Problem Set #4  
Fall 2006  
SOLUTIONS

6-14 The definition relating absorbance and transmittance is

\[ A = - \log_{10} T \]

This equation inverted gives

\[ T = 10^{-A} \]

For these three examples, we have

(a) \( T = 10^{-0.375} = 0.422 = 42.2\% \)
(b) \( T = 10^{-1.325} = 0.0743 = 4.73\% \)
(c) \( T = 10^{-0.012} = 0.973 = 97.3\% \)

6-15 This is just the reverse of the above equation. The only trick is to make sure that you take the percent transmittance data and divide by 100 to get transmittance. Remember that transmittance must be a number between 0 and 1.

(a) \( A = -\log_{10} (0.336) = 0.477 \)
(b) \( A = -\log_{10} (0.921) = 0.0357 \)
(c) \( A = -\log_{10} (0.0175) = 1.757 \)

7-12 The diffraction grating equation is just directly applied.

\[ \sin \alpha + \sin \beta = kN\lambda \]

\[ \frac{\sin 60^\circ + \sin 10^\circ}{(1)(500 \times 10^{-6} \text{ m} \text{m})} = 2079 \text{ lines/mm} \]

If we follow the notation of the text, then we write the grating equation with the line spacing, rather than the number of lines. We find:

\[ d = \frac{n\lambda}{\sin \alpha + \sin \beta} = \frac{(1)(500 \times 10^{-6} \text{ m} \text{m})}{\sin 60^\circ + \sin 10^\circ} = 4.809 \times 10^{-4} \text{ mm} \]

Here \( d \) is the separation between lines. It means that there is 1 line in 4.809 x 10^{-4} mm. If we take the reciprocal and convert it to mm, we will have the number of lines/mm for the grating.

\[ N = \frac{1}{d} = 2079 \text{ mm}^{-1} \]

7-14 This is another application of the diffraction grating equation, this time solving for wavelength. Since it gives us the grating constant, use the form of the equation in the notes.
(a) The angle of incidence is 50˚ while the angle of reflection is 20˚. For first order radiation we find
\[ n = 1 \]
\[ \lambda = \frac{\sin 50˚ + \sin 20˚}{72 \text{ mm}^{-1}} = \frac{0.7660 + 0.3420}{72} = 0.0154 \text{ mm} = 15.4 \mu \text{m} \]
and for \( n = 2 \)
\[ \lambda = \frac{\sin 50˚ + \sin 20˚}{144 \text{ mm}^{-1}} = \frac{0.7660 + 0.3420}{144} = 0.0077 \text{ mm} = 7.7 \mu \text{m} \]

(b) Same thing except that the reflection angle is 0˚.
\[ n = 1 \]
\[ \lambda = \frac{\sin 50˚ + \sin 0˚}{72 \text{ mm}^{-1}} = \frac{0.7660 + 0}{72} = 0.0106 \text{ mm} = 10.6 \mu \text{m} \]
and for \( n = 2 \)
\[ \lambda = \frac{\sin 50˚ + \sin 0˚}{144 \text{ mm}^{-1}} = \frac{0.7660 + 0}{144} = 0.0053 \text{ mm} = 5.3 \mu \text{m} \]

7-15 Identifying a radiation source, a wavelength selector, a sample holder, and a detector are the essential components of a spectroscopic experiment. For each case we could suggest the following:

<table>
<thead>
<tr>
<th>Purpose</th>
<th>Source</th>
<th>Wavelength</th>
<th>Holder</th>
<th>Detector</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a)</td>
<td>W lamp</td>
<td>Glass prism</td>
<td>Glass window</td>
<td>PMT</td>
</tr>
<tr>
<td>(b)</td>
<td>Globar</td>
<td>Grating 50l/mm</td>
<td>KBr window</td>
<td>Golay cell</td>
</tr>
<tr>
<td>(c)</td>
<td>W lamp</td>
<td>Green filter</td>
<td>Pyrex test tube</td>
<td>Si diode</td>
</tr>
<tr>
<td>(d)</td>
<td>Nichrome wire</td>
<td>Interference filter</td>
<td>TIBr window</td>
<td>Thermocouple</td>
</tr>
<tr>
<td>(e)</td>
<td>Gas/oxygen flame</td>
<td>Quartz prism</td>
<td>Flame</td>
<td>PMT</td>
</tr>
<tr>
<td>(f)</td>
<td>Ar lamp</td>
<td>Grating 3000 l/mm</td>
<td>KBr window</td>
<td>PMT</td>
</tr>
<tr>
<td>(g)</td>
<td>W lamp</td>
<td>Glass prism</td>
<td>Glass window</td>
<td>Photoconductor</td>
</tr>
</tbody>
</table>

7-19 (a) Insert the values into the expression, pick a reasonable angle (45˚) and convert the result into units of nm/mm, the more reasonable units to be using when working with such a spectrometer in the visible region of the spectrum. Another common equation uses \( \beta \) as 0˚. The answer is slightly different, but still correct.
7-19 (b) The resolving power is
\[ R = k N \lambda \text{grating} = (1) (2000 \text{ mm}^{-1}) (30.0 \text{ mm}) = 6.0 \times 10^4 \]

7-19 (c) The resolving power is also the ratio of wavelength difference to wavelength. We have
\[ R = \frac{\lambda}{d\lambda} = 6.0 \times 10^4 \]
\[ d\lambda = \frac{\lambda}{R} = \frac{560 \text{ nm}}{6.0 \times 10^4} = 0.0093 \text{ nm} \]