Problem 2)

a) $\rho_{\text{total}}(\boldsymbol{r},t) = \rho_1(\boldsymbol{r},t) + \rho_2(\boldsymbol{r},t)$.

b) $\boldsymbol{J}_{\text{total}}(\boldsymbol{r},t) = \rho_1(\boldsymbol{r},t)\boldsymbol{V}_1(\boldsymbol{r},t) + \rho_2(\boldsymbol{r},t)\boldsymbol{V}_2(\boldsymbol{r},t)$.

c) No. The continuity equation is based on the principle of conservation of charge. Since *individual* species 1 and 2 in this example are *not* conserved, the continuity equation does *not* apply to them as separate entities. For example, the change of charge density with time, $\partial\rho_1/\partial t$ or $\partial\rho_2/\partial t$, may have nothing to do with the inflow or outflow of charge produced by the local $\boldsymbol{\nabla}\cdot\boldsymbol{J}_1(\boldsymbol{r},t)$ or $\boldsymbol{\nabla}\cdot\boldsymbol{J}_2(\boldsymbol{r},t)$. Rather, the change of charge density may be caused by recombination of the two species.

d) Yes, the combined system satisfies the continuity equation $\boldsymbol{\nabla}\cdot\boldsymbol{J}_{\text{total}}(\boldsymbol{r},t) + \partial\rho_{\text{total}}(\boldsymbol{r},t)/\partial t = 0$, because the total charge is a conserved entity. When, for example, Na^+ and Cl^- ions in a salt solution combine, we lose one unit of positive charge *and* one unit of negative charge, but the total amount of charge in the system remains the same.