

# Memo

To : SBE  
From : JAH  
Subject : Necessity of metals (like cobalt) in nutrient solutions  
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## INTRODUCTION

One of the pillars of life is activity of enzymes. These enzymes are responsible for many of the chemical conversions that take place in the cells of all living organisms.

Enzymes predominantly consist of proteins, which are in turn constructed from amino acids in a way that is determined by DNA. Enzymes can be (very) large molecules but the actual active site is often just a single atom. This is practically always a metal that can relatively easy change its valence, like iron, nickel, cobalt etc. Without these metals, life is impossible.

In the period from 1930 to 1970, there was a strong interest in how biological systems respond holistically to the chemical elements. This lead to the identification of major elements that commonly participate in metabolic processes within diverse microbiological systems, specifically H, C, O, N, P, S, Cl, K, Na, Ca, Mg, Se, Zn, Fe, Mn, Cu, Co, Ni, and Mo.

The essential function of the certain metals in living organisms is often well known. Examples will be given further down below.

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Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period 1	H																	He
Period 2	Li	Be											B	C	N	O	F	Ne
Period 3	Na	Mg											Al	Si	P	S	Cl	Ar
Period 4	K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Period 5	Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Period 6	Cs	Ba	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn

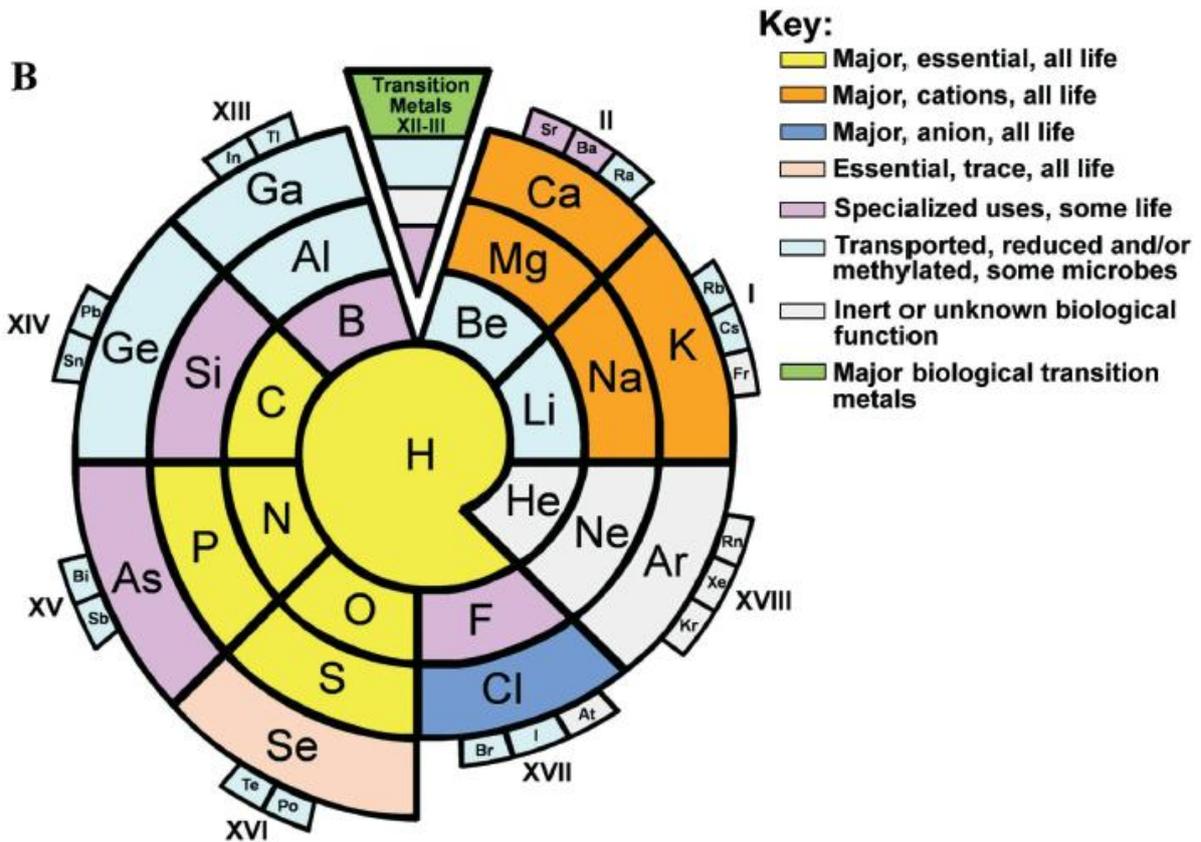


Figure 1: Periodic representation of the main elements. (A) Conventional with linear columns and rows (B) Spiral representation of the elements with cluster elements that are prominent in biological systems [Wackett et al, 2004].



