

Playing Cards for Instrumental Analysis Exam Review

Learning objectives

After completing this activity, students should be able to

- recognize names and functions of analytical instrument components
- identify a set of instrument components for a specific analytical application
- describe how a given set of instrument components go together for a specific application

Instructor's manual

This card game was designed for review sessions before instrumental analysis exams. In the class session preceding an exam, groups of 3-5 students play the game using a card set that reviews a specific instrument category (e.g. spectroscopy). Students draw and discard cards, attempting to collect one from each suit that comprise a logical set of components for a specific application (e.g. obtaining an infrared spectrum of polyvinyl alcohol) and then explain why their set would work. A typical round of play should last around 5 minutes, but can be longer depending upon the luck of the draw.

A deck of cards is created for a given instrument category, and contains approximately 30 cards. Each card in the deck is marked with one of four or five suits (categories) and a specific instrument component or sample/application. Tables 1-3 lists example cards for three card sets (UV-Vis-IR spectroscopy, mass spectrometry and chromatography). For cards that indicate a sample type, chemical structures could be included. Each deck should have a minimum of six cards for each of the suits, with at least two cards in each suit that work with each sample card; cards can be duplicated (for example a deck could include three cards with quartz as the optical material) and the deck could include “wild” cards (with or without specifying the suit). There should be approximately the same number of cards for each suit in the deck. Cards should represent the content that students are expected to know for the exam.

Playing cards can be created easily by writing on 3”x4” index cards. Color-coded index cards and/or colored markers are useful for distinguishing suits; suits should also be indicated with words or graphics to accommodate those who are colorblind.



Figure 1. Left: Color-coded index cards (Amazon.com). Right: A sample winning hand from a spectroscopy card set created in Microsoft Publisher.

Software such as PowerPoint or Publisher can be used for creating more professional-looking cards printed on cardstock, but it can be challenging to print and cut the cards uniformly. Printing information on labels and then adhering them to index cards or to blank playing cards that can be purchased online might work better. A Cricut machine might be a good option for producing higher quality cards. Keep in mind that the simpler method of hand-writing on index cards makes it possible for additional cards to be created rapidly as needed.

To introduce the game, the instructor should remind students of the types of instruments that will be covered on the exam and that can be built from the cards in the deck (e.g. Raman spectrometer, FTIR spectrometer.) For the chromatography set, it is important to note that both gas and liquid chromatography components are included in the deck. The instructor should review the object and rules of the game; for a large class, the instructor should provide printed rules for each group.

Game Instructions

Players

For the best experience, students should play in groups of 3-5.

Object

The object of the game is to achieve a hand with one card from each suit that comprises a logical instrument combination for the displayed sample/application. For the spectroscopy deck, if the sample card is “visible absorbance measurements to quantify red dye no. 40”, an example winning hand could include tungsten lamp, grating monochromator, silicate glass and vacuum phototube, because these are viable components for a visible absorption spectrometer. If included, a wild card substitutes for any component (of a suit, if specified).

The Deal

One student, acting as the dealer, separates the sample/application cards from the rest of the deck, shuffles them and places one card face-up in front of each player¹. The dealer shuffles the remaining cards and deals four cards to each player face-down. The remaining cards are placed (face-down) in the center as the draw pile, and the top card is turned over and placed next to the draw pile to start the discard pile.

The Play

Students look at their cards and the student to the left of the dealer goes first. The student chooses one card from either the discard pile or the draw pile, and then discards one card to end the turn. If the draw pile is depleted, the cards of the discard pile (except the top card) should be shuffled and used again as the draw pile. Play continues clockwise around the group until a player decides at the end of their turn that they have achieved a complete set (one card from each suit that comprises a logical set for their sample/ application card). That player should lay their cards face-up on the table and explain why their set makes sense. For example, if the sample/application is the fluorescence spectrum of quinine, and the hand includes xenon arc lamp, two monochromators, quartz, and photomultiplier tube, the student should explain that two monochromators are needed in fluorescence measurements for separation of both the excitation and the emission wavelengths, xenon arc lamps yield high intensity in the UV-Vis

¹ The author thanks the reviewers for suggesting this step in the game and other helpful comments.

range, photomultipliers are sensitive detectors of UV-Vis radiation, and quartz transmits UV-Vis radiation. If a wild card is included, the student could be asked to state what it represents. Other players can challenge the hand. The instructor should confirm the hand or else rule that the game is not over and play should continue.

