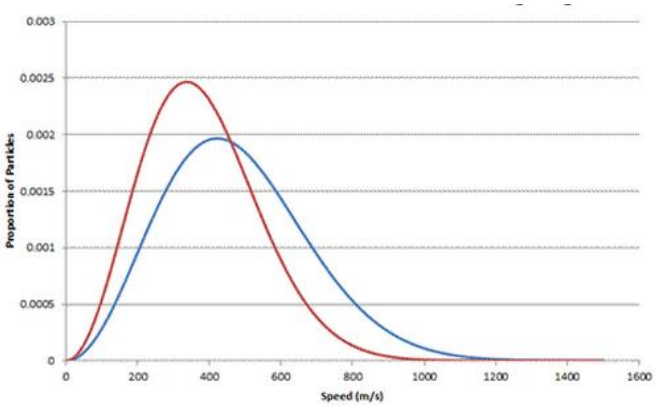
b) For each segment, indicate whether the added heat is being used to break intermolecular forces or increase the kinetic energy of the substance.

c) Why does segment "2" require more energy than segment "4"?

d) Which constants would be required to calculate the heat involved for each segment of the curve?

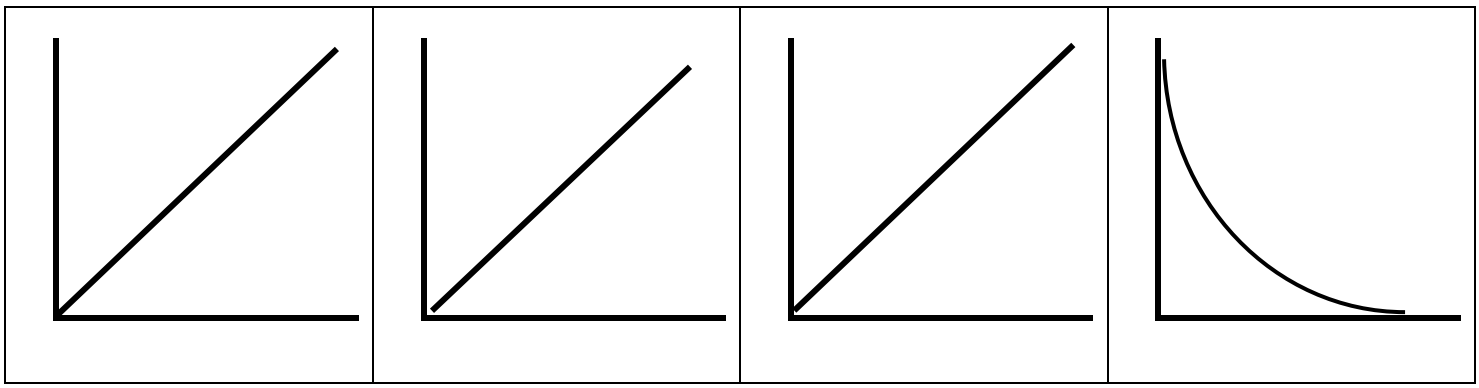
5. The graph below shows the distribution if molecular speeds for samples of CO_2 and N_2 at the same temperature.

(a) Label the curves and justify your answer.

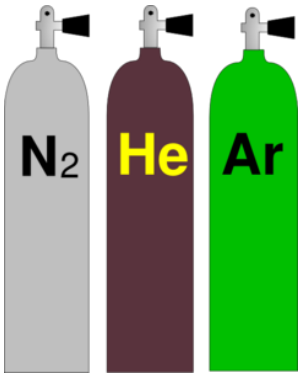


(b) Sketch the curve expected for Ne

6. The following graphs are commonly used in the study of gas laws. Assuming constant moles, label the axis for each curve showing the relationships among pressure, temperature, and volume.



