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Honors Chemistry Course—This option is designed to take students through the content at the depth and pace appropriate for an honors class. Time is built into the pacing for group and individual projects. The projects are assigned after completing specific chapters.

After Chapter 2—Analyzing Data
Individual Project (5 periods or 2.5 blocks)
Earth's Atmospheric Ozone Levels

Student Information:
Have students research ozone levels in Earth's stratosphere throughout the past decade for North America and South America. Direct each student to develop a table to record his or her data and then develop a graph to show a comparison of the data collected. Have the student note any trends or variances in ozone levels.

Teacher Information:
Students should use several sources to check for trends or variations in ozone level statistics recorded in their tables. The tables should be developed before students begin their research. The graph should reflect any uncertainty of statistics and indicate any trends or lack of trends. Students should use colors, textures, labels, or other features to make the graph easier to interpret.

After Chapter 6—The Periodic Table and Periodic Law
Group Project (5 periods or 2.5 blocks)
Energy-Level Transitions

SAFETY SYMBOLS: F, K, L, D

Student Information:
Direct each student group to research an experimental method for analyzing an element's atomic emission spectrum to determine how much energy is involved in a particular energy-level transition. Work with the group to set up an apparatus that enables students to implement the method. Have the group compare its experimentally obtained ΔE value with the accepted value. Prior to experimentation, assess any hazards and instruct students about appropriate precautions, techniques, and protective measures.

Teacher Information:
Safety Suggestions:

1. Use only GFI-protected electrical receptacles with high-voltage transformers. Remind students to keep the high-voltage transformers away from water.
2. Do not use mercury vapor discharge tubes.

3. Glass gas discharge tubes are fragile and can break easily. Remind students to use caution in handling them.

Groups may carry out such a spectral-analysis method with a high-voltage transformer, an element's gas-discharge tube, metersticks, clamps and stands, and a precision diffraction grating. Because one student must view the spectral lines through the grating and other students must note the lines' positions, several students are required to perform the investigation.

Groups should gather the following experimental data: the order of the line (*n* or *n*'); the distance between lines on the diffraction grating (*d*); the distance between the gas-discharge tube and the grating (*L*); the distance between the gas-discharge tube and the line (*x* or *x*'). With such data, students may calculate the diffraction angle (θ or θ) with the relationship tan $\theta = x/L$, the wavelength with $n\lambda = d\sin\theta$, and the energy change with $\Delta E = hc/\lambda$, where h is Planck's constant (6.626×10^{-34} J•s) and c is the speed of light in a vacuum (3.00×10^{8} m/s).

The following table shows sample student data and calculated values for hydrogen's red line (Balmer Series). The accepted λ is 6.563×10^{-7} m and accepted ΔE is 3.03×10^{-19} J. Students obtained the data using a diffraction grating with 300 lines/mm.

Sample Student Data					
n or *n*'	*d* (m)	*L* (m)	*x* or *x*' (m)	θ or θ (°)	λ (m)
1	3.33×10^{-6}	1.00	0.204	11.5	6.64×10^{-7}
1'	3.33×10^{-6}	1.00	0.200	11.3	6.53×10^{-7}
2	3.33×10^{-6}	1.00	0.430	23.3	6.59×10^{-7}
2'	3.33×10^{-6}	1.00	0.440	23.8	6.72×10^{-7}

Average $\lambda = 6.62 \times 10^{-7}$ m

$\Delta E = ((6.626 \times 10^{-34} \text{ J•s})(3.00 \times 10^{8} \text{ m/s})) \div (6.62 \times 10^{-7} \text{ m}) = 3.00 \times 10^{-19}$ J

After Chapter 9—Chemical Reactions
Individual Project (5 periods or 2.5 blocks)
Solution Identification

SAFETY SYMBOLS: G, K, L, D, I, O

Student Information:
Supply each student with a porcelain well plate, watch glasses, distilled or deionized water in a dispensing bottle, and five Beral pipettes labeled *Q1-Q5*. Each Beral pipette contains one of the following aqueous solutions, all approximately 0.1*M*: silver nitrate, hydrochloric acid, nitric acid, calcium chloride, and sodium carbonate. Students will design and carry out an experiment that will determine the identities of the solutions.

