



Isaac Chemistry: Automatic Question Marking for Subject Fluency

Andrea Chlebikova ✉, Senior Project Chemist, Isaac Physics

Department of Physics, University of Cambridge

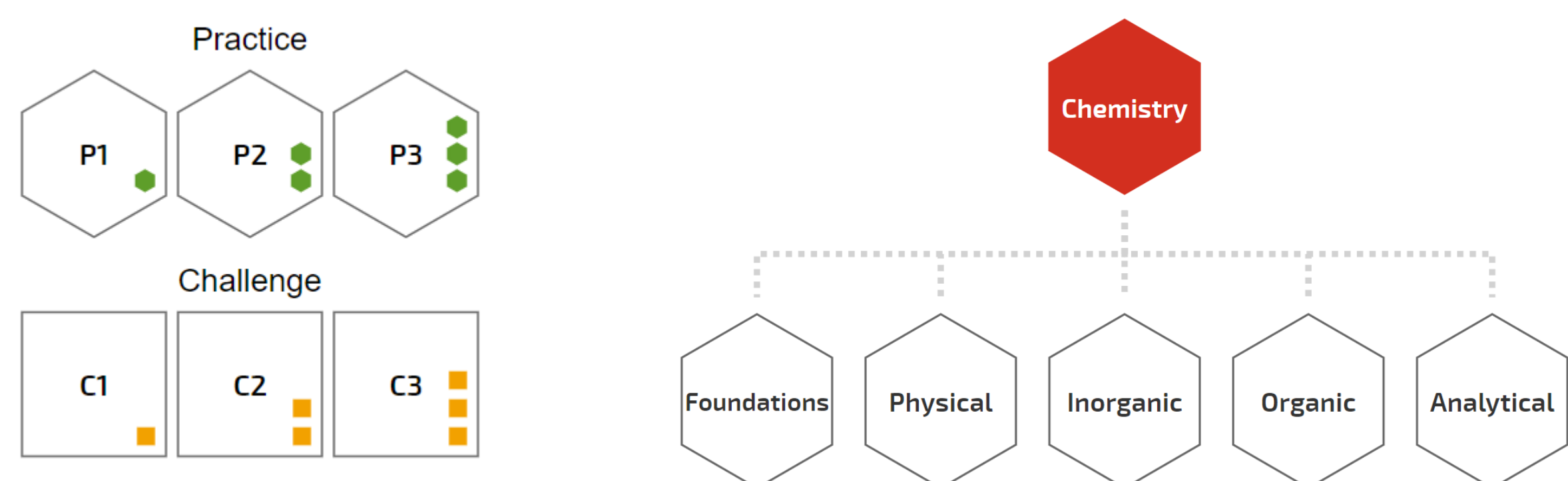


Background

- Isaac is an Open Platform for Active Learning (OPAL) originally set up to support the development of maths and problem-solving skills in physics students
- The platform is now widely used by physics teachers to set students work (which is marked automatically), and by students to learn independently, with evidence that using Isaac Physics is associated with attainment raising [1].
- Until 2021, the chemistry content was limited to physical chemistry, but since then a large amount of new content has been added as part of the STEM SMART project [2]: a programme which supports thousands of students from disadvantaged backgrounds with the ambition to study STEM subjects at university, setting them weekly work to consolidate their understanding and holding weekly online tutorials, as well as providing mentoring sessions with current undergraduates and a residential for highly-engaged students.
- Students benefit from immediate feedback when inputting their answers on the Isaac platform, and can attempt to correct their submission.
- The platform is entirely free to use, and by creating an account, the user's answers will be stored. Teacher accounts can create groups for their classes and set assignments to their students. They can then monitor and download progress on the assignment questions.

