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| 25: Radioactivity 1Nuclear Radius and Types of Radiation |
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| Paper 2 |  |
| 17: Thermal Physics 1Specific Heat Capacity and Latent Heat | 1. Qualitative study of Rutherford scattering.
2. Appreciation of how knowledge and understanding of the structure of the nucleus has changed over time.
3. Their properties and experimental identification using simple absorption experiments; applications eg to relative hazards of exposure to humans.
4. Applications also include thickness measurements of aluminium foil paper and steel.
5. Inverse-square law for γ radiation: $I=\frac{k}{x^{2}}$
6. Experimental verification of inverse-square law.
7. Applications eg to safe handling of radioactive sources.
8. Background radiation; examples of its origins and experimental elimination from calculations.
9. Appreciation of balance between risk and benefits in the uses of radiation in medicine.

**Required practical 12:** Investigation of the inverse-square law for gamma radiation.  |
| 18: Thermal Physics 2Gas Laws and the MKTM |
| 19: Gravitational FieldsField Strength and Potential |
| 20: Electric FieldsFields Strength and Potential |
| 21: Fields ComparisonsOrbits and Comparisons |
| 22: CapacitorsEnergy Stored and Exponential Decay |
| 23: Magnetic Fields 1Magnetic Forces and Flux |
| 24: Magnetic Fields 2Induction and Transformers |
| 25: Radioactivity 1Nuclear Radius and Types of Radiation |
| 26: Radioactivity 2Modes and Rate of Decay |
| 27: Nuclear Physics Binding Energy, Fission and Fusion |
| Paper 3 |
| 28: Electron DiscoverySpecific Charge and Millikan |
| 29: Wave-Particle DualityWaves, Quantum and Microscopes |
| 30: Special RelativityMichelson-Morley & Relativistic Speed |

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| **Monday: Radiation Notes**Complete this table comparing the properties of alpha, beta and gamma radiation.

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|  | Alpha | Beta | Gamma |
| Structure (or nature) |  |  |  |
| Relative mass |  |  |  |
| Relative charge |  |  |  |
| Deflection by EM field? |  |  |  |
| Ionising power |  |  |  |
| Penetrating power |  |  |  |
| Range in air |  |  |  |
| Stopped by: |  |  |  |

**Medical tracers**Describe how a gamma emitter is used in medical diagnosis.…………………………………………………………………………..…….………………………………………………………………………..…………………………………………………………………………..…….………………………………………………………………………..…………………………………………………………………………..…….………………………………………………………………………..Explain why only gamma radiation is suitable.…………………………………………………………………………..…….………………………………………………………………………..………………………………………………………………………..……….………………………………………………………………………..

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| A Geiger-Muller tube connected to a counter can be used to detect the amount of ionising radiation present. The tube is filled with a non-conducting gas.Outline what happens when ionising radiation enters the tube and how this leads to a ‘count’. |  |

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Describe how the background count rate could be found.…………………………………………………………………………..…….………………………………………………………………………..………………………………………………………………………..……….………………………………………………………………………..What does the term ‘corrected count rate’ mean?…………………………………………………………………………..…….………………………………………………………………………..………………………………………………………………………..……….………………………………………………………………………..The inverse square law is given on our equation sheet as:$$I=\frac{k}{x^{2}}$$Symbol $I$ Quantity …………………………………………………………………………………………… Units ……………………… or ……………………………………………………………………………………………………………………………………..Symbol $x$ Quantity …………………………………………………………………………………………… Units ………………………Symbol $k$ Quantity ……………………………………………………………………………….……….……………………………………. It definitely doesn’t represent: ….………………………………………………………….….………….……………………….We often use the inverse square law to predict the count rate at a second point when the count rate at another point is known.$$I\_{1}\left(x\_{1}\right)^{2}=I\_{2}\left(x\_{2}\right)^{2}$$The inverse square law doesn’t take into account the background count rate.Before using the inverse-square law we need to …………………………………………………………………………………………....If asked for the reading on the counter we need to …………………………………………………………………………………………....The inverse square law can be investigated using a set-up as shown in the diagram.**https://app.doublestruck.eu/content/AG_PH/HTML/Q/Q13SIP207_files/img01.png**If the results from the investigation followed the inverse square law sketch the graphs that would be obtained. How else could you tell if the results follow the inverse square law?………………………………………………………………….…………….……………………………………………………….………………..……………………………………………………………………….……….……………………………….………………………………………..Why might the results not follow the inverse square law?……………………………………………………………………….……….……………………………….………………………………………..………………………………………………………………….…………….……………………………………………………….………………..……………………………………………………………………….……….……………………………….……………………………………….. |

