Worksheet 3 – Answers to Critical Thinking Questions

The worksheets are available in the tutorials and form an integral part of the learning outcomes and experience for this unit.

Model 1: Two charged Particles Separated by a Distance *r*

1. V gets smaller in magnitude.

2. $V \to 0$ as $r \to \infty$.

3. $V > 0$: a repulsive interaction.

4. $q_{\text{proton}} = +e$

5. $V < 0$: an attractive interaction.

6. The potential is negative and decreases in magnitude as r increases until it reaches zero at ionization.

7.

$$V = \underbrace{k \times \frac{(+2)\times(-1)e^2}{r}}_{\text{electron 1 with nucleus}} + \underbrace{k \times \frac{(+2)\times(-1)e^2}{r}}_{\text{electron 2 with nucleus}} + \underbrace{k \times \frac{(-1)\times(-1)e^2}{2r}}_{\text{electron 1 with electron 2}}$$

$V = -\dfrac{7ke^2}{2r}$: overall attractive.

Model 2: Electron Energy

1.

n	E_n (J)	r_{average} (m)
1	-218×10^{-20}	0.529×10^{-10}
2	-54.5×10^{-20}	2.12×10^{-10}
3	-24.2×10^{-20}	4.76×10^{-10}
4	-13.6×10^{-20}	8.46×10^{-10}
5	-8.72×10^{-20}	13.2×10^{-10}
6	-6.06×10^{-20}	19.0×10^{-10}

2. See left hand graph below.

3. The energy of the levels gets smaller in magnitude and they get closer together as n increases. The average size of the orbit gets rapidly larger as n increases.

4. The energy of the electron tends to zero and the orbit tends to infinity when n becomes very large.

Model 3: Atomic Spectroscopy

1. Shown as red lines on the left hand graph below.

2. $n = 4 \rightarrow n = 3$: $\Delta E = -10.6 \times 10^{-20}$ J; $E_{photon} = -\Delta E = +10.6 \times 10^{-20}$ J or 0.66 eV
   $n = 4 \rightarrow n = 2$: $\Delta E = -40.9 \times 10^{-20}$ J; $E_{photon} = -\Delta E = +40.9 \times 10^{-20}$ J or 2.55 eV
   $n = 4 \rightarrow n = 1$: $\Delta E = -204 \times 10^{-20}$ J; $E_{photon} = -\Delta E = +204 \times 10^{-20}$ J or 12.8 eV

3. (a) $n = 2 \rightarrow n = 5$
   (b) $n = 3 \rightarrow n = 7$

Workshop: Unit conversions for electromagnetic radiation (photons)

1. E is the energy (J), h is Planck's constant (J s), ν is the frequency (Hz or s^{-1}), c is the speed of light (m s^{-1}) and λ is the wavelength (m).

2. (a) 6.93×10^{16} Hz
   (b) 1.28×10^{18} Hz
   (c) 6.56×10^{13} Hz

3. (a) 6.29×10^{-2} m
   (b) 1.07×10^{6} cm
   (c) 5.0×10^{9} mm

4. (a) 7.80×10^{-18} J $photon^{-1}$ or 4690 kJ mol^{-1}
   (b) 1.6855×10^{-23} J $photon^{-1}$ or 0.010150 kJ mol^{-1}

5 . (a) $\lambda = 1.61 \times 10^{-7}$ m and $\nu = 1.86 \times 10^{15}$ Hz
   (b) $\lambda = 5.60 \times 10^{-7}$ m and $\nu = 5.35 \times 10^{14}$ Hz

Workshop: Unit conversion for wave-particles with rest mass

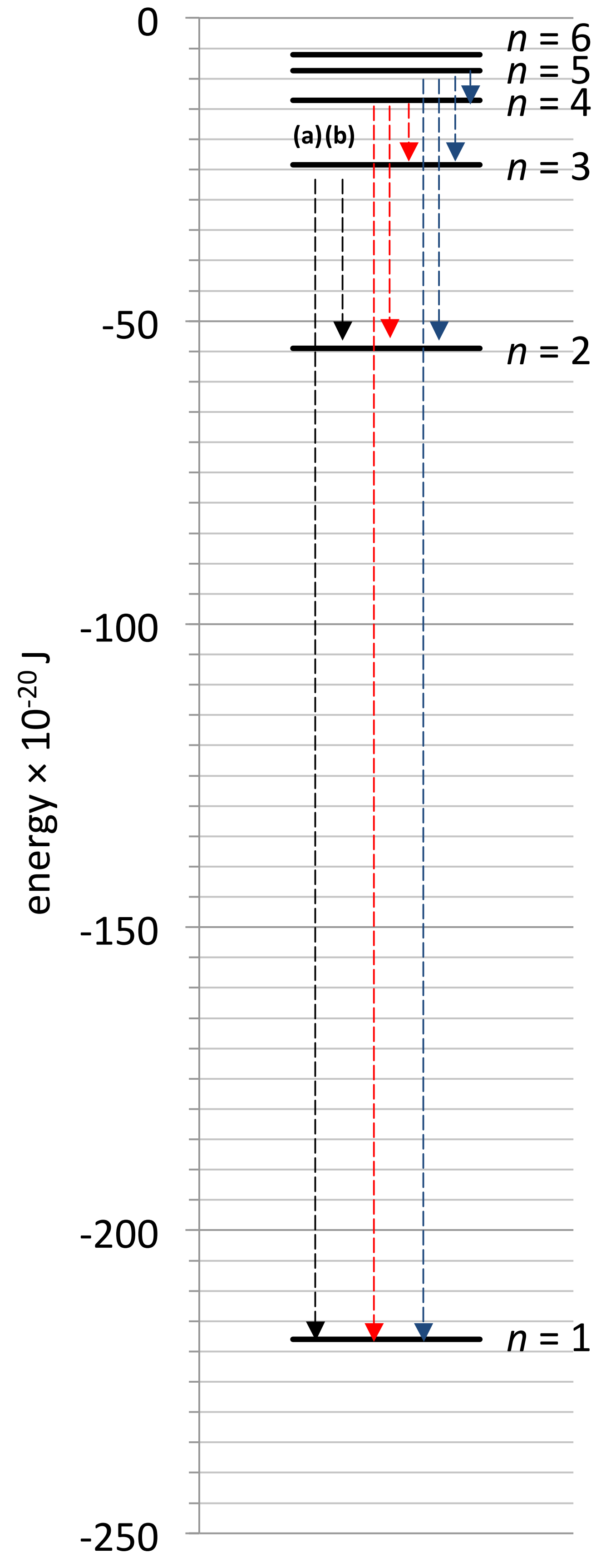
1. E is the energy (J), m is the mass (kg), v is the velocity (m s^{-1}), λ is the wavelength (m) and h is Planck's constant (J s).

