

Michael Smith National Science Challenge 2004

Thursday, April 8th, 2004

9-10 Pacific, 10-11 Mountain, 11-12 Central,
12-1 Eastern, 1-2 Atlantic, 1:30-2:30 Newfoundland

Instructions

1. Do not open the exam booklet until you are told to do so.
2. Be certain that you understand all the instructions. If you are unsure about something, ask your supervisor to explain it.
3. This exam is closed-book. No notes of any kind (printed or electronic) are allowed.
4. You may use calculators (including graphing calculators) and papers for rough work.
5. You should have 2 separate items: 1 exam booklet and 1 answer sheet.
6. This exam booklet consists of **10 pages** (including a **data sheet** on page 3 of this booklet). Check to make sure you have all the pages.
7. The answer sheet consists of 1 page – all your answers should be marked on the answer sheet (**not** on this exam booklet). Only your answer sheet will be collected at the end of the exam.
8. On your answer sheet, print your general and contact information clearly. Only those who do so can be counted as official contestants.
9. This is a multiple-choice test. Each question is followed by 5 possible answers marked A, B, C, D, E. Only one of these is correct.
10. To mark a multiple-choice response on the answer sheet, use a pencil to **draw a circle** around the letter of your choice and **blacken the circle completely**.
11. When your supervisor instructs you to begin, you will have **60 minutes** to finish the exam.

Scoring

1. Each correct answer is worth 5 credits in Part A and 8 credits in Part B.
2. There is no penalty for an incorrect answer.
3. Each unanswered question is worth 2 credits, to a maximum of 20 credits.

Teachers

Please courier the following **3 items** to Prof. Chris Waltham, Department of Physics & Astronomy, 6224 Agricultural Road, UBC, Vancouver, BC, V6T1Z1 before the end of **Thursday, April 8, 2004**:

1. the completed student registration form(s)
2. students' answer sheets
3. a cheque payable to University of British Columbia, for \$10.00 per answer sheet returned.

Named in Honour of Michael Smith

UBC Professor, Nobel Laureate in Chemistry (1993) for contributions to DNA-based chemistry.

Presented by

UBC Faculty of Science
NSERC PromoScience

Exam Committee

Chris Waltham, UBC Department of Physics and Astronomy
Andrzej Kotlicki, UBC Department of Physics and Astronomy
Peter Newbury, UBC Department of Physics and Astronomy
Chelsea Taylor, UBC Department of Physics and Astronomy
Tony Griffiths, UBC Department of Botany
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Stuart Sutherland, UBC Department of Earth and Ocean Sciences

