

2014 AP Chemistry Exam Results

2014 AP Annual Conference
Philadelphia, PA

Roger Kugel, Chief Reader
University of Cincinnati

Outline

- ▶ Developing the exam
- ▶ Exam Logistics
- ▶ Grading the free response section
- ▶ Performance on the 2014 exam
- ▶ Score setting
- ▶ Becoming an AP Reader



Developing the Exam

Developing the Exam

- ▶ Question Writing
 - ▶ Free response questions (FRQs) written by the Test Development Committee (TDC)
 - ▶ Experienced college faculty and AP chemistry teachers

2013-2014 TDC

▶ **Co-Chairs**

- ▶ David Yaron, Carnegie-Mellon University, Pittsburgh, PA
- ▶ Jamie Benigna, The Roeper School, Birmingham, MI

▶ **Members**

- ▶ Angelica Stacy, UC Berkeley, Berkeley, CA
- ▶ Rene Cole, University of Iowa, Iowa City, IA
- ▶ Paul Price, Trinity Valley School, Fort Worth, TX
- ▶ Trinna Johnson, Dunwoody High School, Dunwoody, GA

▶ **Chief Reader**

- ▶ Roger Kugel, University of Cincinnati, Cincinnati, OH

▶ **ETS Assessment Developers**

- ▶ Thomas G. Corley and Irene Kijak

▶ **College Board Advisor**

- ▶ John Hnatow, Goucher College, Baltimore, MD

2013-2014 TDC



Developing the Exam

- ▶ TDC reviews and discusses exam questions at 5 meetings per year.
- ▶ ETS checks for fairness
- ▶ Multiple choice questions (MCQs) are pre-tested at colleges then analyzed by ETS for balance, difficulty, and breadth.
- ▶ Exam construction and final review by TDC is completed about one year prior to administration.

Developing the Exam (2)

- ▶ Each committee member sees all the questions at various stages.
- ▶ CR, Committee co-Chairs, and ETS ADs review 4 to 5 times.
- ▶ Final test is also reviewed by former CRs, Committee co-Chairs ('fresh eyes').

Criteria for a FRQ

- ▶ Does it address a theme?
- ▶ Does it have depth vs. breadth?
- ▶ Is it straightforward?
- ▶ Does it allow for clear grading rubrics?
- ▶ Does it use the full scale of points?
- ▶ Is it worth asking?
- ▶ Does it discriminate?
- ▶ Is it in the curriculum?
 - ▶ 6 BI's, 117 LO's, 7 SP's, 5 ToM's, 5 ALDs
- ▶ Does it probe conceptual understanding?

New exam format

▶ Section 1

▶ 60 MCQs

▶ 4 options instead of 5

} 60 scorable points

▶ Section 2

▶ 7 FRQs instead of 6

▶ 3 10-point FRQs

▶ 4 4-point FRQs

} 46 scorable points

▶ Both sections scaled to 50 exam points



Exam Logistics

Grading the Exam

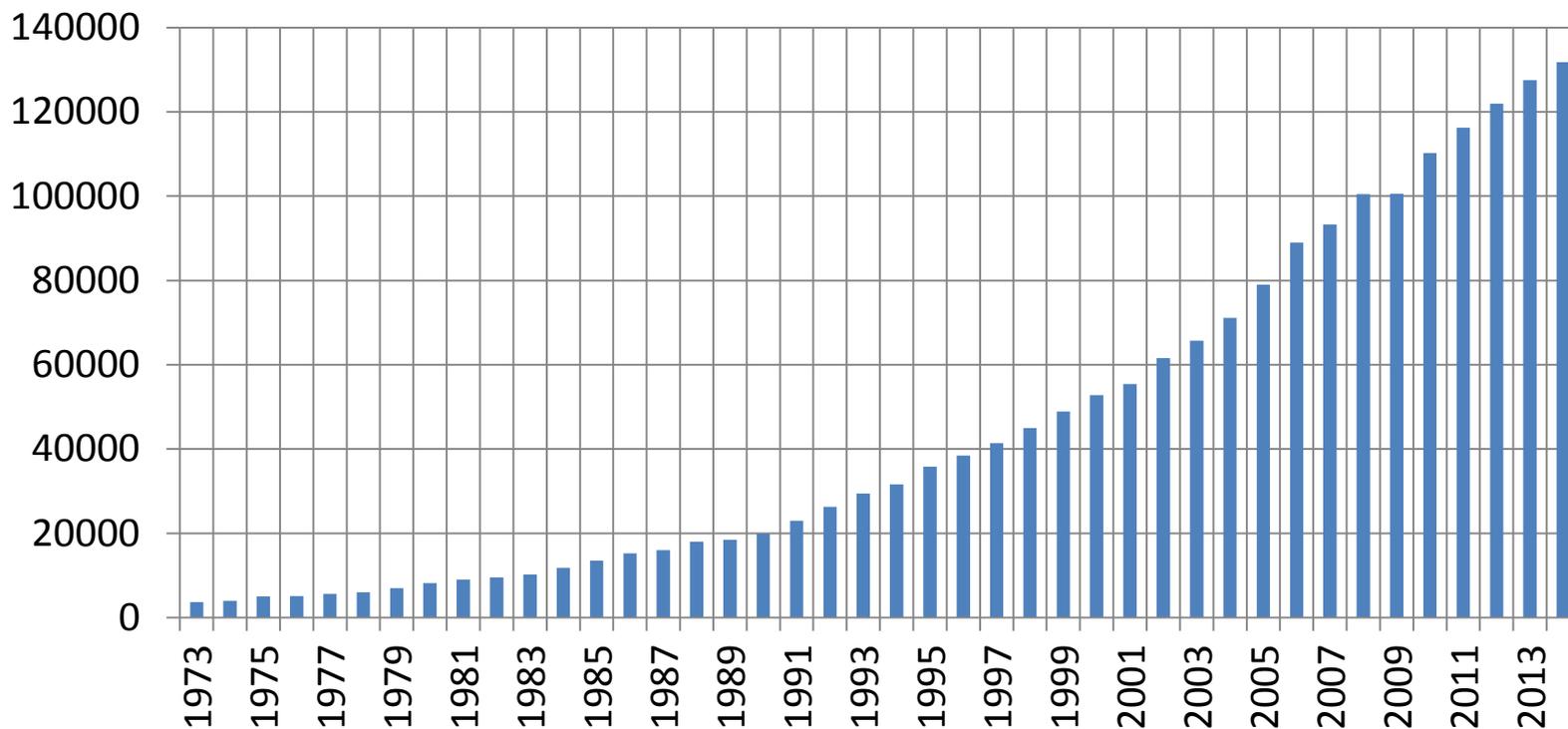
- ▶ How big is the task?
 - ▶ Form O 131786
 - ▶ Alt/Exc +17606
 - ▶ Total exams 149392 X 7 items
 - ▶ Total responses 1.046×10^6
- ▶ 292 Readers and Leaders

