Question 1:

Pure ZrO_2 exhibits a phase transformation from the tetragonal structure to the monoclinic structure at 950°C. This transformation induces a volume increase of about 4-6% which can result in a catastrophic fracture and, hence, structural unreliability of the fabricated components.

a) In spite of this fact, explain a method how to produce stable and comparatively strong ZrO_2 pieces.

Retention of t→m phase transformation by doping ZrO_2 with 3 % Y_2O_3 or MgO, CeO_2, CaO. Controlling the composition by adding the stabilizing oxides allows a lowering of the transformation temperature which kinetically inhibits the phase transformation.

b) Describe two transformation induced toughening mechanisms in ZrO_2.

Both mechanisms are triggered by doping ZrO_2 with 3-8% Y_2O_3 to obtain a microstructure containing metastable tetragonal grains with a grain size of 0.5-3 µm in a cubic matrix.

Stress induced transformation toughening:

Upon the application of stress, the tetragonal phase will transform into the monoclinic phase. The volume increase accompanying the transformation creates a compressive strain field in the vicinity of the crack tip which opposes the crack propagation and "squeezes" the crack together.

Stress induced microcrack toughening:

The phase transformation and thus the volume increase of the grains induces tensile stresses that may initiate microcracks around the transformed grains. A propagating crack will be stopped as the stress field of this crack is dissipated by the formation of those microcracks.

Question 2:

Although Al_2O_3 has a high stiffness, it shows a brittle character with a low stress intensity factor (K_{Ic}). What would you suggest to increase the toughness of Al_2O_3?

The toughness of Al_2O_3 can be increased by doping with ZrO_2 (~ 15vol%). A fine grained ZrO_2 added to Al_2O_3 will not exhibit a t→m phase transformation and will preserve its tetragonal form at room temperature. Following an applied external stress, the volume change accompanying transformation will lead to stress induced transformation toughening and/or stress induced microcrack toughening of Al_2O_3.