**SBML Model Report**

# Model name: "Jones1994_BloodCoagulation"

May 28, 2014

## 1 General Overview

This is a document in SBML Level 2 Version 4 format. This model was created by the following two authors: Michael Schubert[1] and Vijayalakshmi Chelliah[2] at June sixth 2011 at 5:21 p. m. and last time modified at May 28th 2014 at 2:02 p. m. Table 1 shows an overview of the quantities of all components of this model.

Table 1: Number of components in this model, which are described in the following sections.

| Element | Quantity | Element | Quantity |
|---|---|---|---|
| compartment types | 0 | compartments | 1 |
| species types | 0 | species | 18 |
| events | 0 | constraints | 0 |
| reactions | 20 | function definitions | 1 |
| global parameters | 22 | unit definitions | 0 |
| rules | 2 | initial assignments | 0 |

### Model Notes

Jones1994_BloodCoagulationThis model is built based on theexperimental findings described in Lawson et al., 1994(PMID:8083241)

This model is described in the article:A model for the tissue factor pathway to thrombin. II. A mathematical simulation.Jones KC, Mann KG.J. Biol. Chem. 1994 Sep; 269(37): 23367-23373

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Abstract:

A mathematical simulation of the tissue factor pathway to the generation of thrombin has been developed using a combination of empirical, estimated, and deduced rate constants for reactions involving the activation of factor IX, X, V, and VIII, in the formation of thrombin, as well as rate constants for the assembly of the coagulation enzyme complexes which involve factor VIIIa-factor IXa (intrinsic tenase) and factor Va-Xa (prothrombinase) assembled on phospholipid membrane. Differential equations describing the fate of each species in the reaction were developed and solved using an interactive procedure based upon the Runge-Kutta technique. In addition to the theoretical considerations involving the reactions of the tissue factor pathway, a physical constraint associated with the stability of the factor VIIIa-factor IXa complex has been incorporated into the model based upon the empirical observations associated with the stability of this complex. The model system provides a realistic accounting of the fates of each of the proteins in the coagulation reaction through a range of initiator (factor VIIa-tissue factor) concentrations ranging from 5 pM to 5 nM. The model is responsive to alterations in the concentrations of factor VIII, factor V, and their respective activated species, factor VIIIa and factor Va, and overall provides a reasonable approximation of empirical data. The computer model permits the assessment of the reaction over a broad range of conditions and provides a useful tool for the development and management of reaction studies.

This model is hosted on BioModels Database and identified by: BIOMD0000000336.

To cite BioModels Database, please use: BioModels Database: An enhanced, curated and annotated resource for published quantitative kinetic models.



## 2 Unit Definitions

This is an overview of five unit definitions which are all predefined by SBML and not mentioned in the model.

### 2.1 Unit `substance`

**Notes** Mole is the predefined SBML unit for `substance`.

**Definition** mol

### 2.2 Unit `volume`

**Notes** Litre is the predefined SBML unit for `volume`.

**Definition** l

### 2.3 Unit `area`

**Notes** Square metre is the predefined SBML unit for `area` since SBML Level 2 Version 1.

**Definition** $\mathrm{m}^2$

### 2.4 Unit `length`

**Notes** Metre is the predefined SBML unit for `length` since SBML Level 2 Version 1.

**Definition** m

### 2.5 Unit `time`

**Notes** Second is the predefined SBML unit for `time`.

**Definition** s

## 3 Compartment

This model contains one compartment.

Table 2: Properties of all compartments.

| Id | Name | SBO | Spatial Dimensions | Size | Unit | Constant | Outside |
|---|---|---|---|---|---|---|---|
| `compartment_1` | compartment_1 | | 3 | 1 | litre | ☑ | |

### 3.1 Compartment `compartment_1`

This is a three dimensional compartment with a constant size of one litre.

**Name** compartment_1

## 4 Species

This model contains 18 species. Section 9 provides further details and the derived rates of change of each species.

Table 3: Properties of each species.

