

AQA Questions from 2004 to 2006

Particle Physics Mark scheme

1. (a) (i) 94 (protons) (1)
(ii) 145 (neutrons) (1)
(iii) 93 (electrons) (1) 3
- (b) same number of protons
[or same atomic number] (1)
different number of neutrons/nucleons
[or different mass number] (1) 2 [5]
2. (a) pair production (1) 1
- (b) (i) the γ ray must provide enough energy to provide for the (rest) mass (1)
any extra energy will provide the particle(s) with **kinetic** energy (1)
(ii) $(0.511 + 0.511) = 1.022$ (MeV) (1) 3
- (c) any pairing of a particle with its corresponding antiparticle (e.g. $p + \bar{p}$) (1) 1 [5]
3. (a) intensity determines the number of photons per second (1)
fewer photoelectrons per second (1)
(individual) photon energies are not changed (1)
with no change in the (kinetic) energy/speed (1)
one photon interacts with one electron (1) 3
- (b) energy of a photon is proportional to frequency (or $E = hf$) (1)
photon of red light has less energy than a photon of blue light
[or $f_{\text{red}} < f_{\text{blue}}$ or $\lambda_{\text{red}} > \lambda_{\text{blue}}$] (1)
the energy is insufficient to overcome the work function of the metal
[or the frequency is below the threshold frequency] (1) 3
- (c) (i) $f\left(\frac{3.0 \times 10^8}{200 \times 10^{-9}}\right) = 1.5 \times 10^{15}$ Hz (1)

$$(ii) \quad f_0 \left(= \frac{\phi}{h} \right) = \frac{2.3 \times 10^{-19}}{6.63 \times 10^{-34}} \quad (1)$$

$$= 3.5 \times 10^{14} \text{ Hz} \quad (1)$$

$$(3.47 \times 10^{14} \text{ Hz})$$

(iii) (use of $hf = \phi + E_k$ gives)

$$E_k (6.63 \times 10^{-34} \times 1.5 \times 10^{15}) - 2.3 \times 10^{-19} \quad (1)$$

$$7.6 \times 10^{-19} \text{ (J)} \quad (1)$$

$$(7.645 \times 10^{-19} \text{ (J)})$$

(allow C.E for value of f from (i))

5

[11]

4. (a) (i) (3.40-1.51 = 1.89)

$$\Delta E = 1.89 \times 1.60 \times 10^{-19} \text{ (J)} \quad (1)$$

$$(= 3.02 \times 10^{-19} \text{ (J)})$$

$$f \left(= \frac{\Delta E}{h} \right) = \frac{3.02 \times 10^{-19}}{6.63 \times 10^{-34}} \quad (1)$$

$$(= 4.56 \times 10^{14} \text{ Hz})$$

$$(ii) \quad \lambda \left(= \frac{c}{f} = \frac{3.00 \times 10^8}{4.56 \times 10^{14}} \right) = 6.5(8) \times 10^{-7} \text{ m} \quad (1)$$

(use of $f = 4.6 \times 10^{14}$ gives $\lambda = 6.5 \times 10^{-7} \text{ m}$)

3

(b) (i) 6 (wavelengths) (1)

$$(ii) \quad (1.51 - 0.85) = 0.66 \text{ (eV)} \quad (1)$$

2

(c) mercury vapour at low pressure is conducting (1)
atoms of mercury are excited by electron impact (1)
producing (mainly) ultra violet radiation (1)
which is absorbed/ excites the coating (1)
which, upon relaxing, produces visible light (1)
electrons cascade down energy levels (1)

3

[8]

5. (a) $n + \nu_{(e)}$ (1)(1)
 μ^- (1)
 K^+ (1) 4
- (b) $d \rightarrow u + \beta^- + \nu_{(e)}$ (1)(1) 2
- (c) (i) weak interaction (1)
lepton (1)
electromagnetic and gravitational (1) 3 [9]
6. (a) ${}^{12}_6\text{C}$ (1) 1
- (b) $2e$ (1)
 $= (2 \times 1.6 \times 10^{-19}) = 3.2 \times 10^{-19} \text{ C}$ (1) 2
- (c) $\left(\frac{Q}{m}\right) = \frac{6 \times 1.6 \times 10^{-19}}{14 \times 1.67 \times 10^{-27}}$ (1)
 $= 4.1(1) \times 10^7 \text{ C kg}^{-1}$ (1) 2 [5]
7. (a) work function (1)
minimum energy to remove an electron from the surface of a metal (1) 2
- (b) incident photon energy is fixed
[or photoelectron receives a fixed amount of energy] (1)
photon loses all its energy in a single interaction (1)
electron can lose various amounts of energy to escape from the metal (1)
electrons have a maximum energy = photon energy – work function (1) Max 3
- (c) (i) $\phi = hf - E_k$ (1)
 $= 6.63 \times 10^{-34} \times 1.8 \times 10^{15} - 4.2 \times 10^{-19}$ (1)
 $= 7.7(3) \times 10^{-19} \text{ (J)}$ (1)
- (ii) $f_0 = \frac{7.73 \times 10^{-19}}{6.63 \times 10^{-34}}$ (1)
 $= 1.2 \times 10^{15} \text{ Hz}$ (1) ($1.17 \times 10^{15} \text{ Hz}$)
(allow C.E. for value of ϕ from (i)) 5

