


# MDR1 TR ATPase Assay Protocol

CAT. NO. SBAT01

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## Determination of the interaction of drugs with the human MDR1 (ABCB1) transporter using the ATPase Assay

**For the following membrane products:**  
SB-MDR1-Sf9-ATPase

**Version Number:**

1.1

**Effective date:**

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**Related Procedures:**

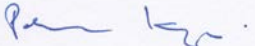
SOP 201: Fee-for Service Screening

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## 1. Introduction

SOLVO Biotechnology has developed a number of assay systems based on the detection of the ATPase activity of ABC transporter proteins. These assays are performed using purified membrane vesicles from Sf9 (*Spodoptera frugiperda*) or mammalian cells, expressing high levels of a selected human ABC transporter protein. The following protocol describes the ATPase assay for measuring human MDR1 (PgP, ABCB1).

## 2. Assay principle

ABC transporters pump substrates out of the cell by using ATP hydrolysis as an energy source. ATP hydrolysis yields inorganic phosphate (Pi), which can be detected by a simple colorimetric reaction. The amount of Pi liberated by the transporter is proportional to the activity of the transporter.

Membrane preparations containing ABC transporters show a baseline ATPase activity that varies for different transporters. Transported substrates increase this baseline ATPase activity, while inhibitors or slowly transported compounds inhibit the baseline ATPase activity and/or the ATPase activity measured in the presence of a stimulating agent. Both activation and inhibition studies can be performed.

This assay is a modification of the method of *Sarkadi et al., J. Biol. Chem. 267:4854 (1992)*.



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### **3. Deliverables**

- Frozen membrane vesicles, containing 5 mg/ml membrane protein in Eppendorf tubes, labeled with volume, catalog number (transporter) and date of production.
- Data sheet indicating protein content, volume, basal and maximal vanadate sensitive ATPase activities and date of expiry of frozen membrane stocks.
- Assay protocol.

### **4. Equipment needed**

- Water bath/incubator, 37 °C
- Automatic pipettes, multichannel-pipette with corresponding tips
- 96 well microtiter plates
- Microplate reader with absorbance filter suitable for measuring OD between 630 and 850 nm



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## 5. Materials

<i>Substance</i>	<i>Cat. Number</i>	<i>Storage</i>
<b>Tris-Base</b> (Tris[hydroxymethyl]aminomethane)	Sigma T-1503	RT, >1year
<b>MOPS</b> (3-[N-Morpholino]propanesulfonic acid)	Sigma M-1254	RT, >1year
<b>EGTA</b>	Sigma E-3889	RT, >1year
<b>KCl</b>	Sigma P-9333	RT, >1year
<b>Na-azide</b>	Sigma S-8032	RT, >1year
<b>DTT</b>	Sigma D-5545	4 °C, >1 year
<b>SDS</b>	Sigma L-6026	RT, >1year
<b>KH<sub>2</sub>PO<sub>4</sub></b>	Sigma P-5379	RT, >1year
<b>Verapamil</b>	Sigma V-4629	RT, >1year
<b>Na-Orthovanadate (Na<sub>3</sub>VO<sub>4</sub>)</b>	Sigma S-6508	RT, >1year
<b>ATP (disodium salt)</b>	Sigma A-2383	-20 °C, >1 year
<b>MgCl<sub>2</sub> (hexahydrate)</b>	Sigma M-2670	RT, >1year
<b>Zinc acetate (dihydrate)</b>	Sigma Z-4540	RT, >1year
<b>Ammonium-molybdate (tetrahydrate)</b>	Sigma A-7302	RT, >1year
<b>Ascorbic acid</b>	Pharmacy grade	4 °C, >1 year
<b>DMSO</b>	Sigma D-2650	RT, >1year
<b>MilliQ water</b> MilliQ water is made by filtering distilled water through a Millipore Ultra-Pure Water System Purification Pak. Use MilliQ water to make all solutions.	Millipore 67733	RT, >1year