7. The questions below refer to the cylinders of gas shown, all at 295 K with the same volume and pressure.

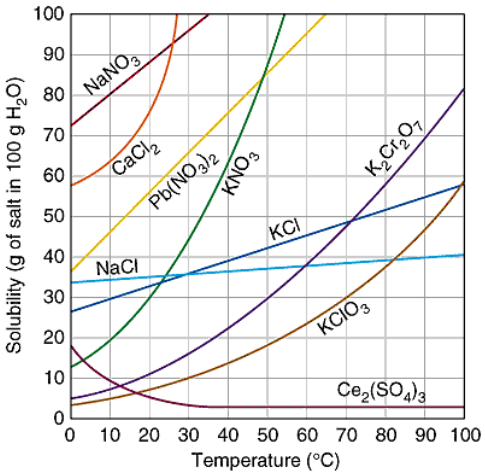


(a) Which gas has the greatest velocity? Justify your answer.

(b) Assuming the mass of the empty cylinders is the same, which cylinder would have the greatest mass? Justify your answer.

(c) Which gas has the greatest kinetic energy? Justify your answer.

8. Answer the questions regarding the solubility curves shown.



a) What forces of attraction are broken and which are formed during the dissolving process for the substances formed? Which requires energy?

b) A solution is made using 70. g of potassium dichromate. Is the solution unsaturated, saturated, or supersaturated at 80°C? (highlight answer)

c) A solution is made using 70. g of potassium nitrate. Is the solution unsaturated, saturated, or supersaturated at 80°C? (highlight answer)

d) A solution is made using 70. g of lead(II) nitrate at 40°C. If a crystal of lead(II) nitrate were added to the solution, would expect to see:
   a. The crystal to dissolve
   b. The crystal to float to the bottom
   c. The crystal to grow

e) Justify your answer from (d):

f) A solution is made using 70. g of cerium sulfate at 40°C. If a crystal of cerium sulfate were added to the solution, would expect to see:
   a. The crystal to dissolve
   b. The crystal to float to the bottom
   c. The crystal to grow

g) Justify your answer from (f):

h) A solution is made using 48 g of potassium chlorate at 90°C. How many grams would precipitate out of solution if the temperature were decreased to 30°C?

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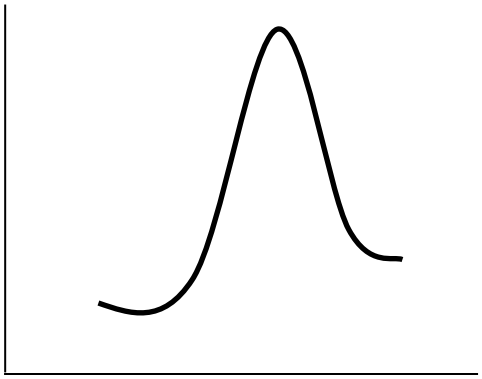
D. Kinetics

1. Sketch the effect of adding a catalyst on the potential energy curve below. Circle the energy values that change upon the addition of a catalyst.



Energy of reactants

Energy of activated complex

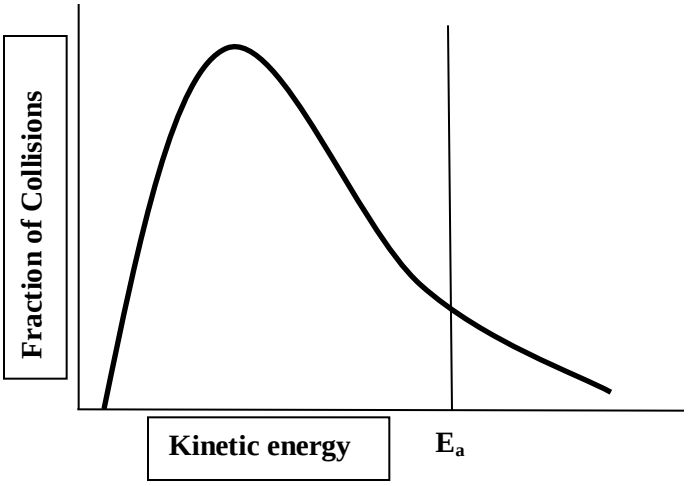
Activation energy

Energy of products

Enthalpy of reaction

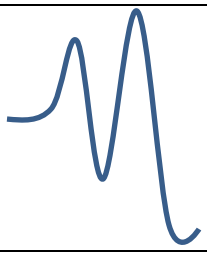
2. The graph below shows the distribution of fraction of collision versus kinetic energy for a reaction at 450 K.