149,392 AP Chemistry Exams



AP Chemistry growth curve

AP Chem Operational Exam Volume



2014 Reading site: Louisville, KY





Grading the Exam

Goals for grading

Student responses are read with:

1. accuracy
2. fairness
3. consistency
4. discrimination
5. timeliness

The grading process

- ▶ Rubric development
- ▶ The reading itself
- ▶ Score setting

Rubric development

- ▶ Version 0.90
 - ▶ Chief Reader/Development Committee
- ▶ Version 0.99
 - ▶ 7 Question Leaders/Chief Reader
- ▶ Version 1.0
 - ▶ 3 or 6 Table Leaders/Question Leader
- ▶ Board notes
 - ▶ 8 Readers/Table Leader

Training

- ▶ Spend the morning of the first day of the Reading getting all of the Readers assigned to a given question “on the same page” by applying the rubric together to selected sample papers.

“Buddy” reading

- ▶ After training, readers may work in pairs to score the same papers. They discuss any differences and come to a consensus. If they can't agree, they bring the issue to their TL. Typically, they can read consistently on their own within 20-40 “buddy-read” papers.

“Back-reading”

- ▶ Assign 8 Readers to a TL who will “back-read” his/her Readers. Meanwhile, the QL will “back-read” the TL’s assigned to him/her. When a reader’s score differs from the Leader’s score by more than ± 1 , the Leader discusses the application of the rubric with the reader.

Ensure consistency

- ▶ Maintain a statistical record of each Reader's performance. When a Reader's average score deviates from the overall average, it likely means that the Reader is being too generous or too stingy when applying the rubric. Table Leaders know to back-read those Readers more often to bring them closer to the question mean.

How do students earn points?

- ▶ Only whole numbers of points can be earned.
- ▶ Contradictory wrong information can neutralize credit for correct information.
- ▶ On one problem, a single penalty for significant figures may be applied.
- ▶ Each part of problem is graded independently, but consistently with answers to previous parts.
- ▶ Students lose no more than 1 point/Question for math errors.

Timeliness

- ▶ 1.05×10^6 responses
- ▶ 292 readers
- ▶ 7 days of 7.5 hrs = 52.5 hrs
- ▶ Rate calculation:

$$\text{Rate} = \frac{1.05 \times 10^6}{292 \times 52.5} = 68.5 \frac{\text{responses}}{\text{reader} \cdot \text{hr}}$$

(Average reading rate = 1.14 per min)

Consistency

In 2014 the sum of the standard deviations of average reader scores by question was ± 0.72 points out of 46.

In the unlikely event that a student's exam was graded by a low-scoring reader on every question, that student's grade will deviate by less than 1 point overall from its randomly scored duplicate.



Student Performance



FRQ 1 Gravimetric Analysis

FRQ 1 The premise

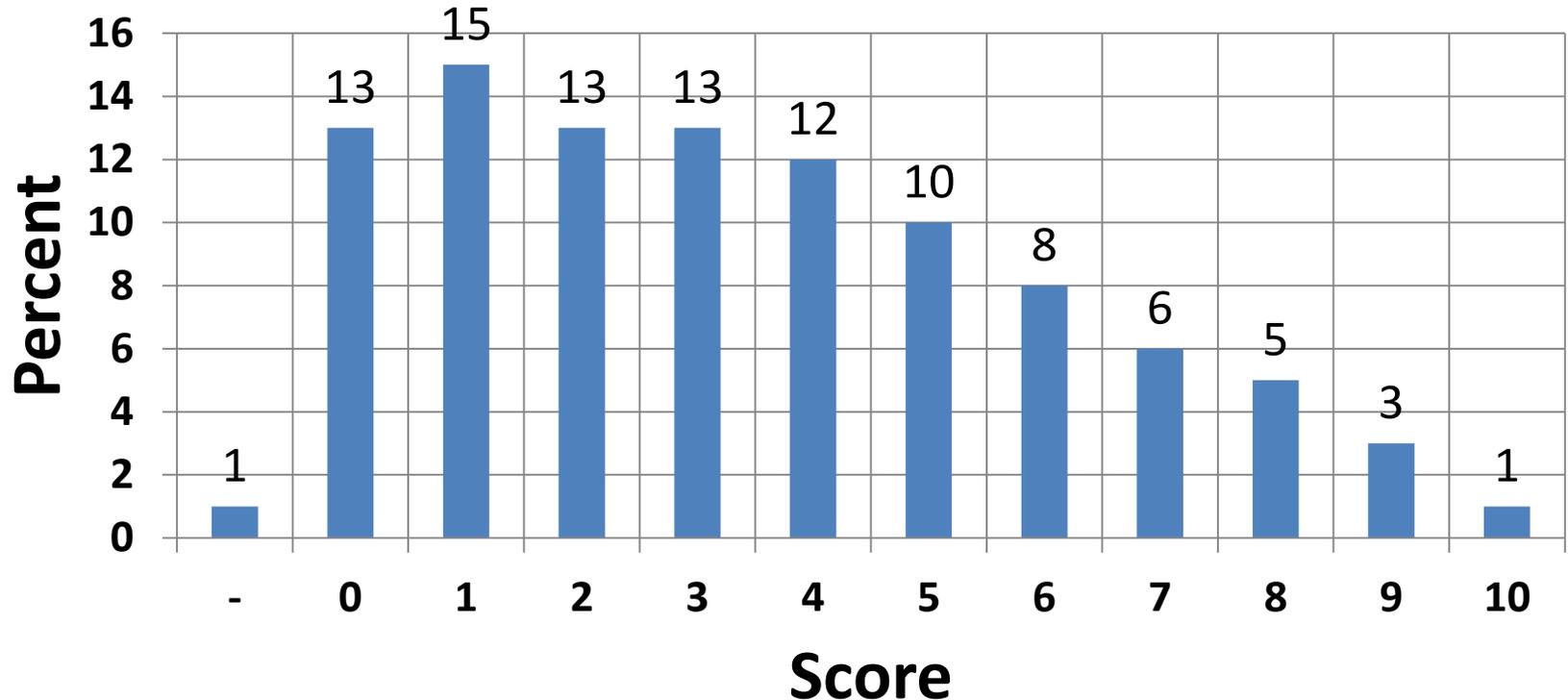
Students were given data for a gravimetric analysis of KI in an iodide tablet, by dissolving the tablet, adding lead nitrate, filtering, and drying and weighing the precipitate 3 X.

