

Suggested Labs Overview

S-96

Where to start? There are literally hundreds of potential lab situations that one might be asked about, so we have to take a pragmatic view in relation to what might be asked. One way to go is to look to the College Board's published AP chemistry lab manual. Of course, that MUST be *the* best source, right? Well, possibly, but what you should definitely understand is that the 16 labs that are published in that book are NOT 'required' as such, rather they are offered as 'a resource for teachers.' With that in mind, we should look at each of them, but also keep their 'non-requirement' in mind. Of course, you are much more likely to be successful on lab-based questions if you appreciate a wider, more general understanding of lab situations beyond these 16, but for practical purposes we must narrow things down somewhat. What follows is my summary of the 16 labs that appear in the College Board's lab manual, and is adapted from Chapter 27 of my AP Chemistry Crash Course book.

1. How does the [] of a colored sol'n relate to absorbance?

What is this about?

- The Beer-Lambert law and the relationship between the [] of a colored solution and the amount of light that it absorbs

What do I need to know?

- $A = \epsilon b c$
- There is a linear relationship between A and c
- That the optimum λ to use in a colorimeter or spec. is that of the complementary color to the color of the sol'n (i.e., the color that gives the highest absorbance)
- Procedure for diluting sol'ns including appropriate glassware (buret, pipet, volumetric flask, safety)
- That this procedure is only useful for colored solutions, often those of transition metals

What might I be asked?

- The procedure and calculations associated with dilution, including the use of appropriate glassware and the order of mixing
- To plot or interpret a graph of absorbance against concentration
- To select an appropriate λ of incident light

Sample Question:

Why are solutions of sodium chloride and magnesium nitrate unsuitable for analysis via a colorimeter in a Beer-Lambert law experiment?

Answer:

Both solutions are colorless, and as a result their absorbance will not vary with [] of solution.

2. What is the composition of an alloy?

What is this about?

- Analysis of an alloy using the Beer-Lambert law

What do I need to know?

- That alloys are mixtures of metals
- That an alloy can be dissolved in an acid to produce a solution of metals ions, and that if the resulting solution is colored, then it can be analyzed using the Beer-Lambert law as outlined in experiment 1., above

What might I be asked?

- As Expt. 1., above.

Sample Question:

Brass is an alloy that contains copper metal. Copper(II) ions impart a blue color to an aqueous solution that includes them, and as such a solution containing them can be used to determine concentration in a Beer-Lambert experiment. A common method of converting copper metal to copper(II) ions is to react copper metal with concentrated nitric acid. Identify the type of reaction taking place.

Answer:

REDOX

3. How can we determine the concentration of an aqueous ion in solution?

What is this about?

- The stoichiometry, and prediction of, ppt reactions

What do I need to know?

- Solubility rules
- The theory of double displacement precipitation reactions, and how to write a net ionic equation
- Simple stoichiometry of solutions
- Procedures for simple gravimetric analysis including adding excess reactant to ensure all target ions are precipitated, correct filtering procedure, and the need for washing, drying and careful weighing of precipitates

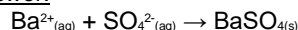
What might I be asked?

- To select an appropriate ionic solution to precipitate the ion that is to be analyzed
- To write full, ionic and net ionic equations
- The procedure for precipitation
- Stoichiometric calculations relating to concentration, volume, mass, moles and %s

Sample Question:

Write the net ionic equation for the rxn of barium nitrate solution with sodium sulfate solution.

Answer:



4. What is the concentration of an acid?

What is this about?

- The titration of an acid and a base

What do I need to know?

- Neutralization rxns, i.e., acid + base \rightarrow salt + H₂O
- Titration procedure including washing and filling burets and pipets, selection of indicators
- How to prepare a standard solution
- Titration curves incl. pH and buffer implications

What might I be asked?

