That's the point*group!*

a roll and write board game

AUTHORS: Michał Kaźmierczak PhD and Ewa Patyk-Kaźmierczak PhD, Adam Mickiewicz University Poznań

NUMBER OF PLAYERS: 1-4

AGE OF PLAYERS: 12+

TIME: 5-10 'per player'

BACKGROUND:

We are surrounded by symmetry. From the wings of butterfly to the Taj Mahal. Symmetry is ubiquitous; however, it is sometimes invisible to the naked eye. Too small to be observed directly, entities such as molecules, ions or atoms can arrange in solid state in a highly-ordered manner forming a crystal consisting of periodically repeating motif called unit cell. The entities constituting single unit cell can be additionally ordered by symmetry elements (for example mirror plane). The symmetry of a finite form that is crystal, can be described by one of 32 crystallographic point groups (classified into 7 crystal systems). A point group is a complete symmetry displayed by an isolated object or group of objects, with at least one point common to all the symmetry elements, with crystallographic point groups limited to contain symmetry elements from only 10 non-translational symmetry elements (Appendix 1). Symmetry elements of each point group (their type, number and orientation) can be graphically illustrated by stereographic projection (Appendix 2). In stereographic projection, points from the surface of a sphere are mapped on its equatorial plane. To represent a point group, the point on the sphere would be the intersection of the symmetry element with the sphere. As all symmetry elements of the point group have at least one point in common, this point would be orientated in the centre of a sphere, with the same point being an origin of the coordinate system (orthogonal or hexagonal) used to describe the orientation of symmetry elements. Depending on the crystal system, symmetry elements can be positioned in the axes of the coordinate system, in diagonals or space diagonals, with symmetry axes always aligned along them and the mirror planes perpendicular. Therefore, depending on the orientation of a symmetry element and its type, it will be represented on the stereographic projection by a straight/curved line or full circle (mirror plane if it is at 90° /45° angle to equatorial plane, or in the equatorial plane, respectively), by single symbol (if an axis intersects the sphere at any point other than the equatorial plane) or by two symbols (if the axis lies in the equatorial plane, with the symbols being on the opposite sides of the projection). In That's the point (group)! – a roll and write board game, 30 point groups are used to create a player sheet (two simplest are excluded to improve gaming experience). For clarity, projections are shown without symmetry equivalent points.

THE AIM OF THE GAME:

Earn as many points as possible by completing stereographic projections of crystallographic point groups in 10 rounds.

CCDC Engagement Grant
Michał Kaźmierczak, PhD
Ewa Patyk-Kaźmierczak, PhD

That's the pointgroup!

a roll and write board game

SETUP

PREPARE:

- A pencil for each player.
- Printed copy of game sheet for each player.
- Printed copy of a reference card allowing to use standard K6 dice or any device with Internet access.

Each player receives a game sheet with lineouts of point groups divided into crystal systems and a pen.

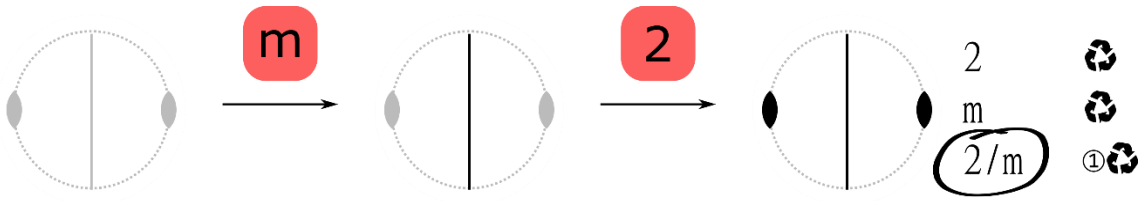
Prepare 2N+2 dice according to the number of players (N). Exactly half of them (N+1) are considered dice A and its faces should be covered with faces provided in the Preparation Sheet. Instead, you can prepare two distinct (colours, sizes etc.) sets of N+1 dice and use reference card to translate faces from classic six-sided dice to dice used in the game. Alternatively, visit the website with virtual dices http://kax.home.amu.edu.pl/dice/).

