Michael Smith Science Challenge

2014

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Analysis

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Introduction

The Michael Smith Challenge is a national science contest written by students in Grade 10 or lower. It was piloted in the province of British Columbia in April 2002, and has run nationally every year since. It is intended to spark enthusiasm in the many different fields of science among young Canadian students. The contest is designed to challenge students' logical and creative thinking with a minimum amount of memorization. The Michael Smith Science Challenge is the only nationwide competition covering all science subjects taught in grade 10/niveau 4. It is offered in English and French.

This year, 180 teachers from 9 provinces registered for the contest, with the provincial registration shown in Figure 1. A total of 1936 students were registered.

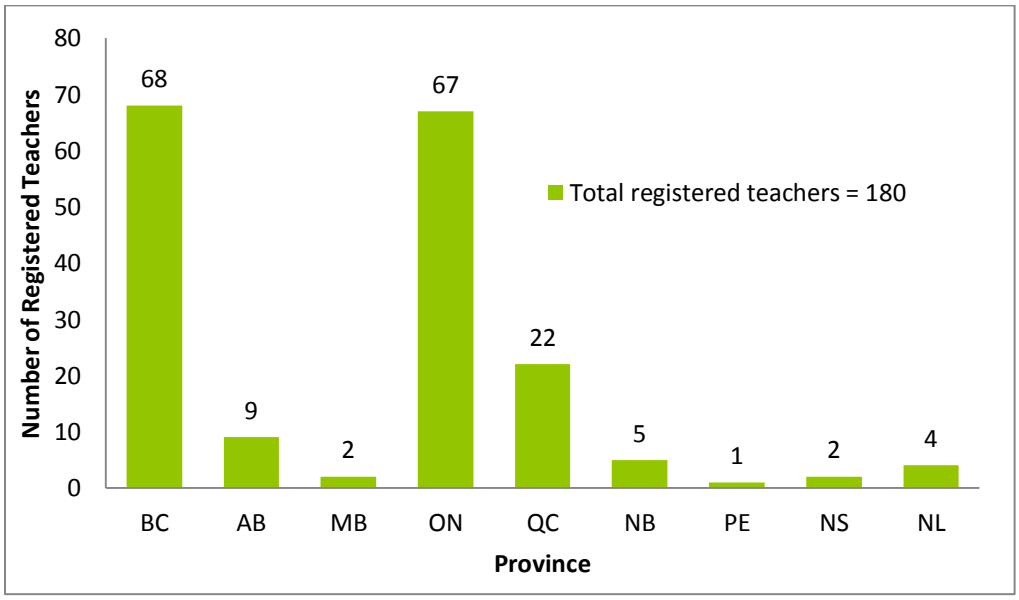


Figure 1: The number of teachers who registered for the challenge in each province.

The most significant change in registration for the 2014 contest was the 17% increase in Ontario's student participation over last year (2013), presumably due to last year's teacher strike. Papers were submitted for 90% of all registered students. A total of 1753 students participated in this year's contest. This is a slight increase (+1.1%) over last year and a new record for the challenge. The distribution by province is shown in Fig. 2.

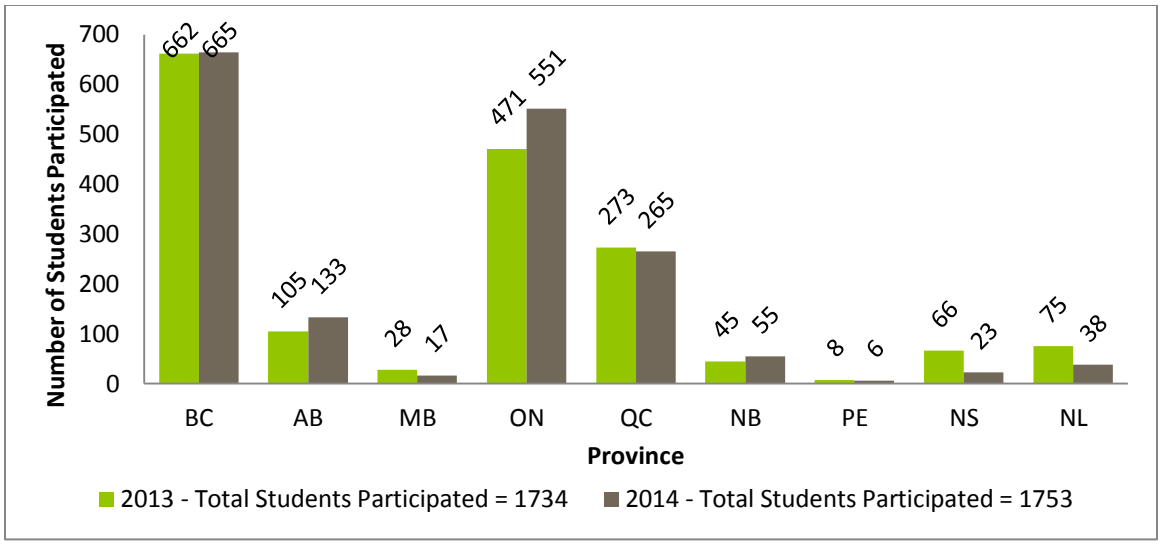


Figure 2: Student participation by province in the 2013 and 2014 Michael Smith Challenges.

