MARINE AND OCEAN CHEMISTRY

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Read the details of the information provided below from the sources recommended as a reference.

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PLAN – CONTENT – REFERENCES

1. Introduction
2. The water in seawater
3. Salinity, chlorinity, conductivity, and density
4. Major constituents of seawater
5. Simple gases
6. Salts in solution
7. Carbon dioxide
8. Nutrients
9. Trace metals and other minor elements
10. Chemical extraction of useful substances from the sea

References:

1. An Introduction to the Chemistry of the Sea, Michael E. Q. Pilson
2. Marine Chemistry & Geochemistry, John H. Steele et al.
3. Chemistry in the Marine Environment, R. E. Hester and R. M. Harrison
4. Marine Chemistry, P. J. Wangersky

MAJOR CONSTITUENTS OF SEAWATER

1. Concentrations
2. Residence times

CONCENTRATION

- All the chemical elements in the periodic table that can be found on Earth must be present to some extent in seawater, although not quite all have been detected there yet.
- For a variety of reasons it is convenient to consider separately the major and minor constituents.

- In a continuum of concentrations, it is convenient to pick a value of one part in one million (1 ppm or 1 mg/kg) as a lower limit for the concentrations of major constituents.
- Substances present above this concentration may have a detectable influence on the density.
- Most of the substances that occur in concentrations **greater than 1 mg/kg are conservative** – that is, they are found in nearly constant proportions to each other and to the salinity.
- Most of the substances present in concentrations of **less than 1 mg/kg are not conservative**.
- There are 11 substances included among the major constituents, and there are a couple more that could be included but conventionally have not been.

At salinity (PSS 1978) S = 35‰, t = 20 °C				
	mg kg^{-1} S^{-1}	g kg^{-1}	mmol kg^{-1}	mM
Na^+	**308.1**	**10.782**	**469.00**	**480.61**
K^+	11.40	0.399	10.21	10.46
Mg^{2+}	**36.68**	**1.284**	**52.82**	**54.13**
Ca^{2+}	**11.76**	**0.4115**	**10.27**	**10.52**
Sr^{2+}	0.223	0.0078	0.090	0.092
Cl^-	**552.93**	**19.353**	**545.87**	**559.39**
SO_4^{2-}	**77.49**	**2.712**	**28.235**	**28.935**
HCO_3^-	3.217	0.1126	1.845	1.831
CO_3^{2-}	0.317	0.0111	0.184	0.189
CO_2	0.0017	0.0006	0.013	0.0133
Br^-	1.923	0.0673	0.842	0.863
$B(OH)_3$	0.591	0.0207	0.334	0.342
$B(OH)_4^-$	0.186	0.0065	0.082	0.0839
F^-	0.037	0.00130	0.068	0.070
Totals	1004.87	35.170	1119.87	1147.60
Alkalinity	-	-	2.300	2.37
Everything else	-	0.03	-	-
Water	-	964.80	53.554	54.880

RESIDENCE TIMES

- One approach to evaluating the possibilities for non-conservative behavior is to calculate the residence time of the substance.
- **The residence time** is the length of time (using the symbol τ) it would take for the input of a substance into the ocean, to replace the amount present.

$$\tau = \frac{mass\ present}{input\ rate}$$

- If **the ocean is in steady state** with respect to the substance, then **the rate of output must equal the rate of input**, and the **total mass present will remain constant**.

River input	12.5×10^{12} mol yr^{-1}
Exchange at spreading centers	3.3×10^{12} mol yr^{-1}
Groundwater discharge	5.0×10^{12} mol yr^{-1}
Total input	20.8×10^{12} mol yr^{-1}

- Rough estimates of the residence times of some of the major constituents in seawater give the following values:

Na^+	70×10^6 yr	Sr^{2+}	6×10^6 yr
K^+	7×10^6 yr	Cl^-	100×10^6 yr
Mg^{2+}	14×10^6 yr	Br^-	100×10^6 yr
Ca^{2+}	0.7×10^6 yr	SO_4^{2-}	10×10^6 yr

- These additional constituents have residence times much longer than that of calcium and very much longer than the mixing time of the ocean.

- Therefore, they should all behave conservatively unless, as with calcium and strontium, there is some active process that might significantly redistribute them within the water column.