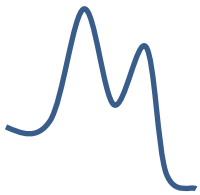
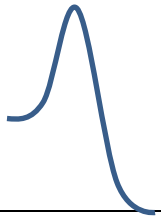
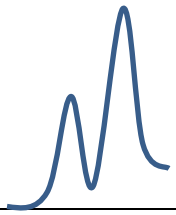
(a) Sketch the curve for 600 K. What are the three changes that are observed in the curve? What happens to the fraction of collisions with energy greater than the activation energy? Justify your answer in terms of collision theory.



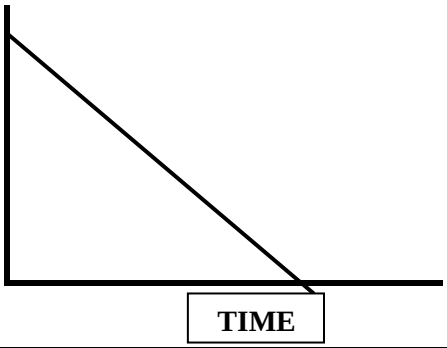
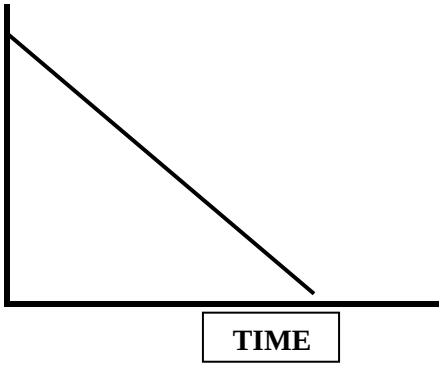
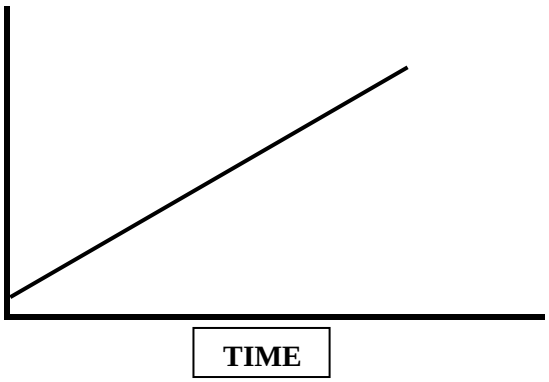
(b) Indicate the effect on the drawing upon the addition of a catalyst. What happens to the fraction of collisions with energy greater than the activation energy? Justify your answer in terms of collision theory.

3. Draw and label axis for the curves below. Match the curves with the appropriate description.

A. **exothermic** reaction with a **2** step mechanism where the **first** step is slow.	**B. endothermic** reaction with a **2** step mechanism where the **first** step is slow.
C. **endothermic** reaction with a **2** step mechanism where the **second** step is slow.	**D. exothermic** reaction with a **1** step mechanism.
E. **exothermic** reaction with a **2** step mechanism where the **second** step is slow.	**F. endothermic** reaction with a **1** step mechanism.
	