Question 1

Given the 4 pairs of nutrition labels below, match each pair to the options listed on the next page. Write the appropriate letter (a-h) in the spaces provided.

Marking Scheme:
2.5 Marks: *Correctly matching each pair in the correct order*

Label 1A (per 140 g): ___

Amount	% Daily Value
Calories 230	
Fat 5 g	**8** %
Saturated 1 g	**7** %
+ Trans 0 g	
Cholesterol 120 mg	
Sodium 104 mg	**4** %
Carbohydrate 0 g	**0** %
Fibre 0 g	**0** %
Sugars 0 g	
Protein 43 g	

Vitamin A	1 %	Vitamin C	0 %
Calcium	2 %	Iron	8 %

Label 1B (per 100 g): ___

Amount	% Daily Value
Calories 300	
Fat 25 g	**38** %
Saturated 10 g	**55** %
+ Trans 0.5 g	
Cholesterol 65 mg	
Sodium 60 mg	**3** %
Carbohydrate 0 g	**0** %
Fibre 0 g	**0** %
Sugars 0 g	
Protein 17 g	

Vitamin A	0 %	Vitamin C	0 %
Calcium	0 %	Iron	15 %

Label 2A (per 250 mL): ___

Amount	% Daily Value
Calories 160	
Fat 8 g	**12** %
Saturated 5 g	**26** %
+ Trans 0.2 g	
Cholesterol 30 mg	
Sodium 125 mg	**5** %
Carbohydrate 12 g	**4** %
Fibre 0 g	**0** %
Sugars 12 g	
Protein 8 g	

Vitamin A	10 %	Vitamin C	0 %
Calcium	30 %	Iron	0 %

Label 2B (per 250 mL): ___

Amount	% Daily Value
Calories 90	
Fat 0 g	**0** %
Saturated 0 g	**0** %
+ Trans 0 g	
Cholesterol 5 mg	
Sodium 125 mg	**5** %
Carbohydrate 13 g	**4** %
Fibre 0 g	**0** %
Sugars 13 g	
Protein 9 g	

Vitamin A	10 %	Vitamin C	0 %
Calcium	30 %	Iron	0 %

Label 3A (per 71 g): ___

Amount	% Daily Value
Calories 170	
Fat 2 g	**3** %
Saturated 0.4 g	**2** %
+ Trans 0 g	
Cholesterol 0 mg	
Sodium 350 mg	**15** %
Carbohydrate 32 g	**11** %
Fibre 4 g	**16** %
Sugars 2 g	
Protein 7 g	

Vitamin A	0 %	Vitamin C	0 %
Calcium	4 %	Iron	10 %

Label 3B (per 71 g): ___

Amount	% Daily Value
Calories 170	
Fat 1.5 g	**2** %
Saturated 0.3 g	**2** %
+ Trans 0 g	
Cholesterol 0 mg	
Sodium 340 mg	**14** %
Carbohydrate 34 g	**11** %
Fibre 1 g	**4** %
Sugars 3 g	
Protein 6 g	

Vitamin A	0 %	Vitamin C	0 %
Calcium	4 %	Iron	20 %

Label 4A (per 355 mL): ___

Amount	% Daily Value
Calories 160	
Fat 0 g	**0** %
Saturated 0 g	**0** %
+ Trans 0 g	
Cholesterol 0 mg	
Sodium 40 mg	**2** %
Carbohydrate 42 g	**14** %
Fibre 0 g	**0** %
Sugars 42 g	
Protein 0 g	

Vitamin A	0 %	Vitamin C	0 %
Calcium	0 %	Iron	0 %

Label 4B (per 355 mL): ___

Amount	% Daily Value
Calories 170	
Fat 0 g	**0** %
Saturated 0 g	**0** %
+ Trans 0 g	
Cholesterol 0 mg	
Sodium 25 mg	**1** %
Carbohydrate 38 g	**13** %
Fibre 0 g	**0** %
Sugars 34 g	
Protein 2 g	

Vitamin A	0 %	Vitamin C	160 %
Calcium	4 %	Iron	0 %

Pair possibilities (may be in reverse order):

a. White Bread and b. Whole Wheat Bread
c. Orange Juice and d. Carbonated Soft Drink
e. Chicken Breast and f. Ground Beef
g. Homogenized (3.25%) Milk and h. Skim Milk

Label Pair 1: 1A corresponds to *e. Chicken Breast*, while 1B corresponds to *f. Ground Beef*. The most obvious clues were in the fat and iron contents of the two meats. Chicken breast is a leaner meat than ground beef. Ground beef, as a red meat, is high in iron content.

