# 07 Atomic, Nuclear and Particle review answers

## NUCLEAR PHYSICS:

1. (a) State the properties of alpha, beta and gamma radiation (constituents, speed, penetration, ionization, mass, charge)

| Type of Radiation | Alpha particle (2 protons, 2 neutrons) | Beta particle (high speed electron) | Gamma ray (high frequency electro-magnetic wave) |
|---|---|---|---|
| Symbol | $\alpha$ or ${}^4_2\alpha$ or ${}^4_2He$ | $\beta$ or $\beta^-$ | (can look different, depends on the font) $\gamma$ |
| Mass (atomic mass units) | 4 | 1/2000 | 0 |
| Charge | +2 | -1 | 0 |
| Speed | slow | fast | very fast (speed of light) |
| Ionising ability | high | medium | low |
| Penetrating power | low | medium | High |
| Stopped by: | paper | aluminium | Lead |

(b) Uranium can fission if struck by a neutron. If the energy released by such a fission reaction is 4.3MeV what statement can you make about the mass of the products formed?
**The products will be lighter by 4.3/931.5 u = 0.0046u**

2. Radium 224 decays by alpha emission into Radon 220. (Masses: Ra(224)=224.02022u, Rn(220)=220.01140u, He(4)=4.00260). Calculate the energy produced in this reaction.
**Mass defect = u * (224.02022 - 220.01140 - 4.00260) = 0.00622u**
**Mass[u] x931.5 = Energy = 5.8 MeV**

3. (a) Explain the terms nuclide, nucleon, proton number Z and neutron number N.
**A nuclide is a particular type of nucleus having a distinct number of neutron and protons for example the U-235 nuclide, A nucleon is a component part of a nucleus (i.e. a proton or a neutron). Proton number is the number of protons in a nuclide. Neutron number is the number of neutrons in a nuclide.**

(b) By referring to the particles contained in a nucleus explain the term isotope.
**Nulcei of different isotopes of the same element have different numbers of neutron but the same number of protons.**

(c) Without referring to the particles contained in a nucleus explain the term isotope.
**Nulcei of different isotopes of the same element have different masses but the same charge.**

**4.** *Copy and complete*

Nuclear stability is governed chiefly by the balance between **electrostatic** repulsion between the **protons** and **attraction** between the protons and **neutrons** (**strong nuclear** force) The neutron:proton ratio in a small atom is **1:1** to maximise the **strong nuclear** force but in a larger nucleus the electrostatic repulsion is more significant and the ratio **increases** to **1.5:1** to reduce this repulsion.

**5.** Write the equations for the following reactions:

a) Carbon 14 decaying by B minus radiation

b) Uranium 238 decaying by alpha radiation,

c) Lithium 6 absorbing a neutron and emitting an alpha particle.

$$^{14}_{6}\mathrm{C} \rightarrow\ ^{14}_{7}\mathrm{N} +\ ^{0}_{-1}\beta^{-} +\ ^{0}_{0}\bar{V}$$

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

$$^{6}_{3}\mathrm{Li} +\ ^{1}_{0}\mathrm{n} \rightarrow\ ^{3}_{1}(\mathrm{H}) +\ ^{4}_{2}\alpha$$

**Atomic numbers: Carbon: 6, Uranium:92, Nitrogen: 7, Lithium: 3, Thorium 90.**

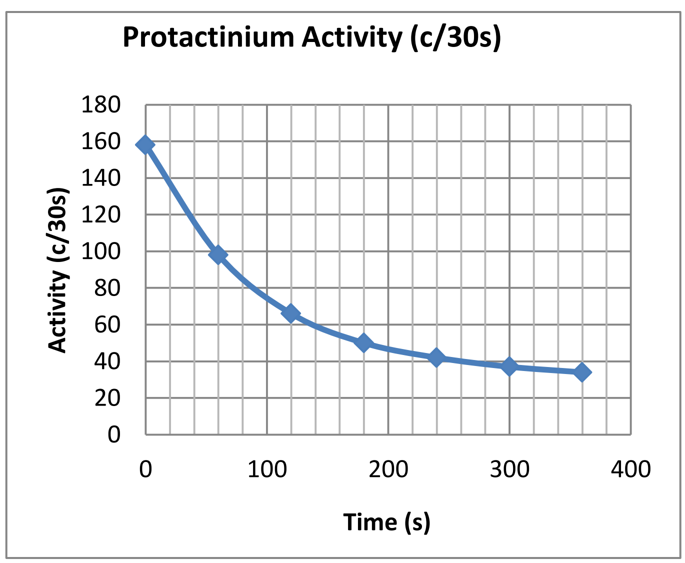
**6.** The radioactivity of a sample of Protactinium was recorded using a Geiger counter and the following results were obtained:

| Time interval | 0-30s | 60-90s | 120-150s | 180-210s | 240-270s | 300-330s | 360-390s |
|---|---|---|---|---|---|---|---|
| Counts in 30s | 158 | 99 | 67 | 50 | 42 | 37 | 34 |
| **Counts due to source** | **128** | **69** | **37** | **20** | **12** | **7** | **4** |

(a) The count rate without the Protactinium present was 30. Write down the count rate due to the protactinium source and sketch a graph of this count rate against time.

(b) State and explain whether the half life of protactinium is greater or less than 60s.

It is greater than 60s. Time taken for activity to halve (from graph) is about 80s. Each 60s interval is more than half the activity of the previous 60s



**7.** (a) Explain how both absorption and emission spectra in elements provide evidence for the Bohr model of the atom and atomic energy levels.

**Specific frequencies of electrons are absorbed/emitted therefore the atoms are absorbing/emitting discrete amounts of energy as their energy levels change.**

(b) Describe an experiment to observe emission spectra.

**Electricity is passed through a tube containing a gas at low pressure. And the resulting light viewed through a spectrometer.**

(c) Determine the wavelength of the photons emitted by a Hydrogen atom when the electron moves from:

(i) n=2 state with an energy level of -3.4eV to its ground state of n=1 with an energy level of -13.6eV?

**E = hf ..with E in Joules… so $f=E/h = (13.6-3.4)x1.6x10^{-19}/6.63x10^{-34} = 2.46x10^{15}m$**

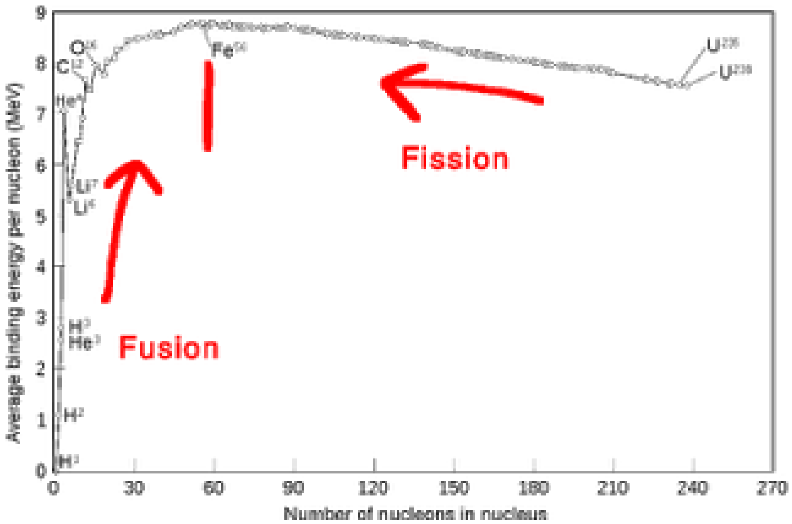
(ii) n=4 state with an energy level of -0.8eV to its ground state of n=2 with an energy level of -3.4eV?

**$f=E/h = (3.4-0.8)x1.6x10^{-19}/6.63x10^{-34} = 6.76x10^{14}m$**

**8.** The atomic mass of Nitrogen is 14 and its atomic number is 7. Rutherford bombarded Nitrogen nuclei with alpha particles and produced oxygen and released a proton. This was the first example of artificial transmutation. Write a nuclear transformation equation for this.

$$^{14}_{7}N + ^{4}_{2}\alpha \rightarrow ^{17}_{8}(O) + ^{1}_{1}p$$

**9.** Draw and annotate a graph showing the variation with nucleon number of the binding energy per nucleon. Use this graph to account for the fact that both nuclear fusion and fission can be a source of energy.