4. Answer the following regarding graphical analysis in kinetics

Label the y-axis assuming a zero order reaction. **What is the intercept?** **How would the rate constant, *k*, be determined from the graph?** **Sketch a line indicating the changes observed upon the addition of a catalyst. Make sure you consider changes to the shape, intercept, and slope.**	
Label the y-axis assuming a first order reaction. **What is the intercept?** **How would the rate constant, *k*, be determined from the graph?** **Sketch a line indicating the changes observed upon the addition of a catalyst. Make sure you consider changes to the shape, intercept, and slope.**	
Label the y-axis assuming a second order reaction. **What is the intercept?** **How would the rate constant, *k*, be determined from the graph?** **Sketch a line indicating the changes observed upon the addition of a catalyst. Make sure you consider changes to the shape, intercept, and slope.**	

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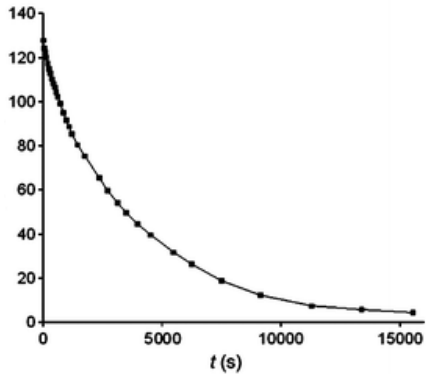
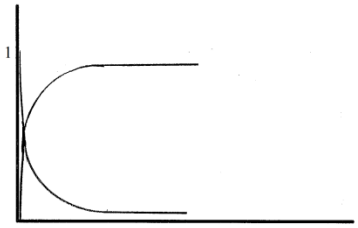
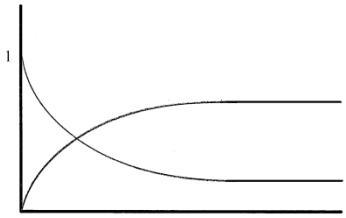
This graph shows the change in concentration versus time for a reaction. Explain how this graph could be used to determine whether the order is zero, first, or second. You must include all three possibilities in your answer.	

E. Equilibrium

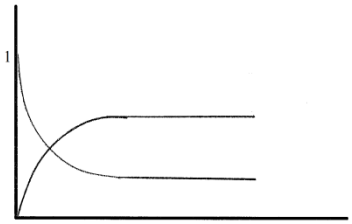
1. Answer each of the following questions based on the graphs. Each question may have more than one answer or the answer of "none".



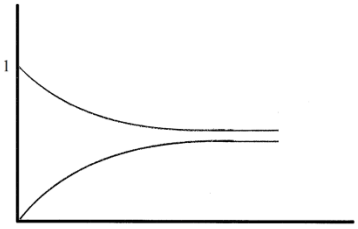
Graph A



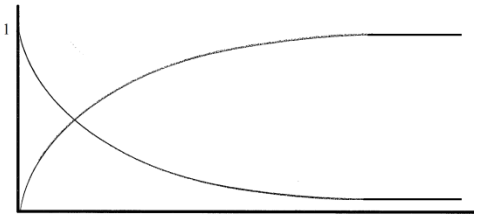
Graph B



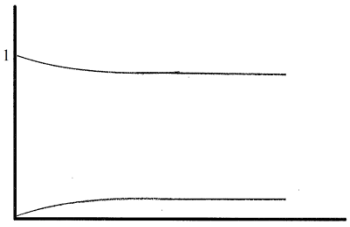
Graph C



Graph D



Graph E



Graph F

M(g) → N(g)

The six graphs above all refer to the reaction shown above. All graphs have the same units and scale on each axis and the starting amount of M(g) is the same for all graphs. Answer the following questions based on the graphs shown.