FRQ 1 The question

- ai. **Write** the net ionic equation (1 pt)
- a. **Explain** why a net ionic equation is appropriate. (1 pt)
- b. **Explain** why the ppt is dried and weighed 3X. (1 pt)
- c. Is $[K^+] >$, $<$, or $=$ to $[NO_3^-]$, **justify**. (1 pt)
- d. **Calculate** moles of ppt. (1 pt)
- e. **Calculate** % I⁻ in tablet. (2 pts)
- f. Effect of water volume on % I⁻. **Justify** answer. (1 pt)
- gi. Will silver nitrate ppt iodide? **Justify** answer. (1 pt)
- gii. Will a ± 0.01 g balance allow 3 sig figs? **Justify** (1 pt)

FRQ 1 Score distribution

Q1 scores: mean = 3.41



FRQ 1 Student performance

Question mean: 3.41/10

Modal score: 1/10

No credit: 14.2%

Full credit: 0.8%

FRQ 1 Most common errors

- ai. $\text{Pb}^{2+} + 2 \text{I}^- \rightarrow \text{PbI}_2$ Wrong or no charges; failure to balance; wrong stoich.
- aii. Why N.I.E.? General definition of N.I.E. failed to earn pt.
- b. Why 3 dryings and weighings? To get more accurate mass; take an average
- c. Is $[\text{K}^+] >, <, \text{ or } = [\text{NO}_3^-]$? Equal because of stoich.; or used conc. of stock soln.
- d. Moles of product? Failure to subtract mass of filter paper; calc. errors.
- e. % I? Failure to use experimental data; calc. %I in KI (55.1%) or in PbI_2 (76.4%)

FRQ 1 Most common errors

- f. Effect of excess H_2O ? Restate the assertion: H_2O does not affect the % I.
(Had to state the excess H_2O is removed by filtering and drying).
- gi. Will AgI ppt? “Yes, because AgI is insoluble” did not earn credit.
(Had to cite K_{sp} value or solubility rules).
- gii. Will 0.01 g balance allow 3 sig figs? Failure to state that mass of AgI < 1 g;
Many students confused sig figs and decimal places.

FRQ 1 How to improve?

Carry out *meaningful laboratory experiments* involving gravimetry.

Ask students to *explain* why they are doing each step in a given procedure.

Quiz them with, “What would happen if...?” or “When does the amount of H₂O matter?” questions.

FRQ 1 How to improve?

Practice time management skills. Many students over-answered Question 1 because it was the first question on the test and it required many explanations. These students may have run out of time on Questions 6 and 7.



FRQ 2 Acid-Base Chemistry

FRQ 2 The premise

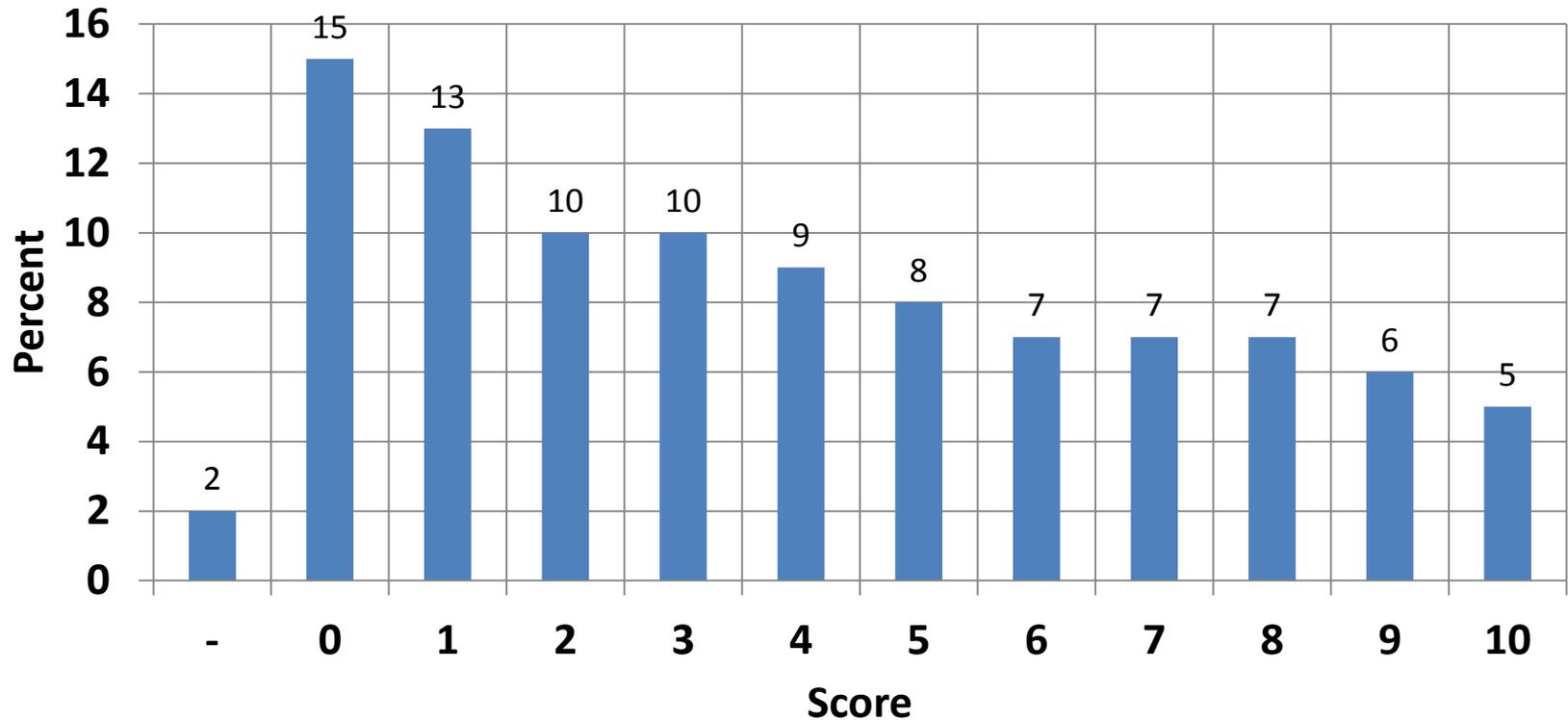
Students were given an acid-base equilibrium equation for the reaction of propanoic acid with H_2O . They were asked to identify a conjugate A-B pair, calculate K_a , calculate a molarity from titration data, and answer (and explain) 3 T-F questions about acids and bases.

