1. (a) (i) origins of background radiation:

cosmic rays
ground, rocks and buildings
air
nuclear weapons testing/nuclear accidents
nuclear power
discharge/waste from nuclear power
medical waste
any three **(1) (1)**any two **(1)**

(ii) (use of *C* = *C*0 e–λt gives) (84 – 3) = (110 – 3) e–λ×600 **(1)**

**(1)**

= 4.6(4) × 10–4 (s–1) **(1)**

(iii) (use of = – λ*N* gives) *N* = **(1)**

= 2.3**(1)** × 105 (nuclei) **(1)**(allow C.E. for value of λ from (ii)

**7**

(b) *α* radiation is highly **ionising**, hence causes cancer/damage cells/
DNA/kill cells **(1)**

**outside**: less damage plus reason
(e.g. absorbed by dead skin some *α*’s directed away from body) **(1)**[or reference to burning]

**inside**: more damage plus reason
(e.g. all *α*’s absorbed living tissue will absorb *α* radiation can reach
vital organs) **(1)**

**3**

**QWC 1**

[10]

2. (a) graph passes through N = 10/11 when Z = 10 and N increases as Z
increases **(1)**
N = 115 → 125 when Z = 80 and graph must bend upwards **(1)**

**2**

(b) (i) **W** at *Z* > 60 just (within one diagonal of a square) below line **(1)**

(ii) **X** just (within one diagonal of a square) above line **(1)**

(iii) **Y** just (within one diagonal of a square) below line **(1)**

**3**

(c) working showing the change due to emission of four α particles **(1)**
four β– particles **(1)**

**1**

(d) Any **two** from the following list of processes:

β+
describe the changes to *N* (up by 1) and *Z* (down by 1)
[or allow p change to n]

α
move closer to line of stability
[or state the proton to neutron ratio is reduced]

p
only if nuclide is **very** proton rich
[or electrostatic repulsion has to overcome the strong nuclear force]
[or highly unstable]
[or rare process]

e– capture
describe the changes to *N* (up by 1) and *Z* (down by 1)
allow p changes to n

marking: listing **two** processes **(1)**
discussing **each** of the two processes **(1)** **(1)**

**3**

**QWC 1**

[10]

**3.**

(a) graph to show:
electron intensity decreasing with angle of diffraction **(1)**to a non-zero first minimum **(1)**

**2**

(b) (i) last column of table completed correctly **(1)**with either

|  |  |
| --- | --- |
|  | ***A*1/3** |
|  | 5.93 |
|  | 4.93 |
|  | 3.83 |
|  | 3.04 |
|  | 2.29 |

or

|  |  |
| --- | --- |
|  | ***R*3/(10 -45m3)** |
|  | 295 |
|  | 165 |
|  | 82.3 |
|  | 40.4 |
|  | 18.8 |

axes cover more than 50% of graph sheet **(1)**all points plotted correctly using labelled axes
(i.e. *x*-axis A1/3, *y*-axis *R*/10–15m or *x* axis *A*, *y*-axis *R*3/10–45m3) **(1)**

(ii) gradient = *r0* **(1)** [or gradient = *r03*]
gives *r0* = (1.1 ± 0.1) × 10–15m **(1)**

**5**

(c) electrons are not subject to the strong nuclear force **(1)**(so) electron scattering patterns are easier to interpret **(1)**electrons give greater resolution
[or electrons are more accurate because they can get closer]
[or α particles cannot get so close to the nucleus because of
electrostatic repulsion] **(1)**electrons give less recoil **(1)**(high energy) electrons are easier to produce
[or electrons have a lower mass/ larger *Q/m*, so easier to accelerate] **(1)**(in Rutherford scattering) with *α* particles, the closest distance
of approach, not *R* is measured **(1)**

**max 3**

**QWC 1**

[10]

4.

(a) (i) an electron **(1)**

**1**

(ii) change in *A* = 0 **(1)**

change in *Z* = +1 **(1)**

**2**

(b) (i) **(1)**

**or** *n* → *p* + *e*– + 

**or** *d* → *u* + *e*– + 

**1**

(ii) lepton number must be conserved **(1)**

lepton number before decay equals zero

hence after decay lepton number of electrons cancels with lepton

number of anti-neutrino **or** zero on both sides **(1)**

**2**

(iii) hypothesis needs to be tested by experiment **(1)**

experiment must be repeatable **(1)**

**or** hypothesis rejected

**2**

**[8]**

**5.**

(a) the amount of energy required to separate a nucleus ✓
into its separate neutrons and protons / nucleons ✓
(or energy released on formation of a nucleus ✓
from its separate neutrons and protons / constituents ✓)

*1st mark is for correct energy flow direction*

*2nd mark is for binding or separating nucleons (nucleus is in the question but a reference to an atom will lose the mark)*

*ignore discussion of SNF etc*

*both marks are independent*

**2**

(b) (i) ✓

*must see subscript and superscripts*

**1**

(ii) binding energy of U
= 235 × 7.59 ✓ ( = 1784 (MeV))
binding energy of Tc and In
= 112 × 8.36 + 122 × 8.51 ✓
( = 1975 (MeV))
energy released ( = 1975 – 1784) = 191 (MeV) ✓ (allow 190 MeV)