Have each student study and write chemical equations for all possible double-replacement reactions involving the five solutions. The student should look up the properties of all reactants and products in a chemistry handbook under physical properties of inorganic compounds. Prior to experimentation, assess any hazards and instruct students about appropriate precautions, techniques, and protective measures.

Teacher Information:
Safety Suggestions:
1. Review MSDS for each chemical solution with students prior to doing lab work.
2. Review student procedures before they perform their experiments.
3. Remind students to wash hands after handling the solutions.

Preparation:

Prepare 0.1*M* stock solutions of silver nitrate, hydrochloric acid, nitric acid, calcium chloride, and sodium carbonate. The students are informed of the identities of the compounds but not which number corresponds to the compound.

Suggested Procedure:

1. Place one or two drops of solution Q1 in each of five wells.
2. Add one or two drops of solution Q2 into well 2. Continue until all solutions are tested against solution Q1.
3. Repeat the process testing against each solution.

Sample Student Data					
	Q1	Q2	Q3	Q4	Q5
Q1	X	Ppt	NR	Ppt	Ppt
Q2	Ppt	X	NR	NR	Gas
Q3	NR	NR	X	NR	Gas
Q4	Ppt	NR	NR	X	Ppt
Q5	Ppt	Gas	Gas	Ppt	X

Q1 is $AgNO_3$.
Q2 is HCl.
Q3 is HNO_3.
Q4 is $CaCl_2$.
Q5 is Na_2CO_3.

After Chapter 13—Gases
Group Project (10 periods or 5 blocks)
Quantitative Analysis

SAFETY SYMBOLS: G, K, L, I, O

Student Information:
Assign each student group a nonuniform mixture of three solid compounds: silver nitrate, sodium acetate, and sodium chloride. Tell students you will provide 0.1*M* stock solutions of sodium chloride and silver nitrate. Have the groups design and carry out a procedure to determine the mass percent of each compound in the mixture.

Have each student study and write chemical equations for all possible double-replacement reactions involving the three compounds and two solutions. The student will look up the properties of all reactants and products in a chemistry handbook under physical properties of inorganic compounds. Prior to investigation, assess any hazards, and instruct students about appropriate precautions, techniques, and protective measures.

Teacher Information:
Safety Suggestions:
Review MSDS for each chemical with students prior to doing lab work.

Preparation:

1. Prepare 0.1*M* sodium chloride and 0.1*M* silver nitrate stock solutions.
2. Prepare a mixture containing approximately 5.0 g each of silver nitrate, sodium acetate, and sodium chloride, and place the mixture in a sample bottle. Note the exact mass of each compound.

Suggested procedure:

1. Place the mixture in a 100-mL beaker.

2. Measure 50 mL of water in a graduated cylinder. Carefully rinse the sample bottle with a small amount of water and pour the resulting solution into the beaker containing the solid sample.
3. Add the remaining water in the graduated cylinder to the sample in the beaker.
4. If a precipitate forms, filter the solution. Collect and dry the precipitate. Measure and record the mass of the dry precipitate.
5. Divide the remaining solution into three portions. Label each portion with a number. Record the volume of each.
6. To Solution 1, add one drop of 0.1*M* silver nitrate. If a precipitate forms, continue to add drops one at a time until no more precipitate forms. Filter the solution and collect and dry the precipitate. Measure and record the mass of the dry precipitate.
7. To Solution 2, add one drop of 0.1*M* sodium chloride. If a precipitate forms, continue to add drops one at a time until no more precipitate forms. Filter the solution, collect and dry the precipitate. Measure and record the mass of the dry precipitate.
8. Identify each precipitate based on the possible reactions and properties of the products.
9. Use the mass of each original solid compound and the mass of each precipitate to determine the mass percent of each compound in the mixture.