| Id | Name | Compartment | Derived Unit | Constant | Boundary Condition |
|---|---|---|---|---|---|
| IX | IX | compartment_1 | $\text{mol} \cdot \text{l}^{-1}$ | ⊟ | ⊟ |
| IX_TF_VIIa | IX_TF_VIIa | compartment_1 | $\text{mol} \cdot \text{l}^{-1}$ | ⊟ | ⊟ |
| TF_VIIa | TF_VIIa | compartment_1 | $\text{mol} \cdot \text{l}^{-1}$ | ⊟ | ⊟ |
| IXa | IXa | compartment_1 | $\text{mol} \cdot \text{l}^{-1}$ | ⊟ | ⊟ |
| X | X | compartment_1 | $\text{mol} \cdot \text{l}^{-1}$ | ⊟ | ⊟ |
| X_TF_VIIa | X_TF_VIIa | compartment_1 | $\text{mol} \cdot \text{l}^{-1}$ | ⊟ | ⊟ |
| Xa | Xa | compartment_1 | $\text{mol} \cdot \text{l}^{-1}$ | ⊟ | ⊟ |
| VIIIa_IXa | VIIIa_IXa | compartment_1 | $\text{mol} \cdot \text{l}^{-1}$ | ⊟ | ⊟ |
| X_VIIIa_IXa | X_VIIIa_IXa | compartment_1 | $\text{mol} \cdot \text{l}^{-1}$ | ⊟ | ⊟ |
| V | V | compartment_1 | $\text{mol} \cdot \text{l}^{-1}$ | ⊟ | ⊟ |
| Va | Va | compartment_1 | $\text{mol} \cdot \text{l}^{-1}$ | ⊟ | ⊟ |
| VIII | VIII | compartment_1 | $\text{mol} \cdot \text{l}^{-1}$ | ⊟ | ⊟ |
| VIIIa | VIIIa | compartment_1 | $\text{mol} \cdot \text{l}^{-1}$ | ⊟ | ⊟ |
| IIa | IIa | compartment_1 | $\text{mol} \cdot \text{l}^{-1}$ | ⊟ | ⊟ |
| II | II | compartment_1 | $\text{mol} \cdot \text{l}^{-1}$ | ⊟ | ⊟ |
| II_Va_Xa | II_Va_Xa | compartment_1 | $\text{mol} \cdot \text{l}^{-1}$ | ⊟ | ⊟ |
| Va_Xa | Va_Xa | compartment_1 | $\text{mol} \cdot \text{l}^{-1}$ | ⊟ | ⊟ |
| mIIa | mIIa | compartment_1 | $\text{mol} \cdot \text{l}^{-1}$ | ⊟ | ⊟ |

# 5 Parameters

This model contains 22 global parameters.

Table 4: Properties of each parameter.

| Id | Name | SBO | Value | Unit | Constant |
|---|---|---|---|---|---|
| k1 | k1 | 0000036 | $2 \cdot 10^7$ | | ☑ |
| k2 | k2 | 0000036 | $2 \cdot 10^7$ | | ☑ |
| k3 | k3 | 0000036 | $10^7$ | | ☑ |
| k4 | k4 | 0000036 | $2 \cdot 10^7$ | | ☑ |
| k5 | k5 | 0000036 | $10^7$ | | ☑ |
| k6 | k6 | 0000036 | $10^8$ | | ☑ |
| k7 | k7 | 0000036 | $10^7$ | | ☑ |
| k8 | k8 | | $4 \cdot 10^8$ | | ☑ |
| k9 | k9 | 0000038 | 0.005 | | ☑ |
| k10 | k10 | 0000038 | 0.400 | | ☑ |
| k11 | k11 | 0000035 | 0.300 | | ☑ |
| k12 | k12 | 0000035 | 1.150 | | ☑ |
| k13 | k13 | 0000035 | 8.200 | | ☑ |
| k14 | k14 | 0000035 | 32.000 | | ☑ |
| k15 | k15 | 0000036 | 100000.000 | | ☑ |
| k16 | k16 | 0000038 | 24.000 | | ☑ |
| k17 | k17 | 0000038 | 44.000 | | ☑ |
| k18 | k18 | 0000038 | 0.001 | | ☑ |
| k19 | k19 | 0000038 | 70.000 | | ☑ |
| k20 | k20 | | 0.020 | | ☑ |
| I | I | | 0.000 | | ☐ |
| IIa_plus_1-_2mIIa | IIa+1.2mIIa | | 0.000 | | ☐ |

# 6 Function definition

This is an overview of one function definition.

## 6.1 Function definition function_4_VIIIa_IXa_degradation_2

**Name** function_4_VIIIa_IXa_degradation_2

**Arguments** I, [VIIIa_IXa], vol (compartment_1)

#### Mathematical Expression

$$\frac{\mathrm{vol}\left(\mathrm{compartment\_1}\right) \cdot \left|\mathrm{I} - [\mathrm{VIIIa\_IXa}]\right| + \left(\mathrm{I} - [\mathrm{VIIIa\_IXa}]\right)}{\mathrm{vol}\left(\mathrm{compartment\_1}\right)} \tag{1}$$

## 7 Rules

This is an overview of two rules.

### 7.1 Rule IIa_plus_1_2mIIa

Rule `IIa_plus_1_2mIIa` is an assignment rule for parameter `IIa_plus_1_2mIIa`:

$$\mathrm{IIa\_plus\_1\_2mIIa} = [\mathrm{IIa}] + 1.2 \cdot [\mathrm{mIIa}] \tag{2}$$

### 7.2 Rule I

Rule `I` is a rate rule for parameter `I`:

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{I} = \left(\left(\left|\mathrm{I} - [\mathrm{VIIIa\_IXa}]\right|\right) + \left(\mathrm{I} - [\mathrm{VIIIa\_IXa}]\right)\right) \cdot \mathrm{k20} \tag{3}$$

# 8 Reactions

This model contains 20 reactions. All reactions are listed in the following table and are subsequently described in detail. If a reaction is affected by a modifier, the identifier of this species is written above the reaction arrow.