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## 6. Solutions

### 6.1. Stock solutions

<i>Solution</i>	<i>Storage</i>
<b>1.7 M Tris</b> Dissolve 20.587 g of Tris in 100 ml distilled water.	4 °C, >1 year
<b>0.1 M MOPS-Tris</b> Dissolve 2.09 g of MOPS in 90 ml distilled water, adjust pH to 7.0 with 1.7 M Tris (about 2 ml). Bring solution to 100 ml with distilled water.	4 °C, >1 year
<b>100 mM EGTA-Tris pH 7.0</b> Dissolve 3.804 g of EGTA in about 10 ml of 1.7 M Tris. Add 80 ml of distilled water and adjust pH to 7.0 with 1.7 M Tris. Bring solution to 100 ml with distilled water.	4 °C, >1 year
<b>1 M KCl</b> Dissolve 7.46 g of KCl in 100 ml distilled water.	4 °C, >1 year
<b>0.1 M Na-azide</b> Dissolve 0.65 g of Na-azide in 100 ml distilled water.	4 °C, >1 year
<b>0.1 M DTT</b> Dissolve 0.3086 g of DTT in 20 ml distilled water.	-20 °C in small aliquots
<b>5% SDS</b> Dissolve 5 g of SDS in 100 ml distilled water.	RT, > 1 year
<b>100 mM KH<sub>2</sub>PO<sub>4</sub></b> Dissolve 0.1361 g of KH <sub>2</sub> PO <sub>4</sub> in 10 ml distilled water.	-20 °C in small aliquots
<b>Phosphate standard solutions</b> 0.5 mM, 1 mM, 2 mM, 4 mM and 8 mM KH <sub>2</sub> PO <sub>4</sub> prepared from 100 mM stock in distilled water.	-20 °C in small aliquots
<b>60 mM Na-Orthovanadate</b> 60 mM Na-Orthovanadate in distilled water.	-20 °C in small aliquots
<b>0.2 M MgATP</b> Dissolve 2.2 g of ATP and 0.8 g MgCl <sub>2</sub> in 10 ml of distilled water and adjust pH to 7.0 with 1.7 M Tris. Bring solution to 20 ml with distilled water.	-20 °C in small aliquots



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<i>Solution</i>	<i>Storage</i>
<b>2 mM Verapamil</b> 2 mM Verapamil in DMSO.	-20 °C in small aliquots
<b>15mM Zinc Acetate</b> Dissolve 330 mg of Zinc Acetate in 100 ml of distilled water.	4 °C, 2 weeks
<b>35 mM Ammonium Molybdate in 15 mM Zinc Acetate pH 5.0</b> Dissolve 0.432 g of Ammonium Molybdate in 10 ml of Zn Acetate Store in a container wrapped with aluminum foil in the dark.	Prepare fresh
<b>10% Ascorbic Acid pH 5.0</b> Dissolve 3 g Ascorbic Acid in 30 ml distilled water and adjust pH to 5.0 with NaOH (prepared freshly).	Prepare fresh

## 6.2. Assay-mix

<i>Ingredient</i>	<i>Volume (µl)</i>	<i>Final concentration</i>
0.1 M MOPS-TRIS, pH 7.0	5,000	50 mM
1 M KCl	500	50 mM
0.1 M Na-azide	500	5 mM
0.1 M DTT	200	2 mM
100 mM EGTA-TRIS, pH 7.0	10	0.1 mM
Distilled Water	3,790	
Total volume	10,000	

Add DTT freshly before use. The rest of the solutions can be pre-mixed and stored at 4 °C.





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## **7. Main steps of the assay**

1. Preparation of the assay-mix
2. Preparation of membrane suspension in assay-mix, in case of inhibition studies addition of a known substrate, distribution onto microplates
3. Serial dilution of the drugs to be assayed, addition of reagents to the plate wells
4. Preincubation at 37 °C, starting the assay by the addition of MgATP
5. Incubation at 37 °C, termination of the ATPase activity by SDS
6. Measurement of the Pi liberation by spectrophotometry
7. Calculation of the results by using the OD values, compared to standard phosphate concentrations

## **8. What is the signal composed of?**

As a result of the relatively complex composition of the assay, transporter activities from OD values can only be calculated with adequate controls. Therefore it is important to understand how the different experimental conditions modify the readout (OD, reflecting Pi concentration). The Pi measured is composed of the following elements:

