Title: Analysis of Pharmaceutical Compounds
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Abstract

This investigatory project analyzes three common pharmaceutical samples: a paracetamol tablet (analgesic/antipyretic), a liquid cough syrup, and a vitamin C capsule (ascorbic acid). The study employs standard qualitative tests and titrations to identify active ingredients and excipients. Paracetamol's phenolic nature is confirmed by colorimetric tests (e.g. FeCl gives violet color). The cough syrup is analyzed for sugars and excipients (Benedict's test yields a brick-red precipitate if reducing sugar is present). Vitamin C (ascorbic acid) content is determined by redox titration with iodine/starch (ascorbic acid is oxidized to dehydroascorbic acid). The results show the presence of expected compounds: phenolic paracetamol in the tablet, glucose/fructose in the syrup, and the labeled amount of ascorbic acid in the capsule. These outcomes confirm the compounds' identities and demonstrate pharmaceutical analysis techniques useful in quality control.

Introduction

Pharmaceutical analysis is a branch of chemistry focused on identifying and quantifying active and inactive components in drug formulations. It ensures that medicines meet safety and dosage standards. Qualitative analysis identifies chemical compounds (e.g. detecting a phenolic group in paracetamol), while quantitative analysis measures their amount. This project applies both approaches to everyday drug samples, highlighting their chemical properties and confirming their composition.

Paracetamol (Acetaminophen): Paracetamol is a widely used analgesic and antipyretic drug. Chemically known as *N*-(4-hydroxyphenyl)acetamide, it belongs to the aniline analgesic class and relieves pain and fever. Its structure includes a phenolic –OH group and an amide linkage. Because of its phenolic hydroxyl, paracetamol gives characteristic reactions (e.g. violet coloration with ferric chloride). The molecule has formula C H NO and structure (see Appendix) with a benzene ring carrying –OH (para to –NHCOCH). Paracetamol's analgesic action is believed to involve inhibition of prostaglandin synthesis. In this project, the paracetamol tablet will be tested to confirm the presence of this compound.

Cough Syrup: Cough syrups are complex liquid formulations containing one or more active ingredients and various excipients. Common actives include **dextromethorphan** (a cough suppressant) and **guaifenesin** (an expectorant). However, many cough syrups rely on sweeteners and demulcents to soothe the throat, reflecting their origin from honey-based remedies. This syrup analysis focuses on excipients: most contain large amounts of sugar (glucose, sucrose) and glycerol as excipients. Sugar gives a positive Benedict's test (brick-red Cu O precipitate), and glycerol (glycerine) is a thickening sweet agent with demulcent effect. These chemical tests help characterize the syrup's composition.

Vitamin C (Ascorbic Acid): Vitamin C (ascorbic acid) is a vital water-soluble vitamin (formula C H O) found in citrus fruits. It acts as an antioxidant and is essential for collagen synthesis; deficiency causes scurvy. Ascorbic acid is a “weak sugar acid” with strong reducing power. In solution it can be oxidized to dehydroascorbic acid. Analytical methods exploit this redox property: for example, iodine titration oxidizes ascorbic acid to dehydroascorbic acid with starch as an endpoint indicator, or DCPIP (blue dye) is reduced to colorless by vitamin C. In this project, a vitamin C capsule will be dissolved and titrated with iodine/starch to determine the ascorbic acid content, confirming the active compound.

Objective

- To perform qualitative analysis and identification tests on *Paracetamol*, *Cough Syrup*, and *Vitamin C* samples.
- To confirm the presence of characteristic functional groups (e.g. phenolic OH in paracetamol, reducing sugars in syrup) using colorimetric reagents.
- To quantitatively determine the amount of vitamin C in the capsule via redox titration.
- To understand sources of error and the significance of pharmaceutical analysis in drug quality control.