Content

As the new chemistry questions have been added for the purposes of STEM SMART, they cover the core content of A Level (or equivalent) courses. There are also some more challenging questions that push students' understanding and problem solving beyond what is expected before university. The questions are subdivided by difficulty into practice or challenge questions (with three further divisions in each) and classified into the following fields and topics:



- Foundations:** Numerical Skills, Atomic Structure, Stoichiometry, Gas Laws
- Physical:** Kinetics, Energetics, Entropy, Equilibrium, Acids & Bases, Electrochemistry
- Inorganic:** Periodic Table, Bonding & IMFs, Redox, Transition Metals
- Organic:** Functional Groups, Isomerism, Reactions, Aromaticity, Reactions (aromatics), Polymers
- Analytical:** Chromatography, Mass Spectrometry, IR Spectroscopy, NMR Spectroscopy, Electronic Spectroscopy

Questions can be found according to the above classification by using the question finder on the site (QR code in top right): https://bit.ly/chem_questions. Collections of questions have also been created by subtopic, with details of what each collection contains:

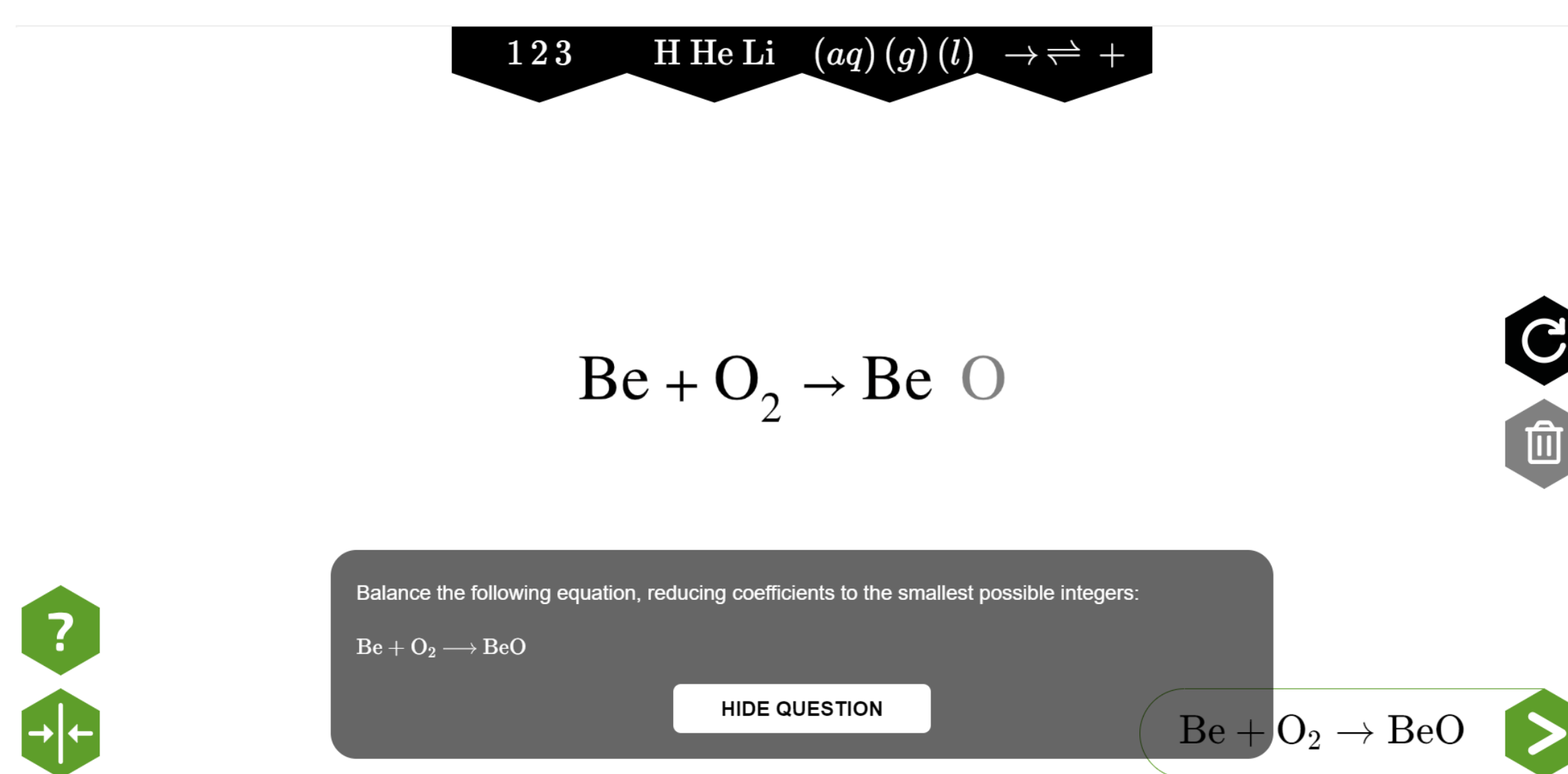
https://isaacphysics.org/pages/boards_by_topic_chem