FRQ 2 The question

- a. **Write** a Brønsted-Lowry conjugate A-B pair. (1 pt)
- b. **Calculate** K_a from pH and concentration. (3 pts)
- ci. Is pH = 7.00? **Explain**. (1 pt)
- cii. Is $[HCl] < [PA]$? **Explain**. (1 pt)
- d. **Calculate** molarity of PA. (2 pts)
- e. Is a different indicator needed? **Justify** answer. (2 pts)

FRQ 2 Score distribution

Q2 scores: mean = 3.99



FRQ 2 Student performance

Question mean: 3.99/10

Modal score: 0/10

No credit: 16.9%

Full credit: 5.3%

FRQ 2 Most common errors

- a. Brønsted-Lowry conjugate A-B pair. **Failing to indicate a conjugate pair.**
- b. Calculate K_a . **A wide variety of miscalculations.**
- ci. Is $\text{pH} = 7.00$? **Mixing equal moles of A and B always results in $\text{pH} = 7.00$; or A strong base “overpowers” a weak acid.**
- cii. Is $[\text{HCl}] < [\text{PA}]$ if pH s are equal? **Equal concentrations of acids always have equal pH ; or confusing dissociation and dissolution (HCl dissolves completely but PA does not).**
- d. Calculate the molarity of PA from titration data. **A variety of miscalculations.**
- e. Will a different indicator be needed? **Comparing pH to $\text{p}K_a$ or $\text{p}K_a$ to K_a ; or comparing close K_a or $\text{p}K_a$ values and declaring them significantly different.**

FRQ 2 How to improve?

Have students *show work and methods* for solving problems. Stress process over rote.

Stress the difference between moles and molarity.

Provide *experimental opportunities* to measure pH at various points in a titration of a weak acid or a weak base.



FRQ 3 Electrochemistry

FRQ 3 The premise

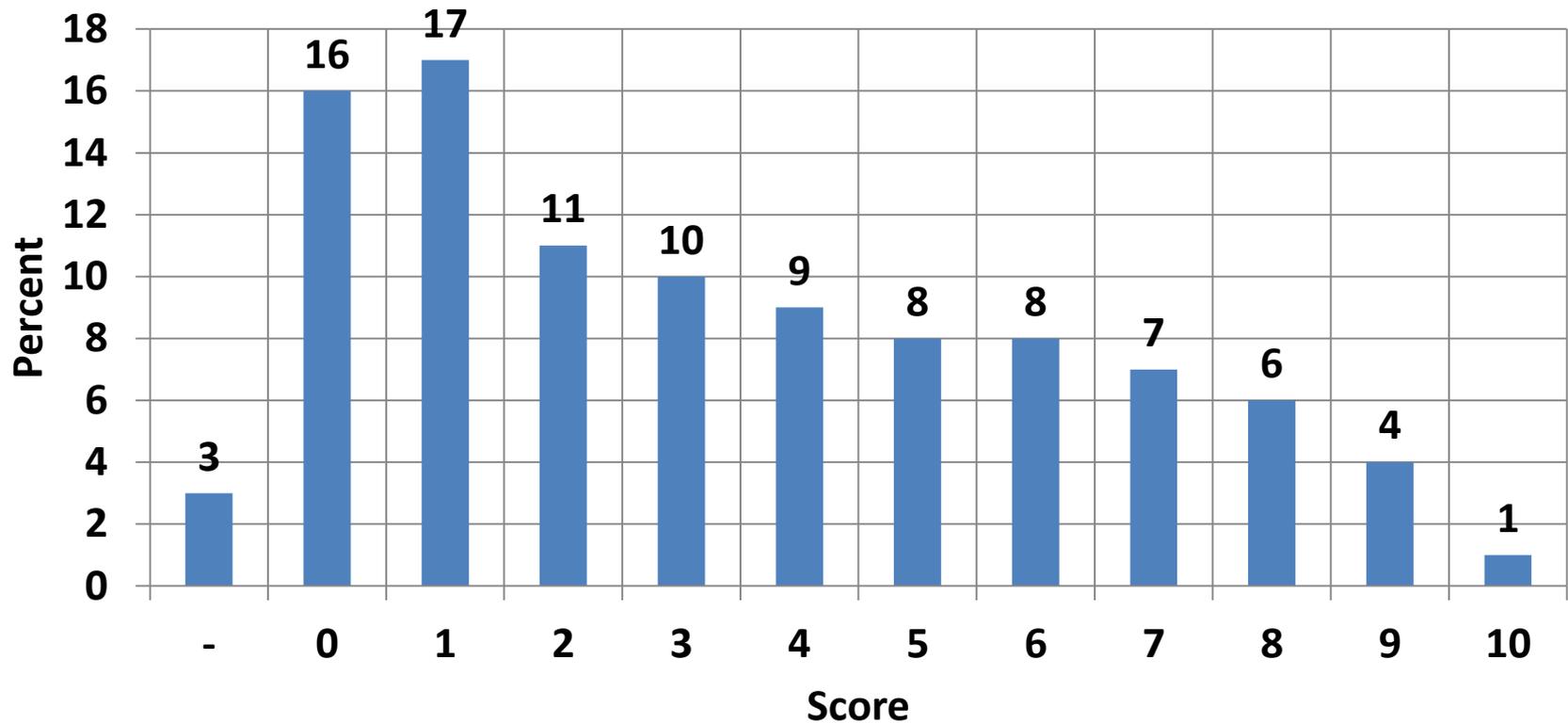
Students were given a standard cell with Cu and Sn electrodes. They were to identify where oxidation occurs, where the lost mass goes, and to draw particle motion in the salt bridge. They were then to explain the performance of a non-standard cell. Finally, they were to write an equation for a described reaction, justify its favorability, and calculate ΔG° from E° .

