Extractive spectrophotometric determination of copper(II) and its applications in pharmaceutical samples and alloys

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A new reagent isonitrosopropiophenone thiosemicarbazone (HINPTC) is proposed for extraction and spectrophotometric determination of copper. The reagent HINPTC reacts with copper to give yellow coloured complex, which can be quantitatively extracted into isooamyl alcohol at pH 10. The organic extract shows maximum absorption at 390 nm where absorption due to a similarly prepared reagent blank is negligible. The Beer’s law is followed in the concentration range 0.5-6.0 µg/mL of copper. The molar absorptivity and Sandell’s sensitivity of Cu(II)-HINPTC complex are $5.826 \times 10^3$ /mol/cm and 0.010 µg/mL/cm$^2$, respectively. The stoichiometry of extracted species is found to be 1:2 (M : L). The proposed method is rapid, sensitive, reproducible and is applied for the determination of copper in synthetic mixtures and real samples like pharmaceuticals, aluminium alloys (Al chips and Al pins), and brass ash. It also provides a relative inexpensive alternative to more expensive instrumental method like AAS.

Keywords: Copper determination, Isonitrosopropiophnone thiosemicarbazone, Extractive spectrophotometry, Separation

IPC: Int Cl.: C 01, A 61L

Introduction

The major portion of the world’s production of copper is utilized by the electrical industries. Because of its excellent electrical conductivity, it is a dominant electrical material. Copper is present in all body tissues, but liver, brain, heart, and kidney contain the maximum amounts. Excess of copper concentration can cause adverse effect on the human body. The diseases that arise due to the deficiency of copper are anemia and hair kinkly, while excess of copper can result into a disease like jaundice. There is always, therefore, a need for better, rapid, sensitive and selective methods for determination of Cu(II). Atomic absorption spectrometric (AAS) method for routine estimation of copper is expensive. Several complexing agents have been reported for the extraction and spectrophotometric determination of copper$^{1-9}$. However, these methods suffer from various limitations such as, heating required$^1$, long time for colour development$^2$, long extraction period$^3$, small Beer's range$^4$-5, use of optical fiber$^6$ and interferences from many ions$^7$-9. In the present method, isonitrosopropiophenone thiosemicarbazone (HINPTC) has been used as a new analytical reagent for the extraction and spectrophotometric determination of copper. Also, with increasing importance of thio compounds as a superior chelating agent/extractants with potential medicinal application and the recent upsurge in the use of coordination compounds in industry and medicine makes the method interesting as it can be employed for efficient copper determination at trace level in various synthetic, pharmaceutical, and alloys samples. The results obtained were compared with those obtained by known method (Sodium diethyldithiocarbamate) and with certified values of copper. The proposed method is sensitive, rapid, and free from many limitations.

Materials and Methods

Instruments

An Elico pH-meter was employed for the pH measurements while absorbance measurements were carried out on Bausch and Lomb spectrophotometer (Spectronic-20).

Chemicals

A stock solution of copper(II) (5000 µg/mL) was prepared by dissolving calculated amount of CuSO$_4$.5H$_2$O in doubly distilled water containing 2 mL of conc. H$_2$SO$_4$. The solution was then diluted to
250 mL with distilled water and standardized by known method\textsuperscript{11}. Dilute solutions were prepared from this stock solution, as required. The reagent HINPTC was synthesized by the procedure reported in the literature by the reaction of isonitrosopropiophenone with thiosemicarbazide in the presence of glacial acetic acid\textsuperscript{12}. 0.5 per cent reagent solution in DMF was used for all extraction studies.

**Development of Method**

To an aliquot of Cu(II) solution was added 1 mL of 0.5 per cent solution of HINPTC in DMF, followed by 1 mL of borate buffer to adjust the pH to 10.0. The volume was made up to 10 mL with distilled water and equilibrated with 10 mL of isoamyl alcohol for 30 s. The yellow coloured organic phase was separated and anhydrous sodium sulphate was added to remove traces of water. The absorbance of the organic phase was measured against a similarly prepared reagent blank at 390 nm. The amount of copper present was computed from the standard calibration curve.

