

07 Atomic and Nuclear and Physics 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	α or ${}^4_2\alpha$ or ${}^4_2\text{He}$	β or β^-	(can look different, depends on the font) γ
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 $4.3/931.5 \text{ u} = 0.0046\text{u}$

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.

$$\text{Mass defect} = \text{u} * (224.02022 - 220.01140 - 4.00260) = 0.00622\text{u}$$

$$\text{Mass}[\text{u}] \times 931.5 = \text{Energy} = 5.8 \text{ MeV}$$

3. 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.

Nuclei 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.

Nuclei of different isotopes of the same element have different masses but the same charge.

4. Copy and complete

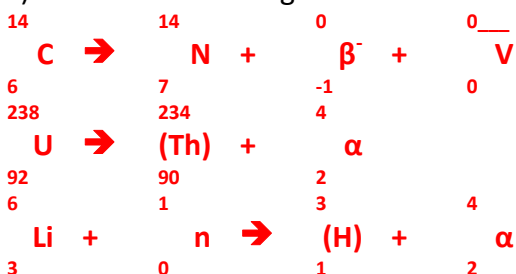
Nuclear stability is governed chiefly by the balance between **electrostatic** repulsion between the **protons** and **attraction** between the protons and **neutrons** (**strong nuclear** force) The neutron:proton ratio in a small atom is **1:1** to maximise the **strong nuclear** force but in a larger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



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

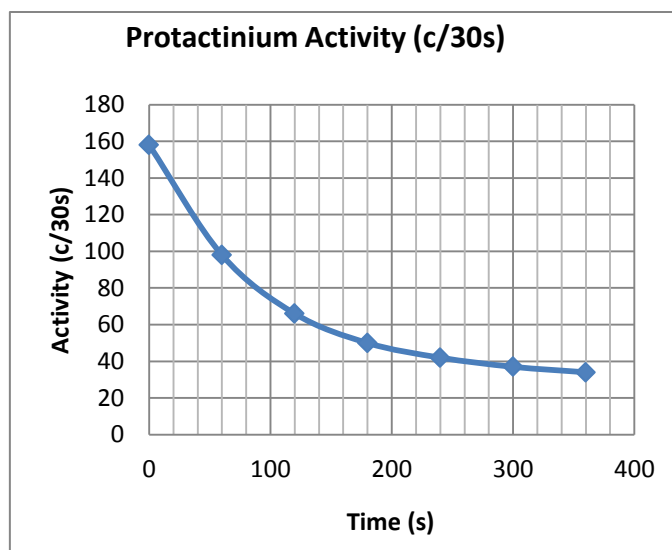
6. The radioactivity of a sample of Protactinium was recorded using a Geiger counter and the following results were obtained:

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.

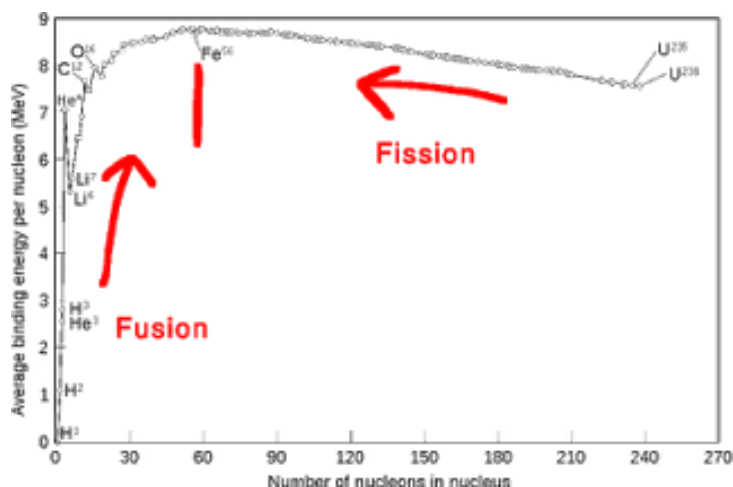
It is greater than 60s. Time taken for activity to halve (from graph) is about 80s. Each 60s interval is more than half the activity of the previous 60s



7. 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.



8. 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

9. Geiger and Marsden performed an experiment firing alpha particles at a thin gold foil.
 (a) Explain the conclusions that were drawn from this experiment and how they fit in with the Rutherford model of the atom that these results gave rise to.

Most of the alpha particles passed through the gold with little or no deflection so suggesting most of the structure is empty.

Some of the alpha particle rebounded strongly suggesting there are parts of the structure that repel the alpha particles and that these parts are significantly more massive than the alpha particle. (i.e. small but (relatively) massive positive parts)

- 10.** (a) Write down Einstein's mass-energy equivalence relationship. **$E=mc^2$.**
- (b) The unified mass unit (u) is defined as one twelfth the mass of a Carbon 12 atom and 6.03×10^{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 $m/N_A = 0.001 \text{ kg} / 6.03 \times 10^{23}$ so $u = 1.66 \times 10^{-27} \text{ kg}$
- (ii) Calculate the energy equivalent of u in Joules
 $E = mc^2 = 1.66 \times 10^{-27} \times (3 \times 10^8)^2 = 1.49 \times 10^{-7} \text{ J}$
Alternatively look up u in data booklet
 $u = 930 \text{ MeV}c^{-2}$
 $E = mc^2$ gives energy equivalent of u to be 930MeV
 $930 \times 10^6 * 1.6 \times 10^{-19} = 1.49 \times 10^{-7} \text{ J}$
- (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.