Name of the Student:_____
Max. Marks : 20 Marks **Time : 20 Minutes**

Q1.

(a) Nuclear radii can be estimated using either alpha particles or high-energy electrons.

State **two** advantages of using high-energy electrons rather than alpha particles for this estimate.

1 _____

_____

_____

2 _____

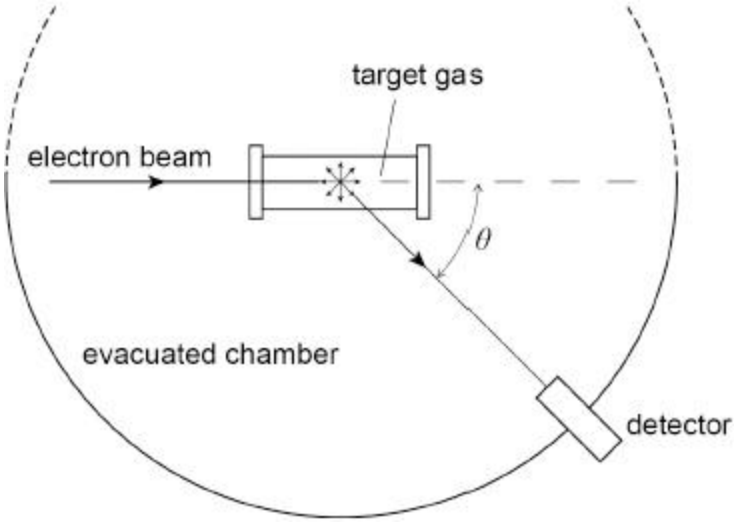
_____

_____

(2)

(b) **Figure 1** shows a beam of electrons, each with the same high energy, incident on a target gas.
The electrons are diffracted by the nuclei in the gas.
The intensities of these diffracted electrons are measured at various angles θ.
The data are used to determine the nuclear radius R of the atoms in the gas.

Figure 1



Sketch on **Figure 2** a graph showing how the electron intensity varies with θ.

Figure 2

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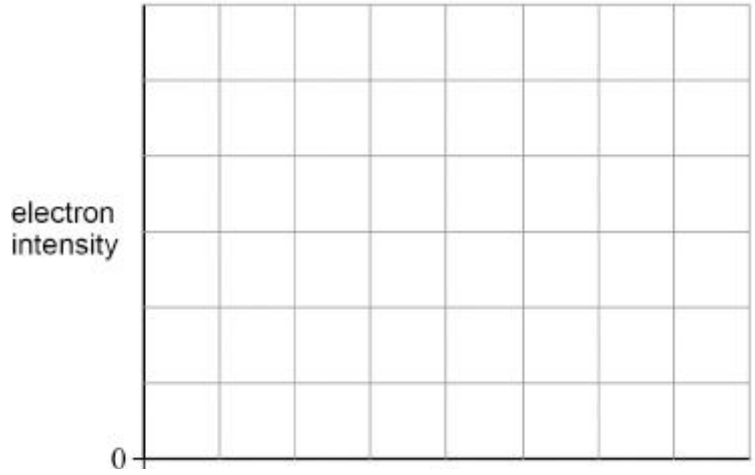

(2)

(c) The radius R of a nucleus is related to its nucleon number by $R = R_0 A^{\frac{1}{3}}$.

Show that this equation is consistent with the idea that all nuclei have the same density.

(2)

(d) The equation $R = R_0 A^{\frac{1}{3}}$ is derived from experimental data.

Suggest **one** reason why the constant density of nuclear material derived from this equation is only approximate.

_____

_____

_____

(1)

(e) The measured radius R of $^{35}_{17}\mathrm{Cl}$ is 4.02×10^{-15} m.

Calculate an estimate of

- the constant R_0
- the density of nuclear material.

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R_0 = _____ m density = _____ kg m^{-3}

(3)

(Total 10 marks)

Q2.

(a) Carbon is used as the moderator in some thermal nuclear reactors.

Identify **one** other material commonly used as a moderator.

_____

(1)

(b) State **two** benefits of slowing down the neutrons released during fission.