**Tuesday: Inverse Square Law Exam Questions**

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| **Q132(a)**   Which ionizing radiation produces the greatest number of ion pairs per mm in air? Tick (✓) the correct answer.

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| α particles |   |
| β particles |   |
| γ rays |   |
| X−rays |   |

**(1)****Q132(bi)**   Complete the table showing the typical maximum range in air for α and β particles.

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| --- | --- | --- |
|    | **Type of radiation** | **Typical range in air / m** |
|   | α |   |
|   | β |   |

**(2)****Q132(bii)**   γ rays have a range of at least 1 km in air.However, a γ ray detector placed 0.5 m from a γ ray source detects a noticeably smaller count-rate as it is moved a few centimetres further away from the source.Explain this observation....................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................... **(1)****Q132(c)**   Following an accident, a room is contaminated with dust containing americium which is an α−emitter.Explain the most hazardous aspect of the presence of this dust to an unprotected human entering the room......................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................... **(2)** **(Total 6 marks)****Q133(a)**   The exposure of the general public to background radiation has changed substantially over the past 100 years.State **one** source of radiation that has contributed to this change..................................................................................................................................................................................................................................................................................................................................................................................................... **(1)****Q133(b)**   A student measures background radiation using a detector and determines that background radiation has a mean count-rate of 40 counts per minute. She then places a γ ray source 0.15 m from the detector as shown below. With this separation the average count per minute was 2050.The student then moves the detector further from the γ ray source and records the count-rate again.**Q133(bi)**   Calculate the average count-rate she would expect to record when the source is placed 0.90 m from the detector.count-rate = ................................................ min–1 **(3)****Q133(bii)**  The average count per minute of 2050 was determined from a measurement over a period of 5 minutes. Explain why the student might choose to record for longer than 5 minutes when the separation is 0.90 m......................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................... **(1)****Q133(biii)**   When the detector was moved to 0.90 m the count-rate was lower than that calculated in part **(bi)**. It is suggested that the source may also emit β particles.Explain how this can be checked............................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................... **(2)** **(Total 7 marks)** |

**Wednesday: Types of Radiation Extended Writing**

A radioactive source used in a school laboratory is thought to emit α and γ. Describe an experiment that may be used to verify the types of radiation emitted by the source. The experiment described should allow you to determine how the intensity of radiation caries with distance in air or with thickness of suitable absorbers. Your answer should include:

* The apparatus you would use
* Any safety precautions you would take
* The measurements you would make
* How the measurements would be used to reach a final decision about the emitted radiation.

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**Wednesday: Nuclear Radius and Types of Radiation Definitions**

