Nuclear Radius - Answers

1. (a) (i) $R_D = 1.3 \times 2^{1/3} = 1.64$ fm **(1)** $R_T = 1.3 \times 3^{1/3} = 1.64$ fm **(1)**

(ii) energy at 'contact' = $\frac{Q_1 Q_2}{4\pi\varepsilon_0 r}$ **(1)**

$= \frac{e^2}{4\pi\varepsilon_0 \times (3.51 \times 10^{-15})}$ **(1)**

$= 6.56 \times 10^{-14}$ J **(1)**

$\frac{6.56 \times 10^{-14}}{1.6 \times 10^{-13}} = 4.10$ MeV **(1)** max 5

(b) energy of nucleus = 3/2 kT **(1)**

$6.56 \times 10^{-14} = 3/2 \times 1.38 \times 10^{-23} \times T$ **(1)**

gives $T = 3.2 \times 10^9$ K **(1)** (marks available for alternative sensible use of energy data)

reference to range of speeds (or energies) of nuclei (or atoms) **(1)** max 3

[8]

2. (a) $m = 4.0026 \times 1.66 \times 10^{-27}$ (kg) **(1)** (= 6.6×10^{-27} kg – electron masses are not significant)

kinetic energy ($=\frac{1}{2}m\upsilon^2$) $= 0.5 \times 6.65 \times 10^{-27} \times (2.00 \times 10^7)^2$ **(1)**

(= 1.33×10^{-12} J) 2

(b) loss in k.e. = gain in p.e. **(1)**

loss of ke. [or 1.33×10^{-12}] = $\frac{Qq}{4\pi\varepsilon_0 R}$ **(1)** $\left(= \frac{2Ze^2}{4\pi\varepsilon_0 R}\right)$

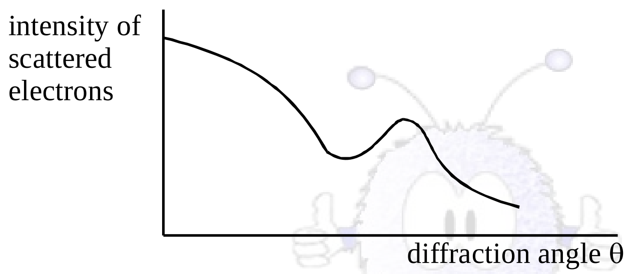
$R = \frac{2 \times 79 \times (1.6 \times 10^{-19})^2}{4\pi \times 8.85 \times 10^{-12} \times 1.33 \times 10^{-12}}$ **(1)**

$= 2.73 \times 10^{-14}$ m **(1)** 4

(c) *any valid point including*:
strong force complicates the process (*)
scattering caused by distribution of protons not whole nucleon distribution (*)
α particles are massive causing recoil of nucleus which complicates results (*)
(*) any **one (1)** 1

[7]

3. (a)

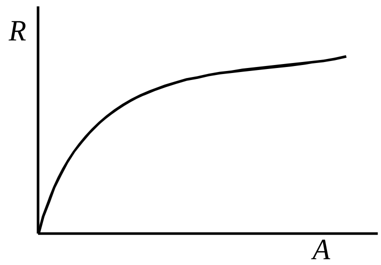


graph shows a minimum **(1)**
which does not touch the axis **(1)** 2

(b) the (de Broglie) wavelength of high energy electrons is comparable to nuclear radii [or not subject to the strong nuclear force] **(1)** 1

(c) nuclear density is constant **(1)**
separation of neighbouring nucleons is constant
[or nucleons are close-packed] **(1)** 2

(d)



correct curve **(1)** 1

(e) $R = r_0 A^{\frac{1}{3}}$ **(1)**

$R_0 \left(= R_c \left(\frac{A_0}{A_c} \right)^{\frac{1}{3}} \right) = 3.04 \times 10^{-15} \times \left(\frac{16}{12} \right)^{\frac{1}{3}}$ **(1)**

$R_0 = 3.35 \times 10^{-15}$ m **(1)** 3

[9]

4. $(R^3 = R_0^3 A)$

plot R^3 against A with axes labelled **(1)**
units on axes **(1)**
scales chosen to use more than 50% of page **(1)**

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element	$R/10^{-15}$ m	A	$R^3/10^{-45}$ m^3
carbon	2.66	12	18.8
silicon	3.43	28	40.4
iron	4.35	56	82.3
tin	5.49	120	165.5
lead	6.66	208	295

calculate data for table **(1)**
plot data **(1)(1)** lose one mark for each error
calculation of gradient

e.g. gradient = $\frac{300 \times 10^{-45}}{213}$ **(1)** (= 1.41×10^{-45} m^3)

r_0 (= gradient)$^{1/3}$ **(1)**

= $(1.41 \times 10^{-45})^{1/3} = 1.1(2) \times 10^{-15}$ m **(1)**

alternative:

plot R against $A^{1/3}$ with axes labelled **(1)**
units on axes **(1)**
scales chosen to use more than 50% of page **(1)**

Nuclear Radius - Answers

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element	$R/10^{-15}$ m	A	$A^{1/3}$
carbon	2.66	12	2.29
silicon	3.43	28	3.04
iron	4.35	56	3.83
tin	5.49	120	4.93
lead	6.66	208	5.93

calculate data for table **(1)**
plot data **(1)(1)** lose one mark for each error
calculation of gradient

e.g. gradient = $\frac{6.72 \times 10^{-15}}{6.0}$ **(1)** = $(1.1(2) \times 10^{-45}\ \text{m}^3)$

r_0 = gradient **(1)**
= $1.1(2) \times 10^{-15}$ m **(1)**
[or plot lnR against lnA...] max 8

(b) assuming the nucleus is spherical
ignoring the gaps between nucleons
assuming all nuclei have same density
assuming total mass is equal to mass of constituent nucleus
any one assumption **(1)**

$$M = \frac{4}{3}\pi R^3 \rho \ \textbf{(1)}$$

$$\left(\therefore M = \frac{4}{3}\pi R_0^3\, a\rho\right)$$

$$\left(\therefore \rho = \frac{3m}{4\pi R_0^3}\right) = \frac{3 \times 1.67 \times 10^{-27}}{4\pi \times (1.12 \times 10^{-15})^3} \ \textbf{(1)}$$

= 2.8×10^{17} kgm^{-3} **(1)** 4

[12]