Label Pair 2: 2A corresponds to *g. Homogenized (3.25%) Milk*, while 2B corresponds to *h. Skim Milk*. The calcium and fat content were the biggest clues. Both options are high in calcium, which suggests the milk pair, and 2B contains no fat, which suggests skim milk.

Label Pair 3: 3A corresponds to *b. Whole Wheat Bread*, while 3B corresponds to *a. White Bread*. The biggest clue lay in the fibre content. These were the only labels that showed signs of fibre, with 3A showing 4x as much fibre as 3B. This suggests 3A being whole wheat bread and 3B being white bread.

Label Pair 4: 4A corresponds to *d. Carbonated Soft Drink*, while 4B corresponds to *c. Orange Juice*. The biggest clues lay in the sugar and vitamin C content. Both drinks were very high in sugar (which eliminated the other liquid pair of milk), and 4B contained 160% of a daily serving of vitamin C. As a citrus fruit, oranges are very high in vitamin C. By process of elimination, this left 4A as the soft drink.

We designed the challenge to start with an easy question, and this question did have the highest average of 6.91/10. The most common mistake seen was changing the order of the chicken breast and ground beef. A pitfall of a handful of students was failing to realize that each pair was meant to stay together. This often resulted in no marks being given because each pair was marked as a whole.

Question 2

There have been numerous scientific articles examining the breeding habits and population size of various organisms over the last few years. Many of the authors of these articles have noted significant and rapid changes in their breeding behaviour and large fluctuations in population sizes. While some populations are shrinking, others are thriving.

a) Can you think of a reason why these changes have occurred? (2 marks)

Some of the top scoring solutions included:

- Global warming or climate change caused by human produced greenhouse gas emissions.
- Habitat destruction caused by urban expansion and increased resource extraction.
- Pesticides and fertilizers which disrupt the natural food chain.
- Hunting and poaching of certain species which throws dependent populations off balance.

The key feature that ties these together is recent, destructive human activity.

b) How might such changes in reproduction and replication of organisms affect humans? (8 marks)

Some of the top scoring solutions included:

- Food supplies could be harmed by increased populations of pests.
- Wild animals could move into urban areas if their population grows or their habitat shrinks.
- New diseases could be transmitted to humans if ecosystems change.
- Lumber and fishing industries could be harmed by decreasing tree and fish populations.
- Tourism could be affected in certain areas due to changes in an area's biodiversity.

These effects all connect back to a change for humanity, not just changes in nature.

***Marking Scheme**:*
***2 Marks (part A):** A large scale and well defined cause that has developed in the last few years (i.e. global warming, climate change, habitat loss caused by human development)*

***1 Marks (part A):** A possible cause that isn't specific enough or isn't argued well enough, or a symptom of something even larger (i.e. environmental damage, habitat loss, food shortages, pollution)*

***2 Marks (part B):** Given for each complete and detailed effect that could affect humanity*

***1 Mark (part B):** Given for each effect that could affect humanity but is too specific, too unlikely, or is lacking enough detail to be convincing*

***0 Marks (part B):** Given if an answer is incorrect or does not state how humans or humanity would be affected (ex. decreasing fish populations can negatively affect humanity, but how?)*