- To write a neutralization equation
- To detail the procedure of a titration (rinsing and filling burets and pipets including filling the tip of a buret; using a pipet to accurately dispense the analyte, and the buret to accurately dispense the titrant; the use of an Erlenmeyer flask as the reaction vessel; the addition of a few drops of a suitable indicator (from data given); potential for the use of a white tile to help observe end point)
- To perform calculations relating to concentration, volume and pH (Henderson-Hasselbalch)

Sample Question:

In the titration of a strong acid using a strong base as the titrant, a student uses an indicator that changes color at a pH of approx. 2. What effect does that have on the volume of titrant added to the flask? (Reference in terms 'end-point' and 'equivalence point' in your answer).

Answer:

Too little titrant will be added. End-point will occur long before the equivalence point of approx. 7.

5. What are the components of the mixture that makes up a food dye?

What is this about?

- Chromatography as a separation technique

What do I need to know?

- Chromatography involves a moving phase and a stationary phase and that separation depends on the components affinity for one or the other
- How to calculate an Rf value

What might I be asked?

- To interpret a chromatogram to analyze a mixture
- To calculate a Rf value
- Outline procedure for simple chromatography experiment.
- To choose an appropriate solvent to separate a mixture based on polarities

Sample Question:

When comparing the Rf values of two components of a mixture on a single chromatogram, what does a large Rf value for one of the components tell us?

Answer:

The larger the Rf value, the further the component traveled with the solvent. So it can be deduced that the component with the larger Rf value has either a higher affinity for the moving phase, or a lower affinity for the stationary phase.

6. How can we relate bonding to properties?

What is this about?

- The influence that bonding has on observable and measurable properties

What do I need to know?

- The general properties and characteristics associated with ionic, covalent and metallic materials

What might I be asked?

- To predict or explain behavior of materials in relation to properties such as; electrical and thermal conductivity, solubility in polar and non-polar solvents, hardness, melting point, boiling point etc.

Sample Question:

In an experiment, it is found that a particular white, crystalline solid does not conduct electricity when it is a solid, but does conduct when it is in solution or molten. What do these observations suggest about the bonding present in the solid?

Answer:

It is predominantly ionic since as in an ionic solid the ions cannot freely move and cannot conduct electricity, but when in solution or molten the ions can move freely, and they can conduct.

7. How efficient are chemical processes?

What is this about?

- Stoichiometry, percentage yield and atom economy

What do I need to know?

- Solubility rules, precipitation rxns, write a net ionic equation

- Simple stoichiometry of solutions
- Procedures for simple gravimetric analysis including adding excess reactant to ensure all target ions are precipitated, correct filtering procedure, and the need for washing, drying and careful weighing of precipitates
- Percentage yield calculations
- Atom Economy calculations (% atom economy = [mass of desired product/mass of all products]*100)
- How to perform a calculation relating to decomposition of hydrated salts

What might I be asked?

- To find x in (for example), the formula $MgSO_4 \cdot xH_2O$
- Stoichiometric calculations relating to concentration, volume, mass, moles and percentage yield and percent atom economy

Sample Question:

What is meant by 'heating to constant mass', in an experiment designed to analyze the number of moles of water present in a hydrated salt?

Answer:

Heating the salt until all of the water of crystallization has been driven off, so only the anhydrous salt remains, and the mass of the salt ceases to change.

8. How can we quantitatively analyze substances using a reduction-oxidation reaction?

What is this about?

- REDOX reactions and their analysis via titrations

What do I need to know?

- A definition and understanding of oxidation and reduction
- How to write and combine half-reactions
- Common oxidizing and reducing agents and their half-reactions
- A procedure for titration

What might I be asked?

- To write half-reactions
- To combine half-reactions
- To perform calculations relating to titration data (reacting ratios, concentration and volume etc.)

Sample Question:

When using potassium manganate(VII) as the titrant in the titration of a solution of iron(II) ions, what is observed at the end-point?

Answer:

A permanent, light pink color caused by the final drop of manganate(VII) solution being in excess, after the iron(II) ions have been exhausted.

9. Separation of Mixtures

What is this about?

- Separation techniques based upon solubility of components intermolecular and intra forces

What do I need to know?

