The chemical composition of Earth's atmosphere III: the noble gases

Mole %	*Name*	*Chemical formula*	*Residence Time*
78.084	Nitrogen	N_2	10^6-10^7 years
20.948	Oxygen	O_2	3000-10,000 years
0.934	**Argon**	**Ar**	**Forever**
0.004 - 4	Water vapor	H_2O	~10 days
0.0385 (385 ppm)	Carbon dioxide	CO_2	2-10 years
0.001818 (18.18 ppm)	**Neon**	**Ne**	**Forever**
0.000524 (5.24 ppm)	**Helium**	**He**	**~10^6 years**
0.00017 (1.7 ppm)	Methane	CH_4	2-10 years
0.000114 (1.14 ppm)	**Krypton**	**Kr**	**Forever**
0.00005 - 0.0010	Stratospheric ozone	O_3	
0.000055 (0.55 ppm)	Hydrogen	H_2	4-8 years
0.000033 (0.33 ppm)	Nitrous oxide	N_2O	5-200 years
0.0000050 - 0.0000200	Carbon monoxide	CO	60-200 days
0.0000087 (87 ppb)	**Xenon**	**Xe**	**Forever**
0.0000010 - 0.0000500	Tropospheric ozone	O_3	
0.0000005 - 0.0000020	NMHC	C_xH_y	
0.0000000540 (540 ppt)	CFC12	CF_2Cl_2	>80 years
0.00000005 (500 ppt)	Carbonyl sulfide	OCS	~ 2 years
0.0000000265 (265 ppt)	CFC11	$CFCl_3$	~80 years
0.00000001 - 0.000001	Hydrogen peroxide	H_2O_2	1 day
0.00000001 - 0.0000001	Formaldehyde	CH_2O	5-10 days
0.0000000098 (98 ppt)	Carbon tetrachloride	CCl_4	≥ decades
0.0000000065 (65 ppt)	Methylchloroform	CH_3CCl_3	~7 years
0.000000001 - 0.0001	Nitrogen oxides	NO_x	A few days
0.000000001 - 0.0000001	Ammonia	NH_3	A few days
0.000000001 - 0.0000001	Sulfur dioxide	SO_2	hours to weeks
0.000000001 - 0.00000001	Dimethyl sulfide	CH_3SCH_3	<1 day
0.0000000001 - 0.00000003	Carbon disulfide	CS_2	~40 days
0.0000000005 - 0.00000005	Hydrogen sulfide	H_2S	<5 days
0.0000000002 (2 ppt)	Hydroperoxyl radical	HO_2	
0.000000000005 (0.05 ppt)	Hydroxyl radical	OH	≤ a few seconds

Next in abundance after the atmosphere's big two, N_2 and O_2, is argon, and close behind are the other noble gases. The most general explanation for the relative abundance of the noble gases, compared to the components lower in the list, is that they have no sink from the atmosphere. Their inert behavior means that, once they have degassed from the solid earth into the atmosphere, most of them have nowhere else to go. Hence the "forever" listed as the residence time of most of the noble gases at left.

Another reason for the abundance of argon and helium is that they are produced by radioactive decay. The great abundance of ^{40}Ar relative to ^{39}Ar in the atmosphere indicates that most of the atmosphere's Ar has come from radioactive decay of ^{40}K via electron capture. ^4He is even more disproportionately abundant relative to ^3He, and seemingly most of the Earth's present atmospheric helium has come from alpha decay of U and Th, which produces alpha particles that are identical to ^4He nuclei.

The one noble gas with a finite residence time is helium. That's because Earth's gravitational field allows hydrogen and helium, the lightest gases, to escape to space. Thus the residence time shown here is in effect an "escape time". The atmosphere of an Earth with a stronger gravitational field would have much more helium than our actual atmosphere.

These thoughts combine to explain the abundance of argon: it is the noble gas produced by radioactive decay that cannot escape to space, and so it is relatively abundant in the air we breath.

Sources: see Part I of this series.