***0 Marks (part B):** Given for each repetition of an effect*

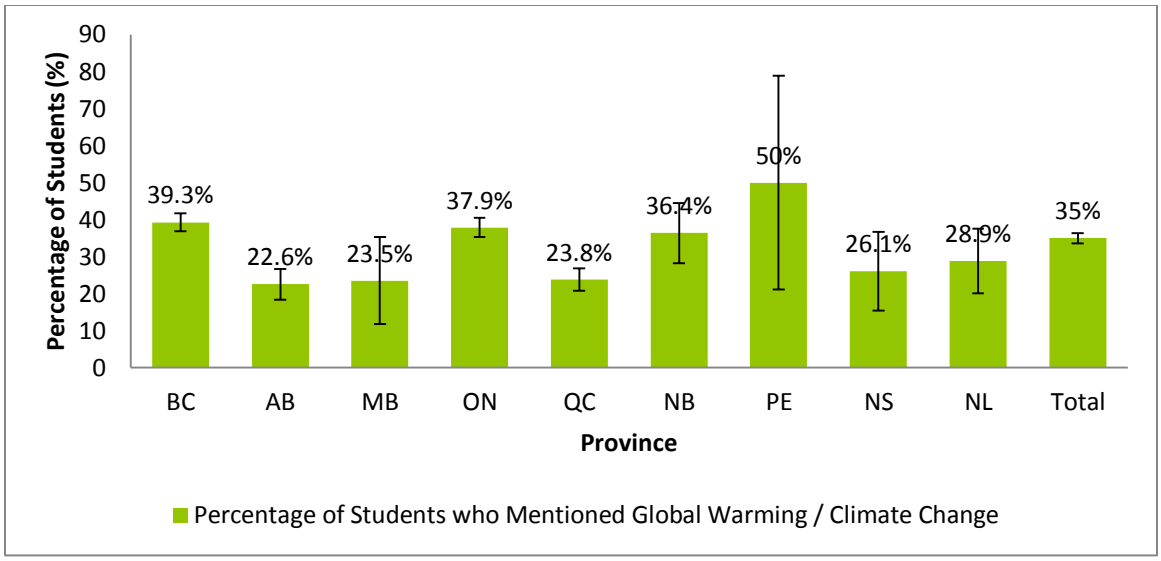


Figure 3: The percentage of students who mentioned global warming and/or climate change in their answers.

The average score for this question was 5.57/10. Global warming or climate change was the answer we expected to see most frequently for part A, but only 35% of students gave that as an answer. This percentage varied significantly between provinces, as can be seen in figure 3 above. The error bars in the figure are due to the varying sample sizes for each province. Mentioning global warming / climate change had little effect on the overall marks distribution, which showed all provinces having averages in the range of 5/10 to 6/10. Overall this question was done well and had 21% of students receive 10/10.

Question 3

Estimate how much noise (expressed in decibels, dB) could be made by 60,000 Edmonton Eskimos fans at Commonwealth Stadium when measured on the field with the fans an average of 80 m distant?

No prior knowledge of sound is needed to attempt this question; all you need to know is this:

> One person shouting can produce a noise level of 90 dB at 10 m, 84 dB at 20 m, and 78 dB at 40 m. Two people shouting together can produce a noise level of 93 dB at 10 m, 87 dB at 20 m, and 81 dB at 40 m. Four people shouting together can produce a noise level of 96 dB at 10 m, 90 dB at 20 m, and 84 dB at 40 m.

The noise level is reduced by 6 dB as distance was doubled in all cases, so by this pattern one person shouting would produce a noise level of 72 dB @ 80 m.

As the number of people was doubled, the noise level was increased by 3 dB. Because 60000 is approximately 2^{16} (65536), 60000 people shouting should increase the noise level by approximately 48 dB (16 x 3 dB = 48 dB).

Adding the distance noise level to the noise level caused by additional people gives 120 dB as a final answer (72 dB + 48 dB = 120 dB).

***Marking Scheme**:*

***1 Mark:** Making a note of the double distance and -6dB relationship*

***1 Mark:** Making a note of the double population and +3dB relationship*

***2 Marks:** Using powers of 2 to reach 6000, which is approximately 2^{16}*

***2 Marks:** Showing a correct calculation for the effect that 60000 people would have on the sound level at any distance*

***2 Marks:** Showing a correct calculation for the effect that 80 m distance would have on the sound level with any number of people*

***2 Marks:** A final answer of approximately 120dB*

The average score on this question was 4.33/10. 21% achieved a top mark of 10/10. Over a third (38%) of students made note of both relationships between distance and the number of people, 24% of students only made note of one relationship, and 38% of students didn't note either.

Question 4

On August 6, 2012, NASA's Curiosity rover landed on the surface of Mars. One of the mission's goals was to look for water on the planet.

a) If you had to design an experiment to search for water on Mars, what properties of water would you use for the test? (4 marks)

Some of the top scoring properties included:

- Water's melting / boiling point (when sample is pressurized to 1atm)
- The density of water's solid state is less than its liquid state
- Impure liquid water is electrically conductive
- pH of pure liquid water is 7
- Signs of Martian life means water must be nearby

These properties may not all be unique to water, but they could plausibly narrow down what a sample could be. Marks were given to properties of liquid water only if heating was mentioned, even though the low atmospheric pressure of Mars would cause ice to sublimate and not melt.

b) How would you test these properties? (6 marks)

Some of the top scoring solutions included:

- Heat sample that may contain ice at the same surface pressure as Earth until it reaches 0°C and use a moisture sensor to check for liquid water.
- Use anhydrous cobalt chloride paper in a heated sample and look for a colour change.
- Measure the volume and mass of a sample that looks to be mainly ice and see if its density is close to that of ice.

Many solutions involved bringing the Martian water to its more familiar liquid state for testing. Testing liquid water was accepted as long as there was mention of heating it first.

