

# Oxford Resources for IB

## Physics – 2023 Edition

### Answers

#### Theme E – Nuclear and quantum

##### E.1 – Structure of the atom

###### Practice questions – Page 597

- 1 128
- 2 a. 12 fm  
b. 26 MeV

###### Practice questions – Page 601

- 3 a. i. 1550 nm  
ii. 258 nm  
b. from  $-2.30$  eV to  $-6.30$  eV
- 4 a. 2.10528 eV and 2.10315 eV  
b.  $2.13 \times 10^{-3}$  eV

###### Practice questions – Page 610

- 5 a. As the spectrum is a series of lines these energy states must be discrete not continuous.  
b. The wavelengths absorbed/emitted by the gas are unique to the atoms in the sample. By matching the wavelengths to known spectra the atomic species in the sample can be identified.
- 6 a. 3  
b. arrow from  $-2.74$  eV to  $-5.01$  eV  
c.  $\lambda = \frac{hc}{E} = \frac{1.24 \times 10^{-6}}{-2.74 + 5.01} = 546 \text{ nm}$
- 7 a.  $3.14 \times 10^{-19}$  J  
b.  $8.0 \times 10^{15}$  photons
- 8 a. B  
b. i.  $n = 3$   
ii.  $2.4 \times 10^{-19}$  J  
iii. Use the following  
$$f = \frac{E_3 - E_1}{h}$$
where  $E_3$  and  $E_1$  should be calculated using Bohr's formula for energy levels.  
c.  $n = 5$

## E.2 – Quantum physics

### Practice questions – Page 618

- 1 a.  $1.0 \times 10^{15}$  Hz  
b. i.  $1.4 \times 10^{-19}$  J      ii.  $5.5 \times 10^5$  m s<sup>-1</sup>  
c. i. unchanged      ii. increases
- 2 a.  $7.3 \times 10^5$  m s<sup>-1</sup>  
b. 330 nm
- 3 a. 2.6 eV  
b. 1.1 V

### Practice questions – Page 624

- 4 a. 1.7 keV  
b.  $3.6 \times 10^{-12}$  m  
c. 120°
- 5 a. incident:  $6.2 \times 10^{-11}$  m, scattered:  $6.6 \times 10^{-11}$  m  
b. 1.2 keV
- 6 a. The particle model suggests that the energy of a photon is directly proportional to its frequency. A scattered X-ray has a smaller frequency (longer wavelength) and therefore smaller energy than the incident X-radiation. Typical processes for a wave model (e.g., scattering, diffraction) do not involve a wavelength shift. Compton modelled the interaction between an X-ray photon and a free electron using a mechanical collision process. His theoretical predictions were confirmed by the data that he collected. This showed that the photons were interacting as particles, not waves. Therefore, this observation supports the particle model.  
b. 160°  
c.  $4.8 \times 10^{-23}$  N s

### Practice questions – Page 627

- 7 a.  $1.0 \times 10^{-15}$  m  
b.  $3.9 \times 10^{-11}$  m
- 8  $8 \times 10^{-2}$  eV

## E.3 – Radioactive decay

### Practice questions – Page 634

- 1 a.  ${}_{92}^{238}\text{U} \rightarrow {}_{90}^{234}\text{Th} + {}_2^4\alpha$   
b. 146
- 2 a.  ${}_{95}^{241}\text{Am} \rightarrow {}_{93}^{237}\text{Np} + {}_2^4\alpha$   
b. 93 keV

### Practice questions – Page 635

- 3 Electron ( ${}_{-1}^0\beta$ ) and electron antineutrino ( $\bar{\nu}_e$ ).
- 4  ${}_{9}^{18}\text{F} \rightarrow {}_{8}^{18}\text{O} + {}_{+1}^0\beta + \nu_e$

