

GPG30

Appendix 3 & 6 Estimating surface activity

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Contamination Detectors

- detect emissions, operates in pulse mode
- practical calibrations (cheap, quick, reproducible)
- use calibrated sources of emissions
- Calibration Factor (E) relates the response (in cps) of the monitor to the number of emissions approaching the face of the detector

Emission rate = monitor reading x CF(E)

CF(E) \equiv GPG14 Calibration Factor

(response to “perfect” ISO8769 sources)

- legislation in terms of activity
- need means of converting detector reading (emission rates) into activity
- P-factor

Activity = monitor reading x CF(E) x P

P-Factor (*GPG 30*)

The P-factor is defined as the ratio of particle or photon generation rate to the emission rate from the surface.

- relates to nature of the activity distribution of activity within the active layer
- independent of the “ideal” monitor 2π efficiency
- converts emission measurements into activity
 - a single number
- Works for simple decays
 - *Pure β (single branch)*
 - *Pure α (single branch)*
 - *Pure γ (single photon)*
- All other cases (beta + gamma, alpha + gamma, e.c. + gamma, multiple branches/photons)
- Works but you need to think about it!

Appendix 3 Estimating surface activity

- Process:
 - determine 2π efficiencies of detector
(*across range of energies for α , β and γ*)
 - determine individual pathways of decay process
(*identify emissions and probabilities of occurrence/decay*)
 - estimate 2π efficiency and P-factor for each emission
 - calculate CF for the pathway
(*taking into account decay scheme and P-factor(s)*)
 - calculate combined CF for all pathways combined
 - take reading (emission rates)
 - apply CF
 - activity
- For *simple* cases (one pathway, one emission), one P-factor can be used
- We didn't think hard enough about the non-simple cases!

Appendix 3 Estimating surface activity

- **Source yield factor (emission probability)**

The probability of emission of a particular type and energy of radiation from the nucleus may not be 1.0 (or 100% chance of emission) or for every disintegration there may be more or less than 1 photon or particle emitted per second. This will affect the P factor.

- It's an invention which doesn't help

Simple cases

One Bq of a particular radionuclide may produce:

- (i) a single emission, e.g. ^{14}C , this produces 1 β emission per second of energy 156 keV (max). This corresponds to a P-factor of 2. (GPG30)
 - *1st sentence correct. 2nd sentence incorrect - confuses two effects*
- (i) a radionuclide which just emits one single emission, e.g. ^{14}C . 1 Bq produces 1 β emission per second into 4π . For an ideal source (no absorption, no attenuation, no backscatter,...) the number of β 's emitted from the surface (into 2π) is 0.5 per second.
 - *So, in this case, the ratio between the activity and the emissions into 2π is 2, i.e. the P-factor is 2.*