Marking Scheme:

1 Mark (part A): *Given for each unique and testable property of water*

2 Marks (part A): *Given for mentioning the effect that Martian atmospheric pressure would have on water*

0 Marks (part A): *Given for a vague or untestable answer*

Maximum 2 Marks (part A): *Given if the listed properties require that the water be in a liquid or pure state*

2 Marks (part B): *Given for a realistic and complete test*

1 Mark (part B): *Given for a realistic test that is missing an important feature (ex, "heat a sample to 100°C and look for steam" without changing pressure)*

0 Marks (part B): *Given for a test that is too vague, unreasonable, or incorrect (ex, "take soil samples")*

The average mark for this question was 2.62/10, the second lowest of the six. Only 16 students managed to achieve full marks for this question. Many students failed to take into consideration that water on Mars would almost certainly be frozen, as the average Martian temperature is well below water's melting point and the atmospheric pressure is too low to allow for liquid water. 35% of students suggested tests that could only be performed on liquid water. 33% of students mentioned checking the melting or boiling points of water as an identifiable property, but only 4% of those mentioned the pressure dependence of these properties. Most students were able to come up with a useful property or two, but few were able to come up with possible testing methods or a way to single out a sample definitely as water.

Question 5

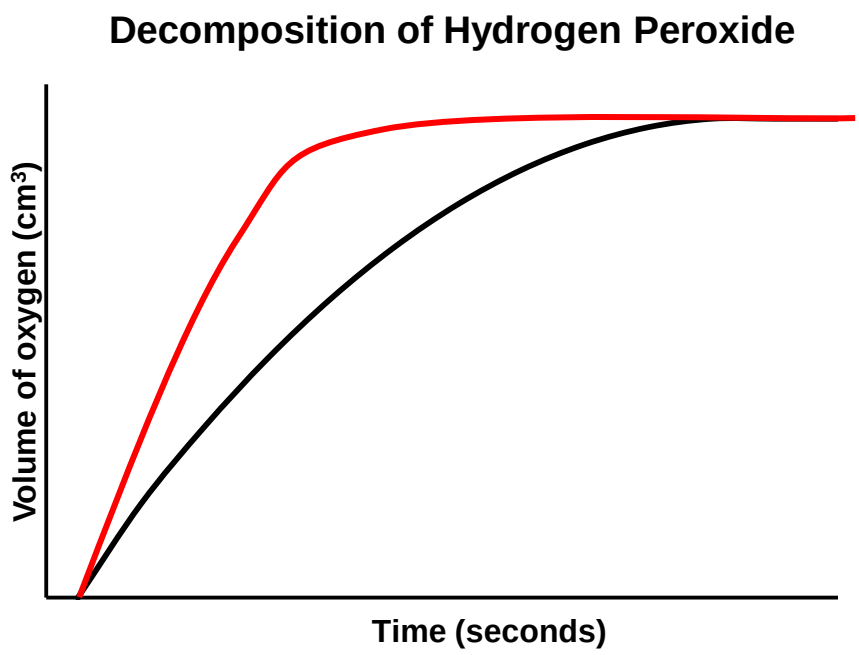
Hydrogen peroxide (H_2O_2) is a common chemical with many applications, including cleaning wounds and bleaching hair.

a) Fill in the missing product in the following decomposition reaction, and indicate the phase (*s* = solid, *l* = liquid, *g* = gas) of each product. (2 marks)

$$2H_2O_2(l) + KI(s) \longrightarrow O_2(g) + KI(s) + 2H_2O(l)$$

The missing product can be guessed by counting how much of each element is present on each side of the equation. This method leaves 4 hydrogen and 2 oxygen atoms missing on the product side. These can be combined into a familiar formula, H_2O, and then multiplied by 2 to get the appropriate number of atoms. The phases can be guessed from past knowledge; at room temperature, water is liquid, oxygen is gaseous, and the catalyst will not change from its already solid state.

b) A catalyst increases the rate of a chemical reaction without being consumed. The following graph shows the uncatalyzed decomposition of hydrogen peroxide. Clearly draw on the graph the line you would expect to result from the catalyzed decomposition of hydrogen peroxide. (3 marks)



The catalyzed curve is that of a faster reaction rate, meaning that it will be compressed on the time axis. This results in a curve of similar shape, but with a steeper slope and same final volume.

Marking Scheme:

1.5 Marks (part A): *Missing product is $2H_2O$*

1 Mark (part A): *Missing product is $1H_2O$ (right product, not balanced)*

+0.5 Marks (part A): *All 3 product phases correct*

0.5 Marks (part A): *$2O_2(g) + KI(s) + 2H_2(g)$ (wrong product but still balanced with a good guess for the H_2 state)*

1 Mark (part B): *Catalyzed curve steeper than original curve*

1.5 Marks (part B): *Catalyzed curve ends at same volume as original curve*

0.5 Marks (part B): *Catalyzed curve has similar curvature to original curve*

c) Draw a clearly labeled diagram of an experimental set up that could be used to measure the rate of decomposition of hydrogen peroxide. (5 marks)

Some diagrams that earned full marks included:

- A beaker covered by a balloon that fills with O_2 gas and has its diameter measured every few seconds.
- An O_2 sensor connected to a computer that checks the O_2 concentration continuously and plots it to a graph.
- A hose connected to the reaction beaker that carries the O_2 gas into a water filled container. By counting the number of bubbles seen at a specific time interval, a rate can be found.