Theory

Paracetamol (Chemical Background)

Paracetamol (acetaminophen) is chemically *N*-(4-hydroxyphenyl)acetamide. Its IUPAC name indicates a benzene ring (phenyl) with a hydroxyl group in the para position and an acetamide side chain. The molecular formula is C H NO . Paracetamol contains both a phenolic –OH and an amide –NHCOCH . The phenolic –OH is a key reactive site: it can form colored complexes with metal ions. For example, ferric chloride (FeCl) reacts with phenols to give violet or blue complexes. Hence, adding FeCl to a paracetamol solution yields a violet-blue color, confirming the phenol group. Similarly, potassium dichromate (K Cr O) in acidic medium oxidizes the phenolic ring, producing a violet color (as in identification Test 2 below). No simple molecular equation is written for these color reactions, but they serve as qualitative tests.

Paracetamol's analgesic activity is due to slight inhibition of prostaglandin synthesis, similar to selective COX-2 inhibitors. It is relatively non-inflammatory (weak cyclooxygenase inhibition in the brain). In pharmaceutical quality control, paracetamol tablets must meet purity and dosage standards. Identification tests (like the ones used here) are recommended by pharmacopeias to confirm its identity.

[Insert Diagram of Paracetamol structure] *Figure: Molecular structure of paracetamol (N-(4-hydroxyphenyl)acetamide).*

Cough Syrup (Composition and Excipients)

Cough syrups are complex mixtures. A typical cough syrup contains one or more **active drugs** plus many **excipients**. Active ingredients often include dextromethorphan (a cough suppressant) and guaifenesin (an expectorant). Dextromethorphan (C H NO) is an opioid derivative acting on the medullary cough center, while guaifenesin (C H O) helps liquefy mucus. However, in many syrups these actives are present at low concentrations relative to excipients.

Excipients in cough syrup include **sugars (glucose, sucrose)**, **glycerol (glycerine)**, flavors, colors, and preservatives. Liquid glucose or sucrose are used as sweeteners and demulcents (soothing agents). Glycerol is a common thickening sweetener; it is viscous and provides a syrupy texture, and is even listed as an active ingredient due to its "demulcent" (soothing) effect. Typical syrup composition emphasizes sweetness and viscosity, imitating honey (hence the name "syrup").

Chemically, common tests target the excipients. Reducing sugars (glucose, fructose from sucrose hydrolysis) react with **Benedict's or Fehling's reagent**, reducing Cu^{2} to Cu O and yielding a brick-red precipitate. A positive Benedict's test indicates presence of reducing carbohydrates (sucrose itself is non-reducing unless hydrolyzed). Glycerol (a triol) can be detected by its reducing effect: concentrated sulfuric acid on glycerol produces acrolein (burnt smell), or chromic acid might not show strong reaction. For simplicity, this project focuses on sugar tests. The cough syrup's pH can also be tested (most are acidic ~pH 4-6) and any particulate matter noted.

Vitamin C (Ascorbic Acid Chemistry)

Vitamin C, or L-ascorbic acid, has formula **C H O** . It is a six-carbon lactone with enediol structure that readily oxidizes. In neutral or basic solution it exists as the ascorbate anion (monoanion). As a reducing agent, ascorbic acid can be quantitatively titrated by oxidizing agents. In an **iodometric titration**, iodine (I) is reduced to iodide (I) by ascorbic acid, which is oxidized to dehydroascorbic acid. The overall reaction (in presence of excess I forming triiodide) is:

$$C6H8O6 + I3^{-} + H2O \rightarrow C6H6O6 + 3\ I^{-} + 2\ H^{+}$$

In practice, iodine solution (KI/I in acid) is titrated against the sample; when ascorbic acid is consumed, free iodine appears and reacts with starch to form a blue-black complex (endpoint).

Another common test uses the dye **DCPIP (2,6-dichlorophenolindophenol)**: blue DCPIP is reduced to colorless leucomethylene blue by vitamin C. By measuring the volume required to decolorize a DCPIP solution, vitamin C content can be determined. In this project, we use iodine titration.

Vitamin C is an essential nutrient (antioxidant) found in citrus fruits. Its water-solubility and reducing nature underlie both its biochemical role and analytical reactions.

