A Level AQA Physics

3 Properties of particles – answers

Question	Answers	Extra information	Marks	AO	Spec. reference
01.1	Energy/momentum was not conserved		1	1	3.2.1.7
01.2	$n \rightarrow p^{+} + e^{-} + \overline{\nu}$		1	1	3.2.1.2
01.3	Lepton		1	1	3.2.1.5
01.4	Charge is conserved in both decays Baryon number is not conserved in the first decay Lepton number is not conserved in the second decay		1 1 1	3	3.2.1.7
01.5	Proton		1	1	3.2.1.5
01.6	A neutron is a hadron, but the weak interaction is responsible for this reaction/leptons are produced		1	3	3.2.1.5
02.1	$u \rightarrow d + e^{+} + \nu_e$		1	2	3.2.1.6
02.2	Lepton number: $0 = 0 + (-1) + (+1)$ Charge: $+\frac{2}{3} = -\frac{1}{3} + (+1) + 0$ Baryon number: $\frac{1}{3} = \frac{1}{3} + 0 + 0$	Numbers consistent with equation All particle numbers must be present in each equation for the mark	1 1 1	2	3.2.1.7
02.3	Energy/momentum		1	1	3.2.1.7
02.4	$\mu^{+} \rightarrow e^{+} + \nu_e + \overline{\nu_\mu}$		1	3	3.2.1.5
02.5	Two correct points, for example: Only leptons are produced in antimuon decay Both decays produce a positron and an electron neutrino	One similarity and one difference	 1 1	1	3.2.1.5
03.1	Correct similarity and difference, for example: Mesons and baryons are both hadrons/composed of quarks Mesons contain two quarks/quark-antiquark pairs, but baryons contain three quarks	One similarity and one difference	 1 1	1	3.2.1.5

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03.2	Protons interact using the strong nuclear force only Kaons are formed by the strong interaction but decay by the weak interaction		1 1	2	3.2.1.4
03.3	One up and one strange antiquark, or $u\bar{s}$		1	1	3.2.1.6
03.4	Weak interaction Strangeness is not conserved/a quark has decayed		1 1	3	3.2.1.4
03.5	The equipment required is too big and expensive/scientists working in a range of disciplines are needed to produce the reactions		1	1	3.2.1.5
04.1	Proton – two up quarks and one down quark, or uud Antiproton – two up antiquarks and one down antiquark, or $\overline{uud}$		1 1	1	3.2.1.6
04.2	The charge on an up quark is $+\frac{2}{3}$, on an anti-up quark is $-\frac{2}{3}$, on a down quark is $-\frac{1}{3}$, and on an anti-down quark is $+\frac{1}{3}$ uud – total charge = $\left(+\frac{2}{3}\right) + \left(+\frac{2}{3}\right) + \left(-\frac{1}{3}\right) = +1$ $\overline{uud}$ – total charge = $\left(-\frac{2}{3}\right) + \left(-\frac{2}{3}\right) + \left(+\frac{1}{3}\right) = -1$	Charges on quarks Two equations showing +1 and −1	1 1	2	3.2.1.6
04.3	$uud + \overline{uud} \rightarrow u\bar{d} + d\bar{u} + u\bar{u}$ $u\bar{d}$ is a π^+ meson $d\bar{u}$ is a π^- meson	Evidence of quark structure of products from p and anti-p $q\bar{q}$ match each particle	1 1 1	2	3.2.1.6
04.4	Quarks have a baryon number of $+\frac{1}{3}$, antiquarks $-\frac{1}{3}$ $u\bar{u}$ annihilate, total baryon number does not change because the total is zero		1 1	2	3.2.1.6
05.1	The particles are all made up of quarks/there are no leptons produced		1	2	3.2.1.6
05.2	$p^+ + \pi^- \rightarrow K^+ + \Sigma^-$ Negative Charge before is zero; if kaon is positive, sigma must be negative		 1 1	2	3.2.1.5

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05.3	$\mathrm{uud} + \mathrm{d\bar{u}} \rightarrow \mathrm{u\bar{s}} + \mathrm{dds}$ LHS: udd RHS: $\mathrm{udd} - \mathrm{u\bar{s}} = \mathrm{dds}$ Charge $= -\frac{1}{3} - \frac{1}{3} - \frac{1}{3} = -1$	Evidence of use of quark structure	1 1	2	3.2.1.6
05.4	The kaon is produced by the strong interaction But it decays by the weak interaction		1 1	1	3.2.1.5
06.1	Correct examples, for example: Hadron: proton, neutron, kaon, pion Lepton: electron, muon, neutrino		 1 1	1	3.2.1.5
06.2	Hadrons can interact by all four interactions if they are charged (strong, weak, electromagnetic, gravitational) Leptons do not interact by the strong interaction		1 1	1	3.2.1.5
06.3	pions are composed of 2 quarks	A pion does not include the proton as a decay product	1	2	3.2.1.5
06.4	$\mathrm{p} + \pi^- \rightarrow \pi^0 + \mathrm{X}$ $\mathrm{uud} + \mathrm{d\bar{u}} \rightarrow \mathrm{u\bar{u}} + \mathrm{udd}$ X is a neutron Conservation of charge: $+1 + -1 \rightarrow 0 + 0$ Conservation of baryon number: $+1 + 0 \rightarrow 0 + 1$	Conservation of charge/baryon number/quark number	1 1 1	2	3.2.1.7
06.5	Particles have a (de Broglie) wavelength And are scattered/diffracted if the wavelength is the same order of magnitude as the particles from which it is scattered; here an atom has a diameter ~10^{-10} m		1 1	2	3.2.2.4
06.6	$\lambda = \frac{h}{p}, p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{10^{-10}}$ $= 6.63 \times 10^{-24}\ \mathrm{kg\,m\,s^{-1}}$	Use of $p = \frac{h}{\lambda}$ Answer	1 1	2	3.2.2.4