*1st mark is for 235 × 7.59 seen anywhere
2nd mark for 112 × 8.36 + 122 × 8.51 or 1975 is only given if there are no other terms or conversions added to the equation (ignore which way round the subtraction is positioned)
correct final answer can score 3 marks*

**3**

(iii) energy released
= 191 × 1.60 × 10−13 ✓
( = 3.06 × 10−11 J)
loss of mass ( = *E / c*2 )
= 2.91 × 10−11 / (3.00 × 108)2)
= 3.4 × 10−28 (kg) ✓
or
= 191 / 931.5 u ✓ ( = 0.205 u)
= 0.205 × 1.66 × 10−27 (kg)
= 3.4 × 10−28 (kg) ✓

*allow CE from (ii)
working must be shown for a CE otherwise full marks can be given for correct answer only*

*note for CE
answer = (ii) × 1.78 × 10−30*

*(2.01 × 10−27 is a common answer)*

**2**

(c) (i) line or band from origin, starting at 45° up to Z approximately = 20 reading
*Z* = 80, *N* = 110→130 ✓

*initial gradient should be about 1 (ie Z = 20 ; N = 15 → 25) and overall must show some concave curvature. (Ignore slight waviness in the line)
if band is shown take middle as the line
if line stops at N > 70 extrapolate line to N = 80 for marking*

**1**

(ii) fission fragments are (likely) to be above / to the left of the line of stability ✓
fission fragments are (likely) to have a larger *N* / *Z* ratio than stable nuclei
or
fission fragments are neutron rich owtte ✓
and become neutron or β− emitters ✓

*ignore any reference to α emission
a candidate must make a choice for the first two marks
stating that there are more neutrons than protons is not enough for a mark
1st mark reference to graph
2nd mark – high N / Z ratio or neutron rich
3rd mark beta minus
note not just beta*

**3**

[12]

6.

(a) (i) energy separate nucleons **(1)**



energy associated with the strong force **(1)**

(ii) mass of nucleus < total mass of constituent nucleons **(1)**Δ*m* is difference between mass of nucleus and total mass
of nucleons **(1)**[Δ*m* = *Zm*p + (*A* – *Z*)*m*n – *m*nucleus **(1) (1)**]

*E*b = (Δ*m*)*c*2 **(1)**[or *E*b is energy equivalent of mass defect using *E* = *mc*2]

**max 4**

**QWC 1**

(b) mass of nucleus = 63.92915 – (30 × 0.00055) = 63.91265 (u) **(1)**Δ*m* = (30 × 1.00728) + (34 × 1.00867) – 63.91265 **(1)**= 0.60053 (u) **(1)***E*b = 0.60053 × 931.3 = 559.3 (MeV) **(1)**

*E*b/nucleon = = 8.74 (MeV/nucleon) **(1)**

(allow C.E. for Δ*m* and *E*b)

**5**

(c) nucleus has high value of *E*b/nucleon
[or is near maximum of *E*b/nucleon vs *A* curve] **(1)**

**1**

**[10]**

**7.**

(a) (i) 1/12 the mass of an (atom) of / carbon−12 / C12 

*a reference to a nucleus loses the mark*

**1**

(ii) separated nucleons have a greater mass (than when inside a nucleus)

*an answer starting with ‘its’ implies the nucleus*

because of the (binding) energy added to separate the nucleons or energy is released when a nucleus is formed (owtte) 

*marks are independent*

*direction of energy flow or work done must be explicit*

**2**

(b) nuclei need to be close together (owtte) for the Strong Nuclear Force to be involved or for fusion to take place 

*e.g. first mark – within the range of the SNF*

but the electrostatic / electromagnetic force is repulsive (and tries to prevent this) 

(if the temperature is high then) the nuclei have (high) kinetic energy / speed (to overcome the repulsion) 

*3rd mark is for a simple link between temperature and speed / KE*

**3**

(c) (i) 15 

*give the middle mark easily for any e or β with a + in any position*



12 

**3**

(ii) Δmass = 4 × 1.00728 − 4.00150 − (2 × 9.11 × 10−31 / 1.661 × 10−27)
or
Δmass = {4 × 1.00728 − 4.00150 − 2 × 0.00055}(u) 

*(4×1.00728=4.02912)*

*1st mark – correct subtractions in any consistent unit. use of mp = 1.67 × 10−27 kg will gain this mark but will not gain the 2nd as it will not produce an accurate enough result*

Δmass = 0.02652(u) 

*2nd mark - for calculated value*

*0.02652u*

*4.405 × 10−29 kg*

*3.364 × 10−12 J*

Δbinding energy (= 0.02652 × 931.5) {allow 931.3}

Δbinding energy = 24.7 MeV 

*3rd mark – conversion to Mev*

*conversion mark stands alone*

*award 3 marks for answer provided some working shown - no working gets 2 marks*

*(2sf expected)*

**3**

[12]