Table 5: Overview of all reactions

| № | Id | Name | Reaction Equation | SBO |
|---|---|---|---|---|
| 1 | R1 | R1 | $\text{IX} + \text{TF\_VIIa} \rightleftharpoons \text{IX\_TF\_VIIa}$ | |
| 2 | R1b | R1b | $\text{IX\_TF\_VIIa} \longrightarrow \text{TF\_VIIa} + \text{IXa}$ | |
| 3 | R2 | R2 | $\text{X} + \text{TF\_VIIa} \rightleftharpoons \text{X\_TF\_VIIa}$ | |
| 4 | R2b | R2b | $\text{X\_TF\_VIIa} \longrightarrow \text{TF\_VIIa} + \text{Xa}$ | |
| 5 | R3 | R3 | $\text{X} + \text{VIIIa\_IXa} \rightleftharpoons \text{X\_VIIIa\_IXa}$ | |
| 6 | R3b | R3b | $\text{X\_VIIIa\_IXa} \longrightarrow \text{VIIIa\_IXa} + \text{Xa}$ | |
| 7 | R4 | R4 | $\text{IX} + \text{Xa} \longrightarrow \text{Xa} + \text{IXa}$ | |
| 8 | R5 | R5 | $\text{V} + \text{Xa} \longrightarrow \text{Xa} + \text{Va}$ | |
| 9 | R6 | R6 | $\text{VIII} + \text{Xa} \longrightarrow \text{Xa} + \text{VIIIa}$ | |
| 10 | R7 | R7 | $\text{V} + \text{IIa} \longrightarrow \text{IIa} + \text{Va}$ | |
| 11 | R8 | R8 | $\text{VIII} + \text{IIa} \longrightarrow \text{IIa} + \text{VIIIa}$ | |
| 12 | R9 | R9 | $\text{II} + \text{Va\_Xa} \rightleftharpoons \text{II\_Va\_Xa}$ | |
| 13 | R9b | R9b | $\text{II\_Va\_Xa} \longrightarrow \text{Va\_Xa} + \text{mIIa}$ | |
| 14 | R10 | R10 | $\text{mIIa} + \text{Va\_Xa} \longrightarrow \text{Va\_Xa} + \text{IIa}$ | |
| 15 | R11 | R11 | $\text{VIIIa} + \text{IXa} \rightleftharpoons \text{VIIIa\_IXa}$ | |
| 16 | R12 | R12 | $\text{Va} + \text{Xa} \rightleftharpoons \text{Va\_Xa}$ | |
| 17 | R7_atn | R7_atn | $\text{V} + \text{mIIa} \longrightarrow \text{mIIa} + \text{Va}$ | |
| 18 | R8_atn | R8_atn | $\text{VIII} + \text{mIIa} \longrightarrow \text{mIIa} + \text{VIIIa}$ | |
| 19 | R4_atn | R4_atn | $\text{IX} + \text{Va\_Xa} \longrightarrow \text{Va\_Xa} + \text{IXa}$ | |
| 20 | VIIIa_IXa-_degradation | VIIIa_IXa_degradation | $\text{VIIIa\_IXa} \xrightarrow{\text{VIIIa\_IXa}} \emptyset$ | |

## 8.1 Reaction R1

This is a reversible reaction of two reactants forming one product.

**Name** R1

### Reaction equation

$$\text{IX} + \text{TF\_VIIa} \rightleftharpoons \text{IX\_TF\_VIIa} \tag{4}$$

### Reactants

Table 6: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| IX | IX | 0000010 |
| TF_VIIa | TF_VIIa | 0000010 |

### Product

Table 7: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| IX_TF_VIIa | IX_TF_VIIa | 0000011 |

### Kinetic Law

**SBO:0000101** mass action rate law for second order forward, first order reverse, reversible reactions, two reactants, continuous scheme

**Derived unit** contains undeclared units

$$v_1 = \text{vol}\,(\text{compartment\_1}) \cdot (\text{k6} \cdot [\text{IX}] \cdot [\text{TF\_VIIa}] - \text{k16} \cdot [\text{IX\_TF\_VIIa}]) \tag{5}$$

## 8.2 Reaction R1b

This is an irreversible reaction of one reactant forming two products.

**Name** R1b

### Reaction equation

$$\text{IX\_TF\_VIIa} \longrightarrow \text{TF\_VIIa} + \text{IXa} \tag{6}$$

**Reactant**

Table 8: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| IX_TF_VIIa | IX_TF_VIIa | 0000010 |

### Products

Table 9: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| TF_VIIa | TF_VIIa | 0000011 |
| IXa | IXa | 0000011 |

### Kinetic Law

**SBO:0000049** mass action rate law for first order irreversible reactions, continuous scheme

**Derived unit** contains undeclared units

$$v_2 = \mathrm{vol}\left(\mathrm{compartment\_1}\right) \cdot \mathrm{k11} \cdot [\mathrm{IX\_TF\_VIIa}] \tag{7}$$

## 8.3 Reaction R2

This is a reversible reaction of two reactants forming one product.

**Name** R2

### Reaction equation

$$\mathrm{X} + \mathrm{TF\_VIIa} \rightleftharpoons \mathrm{X\_TF\_VIIa} \tag{8}$$

### Reactants

Table 10: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| X | X | 0000010 |
| TF_VIIa | TF_VIIa | 0000010 |

### Product

Table 11: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| X_TF_VIIa | X_TF_VIIa | 0000011 |

### Kinetic Law

**SBO:0000101** mass action rate law for second order forward, first order reverse, reversible reactions, two reactants, continuous scheme

**Derived unit** contains undeclared units

$$v_3 = \mathrm{vol}\left(\mathrm{compartment\_1}\right) \cdot \left(\mathrm{k6} \cdot [\mathrm{X}] \cdot [\mathrm{TF\_VIIa}] - \mathrm{k17} \cdot [\mathrm{X\_TF\_VIIa}]\right) \tag{9}$$

## 8.4 Reaction R2b

This is an irreversible reaction of one reactant forming two products.