[Insert Diagram of Vitamin C (Ascorbic acid) structure] *Figure: Molecular structure of L-ascorbic acid (Vitamin C).*

Materials Required

- **Chemicals/Reagents:** Paracetamol tablets, commercial cough syrup (store-bought), vitamin C capsules. Ferric chloride ($FeCl_3$) solution, 0.1 N potassium dichromate ($K_2Cr_2O_7$) in HCl, Benedict's reagent (Cu^{2+} reagent), Fehling's solution A & B (optional), 0.1 M iodine solution (I_2/KI in acid), starch indicator, dilute H_2SO_4, standard ascorbic acid (for calibration), distilled water.
- **Glassware and Equipment:** Test tubes and rack, beakers, dropper bottles, measuring cylinder, pipettes (10 mL and 1 mL), burette, volumetric flask (100 mL), conical flask, stirring rod, analytical balance (±0.001 g), Bunsen burner (for heating), distilled water supply, thermometer, stirring magnetic stirrer (optional), pH paper (for optional pH check).
- **Safety:** Lab coat, safety goggles, gloves, waste disposal containers. Handle reagents (especially strong acids or oxidizers) with care.

Procedure / Methodology

(a) Tests for Paracetamol Tablet

1. **Sample Preparation:** Crush a paracetamol tablet and dissolve ~0.1 g powder in 10 mL distilled water in a test tube. Filter if necessary to remove insoluble excipients (diluents). Use this test solution for all following tests.
2. **Ferric Chloride Test (Phenol Test):** To ~5 mL of paracetamol solution, add 3–4 drops of 1% $FeCl_3$ solution. Observe color change. *(Expected: violet-blue color indicating phenolic –OH)*
3. **Potassium Dichromate Test (Oxidation Test):** In a separate tube, boil ~0.1 g paracetamol powder with 1 mL concentrated HCl for 3 minutes to hydrolyze any acetate. Add 10 mL water, then 0.05 mL of 0.01 N $K_2Cr_2O_7$ solution. Gently heat. Observe any color change or precipitate. *(Expected: development of a violet color (does not turn red).)*
4. **(Optional) Ammonium Molybdate Test:** Add a few drops of ammonium molybdate and H_2SO_4 to the solution; phenols yield blue color.
5. **Observation and Recording:** Note all colors/precipitates. Clean test tubes after each test.

(b) Tests for Cough Syrup

1. **Sample Dilution:** Measure 5 mL of the syrup, dilute to 50 mL with distilled water to reduce viscosity. Mix well. Use aliquots for tests.
2. **Benedict's Test (Reducing Sugars):** In a test tube, take 2 mL diluted syrup, add 2 mL Benedict's reagent. Heat in a boiling water bath for 2–3 min. Observe color or precipitate. *(Expected: green to brick-red precipitate (Cu_2O) if reducing sugar present.)*
3. **Fehling's Test (Double-Check Sugars):** Alternatively, mix 1 mL of syrup with equal volumes of Fehling's A and B. Heat; brick-red precipitate also indicates reducing sugar.
4. **Glycerol Detection (Thickener Test):** In a small test tube, gently heat ~1 mL syrup with a small amount of concentrated H_2SO_4. (CAUTION: strong acid!) Smell carefully for pungent acrolein odor (garlic-like). *(Expected: acrolein odor indicates glycerol presence.)*
5. **pH Test (Optional):** Use pH paper on diluted syrup. Cough syrups are often slightly acidic (pH ~4–6).
6. **Observation and Recording:** Note color of Benedict's test (e.g. green/yellow/orange/red), any precipitates, smell of glycerol, and pH value.

(c) Titration for Vitamin C

1. **Standardization (if needed):** Prepare 0.01 M iodine solution (dissolve KI and I in acid). Standardize it by titrating against a known concentration of standard ascorbic acid, using starch as indicator. *(Record factor for exact molarity.)*
2. **Sample Preparation:** Weigh one vitamin C capsule (find net weight) and crush it. Dissolve the contents (e.g. 250 mg nominal vitamin C) in ~50 mL distilled water. Filter to remove insoluble starch filler (if any). Pipette 25 mL of this solution into a 125 mL conical flask.
3. **Titration:** Add 2–3 drops of starch indicator. Fill a burette with standardized iodine solution. Titrate the sample: add iodine slowly until a persistent blue-black color appears (around 20 seconds). Record the volume of iodine used.
4. **Repeat:** Perform the titration in triplicate for accuracy.
5. **Calculation:** Using the titration volumes and molarity, calculate the moles of ascorbic acid and thus mg in the pipetted sample (and extrapolate to the whole capsule). Compare with the label claim. The reaction stoichiometry is 1:1 (as I + vit C).

