Rate-Independent Constructs for Chemical Computation

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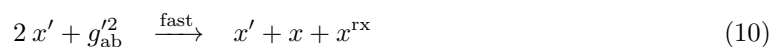## Appendix: Multiplication Reactions

System Initialization   We use a small set of reactions to implement the iterative loop of the operation.

$$x + x'_{\mathrm{ab}} + y'_{\mathrm{ab}} \quad \xrightarrow{\text{slow}} \quad x + g^P \tag{1}$$

$$g^P + x' \quad \xrightarrow{\text{fast}} \quad x' \tag{2}$$

$$g^P + y' \quad \xrightarrow{\text{fast}} \quad y' \tag{3}$$

$$g^P \quad \xrightarrow{\text{slow}} \quad g^1 + g^2 \tag{4}$$

Copying   We use our copier module to implement the line of pseudo-code `z = z + y`.

$$g^1 + y \quad \xrightarrow{\text{slow}} \quad g^1 + y' \tag{5}$$

$$g^1 + y_{\mathrm{ab}} \quad \xrightarrow{\text{slow}} \quad \varnothing \tag{6}$$

$$g^1_{\mathrm{ab}} + y' \quad \xrightarrow{\text{slow}} \quad y + z \tag{7}$$

Decrement   We use our decrement module to implement the line of pseudo-code `x = x - 1`.

$$x + g^2 \quad \xrightarrow{\text{slow}} \quad x' + g^2 \tag{8}$$

$$g^2 + x_{\mathrm{ab}} \quad \xrightarrow{\text{slow}} \quad \varnothing \tag{9}$$

$$2\,x' + g'^2_{\mathrm{ab}} \quad \xrightarrow{\text{fast}} \quad x' + x + x^{\mathrm{rx}} \tag{10}$$

$$x^{\mathrm{rx}} \quad \xrightarrow{\text{slow}} \quad \varnothing \tag{11}$$

$$x' + x^{\mathrm{rx}}_{\mathrm{ab}} + g'^2_{\mathrm{ab}} \quad \xrightarrow{\text{slow}} \quad \varnothing \tag{12}$$

Absence Indicators   Four absence indicators are needed by this system; they are of the same form as all others described in this paper.