**Name** R2b

### Reaction equation

$$\mathrm{X\_TF\_VIIa} \longrightarrow \mathrm{TF\_VIIa} + \mathrm{Xa} \tag{10}$$

### Reactant

Table 12: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| X_TF_VIIa | X_TF_VIIa | 0000010 |

### Products

Table 13: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| TF_VIIa | TF_VIIa | 0000011 |
| Xa | Xa | 0000011 |

### Kinetic Law

**SBO:0000049** mass action rate law for first order irreversible reactions, continuous scheme

**Derived unit** contains undeclared units

$$v_4 = \mathrm{vol}(\mathrm{compartment\_1}) \cdot \mathrm{k12} \cdot [\mathrm{X\_TF\_VIIa}] \tag{11}$$

## 8.5 Reaction R3

This is a reversible reaction of two reactants forming one product.

**Name** R3

### Reaction equation

$$\mathrm{X} + \mathrm{VIIIa\_IXa} \rightleftharpoons \mathrm{X\_VIIIa\_IXa} \tag{12}$$

### Reactants

Table 14: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| X | X | 0000010 |
| VIIIa_IXa | VIIIa_IXa | 0000010 |

### Product

Table 15: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| X_VIIIa_IXa | X_VIIIa_IXa | 0000011 |

### Kinetic Law

**SBO:0000101** mass action rate law for second order forward, first order reverse, reversible reactions, two reactants, continuous scheme

**Derived unit** contains undeclared units

$$v_5 = \mathrm{vol}(\mathrm{compartment\_1}) \cdot (\mathrm{k6} \cdot [\mathrm{X}] \cdot [\mathrm{VIIIa\_IXa}] - \mathrm{k18} \cdot [\mathrm{X\_VIIIa\_IXa}]) \tag{13}$$

## 8.6 Reaction R3b

This is an irreversible reaction of one reactant forming two products.

**Name** R3b

### Reaction equation

$$X\_VIIIa\_IXa \longrightarrow VIIIa\_IXa + Xa \tag{14}$$

### Reactant

Table 16: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| X_VIIIa_IXa | X_VIIIa_IXa | 0000010 |

### Products

Table 17: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| VIIIa_IXa | VIIIa_IXa | 0000011 |
| Xa | Xa | 0000011 |

### Kinetic Law

**SBO:0000049** mass action rate law for first order irreversible reactions, continuous scheme

**Derived unit** contains undeclared units

$$v_6 = \mathrm{vol}\left(\mathrm{compartment\_1}\right) \cdot \mathrm{k13} \cdot [\mathrm{X\_VIIIa\_IXa}] \tag{15}$$

## 8.7 Reaction R4

This is an irreversible reaction of two reactants forming two products.

**Name** R4

### Reaction equation

$$IX + Xa \longrightarrow Xa + IXa \tag{16}$$

### Reactants

Table 18: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| IX | IX | 0000010 |
| Xa | Xa | 0000461 |

### Products

Table 19: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| Xa | Xa | 0000461 |
| IXa | IXa | 0000011 |

### Kinetic Law

**SBO:0000045** mass action rate law for second order irreversible reactions

**Derived unit** contains undeclared units

$$v_7 = \mathrm{vol}\left(\mathrm{compartment\_1}\right) \cdot \mathrm{k15} \cdot [\mathrm{IX}] \cdot [\mathrm{Xa}] \tag{17}$$

## 8.8 Reaction R5

This is an irreversible reaction of two reactants forming two products.

**Name** R5

### Reaction equation

$$\mathrm{V} + \mathrm{Xa} \longrightarrow \mathrm{Xa} + \mathrm{Va} \tag{18}$$

### Reactants

Table 20: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| V | V | 0000010 |
| Xa | Xa | 0000461 |

### Products

Table 21: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| Xa | Xa | 0000461 |
| Va | Va | 0000011 |

### Kinetic Law

**SBO:0000045** mass action rate law for second order irreversible reactions

**Derived unit** contains undeclared units

$$v_8 = \mathrm{vol}\left(\mathrm{compartment\_1}\right) \cdot \mathrm{k1} \cdot [\mathrm{V}] \cdot [\mathrm{Xa}] \tag{19}$$

## 8.9 Reaction R6

This is an irreversible reaction of two reactants forming two products.

**Name** R6

### Reaction equation

$$\mathrm{VIII} + \mathrm{Xa} \longrightarrow \mathrm{Xa} + \mathrm{VIIIa} \tag{20}$$

### Reactants

Table 22: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| VIII | VIII | 0000010 |
| Xa | Xa | 0000461 |

### Products

Table 23: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| Xa | Xa | 0000461 |
| VIIIa | VIIIa | 0000011 |

### Kinetic Law

**SBO:0000045** mass action rate law for second order irreversible reactions

**Derived unit** contains undeclared units

$$v_9 = \mathrm{vol}\left(\mathrm{compartment\_1}\right) \cdot \mathrm{k3} \cdot [\mathrm{VIII}] \cdot [\mathrm{Xa}] \tag{21}$$

## 8.10 Reaction R7

This is an irreversible reaction of two reactants forming two products.

