

**Assessment Schedule – 2012**

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

**Evidence Statement**

Q	Evidence	Achievement	Merit	Excellence
ONE (a)(i)	Because it has most nucleons, $^{238}\text{U}$ has the highest total binding energy. Even though it has a smaller BE / n than Ca, Mn, Fe, Ni, Pb, the difference in BE / n is SMALL compared to the increase in number of nucleons.	$^1_{238}\text{U}$ OR $^{62}\text{Ni}$ with indication of comparison to Fe. OR As Nickel has more nucleons / larger mass number (allow largest atomic mass / largest nucleus).	$^1$ As for achievement AND EITHER: As Uranium has the largest / most number of nucleons / largest mass number (allow largest atomic mass / largest nucleus). OR As Nickel has more nucleons / larger mass number than Fe. OR Shows calculations to support choice).	

<p>(ii)</p>	<p><math>^1\text{H}</math> has zero binding energy as it is a single proton. When protons fuse to form larger nuclei, energy is released, as the strong force overcomes the electromagnetic repulsion between the protons (<math>^1\text{H}</math> nuclei). This releases energy as the fused nucleus is at a lower energy state (and therefore has less mass). This can be seen by the larger binding energy per nucleon of the fused nuclei.</p> <p>As seen in the diagram, there is a big difference in BE / n between small nuclei (left hand side), so an increase in mass number due to fusion will release a large amount of energy per nucleon involved in the fusion process.</p> <p>Since stars have a large amount of hydrogen and conditions (high temperature and pressure) which allow hydrogen fusion to occur, stars are able to produce a large amount of energy.</p>	<p><sup>1</sup> Fusion releases energy OR H has zero BE / n. OR Stars produce energy by fusion. OR High BE / n means lower energy nucleons. OR Compares energy / BE / BE per nucleon or mass of products and reactants without link to fusion.</p>	<p><sup>1</sup> Compares energy of products and reactants of fusion (accept combine / joining nuclei / nucleons): (Fused products have <b>higher</b> BE / n or BE, so energy is released. OR Fused products have <b>lower</b> mass / <b>lower</b> average mass per nucleon so energy is released. OR Fused products have higher BE / n or BE and so have moved to a lower energy state). <u>OR</u> Comments on size of energy released by fusion: (Difference in BE / n is <b>large</b> therefore <b>large</b> amount of energy released in fusion. OR Difference in mass per nucleon is <b>large</b> so <b>large</b> amount of energy released in fusion. OR <b>Large</b> amount of hydrogen / large number of reactions / fast rate of reactions therefore large amount of energy released in fusion).</p>	<p><sup>1</sup> Compares energy of products and reactants: Fused products have <b>higher</b> BE / n or BE, so energy is released. OR Fused products have <b>lower</b> mass / <b>lower</b> average mass per nucleon so energy is released. OR Fused products have higher BE / n or BE and so have moved to a lower energy state. <u>AND</u> Comments on size of energy released by fusion: Difference in BE / n is <b>large</b> therefore <b>large</b> amount of energy released in fusion. OR Difference in mass per nucleon is <b>large</b> so <b>large</b> amount of energy released in fusion. OR <b>Large</b> amount of hydrogen / large number of reactions / fast rate of reactions therefore large amount of energy released in fusion.</p>
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<p>(iii)</p>	<p>Iron cannot release energy by fusion (or fission), because larger atoms have lower binding energy per nucleon and so energy is required to fuse Fe / Ni (or split Fe / Ni).</p>	<p><sup>1</sup> Fe and Ni have <b>highest</b> BE / n. OR Fe and Ni have the <b>lowest</b> mass per nucleon. OR Energy <b>needed</b> for fusion / fission of Fe / Ni. OR Fe / Ni will not release energy during fission / fusion. OR Fe and Ni nuclei / nucleons in <b>lowest</b> energy state. OR Fe and Ni are the most stable nucleus / have most stable nucleons.</p>	<p><sup>1</sup> LINKS Fe and Ni have <b>highest</b> BE / n. OR Fe and Ni have the <b>lowest</b> mass per nucleon. OR Fe and Ni nuclei in <b>lowest</b> energy state). AND (Energy <b>needed</b> for fusion / fission of Fe / Ni. OR Fe and Ni will not release energy during fission / fusion.</p>	
<p>(b)</p>	<p><math>{}^{12}_6\text{C} + {}^{12}_6\text{C} \rightarrow {}^{20}_{10}\text{Ne} + {}^4_2\text{He}</math>  <math>(12 \times 12.29 \times 10^{-13} \text{ J} \times 2) \rightarrow</math>  <math>(20 \times 12.85 \times 10^{-13} \text{ J}) + (4 \times 11.32 \times 10^{-13} \text{ J})</math>  <math>(294.96 \times 10^{-13} \text{ J}) \rightarrow (302.28 \times 10^{-13} \text{ J})</math>                  difference = <math>7.28 \times 10^{-13} \text{ J}</math> = energy released  <math>E = \Delta mc^2</math>  <math>\Delta m = \frac{E}{c^2} = \frac{7.32 \times 10^{-13}}{(3.0 \times 10^8)^2} = 8.13 \times 10^{-30} \text{ kg}</math>                  NOTE: missing <math>\times 10^{-13}</math> is not a transcription error.</p>	<p><sup>2</sup> Correct calculation of binding energy of 2 nuclides. OR Energy difference calculated without multiplying by number of nucleons (<math>0.41 \times 10^{-13}</math>). OR Correct working for mass deficit for any energy difference</p>	<p><sup>2</sup> Correct energy released OR Correct working for mass deficit but multiplying BE / n by number of protons or omitting <math>\times 10^{-13}</math> OR Correct working with minor error (eg c instead of <math>c^2</math>, ONE incorrect rearranging)</p>	<p><sup>2</sup> Correct answer showing sufficient working</p>