In both the fission and fusion the binding energy increases which means that energy is released in the transformations

**10.** (a) Write down Einstien's mass-energy equivalence relationship. **$\Delta E=\Delta mc^2$.**

(b) The unified mass unit (u) is defined as one twelfth the mass of a Carbon 12 atom and $6.03\times10^{23}$ of these have a mass of 12 grams.

(i) Use this data to calculate the mass of u.

**1/12 of mass of 12g of carbon = 0.001kg**

**One atom has mass of $m/N_A$ = 0.001 kg / $6.03\times10^{23}$ so u = $1.66\times10^{-27}$ kg**

(ii) Calculate the energy equivalent of u in Joules

**$E = mc^2 = 1.66\times10^{-27} \times (3\times10^8)^2 = 1.49\times10^{-7}$J**

**Alternatively look up u in data booklet**

**u = $930MeVc^{-2}$**

**$E = mc^2$ gives energy equivalent of u to be 930MeV**

**$930\times10^6 * 1.6\times10^{-19} = 1.49\times10^{-10}$J**

(c) Define binding energy (of a nucleus) and explain how an increase in binding energy results in a loss of mass.

**Binding energy is the work done to completely separate all of the nucleons in a nucleus.**

**If binding energy increases then this energy level of the nucleons is higher. This energy must have been created from the mass.**

**11. A Feynman diagram describes the quantum dynamics of particle reactions.**

**The diagram opposite shows the transformation of a neutron into a proton.**

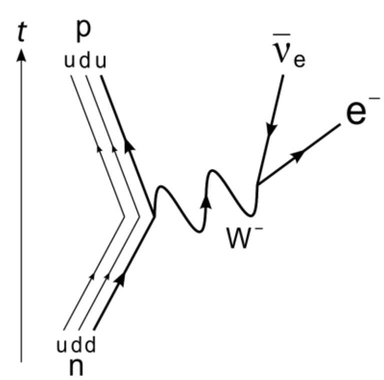
**(a) What is the exchange particle in this reaction?**

**A W- boson.**

**(b) Which force acts in this reaction?**

**Weak nuclear force.**

**(c) Which lepton is created?**



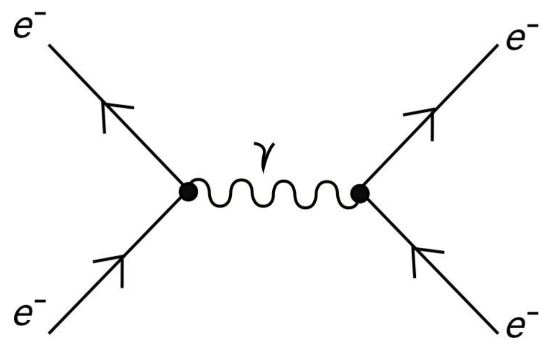
An electron.

(d) Explain how lepton number is conserved.

An anti-neutrino is also created which has a lepton number of -1.

(e) What is the baryon number before and after?

ONE. (each quark has a baryon number of 1/3).



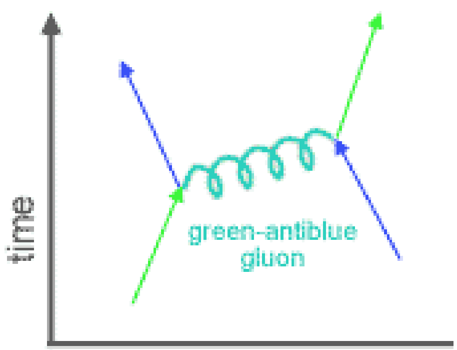

12. The diagram opposite represents the repulsion between two particles.

(a) What is the exchange particle involved?

A photon.

(b) Which force acts in this interaction?

Electromagnetic force.




13. The diagram to the left shows interaction between quarks.

(a) This interaction might be inside which type of particle?

A baryon (hadron or meson)

(b) Explain why quarks are not found on their own.

Colour confinement is always respected. There cannot be a overall colour charge in a particle.