FRQ 3 The question

- a. **Identify** the site of oxidation and **explain** reasoning. (1 pt)
- b. **Identify** where the mass goes. (1 pt)
- c. **Draw** a particle view of the salt bridge. (2 pts)
- di. Is E $>$, $<$, or $= E^\circ$? **Justify** answer. (1 pt)
- dii. Will nonstandard cell run for longer, shorter, or same time as standard cell? **Justify** answer. (1 pt)
- ei. **Write** N.I.E. for reaction and **justify** favorability. (2 pts)
- eii. **Calculate** ΔG° from E° . (2 pts)

FRQ 3 Score distribution

Q3 scores: mean = 3.33



FRQ 3 Student performance

Question mean: 3.33/10

Modal score: 1/10

No credit: 19.0%

Full credit: 1.4%

FRQ 3 Most common errors

- a. The site of oxidation. Failure to explain in terms of observations. "The anode always loses mass."
- b. Where did the mass go? "To electrons" or "To the Cu electrode"
- c. Particle view of salt bridge. Drawings showing electrons carrying charge or drawings showing Cu and Sn ions carrying charge.
- di. Effect of reducing both cell concentrations by $\frac{1}{2}$. Incorrect intuitive answer: "cell potential decreases." (Note: the Nernst equation was often successfully referenced).
- dii. Effect on cell operating time. Same time, because voltage (or current) is the same, or because time is independent of concentration; or shorter time because the voltage decreased.

FRQ 3 Most common errors

- ei. N.I.E. and explain favorability. Giving equations that were not net ionic; or including electrons; or writing half reactions. Attempts to justify favorability in terms of the (unavailable) ΔH and ΔS . Stating “Cu is higher in the table so it is reduced.”
- eii. Calculate ΔG° . Various calculation errors. Students using a wrong E° , determined in ei, could earn full credit.

FRQ 3 How to improve?

Carry out *electrochemical lab exercises* and have students *explain* what is happening in each compartment (including the salt bridge).

| | |
|--|-----------|
| Mass of 1 mole of Sn atoms: | 118.71 g |
| Mass of 2 moles of electrons: | 0.00110 g |
| <hr/> | <hr/> |
| Mass of 1 mole of Sn ²⁺ ions: | 118.71 g |

Have students *draw particle views* of oxidation, reduction, and current flow.



FRQ 4 Gas-solid Equilibrium

FRQ 4 The premise

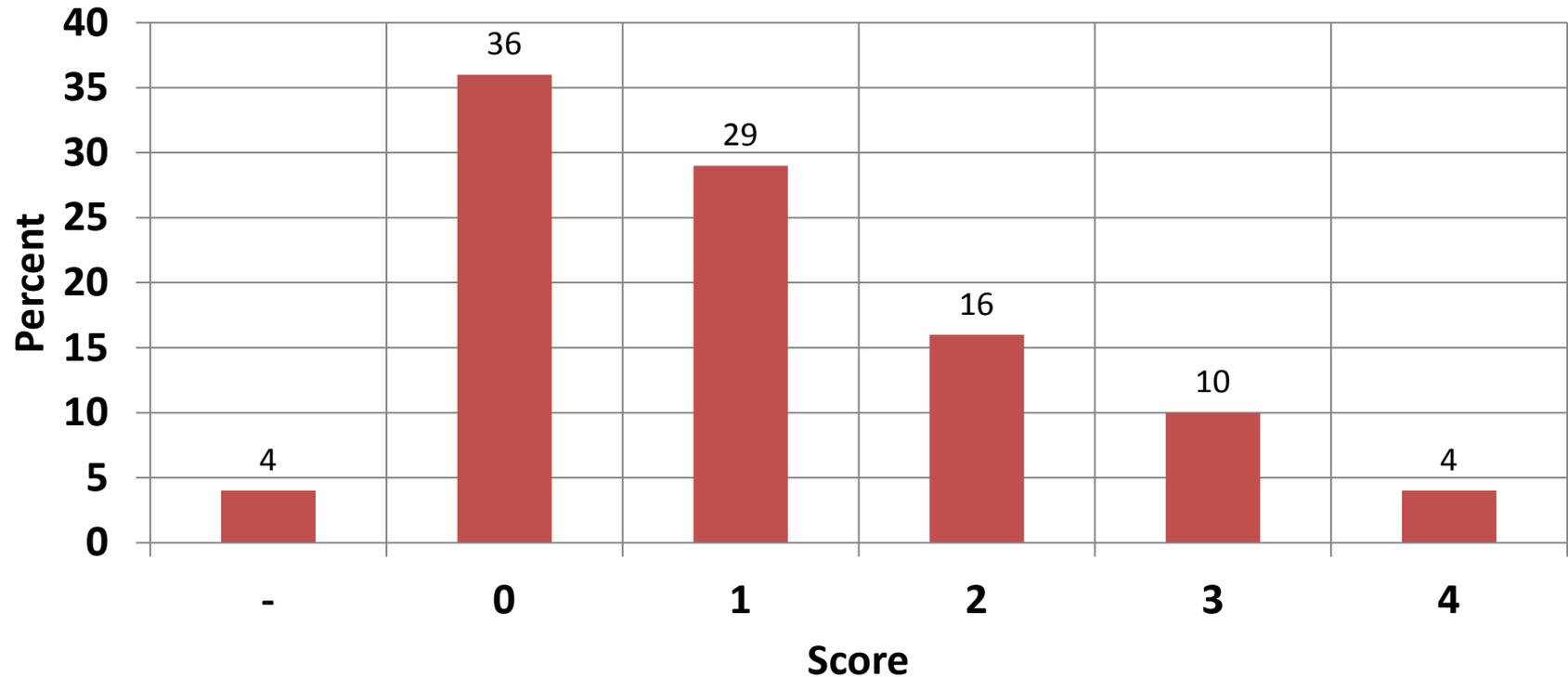
Students were given graphical data for the thermal decomposition of $\text{CaCO}_3(\text{s})$. They were to calculate the number of moles of $\text{CO}_2(\text{g})$ produced, determine if the system had reached equilibrium, and state if the data was sufficient to find K_p .

FRQ 4 The question

- Calculate moles of $\text{CO}_2(g)$. (1 pt)
- State and explain if equilibrium had been reached. (1 pt)
- Determine and explain effect of adding $\text{CO}_2(g)$. (1 pt)
- State and justify if data is sufficient to find K_p . (1 pt)

FRQ 4 Score distribution

Q4 scores: mean = 1.09



FRQ 4 Student performance

Question mean: 1.09/4

Modal score: 0/4

No credit: 40.5%

Full credit: 4.4%

FRQ 4 Most common errors

- a. Moles of $\text{CO}_2(g)$. Various calculation errors.
- b. Equilibrium? Stating the pressure had “leveled off.” Giving the definition of equilibrium.
- c. Effect of added $\text{CO}_2(g)$? Giving a definition of equilibrium and not referring to the data. Discussing collision theory or reaction rates. Answering “yes” or “no.”
- d. Sufficient data for K_p ? Failing to realize that K_p was determined only by gas pressures. Simply giving the K_p expression.