HOW TO PLAY:

Select the first player in any way. At the beginning of each round the first player rolls all the dices and selects one of them, then all other players in clockwise order select one of the remaining dices. When the last player selects first dice in this round they immediately select second dice and other players do the same in anticlockwise order. There are two types of dice: A with 3 faces with mirror plane symbol: m, and 3 faces with 2-fold axis symbol: 2; dice B with 2 faces $4/\bar{4}$ (allowing to choose between 4-fold and 4-fold rotoinversion axis), 2 faces $3/\bar{3}$ (allowing to choose between 3-fold and 3-fold rotoinversion axis), 1 face with question mark (joker, can be used as any symbol, including symbols for 6-fold and 6-fold rotoinversion axes), and reroll (reroll a dice as long as this face is visible).Then players simultaneously mark the symmetry elements (for the graphical and numerical symbols of symmetry elements see Appendix 1) on the game sheet (all possible projections are shown in Table 2). Note that $m\bar{3}m$ point group is too complicated to be finished in 10 rounds of the game. Therefore, some of mirror planes are already drawn with black solid lines.

At any stage, the player can decide to conclude drawing of a point group. They mark the corresponding number of points (number in the circle i.e. ②) and for any ♻ signs granted for the completion of the specific point group they can copy a symmetry element form this projection to any other projection on the game sheet (a symmetry element can be copied more than once if the number of ♻ signs allows it).

Example:



In terms of scoring and bonuses, only the highest-symmetry completed point group is rewarded (if drawing is unfinished, point group is downgraded to closest legitimate point group). Once the player concludes drawing of given point group, the drawing cannot be resumed.

CCDC Engagement Grant
Michał Kaźmierczak, PhD
Ewa Patyk-Kaźmierczak, PhD

The first player who concludes drawing all projections from the crystal system (or from a combined "monoclinic & orthorhombic systems") unlocks signs for this system. All point groups in given system must be concluded at any legitimate point group (i.e. any points or bonuses are rewarded for it). If two or more players conclude all projections from the same crystal system at the same time all are granted the bonus. The bonus needs to be used at the time it is granted.

The game is finished after 10 rounds and the winner is the person with the highest number of points. In solo variant player is trying to get the highest score:

NUMBER OF POINTS	LEVEL
≤15	Student
16-20	Young crystallographer
21-25	Seasoned crystallographer
≥25	The expert

DIFFICULTY LEVELS:

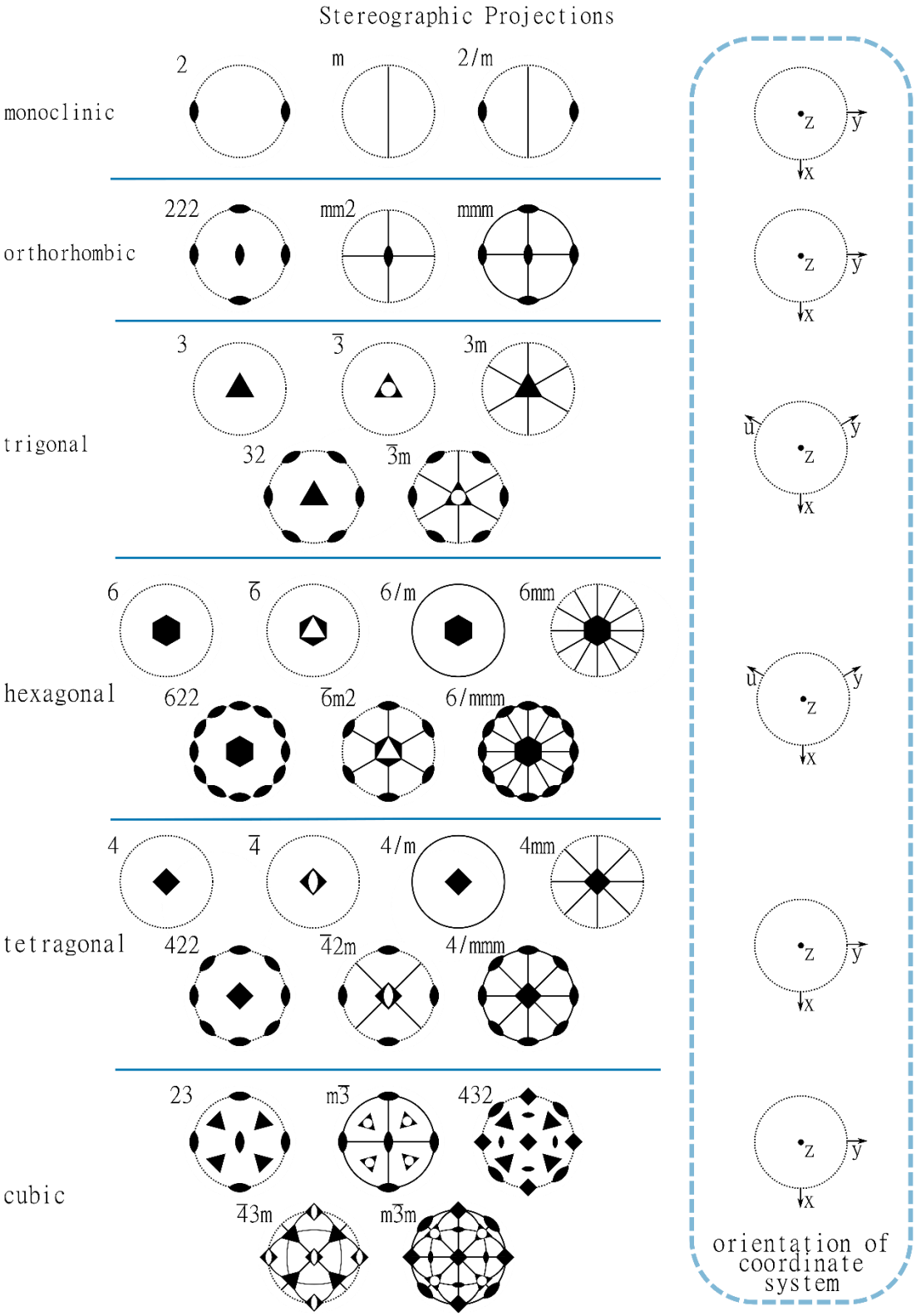
Beginner: place a *cheat-sheet* (Appendices 1 and 2) next to the game sheet with all the symmetry elements and space groups drawn and explained.

Advanced: During the game you cannot refer to the symmetry elements table and space groups drawings. At any stage of the game the players can challenge each other for incorrect projections, and if a mistake is found, the player who made it loses 5 points and the challenger gains 5 points. However, if the challenge was not valid, the challenger loses 5 points, while the player who was challenged receives 5 points.

APPENDIX 1

Symmetry element			Symmetry operation
Name	Hermann-Mauguin symbol	Graphical symbol	
Identity	1		Rotation of 360°
Center of inversion	$\bar{1}$		Inversion
Mirror plane	m		Reflection
2-fold axis	2		Rotation of 180°
3-fold axis	3		Rotation of 120°
4-fold axis	4		Rotation of 90°
6-fold axis	6		Rotation of 60°
3-fold rotoinversion axis	$\bar{3}$		Rotation of 120° + inversion
4-fold rotoinversion axis	$\bar{4}$		Rotation of 90° + inversion
6-fold rotoinversion axis	$\bar{6}$		Rotation of 60° + inversion

APPENDIX 2



CCDC Engagement Grant
Michał Kaźmierczak, PhD
Ewa Patyk-Kaźmierczak, PhD