**Practice questions – Page 642**

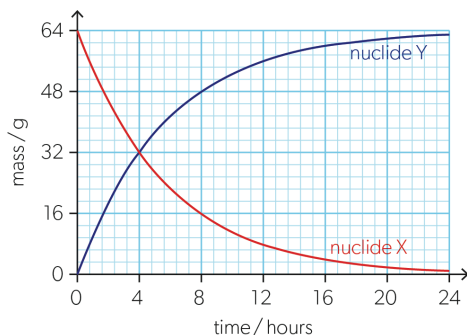
- 5 a. i. 0.137005 u      ii. 127.6 MeV  
 b. i. 0.543708 u      ii. 506.5 MeV  
 c. i. 1.756788 u      ii. 1.636 GeV
- 6 a.  $1.1 \times 10^{12}$  J  
 b. 300 MWh

**Practice questions – Page 645**

- 7 a. 7.976 MeV  
 b. 8.732 MeV  
 c. 7.868 MeV
- 8 a. 4.3 MeV  
 b. 632 keV

**Practice questions – Page 652**

- 9 a. 3 days  
 b.  $0.031A_0$   
 c. 12 days
- 10 a. 56 g  
 b. 24 hours  
 c.



- 11 8.03 days  
 12 B

**Practice questions – Page 656**

- 13 a.  $4 \text{ count s}^{-1}$   
 b.  $5 \text{ count s}^{-1}$
- 14  $60 \text{ count minute}^{-1}$

**Practice questions – Page 660**

- 15 a.  $2.86 \times 10^8 \text{ Bq}$   
 b. 244 days  
 c.  $4.30 \mu\text{g}$
- 16 a.  $5.7 \times 10^{-3} \text{ s}$   
 b. 50 Bq

**Practice questions – Page 661**

- 17 a.  $1.55 \times 10^{-7}$  s  
b. 51.9 days  
c. 170 days
- 18 a.  $1.4 \times 10^{-11}$  s  
b.  $37000 \text{ s}^{-1}$

**E.4 – Fission****Practice questions – Page 671**

- 1 a.  $2.8 \times 10^{-11}$  J  
b.  $7.9 \times 10^{-4}$   
c. 5.3 kg
- 2 a. 3  
b. 188 MeV

**E.5 – Fusion and stars****Practice questions – Page 682**

- 1  $3 \times 2.573 - 2 \times 1.112 = 5.495$  MeV
- 2 a. 3.27 MeV  
b.  $7.84 \times 10^{13}$  J
- 3 4.8 MeV
- 4 a.  $6.1 \times 10^{11}$  kg  
b.  $4.3 \times 10^9$  kg

**Practice questions – Page 686**

- 5 a.  $6.3L_{\odot}$   
b. main sequence star
- 6  $10R_{\odot}$
- 7 D

**Practice questions – Page 693**

- 8 a. Mu Columbae has more hydrogen in the core than the Sun but its rate of fusion is much higher, so hydrogen fusion processes will stop much earlier than in the Sun.
- b. The Sun will fusion helium into carbon in the red giant stage but will not reach temperatures high enough for fusion of heavier elements. Mu Columbae is likely to become a supergiant star, fusing heavier elements than helium until it develops an iron core.
- c. The mass of the Sun is less than the Chandrasekhar limit so its final evolutionary stage will be white dwarf. Mu Columbae will undergo supernova explosion and its remnant mass may be greater than the Oppenheimer-Volkoff limit, leading to a formation of a black hole.

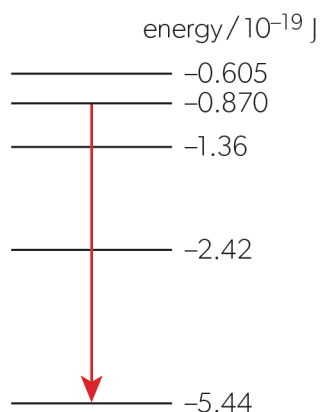
- 9 a. Relatively small radius and luminosity, relatively large surface temperature and density  
 b. The inward gravitational forces are balanced by electron degeneracy pressure.  
 c. White dwarfs do not undergo fusion and the energy they radiate comes from residual thermal energy of the star.

