Name: ____

Year 11 Physics 2015

Unit 1
Nuclear Physics and Radioactivity

Diagnostic Test 1
Atomic Structure, Radioactivity and the basic properties of Nuclear Radiation

Recommended writing time: 40 minutes
Total number of marks available: 30 marks

Section A – Multiple Choice Questions (10 marks)

Section B – Short Answer Questions (20 marks)

Conditions and restrictions

- This diagnostic test is to be completed at home in the allocated time under test conditions.
- You are permitted to use: pens, pencils, highlighters, erasers, sharpeners, ruler and an approved scientific calculator.
- **You are NOT allowed to refer to your textbook or to make use of any written notes whilst undertaking this task.**

  (*It is designed for you to determine what you have learned and understood so far, and what you need to go back over, and where necessary get additional help from your teacher.* ☺)
- After completing this diagnostic test you need to correct it using the supplied solutions. It is then to be handed in to your teacher.

Materials supplied

- Question and answer book of 12 pages.
- Detachable periodic table and a formula and data sheet.

Instructions

- Print your name in the space provided on the top of the front page.
- Attempt all questions.
- All written responses must be in English.

Section A – Multiple Choice Questions (10 marks)

Specific instructions for Section A

Section A consists of 10 multiple-choice questions. Choose the response that is **correct** or that **best answers** the question.

- Write the letter corresponding to your chosen answer in the box at the end of each question.
- A correct answer is worth 1 mark, an incorrect answer scores 0.

Questions 1 to 3 relate to the following information.

Americium-241, ${}^{241}_{95}\text{Am}$, is a man made radioisotope of the element Americium that is sometimes used in household smoke detectors. When an atom of Am-241 undergoes radioactive decay it emits both alpha (α) radiation and a gamma (γ) radiation.

Question 1

The number of *protons* in the nucleus of a ${}^{241}_{95}\text{Am}$ atom is:

A. 336 **B.** 241 **C.** 146 **D.** 95

Question 2

The number of *neutrons* in the nucleus of a ${}^{241}_{95}\text{Am}$ atom is:

A. 336 **B.** 241 **C.** 146 **D.** 95

Question 3

Figure 1 shows three possible pathways, **X**, **Y** and **Z**, between two electrically charged plates that the radiation emitted by a decaying ${}^{241}_{95}\text{Am}$ atom could travel along after leaving the lead box.

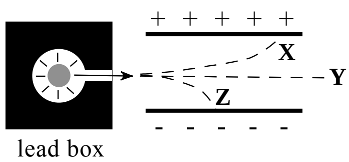


Figure 1

Which one of the choices **A – F** correctly describes the paths taken by the α-radiation and γ-radiation respectively?

	A.	**B.**	**C.**	**D.**	**E.**	**F.**
α-particle	X	X	Y	Y	Z	Z
γ-ray	Y	Z	X	Z	X	Y

Question 4

A radioisotope emits beta (β) radiation. From which part of the radioisotope will the beta (β) radiation be emitted?

A. The electron cloud

B. The nucleus

C. From the information provided it cannot be determined from which part of the radioisotope the beta (β) radiation is emitted.

Question 5

Which one or more of the following isotopes is definitely radioactive?

A. $^{237}_{93}Np$

B. $^{209}_{83}Bi$

C. $^{181}_{73}Ta$

D. $^{152}_{63}Eu$

Question 6

Which one of the following statements, **A – C**, correctly explains how the penetrating ability of a radioactive emission relates to its ability to ionise other atoms?

A. There is no relationship between the penetrating ability of a radioactive emission and its ability to ionise other atoms.

B. Radioactive emissions with a high ionising ability have greater penetrating ability.

C. Radioactive emissions with a low ionising ability have greater penetrating ability.

Question 7

A radioactive sample is emitting alpha, beta and gamma radiation into the air. A single sheet of paper is placed between the radioactive sample and a Geiger counter that is about 5.0 centimetres from, and pointed towards the sample. The Geiger counter would be most likely to detect:

A. gamma radiation only

B. beta and gamma radiation only

C. alpha radiation only

D. alpha, beta and gamma radiation

E. beta radiation only

Question 8

Which one of the following radioactive emissions, **A – D**, has the greatest *ionising* ability?

A. A gamma ray with 0.95 MeV of energy

B. A gamma ray with 750 keV of energy

C. An alpha particle with 5.4 MeV of energy

D. A beta particle with 1.6 MeV of energy

Question 9

Which one of the following radioactive emissions, **A – D**, has the greatest *penetrating* ability?

