

Name of the Student: _____

Max. Marks : 24 Marks

Time : 24 Minutes

Q1.

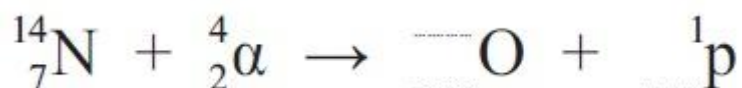
Electrical power generated by nuclear fission makes an important contribution to world energy needs. However Rutherford, who is credited with the discovery and first splitting of the nuclear atom, later said: "The energy produced by the breaking down of the atom is a very poor kind of thing. Anyone who expects a source of power from the transformation of these atoms is talking moonshine."

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Rutherford carried out experiments that involved firing alpha particles at nitrogen atoms.

(a) (i) Complete the equation for the interaction between nitrogen and alpha particles.

(1)

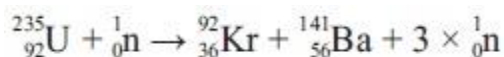


(ii) This interaction requires a small energy input. Other similar nuclear reactions may give an energy output of no more than 20 MeV, giving some justification to Rutherford's statement. Suggest why Rutherford's statement eventually turned out to be very inaccurate.

(1)

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(b) Uranium-235 is able to undergo fission when it absorbs a neutron to become uranium-236. The equation below shows a possible fission reaction



Use the data in the table to show that the energy released by the fission of one uranium nucleus is about 170 MeV.

Isotope	Mass / 10^{-27} kg
${}^{235}\text{U}$	390.29989
${}^{141}\text{Ba}$	233.99404
${}^{92}\text{Kr}$	152.64708
${}^1\text{n}$	1.67493

(4)

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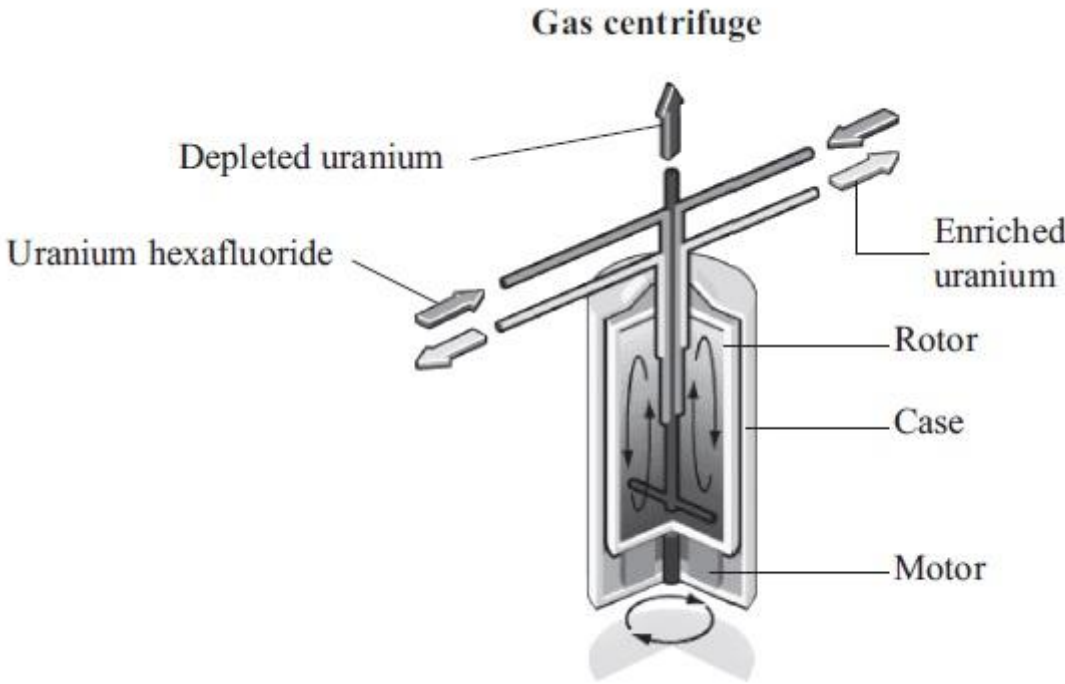
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(c) Naturally occurring uranium is more than 99% uranium-238. Fuel for a fission reactor requires at least 3% of the uranium to be uranium-235.

Uranium hexafluoride gas is used during the uranium enrichment process. It is fed into a centrifuge, and a rotating cylinder (rotor) sends the uranium-238 to the outside of the cylinder, where it can be drawn off, while the uranium-235 diffuses to the center of the cylinder.



(i) Give **one** similarity and **one** difference between the nuclei of uranium-238 and uranium-235.

(2)

Similarity

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Difference

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(ii) The rotor has a diameter of 30 cm and spins at a rate of 60,000 revolutions per minute. Calculate the centripetal acceleration at the rim of the rotor.

(2)

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Centripetal acceleration =

(iii) The rotor is subjected to huge forces because of the high spin rate.

Give **two** mechanical properties essential for the material from which the rotor is made.

Property 1

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Property 2

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(d) The waste heat from some power stations is transferred to water.

The San Onofre Nuclear Generating Station in California has reactors with a total output power of 2200 MW. These reactors circulate sea water at an average mass flow rate of $7.0 \times 10^4 \text{ kg s}^{-1}$. The water is heated to approximately 11 K above the input temperature as it flows through condensers, before being discharged back into the ocean.



Show that the rate at which energy is removed from the reactors is about 3000 MW, and hence estimate a value for the efficiency of the electrical power generation process.

specific heat capacity of the sea water = $3990 \text{ J kg}^{-1} \text{ K}^{-1}$

(4)

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Efficiency =
(Total for question = 16 marks)

Q2.

At the Culham Centre for Fusion Energy (CCFE) experiments are carried out to investigate nuclear fusion and the properties of plasmas. A plasma consists of ionised gas, containing positive ions and electrons.

In a plasma experiment 5.0 mg of deuterium, an isotope of hydrogen, occupies a volume of 98 m³. The temperature of deuterium is raised to 1.3 × 10⁸ K. In this experiment, the deuterium behaves as an ideal gas.

(i) Calculate the pressure due to the deuterium ions.

mass of deuterium ion = 3.3 × 10⁻²⁷ kg

(3)

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Pressure =

(ii) Calculate the root mean square speed of the deuterium ions at this temperature.

(2)

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Root mean square speed =

(iii) The temperature of the plasma is monitored using the Doppler effect. Light from a laser is directed into the plasma and the wavelength of the light reflected is measured.

The Doppler shift observed when light is reflected by a deuterium ion is twice the Doppler shift that would be observed for a source of light moving at the same speed as the deuterium ion.

Calculate the maximum wavelength of light that would be detected after reflection from a deuterium ion moving at 1.5 × 10⁶ m s⁻¹.

wavelength of laser light = 1064 nm

(3)

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Maximum wavelength detected =

(Total for question = 8 marks)