**Effect of Diverse Ions**

Copper(II) could be extracted in the presence of large number of foreign ions. Under the optimum experimental condition, the effect of diverse ions on the extraction of copper(II) (30 µg) was investigated. The solutions of diverse ions, required for interference studies, were prepared by dissolving their commonly available chemically pure salts in distilled water or in dilute acids to give \( \leq 10 \text{ mg/cm}^3 \) conc. of the cations and \( \leq 20 \text{ mg/cm}^3 \) concentration of the anions.

**Determination of Copper in Synthetic Mixtures**

The usefulness of the method developed was demonstrated by determination of copper in various synthetic mixtures of associated elements (Table 1). The results obtained were in good agreement with those obtained by known technique.

<table>
<thead>
<tr>
<th>Sl No.</th>
<th>Name of sample</th>
<th>Cu found by present method*</th>
<th>Cu found by known method\textsuperscript{©}</th>
<th>Certified value</th>
<th>Standard deviation</th>
</tr>
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<td>Synthetic mixture#</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>1</td>
<td>Cu(20), Cd(50), Zn(100)</td>
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<td>2</td>
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<td>19.92</td>
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<td>Cu(20), Mn(50), Zn(20)</td>
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<td>6</td>
<td>Supradyn (Nicholas piramal)</td>
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<td>0.861</td>
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<td>7</td>
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<td>8</td>
<td>Mitovit Alloys samples\textsuperscript{b}</td>
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<td>0.635</td>
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<tr>
<td>9</td>
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<td>5.43</td>
<td>5.44</td>
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<tr>
<td>10</td>
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<tr>
<td></td>
<td>Brass ash\textsuperscript{b}</td>
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<tr>
<td>11</td>
<td>Ita Lab/748</td>
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<td>0.099</td>
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<td>13</td>
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<td>5.34</td>
<td>0.014</td>
</tr>
</tbody>
</table>

# Values are in µg. * Mean of five determinations b values are percentage, © sodium diethyl dithiocarbamate method, ® Values in mg
Determination of Copper in Pharmaceutical and Alloys

Samples

The pharmaceutical sample was treated with (5+5) mL of aqua-regia and heated to near dryness, followed by treatment with 1 mL HClO4 to decompose organic matter. Finally the residue obtained was extracted with 10 mL of 2.0 M HNO3, the solution filtered and diluted to known volume. Suitable aliquots of this solution were used for copper determination. Replicate analyses were carried out. Interfering ions were masked by using suitable masking agent. The results are shown in Table 1.

Different alloy samples were analyzed for copper content. Brass ash sample was dissolved in (5+5) mL aqua-regia, evaporated to minimum volume and extracted with 10 mL of 2.0 M HNO3 and diluted to known volume with double-distilled water. A suitable aliquot was taken for the estimation of copper for replicate analyses.

Aluminium chips and pins samples were dissolved by heating with 5-7 mL conc. HCl and 2 mL HNO3. The solution was evaporated to almost dryness. The residue was extracted in 20-25 mL of distilled water and diluted to known volume. A suitable aliquot of this dilute solution was employed for copper determination by the method developed in present work. The results are shown in Table 1.

Analyses of samples were also carried out by sodium diethyldithiocarbamate method.

Results and Discussion

The absorption spectrum of copper(II)–HINPTC complex, extracted into isoamyl alcohol recorded against a similarly prepared reagent blank showed an absorption maximum at 390 nm (Figure 1, Curve A), where absorption due to the reagent blank was negligible (Figure 1, Curve B). Hence, all absorption measurements were carried out at 390 nm against a similarly prepared reagent blank.

The effect of pH on the extraction of copper(II) into isoamyl alcohol was studied over a wide pH range. It was found that the complex could be quantitatively extracted in the pH range of 9.5-10.2 where percentage extraction was found to be over 99.55 per cent. A pH of 10.0 was therefore employed in the subsequent studies. The reagent was always added prior to pH adjustment to avoid precipitation.