Non-simple cases

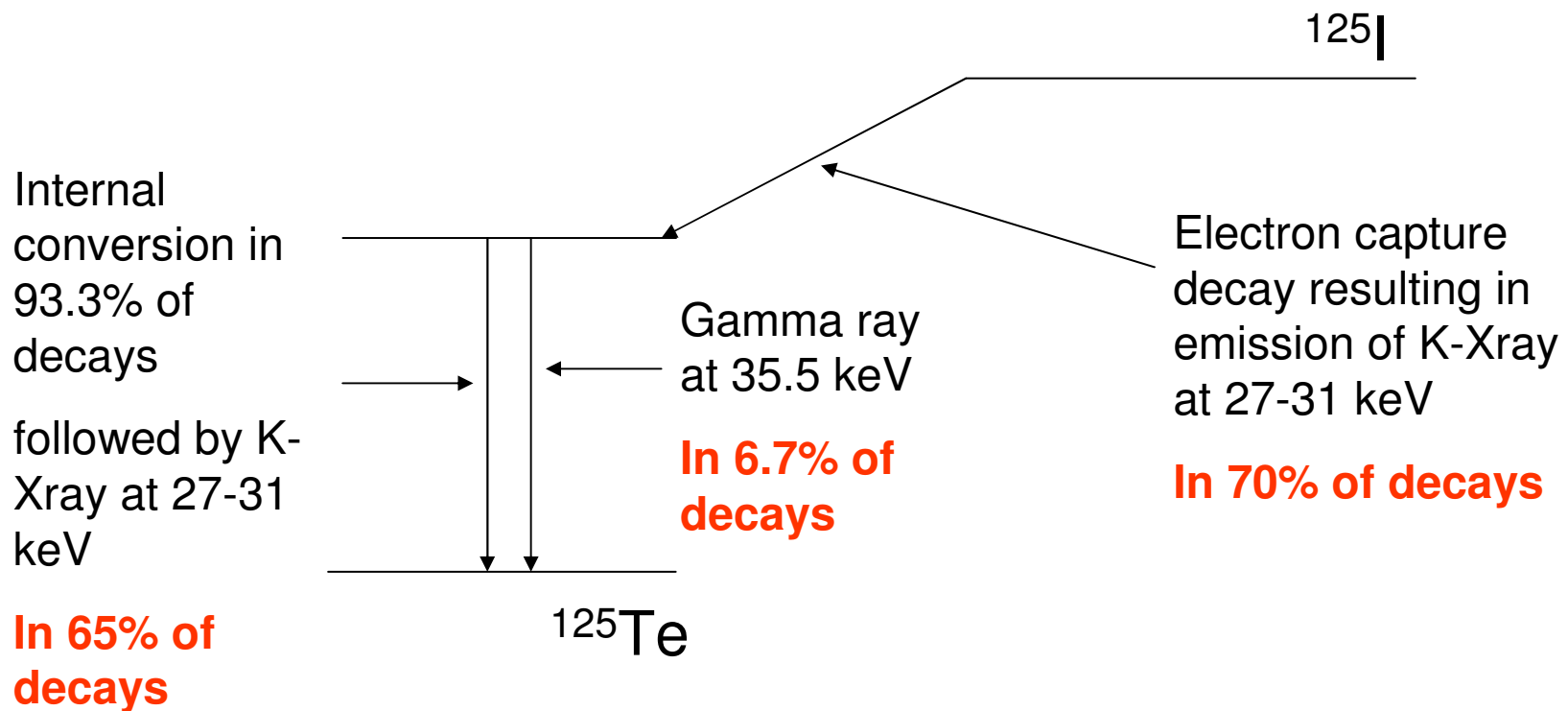
(ii) multiple emissions, e.g. ^{125}I ,
this produces approx. 1.466 X, γ
photons per second in the
energy region 27-35 keV.

The observed emission rate
(in the 2π direction) of 0.733
photons per second corresponds
to an activity of 1Bq **and hence,**
a P-factor of 1.36 (1/0.733).

Photon energy (keV)	Emission probability (%)
27.2	39.8
27.5	74.3
31.0	25.8
35.5	6.7
Total	146.6