_____a. Which graph(s) show a thermodynamically favored reaction? **JUSTIFY:**

_____b. Which graph(s) show a non-thermodynamically favored reaction? **JUSTIFY:**

_____c. Which graph(s) show a reaction where ΔG is negative and the K_{eq} value is closest to one? **JUSTIFY:**

_____d. Which graph(s) show a reaction where ΔG is negative and the kinetics of the reaction is the slowest? **JUSTIFY:**

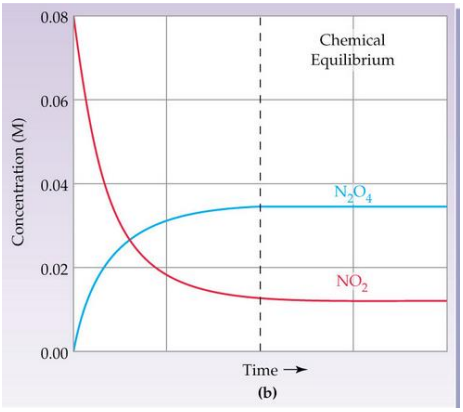
_____e. Which graph(s) show a reaction where ΔG is negative and the kinetics of the reaction is the fastest? **JUSTIFY:**

_____f. Which graph(s) shows the largest value for the equilibrium constant, K_{eq}? **JUSTIFY:**

_____g. Which graph(s) shows the smallest value for the equilibrium constant, K_{eq}? **JUSTIFY:**

_____h. Rank the speed of the reaction, from slowest to fastest for graphs, A, B and C. **JUSTIFY:**

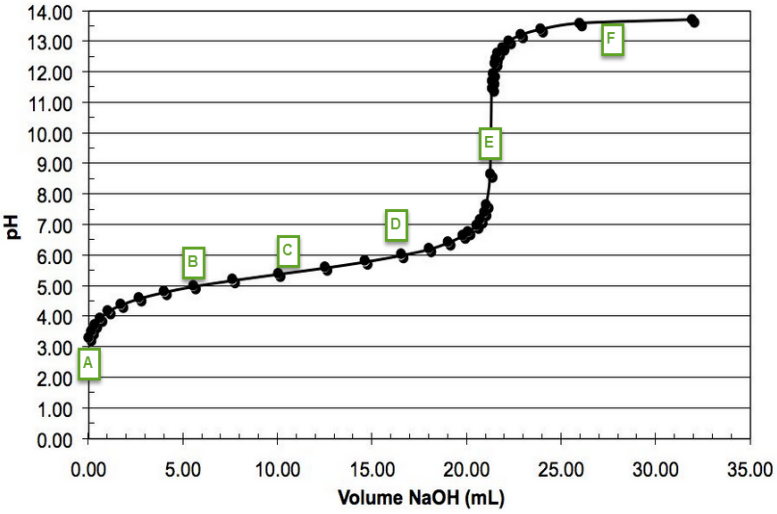
2. The graph below shows the progression of the reaction $2NO_2\ (g) \rightleftarrows N_2O_4(g)$. Suppose NO_2 was injected into the mixture at the dotted line. Sketch what would happen to both concentrations each if NO_2 was added until it's concentration reached 0.03 *M*.



F. Acids & Bases

1. A weak acid was titrated with sodium hydroxide.

Match the description with the correct points on the titration curve. Letters can be used more than once and a description may have more than one letter. **IMPORTANT**: This refers to the species that have acid/base properties. Don't forget **SPECTATOR IONS** are also swimming around in the solution!