Many variations of these experiments existed and received high marks.

1 Mark (part C): *Experiment shows a closed system*

1 Mark (part C): *Experiment measures the volume of O_2 produced*

2 Marks (part C): *Experiment takes measurements with a timed sample interval*

1 Mark (part C): *Experiment measures time, but not at specific intervals*

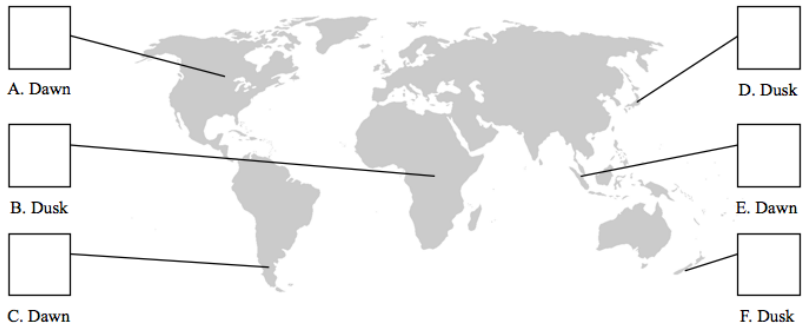
1 Mark (part C): *Diagram is clear and well labeled*

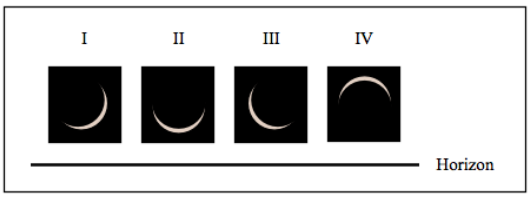
The average mark for this question was 3.48/10. A third of students (33%) did not attempt part C. The most frequent mistake for part B was showing that the catalyzed reaction would create more O_2 gas than the uncatalyzed reaction; the final quantity is independent of the initial rate. Another mistake frequently seen for part C was only taking one measurement of volume after the reaction had appeared to finish, instead of measuring the volume as a function of time. A total of 35 students (2%) achieved top marks for this question.

Question 6

A thin crescent Moon is sometimes visible in the sky around dawn and dusk.

Imagine you are standing somewhere on the Earth at the time of one of the equinoxes (around March 21 or September 21). You see a crescent Moon close to the horizon. Match the pictures I-IV with times and locations A-F and write the number of the picture in the boxes.





Marking Scheme:

2 Marks: *For giving paired answers for A/F, C/D, and B/E (each pair must have a unique answer)*

3 Marks: *For giving the correct answer for each pair of A/F, C/D, and B/E*

1 Mark: *For each unpaired and correct answer*

9 Marks: *Given for a swapped hemisphere version of the correct answer, i.e. I, II, III, III, II, I*

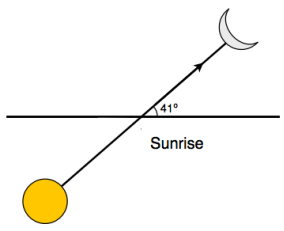
10 Marks: *Given for all correct answers*

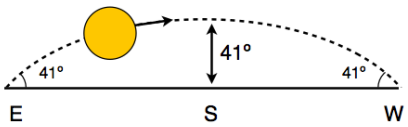
Maximum 6 Marks: *Score is capped at 6/10 if option IV is chosen at any point*

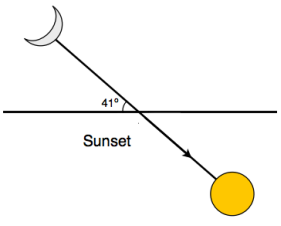
Maximum 0 Marks: *Given if the same option is chosen 5 or 6 times*