After Chapter 19—Redox Reactions
Individual Project (5 periods or 2.5 blocks)
Preparation and Testing of a Buffer

SAFETY SYMBOLS: G, K, L, O

Student Information:
Direct each student to prepare a specific volume of an inorganic buffer solution of a given pH at 298 K. The solution will have a total solution molarity of buffering ions or molecules. Have each student devise and carry out a procedure to prepare the assigned buffer solution, then check the pH of the solution with a calibrated pH meter. If the pH differs significantly from the assigned value, have each student revise his or her calculations and procedure and prepare the solution correctly. Prior to experimentation, assess any hazards and instruct students about appropriate precautions, techniques, and protective measures.

Teacher Information:
Safety Suggestions:
Review MSDS for each chemical solution with students prior to doing lab work.

Suggested Procedure:
Assign a pH of 10.50, a total solution molarity of 0.082, and a solution volume of 0.100 L. Of the conjugate acid-base pairs presented in Chapter 18, the one best suited for this buffer is the hydrogen carbonate-carbonate system. K_a for the $HCO_3^- \leftrightarrows H^+ + CO_3^{2-}$ equilibrium is 4.7×10^{-11}. Therefore, a solution with equimolar concentrations of HCO_3^- and CO_3^{2-} will have a pH of $-\log(4.7 \times 10^{-11}) = 10.33$, which is close to the desired pH.

The desired hydrogen-ion concentration is calculated as follows:

$[H^+] = \text{antilog}(-10.50) = 3.2 \times 10^{-11}$

Inserting this value into the equilibrium expression allows one to calculate the concentration ratio of carbonate ions to hydrogen carbonate ions.

$$K_a = \frac{[H^+][CO_3^{2-}]}{[HCO_3^-]}$$

$$4.7 \times 10^{-11} = \frac{(3.2\times 10^{-11})[CO_3^{2-}]}{[HCO_3^-]}$$

$$1.5 = \frac{[CO_3^{2-}]}{[HCO_3^-]}$$

Letting $x = [HCO_3^-]$, $[CO_3^{2-}] = 1.5x$
$0.082\ M = x + 1.5x = 2.5x$
$x = 0.033M$
Therefore, $[HCO_3^-]$ is $0.033M$ and $[CO_3^{2-}]$ is $0.049M$.

The student should calculate the masses of compounds, such as $NaHCO_3$ and Na_2CO_3, required to prepare the assigned volume of a solution that is $0.033M$ in HCO_3^- and $0.049\ M$ in CO_3^{2-}. Then, the student would prepare the buffer solution and check the pH experimentally.

Note: You can simplify the project slightly by not assigning a specific total solution molarity (excepting the concentrations of hydrogen and hydroxide ions).

After Chapter 24–Nuclear Chemistry
Group or Individual Project (10 periods or 5 blocks)
Vitamin-C Analysis

SAFETY SYMBOLS: G, K, L, I, O

Student Information:
Direct the student groups to research the chemical and structural formulas of vitamin C (ascorbic acid), its properties, and how the vitamin functions in the body. Have the groups research the methodology for determining the vitamin-C content of various liquids by oxidation-reduction titration. Then, have students prepare the necessary solutions to carry out such an analysis. The students can perform the analysis on liquids, such as pineapple juice, orange juice, grapefruit juice, white grape juice, tomato juice, apple juice, milk, sports drinks, and so on. Prior to experimentation, assess any hazards and instruct students about appropriate precautions, techniques, and protective measures. Because students might find the results interesting, instruct the group to prepare and give a presentation to the entire class.

Teacher Information:
Safety Suggestions:

1. Review MSDS for each chemical solution with students prior to doing lab work.
2. Remind students to use caution in working with iodine solution—irritates eyes and skin, stains clothing.

Ascorbic acid is easily oxidized by a mild oxidizing agent such as molecular iodine, and students might assume that the redox reaction between ascorbic acid and iodine occurs in a 1:1 mole ratio. The group should prepare a standard iodine solution that is approximately 0.005*M* and use the solution to titrate 10 mL or 25 mL samples of each liquid. Students may prepare the solution accurately, or they may prepare a solution that is approximately 0.005*M* and standardize it against 25.0-mg samples of reagent-grade ascorbic acid dissolved in distilled or deionized water. Students may prepare a starch solution to indicate the endpoint of each titration, or you may purchase a commercial starch solution for that purpose.