1. There is some Pi present in the final assay suspension (containing the membranes and ATP). This is mainly due to the contamination of the membranes and ATP with Pi, and some non-enzymatic ATP hydrolysis.
2. Some of the ATPase activities in the membranes are Na<sub>3</sub>VO<sub>4</sub> insensitive. This is important to determine since the transporter-specific Na<sub>3</sub>VO<sub>4</sub> sensitive activity can only be calculated by subtracting this background Na<sub>3</sub>VO<sub>4</sub> insensitive activity. This activity may somewhat vary with membrane stocks, thus including this control in the calculations also decreases inter-assay variability.



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3. Membranes always contain a small amount of  $\text{Na}_3\text{VO}_4$  sensitive ATPase activity not related to transporter ATPase. This can be assayed by measuring the  $\text{Na}_3\text{VO}_4$  sensitive ATPase activity of a control membrane (purified from cells infected with a virus expressing e.g. beta-galactosidase). This experiment is routinely performed in our laboratory to validate membrane production and purification. If you wish to set up this control experiment, control membranes are available from SOLVO Biotechnology.
4. The rest of the signal is the transporter specific ATPase activity of the membrane suspension, which is  $\text{Na}_3\text{VO}_4$  sensitive. Transporters show some baseline ATPase activity that varies for different transporters and different membrane preparations. Substrates of the transporter stimulate the baseline ATPase activity, while inhibitors or slowly transported compounds inhibit the baseline ATPase activity.
5. Some drugs are colorful or might interfere with the assay in any other nonspecific way. In order to separate any nonspecific effect test drugs should be assayed with and without the presence of 1.2 mM  $\text{Na}_3\text{VO}_4$ .

## 9. Solvents

Throughout this protocol DMSO is used as a general solvent of test drugs; the final concentration of DMSO is 2% in the assay during the incubation period. Controls are also designed according to this. However, the assay tolerates up to 2 % of a wide range of organic solvents (DMSO, ethanol, methanol, acetonitrile). If you are using a different solvent replace DMSO with that solvent in all controls.

## 10. Controls

We suggest the following controls to set up for measuring the different elements of the signal. Perform all controls in duplicates.



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**Ctrl 1: Assay background control:** add 40  $\mu\text{l}$  membrane in assay mix and 40  $\mu\text{l}$  5% SDS to the wells. Add 1  $\mu\text{l}$  DMSO. Preincubate at 37 °C for 5 minutes. Add 10  $\mu\text{l}$  of 25 mM MgATP to the wells and incubate at 37 °C. Develop color reaction for inorganic phosphate. This will show the Pi present in the well without any enzymatic ATP hydrolysis. Ctrl 1 serves as a quality check of the components of the assay mix, solvents, and the ATP and membrane used.

**Ctrl 2:  $\text{Na}_3\text{VO}_4$  insensitive ATPase activity:** add 40  $\mu\text{l}$  membrane in assay mix and 1  $\mu\text{l}$  of 60 mM  $\text{Na}_3\text{VO}_4$  to the wells (final  $\text{Na}_3\text{VO}_4$  concentration is 1.2 mM). Add 1  $\mu\text{l}$  DMSO. Preincubate at 37 °C for 5 min. Start the reaction by adding 10  $\mu\text{l}$  of 25 mM MgATP to the wells and incubate at 37 °C. Stop the reaction by adding 40  $\mu\text{l}$  5% SDS at the end of the incubation period and develop color reaction for inorganic phosphate. This will show the ATPase activity not sensitive to  $\text{Na}_3\text{VO}_4$ .



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**Ctrl 3: Baseline ATPase activity:** add 40 µl membrane in assay mix. Add 1 µl DMSO. Preincubate at 37°C for 5 min. Start the reaction by adding 10 µl of 25 mM MgATP to the wells and incubate at 37 °C. Stop the reaction by adding 40 µl 5% SDS at the end of the incubation period and develop color reaction for inorganic phosphate. This will show the basic level of Pi liberation in the presence of a given membrane, transporter and solvent for the drugs. For obtaining the vanadate-sensitive baseline ATPase activity subtract Ctrl 2.