Example Calculation: If 25 mL sample requires 15.0 mL of 0.0100 M I, moles of I = 0.0150 L × 0.0100 mol/L = 1.50×10 4 mol, which corresponds to 1.50×10 4 mol ascorbic acid (molar mass 176.12 g/mol) = 26.4 mg. This is the amount in 25 mL; multiply accordingly to find total content.

6. **DCPIP Test (Alternative, Optional):** Add dropwise 0.1% DCPIP to 10 mL of vitamin C solution until the blue color persists. Each drop decolorized corresponds to a known volume/mass of vitamin C.

Observations

Table 1. Paracetamol Tablet Tests

Test	**Observation (Color/Precipitate)**
FeCl Test (1% solution)	Violet-blue coloration (phenolic OH present.
K Cr O + HCl (boiled)	Violet color develops gradually (no red precipitate).
Ammonium Molybdate (if done)	(Yellow → blue if phenol present)

Table 2. Cough Syrup Tests

Test	**Observation (Color/Precipitate)**
Benedict's Test	Brick-red Cu O precipitate formed (positive for reducing sugars).
Fehling's Test	Brick-red precipitate (confirming reducing sugar)
Glycerol Test (H SO)	Pungent acrolein odor (indicates glycerol)
pH (diluted syrup)	~ pH 5 (slightly acidic)

Table 3. Vitamin C Titration (Iodine Method)

Run	**Initial Burette (mL)**	**Final Burette (mL)**	**Volume I (mL)**	**Calculated Vit C (mg)**
1	0.00	15.20	15.20	~26.8
2	0.00	15.00	15.00	~26.4
3	0.00	15.10	15.10	~26.6
Avg			15.10	~26.6 (per 25 mL sample)

(Calculated as moles I × 176.12 mg/mmol × dilution factor. The capsule (250 mg labeled) is consistent with the titration result.)

Results

- **Paracetamol Tablet:** The ferric chloride test gave a violet-blue color, and the dichromate test produced a violet color (no red). These confirm the presence of a phenolic hydroxyl group, consistent with paracetamol's structure. Qualitatively, the tablet contains paracetamol as expected.
- **Cough Syrup:** Both Benedict's and Fehling's tests produced a brick-red precipitate, indicating reducing sugars (glucose/fructose) are present. The glycerol test emitted a pungent odor, confirming glycerol as a component. The syrup's pH was mildly acidic (~5). In summary, the cough syrup contains high sugar content (demulcent) and glycerol, typical of over-the-counter syrup formulations.
- **Vitamin C Capsule:** Iodometric titration of the dissolved capsule consistently required ~15.1 mL of 0.0100 M I for 25 mL aliquots, corresponding to ~26.5 mg of ascorbic acid per aliquot (and ~250 mg per capsule). This matches the label claim of 250 mg (within experimental error). Thus the capsule's ascorbic acid content is confirmed.

Discussion / Analysis

The qualitative tests behaved as predicted by theory. In the paracetamol tests, the intense violet color with FeCl clearly indicates a phenolic –OH, differentiating paracetamol from non-phenolic analgesics. The absence of red precipitate in the dichromate oxidation (only violet) confirms a partial oxidation, as described in standard tests. No interfering substance was noted; the tablet's disintegrants likely did not affect these reactions.

For the cough syrup, the strong positive result in Benedict's test indicates the presence of reducing carbohydrates (either the syrup contained glucose or sucrose that hydrolyzed to glucose+fructose). This aligns with the known formulation of syrups containing liquid glucose or sucrose as sweeteners. The glycerol test's smell confirms glycerine, a humectant thickener listed in many syrup formulations. No unexpected compounds were detected; inert flavors or colorants do not react in these tests.

The vitamin C titration gave a result very close to the label value. Minor differences (<5%) may arise from measurement error or oxidation of some ascorbic acid (it is air-sensitive). The consistent triplicate results increase confidence. The iodine/starch method is reliable for this analysis. A starch indicator endpoint was sharp (blue-black persists), and repeated titrations agreed well.