### Practice questions – Page 697

- 10 a. The stellar parallax method is only suitable for stars relatively close to Earth where the angles are measurable using present technology. When the method is used from the Earth's surface parallax is further limited by dust and convection currents in the atmosphere. Measurements carried out from satellites extend the range considerably.
- b. i.  $3.5 \times 10^{17}$  kg  
 ii.  $6.5 \times 10^{28}$  W
- c. 4300 K
- d.  $1.7 \times 10^{10}$  m
- 11 a.  $5.5 \times 10^5$  AU  
 b. 0.37 arc-second  
 c.  $1.1 \times 10^{-7}$  W m<sup>-2</sup>
- 12 a. 35.9 ly  
 b.  $14L_{\odot}$   
 c. The luminosity and radius of a star lead to the surface temperature. This gives the position on the HR diagram and its mass. It is the mass that gives an indication of the future evolution of the star whether to white dwarf, neutron star or black hole.

### End-of-theme Questions – Pages 698–699

- 1 a.  $4.6 \times 10^{-19}$  J  
 b.



- 2 a. i. Centripetal force is equal to the electrical force, hence

$$\frac{2ke^2}{r^2} = \frac{mv^2}{r}$$

Algebraical rearrangement of the equation gives the result.

ii.  $E_k = \frac{ke^2}{r}$  and  $E_p = -\frac{2ke^2}{r}$

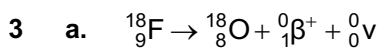
The total energy is the sum  $E_k + E_p$

iii. The total energy decreases so, because of the equation derived in ii., the radius must also decrease.

b. i.  $n = 3, v = 1.44 \times 10^6 \text{ m s}^{-1}$

$$\lambda = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 1.44 \times 10^6} = 5.05 \times 10^{-10} \text{ m}$$

ii.  $2.99 \approx 3$



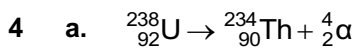
b. i. 630 keV

ii. The decay energy is the same for every decaying nucleus but it is divided between the beta particle and the neutrino in a probabilistic way.

c. i. 110 minutes

ii.  $1.05 \times 10^{-4} \text{ s}^{-1}$

iii. 0.24 mg



b. i. Fusion involves positively charged particles that must have high enough kinetic energy to overcome Coulomb repulsion. Kinetic energy of the particles increases with temperature.

ii. Energy is released when binding energy per nucleon increases, which happens when light nuclei undergo fusion or heavy nuclei undergo fission.

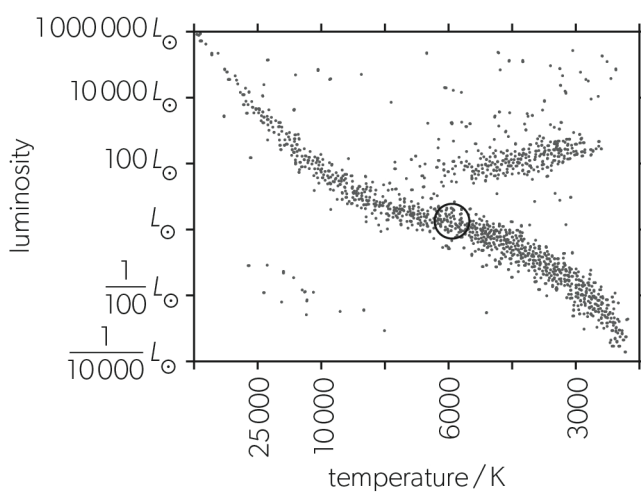
iii. 160 MeV

5 a. i.  $T = \frac{2.9 \times 10^{-3}}{490 \times 10^{-9}} = 5900 \text{ K}$

ii. 2.2

iii.  $1.2L_{\odot}$

b. i.



ii. main sequence star