_____a) Represents a solution that has buffering capacity

_____b) The only species present is the protonated form of the acid (HA).

_____c) pH is calculated from the excess NaOH in solution

_____d) The only species present is the de-protonated (un-protonated) form of the acid (A^-).

_____e) Equivalence point.

_____f) Point at which $pH=pK_a$.

_____g) $[HA] > [A^-]$ (protonate form > de-protonated)

_____h) $[HA] < [A^-]$ (protonate form < de-protonated)

_____i) BEST place to determine the molarity of the acid if the dissociation constant is unknown.

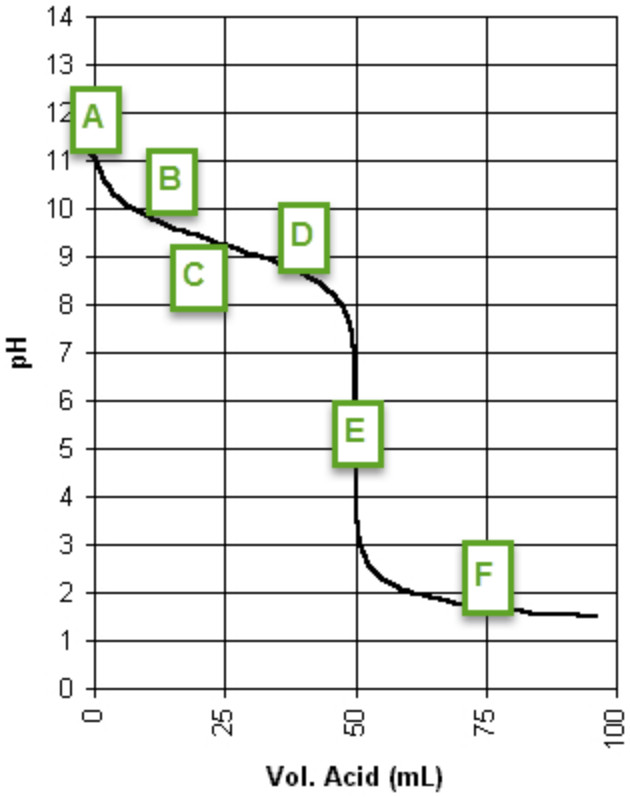
_____j) pH is controlled by the conjugate base.

_____k) Buffer where [HA] > [A^-]

_____l) Buffer where [HA] < [A^-]

2. Explain why the pH is basic at the equivalence point for the titration shown above. Write the equilibrium reaction at this point.

3. A weak base, CH_3NH_2 was titrated with a strong acid. Match the description with the correct points on the titration curve below. Letters can be used more than once and a description may have more than one letter.



_____a) [$CH_3NH_3^+$] > [CH_3NH_2] (protonate form > de-protonated)

_____b) Buffer where [$CH_3NH_3^+$] > [CH_3NH_2]

_____c) BEST place to determine the molarity of the base if the dissociation constant is unknown.

_____d) The only species present is the protonated ($CH_3NH_3^+$).

_____e) The only species present is the de-protonated (un-protonated) form of the base (CH_3NH_2).

_____f) Equivalence point.

_____g) Point at which pOH=pK_b.

_____h) Represents a solution that has buffering capacity

_____i) [$CH_3NH_3^+$] < [CH_3NH_2] (protonate form < de-protonated)

_____j) pH is controlled by the conjugate acid.

_____k) pH is calculated from the excess strong acid in solution

_____l) Buffer where [$CH_3NH_3^+$] < [CH_3NH_2]

4. Explain why the pH is acidic at the equivalence point for the titration shown above. Write the equilibrium reaction at this point.

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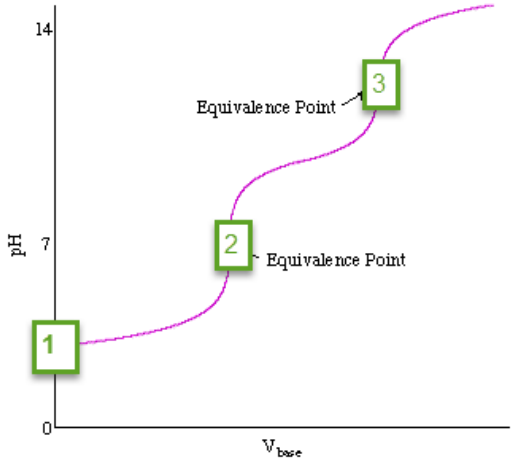
5. The titration curve for the titration of a diprotic acid, H_2Y, with a strong base is shown.