FRQ 4 How to improve?

Have students work equilibrium problems using real data *and have them explain their solutions in words.*

Make sure students use *proper chemical vocabulary* in their explanations, e.g., don't use "dissolve" for "decompose," and don't use "melt" for "dissolve."



FRQ 5 Atomic and Molecular Structure and Periodicity

FRQ 5 The premise

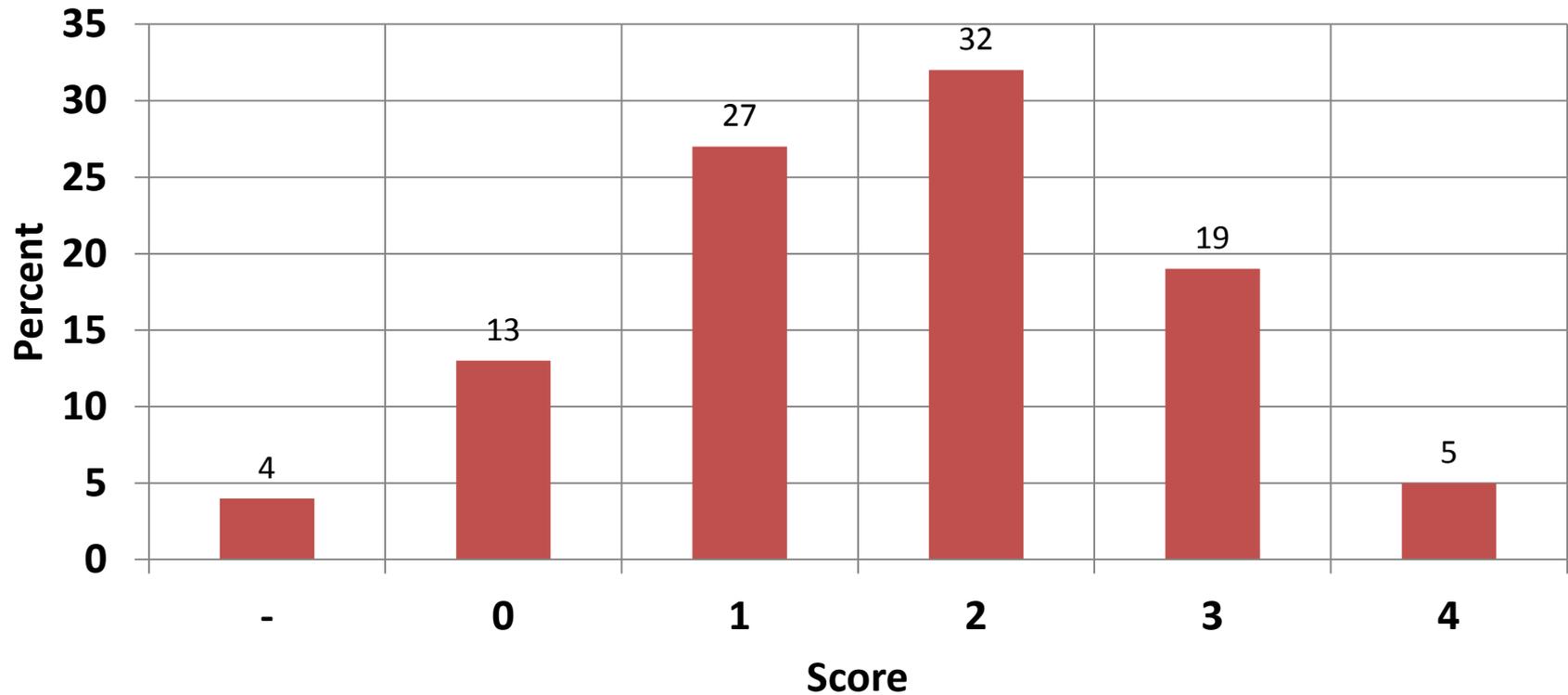
Students were given a series of binary compounds and an hypothesis. They were to predict a compound that fits the hypothesis, complete a Lewis electron dot diagram, make a data-based prediction of molecular structure, and modify the hypothesis to accommodate new data.

FRQ 5 The question

- a. **Predict** the formula of chlorine fluoride. (1 pt)
- b. **Complete** the Lewis structure of ClF_3 . (1 pt)
- c. **Choose** a structure for ClF_3 and **justify** the choice. (1 pt)
- d. **Modify** the hypothesis. (1 pt)

FRQ 5 Score distribution

Q5 scores: mean = 1.67



FRQ 5 Student performance

Question mean: 1.67/4

Modal score: 2/4

No credit: 17.5%

Full credit: 5.3%

FRQ 5 Most common errors

- a. Formula of chlorine fluoride. Formulas ignoring both trend and hypothesis.
- b. Lewis electron dot diagram. Missing some or all of the non-bonding pairs. Drawing multiple bonds between the chlorine and one or more fluorines.
- c. Molecular structure of ClF_3 . Ignoring the data. Explaining why the molecule is T-shaped rather than why T-shaped molecules are polar. Referring to “uneven” sharing of electrons without distinguishing between polar bonds and overall charge distribution.
- d. Modified hypothesis. Restating the original hypothesis. Failing to reference atomic structure (odd number of Fs) and/or periodicity (greater number of Fs as the Principle quantum number of central atom’s valence shell increases).

FRQ 5 How to improve?

Review VSEPR theory for molecules (particularly with expanded octets) and have students *predict molecular structures and polarities*. (Many students had a vague understanding that symmetrically arranged dipoles cancel).