English-to-French Translator

Marie-Pierre Milette, UBC Department of Physics and Astronomy; Tony Teke

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Data Sheet

Fiche de données

| | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|----------------------------|---------------------------|---|---------------------------|----------------------------|---------------------------|---------------------------|---------------------------|----------------------------|---------------------------|----------------------------|---------------------------|---|---------------------------|----------------------------|---------------------------|---------------------------|---------------------------|-----------|-----------|--|--|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------|---------------------------|
| 1 | | | | | | | | | | | | | | | 18 | | | | | | | | | | | | |
| 1 H 1.008 | | | | | | | | | | | | | | | 2 He 4.003 | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | 13 | 14 | 15 | 16 | 17 | | | | | | | | |
| 3 Li 6.941 | 4 Be 9.012 | Relative Atomic Masses (1985 IUPAC) *For the radioactive elements the atomic mass of an important isotope is given | | | | | | | | | | Masses Atomiques Relatives (IUPAC, 1985) *Dans le cas des éléments radioactifs, la masse atomique fournie est celle d'un isotope important | | | | | | | | | | 5 B 10.811 | 6 C 12.011 | 7 N 14.007 | 8 O 15.999 | 9 F 18.998 | 10 Ne 20.180 |
| 11 Na 22.990 | 12 Mg 24.305 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 Al 26.982 | 14 Si 28.086 | 15 P 30.974 | 16 S 32.07 | 17 Cl 35.453 | 18 Ar 39.948 | | | | | | | | | | |
| 19 K 39.098 | 20 Ca 40.08 | 21 Sc 44.956 | 22 Ti 47.88 | 23 V 50.942 | 24 Cr 51.996 | 25 Mn 54.938 | 26 Fe 55.847 | 27 Co 58.93 | 28 Ni 58.69 | 29 Cu 63.55 | 30 Zn 65.39 | 31 Ga 69.72 | 32 Ge 72.61 | 33 As 74.922 | 34 Se 78.96 | 35 Br 79.904 | 36 Kr 83.80 | | | | | | | | | | |
| 37 Rb 85.468 | 38 Sr 87.62 | 39 Y 88.906 | 40 Zr 91.22 | 41 Nb 92.906 | 42 Mo 95.94 | 43 Tc (98) | 44 Ru 101.07 | 45 Rh 102.906 | 46 Pd 106.42 | 47 Ag 107.87 | 48 Cd 112.41 | 49 In 114.82 | 50 Sn 118.71 | 51 Sb 121.76 | 52 Te 127.60 | 53 I 126.90 | 54 Xe 131.29 | | | | | | | | | | |
| 55 Cs 132.905 | 56 Ba 137.33 | 57 La 138.91 | 72 Hf 178.49 | 73 Ta 180.948 | 74 W 183.85 | 75 Re 186.2 | 76 Os 190.2 | 77 Ir 192.2 | 78 Pt 195.08 | 79 Au 196.967 | 80 Hg 200.59 | 81 Tl 204.37 | 82 Pb 207.2 | 83 Bi 208.980 | 84 Po (209) | 85 At (210) | 86 Rn (222) | | | | | | | | | | |
| 87 Fr (223) | 88 Ra 226.03 | 89 Ac 227.03 | 104 Rf (261) | 105 Db (262) | 106 Sg (263) | 107 Bh (262) | 108 Hs (265) | 109 Mt (268) | | | | | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | |
|----------------------------|---------------------------|---------------------------|---------------------------|--------------------------|---------------------------|---------------------------|---------------------------|---------------------------|----------------------------|---------------------------|----------------------------|---------------------------|---------------------------|
| 58 Ce 140.12 | 59 Pr 140.91 | 60 Nd 144.24 | 61 Pm (145) | 62 Sm 150.4 | 63 Eu 151.97 | 64 Gd 157.25 | 65 Tb 158.93 | 66 Dy 162.50 | 67 Ho 164.930 | 68 Er 167.26 | 69 Tm 168.934 | 70 Yb 173.04 | 71 Lu (175) |
| 90 Th 232.038 | 91 Pa 231.04 | 92 U 238.03 | 93 Np 237.05 | 94 Pu (244) | 95 Am (243) | 96 Cm (247) | 97 Bk (247) | 98 Cf (251) | 99 Es (252) | 100 Fm (257) | 101 Md (258) | 102 No (259) | 103 Lr (260) |

| | Symbol Symbole | Value Quantité numérique | |
|--|----------------------|--|---|
| Atomic mass unit | <i>amu</i> | $1.66054 \times 10^{-27} \text{ kg}$ | Unité de masse atomique |
| Avogadro's number | <i>N</i> | $6.02214 \times 10^{23} \text{ mol}^{-1}$ | Nombre d'Avogadro |
| Bohr radius | <i>a₀</i> | $5.292 \times 10^{-11} \text{ m}$ | Rayon de Bohr |
| Boltzmann constant | <i>k</i> | $1.38066 \times 10^{-23} \text{ J K}^{-1}$ | Constante de Boltzmann |
| Charge of an electron | <i>e</i> | $1.60218 \times 10^{-19} \text{ C}$ | Charge d'un électron |
| Dissociation constant (H ₂ O) | <i>K_w</i> | 10^{-14} (25 °C) | Constante de dissociation de l'eau (H ₂ O) |
| Faraday's constant | <i>F</i> | $96\,485 \text{ C mol}^{-1}$ | Constante de Faraday |
| Gas constant | <i>R</i> | $8.31451 \text{ J K}^{-1} \text{ mol}^{-1}$ $0.08206 \text{ L atm K}^{-1} \text{ mol}^{-1}$ | Constante des gaz |
| Mass of an electron | <i>m_e</i> | $9.10939 \times 10^{-31} \text{ kg}$ $5.48580 \times 10^{-4} \text{ amu}$ | Masse d'un électron |
| Mass of a neutron | <i>m_n</i> | $1.67493 \times 10^{-27} \text{ kg}$ 1.00866 amu | Masse d'un neutron |
| Mass of a proton | <i>m_p</i> | $1.67262 \times 10^{-27} \text{ kg}$ 1.00728 amu | Masse d'un proton |
| Planck's constant | <i>h</i> | $6.62608 \times 10^{-34} \text{ J s}$ | Constante de Planck |
| Speed of light | <i>c</i> | $2.997925 \times 10^8 \text{ m s}^{-1}$ | Vitesse de la lumière |

