1. This question is about atomic spectra and energy levels.

Diagram 1 below shows part of the emission line spectrum of atomic hydrogen. The wavelengths of the principal lines in the visible region of the spectrum are shown.

Diagram 2 shows some of the principal energy levels of atomic hydrogen.

Diagram 1

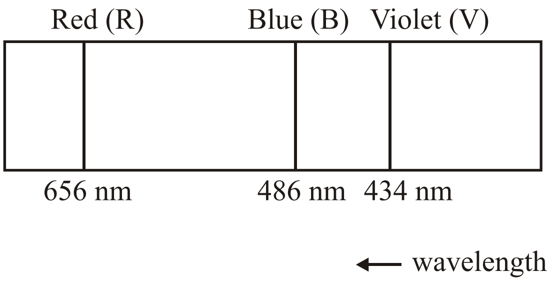
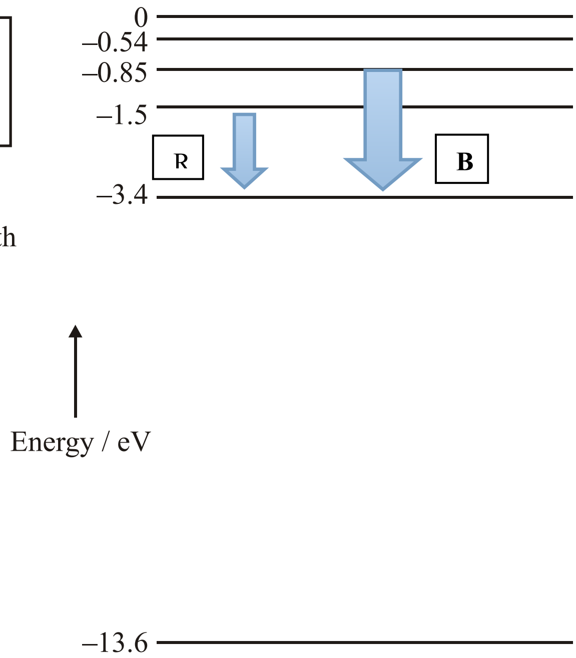


Diagram 2



(a) Name the spectral series shown in diagram 1.

Balmer. (1)

(b) Show, by calculation, that the energy of a photon of red light of wavelength 656 nm is 1.9 eV.

$E=hc/\lambda=6.63*10^{-34}*3*10^{8}/(656*10^{-9})=1.9$.

(3)

(b) On diagram 2, draw arrows to represent

(i) the electron transition that gives rise to the red line (label this arrow R).

(1)

(ii) a possible electron transition that gives rise to the blue line (label this arrow B).

(1)

(Total 6 marks)

2. This question is about the radioactive decay of potassium-40.

A nucleus of the nuclide ${}^{40}_{19}K$ (potassium-40) decays to a stable nucleus of the nuclide ${}^{40}_{18}Ar$ (argon-40).

(a) State the names of the **two** particles emitted in this decay.

Postron and antineutrino

(2)

(b) A sample of the isotope potassium-40 initially contains 1.5×10^{16} atoms. On average, 16 nuclei in this sample of the isotope undergo radioactive decay every minute.

Deduce that the decay constant for potassium-40 is $1.8 \times 10^{-17}\ s^{-1}$.

16/(1.5*10^16*60)=1.77*10^-17/s.

(3)

(c) Determine the half-life of potassium-40.

τ 1/2 =ln(2)/λ=3.85*10^16/s.

(1)
(Total 6 marks)

3. This question is about particle physics.

A neutron can decay into a proton, an electron and an antineutrino according to the reaction

$$n \rightarrow p + e + \bar{v}_e .$$

(a) Deduce the value of the electric charge of the antineutrino.

0

(1)

(b) State whether a proton is a baryon or a lepton.

Baryon..

(1)

(b) State the name of the fundamental interaction (force) that is responsible for this decay.

(1)

The weak interaction

(c) State how an antineutrino differs from a neutrino.

Opposite lepton numbers.

(Total 4 marks)

4. Nuclear binding energy and nuclear decay

(a) State what is meant by a *nucleon*, giving an example of two nucleons.

Nucleon is either a proton or a neutron.

(2)

(b) Explain what a nucleon is made of and what force holds it together. Include a description of the exchange particle that mediates the interaction between nucleons.

Nucleon is made of protons and neutron, which are made of quarks. Gluons hold quarks together

(2)

(c) Define what is meant by the *mass defect* of a nucleus.

The difference in mass between the mass of a nucleus and the mass of its separate nucleons.