2. (a) $\lambda = 1.45 \times 10^{-9}$ m
   (b) $\lambda = 6.38 \times 10^{-9}$ m
   (c) $\lambda = 4.41 \times 10^{-6}$ m

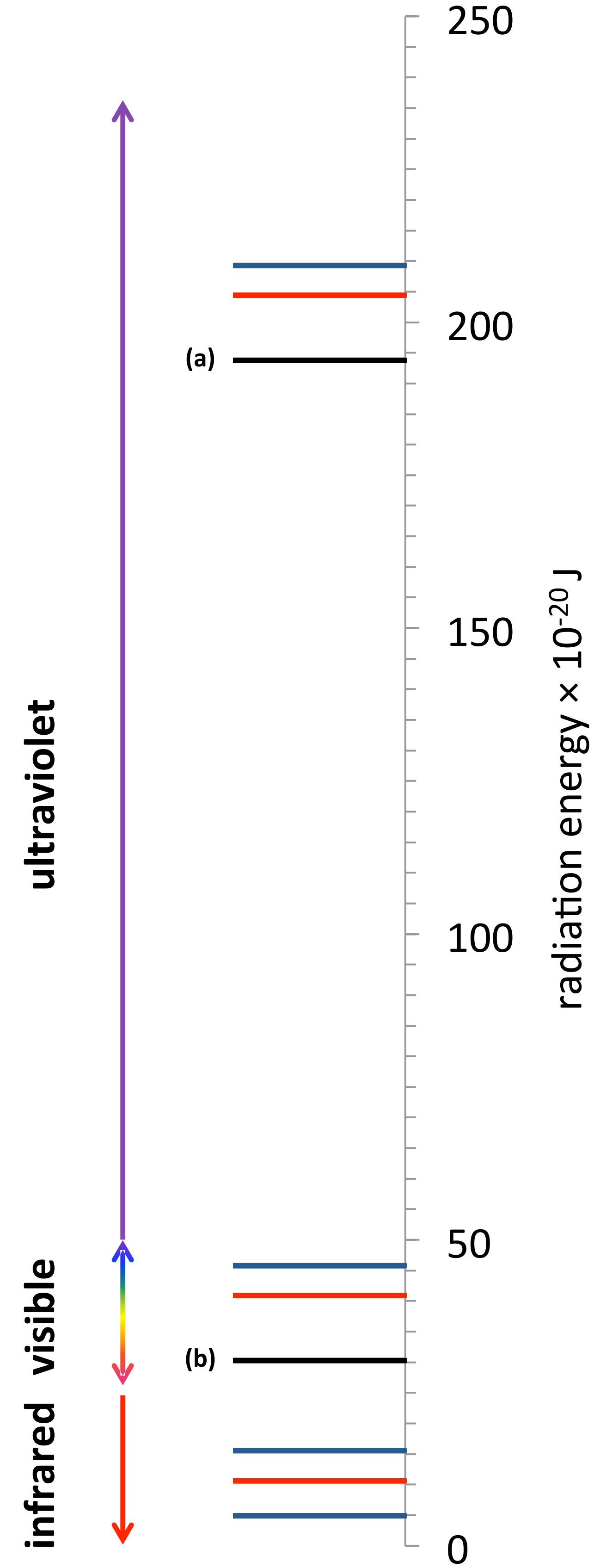
3. (a) $E_{kinetic} = 1.71 \times 10^{-20}$ J
   (b) $E_{kinetic} = 1.12 \times 10^{-38}$ J

4. $E_{kinetic} = 2.3 \times 10^{-20}$ J

Energy levels of the H atom



Atomic Spectrum of the H atom



The calculated transition energies are shown on the diagram on the right: this is how the spectrum arises.