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 $E = hj$) **(1)**
photon of red light has less energy than a photon of blue light
[or/f_{red} </f_{blue} or $\lambda_{red} > \lambda_{blue}$] **(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) $f\left(=\frac{3.0\times10^{8}}{200\times10^{-9}}\right)=1.5\times10^{15}$ Hz **(1)**

(ii) $f_0\left(=\frac{\phi}{h}\right)=\frac{2.3\times10^{-19}}{6.63\times10^{-34}}$ **(1)**

$=3.5\times10^{14}$Hz **(1)**
$(3.47\times10^{14}$Hz)

(iii) (use of $hf=\phi+E_k$ gives)
$E_k\left(6.63\times10^{-34}\times1.5\times10^{15}\right)-2.3\times10^{-19}$ **(1)**

7.6×10^{-19} (J) **(1)**

$(7.645\times10^{-19}$(J)) 5
(allow C.E for value of f from (i))

[11]

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

$\Delta E=1.89\times1.60\times10^{-19}$(J) **(1)**

$(=3.02\times10^{-19}$(J))

$f\left(=\frac{\Delta E}{h}\right)=\frac{3.02\times10^{-19}}{6.63\times10^{-34}}$ **(1)**

$(=4.56\times10^{14}$Hz)

(ii) $\lambda\left(=\frac{c}{f}=\frac{3.00\times10^{8}}{4.56\times10^{14}}\right)=6.5(8)\times10^{-7}\text{ m}$ **(1)**

(use of $f=4.6\times10^{14}$ gives $\lambda=6.5\times10^{-7}$m) 3

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

(ii) (1.51–0.85) = 0.66(eV) **(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 + $v_{(e)}$ **(1)(1)**

μ^- **(1)**

K^+ **(1)** 4

(b) $d \rightarrow u + \beta^- + v_{(e)}$ **(1)(1)** 2

(c) (i) weak interaction **(1)**

lepton **(1)**

electromagnetic and gravitational **(1)** 3

[9]

6. (a) ${}^{12}_{6}C$ **(1)** 1

(b) 2e **(1)**

$= (2 \times 1.6 \times 10^{-19}) = 3.2 \times 10^{-19}$ 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)** $\times 10^7$ 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) $\varphi = hf - E_k$ **(1)**

$= 6.63 \times 10^{-34} \times 1.8 \times 10^{15} - 4.2 \times 10^{-19}$ **(1)**

= 7.7(3) × 10–19 (J) **(1)**

(ii) $f_0 = \frac{7.73 \times 10^{-19}}{6.63 \times 10^{-34}}$ **(1)**

$= 1.2 \times 10^{15}$ Hz **(1)** (1.17×10^{15} 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 $\bar{\text{n}}$ π^0 **(1)**

$V_e e^+ \mu^-$ **(1)**

$\bar{\text{n}}$ e^+ **(1)**

$p e^+ \mu^-$ **(1)** 4

[8]

9. (i) $\lambda\left(=\frac{h}{mv}\right)=\frac{6.63\times10^{-34}}{207\times9.11\times10^{-31}\times3.0\times10^{6}}$ **(1)**

$=1.2 \times 10^{-12}$ m **(1)** (1.17×10^{-12} m)

(ii) $\frac{m_\pi}{m_\mu}=\frac{134.972}{0.510999\times207}$ **(1)**

= 1.3 **(1)** (1.28)

(iii) (same de Broglie wavelength implies same momentum)

$m_\pi v_\pi = m_\mu v_\mu$ **(1)**

$v_\pi=\left(\frac{3.0\times10^{6}}{1.28}\right)=2.3(4)\times10^{6}\ \text{ms}^{-1}$ **(1)**

(use of 1.3 gives 2.3**(1)** $\times 10^6$ ms^{-1})

(allow C.E. from (ii)) 6

[6]

10. (a) (i) when an atom loses an orbiting electron (and becomes charged) **(1)**

(ii) $\dfrac{4.11\times10^{-17}}{1.6\times10^{-19}} = 260$(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) $\left(\dfrac{\text{charge}}{\text{mass}}\right) = \dfrac{7\times1.6\times10^{-19}}{15\times1.67\times10^{-27}}$ **(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) $E = \dfrac{hc}{\lambda}$ **(1)**

$= \dfrac{6.6\times10^{-34}\times3.0\times10^{8}}{4.0\times10^{-7}}$ = 5.0 × 10^{-19} (J) **(1)**
(4.95 × 10^{-19} (J))
and $\left(\dfrac{6.6\times10^{-34}\times3.0\times10^{8}}{2.0\times10^{-7}}\right)$ = 9.9 × 10^{-19} (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^o $\bar{s}d$ **(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 × 10^{15} (Hz) **(1)**
ϕ (= hf_0) = 6.6 × 10^{-34} × 0.50 × 10^{15} **(1)**
= 3.3 × 10^{-19} J **(1)**

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

(c) same gradient **(1)**
drawn above existing line with smaller x intercept **(1)** 2
[10]

15. (a) (i) $\overline{\nu_e} + p \rightarrow n$ **(1)** $+ e^+$ **(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)**
$p + \overline{p}$ 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) k.e. $= \frac{4.1 \times 10^{-18}}{1.6 \times 10^{-19}}$ **(1)**
$= 26$ (eV) **(1)** (25.6 eV)

(ii) (use of $\lambda_{dB} = \frac{h}{mv}$ gives) $\lambda_{dB} = \frac{6.6 \times 10^{-34}}{9.1 \times 10^{-31} \times 3.0 \times 10^{6}}$ **(1)**
$= 2.4 \times 10^{-10}$ m **(1)** (2.42×10^{-10} 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)**
(= 1.05×10^{15} (Hz))
(use of $\lambda = \frac{c}{f}$ gives) $\lambda = \frac{3.0 \times 10^{8}}{1.05 \times 10^{15}}$ **(1)**
$= 2.9 \times 10^{-7}$ m **(1)** (2.86×10^{-7} 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)**
$ß^+$ and ν_e **(1)**
correct overall shape with arrows **(1)** 4

(c)

particle	fundamental particle	meson	baryon	lepton
p		×	✓	×
n		×	✓	×
ß+	✓	×	×	✓
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 $= 1.04 \times 10^{-18}$ (J))
incident energy is greater than the work function **(1)**

[or threshold frequency (= $\frac{\phi}{h}$) = $\frac{7.9\times10^{-19}}{6.6\times10^{-34}}$
$= 1.2 \times 10^{15}$ (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) $= 92 \times 1.60 \times 10^{-19}$
$= 1.47 \times 10^{-17}$ (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) $f = \frac{3.00\times10^{8}}{8.30\times10^{13}}$ (= 3.61×10^{20}) **(1)**

$E = 6.63 \times 10^{-34} \times 3.61 \times 10^{20}$ **(1)**
$= 2.4 \times 10^{-13}$ J **(1)** (2.39×10^{-13} J)

(iii) $E = \frac{2.39\times10^{-13}}{1.60\times10^{-13}}$ **(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) $v = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 3.2 \times 10^{-8}}$ .. **(1)**

$= 2.3 \times 10^4$ m s^{-1} **(1)** (2.27×10^4 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)**

$= 1.7 \times 10^{-11}$ m **(1)**

[or $\lambda \left(= \frac{h}{mv} \right) = \frac{6.63 \times 10^{-34}}{1.67 \times 10^{-27} \times 2.27 \times 10^4}$

$= 1.7 \times 10^{-11}$ m (1.746×10^{-11} 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]