

Percent Copper in Brass

AP® Chemistry Big Idea 1, Investigation 2

An Advanced Inquiry Lab

Introduction

The relative proportions of copper, zinc and iron in brass influence its properties and uses. How can the percent composition of brass be determined to verify these properties?

Concepts

- Spectroscopy
- Beer's law
- Concentration
- Absorbance
- Calibration curve
- Electron transitions

Background

Brass is a generic term for alloys of copper and zinc. In addition to these metals, brass may also contain small amounts of iron, lead, aluminum and tin. More than 300 different brass alloys are known, with uses ranging from decorative hardware to architectural construction, musical instruments, and electrical switches. The amount of copper in brass affects its color, hardness, ductility, mechanical strength, electrical conductivity, corrosion resistance, etc. Visible spectroscopy provides a simple tool for determining the percent copper in brass.

Spectroscopy involves the interaction of electromagnetic radiation and matter. The absorption of electromagnetic radiation results in different types of transitions in a substance, depending on the energy of the radiation. Low energy microwave radiation, for instance, is converted to energy of molecular rotation. Absorption of infrared radiation excites vibrational frequencies associated with covalent bonds in a molecule. Visible and ultraviolet light cause electron transitions between different electron energy levels in a substance. The energy of electromagnetic radiation is quantized, as are the energy levels associated with various transitions, whether rotational, vibrational or electronic. Furthermore, the energies of these transitions are characteristic of an atom, molecule or compound. As a result, the absorption spectra of substances generally consist of specific lines or bands that can be used as a type of fingerprint to identify a substance.

Transition metal ions have filled or partially filled d orbitals. The presence of water molecules or other ligands surrounding a transition metal ion in solution leads to energy differences among the d orbitals. Depending on the metal ion involved, the energy difference may correspond to different wavelengths and energies of visible light. This property of transition metal ions gives many their characteristic—and beautiful—colors.

The concentration of a colored transition metal ion solution can be determined by measuring the color intensity. A visible spectrophotometer is used to measure the absorption of visible light. In general, absorbance is proportional to concentration. The higher the concentration of a transition metal ion solution, the more intense its color will be, and the greater its absorbance. The linear relationship between absorbance (A) and concentration (c) is expressed in Beer's law, Equation 1, where b is the path length in cm and ϵ is a proportionality constant. If c is given in units of molarity (M = moles/L), then ϵ is known as the molar absorptivity coefficient, with units $M^{-1} \text{ cm}^{-1}$.

$$A = \epsilon bc \quad \text{Equation 1}$$

Beer's law can be used to determine the "unknown" concentration of a metal ion in solution if its absorbance is measured. The most accurate way to do this is by means of a standard graph called a *calibration curve*. Plotting absorbance versus concentration for a series of standard solutions, gives rise to a straight line that passes through the origin (see Equation 2).

$$y = mx + b, \text{ where } y = \text{absorbance, } x = \text{concentration, and } b = 0 \quad \text{Equation 2}$$

Using a calibration curve for quantitative analysis evens out fluctuations due to random error and establishes the range of concentration values over which Beer's law is valid.

Chemfax Labs Answers

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