- Ionic salts will tend to dissolve in polar solvents like water
- That large, covalent molecules (often organic in nature) will tend to dissolve in non-polar (often organic) solvents
- Simple filtration techniques

- Simple liquid-liquid separation techniques including knowledge of a separating funnel and its use
- Basic, gravimetric analysis including filtering, drying and massing

What might I be asked?

- To interpret mass data collected via gravimetric analysis
- To predict in which layer (aqueous or organic) various components of a mixture might dissolve

Sample Question:

During gravimetric analysis, why is it important to fully dry, but not excessively heat, solids that are collected by filtration of an aqueous solution?

Answer:

If solids are not completely dry, they will include water, and massing them will lead to anomalously high values being recorded. Excessive heating could cause an unstable solid to decompose, this time causing a mass to be recorded that is too small.

10. How do factors like particle size, concentration and temperature affect the speed of a chemical reaction?

What is this about?

- Kinetics and which factors affect the speed of a reaction

What do I need to know?

- How factors such as particle size, temperature, concentration and catalysts, affect the rate of a reaction
- How those factors are explained at the microscopic level based on chemistry concepts (collision theory, activation energy etc.)
- Dilution techniques and procedures

What might I be asked?

- To design an experiment with controls, to investigate the speed of a chemical reaction (including how to measure the rate of reaction)
- To interpret data that is generated in such an experiment including graphical representations

Sample Question:

Explain why using powdered calcium carbonate, as opposed to large chips of calcium carbonate, makes the reaction between $\text{CaCO}_3(\text{s})$ and aqueous hydrochloric acid, proceed at an increased rate.

Answer:

The powdered calcium carbonate has a greater surface area than the large chips, and as a result far more collisions can take place between the acid and the solid. An increased number of collisions means a faster rate.

11. How can we deduce a rate law experimentally?

What is this about?

- Using initial rate and concentration data to determine a reaction rate law

What do I need to know?

- That rate laws can be determined by the initial rate method
- The relationship btwn changes of rate and orders of rxn
- The shape and interpretation of graphs as they relate to zeroth, first and second order reactions

What might I be asked?

- To interpret [] data generated in, for example, a Beer-Lambert law experiment, and use to determine a rate law
- To interpret or plot a graph to determine a rate law

Sample Question:

Having collected the data in a kinetics experiment, a student plots the reciprocal of the concentration of reactant A (y-axis), against time on the (x-axis), and finds that a straight line is not produced. What does this information alone, tell the student about the order of reaction with respect to the concentration of reactant A?

Answer:

That the order of reaction with respect to reactant A is NOT second order (if it were second order, then a straight line would result in this plot).

12. What is the energy change during the process of dissolving a salt in water?

What is this about?

- Enthalpy of reaction and calorimetry

What do I need to know?

- The application of $q = m c \Delta T$
- The relationship btwn q and enthalpies measured in kJ/mol
- A procedure for calorimetry
- The energy changes associated with dissolving ionic solid
- That certain glassware offers certain degrees of precision

What might I be asked?

- To design an experiment (including selection of concentrations and volumes of solutions) in order to collect temperature change data and convert that data to energy measurements
- To apply $q = m c \Delta T$
- To select glassware based upon the accuracy and precision required

Sample Question:

The standard enthalpy of neutralization for a strong acid with a strong base is approx. -57 kJmol^{-1} . When a neutralization reaction is repeated using a very weak acid such as HCN, and a strong base, the enthalpy of neutralization is found to be only approx. -12 kJmol^{-1} . Explain the difference.

Answer:

The weak acid HCN, will only be partially ionized, and as such, some energy will be required to dissociate it before complete neutralization can take place. This results in a less exothermic reaction.

13. What causes the equilibrium position to shift?

What is this about?

- Le Châtelier's principle

What do I need to know?

- Le Châtelier's principle, predict how changes in conditions (stresses) affect the position of an equilibrium
- That macroscopic observations such as color changes, pH changes etc., can be used to determine the shift in an equilibrium position

What might I be asked?