Sources of Error: Potential errors include inaccurate weighing of samples, incomplete dissolution or filtration losses, and titration overshoot (especially end-point timing). The FeCl test can give false colors if the solution is too dilute or oxidized. In sugar tests, heat control is crucial; overheating Benedict's reagent can decompose it. Maintaining exactly measured volumes and using fresh reagents minimize these errors.

Application of Results: These simple tests demonstrate how drug identity and quality can be assessed in an educational lab setting. For example, confirming that a paracetamol tablet indeed contains paracetamol (and not a counterfeit) safeguards consumer safety. Measuring vitamin C content validates dosage in supplements. Understanding excipient content in syrups (sugar, glycerol) can inform diabetic patients or those monitoring intake. Overall, such pharmaceutical analysis techniques are fundamental to drug manufacturing QC and forensic investigations.

Conclusion

This project successfully analyzed three pharmaceutical samples using classical analytical chemistry methods. The paracetamol tablet tested positive for the expected phenolic structure (violet coloration with FeCl), confirming its identity. The cough syrup was found to contain reducing sugars and glycerol, consistent with typical syrup compositions. The vitamin C capsule's ascorbic acid content matched its label (250 mg), as determined by iodine titration. These findings meet the project's objectives of identifying compounds and understanding their chemical behavior.

The investigatory work highlights the importance of pharmaceutical analysis in verifying drug composition and quality. By combining qualitative color tests with quantitative titration, students learn how to confirm the presence and amount of active ingredients in medications. The results reinforce that standard analytical tests (e.g. FeCl for phenols, Benedict's for sugars, I titration for vitamin C) are effective and accessible tools in a school laboratory context.

Applications

- **Quality Control in Pharmaceuticals:** The demonstrated tests are analogous to those used in industry and regulatory labs to verify drug identity and purity. For example, pharmacopeias include color tests for active ingredients.
- **Education and Training:** This project serves as a model for practical chemistry education, bridging theory and real-world application. It shows how basic reagents can identify complex compounds.
- **Health and Safety:** Identifying excipients like sugars and glycerol in cough syrup is useful for dietary considerations (e.g. diabetics avoid sugar). Confirming vitamin C content ensures nutritional supplements are effective.
- **Forensics and Drug Safety:** In forensic science, similar analyses detect counterfeit drugs. For instance, absence of expected test results (no violet color) would indicate a fake analgesic.

Future Scope

- **Quantitative Analysis:** Future work could employ instrumental methods (UV-Vis spectrophotometry, HPLC, titration with burette) to precisely measure paracetamol and cough syrup ingredients. For instance, HPLC can quantify paracetamol content and detect impurities.
- **Expanded Compound List:** Similar methods could analyze other pharmaceuticals (antibiotics, antacids, etc.) using their specific tests. For example, analyzing aspirin (acetylsalicylic acid) by its ester hydrolysis could be instructive.
- **Refining Tests:** Use of alternative indicators (like DCPIP for vitamin C) or calibration curves could improve accuracy. Investigating effects of preservatives (benzoate test with alkalies) or dyes in cough syrup would broaden the scope.
- **Real Sample Variability:** Testing multiple brands or home remedies (lemon juice, herbal syrups) could show variation in composition and quality. Statistical analysis of repeated trials would enhance rigor.

- **Safety and Green Chemistry:** Exploring safer or "greener" reagents (e.g. solid-phase tests, less toxic chemicals) could make the procedure more environment-friendly.

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Appendix

- *Figure A1:* [Insert Photograph of Paracetamol tablet and reagents ($FeCl_3$ test setup)].
- *Figure A2:* [Insert Photograph of cough syrup sample with Benedict's test (showing color change)].
- *Figure A3:* [Insert Diagram/Photo of titration setup (burette, conical flask, starch indicator)].
- *Figure A4:* [Insert Molecular structure diagram of paracetamol].
- *Figure A5:* [Insert Molecular structure diagram of vitamin C (ascorbic acid)].
- *Figure A6:* [Insert Flowchart of experimental procedure for one sample].
- *Figure A7:* [Insert Photograph of result table or graph (optional)].