

## RULES FOR 1-99 PLAYERS

This first mode is the classical way to play the game; it can be played solo, in small groups or for the more people. The game starts with an introduction to the historical background: *“In 1850, each player inherits a temporary the patent for the “Contact process”, invented by Peregrine Phillips in 1831.*

Ownership of the patent will become permanent if the company you manage during the next year is the most effective and richest.” Each colored die represents a molecule: the blue is sulfur dioxide gas, the red is dioxygen, the white is water and the yellow is the catalyst (an oxide of vanadium). The game lasts for 20 rounds, in each of which the four dice are thrown and each player must choose one to use on his game sheet. Once all the players have chosen their action, the round is marked on the top of the paper sheet. The next round starts and the game continues until the end of the round track is reached.

Blue and red dice are reactants that must be used to perform reactions in both reactors I and II. In reactor I, the player must necessarily combine a red die and a blue die of the same value, automatically creating a violet die of the same value after the arrow in reactor I, and transfer it to reactor II. In the second reactor, the player must combine a violet die (from reactor I) and a white die of the same value, automatically creating sulfuric acid, which is sold for the same amount of money (die value = dollar value). Figure 1 represents this combination of 3 dice of the same value creating the acid through the 3 chemical reactions (1, 2 & 3).

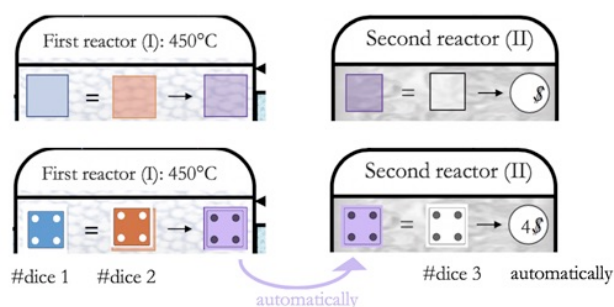


Figure 1. An example of dice combination to illustrate the principle of the game.

There is no order in which the reactants must be brought in (e.g. a white die can be placed in reactor II before a violet die has been obtained). However, once the reaction line is started in a reactor, the value of that line cannot be changed.

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White dice do not just represent water as a reactant; they also represent the water that can be used to keep the first reactor at a constant temperature and thus improve the chemical reaction. Different combinations of numbers are needed (two-way series, brelans or full houses) to “improve” the chemical reaction. Thus, the yield of the first reaction can be increased by plus or minus 1, 2 or 3 depending on the difficulty of the combination. For example, if 1 and 2 white are rolled, the player can add 1 to a reaction in reactor I to increase the product value. These bonuses are permanent and cumulative. Finally, the water can be sold at a third of the value of the die alone, but only once during the game.

The yellow dice are catalysts and do not react but they nevertheless accelerate the reaction and make it more efficient. Different combinations of numbers have to be achieved (from two or three sequences, double pairs or a square) in order to be able to modify the value of all a player’s die by 1, 2 or 3 during the phase of choice, or to change the color of the die (for the square combination). These bonuses are permanent and cumulative. For example, if a player entered a yellow 2 and a yellow 3 in the top line of the catalyst tank, he is able to change by one the value of each die he will pick during the phase of choice until the end of the game. Finally, the catalyst can be sold for one dollar per half value of the die, only once during the game.

Twice in the game, a player can go to the market and buy an improvement of his die:

- for two dollars, he can turn it into a die of the value of his choice

- for one dollar, he can transform it into a die of the value of his choice lower than 4,

Finally, players can also buy stocks on the stock exchange, investing their resources to form a series from 1 to 6 of any chosen color. If this series is complete at the end of the game, the player wins 6 dollars.

Once the 20 rounds are completed, each player counts his money earned by producing the sulfuric acid, on the stock exchange, and from the sale of resources, and deducts the money spent at the market. The richest player wins the game. In case of a tie, the player with the most reactions (I + II) wins and, in case of a further tie, the players share the victory.

An example of a 20 Round game using 1-99 players rules is presented in a table in the supplemental material section.