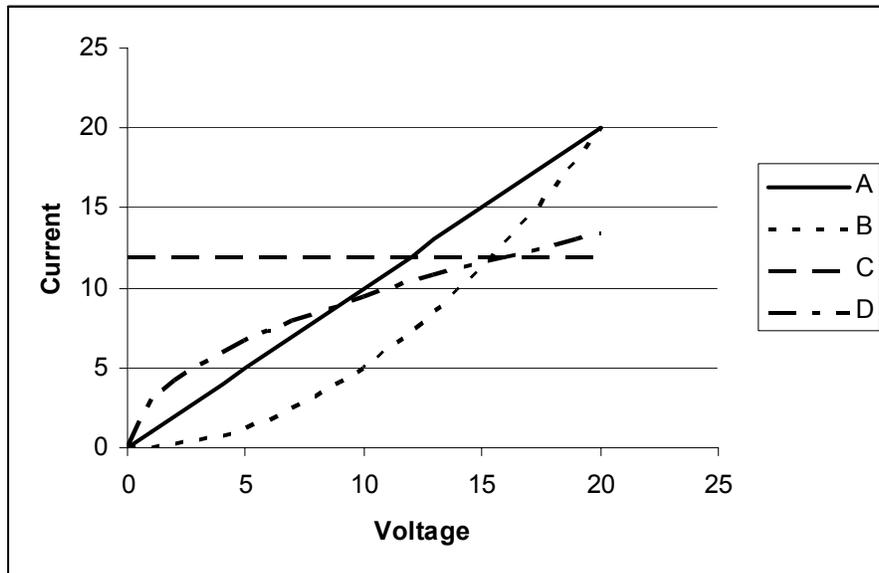
| |
|--------------------------------------|
| 1 Å = 1 x 10 ⁻⁸ cm |
| 1 eV = 1.60219 x 10 ⁻¹⁹ J |
| 1 cal = 4.184 J |
| 1 atm = 101.325 kPa |
| 1 bar = 1 x 10 ⁵ Pa |

Part A (5 credits each)

1. A car is driving at a steady 100 km/h down the highway, going north. Measured from the roadside, what is the velocity of the perimeter of the car tires at the point where they touch the road?

- A 100 km/h north
- B 100 km/h south
- C depends on the size of the tire, but north
- D depends on the size of the tire, but south
- E zero

2. The resistance of a filament in a bulb increases with temperature. Which of the lines below best describes the dependence of the current flowing through the bulb on the applied voltage?



3. Electricity is transmitted at high voltage in order to

- A reduce electrical interference
- B stop people trying to tap into the transmission lines to get free electricity
- C minimize energy lost as heat in the transmission lines
- D make the electricity easier to produce
- E produce high power

4. Radio waves travel at what speed?

- A 340 m/s
- B 340 km/s
- C 340 km/h
- D 300,000 km/s
- E 300,000 km/h

5. If you spent a day at the geographic North Pole at the time of the spring equinox (around March 21), you would see:

- A the Sun skim the horizon all way around
- B the Sun remain directly overhead all the time
- C the Sun pass from the eastern horizon to the western horizon, passing directly overhead at noon
- D the Sun pass from the western horizon to the eastern horizon, passing directly overhead at noon
- E nothing at all; you will remain in total darkness

6. Ernest Rutherford postulated the 'nuclear atom' in which most of an atom is empty space and the mass is concentrated in a small particle (nucleus) at the centre of the atom. If a single electron had the mass of a hockey puck, the nucleus of a hydrogen atom would be approximately as massive as:

- A. A fully loaded NHL hockey equipment bag
- B. The combined mass of the forward line of an NHL team (i.e. three players)
- C. The mass of the team bus (empty)
- D. The mass of the team's hockey arena
- E. The mass of a mountain

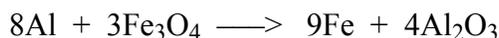
7. When ammonium oxalate $[(\text{NH}_4)_2\text{C}_2\text{O}_4]$ dissolves in water, the ions formed are:

- A. $2\text{N}^{3-} + 8\text{H}^+ + 2\text{C}^{4+} + 4\text{O}^{2-}$
- B. $(\text{NH}_4)^{2+} + \text{C}_2\text{O}_4^{2-}$
- C. $2\text{NH}_4^+ + \text{C}_2\text{O}_4^{2-}$
- D. $\text{NH}_4^{2+} + \text{C}_2\text{O}_4^{2-}$
- E. $2\text{NH}_4^+ + 2\text{CO}^{2-}$

8. Which of the following is NOT a correct chemical formula?

- A. SrBr₂
- B. CaO₂
- C. Mg₃N₂
- D. Na₂S
- E. AlI₃

9. In the 'thermite' reaction given below, how many moles of Al will produce 1 mole of Fe?



- A. 1
- B. 3/4
- C. 9/8
- D. 4/3
- E. 8/9

10. A substance has an empirical formula of CH₂. Its molar mass was determined in a separate experiment and was found to be approximately 80. The most probable molecular formula of the compound is:

- A. C₂H₄
- B. C₃H₆
- C. C₄H₈
- D. C₅H₁₀
- E. C₆H₁₂

11. Which of the following is true about the immediate effect of large volcanic eruptions (e.g. Krakatoa, Mt. Pinatubo) on the Earth's climate?

- A they raise the global temperature due to the outpouring of hot molten rock
- B they raise the global temperature due to the outpouring of greenhouse gases
- C they lower the global temperature due to the outpouring of dust into the atmosphere
- D they lower the global temperature by causing tidal waves
- E they have no measureable effect on the global temperature

12. An earthquake in Japan produces a tsunami which causes damage on the coast of British Columbia. Ships crossing the middle of the Pacific Ocean at this time –

- A mostly sink
- B get a good rocking but mostly stay afloat
- C experience a small rapid wave passing from east to west
- D feel nothing at all as the wave in deep water is too low and flat to notice
- E feel nothing but ships in the Atlantic Ocean are in grave danger

13. Place the following events in the right chronological order (earliest to most recent):

- 1 the appearance of homo sapiens in what is now Canada
- 2 the disappearance of the dinosaurs
- 3 the end of the last ice age
- 4 the development of agriculture
- 5 the extinction of neanderthals

- A 2 5 3 4 1
- B 5 2 3 1 4
- C 2 3 5 4 1
- D 2 1 3 5 4
- E 2 5 3 1 4

14. In a certain diploid plant, $2n = 10$. In a root tip cell in mitotic metaphase, how many DNA molecules are there?

- A 2
- B 10
- C 20
- D 30
- E 40

15. Which of the following organisms does **not** have mitochondria?

- A. *Escherichia coli*
- B. *Saccharomyces cerevisiae*
- C. *Homo sapiens*
- D. *Zea mays*
- E. *Drosophila melanogaster*

16. Transport of photosynthetic products from leaves to roots is carried out by

- A. phloem
- B. xylem
- C. parenchyma
- D. stomata
- E. tracheids

17. Which of the following is not an invasive species in Canada?

- A. gorse
- B. zebra mussels
- C. purple loosestrife
- D. starling
- E. white pine

The following three Geology Questions refer to figure 1 below.

