Claims

1. A method of optimising an instruction set for a chemical synthesis, the method comprising performing a series of optimisation test syntheses, where each optimisation test synthesis includes the steps of:

(i) performing the chemical synthesis in a reaction vessel of a chemical synthesiser operating according to an instruction set to produce a reaction product,

(ii) recording reaction data using an analytical unit of the synthesiser during the chemical synthesis and/or recording product data on the reaction product,

(iii) analysing the reaction data and/or the product data using a control unit of the chemical synthesiser to determine a characteristic of the synthesis; and

(iv) adjusting one or more reaction parameters of the instruction set, to provide an adjusted instruction set,

wherein the optimisation test synthesis is repeated one or more times, and in each repeat of the test synthesis, the chemical synthesis is performed according to the adjusted instruction set, which is adjusted from the previous test syntheses, and

the adjustment to the one or more reaction parameters is made following a prediction that the adjustment will improve the characteristic of the synthesis, wherein the prediction is based on the reaction parameters associated with the reaction data and/or the product data from one or more previous optimisation test syntheses and, where present, one or more previous exploration test syntheses, and

wherein the method is performed autonomously.

2. The method of claim 1, further comprising

performing a series of exploration test syntheses, where each exploration test synthesis includes the steps of:

(i) performing the chemical synthesis in the reaction vessel of the chemical synthesiser operating according to an instruction set to produce a reaction product,

(ii) recording reaction data, using the analytical unit of the synthesiser during the chemical synthesis and/or recording product data on the reaction product,

(iii) analysing the reaction data and/or the product data using the control unit of the chemical synthesiser to determine a characteristic of the synthesis; and

(iv) adjusting one or more reaction parameters of the instruction set, to provide an adjusted instruction set,

wherein the exploration test synthesis is repeated one or more times, and in each repeat of the test synthesis, the chemical synthesis is performed according to the adjusted instruction set, which is adjusted from the previous test syntheses, and

the adjustment to the one or more reaction parameters is made to explore a reaction space wherein the adjustment is based on the reaction parameters associated with the reaction data and/or the product data from one or more previous test syntheses.

3. The method of claim 2, wherein the adjustment to the one or more reaction parameters to explore the reaction space is made by an exploration algorithm of the chemical synthesiser, such as a random search algorithm.

4. The method of claim 2 or 3, wherein the method comprises the series of exploration test syntheses followed by the series of optimisation test syntheses, and where in the optimisation test synthesis, the prediction is based on the reaction parameters associated with the reaction data and/or the product data from one or more previous optimisation test syntheses and one or more previous exploration test syntheses.

5. The method of any one of claims 1 to 4, where in the optimisation test synthesis:

(i) the prediction that the adjustment will improve the characteristic of the synthesis is made by an optimisation algorithm of the chemical synthesiser, such as a genetic or SMBO optimisation algorithm; and/or

(ii) , the prediction that the adjustment will improve the characteristic of the synthesis is based on the comparison of one or more reaction parameters with the reaction data and/or the product data from one or more previous test syntheses, to identify one or more reaction parameters associated with a change in the reaction data and/or the product data, and preferentially adjusting the one or more reaction parameters associated with the change; and/or

(iii) the prediction that the adjustment will improve the characteristic of the synthesis is based on the comparison of one or more reaction parameters with the reaction data and/or the product data from one or more previous test syntheses, to identify one reaction parameter associated with the highest normalised rate of change in the reaction data and/or the product data, and preferentially adjusting the reaction parameters associated with the highest normalised rate of change.

6. The method of any one of claims 1 to 5, wherein the reaction data is selected from reaction colour, reaction temperature, reaction vessel pressure, reaction pH, reaction filter rate, surrounding humidity, surrounding pressure, surrounding temperature, or a combination thereof, preferably reaction colour, reaction temperature or a combination thereof.

7. The method of any one of claims 1 to 6, wherein:

(i) the type of reaction data and/or the sample frequency of reaction data changes depending on the reaction parameters; or

(ii) the type of reaction data and/or the sample frequency of reaction data changes throughout the chemical synthesis.

8. The method of any one of claims 1 to 7, wherein the product data is spectroscopic data, such as UV-Vis, Infra-red, Raman, NMR, or mass spectrometry data; chromatography data, such as gas or high-performance liquid chromatography data; or a combination thereof.