**Table 1.** Example of a 20 Round game using 1-99 players rules.

Round	Die color	Die Number	Position placement
1	Blue	4	Reactant 1
2	White	1	Water heat 1
3	Red	4	Reactant1 (purple 4 produced on reactor II)
4	Yellow	2	Catalyst tank line 1, waiting for a 1
5	White	3	Reactant 2
6	Red	6	Reactant 2
7	Blue	4	Reactant 3
8	White	4	Reactant 1, earning \$4
9	White	2	Water heat 1 – bonus acquired
10	Yellow	6	Catalyst sold – earning \$ 3
11	Yellow	1	Catalyst tank – bonus acquired
12	Red	3	Value changed into a 4 (bonus applied), Reactant 3 (purple 5 produced on reactor II/bonus applied)
13	White	2	Value changed into a 3 (bonus applied), Reactant 2, earning \$3
14	Blue	3	Stock exchange
15	Yellow	3	Value changed into a 2 (bonus applied), Stock exchange
16	Red	1	Stock exchange
17	Red	6	Stock exchange
18	Blue	3	Value changed into a 4(bonus applied), Stock exchange
19	White	4	Value changed into a 5 (bonus applied), Reactant 3, earning \$5
20	Blue	5	Value changed into a 6 (bonus applied), Stock exchange completed, earning \$6
Final score: \$21			

## RULES FOR 2-4 PLAYERS

The second mode is a version for a limited number of players, from 2 to 4, with a major difference: the choice of the die is made clockwise, and no longer simultaneously, and when a die has been chosen it cannot be taken again during the round (with 2 players, each player must take a second die). In this mode, a specific player sheet is used on which the round marker is removed and two specific zones are added, offering a solution in case of blocking (impossibility to play). The first one is in reactor I, where the player can combine a series of 3 dice of reactants (blue or red) in order to produce a violet die; this operation refers to the excess reactants. In case of blockage (i.e., the player cannot or does not want to use his die elsewhere) he can put it in the black hole (Fig 3.b). This action is free for the first die, but costs a penalty thereafter, and even loses the game after 6 dice.

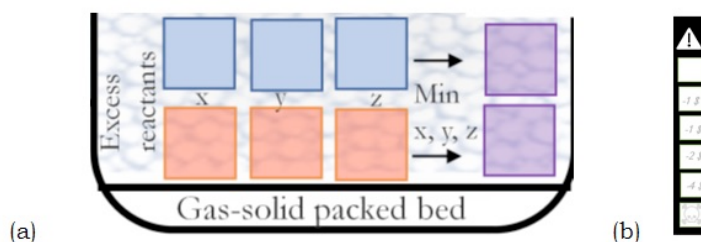
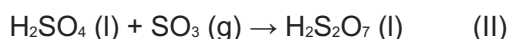
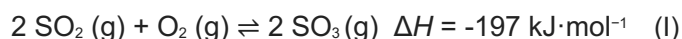


Figure 2. (a) The excess reactant zones. (b) The black hole module: An optional module to give the dice a color.

In this mode, the game lasts until a player has filled the 5 lines of his second reactor (II). Then the game is immediately stopped, and each player counts his points (even players who may have been eliminated) with the same rules as in the previous mode, taking account of the black hole.

## ADVANCED RULES

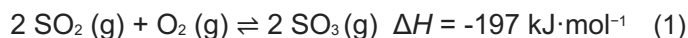
Here, a last version of the game is proposed. In this mode, instead of combining dice of the same values, the player has to combine dice and follow the stoichiometric rules of each reaction (1-2 ratio for reactor I and 1-1 ratio for reactor II):



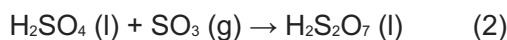
80 Non-integer numbers are authorized and rounded to 1 number after the decimal point. Any excess reactant is lost immediately. For example, a combination of a value 5 blue dice and a value 6 red dice leads to a violet die of value 5, the extra 3.5 value of red is lost. This advanced mode can be played with the two previous versions: 1-99 and 2-4 players with the specific scoresheet (the marker “=” is replaced by the marker “+”,) and the respective rules of dice choice.