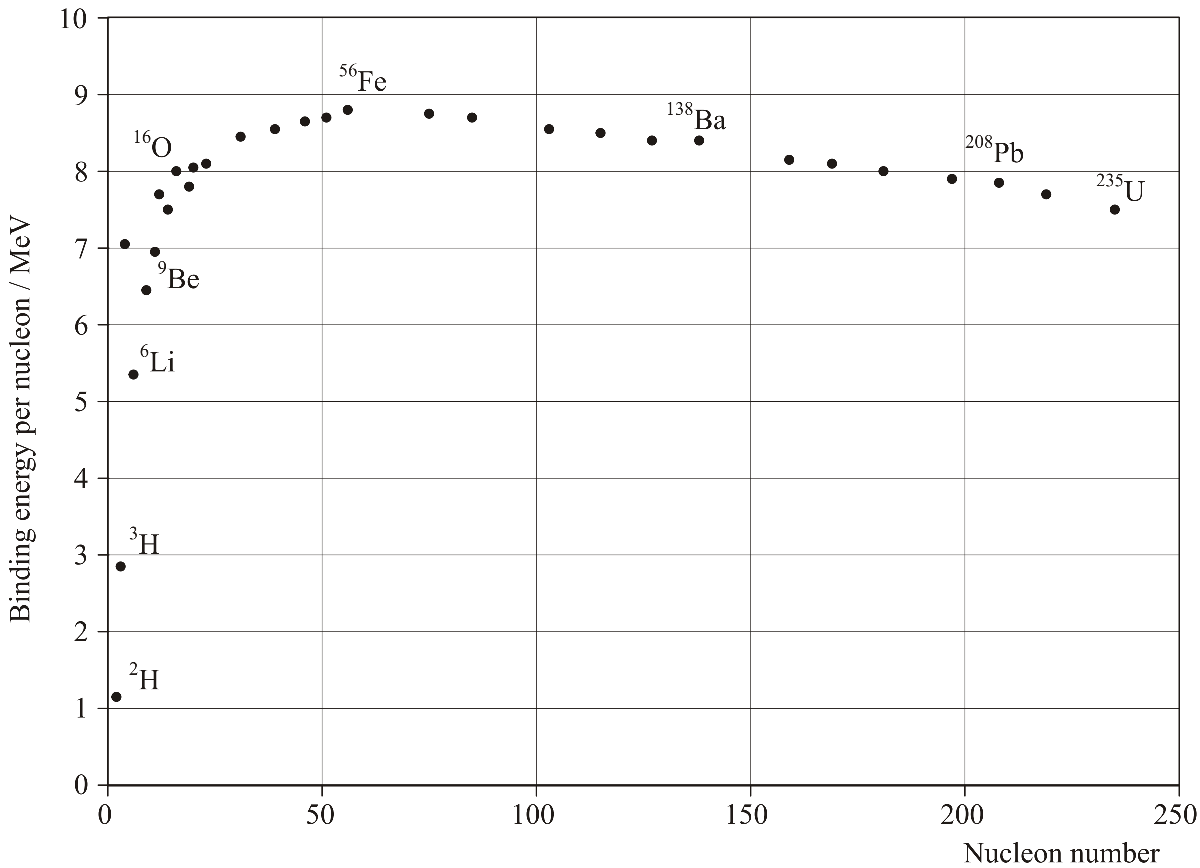
(1)

(c) Define what is meant by the *binding energy* of a nucleus.

Binding energy is the energy required to dissemble to a nucleus into its constituent nucleons.

(1)

The graph below shows the variation with nucleon (mass) number of the binding energy per nucleon.



(c) Use the graph to explain why energy can be released in both the fission and the fusion processes.

Energy release being possible as products have higher average binding energy per nucleon

(3)

(c) Use the graph to explain why there is an abundance of iron (Fe) in the universe.

The binding energy is at its maximum at Fe nickel-56 decays into iron, which is why iron is abundant in the universe.

(2

(d) A sample of carbon-11 has an initial mass of 4.0×10^{-15} kg. Carbon-11 has a half-life of approximately 20 minutes. Calculate the mass of carbon-11 remaining after one hour has elapsed.

Time elapsed $= \tau_{1/2} * 3 = 20 * 3 = 60\ minutes.$

$\left(\frac{1}{2}\right)^3 = \frac{1}{8}; \frac{1}{8} * 4 * 10^{-15} = 5 * 10^{-16}$ kg

(2)

(e) Uranium-238, ${}^{238}_{92}\text{U}$, undergoes α-decay to form an isotope of thorium. Write down the nuclear equation for this decay.

${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}\alpha.$

(2)
(Total 11 marks)

5. This question is about a proton.

The proton is made out of three quarks.

(a) Explain why the three quarks in the proton do not violate the Pauli exclusion principle.

One U quark is up, and one U quark is down (opposite spins); total spin depends on the spin of the D quark...

(2)

(b) Quarks have spin $\frac{1}{2}$. Explain how it is possible for the proton to also have spin $\frac{1}{2}$.

Fermions have half-integer spins; protons are fermions which are subject to Pauli exclusion principle...

(2)
(Total 4 marks)

6. Which **one** of the following correctly gives the number of electrons, protons and neutrons in a neutral atom of the nuclide $^{65}_{29}\text{Cu}$? D

	Number of electrons	Number of protons	Number of neutrons
A.	65	29	36
B.	36	36	29
C.	29	29	65
D.	29	29	36

(1)

7. The unified mass unit is defined as B

A. the mass of one neutral atom of $^{12}_{6}\text{C}$.

B. $\frac{1}{12}$ of the mass of one neutral atom of $^{12}_{6}\text{C}$.

C. $\frac{1}{6}$ of the mass of one neutral atom of $^{12}_{6}\text{C}$.

D. the mass of the nucleus of $^{12}_{6}\text{C}$.

(1)

8. Which of the following provides evidence for the existence of atomic energy levels? A

A. The absorption line spectra of gases

B. The existence of isotopes of elements

C. Energy release during fission reactions

D. The scattering of α -particles by a thin metal film

(1)