Solutions for Topic 7 – Atomic, nuclear, and particle physics

1. a) use collimator and pass through diffraction grating to disperse light

b) $E = hf = \frac{hc}{\lambda} = 4.09 \times 10^{-19}$ J

c) **(i)** need line at -1.35×10^{-19} J to give correct wavelength transitions

(ii) arrow from -1.35×10^{-19} J to -2.41×10^{-19} J: 1880 nm transition
arrow from -1.35×10^{-19} J to -5.44×10^{-19} J: 486 nm transition

2. a) $E = hf = \frac{hc}{\lambda} = 3.03 \times 10^{-19}$ J $= 1.9$ eV

b) **(i)** line from –1.5 to –3.4 eV level

(ii) $\Delta\lambda = 486$ nm so $\Delta E = 2.6$ eV so line from –0.85 to –3.4 eV level

3. a) Isotopes are nuclides of the same element with the same number of protons but different numbers of neutrons

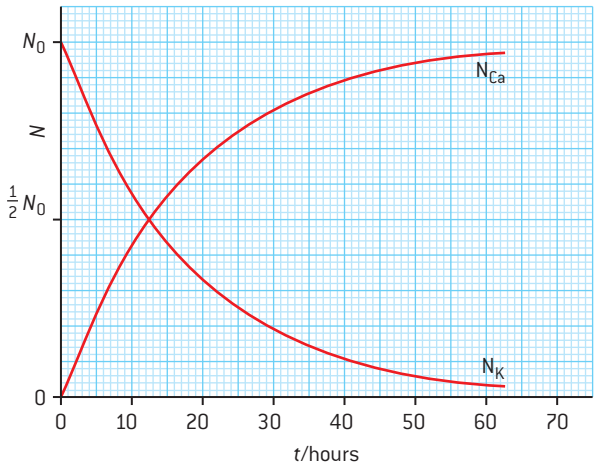
b) beta minus decay – proton number increases by one as neutron is converted to proton; electron antineutrino produced

c) check a sensible line of best fit (exponential decay curve) is drawn

d) half life = time for activity to decrease to half original value
Activity decreases from 3.2×10^5 Bq to 1.6×10^5 Bq in around 8 days

4. a) neutron converting into proton, so beta minus decay; nucleon number (total number of protons and neutrons) stays the same; electron and electron antineutrino also produced

b)



c) point on graph where number of calcium nuclei is 7 times greater than number of potassium nuclei

5. a) proton or neutron

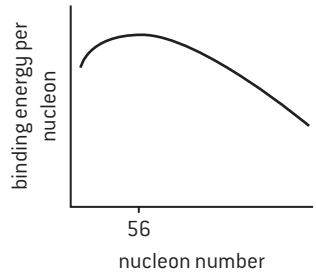
b) work needed to break nucleus into its constituent nucleons

c) most stable nuclide is Fe-56; lighter nuclei are less tightly bound so can release energy when they are fused together; heavier nuclei are less stable and can split into smaller constituents, releasing energy in fission

6. a) mass defect is $3.01603 - (2 \times 1.00728) - 1.00867 = -7.2 \times 10^{-3}$ u
total binding energy is $7.2 \times 10^{-3} \times 931.5 = 6.7$ MeV
3 nucleons so binding energy per nucleon is 2.2 MeV

b) (i) fusion reaction

(ii)



(iii) Helium nucleus is less stable than most stable nuclide, so energy is released when two nuclei are fused together

7. a) nuclear fission is the splitting of a heavy nucleus into smaller nuclei, producing energy; radioactive decay is when an unstable nucleus will spontaneously change into a different nuclear configuration

b) (i) get number of neutrons by balancing charges
${}^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} - {}^{90}_{38}\mathrm{Sr} + {}^{142}_{54}\mathrm{Xe} + 4\,{}^{1}_{0}\mathrm{n}$

(ii) neutron turns into proton, so nucleon number remains the same but proton number increases by one

8. a) nuclear fission

b) $(235.0439 + 1.0087) - (95.9342 + 137.9112 + 2 \times 1.0087) = 0.1898$ u
Energy $= 0.1898 \times 931.5 = 177$ MeV

c) neutrons released can go on to cause more fission reactions, leading to a chain reaction

d) nuclear binding energy

9. a) weak

b) W^+ boson

c) electron neutrino

10. a) (i) allowed (charge and lepton number conserved)

(ii) not allowed (baryon number not conserved)

(iii) not allowed (charge and baryon number not conserved)

b) can have W^+, W^-, or Z boson

11. a) meson (2 quark structure)

b) uud

c) $s\bar{u} + uud = d\bar{s} + u\bar{s} + sss$
baryon number and strangeness both conserved

12. a) exchange particle carries the force between particles; said to be virtual because it is not detected during exchange

b) W^- boson (diagram shows β^- decay)