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| 26: Radioactivity 2Modes and Rates of Decay |
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| Paper 2 |  |
| 17: Thermal Physics 1Specific Heat Capacity and Latent Heat | 1. Random nature of radioactive decay; constant decay probability of a given nucleus;
2. Use of activity,
3. Modelling with constant decay probability.
4. Questions may be set which require students to use
5. Questions may also involve use of molar mass or the Avogadro constant.
6. Half-life equation:
7. Determination of half-life from graphical decay data including decay curves and log graphs.
8. Applications eg relevance to storage of radioactive waste, radioactive dating etc.
9. Graph of *N* against *Z* for stable nuclei.
10. Possible decay modes of unstable nuclei including α, β+, β− and electron capture.
11. Changes in *N* and *Z* caused by radioactive decay and representation in simple decay equations.
12. Questions may use nuclear energy level diagrams.
13. Existence of nuclear excited states; γ ray emission; application eg use of technetium-99m as a γ source in medical diagnosis.
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| 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: Modes of Decay Notes**

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| Sketch a graph of N against Z for stable nuclei.Label where: 1) alpha emitters are found. 2) beta-minus emitters are found. 3) beta-plus emitters are found.Explain why there is this imbalance between proton and neutron numbers by referring to the forces that operate within the nucleus. Your explanation should include the range of the forces and which particles are affected by the forces.…………………………………………………………………………...…………………………………………………………………………...…………………………………………………………………………...…………………………………………………………………………...…………………………………………………………………………...…………………………………………………………………………...…………………………………………………………………………...…………………………………………………………………………...…………………………………………………………………………...…………………………………………………………………………...…………………………………………………………………………... |  |

 ………………………………………………………………………..…….……………………………………………………………………….. ……………………………………………………………………..……….………………………………………………………………………..Complete this nuclear equation showing **alpha** decay.

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| --- | --- |
|  | Change to the number of protons ….…….…Change to the number of neutrons ……….…. |

Complete this nuclear equation showing **beta-minus** decay.

|  |  |
| --- | --- |
|  | Change to the number of protons ….…….…Change to the number of neutrons ……….…. |

Complete this nuclear equation showing **beta-plus** decay.

|  |  |
| --- | --- |
|  | Change to the number of protons ….…….…Change to the number of neutrons ……….…. |

Complete this nuclear equation showing **gamma** emission.

|  |  |
| --- | --- |
|  | Change to the number of protons ….…….…Change to the number of neutrons ……….…. |

Complete this nuclear equation showing **electron-capture** decay.

|  |  |
| --- | --- |
|  | Change to the number of protons ….…….…Change to the number of neutrons ……….…. |

Where does the electron come from? ……………………………………..………………………...……………………………………………

|  |  |
| --- | --- |
| If the decaying nucleus **started** on the dot label where it would end after undergoing the decays listed on the previous page. | If the decaying nucleus **ended** on the dot label where it started from if it underwent the decays listed on the previous page. |
|  |  |

What type of nuclei undergo alpha decay?………………………………………………………………………..……….………………………………………………………………………..What type of nuclei undergo beta-minus decay?………………………………………………………………………..……….………………………………………………………………………..What type of nuclei undergo beta-plus decay?………………………………………………………………………..……….………………………………………………………………………..What type of nuclei undergo gamma emission?………………………………………………………………………..……….………………………………………………………………………..What are the two sources of gamma photons?…………………………………………………………………………..…….………………………………………………………………………..………………………………………………………………………..……….………………………………………………………………………..

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| The Fe-59 nucleus can decay to one of three excited states of the cobalt-59 nucleus as shown below. The total energy released when the Fe-59 nucleus decays is 2.52 × 10–13 J.Calculate the maximum possible kinetic energy, in MeV, of the β– particle emitted when the Fe-59 nucleus decays into an excited state that has energy above the ground state. | https://app.doublestruck.eu/content/AA_PHYS/HTML/Q/QS17L205_files/img01.jpeg |

State the maximum number of discrete wavelengths that could be emitted following the production of Co-59 ………………………….Calculate the longest wavelength of the emitted γ-radiation.  |

**Tuesday: Modes of Decay Exam Questions**

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| **Q136(i)**   On the figure below sketch a graph of neutron number, *N*, against proton number, *Z*, for stable nuclei.                            proton number, *Z* **(1)****Q136(ii)**   With reference to the figure, explain why fission fragments are unstable and explain what type of radiation they are likely to emit initially............................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................... **(3)****(Total 4 marks)****Q137.**  The fissile isotope of uranium, , has been used in some nuclear reactors. It is normally produced by neutron irradiation of thorium-232. An irradiated thorium nucleus emits a *β*− particle to become an isotope of protactinium.This isotope of protactinium may undergo *β*− decay to become .**Q137(a)**     Complete the following equation to show the *β*− decay of protactinium. **(2)****Q137(b)**    Two other nuclei, **P** and **Q**, can also decay into .**P** decays by *β*+ decay to produce and **Q** decays by α emission to produce . The figure below shows a grid of neutron number against proton number with the position of the . isotope shown.On the grid label the positions of the nuclei **P** and **Q**. **(2)****(Total 4 marks)** |

**Wednesday: Stable Nuclei and Decay Extended Writing**

Though individual atoms always have an integer number of atomic mass units, the atomic mass on the periodic table is stated as a decimal number because it is an average of the various isotopes of an element.