**Ctrl 4: Fully activated (maximal) ATPase activity:** add 40 µl membrane in assay mix. For MDR1 ATPase add 1 µl of 2 mM Verapamil (final concentration 40 µM) and 1 µl DMSO. Preincubate at 37 °C for 5 min. Start the reaction by adding 10 µl of 25 mM MgATP to the wells and incubate at 37 °C. Stop the reaction by adding 40 µl 5% SDS/well at the end of the incubation period and develop color reaction for inorganic phosphate. This will show the maximum level of Pi liberation in the presence of a given membrane and transporter. For obtaining the full vanadate-sensitive ATPase activity subtract Ctrl 2.



## 11. Suggested assay layout

We suggest using the following assay layouts. It is designed for a duplicate measurement of 2 different drugs at 8 concentrations (3-fold serial dilution starting from 100  $\mu$ M). Note that in case of inhibition studies test drugs are assayed in the presence of a strong activator.

### 11.1. Activation studies

	1	2	3	4	5	6	7	8	9	10	11	12
	Calibration (Pi/well)		Controls		Test drug A		Test drug A + Na <sub>3</sub> VO <sub>4</sub>		Test drug B		Test drug B + Na <sub>3</sub> VO <sub>4</sub>	
<b>A</b>	0		Ctrl 1		100 $\mu$ M		100 $\mu$ M		100 $\mu$ M		100 $\mu$ M	
<b>B</b>	5 nmol		Ctrl 2		33.3 $\mu$ M		33.3 $\mu$ M		33.3 $\mu$ M		33.3 $\mu$ M	
<b>C</b>	10 nmol		Ctrl 3		11.1 $\mu$ M		11.1 $\mu$ M		11.1 $\mu$ M		11.1 $\mu$ M	
<b>D</b>	20 nmol		Ctrl 4		3.7 $\mu$ M		3.7 $\mu$ M		3.7 $\mu$ M		3.7 $\mu$ M	
<b>E</b>	40 nmol				1.23 $\mu$ M		1.23 $\mu$ M		1.23 $\mu$ M		1.23 $\mu$ M	
<b>F</b>	80 nmol				0.41 $\mu$ M		0.41 $\mu$ M		0.41 $\mu$ M		0.41 $\mu$ M	
<b>G</b>					0.137 $\mu$ M		0.137 $\mu$ M		0.137 $\mu$ M		0.137 $\mu$ M	
<b>H</b>					0.046 $\mu$ M		0.046 $\mu$ M		0.046 $\mu$ M		0.046 $\mu$ M	

### 11.2. Inhibition studies

	1	2	3	4	5	6	7	8	9	10	11	12
	Calibration (Pi/well)		Controls		Test drug A + activator at fixed concentration		Test drug A + Na <sub>3</sub> VO <sub>4</sub> + activator at fixed concentration		Test drug B + activator at fixed concentration		Test drug B + Na <sub>3</sub> VO <sub>4</sub> + activator at fixed concentration	
<b>A</b>	0		Ctrl 1		100 $\mu$ M		100 $\mu$ M		100 $\mu$ M		100 $\mu$ M	
<b>B</b>	5 nmol		Ctrl 2		33.3 $\mu$ M		33.3 $\mu$ M		33.3 $\mu$ M		33.3 $\mu$ M	
<b>C</b>	10 nmol		Ctrl 3		11.1 $\mu$ M		11.1 $\mu$ M		11.1 $\mu$ M		11.1 $\mu$ M	
<b>D</b>	20 nmol		Ctrl 4		3.7 $\mu$ M		3.7 $\mu$ M		3.7 $\mu$ M		3.7 $\mu$ M	
<b>E</b>	40 nmol				1.23 $\mu$ M		1.23 $\mu$ M		1.23 $\mu$ M		1.23 $\mu$ M	
<b>F</b>	80 nmol				0.41 $\mu$ M		0.41 $\mu$ M		0.41 $\mu$ M		0.41 $\mu$ M	
<b>G</b>					0.137 $\mu$ M		0.137 $\mu$ M		0.137 $\mu$ M		0.137 $\mu$ M	
<b>H</b>					0.046 $\mu$ M		0.046 $\mu$ M		0.046 $\mu$ M		0.046 $\mu$ M	