**Name** R7

### Reaction equation

$$\mathrm{V} + \mathrm{IIa} \longrightarrow \mathrm{IIa} + \mathrm{Va} \tag{22}$$

### Reactants

Table 24: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| V | V | 0000010 |
| IIa | IIa | 0000461 |

### Products

Table 25: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| IIa | IIa | 0000461 |
| Va | Va | 0000011 |

### Kinetic Law

**SBO:0000045** mass action rate law for second order irreversible reactions

**Derived unit** contains undeclared units

$$v_{10} = \mathrm{vol}\left(\mathrm{compartment\_1}\right) \cdot \mathrm{k2} \cdot [\mathrm{V}] \cdot [\mathrm{IIa}] \tag{23}$$

## 8.11 Reaction R8

This is an irreversible reaction of two reactants forming two products.

**Name** R8

### Reaction equation

$$\mathrm{VIII} + \mathrm{IIa} \longrightarrow \mathrm{IIa} + \mathrm{VIIIa} \tag{24}$$

### Reactants

Table 26: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| VIII | VIII | 0000010 |
| IIa | IIa | 0000461 |

### Products

Table 27: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| IIa | IIa | 0000461 |
| VIIIa | VIIIa | 0000011 |

### Kinetic Law

**SBO:0000045** mass action rate law for second order irreversible reactions

**Derived unit** contains undeclared units

$$v_{11} = \mathrm{vol}\left(\mathrm{compartment\_1}\right) \cdot \mathrm{k4} \cdot [\mathrm{VIII}] \cdot [\mathrm{IIa}] \tag{25}$$

## 8.12 Reaction R9

This is a reversible reaction of two reactants forming one product.

**Name** R9

### Reaction equation

$$\mathrm{II} + \mathrm{Va\_Xa} \rightleftharpoons \mathrm{II\_Va\_Xa} \tag{26}$$

### Reactants

Table 28: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| II | II | 0000010 |
| Va_Xa | Va_Xa | 0000010 |

### Product

Table 29: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| II_Va_Xa | II_Va_Xa | 0000011 |

### Kinetic Law

**SBO:0000101** mass action rate law for second order forward, first order reverse, reversible reactions, two reactants, continuous scheme

**Derived unit** contains undeclared units

$$v_{12} = \mathrm{vol}\left(\mathrm{compartment\_1}\right) \cdot \left(\mathrm{k6} \cdot [\mathrm{II}] \cdot [\mathrm{Va\_Xa}] - \mathrm{k19} \cdot [\mathrm{II\_Va\_Xa}]\right) \tag{27}$$

## 8.13 Reaction R9b

This is an irreversible reaction of one reactant forming two products.

**Name** R9b

### Reaction equation

$$\mathrm{II\_Va\_Xa} \longrightarrow \mathrm{Va\_Xa} + \mathrm{mIIa} \tag{28}$$

### Reactant

Table 30: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| II_Va_Xa | II_Va_Xa | 0000010 |

### Products

Table 31: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| Va_Xa | Va_Xa | 0000011 |
| mIIa | mIIa | 0000011 |

### Kinetic Law

**SBO:0000049** mass action rate law for first order irreversible reactions, continuous scheme

**Derived unit** contains undeclared units

$$v_{13} = \text{vol}(\text{compartment\_1}) \cdot \text{k14} \cdot [\text{II\_Va\_Xa}] \tag{29}$$

## 8.14 Reaction R10

This is an irreversible reaction of two reactants forming two products.

**Name** R10

### Reaction equation

$$\text{mIIa} + \text{Va\_Xa} \longrightarrow \text{Va\_Xa} + \text{IIa} \tag{30}$$

### Reactants

Table 32: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| mIIa | mIIa | 0000010 |
| Va_Xa | Va_Xa | 0000461 |

### Products

Table 33: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| Va_Xa | Va_Xa | 0000461 |
| IIa | IIa | 0000011 |

### Kinetic Law

**SBO:0000045** mass action rate law for second order irreversible reactions

**Derived unit** contains undeclared units

$$v_{14} = \text{vol}(\text{compartment\_1}) \cdot \text{k5} \cdot [\text{mIIa}] \cdot [\text{Va\_Xa}] \tag{31}$$

## 8.15 Reaction R11

This is a reversible reaction of two reactants forming one product.

**Name** R11

### Reaction equation

$$\mathrm{VIIIa} + \mathrm{IXa} \rightleftharpoons \mathrm{VIIIa\_IXa} \tag{32}$$

### Reactants

Table 34: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| VIIIa | VIIIa | 0000010 |
| IXa | IXa | 0000010 |

### Product

Table 35: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| VIIIa_IXa | VIIIa_IXa | 0000011 |

### Kinetic Law

**SBO:0000101** mass action rate law for second order forward, first order reverse, reversible reactions, two reactants, continuous scheme

**Derived unit** contains undeclared units

$$v_{15} = \mathrm{vol}\left(\mathrm{compartment\_1}\right) \cdot \left(\mathrm{k7} \cdot [\mathrm{VIIIa}] \cdot [\mathrm{IXa}] - \mathrm{k9} \cdot [\mathrm{VIIIa\_IXa}]\right) \tag{33}$$

## 8.16 Reaction R12

This is a reversible reaction of two reactants forming one product.