TWO (a)	$E = hf = \frac{hc}{\lambda}$ $= 6.63 \times 10^{-34} \times \frac{3.0 \times 10^8}{5.89 \times 10^{-7}} = 3.38 \times 10^{-19} \text{ J}$	<sup>2</sup> Correct working for frequency ( $f = 5.09 \times 10^{14} \text{ Hz}$ ) OR Correct answer without any working	<sup>2</sup> Correct answer with some working.	
(b)	$hf = \phi + E_K$ <p>at the threshold frequency</p> $hf = \phi = 2.28 \text{ eV} = 2.28 \times 1.6 \times 10^{-19} = 3.648 \times 10^{-19} \text{ J}$ $f = \frac{\phi}{h} = \frac{3.648 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}} = 5.50 \times 10^{14} \text{ Hz}$ $\lambda = \frac{c}{f} = \frac{3.0 \times 10^8}{5.50 \times 10^{14}} = 5.45 \times 10^{-7} \text{ m}$	<sup>2</sup> Correct conversion of eV into J. ( $3.648 \times 10^{-19} \text{ J}$ ) OR <sup>1</sup> Indication that $E_K = 0$ . OR Indication that $\phi = hf$ .	<sup>2</sup> Correct working and answer for threshold frequency ( $f = 5.50 \times 10^{14} \text{ Hz}$ ). OR Correct working for wavelength, but with incorrect or missing conversion of workfunction ( $8.72 \times 10^{-26}$ if left as 2.28eV). OR Correct working with minor error, eg ONE wrong rearranging.	<sup>2</sup> Correct answer showing sufficient working.  NOTE: $E_K$ cannot be non-zero.
(c)	<p><i>Show that light from a sodium lamp cannot cause photoemission of electrons from sodium metal.</i></p> <p>The wavelength of light needed to release electrons (545nm) smaller than the 589nm light emitted by the sodium light.</p> <p>This means the energy provided by a photon from the sodium lamp doesn't have enough energy to overcome the workfunction of the sodium metal and so no electrons will be released.</p> <p><i>By considering the energy transitions involved in light production and absorption, suggest a possible reason for this.</i></p> <p>Light from the sodium lamp is produced by electrons moving from higher energy levels to lower energy levels, losing this energy as a photon. The photon of wavelength 589nm corresponds to the energy difference between two energy levels in the sodium atom. These two energy levels, therefore, are too close together to allow the emitted photon to have enough energy to release an electron from the sodium metal.</p>	<sup>1</sup> Wavelength needed for release is LESS than sodium line OR Frequency needed for release is HIGHER than sodium line OR Energy is less than workfunction / energy needed to release electron OR Minimum energy of light needed to overcome workfunction / release electron	<sup>1</sup> Compares energy of the <b>photon</b> to the workfunction / energy needed to release OR Difference in energy levels in (gaseous) sodium <b>too small</b> to overcome workfunction	<sup>1</sup> Compares energy of the <b>photon</b> to the workfunction / energy needed to release AND Difference in energy levels in (gaseous) sodium <b>too small</b> to overcome workfunction)