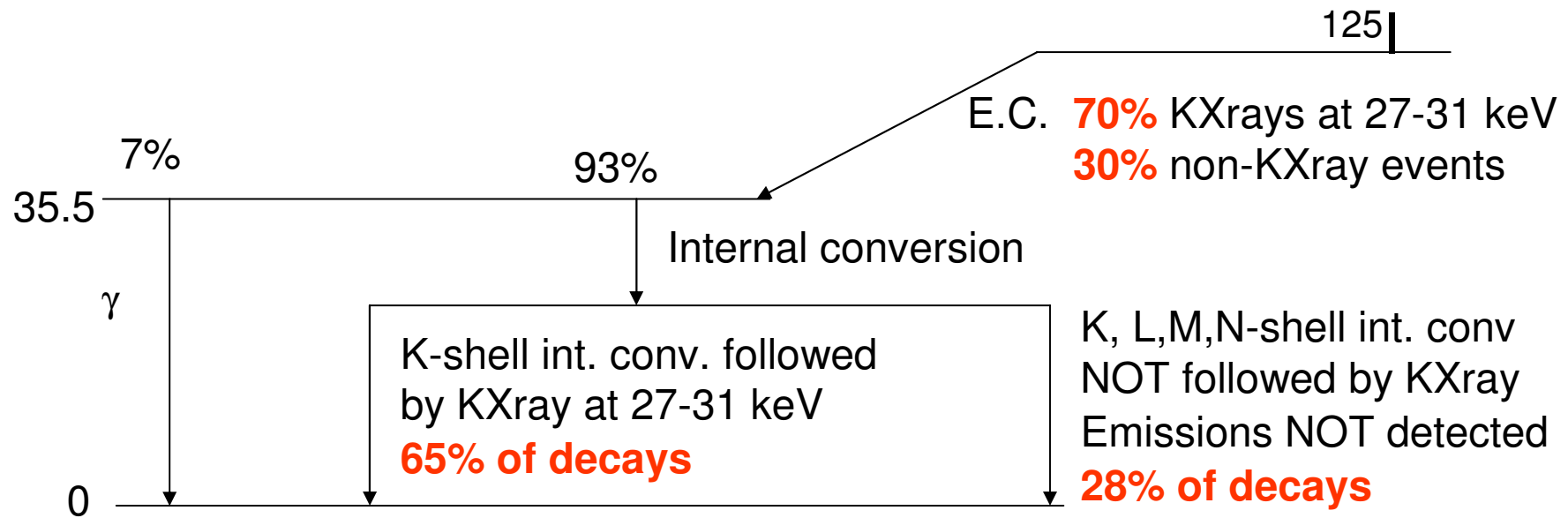
^{125}I Decay Scheme

- In practice, some of the emissions in the table arise from the same decay event.



DETECTOR IN PULSE COUNTING MODE

- All of the decay events occur within an extremely short time – within nanoseconds of each other.
- When the e.c. process AND the internal conversion both produce a K-Xray, the K-Xrays emerge “simultaneously”
- If they both emerge into the 2π which enters the detector, the detector only records ONE event – not two.
- So the GPG30 table is correct but the inference about the P-factor is wrong. There is *some* double counting.

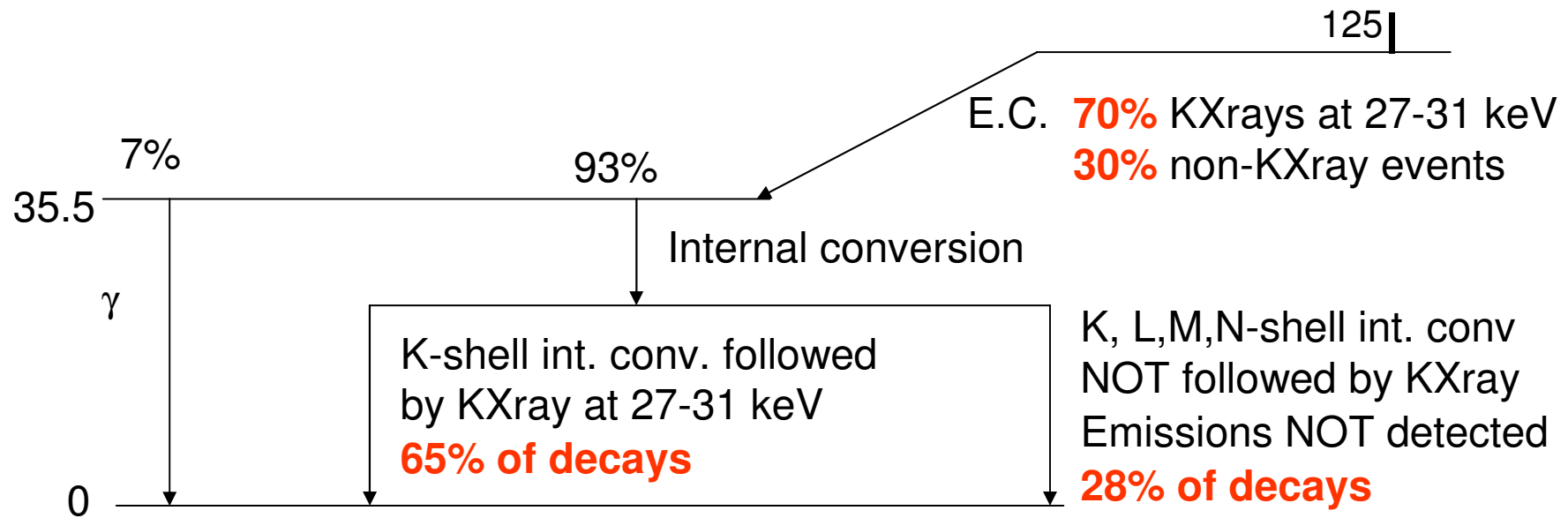


Assume 2π efficiency for K-Xrays and γ are the same and $= \epsilon_{30}$

Efficiency of detection for a real source $= \epsilon_{30}/P$, then count rate in detector from activity A is given by:

$$N = A \left[0.7 \frac{\epsilon_{30}}{P} + 0.7 \left(1 - \frac{\epsilon_{30}}{P} \right) \left(0.07 \frac{\epsilon_{30}}{P} + 0.65 \frac{\epsilon_{30}}{P} \right) + 0.3 \left(0.07 \frac{\epsilon_{30}}{P} + 0.65 \frac{\epsilon_{30}}{P} \right) \right]$$

$$N = A \left[1.42 \frac{\epsilon_{30}}{P} - 0.50 \left(\frac{\epsilon_{30}}{P} \right)^2 \right]$$



