# Assessment Schedule – 2011

## Physics: Demonstrate understanding of atoms, photons and nuclei (90522)

### Evidence Statement

| Q | Evidence | Achievement | Merit | Excellence |
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| ONE (a) | $^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{92}_{36}Kr + {}^{141}_{56}Ba + 3\,{}^{1}_{0}n$<br>OR<br>$^{235}_{92}U \rightarrow {}^{92}_{36}Kr + {}^{141}_{56}Ba + 2\,{}^{1}_{0}n$ | [2] Equation with correct major products and reactants with mass numbers and atomic numbers balanced – mass # and atomic # is shown for all particles. | | |
| | 3 neutrons | [1] Neutron(s) or $^{1}_{0}n$ and no other incorrect particle – allow $\gamma$ – must be product side of the equation<br>Allow incorrect name as long as symbol (including mass and atomic number) is correct | | |

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| (b) | $E = mc^2$<br>$\Rightarrow m = \dfrac{7.45\times10^{-16}}{(3.00\times10^{8})^2} = 8.28\times10^{-33}$ kg<br>If this mass value is added to the rest mass of a neutron, the answer (to the same number of sf) does not change.<br>OR<br>The energy of the neutron's rest mass is<br>$E = mc^2 = 1.6749\times10^{-27}\times\left(3\times10^{8}\right)^2 = 1.50741\times10^{-10}$ J<br>If this energy is added to the kinetic energy of the neutron, the answer doesn't change (to the same number of sf).<br>OR<br>The speed of the moving neutron is given by:<br>$v = \sqrt{\dfrac{2E_K}{m_n}} = \sqrt{\dfrac{2\times7.45\times10^{-16}}{1.6749\times10^{-27}}} = 943189$ m s$^{-1}$<br>The speed is extremely low compared to the speed of light and only at speeds close to the speed of light does mass of the neutron become significant. | [2] Correct mass value ($8.28\times10^{-33}$ kg).<br>OR<br>Calculates the energy of the neutron's rest mass ($1.507\times10^{-10}$ J).<br>OR<br>Calculates speed (943 189 m s$^{-1}$). | [1] Correct reasoning. | |
| (c) | $E = hf$ and $E = \Delta mc^2$<br>$\Delta m = m_{\text{reactants}} - m_{\text{products}}$<br>$m_{\text{reactants}} = (390.2182 + 1.67\underline{\mathbf{49}})\times10^{-27}$<br>$m_{\text{products}} = (152.6167 + 233.9450 + 3\times1.67\underline{\mathbf{49}})\times10^{-27}$<br>$\Delta m = 3.067\times10^{-28}$ kg<br>$E = \Delta mc^2 = 2.7603\times10^{-11}$ J<br>$f = \dfrac{E}{h} = 4.1633\times10^{22} = 4.16\times10^{22}$ Hz | [2] Correct $\Delta m$<br>OR<br>Calculates E using correct method with incorrect mass. | [2] Correct E.<br>OR<br>Correct method with incorrect mass **deficit**, ie some attempt at subtraction of **products/reactants**.<br>OR<br>Correct method but doesn't multiply mass by $c^2$ to get Energy<br>($f = 4.63\times10^{5}$ Hz) | [2] Correct answer and working, eg missing neutrons etc accepted. |

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| (d) | total $p + n$<br>$= 92 \times 1.67\underline{\mathbf{26}} \times 10^{-27} + 143 \times 1.67\underline{\mathbf{49}} \times 10^{-27}$<br>$= 393.3899 \times 10^{-27}$<br>total mass deficit:<br>$= 393.3899 \times 10^{-27} - 390.2182 \times 10^{-27}$<br>$= 3.1717 \times 10^{-27}$ kg<br>$E = mc^2 = 3.1717 \times 10^{-27} \times (3.00 \times 10^8)^2$<br>$= 2.85453 \times 10^{-10} \quad = 2.85 \times 10^{-10}$ J | [2] Correct mass deficit<br>OR<br>Energy calculated with incorrect mass deficit, ie some attempt at subtraction of masses. | [2] Correct answer and working<br>Inclusion of the kinetic energy of the moving electron(s) accepted. | |
| (e) | **Binding energy** is the energy which must be supplied to separate the nucleus into its constituent nucleons (or is the energy released when the constituent nucleons are brought close enough together to form a nucleus).<br>As work has to be done to separate the nucleons, their total energy increases and, accordingly, their mass will increase due to mass-energy equivalence. Therefore the combined mass of the nucleons in the nucleus is less than their combined mass when they are acting as separate particles. | [1] Answer shows understanding of binding energy OR mass equivalence. | [1] Answer shows understanding of binding energy AND mass equivalence. | |
| TWO<br>(a) | A photon is a packet/particle/quantum of (electromagnetic) energy/light<br>It can be produced when an electron in a higher energy level drops to a lower energy level. | [1] Photon is a packet/particle of light / energy.<br>(Do **not** allow "ray of energy", "particle that holds energy".)<br>OR<br>Photon release linked to energy levels. | [1] Photon is a packet / particle of light / energy.<br>(Do **not** allow "ray of energy", "particle that holds energy".)<br>AND<br>Photons are released when an **electron** drops to a lower energy level. | |
| (b) | $J = e \times \text{eV} \quad = 1.60 \times 10^{-19} \times 191$<br>$= 3.056 \times 10^{-17}$ J<br>$E = hf \quad \Rightarrow f = \dfrac{3.056 \times 10^{-17}}{6.63 \times 10^{-34}}$<br>$= 4.60935 \times 10^{16}$ Hz = 4.61 x $10^{16}$ Hz (3sf) | [2] Correct method using incorrect energy value (eg not converted to Joules, $f = 2.88 \times 10^{35}$). | [2] Correct answer and working.<br>*Allow rounding errors in working.* | |