**Name** R12

### Reaction equation

$$\mathrm{Va} + \mathrm{Xa} \rightleftharpoons \mathrm{Va\_Xa} \tag{34}$$

### Reactants

Table 36: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| Va | Va | 0000010 |
| Xa | Xa | 0000010 |

### Product

Table 37: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| Va_Xa | Va_Xa | 0000011 |

### Kinetic Law

**SBO:0000101** mass action rate law for second order forward, first order reverse, reversible reactions, two reactants, continuous scheme

**Derived unit** contains undeclared units

$$v_{16} = \mathrm{vol}\left(\mathrm{compartment\_1}\right) \cdot \left(\mathrm{k6} \cdot [\mathrm{Va}] \cdot [\mathrm{Xa}] - \mathrm{k10} \cdot [\mathrm{Va\_Xa}]\right) \tag{35}$$

## 8.17 Reaction R7_atn

This is an irreversible reaction of two reactants forming two products.

**Name** R7_atn

### Reaction equation

$$\mathrm{V} + \mathrm{mIIa} \longrightarrow \mathrm{mIIa} + \mathrm{Va} \tag{36}$$

### Reactants

Table 38: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| V | V | 0000010 |
| mIIa | mIIa | 0000461 |

### Products

Table 39: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| mIIa | mIIa | 0000461 |
| Va | Va | 0000011 |

### Kinetic Law

**SBO:0000045** mass action rate law for second order irreversible reactions

**Derived unit** contains undeclared units

$$v_{17} = \mathrm{vol}\left(\mathrm{compartment\_1}\right) \cdot \mathrm{k2} \cdot [\mathrm{V}] \cdot [\mathrm{mIIa}] \tag{37}$$

## 8.18 Reaction R8_atn

This is an irreversible reaction of two reactants forming two products.

**Name** R8_atn

### Reaction equation

$$\mathrm{VIII} + \mathrm{mIIa} \longrightarrow \mathrm{mIIa} + \mathrm{VIIIa} \tag{38}$$

### Reactants

Table 40: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| VIII | VIII | 0000010 |
| mIIa | mIIa | 0000461 |

### Products

Table 41: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| mIIa | mIIa | 0000461 |
| VIIIa | VIIIa | 0000011 |

### Kinetic Law

**SBO:0000045** mass action rate law for second order irreversible reactions

**Derived unit** contains undeclared units

$$v_{18} = \text{vol}\,(\text{compartment\_1}) \cdot \text{k4} \cdot [\text{VIII}] \cdot [\text{mIIa}] \tag{39}$$

## 8.19 Reaction R4_atn

This is an irreversible reaction of two reactants forming two products.

**Name** R4_atn

### Reaction equation

$$\text{IX} + \text{Va\_Xa} \longrightarrow \text{Va\_Xa} + \text{IXa} \tag{40}$$

### Reactants

Table 42: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| IX | IX | 0000010 |
| Va_Xa | Va_Xa | 0000461 |

### Products

Table 43: Properties of each product.

| Id | Name | SBO |
|---|---|---|
| Va_Xa | Va_Xa | 0000461 |
| IXa | IXa | 0000011 |

### Kinetic Law

**SBO:0000045** mass action rate law for second order irreversible reactions

**Derived unit** contains undeclared units

$$v_{19} = \text{vol}\,(\text{compartment\_1}) \cdot \text{k15} \cdot [\text{IX}] \cdot [\text{Va\_Xa}] \tag{41}$$

## 8.20 Reaction VIIIa_IXa_degradation

This is an irreversible reaction of one reactant forming no product influenced by one modifier.

**Name** VIIIa_IXa_degradation

### Reaction equation

$$\mathrm{VIIIa\_IXa} \xrightarrow{\mathrm{VIIIa\_IXa}} \emptyset \tag{42}$$

### Reactant

Table 44: Properties of each reactant.

| Id | Name | SBO |
|---|---|---|
| `VIIIa_IXa` | VIIIa_IXa | 0000010 |

### Modifier

Table 45: Properties of each modifier.

| Id | Name | SBO |
|---|---|---|
| `VIIIa_IXa` | VIIIa_IXa | 0000019 |

### Kinetic Law

**Derived unit** contains undeclared units

$$\begin{aligned} v_{20} = &\ \mathrm{vol}\left(\mathrm{compartment\_1}\right) \\ &\cdot \mathrm{function\_4\_VIIIa\_IXa\_degradation\_2}\left(\mathrm{I}, [\mathrm{VIIIa\_IXa}], \mathrm{vol}\left(\mathrm{compartment\_1}\right)\right) \end{aligned} \tag{43}$$