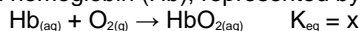
- To predict or explain shifts in equilibrium when changes in temperature, concentration, pressure or catalysts, are

applied to a reaction, and be able to explain each in terms of Le Châtelier's principle

- To interpret particulate diagrams that show relative numbers of species as a function of equilibrium position

Sample Question:

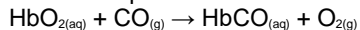
Oxygen in the human body forms an equilibrium mixture with hemoglobin (Hb), represented by the equation below;



Carbon monoxide gas creates a similar equilibrium with hemoglobin, thus;



Calculate the equilibrium constant for the reaction,



Answer:

Since the final equation is the first equation reversed, and added to the second equation, we can take the reciprocal of the first equilibrium constant and multiply in by the second equilibrium constant, to achieve the equilibrium constant for the final reaction.

$$(1/x)(200x) = 200$$

14. What do titration curves tell us about reactions?

What is this about?

- Titration curves of weak and strong acids and bases

What do I need to know?

- The shapes of titration curves for any combination of weak and strong acid
- What the dominant species are, in solution, at all points on the curve (including when titrating weak acids and weak bases, halfway to the equivalence point)
- That when dealing with weak acids and weak bases in titrations with strong bases and strong acids respectively that buffer solutions are produced
- The Henderson-Hasselbalch equation
- The difference between equivalence point and end point

What might I be asked?

- To sketch and interpret titration curves
- To relate the titration curve to pH and pKa values
- To identify dominant species at any point in a titration
- To be able to draw particulate diagrams to demonstrate your knowledge of dominant species
- To perform titration calculations (concentrations, volumes, molar ratio etc.)

Sample Question:

When a weak acid is titrated with a strong base, what can be said of the composition, and the pH, of solution in the Erlenmeyer flask when the titration is halfway to the equivalence point?

Answer:

It will have equal concentrations of acid and conjugate base, and the pH will equal the pKa of the weak acid.

15. What makes a good buffer?

What is this about?

- Buffers

What do I need to know?

- What a buffer is
- How a buffer works and how to write equations to show the buffering action

- The factors that affect a buffers capacity
- The factors that affect a buffers pH (i.e., the application of the Henderson-Hasselbalch equation)
- Where solutions are buffered in relation to titration curves
- The definition of a polyprotic acid
- That pH = pKa halfway to the equivalence point

What might I be asked?

- To interpret or sketch a titration curve in terms of the buffering action possible when a weak acid or weak base is titrated with a strong base or strong acid
- Calculations using the Henderson-Hasselbalch equation
- To identify the pH at the equivalence points of various titration curves

Sample Question:

Which of the following pairs will make the best buffer solution? Explain your answer.

NaOH and NH₃

CH₃COOH and CH₃COO⁻Na⁺

HCl and NaCl

CH₃COOH and NaCl

Answer:

CH₃COOH and CH₃COO⁻Na⁺

This combo is that of a weak acid and its conjugate base.

16. What affects the pH and capacity of a buffer?

What is this about?

- The capacity and pH of buffers

What do I need to know?

- How to interpret the Henderson-Hasselbalch equation in terms of buffer capacity (the concentration of each component) and the desired pH (ratio of each component)

What might I be asked?

- How to perform calculations with the Henderson-Hasselbalch equation and to suggest good combinations of weak acid/base and conjugates, both in terms of concentrations (capacity) and ratio (pH) to achieve desired buffering activity

Sample Question:

If the pH of a buffer is significantly lower than the pKa of the acid component, what does that tell us about the ratio of acid to base components in the buffer?

Answer:

Since **pH = pKa + log([conjugate base]/[acid])** we must be adding a negative number to the pKa in order for the pH to be significantly lower than the pKa. In order for the term **log([conjugate base]/[acid])** to be negative, the ratio **[conjugate base]/[acid]** must be less than 1, i.e., the acid must be in the majority.