

## Nuclear Physics

### Transition Modes and Lifetime of Energy States

#### Given Data and Introduction

Given:

- Energy levels of  $^{16}\text{O}$  as shown in the figure
- Energy levels:
  - 0.0 MeV
  - 6.0 MeV
  - 6.1 MeV
  - 7.0 MeV
  - 7.1 MeV
- Transitions: 1, 2, 3, 4, 5

Tasks:

- Estimate the lifetime of the 7.1 MeV state.
- Identify possible transition modes shown in the figure.

#### Solution

##### Part (a): Estimating the Lifetime of the 7.1 MeV State

###### 1. Introduction to Lifetime Estimation

To estimate the lifetime of the 7.1 MeV state, utilize the transition energy and gamma ray decay formula. Lifetime  $\tau$  is inversely proportional to the transition probability:

$$\tau \propto \frac{1}{\Gamma}$$

where  $\Gamma$  is the transition width.

###### 2. Electric Dipole Transitions:

For a rough estimation, assume the decay process is via electric dipole (E1) transitions, which is common for such energy levels. The lifetime  $\tau$  for E1 transitions is approximated by:

$$\tau \approx \frac{10^3}{E_\gamma^3}$$

Here,  $E_\gamma$  is in MeV and  $\tau$  in  $(10^{-16})$  seconds.

###### 3. Calculation with Approximation:

Using  $E_\gamma = 7.1 \text{ MeV}$

$$\tau \approx \frac{10^3}{(7.1)^3}$$

$$\tau \approx \frac{10^3}{357.91}$$

$$\tau \approx 2.8 \times 10^{-3}, \text{ (in units of } 10^{-16} \text{ seconds)}$$

###### 4. Conversion to Proper Units:

$$\tau \approx 2.8 \times 10^{-3} \times 10^{-16} \approx 2.8 \times 10^{-19} \text{ seconds}$$

**Final Lifetime Estimation:** The estimated lifetime of the 7.1 MeV state is approximately  $(2.8 \times 10^{-19})$  seconds.

## Part (b): Identifying Possible Transition Modes

### 1. Possible Transitions:

According to the given figure, the following transitions are identifiable:

- 1: 6.0 MeV  $\rightarrow$  0.0 MeV
- 2: 7.0 MeV  $\rightarrow$  6.0 MeV
- 3: 7.1 MeV  $\rightarrow$  6.1 MeV
- 4: 7.0 MeV  $\rightarrow$  0.0 MeV
- 5: 6.1 MeV  $\rightarrow$  0.0 MeV

### 2. Visualization and Explanation:

**Transition 1:** Direct drop from 6.0 MeV to ground state.

**Transition 2:** From higher (7.0 MeV) to a lower excited state (6.0 MeV).

**Transition 3:** From 7.1 MeV state to 6.1 MeV.

**Transition 4:** From 7.0 MeV to the ground state directly.

**Transition 5:** From 6.1 MeV to ground state.

Final Transition Modes:

- Transition 1: 6.0 MeV  $\rightarrow$  0.0 MeV
- Transition 2: 7.0 MeV  $\rightarrow$  6.0 MeV
- Transition 3: 7.1 MeV  $\rightarrow$  6.1 MeV
- Transition 4: 7.0 MeV  $\rightarrow$  0.0 MeV
- Transition 5: 6.1 MeV  $\rightarrow$  0.0 MeV

## Final Solution

The estimated lifetime of the 7.1 MeV state is approximately  $(2.8 \times 10^{-19})$  seconds.

The possible transition modes are:

- 1. 6.0 MeV  $\rightarrow$  0.0 MeV
- 2. 7.0 MeV  $\rightarrow$  6.0 MeV
- 3. 7.1 MeV  $\rightarrow$  6.1 MeV
- 4. 7.0 MeV  $\rightarrow$  0.0 MeV
- 5. 6.1 MeV  $\rightarrow$  0.0 MeV