

# 46.1 Reaction energies, activity and decay balances

Name: \_\_\_\_\_ Class: \_\_\_\_\_ Date: \_\_\_\_\_

Total: 11 marks

KEY WORDS Q value Q • activity

## Objective

Compute reaction energy from complete atomic or nuclear mass bookkeeping; Calculate activity from half-life and a simple decay-chain balance; Compare fission and fusion binding changes with charge and nucleon conservation. Original public practice; not an ETS paper.

## 1 Key knowledge and worked examples

$Q = (m_{\text{initial}} - m_{\text{final}})c^2$  with  $1 \text{ u} = 931.5 \text{ MeV}$ . Atomic masses balance electrons directly for  $\beta^-$  and neutral-He  $\alpha$ ;  $\beta^+$  needs explicit electron masses.

$A = \lambda N$  with  $\lambda = \ln 2 / T_{1/2}$ . Equal activities need not mean equal atom counts.

Chains:  $dN_B/dt = \lambda_A N_A - \lambda_B N_B$ ; a long-lived parent gives secular equilibrium of activities.

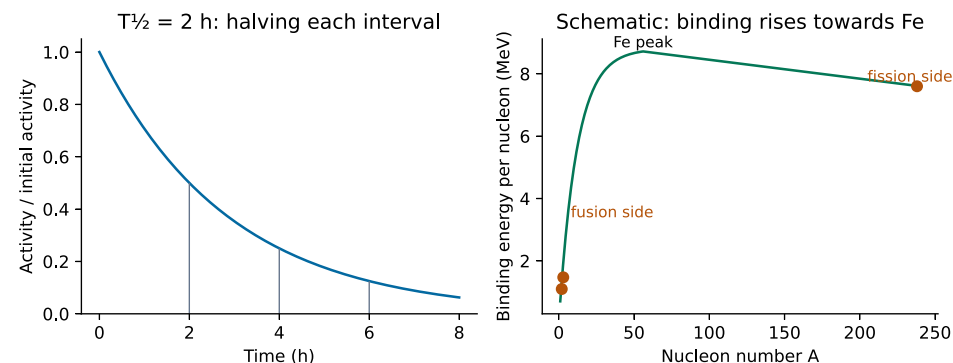
The binding-per-nucleon curve peaks near iron: heavy fission and light fusion both raise total binding and release energy.

### ■ Worked method

Activity is  $A = \lambda N$ , with  $\lambda = \ln 2 / T_{1/2}$ . For  $N = 6.0 \times 10^{12}$  and half-life 2 hours, convert time before calculating.

$$A = (\ln 2)N/T_{1/2} = (\ln 2)(6.0 \times 10^{12})/(7200 \text{ s}) = 5.78 \times 10^8 \text{ Bq.}$$

A decay chain requires both production and loss terms:  $\dot{N}_B = \lambda_A N_A - \lambda_B N_B$ . Equal activities do not imply equal populations. Atomic-mass beta-plus Q values require subtracting  $2m_e c^2$ .



## 2 Practice

2.1 Choose one answer. Using atomic masses  $238.0508 \text{ u}$  ( $^{238}\text{U}$ ),  $234.0436 \text{ u}$  ( $^{234}\text{Th}$ ) and  $4.0026 \text{ u}$  ( $^4\text{He}$ ), the alpha-decay Q value Q is about: [1]

- A 0.46 MeV
- B 2.14 MeV
- C 4.28 MeV
- D 6.55 MeV
- E 9.31 MeV

2.2 Choose one answer. Two samples contain equal numbers of radioactive nuclei; sample X has half the half-life of sample Y. The activity of X is: [1]

- A half that of Y
- B equal to that of Y
- C twice that of Y
- D four times that of Y
- E one quarter that of Y

2.3 A sample starts with activity  $8 \times 10^8 \text{ Bq}$  and half-life 3 h. After 9 h its activity is \_\_\_\_\_  $\times 10^8 \text{ Bq}$ . Show your relation and units. [2]

[2]

[5]