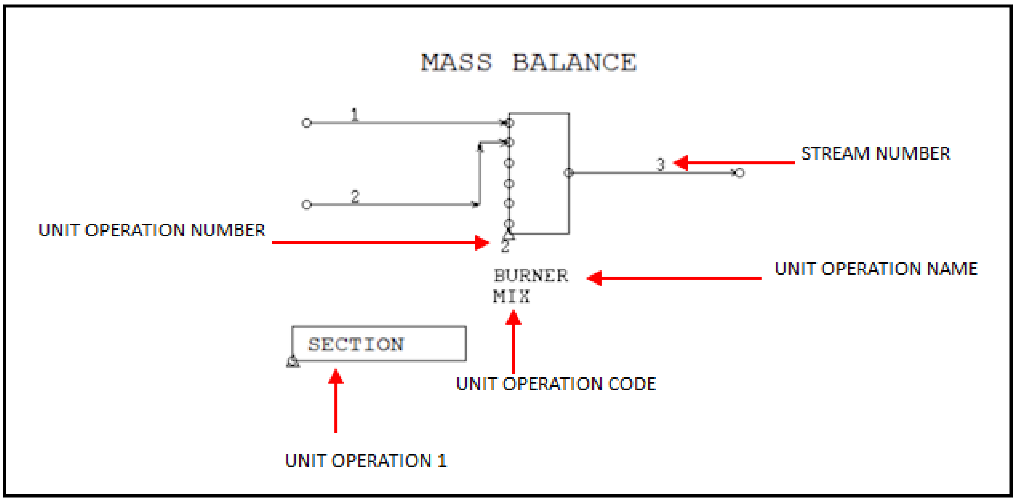
NATURAL GAS BURNER



Rather then setting up the flowsheet in one go we have broken it down into three parts to better explain the many steps involved. While this is a simple one unit operation flowsheet it is the basis for setting up complete flowsheets.

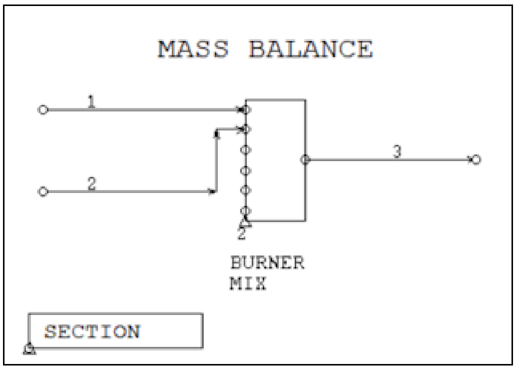
METSIM

A COMPUTER PROGRAM for PROCESS SIMULATION from METSIM International LLC

Natural Gas Burner, Mass Balance

PROBLEM DESCRIPTION

This problem is a simple mass balance combining two streams, natural gas and air, into a single output stream as illustrated in the burner flowsheet below. The output stream flowrate and composition are to be determined. This problem introduces the use of the component selection, flowsheet entry, input stream data specification, and calculation procedures in the model-building process.



Process Data:

- Stream 1 – Natural gas with a flowrate of 100 kg/hr, and a composition of 80% methane CH4 and 20% ethane C2H6 by weight.
- Stream 2 – Air with a flowrate of 3000 Kg/Hr, and a composition of 77% nitrogen N2 and 23% oxygen O2 by weight.

PROBLEM SOLUTION

1. Click on the **Model Parameters Button** . A window appears with a number of clickable tabs.

   A. The window opens on the **Project** Entry window. From here a Title and a Case Identifier and other Project information may be entered.

   B. Click on the **Calc Options Tab** and check the box next to Mass Balance.

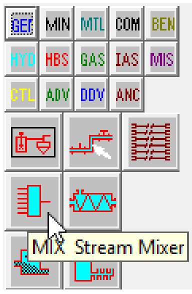
   C. Click on the **Calc Parameters Tab** and set the units of Mass and Time to **KG/Hr.**

2. Click on the **COMP Menu** and then "DBAS Component Database".

   A. A window appears displaying a table of the elements. Select H, O and C and a list of all the components in the database composed of these elements will be called up. Select the following components **CH4, C2H6, CO and CO2**.

   Watch the following video "https://www.youtube.com/watch?v=A37YPKw05hY" for a step by step guide to selecting components.