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07.1	A proton is a charged particle, which experiences a force when it is in an electric field Neutrons have no charge so cannot be accelerated		1 1	1	3.7.3.2
07.2	Particle accelerators had not been built/were too expensive to build		1	3	3.2.1.5
07.3	uud		1	1	3.2.1.6
07.4	Both contain quarks/take part in the strong interaction Mesons contain quark/antiquark pairs, but the proton contains three quarks		1 1	1	3.2.1.5
07.5	Negative		1	2	3.2.1.7
07.6	X is a baryon To conserve baryon number: +1 + 0 = 0 + 0 + (+1)	Baryon Correct equation	1 1	2	3.2.1.7
07.7	Strangeness on LHS = –1 ($s\bar{u}$) On right hand side = +2 ($d\bar{s} + u\bar{s}$) So X has strangeness of –3	–1 on LHS Showing –1 = +2 + (–3)	1 1	2	3.2.1.7
08.1	Mass of nucleus = mass of 26 protons and (56 – 26 =) 30 neutrons Mass = $26 \times 1.673 \times 10^{-27}$ kg + $30 \times 1.675 \times 10^{-27}$ kg = 9.38×10^{-26} kg	Use of A and Z Answer	1 1 1	2	3.2.1.1

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08.2	Resolving momentum in the x-direction $m_{Fe}u_{Fe} = m_{Fe}v_{Fe,x} + m_N v_{N,x}$ OR $m_{Fe}u_{Fe} = m_{Fe}v_{Fe}\cos 25 + m_N v_N \cos 36$ OR $v_N = \dfrac{m_{Fe}u_{Fe} - m_{Fe}v_{Fe}\cos 25}{m_N \cos 36}$ $= \dfrac{9.38\times10^{-26}\times 7.1\times10^7 - 9.38\times10^{-26}\times 4.8\times10^7\cos 25}{2.34\times10^{-26}\cos 36}$ $= 1.38\times10^8\ \mathrm{m\,s^{-1}}$ OR Resolving momentum in the y-direction $m_{Fe}v_{Fe,y} = m_N v_{N,y}$ OR $m_{Fe}v_{Fe}\sin 25 = m_N vN \sin 36$ OR $v_N = \dfrac{m_{Fe}v_{Fe}\sin 25}{m_N \sin 36} = \dfrac{9.38\times10^{-26}\times 4.8\times10^7\sin 25}{2.34\times10^{-26}\sin 36}$ $=1.38\times10^8\ \mathrm{m\,s^{-1}}$	Conservation of momentum, explicit or implied Resolution of momenta in x or y direction Answer Answer given to three significant figures	1 1 1 1	2	3.4.1.4
08.3	In an elastic collision, kinetic energy is conserved Assuming all of the energy of the nuclei was kinetic, if some energy is transferred by gamma rays, there will be less kinetic energy after the collision, so the collision is not elastic	owtte	1 1	2	3.4.1.6

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Question	Answers	Extra information	Marks	AO	Spec. reference
08.4	Total energy of gamma ray = 2 × 139.567 MeV = 279.134 × 1.60×10^{-19} × 10^{6} = 4.47×10^{-11} J $E = hf = \frac{hc}{\lambda}$ $\lambda = \frac{hc}{E}$ = 4.45×10^{-15} m	Energy calculated Answer commensurate with energy ALLOW 4.5 × 10^{-15}	1 1		3.2.1.3
09.1	hf = energy of photon with frequency f / f is frequency of photon/light and h is the Planks constant ϕ = work function / energy required to remove an electron from the surface of a metal E_k = kinetic energy of (ejected) electron		1 1 1	1	3.2.2.1
09.2	Work function = 5.01 × 1.6×10^{-19} J = 8.016×10^{-19} J $E = hf$, $f = \frac{E}{h} = \frac{8.016\times10^{-19}}{6.63\times10^{-34}}$ = 1.21×10^{15} Hz	Energy in joules Substitution	1 1	2	3.2.2.1
09.3	Difference in energy = $hf - \phi$ = 4.2×10^{15} × 6.63×10^{-34} – 8.016×10^{-19} J = 1.98×10^{-18} J $= \frac{1}{2}mv^2$ $v = \sqrt{\frac{2 \times 1.98\times10^{-19}}{9.11\times10^{-31}}}$ = 2.09×10^{6} m s^{-1}	Energy Substitution Answer	1 1 1	2	3.2.2.1
09.4	$\lambda = \frac{h}{mv} = \frac{6.63\times10^{-34}}{9.11\times10^{-31} \times 2.09\times10^{6}}$ = 3.48×10^{-10} m	Substitution Answer	1 1	2	3.2.2.4
09.5	Yes, the wavelength is the same as the order of magnitude as the spacing of atoms		1	3	3.2.2.4

