

What affects the rate of diamond dissolution in melts and fluids?

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Dissolution textures on the surface of natural diamonds originate from diamond dissolution in the mantle source and during kimberlite ascent. Experimental studies have established that high temperature (T), high oxygen fugacity (fO_2), and lower pressure (P) increase diamond dissolution rate. Furthermore, dissolution mechanism varies in different solvents resulting in few types of crystal surfaces: (i) smooth surface with shallow etch pits showing strong control by crystal lattice; (ii) rough surface with deep and complex etch pits controlled by the crystal lattice; and (iii) irregular surfaces and cavities with no obvious relation to the crystallography. Sometimes diamond dissolution is accompanied by surface graphitization. Despite half a century of experimental studies on diamond dissolution and etching, the dissolution mechanism and a quantitative relationship between dissolution kinetics and T , P , fO_2 , and solvent composition are not clear due to the extreme P - T conditions of the reaction.

Here we compiled experimental data on diamond dissolution from 13 papers (144 runs in total) published between 2000 and 2022 and our unpublished experiments. We selected the studies that, in addition to T and P , also report fO_2 , the solvent type, and provide sufficient details to calculate diamond dissolution rate as weight / area * time. These studies cover a large range of temperatures from 600 – 1500°C, pressures from 10^{-4} to 6.3 GPa, and fO_2 corresponding from iron-wustite (IW) to hematite-magnetite (HM) buffers. Where data permits, we used the relationship between the dissolution distance and the time to explore if dissolution rate was controlled by diffusion or interface (surface) reaction. Our results indicate that diffusion-controlled dissolution occurs in melt + fluid systems, whereas fluid or volatile-bearing melts likely follow interface reaction-controlled process. We explored dissolution kinetics as a linear relationship between $\ln K$ (where K is dissolution rate, $\text{mg} / \text{mm}^2 * \text{min}$) vs. (i) $1000/T(K)$; (ii) $1/P(\text{GPa})$; (iii) ΔFMQ and used the Arrhenius plot to obtain a range of activation energies (E_a) for diamond dissolution in different solvents related to dissolution mechanisms. Deciphering the mechanism and kinetics of diamond dissolution improves the use of diamond as a probe of mantle processes and kimberlite ascent rates.