9. The method of any one of claims 1 to 8, wherein the characteristic of the synthesis is:

(i) reaction product yield, reaction product purity, reaction product to starting material ratio, reaction product to impurity ratio, solvent mass consumption, reagent mass consumption or a combination thereof; and/or

(ii) reaction product yield, and the yield is determined by NMR spectroscopy, Raman spectroscopy or high-performance liquid chromatography product data.

10. The method of any one of claims 1 to 9, wherein a reaction parameter for the instruction set is selected from reagent volume, reagent mass, reagent addition rate, solvent volume, solvent mass, solvent addition rate, reaction temperature, rate of change of reaction temperature, reaction pressure, rate of change of reaction pressure, pH, stirring rate, reaction mixture colour and reaction time.

11. The method of any one of claims 1 to 10, wherein one or more of the reaction parameters is a dynamic reaction parameter, wherein the dynamic reaction parameter is a reaction parameter which is determined by the need to satisfy another reaction parameter.

12. The method of claim 11, wherein the dynamic reaction parameter is selected from one or more of:

(i) reagent addition rate, such as reagent addition rate determined by reaction temperature,

(ii) reaction time, such as reaction time determined by reaction colour, and

(iii) reaction temperature, such as reaction temperature determined by reaction pressure.

13. The method of either claim 11 or 12, where in an optimisation test synthesis:

(i) the prediction that the adjustment will improve the characteristic of the synthesis is based on the comparison of one or more dynamic reaction parameters with the reaction data and/or the product data from one or more previous test syntheses, to identify one or more dynamic reaction parameters associated with a change in the reaction data and/or the product data, and preferentially adjusting the one or more dynamic reaction parameters associated with the change; and/or

(ii) the prediction that the adjustment will improve the characteristic of the synthesis is based on the comparison of one or more dynamic reaction parameters with the reaction data and/or the product data from one or more previous test syntheses, to identify a dynamic reaction parameter associated with the highest normalised rate of change in the reaction data and/or the product data, and preferentially adjusting the dynamic reaction parameters associated with the highest normalised rate of change.

14. A chemical synthesiser for use in the method of optimising an instruction set for a chemical synthesis of claims 1 to 13, the synthesiser comprising a reaction vessel, an analytical unit and a control unit, wherein:

the reaction vessel is for the performance of the chemical synthesis according to an instruction set,

the analytical unit is for recording reaction data from the reaction vessel during the chemical synthesis and/or for recording product data on the reaction product, and for reporting the reaction data and/or the product data to the control unit;

the control unit is for analysing the reaction data and/or the product data received from the analytical unit to determine a characteristic of the synthesis, and for adjusting one or more reaction parameters of the instruction set, to provide an adjusted instruction set, wherein the adjustment to the one or more reaction parameters is made following a prediction that the adjustment will improve the characteristic of the synthesis, wherein the prediction is based on the reaction parameters associated with the reaction data and/or the product data from one or more previous optimisation test syntheses, and

wherein the chemical synthesiser is for performing the method autonomously.

15. The chemical synthesiser of claim 14, wherein the analytical unit:

(i) is for recording reaction data during the chemical synthesis and for recording product data on the reaction product; and/or

(ii) comprises a colour sensor, a temperature sensor, a pressure sensor, a pH sensor, a flow rate sensor, a humidity sensor or a combination thereof; and/or

(iii) comprises an infra-red spectrometer, a Raman spectrometer, a NMR spectrometer, a mass spectrometer, a gas chromatography instrument, a high-performance liquid chromatography instrument, or a combination thereof.

16. The chemical synthesiser of claim 14 or 15, wherein one or more of the reaction parameters is a dynamic reaction parameter, and the control unit is for adjusting the dynamic reaction parameter during a test synthesis such that reaction data satisfies another reaction parameter.

17. The chemical synthesiser of claim 16, wherein the control unit adjusts a dynamic reaction parameter selected from one or more of:

(i) reagent addition rate, such as reagent addition rate determined by reaction temperature,

(ii) reaction time, such as reaction time determined by reaction colour, and

(iii) reaction temperature, such as reaction temperature determined by reaction.