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| Paper | A material suitable for blocking alpha radiation. |
| Alpha | Ionising radiation with a relative mass of 4. |
| Gold Foil | Alpha particles were fired at this in Rutherford’s experiment. |
| Increase | If the number of nucleons is increased, this will happen to the nuclear radius. |
| Aluminium | 5 mm of this material will block alpha and beta radiation but not gamma. |
| Metastable | Technetium in an excited state can be described as this. |
| Quadrupled | If the distance between a Geiger counter and gamma source is halved the activity will be … |
| Tracer | A radiopharmaceutical that is injected or ingested. |
| Alpha | The most ionising radiation. |
| Electron Diffraction | A method of measuring the nuclear radius. |
| Cosmic Rays | A source of background radiation from the Sun. |
| Solid Sphere | The model of the atom where it has no inner structure. |
| Electric Potential | Alpha particles gain this type of energy as they approach the gold foil. |
| Planetary | The model of the atom where electrons exist on discrete energy levels. |
| Lead | Along with concrete this material protects against gamma radiation. |
| Nuclear | The model of the atom that first had concentrated mass in the centre. |
| Kinetic | Alpha particles lose this type of energy as they approach the gold foil. |
| Gamma | Uncharged ionising radiation. |
| Plum Pudding | The model of the atom that first contained charged particles. |
| Nothing | If the number of nucleons is increased, this will happen to the nuclear density. |
| Rutherford | This person’s experiment lead to the idea of the nucleus. |
| Closest Approach | A method of estimating the nuclear radius using alpha particles. |
| Quartered | If the distance between a Geiger counter and gamma source is doubled the activity will be … |
| Gamma | The least ionising radiation. |
| Ionising | The type of radiation what alpha, beta and gamma radiation are. |
| Radon Gas | The largest contributor to background radiation. |
| Fallout | A source of background radiation due to nuclear weapons testing and use. |
| Carbon 14 | A source of background radiation due to living things. |

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| --- | --- | --- | --- |
| Alpha | Alpha | Aluminium | Carbon 14 |
| Closest Approach | Cosmic Rays | Electric Potential | Electron Diffraction |
| Fallout | Gamma | Gamma | Gold Foil |
| Increase | Ionising | Kinetic | Lead |
| Metastable | Nothing | Nuclear | Paper |
| Planetary | Plum Pudding | Quadrupled | Quartered |
| Radon Gas | Rutherford | Solid Sphere | Tracer |
| **Thursday: Nuclear Radius Notes**Describe the plum pudding model of the atom.…………………………………………………………………………..…….………………………………………………………………………..………………………………………………………………………..……….………………………………………………………………………..…………………………………………………………………………..…….………………………………………………………………………..Label this diagram of the experimental set-up.Why did the results of this experiment lead to the model of the atom being revised?………………………………………………………………………..……….………………………………………………………………………..………………………………………………………………………..……….………………………………………………………………………..…………………………………………………………………………..…….………………………………………………………………………..Explain what was deduced from the following observations:A) Most of the alpha particles went straight through without deflection.…………………………………………………………………………..…….………………………………………………………………………..………………………………………………………………………..……….………………………………………………………………………..B) 1 in 100 were deflected by small angles.…………………………………………………………………………..…….………………………………………………………………………..………………………………………………………………………..……….………………………………………………………………………..C) 1 in 10000 were deflected by more than 90°.…………………………………………………………………………..…….………………………………………………………………………..………………………………………………………………………..……….………………………………………………………………………..Why did the air need to be removed from the apparatus?…………………………………………………………………………..…….………………………………………………………………………..………………………………………………………………………..……….………………………………………………………………………..Why does the foil need to be very thin?…………………………………………………………………………..…….………………………………………………………………………..…………………………………………………………………………..…….………………………………………………………………………..………………………………………………………………………..……….………………………………………………………………………..The size of the nucleus could be estimated from Rutherford’s scattering experiment. The speed of the alpha particles decreases as they approach the gold nucleus due to the electromagnetic repulsion. The alpha particles will eventually come to a complete stop at point P; the kinetic energy has been transformed into electric potential energy.Derive an equation to calculate the **closest approach** (the closest distance that the alpha particle gets to the nucleus).Calculate the closest approach if the alpha particles were given an initial kinetic energy of:

|  |  |
| --- | --- |
| 2.18 × 10–12 J fired at a $$ nucleus. | 6.50 × 10–13 J fired at a $$ nucleus. |

The size of a nucleus can be calculated by **electron diffraction**. A beam of high energy electrons is fired at 90° to a thin metal foil and the diffraction pattern is observed similar to that of light through a single slit. A calculation can be made using the first minimum in the electron diffraction pattern.