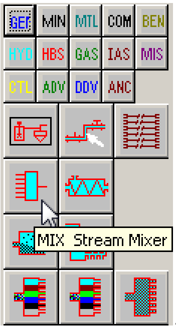
3. Next the FLOWSHEET should be entered and a Stream Mixer, **MIX**, is chosen. Streams 1 and 2 are entered as feed streams, and stream 3 as the product stream.



4. Click on the **Screen Object Button** "GEN"

and then select a Stream Mixer, MIX and then click anywhere on the palette to place the MIX unit operation.

Watch the video "https://www.youtube.com/watch?v=OI15ayfKuE0" for a step by step guide to adding unit operations and streams.



5. INPUT STREAM DATA may now be entered.
Watch the video "https://www.youtube.com/watch?v=GF-hpONsQow" for a guide to entering stream flowrate and composition.

Stream 1 Natural Gas
Flowrate ....100 Kg/Hr
Component Assays................CH_4 0.80
......................C_2H_6 0.20

Stream 2 Air
Flowrate ....3000 Kg/Hr
Component Assays................N_2 0.77
......................O_2 0.23

Stream 3 Offgas
The flowrate and composition of stream 3 is to be determined.

6. The flowsheet is now ready to CALCULATE but before running the Calculation routine the file should be SAVED so that if any errors occur the file can always be called up again and changes made.

A. The Taskbar button Save Model is used to save a flowsheet model directly to file. On activation it overwrites the old file data with that in memory.

Each flowsheet is saved in a single file containing all data, graphics etc. All models are saved as internal format APL component files, (filename.SFW). After a model is loaded, all data becomes immediately available.

It is important therefore, to save the model regularly during development, and almost always prior to calculation. This model should be saved as "WBMIX1".

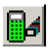
B. The flowsheet may be calculated by using one of the following options .
Watch the video "https://www.youtube.com/watch?v=06N3dt6ao-U" to see how to use the Calculation options.

Calculate one unit operation – on activation any selected unit operation can be calculated.

Calculate Current Section – on activation all unit operations in the current section will be calculated.

Stop Execution - On activation will immediately stop flowsheet calculations. Used to abort calculations as determined by the user.

Calculate Unit Operation Range – used to repeat calculations over the range determined by the user through SCAL.

 Calculate All Unit Operations – used to calculate the full flowsheet from any section. Useful for situations where the user may wish to observe flowsheet changes during simulation.

OUTPUT

Hardcopy output from this problem may be generated by programs in the OUTPUT MENU. Three samples of these output reports are shown on the following page. The output from OIDT – INPUT DATA tabulates all of the case, component, and flowsheet input data. Some of this information is shown below. All of the input and output stream data may be reported by a variety of output programs. The programs OFLW – FLOWRATES BY PHASE and OSTR – COMPONENT ASSAYS BY STREAM were used to generate the data shown.

After checking the results this model should be saved as "WBMIX1 RESULTS" for use later in this workbook.

MASS BALANCE

CASE DEFINITION

Project Information:
Title : MASS BALANCE
Purpose : WorkBook

Data Storage File Name : WBMIX1 Results.sfw
Tolerance Range : 0.001 0.001

Mass Balance Option : ON
Units of Mass : kilogram
Units of Time : hour

FLOWSHEET DATA

NO	OPR	UNIT PROCESS	IS1	IS2	IS3	IS4	IS5	IS6	INV	OS1	OS2	OS3	OS4	OS5	OS6
1	SEC	SECTION	0	0	0	0	0	0	0	0	0	0	0	0	0
2	MIX	BURNER	1	2	0	0	0	0	0	3	0	0	0	0	0

COMPONENT DATA

NO.	NAME	FORMULA	PHC	CMW	SGF		
1	aH2O	H2O	LI3	18.0153	1.0000	0.0000	0.0000
2	gN2	N2	GC8	28.0134	0.0012	0.0000	0.0000
3	gO2	O2	GC8	31.9988	0.0014	0.0000	0.0000
4	gH2O	H2O	GC8	18.0153	0.0008	0.0000	0.0000
5	gCH4	CH4	GC8	16.0430	0.0007	0.0000	0.0000
6	gC2H6	C2H6	GC8	30.0701	0.0013	0.0000	0.0000
7	gCO	CO	GC8	28.0106	0.0012	0.0000	0.0000
8	gCO2	CO2	GC8	44.0100	0.0020	0.0000	0.0000