The effect of HINPTC concentration was studied by carrying out extraction at fixed pH (pH: 10.0) but at varying concentration of reagent. 1.0 mL of 0.1 per cent of the reagent in DMF was found to be sufficient for the quantitative extraction of copper(II) into isoamyl alcohol. Excess of reagent does not have any significant effect on the recovery of copper. 1 mL of 0.2 per cent reagent was therefore used for further studies.

Copper(II) was extracted with HINPTC into various solvents like, chloroform, carbon tetrachloride, benzene, toluene, xylene, n-butyl alcohol, n-butyl acetate, and isoamyl alcohol. The extraction of copper(II) was quantitative in isoamyl alcohol (99.55 per cent), which was therefore selected as solvent for further studies.

To a sample solution containing 30µg of copper(II), 1.0 mL of 0.2 per cent HINPTC solution in DMF and various amounts of the borate buffer solution (pH: 10.0) were added and the extraction with isoamyl alcohol was carried out by the general procedure. The absorbance remained constant for the use of 0.8–1.0 mL of the buffer solution. 1.0 mL of buffer solution was therefore used in all the experiments.

The colour development was instant, however, shaking period was varied between 15–200 s. The optimum period of shaking required for the complete transfer of the coloured complex into organic phase
was found to be 30 s. The studies on the absorbance of the organic extract at different time intervals revealed that the extracted Cu(II)-HINPTC complex was stable for 6 h.

The absorbance of the extracted species was a linear function of copper concentration in the range of 0.5-6.0 µg/mL for copper (II) at 390 nm. The optimum working range, obtained from Ringbom’s plot was found to be 1.0–6.0 µg/mL. Regression coefficient was 0.99 that confirmed that the beer’s range is linear. The Sandell’s sensitivity of the method was found to be 0.01 µg/mL/cm², while the molar absorptivity was 5.826 x 10³ L/mol/cm.

The tolerance limits for the diverse ions investigated were as follows: Tartarate, citrate, oxalate, F⁻, Cl⁻, Br⁻, I⁻, NO₃⁻, NO₂⁻, SO₃²⁻, SO₄²⁻, ClO₃⁻, HPO₄²⁻, BrO₃⁻, IO₃⁻, CO₃²⁻, HCO₃⁻, S₂O₃²⁻, S₂O₄²⁻, SCN⁻, Urea (20 mg each); Na⁺(I), K⁺(I), Li⁺(I), Al(III), Ca(II), Ti(III), W(VI), Mg(II), Mo(VI), Cr(VI), and U(VI) (10 mg each); V(V), Cd(II), and Sn(II) (5 mg each); Bi(III) and Hg(II) (0.1 mg, removed with thiocynate); Co(II) interfered seriously. The tolerance limit was set as the amount of foreign ion that causes an error of not more than ± 2 per cent in the percentage recovery of the metal ion.

The precision and accuracy of the method were determined by analyzing 10 sample solutions of same concentration. The average of ten determinations of 1 mL of stock solution of copper (30 µg/mL) was found to be 30.12 µg with a standard deviation of 0.412 and the deviation from mean at 95 per cent confidence limit was ± 0.294.

The nature of the extracted copper(II) - HINPTC complex was ascertained by the Job's continuous variation method and was found to be 1:2 (M : L) i.e. Cu[HNPTC]₂. This was confirmed by the mole ratio method, which shows sharp break corresponding to mole ratio 1:2. The reaction of copper(II) with the reagent may therefore be represented as follows:

\[ \text{Cu(II)} + 2\text{HINPTC} \rightarrow \text{Cu [INPTC]}_2 + 2\text{H}^+ \]

here INPTC⁻ represents deprotonated ligand.

**Conclusion**

The proposed method can be used for precise determination of copper at microgram level. It offers advantages like, reliability, reproducibility, and good sensitivity, in addition to being simple and instant colour development, and minimum interferences. The method has been successfully applied for the determination of copper at trace level in synthetic mixtures, pharmaceutical samples, and alloys. The results obtained are in good agreement with the certified values and are comparable to those obtained by known method. The method has thus good potential for use by the industry.

**References**

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