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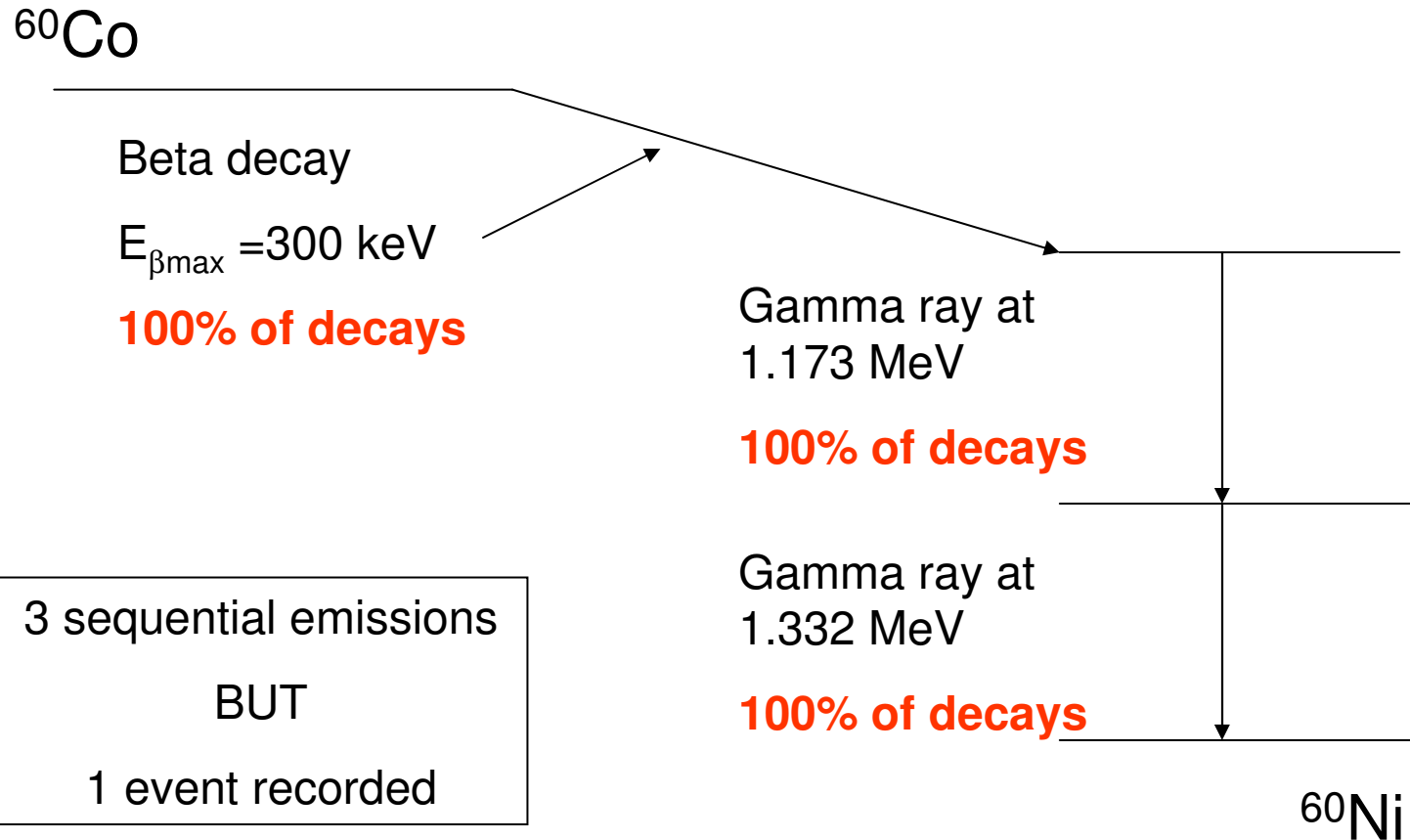
In the ideal case (no absorption in the source, etc) and a “black” detector,