$$\begin{aligned} &\mathrm{function\_4\_VIIIa\_IXa\_degradation\_2}\left(\mathrm{I}, [\mathrm{VIIIa\_IXa}], \mathrm{vol}\left(\mathrm{compartment\_1}\right)\right) \\ &= \frac{\mathrm{vol}\left(\mathrm{compartment\_1}\right) \cdot \left|\mathrm{I} - [\mathrm{VIIIa\_IXa}]\right| + \left(\mathrm{I} - [\mathrm{VIIIa\_IXa}]\right)}{\mathrm{vol}\left(\mathrm{compartment\_1}\right)} \end{aligned} \tag{44}$$

$$\begin{aligned} &\mathrm{function\_4\_VIIIa\_IXa\_degradation\_2}\left(\mathrm{I}, [\mathrm{VIIIa\_IXa}], \mathrm{vol}\left(\mathrm{compartment\_1}\right)\right) \\ &= \frac{\mathrm{vol}\left(\mathrm{compartment\_1}\right) \cdot \left|\mathrm{I} - [\mathrm{VIIIa\_IXa}]\right| + \left(\mathrm{I} - [\mathrm{VIIIa\_IXa}]\right)}{\mathrm{vol}\left(\mathrm{compartment\_1}\right)} \end{aligned} \tag{45}$$

# 9 Derived Rate Equations

When interpreted as an ordinary differential equation framework, this model implies the following set of equations for the rates of change of each species.

Identifiers for kinetic laws highlighted in gray cannot be verified to evaluate to units of SBML `substance` per `time`. As a result, some SBML interpreters may not be able to verify the consistency of the units on quantities in the model. Please check if

- parameters without an unit definition are involved or
- volume correction is necessary because the `hasOnlySubstanceUnits` flag may be set to `false` and `spacialDimensions`> 0 for certain species.

## 9.1 Species IX

**Name** IX

**Initial concentration** $9 \cdot 10^{-8}$ mol $\cdot$ l$^{-1}$

This species takes part in three reactions (as a reactant in R1, R4, R4_atn).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{IX} = -v_1 - v_7 - v_{19} \tag{46}$$

## 9.2 Species IX_TF_VIIa

**Name** IX_TF_VIIa

**Initial concentration** 0 mol $\cdot$ l$^{-1}$

This species takes part in two reactions (as a reactant in R1b and as a product in R1).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{IX\_TF\_VIIa} = v_1 - v_2 \tag{47}$$

## 9.3 Species TF_VIIa

**Name** TF_VIIa

**Initial concentration** $5 \cdot 10^{-9}$ mol $\cdot$ l$^{-1}$

This species takes part in four reactions (as a reactant in R1, R2 and as a product in R1b, R2b).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{TF\_VIIa} = v_2 + v_4 - v_1 - v_3 \tag{48}$$

## 9.4 Species IXa

**Name** IXa

**Initial concentration** 0 mol $\cdot$ l$^{-1}$

This species takes part in four reactions (as a reactant in R11 and as a product in R1b, R4, R4_atn).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{IXa} = v_2 + v_7 + v_{19} - v_{15} \tag{49}$$

## 9.5 Species X

**Name** X

**Initial concentration** $1.7 \cdot 10^{-7}$ mol $\cdot$ l$^{-1}$

This species takes part in two reactions (as a reactant in R2, R3).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{X} = -v_3 - v_5 \tag{50}$$

## 9.6 Species X_TF_VIIa

**Name** X_TF_VIIa

**Initial concentration** 0 mol $\cdot$ l$^{-1}$

This species takes part in two reactions (as a reactant in R2b and as a product in R2).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{X\_TF\_VIIa} = v_3 - v_4 \tag{51}$$

## 9.7 Species Xa

**Name** Xa

**Initial concentration** 0 mol $\cdot$ l$^{-1}$

This species takes part in nine reactions (as a reactant in R4, R5, R6, R12 and as a product in R2b, R3b, R4, R5, R6).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Xa} = v_4 + v_6 + v_7 + v_8 + v_9 - v_7 - v_8 - v_9 - v_{16} \tag{52}$$

## 9.8 Species VIIIa_IXa

**Name** VIIIa_IXa

**Initial concentration** 0 mol $\cdot$ l$^{-1}$

This species takes part in five reactions (as a reactant in R3, VIIIa_IXa_degradation and as a product in R3b, R11 and as a modifier in VIIIa_IXa_degradation).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{VIIIa\_IXa} = v_6 + v_{15} - v_5 - v_{20} \tag{53}$$

## 9.9 Species X_VIIIa_IXa

**Name** X_VIIIa_IXa

**Initial concentration** $0 \text{ mol} \cdot \text{l}^{-1}$

This species takes part in two reactions (as a reactant in R3b and as a product in R3).

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{X\_VIIIa\_IXa} = v_5 - v_6 \tag{54}$$

## 9.10 Species V

**Name** V

**Initial concentration** $2 \cdot 10^{-8} \text{ mol} \cdot \text{l}^{-1}$

This species takes part in three reactions (as a reactant in R5, R7, R7_atn).

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{V} = -v_8 - v_{10} - v_{17} \tag{55}$$

## 9.11 Species Va

**Name** Va

**Initial concentration** $0 \text{ mol} \cdot \text{l}^{-1}$

This species takes part in four reactions (as a reactant in R12 and as a product in R5, R7, R7_atn).