[10]

8. (a) (i) Z^0 with the weak interaction
 gluons or pions with the strong nuclear force
 γ photons with electromagnetic interaction
 gravitons with gravity
 (any exchange particle **(1)** and corresponding interaction **(1)**)
- (ii) transfers energy
 transfers momentum
 transfers force
 (sometimes) transfers charge any two **(1)(1)** 4
- (b) $p \bar{n} \pi^0$ **(1)**
 $V_e e^+ \mu^-$ **(1)**
 $\bar{n} e^+$ **(1)**
 $p e^+ \mu^-$ **(1)** 4 **[8]**
9. (i) $\lambda \left(= \frac{h}{mv} \right) = \frac{6.63 \times 10^{-34}}{207 \times 9.11 \times 10^{-31} \times 3.0 \times 10^6}$ **(1)**
 $= 1.2 \times 10^{-12} \text{ m}$ **(1)** ($1.17 \times 10^{-12} \text{ m}$)
- (ii) $\frac{m_\pi}{m_\mu} = \frac{134.972}{0.510999 \times 207}$ **(1)**
 $= 1.3$ **(1)** (1.28)
- (iii) (same de Broglie wavelength implies same momentum)
 $m_\pi v_\pi = m_\mu v_\mu$ **(1)**
 $v_\pi = \left(\frac{3.0 \times 10^6}{1.28} \right) = 2.3(4) \times 10^6 \text{ ms}^{-1}$ **(1)**
 (use of 1.3 gives $2.3(1) \times 10^6 \text{ ms}^{-1}$)
 (allow C.E. from (ii)) 6 **[6]**
10. (a) (i) when an atom loses an orbiting electron (and becomes charged) **(1)**

- (ii) $\frac{4.11 \times 10^{-17}}{1.6 \times 10^{-19}} = 260(\text{eV})$ (1) (257 (eV)) 2
- (b) (i) the electron in the ground state leaves the atom (1)
with remaining energy as kinetic energy (0.89×10^{-17} J) (1)
- (ii) the orbiting electrons fall down (1)
to fill the vacancy in the lower levels (1)
various routes down are possible (1)
photons emitted (1)
taking away energy (1) Max 4
- (c) E to D and D to B (1)
both in correct order (1) 2 **[8]**
- 11.** (a) (atoms with) same number of protons/same atomic number (1)
different number of neutrons/mass number/ nucleons (1) 2
- (b) (i) 7 protons (1)
8 neutrons (1)
- (ii) $\left(\frac{\text{charge}}{\text{mass}}\right) = \frac{7 \times 1.6 \times 10^{-19}}{15 \times 1.67 \times 10^{-27}}$ (1)
 $= 4.5 \times 10^7$ (C kg⁻¹) (1) (4.47×10^7 (C kg⁻¹)) 4
(allow C.E. for incorrect values in (b) (i))
- (c) (i) (+) 1.6×10^{-19} (C) (1)
- (ii) positive ion (1) 2 **[8]**
- 12.** (a) an electron is excited/promoted to a higher level/orbit (1)
reason for excitation: e.g. electron impact/light/energy externally applied (1)
electron relaxes/de-excited/falls back emitting a photon/
em radiation (1)
wavelength depends on the energy change (1) Max 3
QWC 1
- (b) (i) use of $E = hf$ gives) $E = \frac{hc}{\lambda}$ (1)

$$= \frac{6.6 \times 10^{-34} \times 3.0 \times 10^8}{4.0 \times 10^{-7}} = 5.0 \times 10^{-19} \text{ (J) (1)}$$

$$(4.95 \times 10^{-19} \text{ (J)})$$

$$\text{and } \left(\frac{6.6 \times 10^{-34} \times 3.0 \times 10^8}{2.0 \times 10^{-7}} \right) = 9.9 \times 10^{-19} \text{ (J) (1)}$$

- (ii) (energy of) level B = -1.5×10^{-18} (J) (1)
 level C = (-1.0×10^{-18}) (J) (1) 5 [8]