## PRESENCE OF METALS IN BACTERIA

Metals are naturally part of bacteria. This can be easily determined by analysing bacterial biomass for metals (see Table 1). This has been done for various bacteria.

**Table 1: Presence of metals methanogenic (methane-producing) bacteria as ppm of dried bacterial mass [Scherer and Lippert, 1983].**

Multielement Analyses of Methanogenic Bacteria as Revealed by Inductively-Coupled Plasma Emission Spectrometry<sup>a</sup>

Species	Strain/ DSM-No	Sub- strate	Na	K	S	P	Ca	Mg	Fe	Ni	Co	Mo	Zn	Mn	Cu
<i>M. bryantii</i> <sup>b</sup>	'M.o.H.G./ 862	H <sub>2</sub> -CO <sub>2</sub>	7000	32,500	5650	19,500	180	1900	1350	150	20	25	250	5	160
<i>M. thermoautotrophicum</i> <sup>b</sup>	'Marburg/ 12133	H <sub>2</sub> -CO <sub>2</sub>	5650	54,500	6350	26,000	85	890	1500	110	10	25	50	<5	<10
<i>M. arboriphilus</i> <sup>d</sup>	'A.Z./744	H <sub>2</sub> -CO <sub>2</sub>	3650	52,500	9900	28,500	550	3900	1300	65	15	40	440	5	20
<i>M. smithii</i> <sup>c</sup>	'PS/ 861	H <sub>2</sub> -CO <sub>2</sub>	9000	50,000	7700	25,500	100	2250	1100	95	90	25	630	5	25
<i>Methanobacterium spec.</i> <sup>b</sup>	—	H <sub>2</sub> -CO <sub>2</sub>	16,000	10,500	8300	24,500	(<950)	3900	2850	90	120	65	(>1000)	20	(<300)
<i>M. vannielii</i> <sup>c</sup>	'SB/ 1224	Na- formate	27,000	7000	9200	25,500	(>>1000)	3650	(<5000)	70	85	60	(<1100)	25	30
<i>M. mazei</i> <sup>c</sup>	'S-6'/2053	Meth- anol	40,000	7700	7850	11,500	1700	2900	720	95	35	<10	170	5	10
<i>M. vacuolata</i> <sup>b</sup>	—/1232	Meth- anol	4450	1300	10,500	9500	4200	2800	1600	70	30	30	260	15	40
<i>Methanosarcina spec.</i> <sup>b</sup>	'TM1'/1825	Meth- anol	10,500	1400	12,000	5200	1800	2000	1600	150	50	<10	230	5	<10
<i>M. barkeri</i> <sup>b</sup>	'MS'/800	Meth- anol	4450	4900	12,000	11,500	4300	3100	1100	65	30	25	300	10	10
<i>M. barkeri</i> <sup>b</sup>	'227'/1538	Meth- anol	4550	5100	10,500	18,000	2750	5350	1200	60	25	45	370	10	35

## FUNCTION OF INDIVIDUAL ELEMENTS

The function of the individual elements is often well known. A scan of many literature source lead to the overview presented in Table 2.