VOLUMETRIC FLOW RATE OF STREAMS WITH GASES

NO.	STREAM	TIME	ACFM	SCFM	M3/HR	NM3/HR
1	Natural Gas	100.0000	82.748	74.559	140.590	126.677
2	Combustion Air	100.0000	1521.986	1372.322	2585.870	2331.590
3	Offgas	100.0000	1551.651	1446.882	2636.271	2458.268

NO.	STREAM	KG/HR-LI	KG/HR-GC	KG/HR-TC
1	Natural Gas	0.000000	100.000	100.000
2	Combustion Air	0.000000	3000.000	3000.000
3	Offgas	0.000000	3100.000	3100.000

STREAM DATA

GAS - KG/HR

NO.	STREAM	gN2	gO2	gH2O	gCH4	gC2H6
1	Natural Gas	0.00000	0.000000	0.00000000	80.0000000	20.0000000
2	Combustion Air	2310.00000	690.000000	0.00000000	0.0000000	0.0000000
3	Offgas	2310.00000	690.000000	0.00000000	80.0000000	20.0000000

GAS - WEIGHT PERCENT

NO.	STREAM	gN2	gO2	gH2O	gCH4	gC2H6
1	Natural Gas	0.0000000	0.0000000	0.00000000	80.0000000	20.0000000
2	Combustion Air	77.0000000	23.0000000	0.00000000	0.0000000	0.0000000
3	Offgas	74.5161290	22.2580645	0.00000000	2.5806452	0.6451613

GAS - VOLUME PERCENT

NO.	STREAM	gN2	gO2	gH2O	gCH4	gC2H6
1	Natural Gas	0.0000000	0.0000000	0.00000000	88.2316484	11.7683516
2	Combustion Air	79.2708022	20.7291978	0.00000000	0.0000000	0.0000000
3	Offgas	75.1858908	19.6609995	0.00000000	4.5466737	0.6064361

<u>Natural Gas Burner, Energy Balance</u>

PROBLEM DESCRIPTION

Add chemistry and heat losses to the burner in part one. Determine the output flowrate, composition and temperature.

Process Data:

Inlet stream temperature are 30oC.

Heat Loss is 20%.

Chemical Reactions:

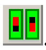
$CH_4 + O_2 = CO + H_2O$ conversion = 100%

$CH_2H_6 + O_2 = CO + H_2O$ conversion = 100%

$CO + O_2 = CO_2$ conversion = 80%

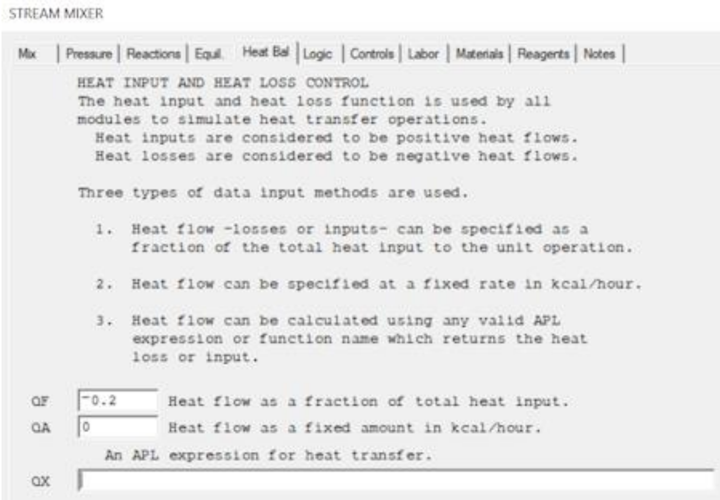
PROBLEM SOLUTION

This example illustrates the use of multiple chemical reactions in a unit operation and the use of the heat balance option. The problem in part one, saved as "WBMIX1 RESULTS" can be loaded and edited to include the new data for this problem. The model can be loaded by using the FILE MENU option **Open…Retrieve Model** or the Taskbar button  **Load Model**. Either of these methods can be used to load an existing flowsheet model file.