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## Assay steps

1. Assemble assay mix and keep it on ice. Place a 96 well plate on ice.
2. Add 40  $\mu$ l of assay mix to the wells used for Pi calibration. Add 10  $\mu$ l of the phosphate standard solutions to the appropriate wells (to obtain 5-80 nmoles of Pi/well). Add 40  $\mu$ l 5% SDS to these wells. Perform in duplicates.
3. Use the predetermined membrane protein concentration (5 mg/ml) to prepare a 1 mg/ml suspension by diluting the membranes in assay mix (mix well).  
In case of inhibition studies remove the amount of membrane suspension required for controls (8 wells). Add the strong activator to the rest of the suspension:

MDR1	25 $\mu$ l 2 mM Verapamil/ml (final concentration 40 $\mu$ M)
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4. Add 40  $\mu$ l of membrane suspension to the desired wells of a 96-well plate.
5. Add the required reagents to controls. Add test drugs in 1  $\mu$ l DMSO.
6. Transfer plates to 37  $^{\circ}$ C, preincubate for 5 min.
7. Prepare a 25 mM MgATP solution by diluting 0.2 M MgATP solution in assay mix.
8. Start the ATPase reaction by the addition of 10  $\mu$ l of 25 mM Mg-ATP.
9. Incubate the plates at 37  $^{\circ}$ C in a water bath, (20 min for MDR1).
10. Stop the ATPase reaction by adding 40  $\mu$ l 5% SDS to each well.
11. Prepare the detection reagent: Add 10 ml of 35 mM Ammonium Molybdate in 15 mM Zinc Acetate to 30 ml of the freshly prepared 10% ascorbic acid. Invert to mix.
12. Add 200  $\mu$ l of detection reagent to each well.
13. Incubate the plates at 37  $^{\circ}$ C for 25 minutes, read the OD between 630 and 850 nm.  
Note that further slow increase in color occurs in ATP-containing wells, due to ATP cleavage caused by the detection reagent.



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## 12. Representing the data

There are two main representations of the data:

### 1. Calculation of specific activities

Calculate the  $\text{Na}_3\text{VO}_4$  sensitive transporter ATPase activities in terms of Pi liberated/mg membrane protein/min. This is obtained by subtracting the Pi liberated in the presence of  $\text{Na}_3\text{VO}_4$  from the Pi liberated without  $\text{Na}_3\text{VO}_4$ . Pi liberated is determined using a  $\text{KH}_2\text{PO}_4$  calibration curve and the results are calculated based on the amount of membrane protein/well and incubation time.

### 2. Calculation of percent transporter ATPase activities

In this representation the baseline ATPase activity (Ctrl 3) and the maximal ATPase activity (Ctrl 4) are taken as 0% and 100% ATPase activity of the transporter, respectively. OD values determined in the presence of test drugs are represented as percent activity on this relative scale. Note that some drugs are inhibitors of the baseline transporter ATPase activity. These will show negative percent values in this representation.



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## **12.1. Calculation of the specific ( $\text{Na}_3\text{VO}_4$ sensitive) transporter ATPase activities**

### **12.1.1. Calculation steps**

1. Set up a calibration curve using the calibration curve OD values and the amount of  $\text{KH}_2\text{PO}_4$  used (nmol/well).
2. Calculate the average OD values of the duplicate measurements of the calibration curve and controls (Ctrl 1, Ctrl 2, Ctrl 3, Ctrl 4), respectively. Calculate the average OD values of your samples.
3. Determine the nanomoles of Pi liberated in the controls and in the samples by using the calibration curve and the average OD values calculated in step 1 and 2.
4. Subtract Pi liberated in Ctrl 2 from Pi liberated in Ctrl 3. This will give you the baseline  $\text{Na}_3\text{VO}_4$  sensitive ATPase activity.
5. Subtract Pi liberated in Ctrl 2 from Pi liberated in Ctrl 4. This will give you the fully activated  $\text{Na}_3\text{VO}_4$  sensitive transporter ATPase activity.
6. Subtract the Pi values determined in the presence of  $\text{Na}_3\text{VO}_4$  from the Pi values measured without  $\text{Na}_3\text{VO}_4$  for each compound examined. This will give you the  $\text{Na}_3\text{VO}_4$  sensitive transporter ATPase activity for each drug and drug concentration assayed.
7. Calculate the  $\text{Na}_3\text{VO}_4$  sensitive transporter ATPase activity in terms of Pi liberated/mg membrane protein/min. Divide the numbers by the amount of membrane protein added to one well and the time of incubation in minutes.