FRQ 6 Polymers, IMFs, Thermo

FRQ 6 The premise

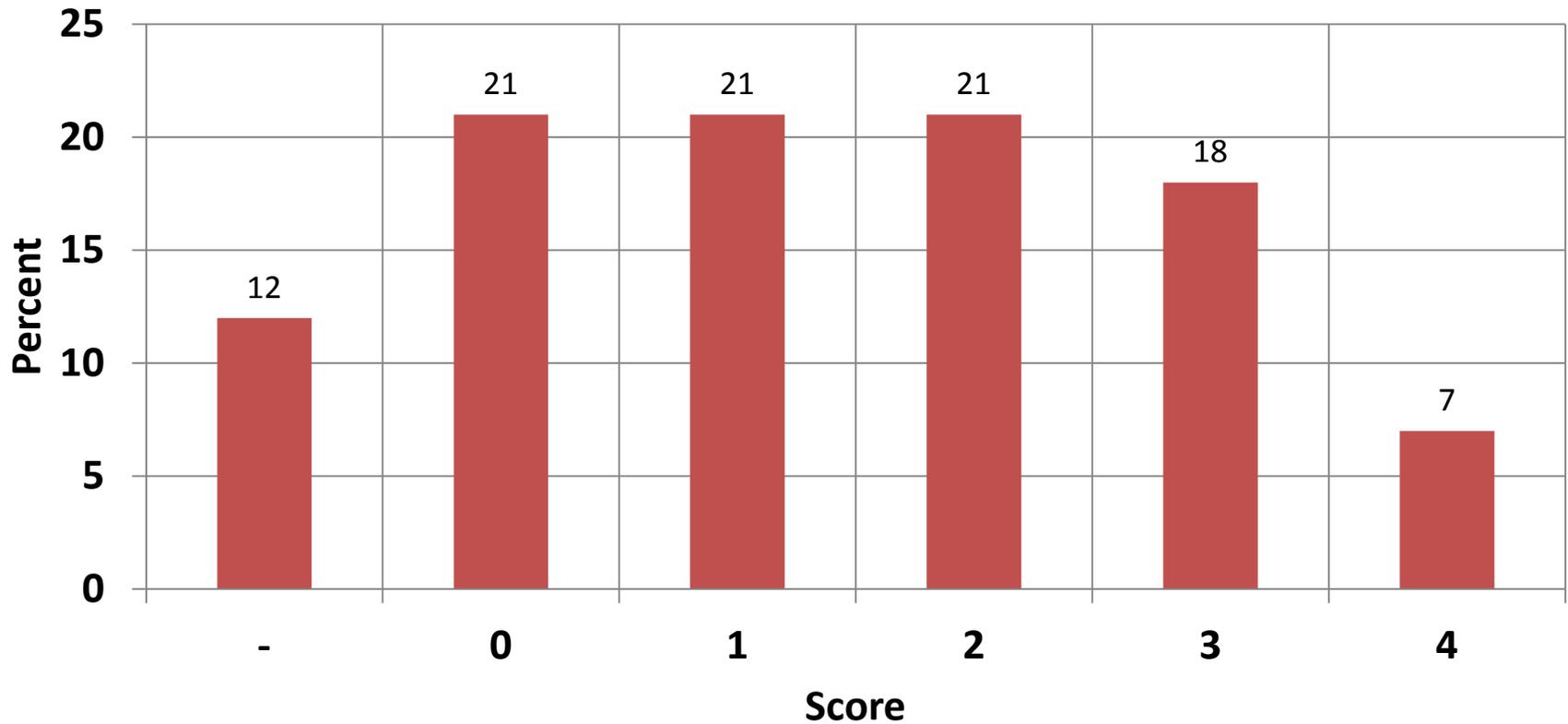
Students were given formulas of two polymers and their corresponding monomers. They were to decide which polymer sank in water and explain why, to explain the difference in the boiling points of the monomers, and to calculate the enthalpy of combustion of one of the monomers.

FRQ 6 The question

- a. **State** which polymer (PP or PVC) sinks in H_2O and **explain** why. (1 pt)
- b. **Explain** the difference in BP of monomers (propene and vinyl chloride) in terms of the IMFs. (1 pt)
- c. **Calculate** $\Delta_c H^\circ$ of propene and **state** if, when burned, it releases more, less, or the same amount of energy as vinyl chloride does. (2 pts)

FRQ 6 Score distribution

Q6 scores: mean = 1.47



FRQ 6 Student performance

Question mean: 1.47/4

Modal score: 0/4

No credit: 32.7%

Full credit: 7.2%

FRQ 6 Most common errors

- a. Which polymer sinks? Using bonding, polarity, IMFs, ionization, size, etc. instead of mass or density arguments.
- b. BP explanation. Confusing IMFs with covalent bonds. Citing molecular properties (polarity or polarizability) instead of intermolecular forces (dipole-dipole or LDFs).
- c. Enthalpy of combustion. Various calculation errors. Misunderstanding that a negative $\Delta_c H^\circ$ means energy is *released*.

FRQ 6 How to improve?

Have students draw *particle-level diagrams* of what occurs when a liquid boils or freezes. *Emphasize that covalent bonds normally remain intact.*

Have students do thermochemical calculations *and relate the sign of their answer to whether the reaction vessel feels warm or cool.*



FRQ 7 Kinetics

FRQ 7 The premise

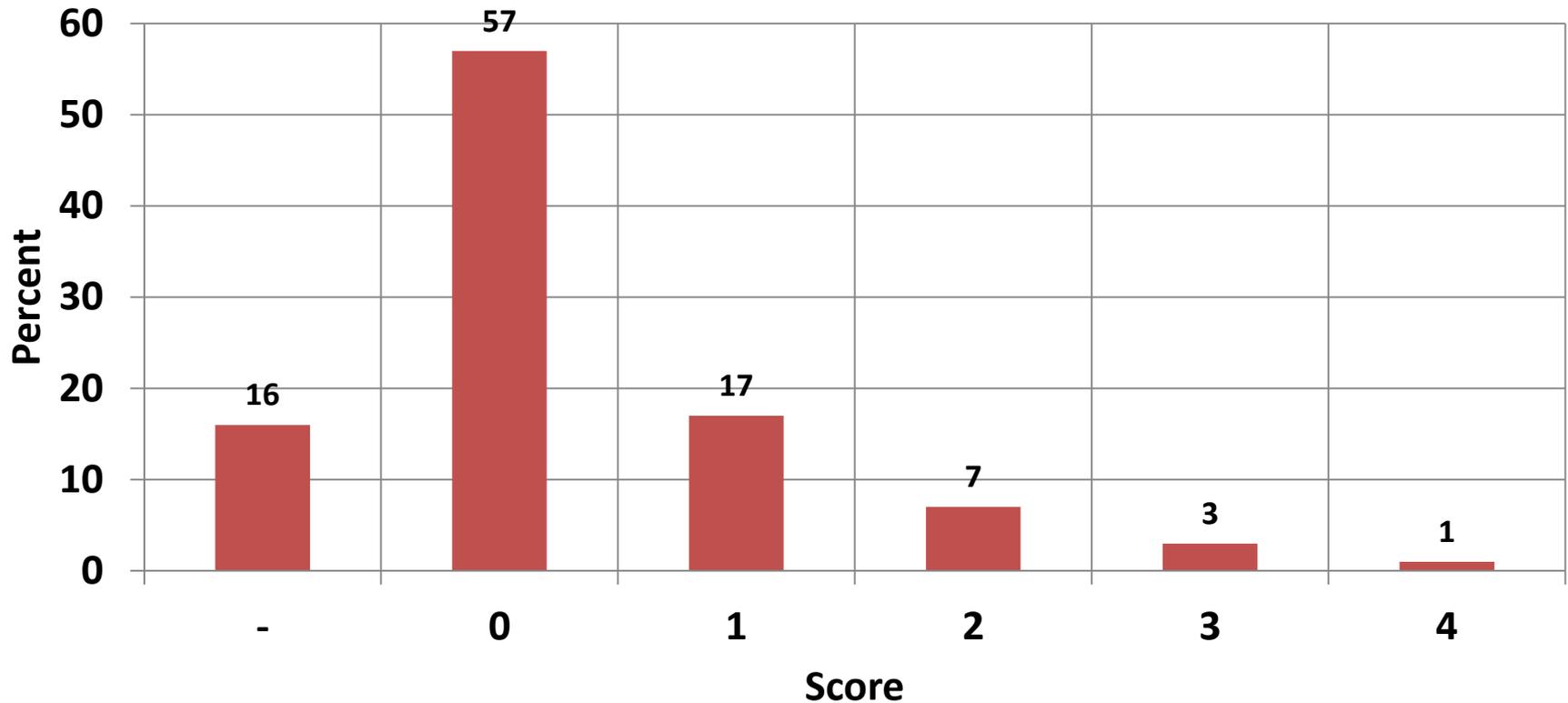
Students were given tabular half-life data for an isomerization reaction. They were to explain how the data supported first order kinetics, calculate the rate constant, determine relative initial rates of two trials, and explain why a trial at a higher temperature had a shorter half-life.