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| The de Broglie wavelength λ of each electron in the beam is about 3.3 × 10−15 m.The graph shows how the relative intensity of the scattered electrons varies with angle due to diffraction by a nuclei. The angle is measured from the original direction of the beam.The angle θ of the first minimum in the electron diffraction pattern is given by:Calculate the radius of this nucleus using information from the graph. |  |

Approximate value of the nuclear radius by: the closest approach of alpha particles: ……………….…..…… the diffraction of electrons: …………….…………..The equation for nuclear radius has been derived from experimental data and is given as:$$R=R\_{0}A^{1/3}$$Symbol $R$ Quantity …………………………………………………………………………………………… Units ………………………Symbol $R\_{0}$ Quantity …………………………………………………………………………………………… Units ………………………Symbol $A$ Quantity ……………………………………………………………………………………………………...………………………Derive an equation for the density of a nucleus.

|  |  |  |  |
| --- | --- | --- | --- |
| Density | Mass of nucleons and a sphere | Nuclear radius | Cancel out |
| $$ρ=\frac{m}{V}$$ |  |  |  |

What is the significance of your final equation? ………….…………….……………………………………………………….………………..……………………………………………………………………….……….……………………………….……………………………………….. |

**Friday: Nuclear Radius Exam Questions**

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| **Q134(a)**   Scattering experiments are used to investigate the nuclei of gold atoms.In one experiment, alpha particles, all of the same energy (monoenergetic), are incident on a foil made from a single isotope of gold.**Q134(ai)**   State the main interaction when an alpha particle is scattered by a gold nucleus..................................................................................................................................................................................................................................................................................................................................................................................................... **(1)****Q134(aii)**  The gold foil is replaced with another foil of the same size made from a mixture of isotopes of gold. Nothing else in the experiment is changed.Explain whether or not the scattering distribution of the monoenergetic alpha particles remains the same....................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................... **(1)****Q134(b)**   Data from alpha−particle scattering experiments using elements other than gold allow scientists to relate the radius *R*, of a nucleus, to its nucleon number, *A*.The graph shows the relationship obtained from the data in a graphical form, which obeys the relationship $R=r\_{0}A^{⅓}$.**Q134(bi)**   Use information from the graph to show that $r\_{0}$ is about 1.4 × 10–15 m.    **(1)****Q134(bii)**   Show that the radius of a $$ nucleus is about 5 × 10–15 m.     **(2)****Q134(c)**   Calculate the density of a $$ nucleus. State an appropriate unit for your answer.     density ......................................... unit ................ **(3)****(Total 8 marks)****Q135(a)**    On the figure below sketch a graph to show how the radius, *R*, of a nucleus varies with its nucleon number, *A*. **(1)****Q135(bi)**    The radius of a gold-197 nucleus $$ is 6.87 × 10–15 m. Show that the density of this nucleus is about 2.4 × 1017 kg m–3.    **(2)****Q135(bii)**    Using the data from part (bi) calculate the radius of an aluminium-27 nucleus, $$ .                                                       answer = ...................................... m **(2)****Q135(c)**    Nuclear radii have been investigated using α particles in Rutherford scattering experiments and by using electrons in diffraction experiments. Make comparisons between these two methods of estimating the radius of a nucleus.Detail of any apparatus used is not required. For each method your answer should contain:•        the principles on which each experiment is based including a reference to an appropriate equation        •        an explanation of what may limit the accuracy of each method•        a discussion of the advantages and disadvantages of each method........................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................... **(6)****(Total 11 marks)** |

**Saturday: Nuclear Radius and Types of Radiation Checklist**

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