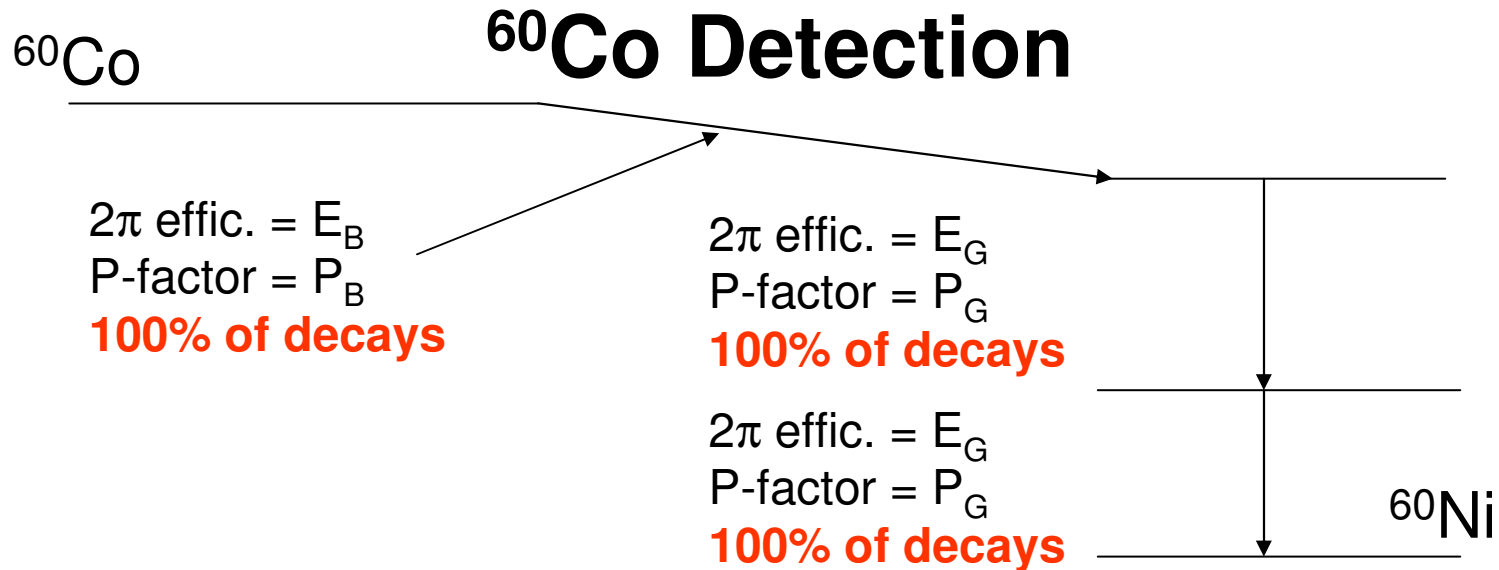
$$\epsilon_{30} = 1 \text{ and } P=2$$

$$N = A \times 0.585 \quad \text{or} \quad A = N \times 1.71$$

(GPG30 suggests $A = N \times 1.36$)

^{60}Co Decay Scheme





$$\begin{aligned}
 N &= A \left[\frac{E_B}{P_B} + \left(1 - \frac{E_B}{P_B} \right) \frac{E_G}{P_G} + \left(1 - \frac{E_B}{P_B} \right) \left(1 - \frac{E_G}{P_G} \right) \frac{E_G}{P_G} \right] \\
 &= A \left[1 - \left(1 - \frac{E_B}{P_B} \right) \left(1 - \frac{E_G}{P_G} \right) \left(1 - \frac{E_G}{P_G} \right) \right]
 \end{aligned}$$

$E_B \neq E_G$ and for real situations $P_B \neq P_G$

GPG30 App 3 and App 6

The process in GPG30 for estimating calibration factors:

- confuses P-factors and inherent 2π efficiency
- the process ignores the effects of coincident emissions resulting from the same decay
- the estimation process is scientifically and logically in error
- Appendix 6 also repeats this error for ^{99m}Tc
- The estimation process needs to be re-visited using sound logic

- All is not lost! – We can write a “simple” step-by-step process
- Detailed decay schemes are freely available on-line for most radionuclides
- Softwares for producing all decay scheme combinations (all the individual pathways) are now available in many national labs

If 2π emission efficiencies are available from GPG14 type calibrations

- Calibration factors could be estimated “at the push of a button” for most radionuclides for any chosen P factors.
- Within accuracies needed for contamination monitoring, some gross simplifications *might* be applicable
- Could be done at same time as type-testing

but

- GPG30 needs radical revision