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| (c) | To release an electron, it must first gain enough energy to overcome the attraction of the positive nuclei in the metal. This minimum amount of energy is called the workfunction of that particular metal.<br>When one photon interacts with one electron, the photon's energy is absorbed by the electron. If the photon's energy is LARGER than the workfunction, the electron has gained enough energy to overcome the attraction to the positive nuclei and escape the metal. Any energy above that to escape the metal will contribute to the electron's kinetic energy.<br>Since the energy of a photon is directly proportional to its frequency, the larger the frequency the larger the energy of the photon. Therefore, for the photon to pass on enough energy to electron in order to be released, the photon must have a minimum frequency. This frequency is called the threshold frequency. | [1] Minimum/enough Energy required/ excited enough to release electron/ required to overcome workfunction/to be raised to its free energy state – this<br>**Must** be stated – not simply implied (accept "photon must have energy higher than *something* to release electron") (Do **not** accept "photon must overcome the threshold frequency")<br>OR<br>Electron absorbs/gains photon's energy/ photon transfers/gives/provides energy to the electron<br>OR<br>Energy of a photon depends on frequency (larger f => larger E) beyond a simple statement of the formula $E = hf$ | [1] Mentions TWO of<br>—Minimum / enough Energy required / excited enough to release electron / required to overcome workfunction / to be raised to its free energy state – this MUST be stated – not simply implied.<br>("Photon must have energy higher than *something* to release electron" accepted.)<br>("Photon must overcome the threshold frequency" not accepted.)<br>OR<br>Electron absorbs / gains photon's energy / photon transfers/gives / provides energy to the electron<br>OR<br>Energy of a photon depends on frequency (larger $f$ => larger E) beyond a simple statement of the formula $E = hf$. | Links all THREE:<br>Minimum/enough Energy required/ excited enough to release electron/ required to overcome workfunction/to be raised to its free energy state – this **must** be stated – not simply implied. ("Photon must have energy higher than *something* to release electron" accepted.)<br>("Photon must overcome the threshold frequency" not accepted.)<br>OR<br>Electron absorbs / gains photon's energy / photon transfers / gives / provides energy to the electron<br>OR<br>Energy of a photon depends on frequency (larger f => larger E) beyond a simple statement of the formula $E = hf$<br>AND causally linked to threshold frequency, eg: therefore there exists a threshold frequency. |
| (d) | $hf = \phi + E_K$<br>$\phi = hf - E_K$<br>$\phi = (6.63 \times 10^{-34} \times 1.53 \times 10^{16}) - 2.18 \times 10^{-18}$<br>$\phi = 1.01439 \text{ x } 10^{-17} - 2.18 \times 10^{-18}$<br>$\phi = 7.96 \times 10^{-18}$<br>$f_{threshold} = \frac{\varphi}{h} = \frac{7.96 \times 10^{-18}}{6.63 \times 10^{-34}} = 1.20 \times 10^{16}$ Hz (3sf) | [2] Correctly substitutes into $hf = \phi + E_K$<br>(Allow correct substitution into incorrectly rearranged formula)<br>OR<br>Attempts to combine both formulae. | [2] Correct value and working for $\phi$. | [2] Correct answer and working. |

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| (e) | When an electron interacts with a photon, the electron absorbs all of the photon's energy.<br>The electron inside the atom of a low density gas can only occupy specific energy levels. In order to lift the electron to a higher energy level, the energy of the photon must provide exactly the difference in energy between the levels. If the energy of the photon does not match any of the energy level transitions, the electron will not absorb the photon. Therefore the exact energy is crucial in whether a photon is absorbed or not.<br>If the energy of the photon is large enough, then it can release the electron from the atom, overcoming the electron's attraction to the nucleus. Once freed, any excess energy is converted to the kinetic energy of the electron which can have any value. Therefore any value above that needed to release the electron from the atom can be absorbed by the electron. | [1] ONE of:<br>• idea of quantised energy levels of electron, (eg discrete / fixed / specific / different energy levels) OR specific / discrete / only some allowed differences in energy levels.<br>• electron absorbs / gains the **photon's** energy / photon gives / provides/ transfers energy to electron.<br>• Energy is needed to overcome the workfunction/attraction of the nucleus/be lifted to its free state.<br>• Energy above minimum for release will also release electrons / any energy above minimum is converted to the kinetic energy of the electron. | [1] EITHER<br>(a) Specific (exact) energy of the **photon** needed to move electron up **because** of **specific** (fixed / discrete / quantise / different) **energy levels** (**not** orbits / shells etc).<br>OR<br>(b) Reason provided why minimum energy for release needed (eg to overcome workfuntion, to raise to free state, to provide ionisation energy etc).<br>AND ONE of<br>• idea of quantised energy levels<br>• energy of photon must equal energy difference between levels. | [1] Statement (a)<br>AND<br>Statement (b)<br>AND ONE of<br>• energy above minimum release energy goes into kinetic energy of the electron.<br>• energy of photon must equal energy difference between levels. |

## Judgement Statement

| Achievement | Achievement with Merit | Achievement with Excellence |
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| 2 **A1** + 2 **A2**+ 1 **A** | 2 **M1** + 2 **M2** + 1 **M** + 1 **A** | 1 **E1** + 1 **E2** + 1 **M1** + 1 **M2** + 1 **M** + 1 **A** |

Note: where the criterion is not specified, the required grade(s) can be from either.