FRQ 7 The question

- a. **Explain** how the data supports 1st order kinetics. (1 pt)
- b. **Calculate** the 1st order rate constant with units. (1 pt)
- c. **Determine** relative initial rates of two trials and **justify** the answer. (1 pt)
- d. **Explain** why the $t_{1/2}$ is less when temperature increases. (1 pt)

FRQ 7 Score distribution

Q7 scores: mean = 0.43



FRQ 7 Student performance

Question mean: 0.43/4

Modal score: 0/4

No credit: 72.6%

Full credit: 1.1%

FRQ 7 Most common errors

- a. How do the data support 1st order? Stating the reaction is zero order, directly contradicting the prompt. Stating that a plot of [cis-butene] vs time would be linear. Stating that $k = 0.693/t_{1/2}$.
- b. Calculate the rate constant. Various miscalculations. Using wrong units or omitting units.
- c. Relative initial rates in trials 1 and 2. Confusing half-life and initial rate. Claiming that reaction rate depends on moles of reactant instead of concentration or pressure. Failing to specify which trial was being referenced.
- d. Explain the smaller half-life at higher temperature. Stating that the activation energy changes with temperature. Stating that the rate constant increases with temperature according to the Arrhenius equation.

FRQ 7 How to improve?

Provide students with opportunities use chemical terminology correctly. E.g., *“reaction rate,” “rate constant,” and “half-life” are interrelated but have different meanings.*

Address the misconception that raising the temperature of a system lowers the activation energy.

FRQ 7 How to improve?

Distinguish between *descriptions* and *explanations*. E.g., The Arrhenius equation *describes how* the rate constant varies with temperature, it does not *explain why* reactions go faster at higher temperature.



General comments

General comments

Conceptual Understanding

1. Verbal **descriptions**--macro
2. Chemical **explanations**--micro
3. **Calculations** with units
4. **Justification** of choices
5. **Formulation** of hypotheses

1. Verbal *descriptions*

Have students *describe in words* what they observe during chemical processes:

- a. identify the *measurables*.
- b. learn the *correct vocabulary*.
- c. design a meaningful *experiment*.

1. Verbal *descriptions*

d. *memorization* is necessary to learn vocabulary and some basic chemical facts. It is not an end in itself, but it can be a useful tool to categorize and access conceptual knowledge

2. Chemical *explanations*

Have students *explain* what they believe is occurring (but cannot see) during chemical processes:

- a. in terms of *chemical principles*
- b. using *particle-level diagrams* when possible

3. *Calculations* with units

Have students solve numerical problems:

- a. *estimating* w/o a calculator is useful for the “order of magnitude”
- b. check *power of ten*
- c. use *dimensional analysis* for correct units

3. *Calculations* with units

d. *algorithmic calculations* are okay only if they are accompanied by *conceptual understanding*

4. *Justification* of choices

Have students *justify* their answers to “T/F” or “>, <, or = to” type questions

a. explaining why they chose an answer tells you if they understood the question or made a lucky guess.

b. If the prompt says “The reaction is 1st order,” don’t start your answer with, “The reaction is 0th order...”

5. *Formulating* hypotheses

Being able to formulate an *hypothesis* is an important higher level scientific skill

a. *inquiry labs* are a natural place to practice this skill



Score Setting Process

Score setting process (4 steps)

- ▶ Establishing Achievement Level Descriptors (ALDs)
- ▶ Engaging a standard-setting panel to recommend cut-scores (1 through 5)
- ▶ Equating the main, alternate, and exception forms
- ▶ Engaging a policy panel to set the cut scores

2014 AP Chemistry Scores

| <u>AP</u> | <u>Percent</u> |
|-----------|----------------|
| 5 | 10.04 |
| 4 | 16.57 |
| 3 | 25.55 |
| 2 | 25.80 |
| 1 | 22.03 |



Become an AP Reader

Become an AP Chemistry Reader

1. Meet and network with chemistry teachers and professors from all over
2. Learn how to write and grade your own exams more consistently and fairly
3. Make lasting friendships
4. Earn a \$1750 stipend
5. Think of it as a an all-expenses-paid “chemistry vacation”

How to become an AP Reader

1. College faculty
 - a) aphighered.collegeboard.org
 - b) Click on “Get Involved”
 - c) Choose “Become an AP Reader”
2. Experienced high school teacher
 - a) apcentral.collegeboard.com
 - b) Click on “Professional Development”
 - c) “College Board Professional Opportunities”
 - d) “Become an AP Reader”

Questions about AP Chemistry

Serena Magrogan,

Director, AP Chemistry CCD

smagrogan@collegeboard.org

Roger Kugel,

Chief Reader

rkugel@smumn.edu