Biophysics of Macromolecules SS2020

PROBLEM SET 2

(1) Protein synthesis

- Bacteria divide every 20 min ⇒ Need to double amount of protein!
- Bacteria have mass of ≈ 1 pg; (→ See Problem Set 1)
- ~~Assume~~ 20% of the cell is protein

$\Rightarrow 0.2 \cdot 1\,pg = 0.2 \cdot 10^{-12}$ g of protein

or roughly $0.2 \cdot 10^{-12} \cdot 6 \cdot 10^{23} \approx 10^{11}$ Da of protein every 20 min;

- Amino acid have on average 100 Da.

⇒ Need to synthesize 10^{9} amino acids in 20 min

- There are $2 \cdot 10^{4}$ ribosomes:

$$\Rightarrow \text{Rate} = \frac{10^{9}\ \text{amino acids}}{2 \cdot 10^{4} \cdot 20\,\text{min} \cdot 60\,\frac{s}{\text{min}}} \approx 40\ \frac{\text{amino acids}}{s}$$

for each ribosome.

② Two-state protein folding

a) $K_{eq} = \frac{[N]}{[U]}$

$$\frac{1-f_u}{f_u} = \frac{1 - \frac{[U]}{[U]+[N]}}{\frac{[U]}{[U]+[N]}} = \frac{[U]+[N]-[U]}{[U]}$$

$$= \frac{[N]}{[U]} = K_{eq} \quad \blacksquare$$

b) $\Delta G_f = -RT \ln(K_{eq})$

$$\Rightarrow \quad K_{eq} = e^{-\frac{\Delta G_f}{RT}} = \frac{1-f_u}{f_u}$$

$$\Rightarrow f_u \left(1 + e^{-\frac{\Delta G_f}{RT}}\right) = 1$$

$$\Rightarrow \quad f_u = \frac{1}{1 + e^{-\frac{\Delta G_f}{RT}}}$$

You get the same result if you consider the two state system, w/ $G_{unfolded} = 0$ and $\Delta G_f = G_{folded} - G_{unfolded}$

The fraction unfolded is equal to the probability of being unfolded

$$f_u = p_u = \frac{e^{-\frac{G_u}{RT}}}{Z}$$

where $Z = \sum_{i=states} e^{-G_i/RT}$ the partition function.

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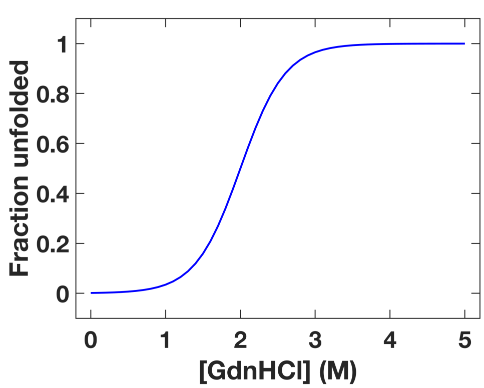
c) See matlab script for the plotting routine.



d) $$f_u = \frac{1}{1 + e^{-\frac{\left(-4 \frac{kcal}{mol}\right)}{0.6\, kcal/mol}}} \simeq 0.0013$$

$$\simeq 10^{-3}$$