1 _____

_____

2 _____

_____

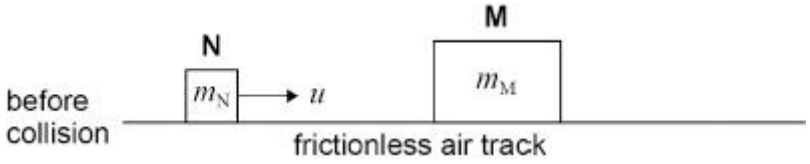
(2)

(c) The collision of a neutron with the nucleus of a moderator atom is modelled using two gliders on a horizontal frictionless air track.

In **Figures 1** and **2** the glider **N** of mass m_N represents the neutron and the glider **M** of mass m_M represents the moderator nucleus.

Figure 1 shows glider **N** travelling with initial speed u towards the stationary glider **M**.

Figure 1



The gliders collide. **N** rebounds with speed v as shown in **Figure 2**.

Figure 2

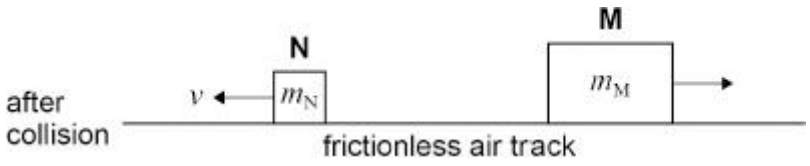


Figure 3 shows the variation of the ratio $\frac{v}{u}$ with the ratio $\frac{m_M}{m_N}$.

Figure 3

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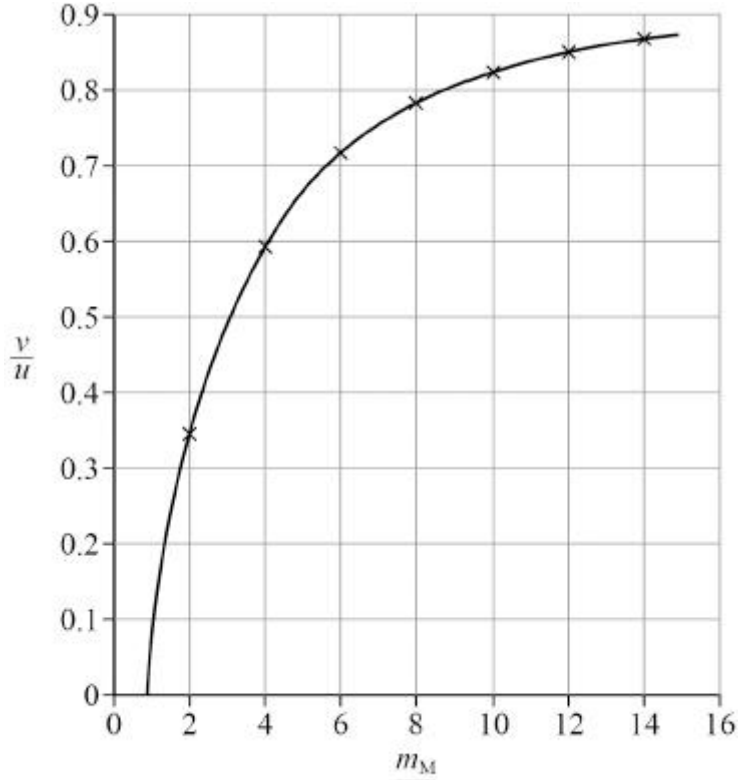

Show that when $\frac{m_M}{m_N}$ is 12, **N** loses about 30% of its initial kinetic energy

in the collision.

(2)

(d) In a reactor, the speed of a fast-moving neutron is reduced by a series of y random collisions with carbon-12 nuclei.

The final kinetic energy E_f of the neutron is

$$E_f = E_0 e^{-by}$$

where E_0 is the initial kinetic energy of the neutron and $b = 0.73$

A thermal neutron has kinetic energy equivalent to that of the average particle of an ideal gas with a temperature of 350 K.

One neutron has an initial kinetic energy of 1.0 MeV.

Calculate the minimum value of y required so that this neutron becomes a thermal neutron.

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y = _____

(3)

(e) Explain, with reference to **Figure 3**, why elements with a small nucleon number are preferred as moderator materials.

_____

_____

_____

_____

_____

_____

(2)

(Total 10 marks)

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