and an indicator (such as eriochrome black T). The standard hardness reagent used for titration has an equivalent hardness of 1 mg/l per ml used.

The hardness of water can be classified according to table 7.4. Although high values of hardness are not organically dangerous, public acceptance of the water supply requires a hardness of well below 150 mg/l. Except for special industrial uses, potable water should have the carbonate hardness reduced to at least 40 mg/l, and the total hardness should be below 75 mg/l. Where it is economically feasible, the carbonate hardness should be reduced to 25 mg/l.

Table 7.4
Hardness Classifications

class	type	hardness
A	soft	below 60 mg/l
B	medium hard	60-120
C	hard	120-180
D	very hard	180-350
E	saline, brackish	above 350

Example 7.15

A 75 ml water sample required 8.1 ml of EDTA. What is the hardness?

$$\text{hardness} = \frac{(8.1)\,\text{ml}(1)\,\text{mg/l}}{(75/1000)} = 108\,\text{mg/l}$$

Example 7.16

Water is found to contain sodium (Na^+, 15 mg/l), magnesium (Mg^{++}, 70 mg/l), and calcium (Ca^{++}, 40 mg/l). What is the hardness?

Sodium is singly-charged, so it does not contribute to hardness. The approximate equivalent weights of the relevant compounds and elements are:

$$Mg : 12 \quad Ca : 20 \quad CaCO_3 : 50$$

The equivalent hardness is

$$(70)\left(\frac{50}{12}\right) + (40)\left(\frac{50}{20}\right) = 392\,\text{mg/l as } CaCO_3$$

Alternatively, appendix A could have been used to convert the ionic concentrations to $CaCO_3$ equivalents.

$$(70)(4.10) + (40)(2.50) = 387\,\text{mg/l as } CaCO_3$$

C. IRON CONTENT

Even in low concentrations, iron is objectionable because it stains bathroom fixtures, causes a brown color in laundered clothing, and affects taste. Water originally pumped from anaerobic sources may contain (Fe^{++}) ferrous ions which are invisible and soluble. When exposed to oxygen, insoluble (Fe^{+++}) ferric oxides form which give water the rust coloration.

Iron is measured optically by comparing the color of a sample with standard colors. The comparison can be made by eye or with a photoelectric *colorimeter*. Iron concentrations greater than 0.3 mg/l are undesirable.

D. MANGANESE CONTENT

Manganese ions are similar in effect, detection, and measurement to iron ions. Manganous manganese (Mn^{++}) oxidizes to manganic manganese (Mn^{++++}) to give water a rust color. An undesirable concentration is 0.05 mg/l.

E. FLUORIDE CONTENT

An optimum concentration of fluoride in the form of a fluoride ion, F^-, is between 0.8 mg/l for hot climates (80°F-90°F average) to 1.2 mg/l for cold climates (50°F average). These amounts reduce the population cavity rate to a minimum without producing significant fluorosis (staining) of the teeth. The actual amount of fluoridation depends on the average outside temperature since the temperature affects the amount of water that is ingested by the population.

Table 7.5
Maximum Fluoride Concentrations

(Note that the 1974 Safe Drinking Water Act and its 1986 amendments set the maximum fluoride concentration at 4 mg/l for all temperatures.)

5-year average of maximum daily air temperatures	fluoride concentrations
(deg F)	(mg/l)
50.0-53.7	2.4
53.8-58.3	2.2
58.4-63.8	2.0
63.9-70.6	1.8
70.7-79.2	1.6
79.3-90.5	1.4

Fluoridation can be obtained by the readily dissociating compounds in table 7.6.