A. A gamma ray with 0.95 MeV of energy

B. A gamma ray with 750 keV of energy

C. An alpha particle with 5.4 MeV of energy

D. A beta particle with 1.6 MeV of energy

Question 10

In which one of the following nuclear transmutations, **A – D**, is the unknown object '**X**' an alpha particle?

A. ${}^{60m}_{27}\mathrm{Co} \rightarrow {}^{60}_{27}\mathrm{Co} + \mathbf{X}$

B. ${}^{198}_{79}\mathrm{Au} \rightarrow {}^{198}_{80}\mathrm{Hg} + \mathbf{X}$

C. ${}^{12}_{7}\mathrm{N} \rightarrow {}^{12}_{6}\mathrm{C} + \mathbf{X}$

D. ${}^{211}_{83}\mathrm{Bi} \rightarrow {}^{207}_{81}\mathrm{Tl} + \mathbf{X}$

End Of Section A

Section B – Short Answer Questions (20 marks)

Specific instructions for Section B

Section B consists of 8 questions. Answer all questions in the spaces provided.

- Your answers should be expressed correctly using appropriate physics terms.
- Numerical answers should be calculated fully and expressed with the appropriate number of significant figures.
- Where an answer box has a unit printed in it, give your answer in that unit.
- In questions where more than one mark is available, appropriate working should be shown.

Question 1 (2 marks)

$^{235}_{92}U$ and $^{238}_{92}U$ are both radioisotopes of uranium. Explain what ***both*** aspects of the term radioisotope mean.

Question 2 (2 marks)

Carbon-12 is stable but Carbon-14 is radioactive. Explain any differences in how these two types of Carbon atoms would interact chemically with other atoms.

Questions 3 and 4 relate to the following information.

In a sample of graphite the nucleus of each carbon atom has a radius of 2.75×10^{-15} m, whereas the atom itself has a radius of 6.80×10^{-11} m. Both the carbon atom and its nucleus can be assumed to be spherical in shape.

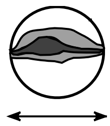
The volume of a sphere can be calculated using the formula: $V = \frac{4}{3}\pi r^3$

Question 3 (2 marks)

Express the volume of a Carbon atom's nucleus to the volume of the atom itself as a percentage.

Question 4 relates to the following additional information.

A marble of diameter 16 mm was used to model the nucleus of a carbon atom.



Question 4 (3 marks)

Calculate the radius of the sphere to be occupied by the electrons in this model of a carbon atom.

m

Question 5 (2 + 2 = 4 marks)

a) Describe the types of forces, and their nature, acting upon the nucleons in the nucleus of an atom.

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b) Explain why radioactive nuclei are unstable.

Question 6 (2 marks)

Complete the following table for the properties of alpha (α), beta (β) and gamma (γ) radiation.

Property	**α – radiation**	**β – radiation**	**γ – radiation**
Mass	heavy	light	none
Charge			
Typical energy	~5 MeV	~1 MeV	~0.1 MeV
Range in air			
Penetration in matter	~10^{-2} mm	a few mm	high
Ionising ability* (*circle correct answer)	low / medium / high	low / medium / high	low / medium / high

Question 7 (2 marks)

Calculate the energy in joules of a gamma ray that has energy of 750 keV.

J

Question 8 relates to the following information.

As an alpha particle travels through air it collides with and ionizes other atoms. On average this happens 100 000 times for each centimetre travelled. Each time an alpha particle ionises another atom the alpha particles loses about 35 eV of energy.

Question 8 (3 marks)

Correct to the nearest millimeter calculate the approximate distance that an alpha particle with 4.8 MeV will travel in air before it loses all of its energy.

cm

End Of Section B

End Of Diagnostic Test

Physics Unit 1– Formula and Data Sheet

Nuclear physics and radioactivity

1	absorbed dose (Gy)	$absorbed\ dose = \frac{E}{m}$
2	dose equivalent	$dose\ equivalent = absorbed\ dose \times quality\ factor$
3	activity level	$A = \frac{A_o}{t^n}$
4	nuclear transmutation	*1 Becquerel (Bq) = 1 nuclear transmutation per second*

Quality Factors

γ - radiation	1
β - radiation	1
slow neutron	3
fast neutron	10
α - radiation	20

1 eV = 1.6 $\times 10^{-19}$ J

Multiplying Prefixes

giga	(G)	$= 10^{9}$
mega	(M)	$= 10^{6}$
kilo	(k)	$= 10^{3}$
milli	(m)	$= 10^{-3}$
micro	(μ)	$= 10^{-6}$
nano	(n)	$= 10^{-9}$