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Question	Answers	Extra information	Marks	AO	Spec. reference
09.6	Decreasing the p.d. decreases the momentum of the electrons Increases the de Broglie wavelength of the electrons Increases the diameter of the rings Decreases the brightness of the rings		1 1 1 1	2	3.2.2.4
10.1	$hf = \phi + E_{k(max)}$ $E_{k(max)} = eV_s$ $\phi = hf - eV_s$ $\phi = \frac{hc}{\lambda} - eV_s$ $= \frac{6.63\times10^{-34}\,\text{J s} \times 3.0\times10^{8}\,\text{m s}^{-1}}{188 \times 10^{-9}\,\text{m}} - 4.5 \times 1.6\times10^{-19}$ $= 3.38\times10^{-19}$ J = 2.11 eV The cathode is made of caesium	Combining equations Work function in J/eV Metal consistent with answer	1 1 1	2	3.2.2.1 3.2.2.2
10.2	If a metal with a higher work function is used the energy required to remove the electron will be greater The kinetic energy of the photoelectron will be smaller, so the stopping potential will be smaller		1 1		3.2.2.1
10.3	The radiation promotes an electron to a higher energy level When the electron moves back to its original state it emits a photon of visible light		1 1		3.2.2.3
10.4	In the scintillator particles collide with the chemical on the screen In the fluorescent tube UV light emitted by mercury atoms is incident on the coating on the inside of the tube In both cases electrons in the atoms of screen / coating are promoted to a higher energy level And emit visible light when they move back down		1 1 1		3.2.2.2 3.2.2.3

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10.5	An electron moves from level **C** to level **B** when the atom absorbs a photon When an electron moves from level **B** to level **C** a photon is emitted The energy / frequency of the photon is the same in each case		1 1 1	2	3.2.2.3
10.6	Energy of photon = $1.8 \times 1.6\times10^{-19}$ J $= 2.89 \times 10^{-19}$ J $\Delta E = (-8.86\times10^{-19}\text{ J} - E) = 2.89\times10^{-19}$ J $E = -5.97\times10^{-19}$ J	Energy of photon Substitution Correct value of energy Negative value	1 1 1 1	3	3.2.2.3
10.7	$\lambda = \frac{hc}{E} = \frac{6.63\times10^{-34} \times 3\times10^{8}}{2.89\times10^{-19}}$ $= 6.87 \times 10^{-7}$ m / 687 nm OR $f = \frac{E}{h} = \frac{2.89\times10^{-19}}{6.63\times10^{-34}} = 4.36\times10^{14}$ Hz No, this is in the visible region / red of the electromagnetic spectrum	Substitution Answer Conclusion	1 1 1	3	3.2.2.4

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Skills box answers

Question	Answer
1	$hf = E_k + \phi$, therefore $f = \dfrac{E_k + \phi}{h}$ E_k =1.1 eV × 1.6×10^{-19} J eV^{-1} = 1.76×10^{-19} J ϕ = 4.08 eV × 1.6×10^{-19} J eV^{-1} = 6.528×10^{-19} J $f = \dfrac{(1.76 + 6.528) \times 10^{-19}\text{ J}}{6.63\times10^{-34}\text{ J s}} = 1.3\times10^{15}$ Hz
2	$hf = E_{k(max)} + \phi$ but in this case, $E_{k(max)} = 0$ ϕ = 2.87 × 1.6×10^{-19} J = 4.59×10^{-19} J therefore threshold frequency = $\dfrac{4.59\times10^{-19}\text{ J}}{6.63\times10^{-34}\text{ J s}} = 6.9\times10^{14}$ Hz
3	Rearrange the equation to make ϕ the subject: $\phi = hf - E_{k(max)}$ $E_{k(max)}$ = 1.3 × 1.6×10^{-19} J = 2.08×10^{-19} J. Photon energy hf = 3.2×10^{-19} J ϕ = 3.2×10^{-19} J – 2.08×10^{-19} J = 1.12×10^{-19} J To convert to eV, divide by 1.6×10^{-19} J eV^{-1}: ϕ = 0.7 eV