### 12.1.2. Expected results

The following table shows the typical baseline and maximal  $\text{Na}_3\text{VO}_4$  sensitive ATPase activities of the MDR1 transporter. All figures are shown in nmol Pi/mg membrane protein/min:

<b>Membrane preparation</b>	<b>Baseline activity</b>	<b>Maximal activity</b>
SB-MDR1-Sf9-ATPase	8-16	35-60

In case of activation studies test drugs that are activators of the baseline ATPase activity of the transporter will increase the rate of ATP cleavage compared to the baseline ATPase activity. The  $\text{Na}_3\text{VO}_4$  sensitive transporter ATPase activity will fall between the baseline  $\text{Na}_3\text{VO}_4$  sensitive ATPase activity and the fully activated  $\text{Na}_3\text{VO}_4$  sensitive ATPase activity. Inhibitors of the baseline ATPase activity will decrease the rate of ATP cleavage compared to the baseline ATPase activity. The  $\text{Na}_3\text{VO}_4$  sensitive transporter ATPase activity will be between 0 and the baseline  $\text{Na}_3\text{VO}_4$  sensitive ATPase activity.

In case of inhibition studies test drugs that are inhibitors of the maximal and/or the baseline ATPase activity will decrease the rate of ATP cleavage compared to the fully activated ATPase activity. The  $\text{Na}_3\text{VO}_4$  sensitive transporter ATPase activity will be between 0 and the maximal  $\text{Na}_3\text{VO}_4$  sensitive ATPase activity.



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## **12.2. Calculation of the percent transporter ATPase activities**

### **12.2.1. Calculation steps**


1. Subtract Ctrl 3 from Ctrl 4. This will give you the OD representing the maximal  $\text{Na}_3\text{VO}_4$  sensitive drug stimulated transporter ATPase activity.
2. Subtract Ctrl 2 from Ctrl 3. This will give you the OD representing the baseline  $\text{Na}_3\text{VO}_4$  sensitive transporter ATPase activity.
3. Subtract the OD values measured in the presence of  $\text{Na}_3\text{VO}_4$  from the OD values measured without  $\text{Na}_3\text{VO}_4$  for each test drug and subtract the OD representing the baseline  $\text{Na}_3\text{VO}_4$  sensitive ATPase activity (determined in step 2) from every difference. This will give you the OD representing the drug stimulated transporter ATPase activity for each drug and drug concentration assayed.
4. Calculate the percent transporter ATPase activities. Simply divide each OD value from step 3 by the OD value calculated in step 1. Multiply the result by 100 to get the results in percentage.

### **12.2.2. Expected results**

The substances used to determine the maximal drug stimulated transporter ATPase activities are strong activators of transporters. In activation studies compounds tested are not expected to give significantly higher activation even at the highest concentrations used, so results greater than 100% are not common. Some drugs are inhibitors (or, sometimes in smaller concentrations activators, while in larger concentrations inhibitors) of the baseline transporter activity. In this case the percent stimulation may turn into negative numbers. Further insight into the ATPase inhibitory effect of drugs can be gained by performing inhibition studies.

In case of inhibition studies per cent inhibition values usually fall between 100% and 0%. However, if a certain drug inhibits both the maximal  $\text{Na}_3\text{VO}_4$  sensitive ATPase activity and the baseline  $\text{Na}_3\text{VO}_4$  sensitive ATPase activity per cent inhibition values



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may turn into negative numbers. Detailed information on whether a certain drug inhibits the baseline ATPase activity and/or the maximal ATPase activity of the transporter can be gained by assaying the test drug for both activation and inhibition.