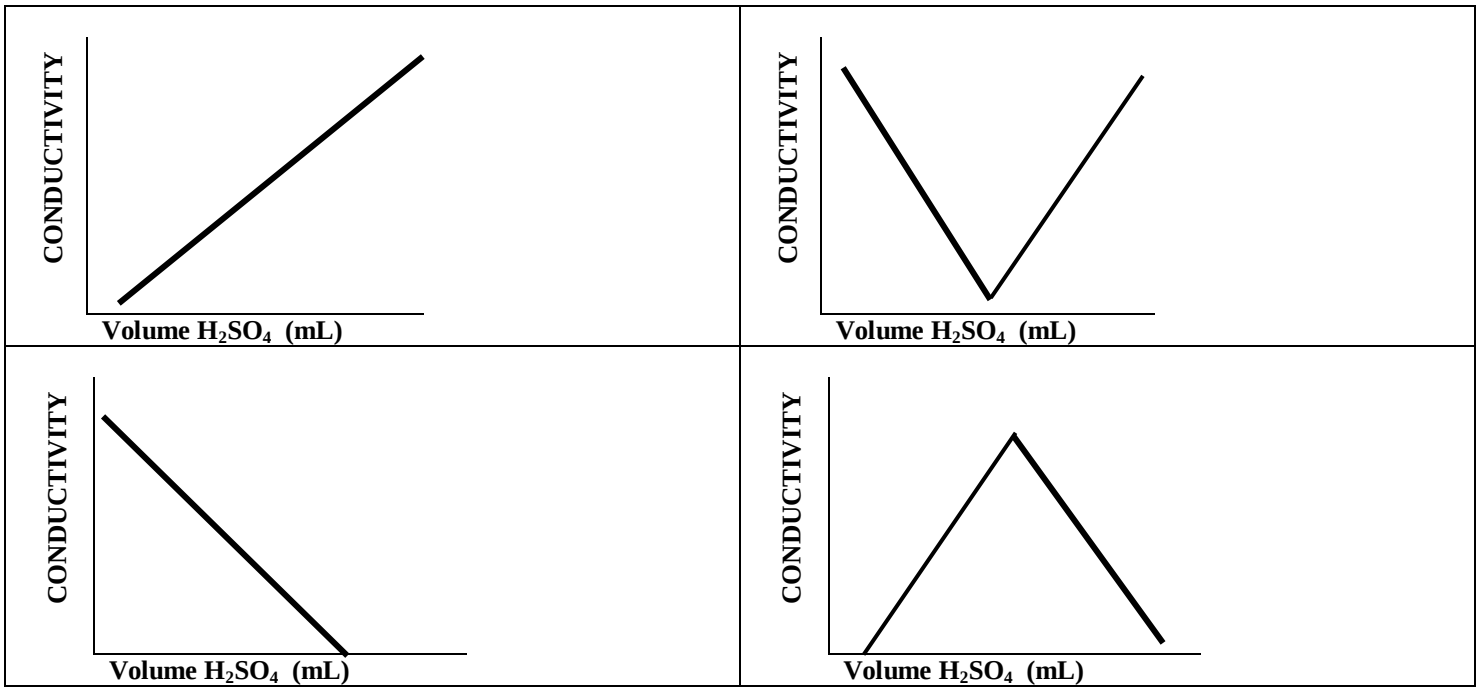


(a) Write the equilibrium reactions and acid dissociation constants for the sequential removal of the protons.

(b) For the acid H_2Y, write the formula of the species present next to each number. Choices: Y^{2-}, HY^-, H_2Y

6. Conductivity can sometimes be used in place of pH to monitor a reaction. Which of the graphs below best represents the change in conductivity for the following reaction as it is titrated past the equivalence point: HINT: WRITE NET IONIC REACTIONS FOR POINTS THROUGHOUT THE TITRATION. **JUSTIFY YOUR CHOICE.**