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{Va} = v_8 + v_{10} + v_{17} - v_{16} \tag{56}$$

## 9.12 Species VIII

**Name** VIII

**Initial concentration** $7 \cdot 10^{-10} \text{ mol} \cdot \text{l}^{-1}$

This species takes part in three reactions (as a reactant in R6, R8, R8_atn).

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{VIII} = -v_9 - v_{11} - v_{18} \tag{57}$$

## 9.13 Species VIIIa

**Name** VIIIa

**Initial concentration** $0 \text{ mol} \cdot \text{l}^{-1}$

This species takes part in four reactions (as a reactant in R11 and as a product in R6, R8, R8_atn).

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{VIIIa} = v_9 + v_{11} + v_{18} - v_{15} \tag{58}$$

## 9.14 Species IIa

**Name** IIa

**Initial concentration** $0\ \mathrm{mol} \cdot \mathrm{l}^{-1}$

This species takes part in five reactions (as a reactant in R7, R8 and as a product in R7, R8, R10).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{IIa} = v_{10} + v_{11} + v_{14} - v_{10} - v_{11} \tag{59}$$

## 9.15 Species II

**Name** II

**Initial concentration** $1.4 \cdot 10^{-6}\ \mathrm{mol} \cdot \mathrm{l}^{-1}$

This species takes part in one reaction (as a reactant in R9).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{II} = -v_{12} \tag{60}$$

## 9.16 Species II_Va_Xa

**Name** II_Va_Xa

**Initial concentration** $0\ \mathrm{mol} \cdot \mathrm{l}^{-1}$

This species takes part in two reactions (as a reactant in R9b and as a product in R9).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{II\_Va\_Xa} = v_{12} - v_{13} \tag{61}$$

## 9.17 Species Va_Xa

**Name** Va_Xa

**Initial concentration** $0\ \mathrm{mol} \cdot \mathrm{l}^{-1}$

This species takes part in seven reactions (as a reactant in R9, R10, R4_atn and as a product in R9b, R10, R12, R4_atn).

$$\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{Va\_Xa} = v_{13} + v_{14} + v_{16} + v_{19} - v_{12} - v_{14} - v_{19} \tag{62}$$

### 9.18 Species mIIa

**Name** mIIa

**Initial concentration** $0 \text{ mol} \cdot \text{l}^{-1}$

This species takes part in six reactions (as a reactant in R10, R7_atn, R8_atn and as a product in R9b, R7_atn, R8_atn).

$$\frac{\mathrm{d}}{\mathrm{d}t}\text{mIIa} = v_{13} + v_{17} + v_{18} - v_{14} - v_{17} - v_{18} \tag{63}$$

## A Glossary of Systems Biology Ontology Terms

**SBO:0000010 reactant:** Substance consumed by a chemical reaction. Reactants react with each other to form the products of a chemical reaction. In a chemical equation the Reactants are the elements or compounds on the left hand side of the reaction equation. A reactant can be consumed and produced by the same reaction, its global quantity remaining unchanged

**SBO:0000011 product:** Substance that is produced in a reaction. In a chemical equation the Products are the elements or compounds on the right hand side of the reaction equation. A product can be produced and consumed by the same reaction, its global quantity remaining unchanged

**SBO:0000019 modifier:** Substance that changes the velocity of a process without itself being consumed or transformed by the reaction

**SBO:0000035 forward unimolecular rate constant, continuous case:** Numerical parameter that quantifies the forward velocity of a chemical reaction involving only one reactant. This parameter encompasses all the contributions to the velocity except the quantity of the reactant. It is to be used in a reaction modelled using a continuous framework

**SBO:0000036 forward bimolecular rate constant, continuous case:** Numerical parameter that quantifies the forward velocity of a chemical reaction involving two reactants. This parameter encompasses all the contributions to the velocity except the quantity of the reactants. It is to be used in a reaction modelled using a continuous framework

**SBO:0000038 reverse unimolecular rate constant, continuous case:** Numerical parameter that quantifies the reverse velocity of a chemical reaction involving only one product. This parameter encompasses all the contributions to the velocity except the quantity of the product. It is to be used in a reaction modelled using a continuous framework

**SBO:0000045 mass action rate law for second order irreversible reactions:** Reaction scheme where the products are created from the reactants and the change of a product quantity is proportional to the product of reactant activities. The reaction scheme does not include any reverse process that creates the reactants from the products. The change of a product quantity is proportional to two reactant quantity

**SBO:0000049 mass action rate law for first order irreversible reactions, continuous scheme:** Reaction scheme where the products are created from the reactants and the change of a product quantity is proportional to the product of reactant activities. The reaction scheme does not include any reverse process that creates the reactants from the products. The change of a product quantity is proportional to the quantity of one reactant. It is to be used in a reaction modelled using a continuous framework.

**SBO:0000101 mass action rate law for second order forward, first order reverse, reversible reactions, two reactants, continuous scheme:** Reaction scheme where the products are created from the reactants and the change of a product quantity is proportional to the product of reactant activities. The reaction scheme does include a reverse process that creates the reactants from the products. The rate of the forward process is proportional to the product of two reactant quantities. The rate of the reverse process is proportional to the quantity of one product. It is to be used in a reaction modelled using a continuous framework.

**SBO:0000461 essential activator:** A substance that is absolutely required for occurrence and stimulation of a reaction

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