Area A - Wavelength comparison:
• Red LED will emit longer wavelengths than 660 nm (accept "longer than red light).
• Blue LED will emit wavelengths longer than 440 nm (accept "longer than blue light).
• Blue LED will emit visible light. Accept named colours.

Area B - Excitation process:
• Excitation mentioned (as first step of fluoresence)
• Photons are absorbed by atoms in coating
• Atoms are excited/gain energy;
• Atomic electrons move to higher energy levels (than n = 2)
• Photons have sufficient energy to promote electrons to high enough levels

Area C - De-excitation process:
• De-excitation or relaxation mentioned (as subsequent step)
• Photons are emitted by atoms in coating
• Atoms de-excite/lose energy
• Atomic electrons move to lower energy levels
• Electrons move to ground state via other energy levels
• Emitted radiation consists of (a range of) lower photon energies/frequencies or longer wavelengths

6

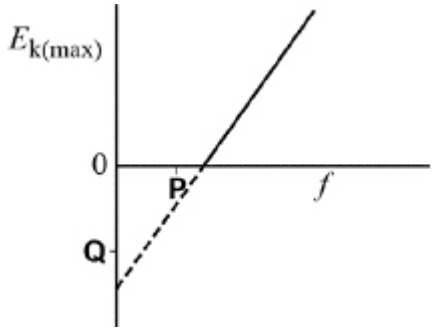
[11]

2. A

0.3×10^{-19} J

[1]

3. C



[1]

4. B

3.3×10^{-19} J

[1]

5. D

It emits photons of UV light following ionisation or excitation.

[1]

6. C

1.6×10^{-18} J

[1]

7. B

muon *electron*

[1]

8. (a) Idea that atoms gains energy (from beta particle) eg atoms excited or atoms/electrons moved to higher energy levels ✓

Idea that atom loses energy by emission of light/photons eg atoms de-excite or electrons move to lower energy levels ✓

Allow ionisation as named process

2

(b) Use of $E = \frac{hc}{\lambda}$ **OR** use of $c = f\lambda$ and $E = hf$ ✓

Condone POT error for λ

3.2×10^{-19} (J) ✓

Allow 3.1×10^{-19} (J) if 6.6×10^{-34} used

2

(c) Use of $W = QV$ **OR** determines pd = 750 V ✓

1.2×10^{-16} (J) ✓

2

(d) Max 3 from: ✓ ✓ ✓

Attempt to count squares **OR** calculate unit area **OR** Statement that area under curve = charge flow

1 small square = 2×10^{-12} (C) ; 1 large square = 5×10^{-11} (C)

Counts number of squares/Determines area

Converts number of squares to charge

Accept 140 to 180 small or 5.5–7 large squares

Accept $\frac{1}{2}$ base × height for triangle of base 12–

16 ns and height 50 mA

Divides their total charge by 1.60×10^{-19}

2×10^{9} ✓

Allow 1 sf answer

4

[10]

9. **A**

[1]

10. **A**

[1]

(e) Award each mark independently

If no mention of maximum KE do not award MP1.

Stopping potential related to maximum kinetic energy of photoelectrons/ $KE_{max} = eV_s$ ✓

(Max) KE = energy of photon – work function/ ϕ.

OR (max) KE increases as (work function is lower and) radiation same ✓

(max) KE increases, so stopping potential increases. ✓

Alternative

Reference to Einstein equation in the form: $hf = \phi + eV_s$ ✓

rearranged to

$V_s = \frac{hf-\phi}{e}$ ✓

So lower work function,(with hf *and e constant,) gives higher* Vs. ✓

3

[12]

12. **B**

[1]

13. **D**

[1]

14. **A**

[1]

15. (a) Particle with equal (rest) mass/energy ✓

but opposite charge/baryon number/lepton number ✓

2

(b) Antiproton ✓

Positron ✓

Do not accept antielectron for positron

2

(c) Rest energy of positron (0.510999) and antiproton (938.257) quoted, or 938.768 (MeV) seen ✓

Multiplies by 1.6 ✓

1.5×10^{-10} (J) ✓

Allow valid use of $E=mc^2$.

Allow any power of ten

Allow credit for 3.0×10^{-10} *(J) for proton–antiproton and electron–positron production*

3

(d) Max 3 ✓ ✓ ✓

Idea that (atomic) energy levels/states are discrete, or (emitted) photon energy is discrete

Idea that a photon is produced by electrons/atoms moving to lower energy levels/states

Allow light/radiation for "photon"

Idea that wavelength/frequency relates to photon energy/ΔE

May see equation relating ΔE to f or λ

Idea that different wavelengths/frequencies are produced

3

[10]

16. **D**

[1]

17. **C**

[1]

18. **C**

[1]

19. **D**

[1]

20. (a) Clear indication of correct process

two correct values for λv from working plus conclusion

(7.35; 7.25; 7.35) ✓

three correct values plus conclusion ✓

Condone no or misuse of powers of 10

Allow use of value of h as the constant to show that v values in table are consistent with the λ values

1

.....

ratio approach $v_1/v_2 = \lambda_2/\lambda_1$ shown for 2 sets of data ✓

shown for two other sets of data + conclusion ✓

May predict one of the values assuming inverse proportionality and compare with table value

(once for 1 mark; twice for 2 marks)

1