Summer 2008 Physics 262, Exam 3: SOLUTIONS

Section A

1. D	5. C	9. C	13. A	17. B	21. A
2. C	6. D	10. A	14. A	18. D	22. C
3. B	7. C	11. A	15. C	19. A	23. D
4. D	8. A	12. B	16. D	20. B	

Section B

1. Water has a specific heat of $4 \times 10^3\,\mathrm{J/(kg \cdot C^o)}$ and latent heat of fusion of $3.3 \times 10^5\,\mathrm{J/kg}$. If I mix 1.0 kg of water at 33 °C with 1.0 kg of ice at 0 °C in a thermally insulated container, how much ice has melted when the mixture comes to thermal equilibrium? Recall that ice melts at 0 °C. [**Hint:** To simplify the calculation, first figure out the *algebraic expression* for the amount of ice that is melted, then insert the numbers given.]

   Answer:
   Use conservation of energy: $Q_{\mathrm{water}} + Q_{\mathrm{ice}} = 0$, where Q is positive when heat is absorbed, and negative when heat is released. The heat absorbed by the water as it cools from 33°C to 0°C is

$$Q_{\mathrm{water}} = m_{\mathrm{water}}\, c_{\mathrm{water}}\, \Delta T,$$

   and the heat absorbed by the ice as it changes its phase to water is

$$Q_{\mathrm{ice}} = m_{\mathrm{ice}}\, L.$$

   Conservation of energy gives

$$m_{\mathrm{water}}\, c_{\mathrm{water}}\, \Delta T + m_{\mathrm{ice}}\, L = 0 \quad \Rightarrow \quad m_{\mathrm{ice}} = -\frac{m_{\mathrm{water}}\, c_{\mathrm{water}}\, \Delta T}{L}.$$

   The final mixture will have ice and water at 0 °C. Substituting in the numbers given in the problem

$$\begin{aligned} m_{\mathrm{water}} &= 1.0\,\mathrm{kg} \\ c_{\mathrm{waver}} &= 4 \times 10^3 \mathrm{J/(kg \cdot C^o)}, \\ \Delta T &= 0\,^{\circ}\mathrm{C} - 33\,^{\circ}\mathrm{C} = -33\,^{\circ}\mathrm{C} \\ L &= 3.3 \times 10^5\,\mathrm{J/kg}, \end{aligned}$$

   gives the mass of the ice that melts,

$$m_{\mathrm{ice}} = -\frac{(1.0\,\mathrm{kg}) \cdot (4 \times 10^3 \mathrm{J/(kg \cdot C^o)}) \cdot (-33\,^{\circ}\mathrm{C})}{3.3 \times 10^5\,\mathrm{J/kg}} = \frac{(4 \times 10^3) \cdot 33}{33 \times 10^4}\mathrm{kg} = \boxed{0.4\,\mathrm{kg}}.$$

2. For which of the following transitions in a hydrogen atom is the wavelength of the emitted light the *longest*? (1) $n = 2$ to $n = 1$ (2) $n = 3$ to $n = 1$ (3) $n = \infty$ to $n = 2$. Justify your answer quantitatively (that is, with numbers).

<u>**Answer:**</u>

The energy of the photon E_{photon} is given by conservation of energy, $E_{\text{photon}} + \Delta E = 0 \Rightarrow E_{\text{photon}} = -\Delta E$, where ΔE is the change in energy of the hydrogen atom. The energy levels of the hydrogen at are $E_n = -E_R/n^2$, where $E_R = 13.6\,\text{eV}$ and n are integers.

(1) For $n = 2 \to n = 1$, $\Delta E = -E_R\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = -\frac{3}{4}E_R \Rightarrow E_{\text{photon}} = \frac{3}{4}E_R$.

(2) For $n = 3 \to n = 1$, $\Delta E = -E_R\left(\frac{1}{1^2} - \frac{1}{3^2}\right) = -\frac{8}{9}E_R \Rightarrow E_{\text{photon}} = \frac{8}{9}E_R$.

(3) For $n = \infty \to n = 2$, $\Delta E = -E_R\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right) = -\frac{1}{4}E_R \Rightarrow E_{\text{photon}} = \frac{1}{4}E_R$.

Since $E_{\text{photon}} = hf = hc/\lambda$, the photon with the lowest energy has the longest wavelength. Since $\frac{1}{4} < \frac{3}{4} < \frac{8}{9}$, the lowest energy and longest wavelength photon corresponds to:

$$\boxed{(3)\ n = \infty \text{ to } n = 2 \text{ transition}}\,.$$