1. Click on the **Model Parameters Button** . A window appears with a number of clickable tabs.

   A. Click on the **Calc Options Tab** and check the box next to Heat Balance.
   B. Add CHEMISTRY to the Burner. Watch the video "https://www.youtube.com/watch?v=ni9x1AK_baU" to see how to add chemistry to a unit operation and then add the chemistry shown above to unit operation number 2, the Burner.
   C. METSIM balances all reactions when the user clicks on the Balance button. If METSIM cannot balance a reaction an error message is generated. Any unbalanced reactions will be noted and should be corrected before proceeding.

2. To add the heat loss data click on the **Heat Bal** tab of the Burner Unit operation then add -0.2 to the **QF** field. This specifies the fraction of the total heat input to be lost. As we are simulating a 20% heat loss -0.2 is entered at QF. Heat losses are entered as negative numbers and heat gains as positive numbers.



3. The flowsheet is now ready to CALCULATE but before running the Calculation routine the file should be SAVED so that if any errors occur the file can always be called up again and changes made. Save the flowsheet as "WBMIX2".

OUTPUT

Three samples of these output reports are shown below. Output the reports OHBS – HEAT BALANCE SUMMARY, OFLW – FLOWRATES BY PHASE and OSTR – COMPONENT ASSAYS BY STREAM.

After checking the results this model should be saved as "WBMIX2 RESULTS" for use later in this workbook.

MASS BALANCE

HEAT BALANCE SUMMARY - 1000 KILOCALORIES/HOUR

OP	PROCESS STEP	INPUT STREAM	HEAT REACT	HEAT SOLUT	ENERGY INPUT	HEAT LOSS	HEAT REQRD	OUTPUT STREAM	TOTAL
1	SECTION	0	0	0	0	0	0	0	0
2	BURNER	4	1098	0	0	-220	0	-882	0

HEAT OF REACTION - 1000 KILOCALORIES/HOUR

NO PROCESS STEP	TOTAL	/MOLE	REACTION
BURNER	618.97	124.13	2 gCH4 + 3 gO2 = 2 gCO + 4 gH2O
BURNER	137.00	205.98	2 gC2H6 + 5 gO2 = 4 gCO + 6 gH2O
BURNER	341.80	67.64	2 gCO + 1 gO2 = 2 gCO2

STREAM TEMPERATURES AND ENTHALPIES

NO.	STREAM	TEMP-C	TEMP-F	KCAL/HR	BTU/HR	KJ/HR
1	Natural Gas	30.00	86.00	513.00	2036.0	2147.0
2	Combustion Air	30.00	86.00	3856.00	15302.0	16134.0
3	Offgas	1026.12	1879.02	881711.00	3498911.0	3689078.0

VOLUMETRIC FLOW RATE OF STREAMS WITH GASES

NO.	STREAM	TIME	ACFM	SCFM	M3/HR	NM3/HR
1	Natural Gas	100.0000	82.748	74.559	140.59	126.677
2	Combustion Air	100.0000	1521.986	1372.322	2585.87	2331.590
3	Offgas	100.0000	6944.162	1459.602	11798.21	2479.880

NO.	STREAM	KG/HR-LI	KG/HR-GC	KG/HR-TC
1	Natural Gas	0.000000	100.000	100.000

2	Combustion Air	0.000000	3000.000	3000.000
3	Offgas	0.000000	3100.000	3100.000

STREAM DATA

GAS - KG/HR

NO.	STREAM	gN2	gO2	gH2O	gCH4	gC2H6
1	Natural Gas	0.00000	0.000000	0.000000	80.0000000	20.0000000
2	Combustion Air	2310.00000	690.000000	0.000000	0.0000000	0.0000000
3	Offgas	2310.00000	316.593545	215.616860	0.0000000	0.0000000

GAS - KG/HR

NO.	STREAM	gCO	gCO2
3	Offgas	35.3874832	222.402112

Natural Gas Burner, Process Control

PROBLEM DESCRIPTION

Control the natural gas burner so that the combustion occurs with 15% oxygen.

Process Control Description

Excess air in the output stream will be controlled using a feedback controller. 85% of the oxygen fed is consumed, the excess reports to the output stream. The ratio of outlet O2 to feed O2 will thus be maintained at 0.15 by adjusting the input air flowrate.

METSIM provides a set of value functions that provide access to flowsheet information. A value function will be used to get information for the feedback controller. Value function definitions along with a detailed explanation can be found in METSIM HELP.

