(1). In a series of observation on displacement of rubber latex spheres of radius 0.212 μm the mean square displacements after selected time intervals were on average as follows:

<table>
<thead>
<tr>
<th>t/s</th>
<th>30</th>
<th>60</th>
<th>90</th>
<th>120</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10^{12} \langle x^2 \rangle / \text{m}^2$</td>
<td>88.2</td>
<td>113.4</td>
<td>128</td>
<td>144</td>
</tr>
</tbody>
</table>

Find the effective viscosity of water at 25 °C. (15%) 

(2). Given the first and second acid constants, $K_a 1 = 4.3 \times 10^{-2}$ and $K_a 2 = 5.6 \times 10^{-11}$ of $H_2CO_3$ (aq), estimate the equilibrium concentrations of $H_2CO_3$ (aq), $HCO_3^-$ (aq) and $CO_3^{2-}$ (aq) when the initial concentration of $H_2CO_3$ is 0.1 M. (15%) 

(3). The following mechanism is proposed to explain the reaction $2NO + O_2(g) \rightarrow 2NO_2(g)$:

$$ NO + NO \rightarrow N_2O_2 $$
$$ N_2O_3 + O_2 \rightarrow NO_2 + NO_2 $$

(a). Use steady-state approximation to derive the following rate law:

$$ \text{rate of formation of } NO_2 = \frac{c [NO]^a [O_2]^b}{a + b [O_2]^b} $$

express a, b, c in terms of $k_a$, $k_b$, and $k_0$. a, b, c are all simple integers, what are they? (15%) 

(b). If the concentration of $O_2$ is very small, which elementary process is considered to be a rate-elementary step? In this case what forms does the rate law become? (5%) 

(4). Show that, if S is regarded as a function of T and V, then $T \, dS = CV \, dT + T \frac{\partial P}{\partial T} \, dV$
and, if S as a function of P and T, then $T \, dS = C_P \, dT - \alpha \, T \, dV \, dP$. (10%) 

(5). With the electrochemical reduction potentials known at 25 °C for

$$ Cu^{2+}(aq) + e^{-} \rightarrow Cu^{+}(aq) \quad E^0 = 0.52 \, V $$
$$ Cu^{2+}(aq) + e^{-} \rightarrow Cu^{+}(aq) \quad E^0 = 0.15 \, V $$

calculate the thermodynamic equilibrium constant at 25 °C for

$$ 2 \, Cu^{+}(aq) \rightarrow Cu^{+}(aq) + Cu^{2+}(aq) $$ (15%) 

(6). A particle is in a state described by the wave function

$$ \psi = \cos(\theta) e^{ikx} \sin(\theta) $$

what is the probability that the particle will be found with a linear momentum (a) $\frac{\hbar}{2\pi}$ (b) $-\frac{\hbar}{2\pi}$ and (c) evaluate into kinetic energy. (15%) 

(7). Show that, for a transition between two incompressible solid phases, $\Delta G$ is independent of the pressure. (10%)