

UNIT 4 PERFORMANCE TASK: CHEMICAL ANALYST FOR A DAY

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Prediction

- (a) After the experimental sample is passed through a Brita water filter (or similar ion-exchange resin), the $[\text{Ca}_{(\text{aq})}^{2+}]$ should be lower.

Materials

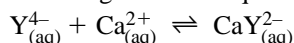
- (b)
- Brita water filter (or similar ion-exchange resin)
 - funnel
 - two 250-mL beakers
 - ring clamp and stand

Procedure

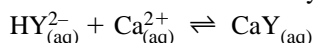
- (c) Two identical samples of hard water are obtained. One is kept as the control; the other is passed through the Brita water filter and collected.

Analysis

- (d) The chemical formula of the EDTA ion can be written as $\text{Y}_{(\text{aq})}^{4-}$. EDTA chelates (or binds) metal ions by forming up to six attractions with the metal ion (see Figure 1): four attractions with the oxygen ends of EDTA and two with the nitrogen atoms. During the titration, EDTA, in the form $\text{Y}_{(\text{aq})}^{4-}$ combines in a 1:1 ratio with calcium as given by the following chemical equation:



EDTA is also commonly available as the disodium salt. If this version of EDTA is used, the equilibrium becomes:



- (e)

	Tap water	Treated water
volume of 0.0100 mol/L EDTA:	4.40 mL	1.60 mL

Tap water analysis:

$$\begin{aligned} n_{\text{EDTA}_{(\text{aq})}} &= C_{\text{EDTA}_{(\text{aq})}} \times V_{\text{EDTA}_{(\text{aq})}} \\ &= 0.0100 \text{ mol/L} \times 4.40 \text{ mL} \end{aligned}$$

$$n_{\text{EDTA}_{(\text{aq})}} = 4.40 \times 10^{-2} \text{ mol/L}$$

Treated water analysis:

$$n_{\text{EDTA}_{(\text{aq})}} = 0.0100 \text{ mol/L} \times 1.60 \text{ mL}$$

$$n_{\text{EDTA}_{(\text{aq})}} = 1.60 \times 10^{-2} \text{ mol/L}$$

The calcium ion concentration in tap water decreased from $4.40 \times 10^{-2} \text{ mol/L}$ to $1.60 \times 10^{-2} \text{ mol/L}$ after being passed through a Brita water filter.

Evaluation

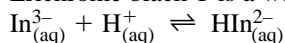
- (f) There were no obvious flaws or sources of error in the experimental design. One minor improvement would be to use a fresh supply of indicator to ensure that the colour change is as crisp as possible.
- (g) The prediction is judged to be adequate because the concentration of the water sample was lower as a result of being passed through the water filter.

Synthesis

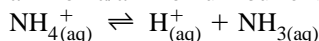
- (h) Both types of titrations involve indicators that are weak acids. The endpoint of each type of titration is signalled by an equilibrium shift of the indicator. However, the colour changes involved in EDTA titrations tend to be more sluggish than acid–base titration endpoints.

- $$\text{Ca}_{(\text{aq})}^{2+} + \text{H}_2\text{Y}_{(\text{aq})}^{2-} \rightleftharpoons \text{CaY}_{(\text{aq})}^{2-} + 2 \text{H}_{(\text{aq})}^{+}$$

Erichrome black T is a dark dye used to signal the endpoint of an EDTA titration. Like acid–base indicators, Erichrome black T is a weak acid (abbrev. $\text{HIn}^{2-}_{(\text{aq})}$) which is in equilibrium with its conjugate base, $\text{In}^{3-}_{(\text{aq})}$:


$$\text{CaIn}_{(\text{aq})}^{-} + \text{H}_{(\text{aq})}^{+} \rightleftharpoons \text{HIn}_{(\text{aq})}^{2-} + \text{Ca}_{(\text{aq})}^{2+}$$

(j) The sharpness of the endpoint increases with pH. However, there is an upper limit to how high the pH can be. If the pH is too high, calcium and magnesium ions begin to precipitate out of solution as $\text{CaCO}_{3(s)}$ and $\text{Mg(OH)}_{2(s)}$. As a result, a compromise of pH 10 is used for this titration. To maintain a constant pH during the titration, an ammonia/ammonium buffer solution is used. The buffering equilibrium involved is:



(k) EDTA can be found in a large variety of consumer and pharmaceutical products:

Meat products – EDTA prevents the discoloration of some meat products.

- arteriosclerosis (hardening of the arteries). EDTA removes calcium deposits, making the arteries flexible again.

- (1) The medical use of EDTA is not without risk. Large doses of EDTA can damage the kidneys. Also, EDTA can cause a drop in the blood sugar levels. This is a particular concern for diabetics who use zinc-based insulin.