PROBLEM SOLUTION

The Burner in "WBMIX2 Results" will be modified by adding a feedback control FBC to maintain 15% excess oxygen in the output stream.

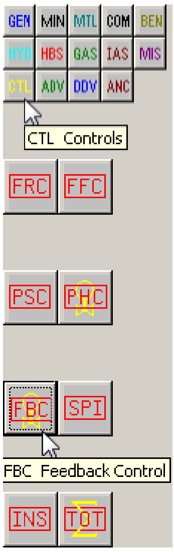
If an output stream parameter is controlled by a feedback controller, the parameter value is compared to the controller set point, and if it is not within the controller convergence tolerance, the main calculation routine returns to the unit operation where the adjusted variable is located. The variable is adjusted according to its variance and the unit operations between the point where the adjusted variable is located and where the controller set point is measured are calculated again until the measured variable and controller set point are re-compared. If it is within the tolerance of the controller the next unit operation in sequence is calculated, and if not the controller sets a new value for the controlled variable, and calculations are repeated until convergence is achieved.

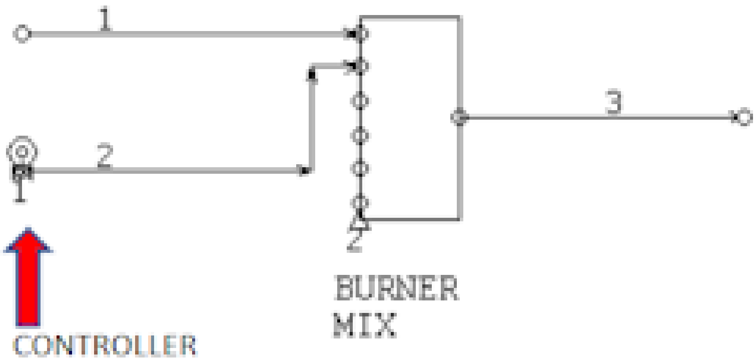
Feedback control is used to control inlet streams and unit operation variables to achieve an outlet composition or flow from a unit operation or group of unit operations. The measured variable is after the unit operation(s) and the variable to be adjusted is either before or within the unit operation(s).

The sequence of calculation is:

- controller uses first flow or variable condition,
- the program calculates the unit operation(s)
- the controller compares the value of the measured variable to the desired value (controller set point).
- if the value is outside the controller tolerance 1E-10, the controller makea a change to the controlled variable
- the program repeats the calculation of the unit operation(s), using the new values

the controller compares the new measured value and if outside the tolerance repeats the calculation or if within the program proceeds with calculation of the next unit operation.





PROCESS CONTROLS

The control strategy may now be entered. A FBC-Feedback Control may be entered which adjusts the flowrate of stream 2, Air, until there is 15% excess oxygen in stream 3, the offgas.

Watch the following video "https://www.youtube.com/watch?v=3EM_8h3zdDU" to see how to add a FBC.

a. Tick the box at ON to turn the controller on.

b. The controller number, CN, is 1.

c. The unit operation, OP, where the set point is calculated should be set to 2. The Burner is unit operation 2. The SECTION in the bottom eft-hand corner is unit operation 1.

d. The unit operation, NO, where the controlled variable, stream 2 the air, is calculated should be set to 2.

e. The Controller Description, ID, is optional but it is recommended that a note be entered for easy identification.

f. The Adjusted Stream or Manipulated Variable, SN, should be entered as s2. This is the air stream that will be manipulated to achieve the desired results.

g. LV and HV is the range over which the controlled variable may be variable may be varied to achieve the desired set point. Appropriate values in this case are 0 and 1000 respectively.

h. The Value Function, VF, requires am APL expression that will returnthe measured process control to compare to thew set point value. The value function to be used in this example is 'C VCWT S', where C is the component number for oxygen and S is the stream number of interest. Refer to the Value Function section of the Help file for a list of the available value functions. In this example, the component number of oxygen is 2, the air inlet stream is 2 and the outlet stream is 3. The value function required in the VF field is;