**Table 2: Function of various elements.**

Component	- Function
Calcium (Ca)	<ul style="list-style-type: none"> <li>- Macronutrient</li> <li>- Required for granule formation (calcium bridging and skeleton) &amp; for stabilising cell wall.</li> <li>- Co-factor in certain enzymes.</li> </ul>



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Cobalt (Co)	<ul style="list-style-type: none"> <li>- Essential for prokaryotes (part of vitamin B12)</li> <li>- Anaerobic bacteria require a higher concentration than aerobic bacteria</li> <li>- Present as co-factor in : transcarboxylase</li> </ul>
Copper (Cu)	<ul style="list-style-type: none"> <li>- Part of oxydases, oxygenases and low molecular weight electron transfer proteins</li> </ul>
Iron (Fe)	<ul style="list-style-type: none"> <li>- Essential in many microbial conversions.</li> <li>- Present in cytochromes, catalases, peroxidases, iron-sulphur proteins, oxygenases and nitrogenases.</li> </ul>
Potassium (K)	<ul style="list-style-type: none"> <li>- Charge carrier</li> <li>- Osmotic balance</li> <li>- Proton motive force system</li> </ul>
Magnesium (Mg)	<ul style="list-style-type: none"> <li>- Required for stability of the ribosome</li> </ul>
Manganese (Mn)	<ul style="list-style-type: none"> <li>- Has overlapping functions with calcium and magnesium.</li> <li>- Activator in many enzymes,</li> <li>- Present in certain superoxide dismutase, pseudo catalase, and in photo system II in oxygenic phototrophs.</li> </ul>
Molybdenum (Mo)	<ul style="list-style-type: none"> <li>- Part of flavin containing enzymes, in molybdenum nitrogenase, sulphite oxidase, nitrate reductase, sulphite oxidase, DMSO-TMAO reductases, some formate dehydrogenases, oxotransferases</li> </ul>
Sodium (Na)	<ul style="list-style-type: none"> <li>- Charge carrier</li> <li>- Osmotic balance</li> <li>- Proton motive force system</li> </ul>
Nickel (Ni)	<ul style="list-style-type: none"> <li>- Present in urease, hydrogenase, coenzyme F430 of methanogens, methyl-S-coenzyme M reductase, carbon monoxide dehydrogenase, nickel superoxide dismutase, glyoxylase I, and a putative nickel cis-trans isomerase.</li> </ul>
Potassium (K)	<ul style="list-style-type: none"> <li>- Charge carrier</li> <li>- Osmotic balance</li> <li>- Proton motive force system</li> </ul>
Selenium (Se)	<ul style="list-style-type: none"> <li>- Part of the amino acid selenocysteine.</li> <li>- Function in formic acid dehydrogenase &amp; some other hydrogenases.</li> </ul>
Sulphur (S)	<ul style="list-style-type: none"> <li>- Essential for amino acids.</li> </ul>