In addition to questions, concept pages on the platform offer students a quick reminder of the important ideas behind a sub-topic, and a glossary offers an overview of important terminology. Both of these are sometimes linked to from hints available to view in a question, but they can also be accessed separately.

Question types

The chemistry questions on the Isaac platform take a number of different forms. For a selection of chemistry questions offering a cross-section of question types, follow this link: https://bit.ly/isaac_chem

- In **numerical questions** we are asked to provide a number (sometimes with an associated unit).
- In **symbolic questions** it is possible to either type a mathematical expression directly (using python-like notation) or use the dedicated editor for input [3].
- In some questions we can use a dedicated **chemistry editor** to input a chemical formula or equation, or edit an expression already provided in the question:



- For **organic chemistry** structure input, we use an external skeletal formula editor [4] that generates a SMILES string which is copied for answer checking.
- Some **multiple-choice** questions require the selection of one correct answer, while some others require the selection of no, one or several of the options.
- Short-answer** questions require the input of a word or short phrase.
- Drag-and-drop** questions require items to be dragged into the correct place:

Feedback and hints

When an answer is submitted, the user immediately learns whether the answer is correct or incorrect, and in some cases (where the incorrect answer is the result of a common mistake or misunderstanding) receives custom feedback.



Some questions contain hints, which can list key information provided in a question, provide the values of any constants that need to be used, link to relevant concept pages, or offer a dedicated tip for the question.

Current work in progress

For extra practice in some areas, separate applications which generate questions with variable inputs are in development. The applications will provide the student with scaffolding for getting to the answer if necessary, and are aimed at “drilling” essential skills.

The idea is illustrated in this demo titration calculation app:

<https://titration-calculation-demo.anvil.app>

Any feedback and ideas to make these apps as useful as possible is welcome.

Future directions

- Wider range of questions for all topics, starting with analytical chemistry
- Improved hint provision, including short videos for getting started on more challenging problems and a consistent hint format
- More concept pages that summarise the core ideas behind different subtopics
- Consolidation of questions into book format (as already available for Physical Chemistry, Maths, and Physics questions on Isaac)
- Content for different year groups (KS3, KS4, University)
- Raising awareness of Isaac in the chemistry teacher community by providing training opportunities on using Isaac Chemistry and presenting findings from our STEM SMART cohorts

References

- [1] L. Jardine-Wright (Isaac Physics), "Impact & engagement summary." https://cdn.isaacphysics.org/isaac/publications/impact_summary_201804_v6.pdf, 2018.
- [2] "STEM SMART." <https://www.undergraduate.study.cam.ac.uk/stem-smart>.
- [3] S. Cummins, I. Davies, A. Rice, and A. R. Beresford, "Equality: A tool for free-form equation editing," in 2015 IEEE 15th International Conference on Advanced Learning Technologies, pp. 270–274, IEEE, 2015.
- [4] B. Bienfait and P. Ertl, "Jsme: a free molecule editor in javascript," *Journal of cheminformatics*, vol. 5, no. 1, pp. 1–6, 2013.