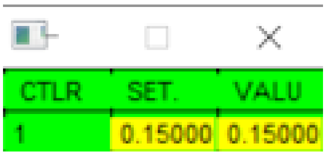
i. (c2 VCWT s3) ÷ c2 VCWT s2

j. The small c in front of the component number in the Value Function above is used to update the component number if changes are made to the order of the components. The small s before the stream number in the Value Function above is used to update the stream number if stream numbers are renumbered. The ÷ in APL is entered via key combination 'Alt +'. The function can be interpreted as the flowrate of oxygen in stream 3 divided by the flowrate of oxygen in stream 2.

k. The set point, SP, is set equal to 0.15 for 15% excess oxygen.

l. The proportionality switch, SL, denotes a direct or indirect acting process. If the value function increases with an increase in the manipulated variable, the process is direct, enter 1 for SL. If the value function decreases, the process is reverse acting, enter a -1 for SL. In this example, the outgoing oxygen to incoming oxygen ratio increases as the air flowrate increases, therefore the process is direct, and a 1 should be entered for SL.

This model should be saved as 'WBMIX3'. The flowsheet can be calculated and the results displayed as before. The actions of the feedback controller may be observed in the feedback control window during calculation.



CLTR FBC Controller Number

SET FBC Set Point Value to Achieve

VALUE FBC Set Point Achieved

OUTPUT

```
                                        MASS BALANCE

                                         INPUT DATA
  2 MIX BURNER
   1.000000   2 gCH4  + 3 gO2 = 2 gCO  + 4 gH2O
   1.000000   2 gC2H6 + 5 gO2 = 4 gCO  + 6 gH2O
   0.800000   2 gCO   + 1 gO2 = 2 gCO2

                      HEAT BALANCE SUMMARY - 1 KILOCALORIES/HOUR

                        INPUT    HEAT    HEAT  ENERGY    HEAT    HEAT  OUTPUT
   OP PROCESS STEP     STREAM   REACT   SOLUT   INPUT    LOSS   REQRD  STREAM   TOTAL
  ---+----------------+-------+-------+-------+-------+-------+-------+-------+-------+
    1 SECTION               0       0       0       0       0       0       0       0
    2 BURNER              513      58       0       0    -114       0    -457       0

                      HEAT OF REACTION - 1000 KILOCALORIES/HOUR

   NO PROCESS STEP    ------TOTAL-----/MOLE---REACTION-----------------------

  BURNER                     0.06     124.13   2 gCH4     + 3 gO2      = 2 gCO      + 4 gH2O
  BURNER                     0.00     205.98   2 gC2H6    + 5 gO2      = 4 gCO      + 6 gH2O
  BURNER                     0.00      67.64   2 gCO      + 1 gO2      = 2 gCO2

                          STREAM TEMPERATURES AND ENTHALPIES

  NO. STREAM          TEMP-C  TEMP-F   KCAL/HR    BTU/HR     KJ/HR
  ---+--------------+-------+-------+---------+---------+---------
    1 Natural Gas    30.0000 86.0000 513.00000 2036.0000 2147.0000
    2 Combustion Air 30.0000 86.0000   0.00000    0.0000    1.0000
    3 Offgas         28.2438 82.8389 457.00000 1813.0000 1912.0000

                            VOLUMETRIC FLOW RATE OF STREAMS WITH GASES

  NO. STREAM             TIME     ACFM     SCFM     M3/HR   NM3/HR
  ---+--------------+--------+--------+--------+--------+--------
    1 Natural Gas    100.0000 82.74825 74.55940 140.5902 126.6772
    2 Combustion Air 100.0000  0.04942  0.04456   0.0840   0.0757
    3 Offgas         100.0000 82.32141 74.60704 139.8650 126.7582

  NO. STREAM         KG/HR-LI KG/HR-GC KG/HR-TC
  ---+--------------+--------+--------+--------
    1 Natural Gas    0.000000 100.0000 100.0000
    2 Combustion Air 0.000000   0.0974   0.0974
    3 Offgas         0.000000 100.0974 100.0974
```

STREAM DATA

GAS - KG/HR

NO.	STREAM	gN2	gO2	gH2O	gCH4	gC2H6
1	Natural Gas	0.00000000	0.00000000	0.00000000	80.0000000	20.0000000
2	Combustion Air	0.07500000	0.02240260	0.00000000	0.0000000	0.0000000
3	Offgas	0.07500000	0.00000000	0.01681690	79.9925121	20.0000000

GAS - KG/HR

NO.	STREAM	gCO	gCO2
3	Offgas	0.01307360	0.0000000