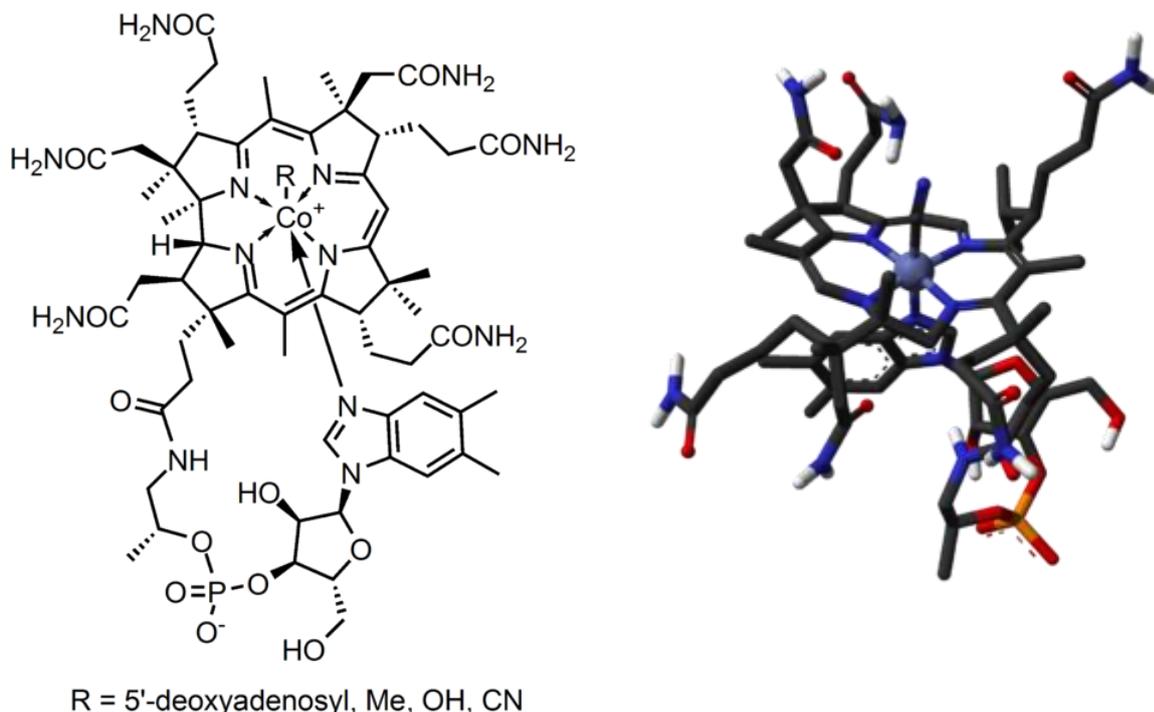
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Zinc (Zn)

- Present in carbonic anhydrase, alcohol dehydrogenase, RNA and DNA polymerases and many DNA-binding proteins, superoxide dismutases en carbonic anhydrases

## Cobalt

An element like cobalt is essential for vitamin B12 (see Figure 2). The function of vitamin B12 is known for many years and is extensively described in an easily accessible source like Wikipedia (see [http://en.wikipedia.org/wiki/Vitamin\\_B12](http://en.wikipedia.org/wiki/Vitamin_B12) )



**Figure 2: Structural 2D and 3D representation of Vitamin B12. The cobalt atom is visible like a spider in a web [Source [http://en.wikipedia.org/wiki/Vitamin\\_B12](http://en.wikipedia.org/wiki/Vitamin_B12)].**

## NUTRIENTS AND HIGH RATE BIOREACTORS

It is undisputed that metals like cobalt, nickel etc are required in small quantities by all living organisms. In the case of food for human and animals, these metals are normally already present in the vegetables, meat etc.

The metals are normally also available in a sufficient concentration in the natural environment.



Certain industry use clean demineralised water. The effluent of such industries will contain insufficient metals to support the growth and activity of microorganisms that perform the useful processes, like conversion of pollutants to methane.

Nutrients (including metals) are typically not transferred via the gas phase. So, when a biological process is applied for the purification of gas, all nutrients, including metals, need to be supplied in sufficient quantities and the proper ratio.

Paques provides its industrial clients a nutrient solution that contains the required metals (including cobalt sulphate) in the proper quantities for optimizing the biological processes in the waste water treatment bioreactors.

## **LITERATURE**

Scherer, P., Lippert, H., and Wolff, G. (1983) "Composition of the major elements and trace elements of 10 methanogenic bacteria determined by inductively coupled plasma emission spectrometry, *Biological Trace Element Research*, 5(3), 149 – 163.

Wackett, L.P., Dodge, A.G., and Ellis, L.B.M. (2004) *Microbial Genomics and the Periodic Table*, *Appl. Env. Microbiol.*, 70(2), 647-655.