13. (a) baryon number $0 + 1 = 1 + 0$ (1)
 lepton number $0 + 0 = 0 + 0$ (1) 3
 charge $0 + 1 = 0 + 1$ (1)

- (b) K^0 $\bar{s}d$ (1)
 π^+ $u\bar{d}$ (1)
 p udu (1)
 correct number of quarks and antiquarks in each (1) 4 [7]

14. (a) minimum (energy/work done) (1)
 energy required to remove an electron from the surface (of the metal) (1) 2

- (b) (i) $E_k = hf - \phi$ (1)
 $f_0 = 0.50 \times 10^{15}$ (Hz) (1)
 $\phi (= hf_0) = 6.6 \times 10^{-34} \times 0.50 \times 10^{15}$ (1)
 $= 3.3 \times 10^{-19}$ J (1)
- (ii) (use of $E_k = hf - \phi$ gives) $E_k = (6.6 \times 10^{-34} \times 2.5 \times 10^{15}) - 3.3 \times 10^{-19}$ (1)
 $= 1.3(2) \times 10^{-18}$ J (1)
 (allow C.E. for incorrect value of ϕ from (i))
 [or (using gradient = $h = \Delta E_k / \Delta f$)
 $\Delta E_k = 6.6 \times 10^{-34} \times 2 \times 10^{15}$ (1)
 $= 1.3(2) \times 10^{-18}$ J (1)] 6

- (c) same gradient (1)
drawn above existing line with smaller x intercept (1) 2
[10]
15. (a) (i) $\bar{\nu}_e + p \rightarrow n + e^+$ (1)
(ii) weak (1)
(iii) W^+ or W^- (1) 4
- (b) γ photon or high energy photon/kinetic energy (1)
converted to a particle and its antiparticle (1)
 $p + \bar{p}$ or $e^- + e^+$ (1) 3
QWC 1 [7]
16. (a) (i) neutron (1)
(ii) electron (1)
(iii) neutron (1) 3
- (b) (i) (X =) 225 (1)
(Y =) 88 (1)
- (ii) $\left(\frac{\text{mass of } {}^{225}_{88}\text{Ra}}{\text{mass of } \alpha \text{ particle}} = \frac{225}{4} \right) = 56(.3)$ (1)
(allow C.E. for value of X from (i)) 3
[6]
17. (a) (i) $\text{k.e.} = \frac{4.1 \times 10^{-18}}{1.6 \times 10^{-19}}$ (1)
 $= 26 \text{ (eV)}$ (1) (25.6 eV)
- (ii) (use of $\lambda_{\text{dB}} = \frac{h}{mv}$ gives) $\lambda_{\text{dB}} = \frac{6.6 \times 10^{-34}}{9.1 \times 10^{-31} \times 3.0 \times 10^6}$ (1)
 $= 2.4 \times 10^{-10} \text{ m}$ (1) ($2.42 \times 10^{-10} \text{ m}$) 4
- (b) (use of $hf = E_1 - E_2$ gives) $f = \frac{(0.90 - 0.21) \times 10^{-18}}{6.6 \times 10^{-34}}$ (1)
 $(= 1.05 \times 10^{15} \text{ (Hz)})$
(use of $\lambda = \frac{c}{f}$ gives) $\lambda = \frac{3.0 \times 10^8}{1.05 \times 10^{15}}$ (1)
 $= 2.9 \times 10^{-7} \text{ m}$ (1) ($2.86 \times 10^{-7} \text{ m}$) 3
[7]

18. (a) (i) (named force) from weak (nuclear), electromagnetic or gravity (1)
 uses a mediating/exchange particle, named particle from $W^{(\pm)}$ (boson),
 (γ) photon or graviton (1)
 to transfer energy/momentum (1)
 when electron emits/receives exchange particle,
 disappearance/creation of new particle occurs (1) QWC 1
- (ii) anti proton (1) max 4

- (b) (i) 3 (quarks) (1)
 (ii) weak (nuclear) (1)
 (iii) proton (1) 3

[7]

19. (a) baryon number
 lepton number
 charge
 strangeness (any three) (1) (1) (1) 3

- (b) Feynman diagram to show:
 p changing to n (1)
 W^+ (1)
 β^+ and ν_e (1)
 correct overall shape with arrows (1) 4

(c)

particle	fundamental particle	meson	baryon	lepton
p		×	✓	×
n		×	✓	×
β^+	✓	×	×	✓
ν_e	✓	×	×	✓

- (1) (1) (1) (1) (one for each correct line) 4

[11]

20. (a) ($E_k =$) maximum (1)
 kinetic energy of the (emitted) (photo) electrons (1) 2