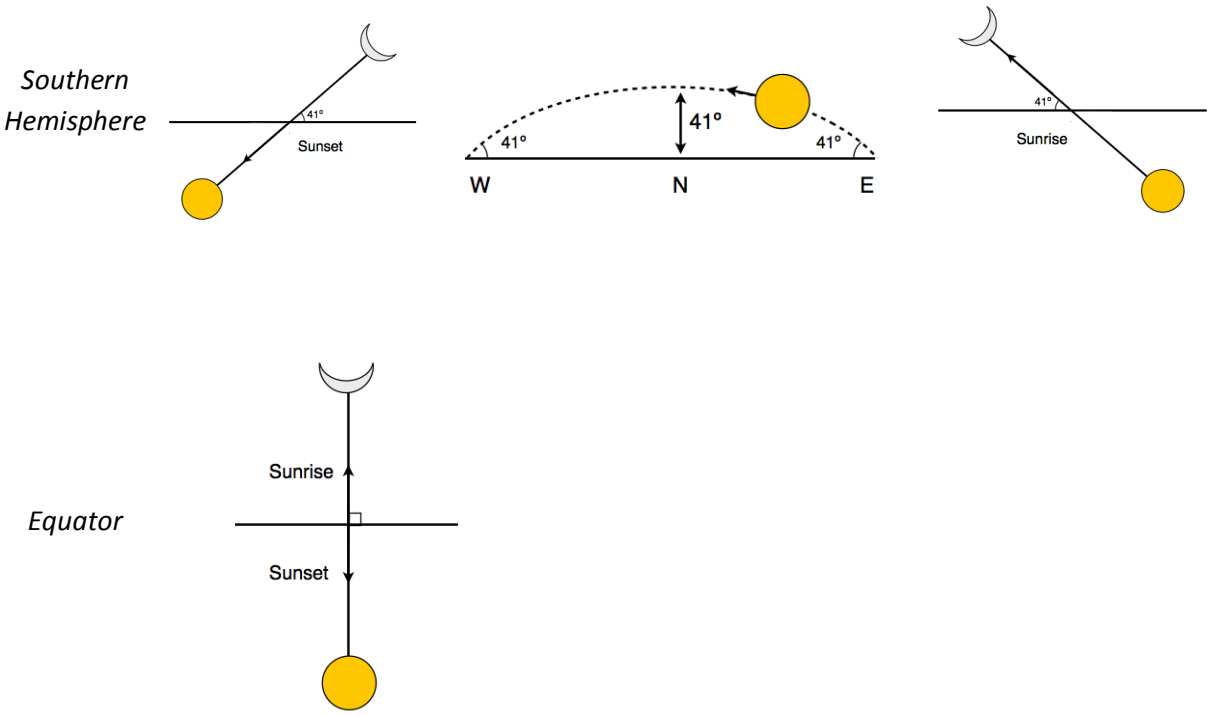
The correct answer is A.*III*, B. *II*, C.*I*, D. *I*, E. *II*, F. *III*. A crescent Moon will only appear close to the Sun, meaning that it will often be washed out and invisible during the day. This means that it is best seen just before sunrise (when the visible part of the Moon is shrinking, or "waning") or just after sunset (when the visible part of the Moon is growing, or "waxing"). At the equinox, the Sun and crescent Moon will appear to travel directly along the equator. The brighter part of the moon faces the sun, so the equator would see the moon shown in option IV at both sunset and sunrise. The following diagrams show the path that the sun and crescent moon follow at sunset and sunrise in the Northern and Southern hemispheres at 49° latitude, as well as the equator. The centre 41° angle is the angle of the Sun's trajectory relative to the horizon while the two side 41° angles are made by a tangent to the Sun's trajectory at sunrise and sunset.

Northern Hemisphere









The average mark for this question was the lowest of the six at 2.56/10. Only 6 students achieved top marks for this question, and only 17 students achieved marks higher than 6/10. Surprisingly, 18% of students selected option IV for location A. Option IV is not only impossible in Canada, but on Earth as a whole. Selecting it for a Canadian sky indicates either quick guesswork or very limited awareness of the night sky. In total, 89% of students selected option IV at some point in their answer. Many students drew diagrams of how the Earth-Moon-Sun system would appear from space, and it is a difficult transformation to infer from these how the Moon would appear from Earth. We also suspect students are confusing images taken from the Space Station or Apollo spacecraft with how the Moon appears from Earth.

Results

Overall

The mark distribution is shown in Fig. 4. The mean was 42.5% and the standard deviation was 15%. The mean scores for each question are shown in Fig. 5.