Periodic table of the elements

atomic number	101	
	Md	element symbol
relative atomic mass	258	
	Mendelevium	name of element

1 **H** 1 Hydrogen																	2 **He** 4 Helim
3 **Li** 7 Lithium	4 **Be** 9 Beryllium											5 **B** 11 Boron	6 **C** 12 Carbon	7 **N** 14 Nitrogen	8 **O** 16 Oxygen	9 **F** 19 Fluorine	10 **Ne** 20 Neon
11 **Na** 23 Sodium	12 **Mg** 24 Magnesium											13 **Al** 27 Aluminium	14 **Si** 28 Silicon	15 **P** 31 Phosphorous	16 **S** 32 Sulfur	17 **Cl** 36 Chlorine	18 **Ar** 40 Argon
19 **K** 39 Potassium	20 **Ca** 40 Calcium	21 **Sc** 45 Scandium	22 **Ti** 48 Titanium	23 **V** 51 Vanadium	24 **Cr** 52 Chromium	25 **Mn** 55 Manganese	26 **Fe** 56 Iron	27 **Co** 59 Cobalt	28 **Ni** 59 Nickel	29 **Cu** 64 Copper	30 **Zn** 65 Zinc	31 **Ga** 70 Gallium	32 **Ge** 73 Germanium	33 **As** 75 Arsenic	34 **Se** 79 Selenium	35 **Br** 80 Bromine	36 **Kr** 84 Krypton
37 **Rb** 86 Rubidium	38 **Sr** 88 Strontium	39 **Y** 89 Yttrium	40 **Zr** 91 Zirconium	41 **Nb** 93 Niobium	42 **Mo** 96 Molybdenum	43 **Tc** 98 Technetium	44 **Ru** 101 Ruthenium	45 **Rh** 103 Rhodium	46 **Pd** 106 Palladium	47 **Ag** 108 Silver	48 **Cd** 112 Cadmium	49 **In** 115 Indium	50 **Sn** 119 Tin	51 **Sb** 122 Antimony	52 **Te** 128 Tellurium	53 **I** 127 Iodine	54 **Xe** 131 Xenon
55 **Cs** 133 Caessium	56 **Ba** 137 Barium	57 **La** 139 Lanthanum	72 **Hf** 179 Hafnium	73 **Ta** 181 Tantalum	74 **W** 184 Tungsten	75 **Re** 186 Rhenium	76 **Os** 190 Osmium	77 **Ir** 192 Iridium	78 **Pt** 197 Platinum	79 **Au** 197 Gold	80 **Hg** 201 Mercury	81 **Tl** 204 Thallium	82 **Pb** 207 Lead	83 **Bi** 209 Bismuth	84 **Po** 209 Polonium	85 **At** 210 Astatine	86 **Rn** 222 Radon
87 **Fr** 223 Francium	88 **Ra** 226 Radium	89 **Ac** 227 Actinium	104 **Rf** 261 Rutherfordium	105 **Db** 262 Dubnium	106 **Sg** 263 Seaborgium	107 **Bh** 264 Bohrium	108 **Hs** 265 Hassium	109 **Mt** 268 Meitnerium	110 **Ds** 271 Darmstadtium	111 **Rg** 272 Roentgenium	112 **Uub**		114 **Uuq**		116 **Uuh**		118 **Uuo**

58 **Ce** 140 Cerium	59 **Pr** 141 Praseodymium	60 **Nd** 144 Neodymium	61 **Pm** 145 Promethium	62 **Sm** 150 Samarium	63 **Eu** 152 Europium	64 **Gd** 157 Gadolinium	65 **Tb** 159 Terbium	66 **Dy** 163 Dysprosium	67 **Ho** 165 Holmium	68 **Er** 167 Erbium	69 **Tm** 169 Thulium	70 **Yb** 173 Ytterbium	71 **Lu** 175 Lutetium
90 **Th** 232 Thorium	91 **Pa** 231 Proactinium	92 **U** 238 Uranium	93 **Np** 237 Neptunium	94 **Pu** 244 Plutonium	95 **Am** 243 Americium	96 **Cm** 247 Curium	97 **Bk** 247 Berkelium	98 **Cf** 254 Californium	99 **Es** 251 Einsteinium	100 **Fm** 257 Fermium	101 **Md** 258 Mendelevium	102 **No** 255 Nobelium	103 **Lr** 256 Lawrencium