<p>(d)(i)</p>	<p>The sun emits a continuous spectrum of visible light. The dark lines are caused by absorption of specific photons. The gases in the atmosphere can only absorb photons which have energies that exactly match the difference in the energy levels of the electrons in the gases. Since the energy of a photon depends on its frequency (wavelength) and therefore its colour, only those specific colour photons which match will be absorbed, leaving a sharp dark line in the full spectrum.</p>	<p><sup>1</sup> Light / colours / wavelengths / frequencies / energy are absorbed by gases / electrons / atoms OR Only light of <b>specific / certain</b> colour / wavelength / frequency / energy is absorbed OR Light / wavelengths / frequencies / colours / energies allow electrons to move to higher energy levels / gain energy  Accept “used up” / “removed” instead of “absorbed”</p>	<p><sup>1</sup> <b>Photons</b> of specific / certain wavelength / frequency / colour / energy are absorbed by electrons which gain energy / move / jump to a higher energy level</p>	
<p>(ii)</p>	<p>The quantised energy levels for each element are fixed and distinct. So the difference in energy between the levels is also fixed and distinctive for a given element. Electrons can move up (absorb photons) as well as move down (emit photons) these distinct energy levels and so they will emit photons at the same colours (frequencies / wavelengths / energies) as they will absorb them. So since the dark lines appear at the precisely the colours (wavelengths / frequencies / energies) that occur in ‘sodium light’, the absorption at these matching colours indicates sodium is present in the sun’s atmosphere.</p>	<p><sup>1</sup> Photon / wavelength / frequency linked directly to sodium / unique spectrum of sodium. OR Emission and absorption lines match.</p>	<p><sup>1</sup> <b>Photon absorbed / emitted</b> or <b>energy levels</b> linked to sodium. AND Emission and absorption lines match.</p>	
<p>For all (c) - d(ii)</p>	<p>In questions (c), d(i) or d(ii) students need to show that:</p> <ul style="list-style-type: none"> <li>• Electrons exist in discrete / quantised energy levels around the atom of a given gas.</li> <li>• Electrons must lose or gain energy to move up or down energy levels.</li> <li>• Electrons absorb or emit photons in order to gain or lose energy and so move up and down energy levels.</li> <li>• The energy of the absorbed or emitted photon must match exactly the difference in energy level of the electron.</li> </ul>	<p>Electrons exist in energy levels. OR Electrons lose or gain energy by emitting or absorbing photons / light / frequencies / wavelengths / colours.</p>	<p>Electrons exist in <b>discrete / quantised / specific / certain</b> energy levels. OR The difference in energy levels of the electron corresponds to the <b>photon</b> energy released or absorbed.</p>	<p>The difference in the <b>discrete / quantised / specific / certain</b> energy levels corresponds to the <b>photon</b> energy emitted or absorbed.</p>

**Judgement Statement**

<b>Achievement</b>	<b>Achievement with Merit</b>	<b>Achievement with Excellence</b>
$1 A^1 + 1 A^2 + 3 A$	$1 M^1 + 1 M^2 + 3 M + 1 A$	$1 E^1 + 1 E^2 + 1 M^1 + 1 M^2 + 1 M + 1 A$

Note: where the criterion is not specified, the required criterion can be from either criterion.