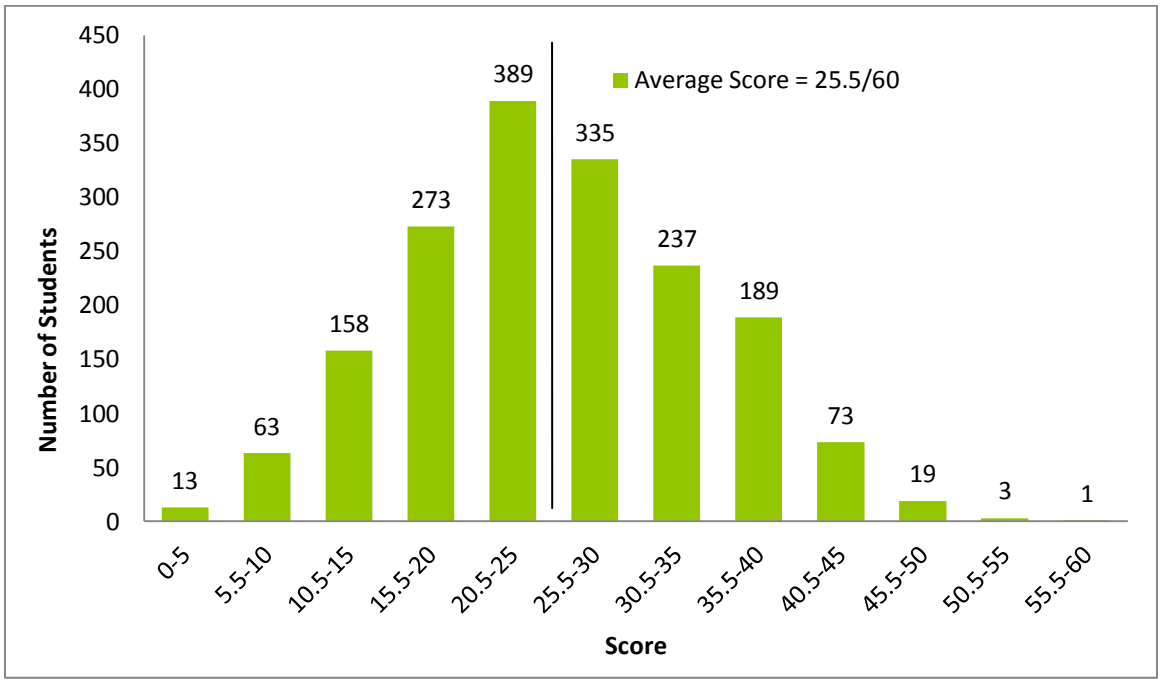


Figure 4: Chart showing the distribution range of marks. The highest mark achieved was 58.5 out of 60 and the average was 25.5 out of 60.

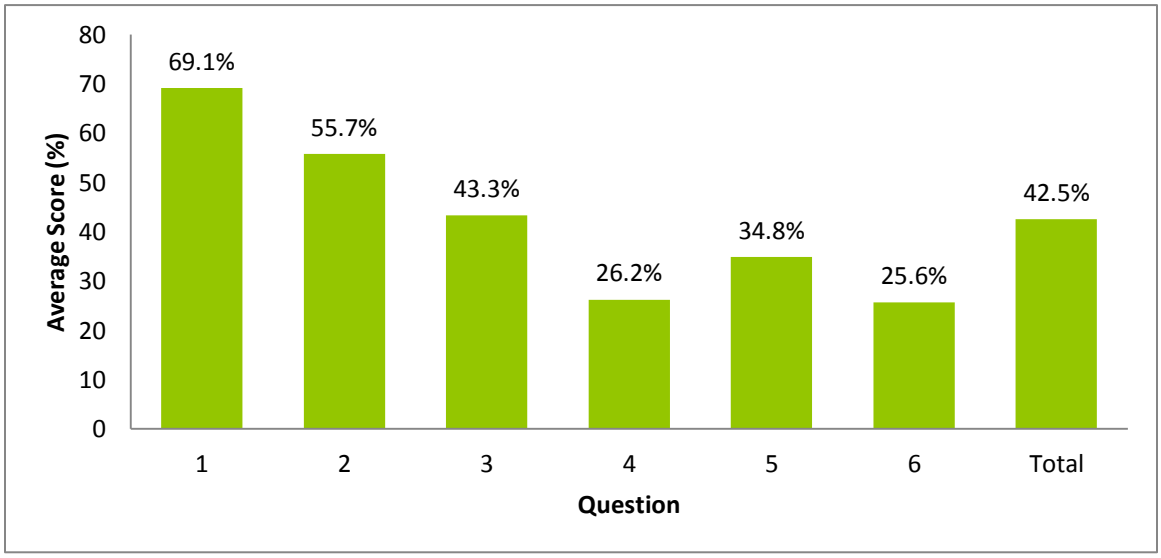


Figure 5: Chart showing the average score on each question.

Awards

The highest scoring student received a prize of $500. The 2nd place student was awarded $250, and the two tied 3rd place students $100 each. The top student from each province who did not receive a national prize was awarded $100. Teachers of all these prize-winning students received a $50 prize. All prizewinners, both students and teachers, received certificates.

Four other types of certificates were awarded, to the top 1%, 3%, 10%, and 25% of students. All students in the top 1% received at least 45.5/60 marks. The students in the top 3% received at least 42.5/60 marks. The students in the top 10% received at least 37.5/60 marks. The top 25% of students received at least 31.5/60 marks.

References

Toews, A., et al. (2013). Analysis – Michael Smith Challenge 2013.
http://outreach.phas.ubc.ca/smith/Documents/MSC2013 - English Solutions.pdf

Kashino, Z., et al. (2012). Analysis – Michael Smith Challenge 2012.
http://outreach.phas.ubc.ca/smith/Documents/MSC2012 - English Solutions.pdf