Using the finite-temperature quasiparticle random phase approximation (FTQRPA) on the basis of the finite temperature Skyrme-Hartree-Fock+Bardeen-Cooper-Schrieffer (BCS) method, we study β-decay half-lives for even-even nuclei in a finite-temperature environment. We find that the β-decay half-life first decreases as the temperature increases for all the nuclei we study, although the thermal effect is found to be small at temperatures relevant to r-process nucleosynthesis. Our calculations indicate that the half-life begins to increase at high temperatures for open-shell nuclei. We discuss this behavior in connection to the pairing phase transition.