

CONTENTS

Dedication	IV
Preface	V
Acknowledgements	VII
Abstract	135
1. A Personal Journey	137
1.1 Education	137
1.2 The Noble Gases: Early Studies	141
1.3 Parisian Days	153
1.4 Tokyo Years	156
1.5 Back to France	159
1.6 Research at the CRPG, Nancy, France	161
2. The Dual Origin of the Atmosphere and the Oceans	165
2.1 Historical Perspectives	167
2.2 The Neon Alphabet: A key to Understanding the Origin of Terrestrial Volatiles	170
2.2.1 The three Ne isotope diagram	170



2.2.2	Which solar neon component?	172
2.3	The Paradoxes of Xenon	176
2.3.1	The first paradox of xenon: The “missing Xe” problem . . .	178
2.3.2	The second paradox of xenon	180
2.3.3	The third paradox of xenon indicates heterogeneous accretion of the Earth	181
3.	Major Volatiles: Carbon and Nitrogen	186
3.1	The Earth as an Old British Hotel Room	186
3.2	Natural Fluxes of Mantle Carbon	187
3.3	Tracing Modern Carbon Fluxes with Atmospheric Helium Isotopes	192
3.4	Terrestrial Nitrogen	195
3.5	The Mantle C/N Ratio and the Carbon Content of the Silicate Earth	201
4.	Intermezzo: Volcanoes and Field Work	205
4.1	Vanuatu	206
4.2	The Ethiopian Magmatic Province	210
4.3	Oldoinyo Lengai in the Maasai Country: The Coolest Volcano on Earth	215
4.4	The European Magmatic Province	218
4.5	Gases from the Deep Mantle: Yellowstone National Park (USA)	219
5.	Lunar Volatiles: the Long-Standing Problem of Nitrogen Isotope Variability and the Sources of Volatles on the Moon	221
6.	The Genesis Mission and the Composition of the Solar Nebula	229
6.1	Sampling Solar Ions with a Spacecraft	229
6.2	Solar Oxygen and the Origin of the Solar System	232
6.3	Solar Nitrogen and the Origin of Terrestrial Volatiles	235
7.	Comets as Witnesses of the Outer Solar System	242
7.1	The First Cometary Samples Returned to Earth: The Stardust Mission	243
7.2	The Rosetta Mission: Origin of Cometary Matter	245
7.3	Contribution of Comets to the Oceans and the Atmosphere	248
8.	The Ancient Earth	254
8.1	Early Environments	254
8.2	Ancient Atmospheric Gases Trapped in Tiny Bubbles	258



8.3 Ancient Oceans 264
8.4 The Archean Atmosphere 266
8.5 Mars and Early Earth: Common and Divergent Evolutions 269

9. Concluding Remarks 272

Appendix: A Recipe for the Atmosphere and the Oceans 274

References 284

Index 305