## 85 CONTACT PROCESS

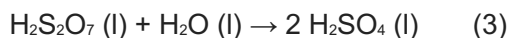
The contact process is the present technique for producing sulfuric acid required at high concentration. In the past, platinum was used to be the catalyst for the reaction, but as it might react with arsenic (present in the sulfur), vanadium oxide (V<sub>2</sub>O<sub>5</sub>) is nowadays chosen. In addition to being a more economic process than the previous method (the lead chamber process), it has also the advantage to produce sulfur trioxide and oleum. The process can be divided into different steps: the first one is the combination of sulfur and oxygen (O<sub>2</sub>) to produce sulfur dioxide; then a reaction happens between oxygen and sulfur dioxide at 450 °C and 1-2 bar with vanadium pentoxide as the catalyst<sup>21</sup>:



95 The sulfur trioxide formed is added to sulfuric acid, giving rise to oleum (disulfuric acid):




The oleum is then added to water to form sulfuric acid, which is very concentrated:




100






The direct dissolution of SO<sub>3</sub> in water is unfeasible due to the highly exothermic nature of the reaction. Acidic vapor or mists are formed instead of a liquid. The game depicted here is a simplified version of the process, focusing on reaction (1), occurring in a gas-solid packed bed (reactor I), and reactions (2) & (3), occurring in a bubbly column (reactor II). A water heat exchanger and the catalyst tank are also depicted in the simplified process flowsheet).


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Score





































Score





































Score











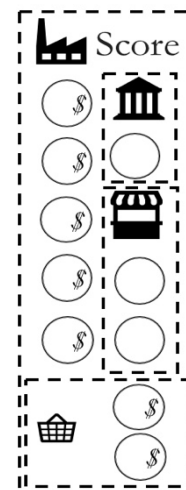
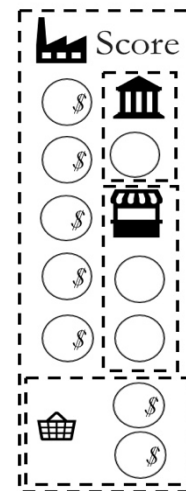
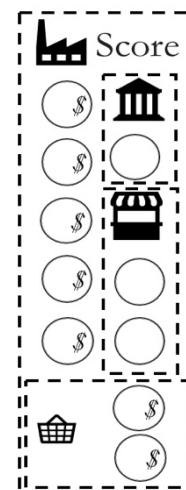
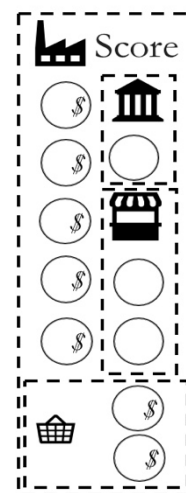



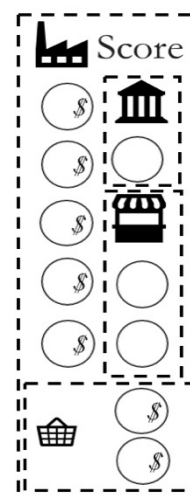
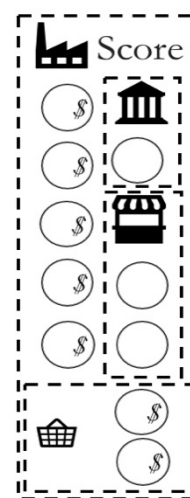
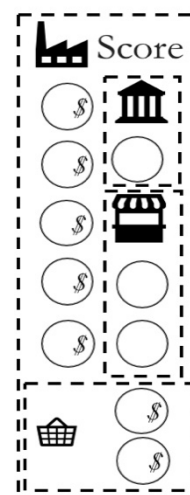
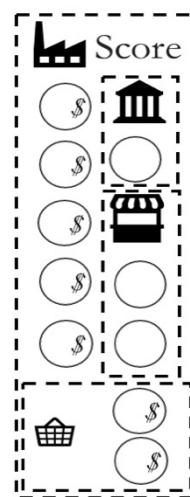













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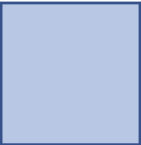







DICE SUPPORT FOR COLORLESS DICES

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Beginner mode:











Resources supplier

			
			
$2\text{SO}_{2(g)}$	$\text{O}_{2(g)}$	$\text{H}_2\text{O}$	$\text{V}_2\text{O}_{5(s)}$

Advanced mode



Resources supplier

			
			
$\text{SO}_{2(g)}$	$\text{O}_{2(g)}$	$\text{H}_2\text{O}$	$\text{V}_2\text{O}_{5(s)}$