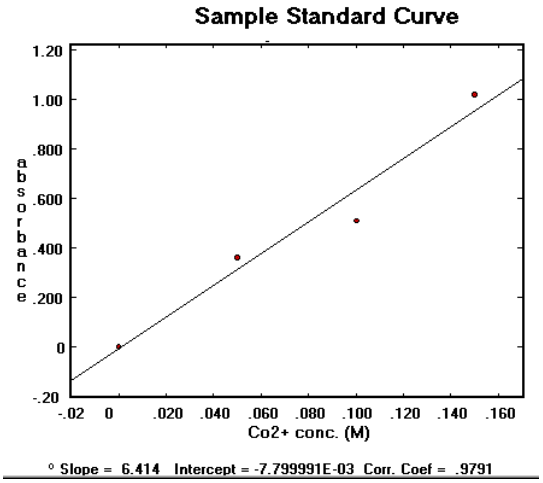
$$H_2SO_4(aq) + Ca(OH)_2(aq) \rightarrow CaSO_4(s) + 2H_2O(l)$$



G. Random Lab

1. Write the formula for Beer's law. Define each term.

2. Calculate the molar extinction coefficient, assuming a path-length of 1 cm. Include units in your answer.



3. Which type of metal ions tend to absorb light in the visible range?

4. Which of the following **MISTAKES (these are not considered experimental ERRORS)** could cause the data point to be BELOW the best fit line? Justify your answer for each one you choose
   (a) The cuvette was not rinsed with solution prior to filling with the cobalt(II) ion solution.

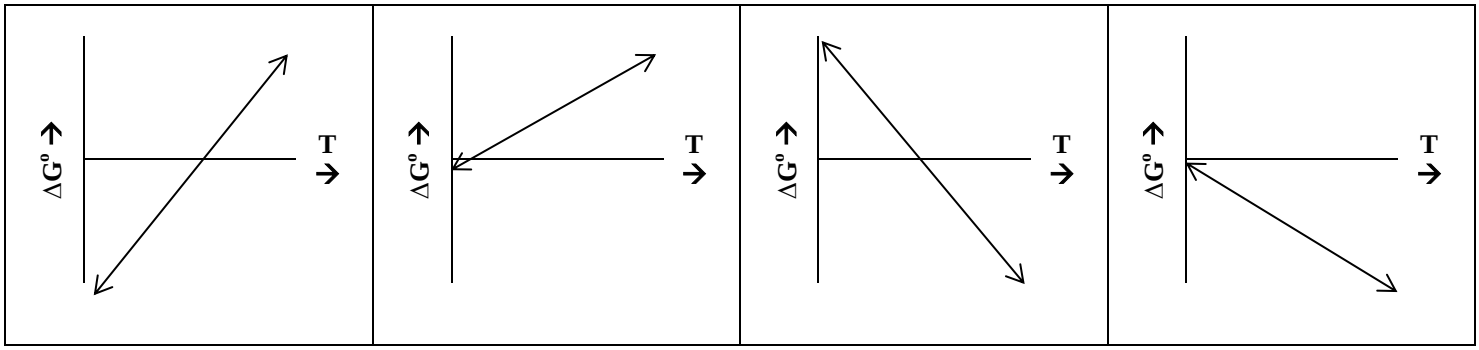
   (b) The wavelength was set lower than the maximum wavelength

   (c) The cuvette had a fingerprint on it that was not wiped off prior to measuring the absorbance

   (d) The cuvette was filled above the line.

H. Thermodynamics

1. Match the following graphs to the situation listed. In all cases, assume enthalpy and entropy are constant over the temperature range. Graphs can be used more than once. Write the letter under the graph and justify your choices.



(A) $\Delta H^o > 0$; $\Delta S^o > 0$JUSTIFICATION:

(B) $\Delta H^o > 0$; $\Delta S^o < 0$JUSTIFICATION:

(C) $\Delta H^o < 0$; $\Delta S^o > 0$JUSTIFICATION:

(D) $\Delta H^o < 0$; $\Delta S^o < 0$JUSTIFICATION:

(E) Enthalpy driven JUSTIFICATION:

(F) Entropy driven JUSTIFICATION: