Equilibrium Studies on Cadmium (II) Interactions with Aspirin and Vitamin C in Aqueous Medium

H.H.M.C.U. Herath and C.V. Hettiarachchi*

Department of Chemistry, Faculty of Science, University of Peradeniya

Introduction

Cadmium has been recognized as a toxic metal and can be poisonous to human beings, because it can directly influence the metabolic processes in the body. Cadmium, in various ways, can enter and accumulate in different body parts like kidney, liver, bones, etc. during the life time, as it has an exceptionally long biological half-life. Short-term exposure to moderate concentrations (200-500 μg/m^3) of freshly generated cadmium fume during less than 1 hour can cause symptoms similar to those of the metal fume fever. (www.euro.who.int) Though, cadmium toxicity in low levels can cause breathing difficulties, cough, fever and pains in body joints etc., accumulation of cadmium in very high concentrations in the body can cause renal failure, cancers, weakened immune system, anemia etc. (Kain and Schwederski, 1994)

Some of the drugs among analgesics, stimulants, and antibiotics, and vitamins have been identified as chelating agents, because of their ability of being good ligands. Although we take these drugs and vitamins to be healthy, they can form complexes with the metals in the body fluid as well. However, the conditions such as pH range, ionic strength and the temperature control the formation of stable complexes between ligands and metal ions. Aspirin and vitamin C are very popular and frequently bought drugs over the counter without medical prescription for the symptoms that are similar to those of cadmium toxicity and it is also possible that vitamin C can come from natural vegetables and fruits to our bodies.

The main objective of this research was the investigation of the interactions in cadmium-aspirin, cadmium-vitamin C and cadmium-Aspirin-Vitamin C complexes under physiological conditions.

Materials and methods

Calvin type pH titrations were carried out using a Biochrom C18 pH meter. The mixtures containing ligands (weak acids) and metal solutions in various concentrations and ratios were titrated against standard sodium hydroxide solutions in the presence of a strong acid (HCl) at a constant temperature (37.0 ± 0.2) °C. Sodium chloride was used to maintain the constant ionic strength (0.15 mol dm^{-3}) in the reaction mixture which ensured constant activity coefficients. Each reaction mixture contained a constant volume (20.00 cm^3) in the beginning of the titration. When [A^-] and $\tilde{n}$ were calculated to obtain average log K_1 and log K_2 values for each binary and ternary complex, volume change was corrected at each point. The equations given below were used for the calculation of stability constants (Irving and Rossotti, 1953).

$$K_1 = \frac{\tilde{n}}{(1-\tilde{n})[A^-]} \quad \text{for } ML_1 \text{ type}$$

$$K_2 = \frac{(\tilde{n}-1)}{(2-\tilde{n})[A^-]} \quad \text{for } ML_2 \text{ type}$$

[A^-] = Free ligand concentration in the reaction medium.

$\tilde{n}$ = average number of ligand molecules bound to the metal ion.

K_1 and K_2 = stability constants.

Results and discussion

Table 1 reveals the summary of the most important results. However, when the ligand and metal concentrations were 1.0 × 10^{-4} mol dm^{-3} and 0.5 × 10^{-4} mol dm^{-3}, respectively, both vitamin C and aspirin did not form complexes under any acidic conditions.

When both ligands were present in the reaction mixtures, either in 1:1 or 1:2 or 2:1 ratios with different metal concentrations (0.5 × 10^{-4} – 1.0 × 10^{-2} mol dm^{-3}), ternary complex systems of

MLX type were formed via either ML or MX binary complexes. In the statistical comparison of the stabilities of ternary systems over binary systems, it was found that the formation of ternary complexes was much more stable than that of binary complexes at all concentration conditions, as the values of Δ log K_m were greater than - 0.6, the reference value (Sigel, 1975).

Conclusions

Both aspirin and vitamin C alone and together can be chelated with trace amounts of cadmium under physiological conditions. The results explain that there is a higher possibility of forming more stable ternary complexes in this environment. According to these results, it can be suggested that vitamin C and aspirin together in suitable concentrations be used to remove toxic cadmium in the body by forming more stable cadmium – aspirin – vitamin C complexes which are water soluble and hence they can be excreted from the body.

References

Irving, H and Rossotti, H. S. (1953) *Journal of Chemical. Society*, 3397-3405.

Kain, W. and Schwederski, B., (1994) *Bioinorganic Chemistry: norganic Elements in the Chemistry of Life,*. Chichester, UK: John Wiley and Sons.

Sigel, H. (1975) *Angewante Chemie*, **14**, 394-402.

www.euro.who.int/document/aiq/6_3cadmium.pdf

Table 1. Summary of results

pH range	[HCl]/ mol dm^{-3}	[Aspirin]/ mol dm^{-3}	[Vit. C]/ mol dm^{-3}	[NaOH]/ mol dm^{-3}	[Metal]/ mol dm^{-3}	log K_1	log K_2
2.9 – 6.5	1.0×10^{-2}	1.0×10^{-2}		1.0×10^{-2}	0.5×10^{-2}		4.1
7.7 – 11.0							3.8
3.0 – 6.2	1.0×10^{-2}	1.0×10^{-3}		1.0×10^{-2}	0.5×10^{-3}	4.4	
8.4 – 10.8						3.9	
3.9 – 6.7	1.0×10^{-3}	1.0×10^{-2}		1.0×10^{-2}	0.5×10^{-2}		6.9
7.7 – 11.0							5.6
4.1 – 6.3	1.0×10^{-3}	1.0×10^{-3}		1.0×10^{-3}	0.5×10^{-3}	4.3	
9.8 – 10.0						4.7	
4.2 – 6.1	1.0×10^{-2}		1.0×10^{-2}	1.0×10^{-2}	0.5×10^{-2}		7.0
7.4 – 11.2							7.1
4.3 – 7.0	1.0×10^{-2}		1.0×10^{-3}	1.0×10^{-2}	0.5×10^{-3}		4.3
7.3 – 11.2							3.4
5.3 – 7.2	1.0×10^{-3}		1.0×10^{-2}	1.0×10^{-2}	0.5×10^{-2}		5.5
7.7 – 11.0							5.2
3.9 – 7.2	1.0×10^{-3}		1.0×10^{-3}	1.0×10^{-3}	0.5×10^{-3}		5.3
7.4 – 10.2							4.6
3.9 – 6.2	1.0×10^{-2}	1.0×10^{-2}	1.0×10^{-2}	1.0×10^{-2}	1.0×10^{-2}	7.0	
8.2 – 9.1							8.5
3.5 – 8.5	1.0×10^{-2}	1.0×10^{-3}	1.0×10^{-3}	1.0×10^{-2}	1.0×10^{-3}	6.8	
8.9 – 9.8							7.1
3.1 – 6.1	1.0×10^{-3}	1.0×10^{-2}	1.0×10^{-2}	1.0×10^{-2}	1.0×10^{-2}	6.6	
6.6 – 9.8							7.1
3.8 – 5.8	1.0×10^{-3}	1.0×10^{-3}	1.0×10^{-3}	1.0×10^{-3}	1.0×10^{-3}	7.4	
6.0 – 9.0							8.7
6.0 – 7.6	1.0×10^{-3}	1.0×10^{-4}	1.0×10^{-4}	1.0×10^{-3}	1.0×10^{-4}	3.5	
8.0 – 9.2							3.5