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PS3 Solution

1a)

The resulting stoichiometric matrix is attached below. In addition to the metabolites and fluxes given to us in the problem statement, additional external metabolites and fluxes were added in order to complete the full reaction cycle (information found from KEGG). Special consideration was needed for *v5* due to it's reversibility; to address this, water was selected as an exchange flux for both the forward and reverse reaction (fluxes *b14* and *b14_reverse*), such that the direction of the reaction determined if the net flow water was into or out of the cell.

	v1	v2	v3	v4	v5	v5_reverse	b1	b2	b3	b4	b5	b6	b7	b8	b9	b10	b11	b12	b13	b14	b14_reverse
ATP	-1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
L-Citrulline	-1	0	0	1	2	-2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
L-Aspartate	-1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
AMP	1	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0
Diphosphate	1	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0
N-(L-Arginino)succinate	1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fumarate	0	1	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0
L-Arginine	0	1	-1	0	-2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H2O	0	0	-1	0	4	-4	0	0	0	0	0	0	0	0	0	0	0	0	0	-1	1
L-Ornithine	0	0	1	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urea	0	0	1	0	0	0	0	0	0	-1	0	0	0	0	0	0	0	0	0	0	0
Carbamoyl phosphate	0	0	0	-1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Orthophosphate	0	0	0	1	0	0	0	0	0	0	0	0	0	-1	0	0	0	0	0	0	0
Oxygen	0	0	0	0	-4	4	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
NADPH	0	0	0	0	-3	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
H+	0	0	0	0	-3	3	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Nitric Oxide	0	0	0	0	2	-2	0	0	0	0	0	0	0	0	0	0	0	-1	0	0	0
NADP	0	0	0	0	3	-3	0	0	0	0	0	0	0	0	0	0	0	0	-1	0	0

1b)

The elemental matrix for the 18 metabolites of the system are shown below. In order to determine if the system is elementally balanced, we can take the transpose of the elemental matrix and multiply it with the above stoichiometric matrix and see if the first 6 columns (i.e. the fluxes in the system *v1* to v5) of the matrix are 0, which indeed it is. Run *Balance.jl* in Julia for results.

	C	H	N	O	P	S
ATP	10	16	5	13	3	0
L-Citrulline	6	13	3	3	0	0
L-Aspartate	4	7	1	4	0	0
AMP	10	14	5	7	1	0
Diphosphate	0	4	0	7	2	0
N-(L-Arginino)succinate	10	18	4	6	0	0
Fumarate	4	4	0	4	0	0

L-Arginine	6	14	4	2	0	0
H2O	0	2	0	1	0	0
L-Ornithine	5	12	2	2	0	0
Urea	1	4	2	1	0	0
Carbamoyl phosphate	1	4	1	5	1	0
Orthophosphate	0	3	0	4	1	0
Oxygen	0	0	0	2	0	0
NADPH	21	30	7	17	3	0
H+	0	1	0	0	0	0
Nitric Oxide	0	0	1	1	0	0
NADP	21	29	7	17	3	0

1c)

We are asked to find maximum rate of urea production i.e. optimize flux *b4* of the system. We can calculate this using FBA according to the following constraints:

$$0 \le v_i \le v_{max}$$
$$0 \le b_i \le 10 \text{ mmol/gDW-hr}$$

where,

$$v_{max} = k_{cat,I} \times E \times \prod \frac{c_i}{c_i + k_m}$$

(Metabolite concentrations c_i were obtained from Park et al.).

Running *FBA.jl* in Julia calculates that the maximum urea production in the system is approximately **1.27 mmol/gDW-hr**.

```
julia> include("FBA.jl")
maximum urea flux=1.2710952000000002
```