Written Response:

Part A:

Stoichiometric matrix is copied from code below

```
#stoichiometric_matrix
#      v1  v2  v3  v4  v5+ v5- b1  b2  b3  b4  b5  b6  b7  b8  b9  b10 b11 b12 b13 b14 b15
S = [  0   0   0  -1   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0   0 ;
       0   0   0   1   0   0   0   0   0   0  -1   0   0   0   0   0   0   0   0   0   0 ;
      -1   0   0   1   2  -2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0 ;
       0   0   0   0   2  -2   0   0   0   0   0   0   0   0   0   0   0   1   0   0   0 ;
       0   0   0   0   3  -3   0   0   0   0   0   0   0   0   0   0   0   0   1   0   0 ;
       0   0  -1   0   4  -4   0   0   0   0   0   0   0   1   0   0   0   0   0  -1   0 ;
      -1   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0   0   0   0   0 ;
      -1   0   0   0   0   0   0   0   0   0   0   1   0   0   0   0   0   0   0   0   0 ;
       1   0   0   0   0   0   0   0   0   0   0   0  -1   0   0   0   0   0   0   0   0 ;
       1  -1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0 ;
       0   1   0   0   0   0   0   0  -1   0   0   0   0   0   0   0   0   0   0   0   0 ;
       0   1  -1   0  -2   2   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0 ;
       0   0   0   0  -3   3   0   0   0   0   0   0   0   0  -1   0   0   0   0   0   0 ;
       0   0   0   0  -3   3   0   0   0   0   0   0   0   0   0  -1   0   0   0   0   0 ;
       0   0   0   0  -4   4   0   0   0   0   0   0   0   0   0   0  -1   0   0   0   0 ;
       0   0   1   0   0   0   0   0   0  -1   0   0   0   0   0   0   0   0   0   0   0 ;
       0   0   1  -1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0 ;
       1   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0  -1 ; ];
```

Where

```
#           Metabolites
# 1   Carbamoyl phosphate [CPH]
# 2   orthophosphate      [PHO]
# 3   Citrulene           [CIT]
# 4   Nitrogen Monoxide   [NO_]
# 5   NADP+               [NAD]
# 6   Water               [H2O]
# 7   Aspartate           [ASP]
# 8   ATP                 [ATP]
# 9   AMP                 [AMP]
# 10  Argino-succinate    [ARS]
# 11  Fumarate            [FUM]
# 12  Arginine            [ARG]
# 13  NADPH               [NPH]
# 14  Hydrogen            [H__]
# 15  Oxygen (diatomic)   [O2_]
# 16  Urea                [URA]
# 17  Ornithene           [ORT]
# 18  Diphosphate         [DPH]
```

Part B:

The original Reconstruction in the HW handout sheet was not balanced. We balanced it by including some extra metabolites from KEGG reaction information.

To check if it was balanced it was solved by hand for the reactions, however this was tedious and a quicker way that was done was to run an Atom matrix, this was generated using the code. After running this we found that our reactions were balanced now. This was due to our addition of the metabolites ATP, AMP, etc that are listed above in part A with sources and sinks for them to enter or leave the system.

Part C:

The Julia code solved for the maximum urea production rate (called optimal in the code)

According to the code

Maximum Urea Production rate is = 1.747663537906137 mmol/gDw-hr

Or 1.75 mmol/gDw-hr

Functioning code printout of the required answers

```
Part A:
18×21 Array{Float64,2}:
  0.0  0.0   0.0  -1.0   0.0   0.0  1.0  0.0  0.0   0.0   0.0  0.0  0.0  0.0   0.0   0.0   0.0  0.0  0.0   0.0   0.0
  0.0  0.0   0.0   1.0   0.0   0.0  0.0  0.0  0.0   0.0  -1.0  0.0  0.0  0.0   0.0   0.0   0.0  0.0  0.0   0.0   0.0
 -1.0  0.0   0.0   1.0   2.0  -2.0  0.0  0.0  0.0   0.0   0.0  0.0  0.0  0.0   0.0   0.0   0.0  0.0  0.0   0.0   0.0
  0.0  0.0   0.0   0.0   2.0  -2.0  0.0  0.0  0.0   0.0   0.0  0.0  0.0  0.0   0.0   0.0   1.0  0.0  0.0   0.0   0.0
  0.0  0.0   0.0   0.0   3.0  -3.0  0.0  0.0  0.0   0.0   0.0  0.0  0.0  0.0   0.0   0.0   0.0  1.0  0.0   0.0   0.0
  0.0  0.0  -1.0   0.0   4.0  -4.0  0.0  0.0  0.0   0.0   0.0  0.0  0.0  1.0   0.0   0.0   0.0  0.0  0.0  -1.0   0.0
 -1.0  0.0   0.0   0.0   0.0   0.0  0.0  1.0  0.0   0.0   0.0  0.0  0.0  0.0   0.0   0.0   0.0  0.0  0.0   0.0   0.0
  ⋮                        ⋮                        ⋮                        ⋮                                    ⋮
  0.0  0.0   0.0   0.0  -3.0   3.0  0.0  0.0  0.0   0.0   0.0  0.0  0.0  0.0  -1.0   0.0   0.0  0.0  0.0   0.0   0.0
  0.0  0.0   0.0   0.0  -3.0   3.0  0.0  0.0  0.0   0.0   0.0  0.0  0.0  0.0   0.0  -1.0   0.0  0.0  0.0   0.0   0.0
  0.0  0.0   0.0   0.0  -4.0   4.0  0.0  0.0  0.0   0.0   0.0  0.0  0.0  0.0   0.0   0.0  -1.0  0.0  0.0   0.0   0.0
  0.0  0.0   1.0   0.0   0.0   0.0  0.0  0.0  0.0  -1.0   0.0  0.0  0.0  0.0   0.0   0.0   0.0  0.0  0.0   0.0   0.0
  0.0  0.0   1.0  -1.0   0.0   0.0  0.0  0.0  0.0   0.0   0.0  0.0  0.0  0.0   0.0   0.0   0.0  0.0  0.0   0.0   0.0
  1.0  0.0   0.0   0.0   0.0   0.0  0.0  0.0  0.0   0.0   0.0  0.0  0.0  0.0   0.0   0.0   0.0  0.0  0.0   0.0  -1.0

Part B:   TRUE, Reaction is elementally balanced

Part C:   The Urea Productin Flux is 1.747663537906137   mmol/gDw-hr
```