Some of these isotopes are stable but others are unstable and need to decay before becoming stable; this can be done by different decay processes. Write a description of these processes, making sure you include:

* A graph of N against Z for stable isotopes
* An explanation of why the graph takes the shape that you have drawn
* A description of the changes that happen to the nucleus during the following decays:

A) alpha B) beta minus C) beta plus D) electron capture and E) gamma emission.

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**Wednesday: Modes and Rates of Decay Definitions**

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| Below the Line | Where beta-plus emitters are found on a N against Z graph. |
| Curve | On a graph of N against t the line would be this shape. |
| Random | Radioactive decay is described as this due to it being impossible to predict it will happen. |
| Short | A high decay constant means the half-life will be …. |
| Half-Life | The time taken for the activity of a radioactive isotope to fall to half its value. |
| Ground State | The lowest, most stable energy level. |
| Half | If the number, N, is halved the activity, A, will … |
| Corrected | The count rate when the background radiation has been removed. |
| Background | The level of radiation that is always present. |
| Beta Plus | Ionising radiation with a relative charge of +1. |
| Beta Minus | Ionising radiation from the decay of a neutron into a proton. |
| High Mass | This type of nucleus is likely to be as alpha emitter. |
| De-excitation | When a nucleus or electron moves to a lower energy level. |
| Straight | On a graph of ln N against t the line would be this shape. |
| Neutron Rich | This type of nucleus is likely to be a beta-minus emitter. |
| Becquerel | The units of activity. |
| Above the Line | Where beta-minus emitters are found on a N against Z graph. |
| Decay Constant | The probability of a nucleus decaying per unit time. |
| Geiger Counter | An instrument used to measure the intensity of ionising radiation. |
| Long | A low decay constant means the half-life will be …. |
| High Energy | This type of nucleus is a gamma emitter. |
| Proton Rich | This type of nucleus is likely to be a beta-plus emitter. |
| Double | If the number, N, is doubled the activity, A, will … |
| Activity | The number of radioactive decays per second. |

|  |  |  |  |
| --- | --- | --- | --- |
| Above the Line | Activity | Background | Becquerel |
| Below the Line | Beta Minus | Beta Plus | Corrected |
| Curve | Decay Constant | De-excitation | Double |
| Geiger Counter | Ground State | Half | Half-Life |
| High Energy | High Mass | Long | Neutron Rich |
| Proton Rich | Random | Short | Straight |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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| **Thursday: Rates of Decay Notes**What is meant by the ‘random nature of decay’? ………………………………………………………………….…………….……………………………………………………….………………..……………………………………………………………………….……….……………………………….………………………………………..What is the ‘decay constant’ of a radioactive isotope?…………………………………………………………………………..…….………………………………………………………………………..………………………………………………………………………..……….………………………………………………………………………..What does a high value mean? ……………………………………..…….………………………………………………………………………..What does a low value mean? ………………….…………………..…….………………………………………………………………………..What is the ‘activity’ of a radioactive isotope?…………………………………………………………………………..…….………………………………………………………………………..………………………………………………………………………..……….………………………………………………………………………..What does a high value mean? ……………………………………..…….………………………………………………………………………..What does a low value mean? ………………….…………………..…….………………………………………………………………………..What is the ‘half-life’ of a radioactive isotope?…………………………………………………………………………..…….………………………………………………………………………..………………………………………………………………………..……….………………………………………………………………………..What does a high value mean? ……………………………………..…….………………………………………………………………………..What does a low value mean? ………………….…………………..…….………………………………………………………………………..There are a few equations in this section so let’s make sure that we know what each symbol stands for and the units used.Symbol Quantity …………………………………………………………………………………………… Units ………………………Symbol Quantity …………………………………………………………………………………………… Units ………………………Symbol Quantity …………………………………………………………………………………………… Units ………………………Symbol Quantity ……………………………………………………………………………………………………...………………………Symbol Quantity ……………………………………………………………………………………………………...………………………Symbol Quantity …………………………………………………………………………………………… Units ………………………Symbol Quantity …………………………………………………………………………………………… Units ………………………The activity of a radioactive isotope is connected to the number of remaining unstable nuclei with the following equations:

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| --- | --- |
|  |  |

Complete this table by calculating the missing values.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *A* | *∆N* | *∆t* | *λ* | *N* |
|  |  | 50 | 5.8 × 10-5 | 2.50 × 1016 |
|  | 5.95 × 1010 |  | 1.23 × 10-6 | 7.83 × 1012 |
| 7.5 × 104 |  | 453 |  | 9.23 × 1010 |
|  | 1.95 × 106 | 30 | 1.06 × 10-5 |  |

The number of radioactive nuclei and the activity both fall exponentially over time and are given by the following equations:

|  |  |
| --- | --- |
|  |  |
| Sketch the graph that would be obtained by plotting data from the equation above. | Rearrange the equation, sketch the graph that would be obtained and state what the y-intercept and gradient would represent. |
|  |  |  |

Complete this table by calculating the missing values.

|  |  |  |  |
| --- | --- | --- | --- |
| *N* | *N*0 | *λ* | *t* |
|  | 8.61 × 1010 | 0.1155 | 12 |
| 2.35 × 1023 |  | 7.87 × 10-3 | 350 |
| 4.79 × 109 | 6.2 × 1010 |  | 1563 |
| 7.53 × 1013 | 1.04 × 1015 | 4.8 × 10-3 |  |

Complete this table by calculating the missing values.

|  |  |  |  |
| --- | --- | --- | --- |
| *A* | *A*0 | *λ* | *t* |
|  | 62 | 0.023 | 45 |
| 4.32 × 1013 |  | 1.28 × 10-4 | 18 400 |
| 4007 | 4600 |  | 134 |
| 15.7 | 160 × 103 | 2.91 × 10-3 |  |

The half-life of an unstable isotope can be calculated by taking measurements from a graph or with the following equation:Complete these tables by calculating the missing values.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| *T1/2* | *λ* |  | *T1/2* | *λ* |  | *T1/2* | *λ* |
|  | 1.25 × 10-2 |  |  | 0.301 |  |  | 8.7 × 10-6 |
|  | 9.87 × 10-3 |  |  | 1.16 × 10-3 |  |  | 1.2 × 10-4 |
| 88 |  |  | 660 |  |  | 8.05 days |  |
| 21600 |  |  | 18 |  |  | 12 hours |  |

What is the problem when dealing activities when the time elapsed is:A) much less than one half-life? …………………………..…….…………………………………..……………………………………………..………………………………………………………………………..……….………………………………………………………………………..B) more than ten half-lives? ……………………….………………..…….………………………………………………………………………..………………………………………………………………………..……….……………………………………………………………………….. |

**Friday: Rates of Decay Exam Questions**

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| **Q138.**    The age of an ancient boat may be determined by comparing the radioactive decay of from living wood with that of wood taken from the ancient boat.A sample of 3.00 × l023 atoms of carbon is removed for investigation from a block of living wood. In living wood one in 1012 of the carbon atoms is of the radioactive isotope , which has a *decay constant* of 3.84 × 10–12 s–1.**Q138(a)**  What is meant by the decay constant?...................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................... **(1)****Q138(b)**    Calculate the half-life of  in years, giving your answer to an appropriate number of significant figures.1 year = 3.15 × 107 s    answer = ..................................... years **(3)****Q138(c)**     Show that the rate of decay of the  atoms in the living wood sample is 1.15 Bq.    **(2)****Q138(d)**   A sample of 3.00 × 1023 atoms of carbon is removed from a piece of wood taken from the ancient boat. The rate of decay due to the  atoms in this sample is 0.65 Bq.Calculate the age of the ancient boat in years.      answer = ............................ years **(3)****Q138(e)**    Give **two** reasons why it is difficult to obtain a reliable age of the ancient boat from the carbon dating described........................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................... **(2)** **(Total 11 marks)****Q139.**   The carbon content of living trees includes a small proportion of carbon-14, which is a radioactive isotope. After a tree dies, the proportion of carbon-14 in it decreases due to radioactive decay.**Q139(ai)**   The half-life of carbon-14 is 5740 years.Calculate the radioactive decay constant in yr−1 of carbon-14.   decay constant ..................................... yr−1 **(1)****Q139(aii)**   A piece of wood taken from an axe handle found on an archaeological site has 0.375 times as many carbon-14 atoms as an equal mass of living wood.Calculate the age of the axe handle in years.    age ......................................... yr **(3)****Q139(b)**   Suggest why the method of carbon dating is likely to be unreliable if a sample is:**Q139(bi)**   less than 200 years old,........................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................**Q139(bii)**   more than 60 000 years old......................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................... **(2)** **(Total 6 marks)** |

**Saturday: Scalars, Vectors and Moments Checklist**

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