Instructor Notes

At the end of a round, it is helpful for the instructor to ask follow-up questions, such as:

- Why do these components fit together?
- What assumptions were made about the sample that led to the choice of instrument components?
- What other components might also work? What are the pros and cons to these different instrument component options?
- In what order are these components connected in an instrument?
- If a wild card was used, what would be an appropriate component for it to represent?
- For the students who did not win, what cards would have completed a set for them?

As time and interest permit, the students can play additional rounds; three rounds typically work well for my class. Occasionally a round will take too much time, such that students become frustrated (wild cards will minimize this occurrence); the round can always be stopped and the students can compare hands to see why there were difficulties obtaining a complete set.

The instructor can adjust rules as necessary to fit the situation. The sample/application cards could be shuffled with the rest of the deck and passed out as part of the hand (if so, increase by one the number of cards that are dealt at the beginning). For a more challenging exercise, the suit/category may be omitted from the cards so that students must also determine which category each item represents.

My students enjoy this activity, and it is effective in promoting questions and discussion in a review session. My classes are very small, making it is easy for me to monitor the game with only one or two groups of students playing at a time. For a large class with multiple groups, it may be necessary to have a system for alerting the instructor when a round has been completed.

Students learn the rules of the game quickly with some guidance from the instructor. Students playing the game soon discover if they have gaps in understanding, and they especially notice which terms they do not know very well; for example, they may not recall if a particular detector is used in gas chromatography or liquid chromatography. I find that students are often more likely to ask questions during the game about what they don't understand than they would in a typical question-and-answer session.

Example Card Sets

Table 1. Spectroscopy set (for instruments including Raman, FT-IR, fluorescence, UV-Vis absorbance)

Suits	Example cards
sample & application	• fluorescence spectrum of quinine (requires UV excitation, emits visible light) • visible absorbance measurements to quantify red dye no. 40 • visible absorbance spectrum of red dye no. 40 • UV absorption measurements to quantify caffeine • infrared spectrum of polyvinyl alcohol • Raman spectrum of polyvinyl alcohol • quantification of lead in water by AAS
optical material	• KBr • NaCl • plastic • quartz • silicate glass • wild card
source	• deuterium lamp • globar • hollow cathode lamp • laser • tungsten lamp • Xe arc lamp • wild card
wavelength selector	• glass filter • grating monochromator • interferometer • spectrograph • two monochromators • wild card
detector	• CCD • diode array • photomultiplier tube • pyroelectric detector • vacuum phototube • wild card

Table 2. Mass spectrometry set

Suits	Example cards ¹
sample	• aromatic hydrocarbons (liquids) • carbohydrates • dissolved metal ions for isotopic distribution determination • drugs on the surface of currency • proteins • steroids
ionization source	• DART • DESI • electrospray ionization • electron ionization • chemical ionization • ICP • MALDI
mass analyzer	• double-focusing • FT-MS • quadrupole ion trap • transmission quadrupole • time-of-flight
detector¹	• electron multiplier • Faraday cup • Faraday array • no separate detector

1. Make duplicate cards as necessary to yield at least six cards for each suit.

Table 3. Chromatography (LC and GC) set

Suits	Example cards
sample	• anions (NO_3^-, Cl^-, Br^-, etc.) • car exhaust • chlorinated pesticides • gasoline • neurotransmitters • organic acids • Pb^{2+} bound to ligands in aqueous solution • proteins • small drug molecules with amine functional groups • sugars (glucose, fructose, etc.) • water-soluble vitamins
mobile phase	• aqueous buffer • CH_3CN, aqueous buffer + cationic ion pair reagent • helium • methanol +water • nitrogen • octane + isopropanol
stationary phase/column	• anion exchange column • C-18 column • Carbowax (polyethylene glycol) • cation exchange column • PLOT column • polydimethylsiloxane • silica bonded to $(\text{CH}_2)_3\text{-CN}$ groups • size exclusion column
detector	• amperometric • conductivity • electron capture • evaporative light scattering • flame ionization • fluorescence • ICP-AES • mass spectrometer • refractive index • thermal conductivity • UV absorbance