- (b) (i) (use of $f = \frac{c}{\lambda}$ gives) $f = \frac{3 \times 10^8}{190 \times 10^{-9}}$
 $= 1.6 \times 10^{15}$ Hz (1) (1.58×10^{15} Hz)
- (ii) energy of incident photon ($= hf$) $= 6.6 \times 10^{-34} \times 1.6 \times 10^{15}$

or 1.1×10^{-18} (J) (1)
 (allow C.E. for value of f from (i))
 (use of $f = 1.58 \times 10^{15}$ gives energy = 1.04×10^{-18} (J))
 incident energy is greater than the work function (1)
 [or threshold frequency ($= \frac{\phi}{h}$) = $\frac{7.9 \times 10^{-19}}{6.6 \times 10^{-34}}$
 = 1.2×10^{15} (Hz) (1)
 (incident) frequency is greater than the threshold frequency (1)]

(iii) number of photons per sec is doubled
 (maximum) photon/electron (kinetic) energy is constant
 number (of photoelectrons) emitted (per second) is increased
 (or doubled)
 one photon collision with one electron (any three) (1) (1) (1) 6
 QWC 1

[8]

21. (a) (i) (charge) = $92 \times 1.60 \times 10^{-19}$
 = 1.47×10^{-17} (C) (1)
 (ii) (magnitude of ion charge) = $3(e)$ (1)
 number of electrons (= $92 - 3$) = 89 (1) 4
 (b) X: number of nucleons [or number of neutrons plus protons or mass number] (1)
 239 (1)
 Y: number of protons [or atomic number] (1)
 94 (1) 4

[8]

22. (a) (i) 9.11×10^{-31} (kg) (1)
 (ii) (use of $E = hf$ and $c = f \lambda$ gives) $f = \frac{3.00 \times 10^8}{8.30 \times 10^{13}}$ (= 3.61×10^{20}) (1)
 $E = 6.63 \times 10^{-34} \times 3.61 \times 10^{20}$ (1)
 = 2.4×10^{-13} J (1) (2.39×10^{-13} J)
 (iii) $E = \frac{2.39 \times 10^{-13}}{1.60 \times 10^{-13}}$ (1)
 = 1.5 (MeV) (1)
 (allow C.E. for value of E from (ii) 6

(b) weak interaction/force (1) 1
 (c) (i) A: neutron or n (1)
 B: W^+ (1)
 C: (electron) neutrino or $\nu_{(e)}$ (1) 3

[10]

23. (a) hadrons are subject to the strong nuclear force
[or hadrons consist of quarks (or antiquarks)] (1) 1
- (b) (i) baryons and mesons (1)
baryons consist of three quarks
antibaryons consist of three antiquarks
mesons consist of a quark and an antiquark (any two) (1) (1) 3
- (c) Q: $0 + 1 = 1 + 0$ (1)
L: $0 - 1 = 0 - 1$ (1)
B: $1 + 0 = 1 + 0$ (1) 3
- [7]**

24. (a) electrons in energy levels/orbits (1)
excited to **higher** levels/orbits (1)
electrons relax/fall down and emit photons/em radiation (1)
photon energies/frequencies are discrete (1)
hence wavelengths are discrete (1)
intensity depends on number of photons per sec max 4
- (b) (ultraviolet) radiation (from mercury vapour) excites/absorbs (1)
the atoms of the powder in the tube (1)
these (atoms) de-excite and produce radiation (1)
radiation is visible light (1) 4
- [8]**

25. (a) (i) (use of $\lambda = \frac{h}{mv}$ gives) $v = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 3.2 \times 10^{-8}} \dots$ (1)
 $= 2.3 \times 10^4 \text{ m s}^{-1}$ (1) ($2.27 \times 10^4 \text{ m s}^{-1}$)
- (ii) (use of λ inversely proportional to m when v is constant, gives)
 $\lambda_p \left(= \lambda_e \frac{m_e}{m_p} \right) = \frac{3.2 \times 10^{-8} \times 9.11 \times 10^{-31}}{1.67 \times 10^{-27}}$ (1)
 $= 1.7 \times 10^{-11} \text{ m}$ (1)
[or $\lambda \left(= \frac{h}{mv} \right) = \frac{6.63 \times 10^{-34}}{1.67 \times 10^{-27} \times 2.27 \times 10^4}$
 $= 1.7 \times 10^{-11} \text{ m}$ ($1.746 \times 10^{-11} \text{ m}$)]
(allow C.E. for value of v from (a) (i) 4
- (b) (i) diffraction (experiments) (1)
(ii) easier to obtain electrons (to accelerate)
[or easier to get λ same size as scattering object] (1) 2
- QWC 2

[6]