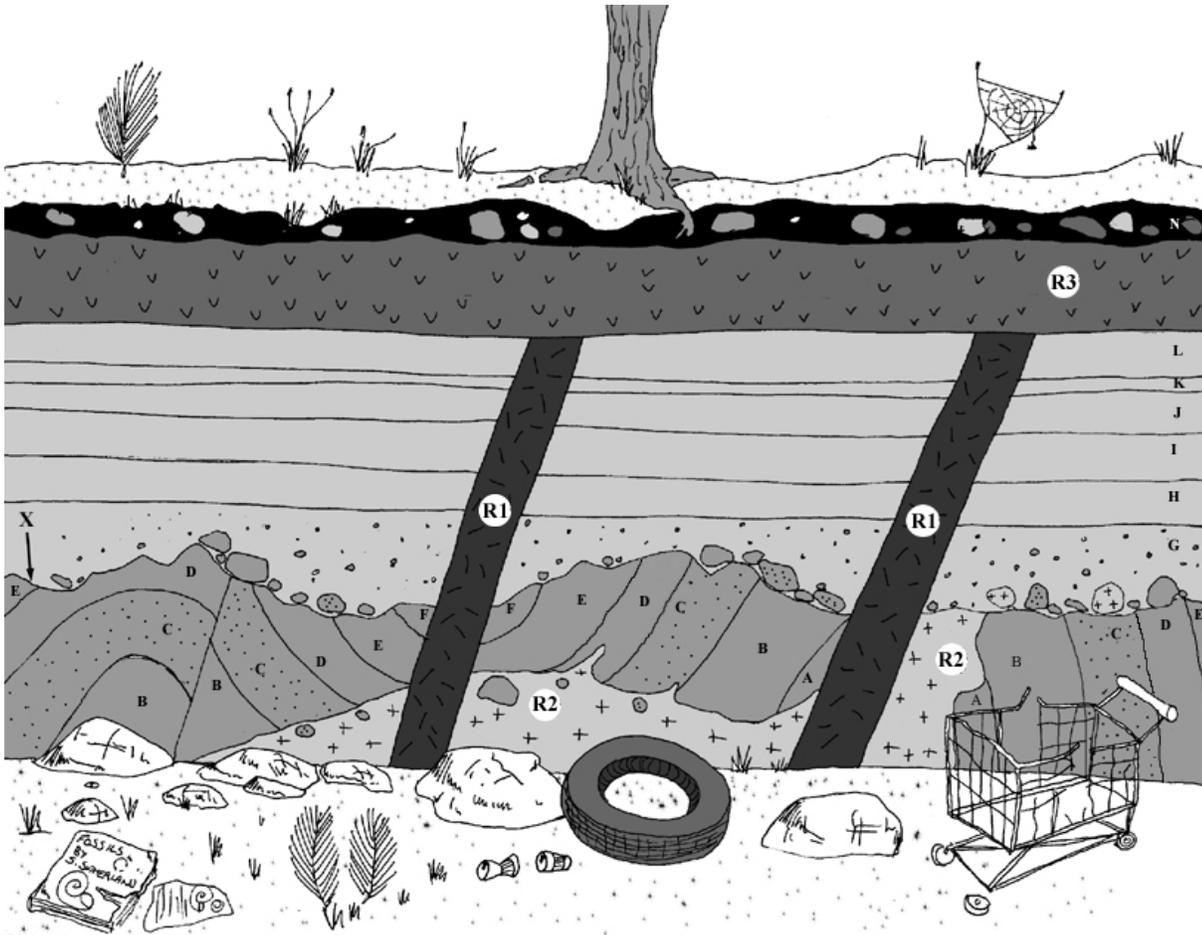


Figure 1 is a field sketch of a quarry face section made by a geologist. R1, R2 and R3 are igneous rocks. Rocks A – L are sedimentary rocks.

18. Which of the following is FALSE?

- A. The folded rocks (A – F) are older than the horizontal rocks (G – L).
- B. The intrusion of igneous rock R2 was probably the most recent geological event to occur.
- C. The igneous Rocks R1 are younger than rocks A - L.
- D. Sedimentary rock G was deposited after the development of the erosion surface (unconformity) at X.
- E. The erosion surface (unconformity) at X developed before the deposition of sedimentary rock L.

19. Which of the following would be the most likely cause of the folding exhibited by rocks A – F on figure 1?

- A. The intrusion of igneous rock R2.
- B. Horizontal forces of compression possibly related to subduction.
- C. Movement of creatures through the rock.
- D. Horizontal forces of compression developed at a mid ocean ridge system.
- E. The activities of drilling for oil.

20. Where would you expect to find thermal metamorphism in Figure 1?

- A. In rocks immediately adjacent to R2
- B. In rock I immediately adjacent to R1.
- C. At the top of Rock L.
- D. In R2 immediately adjacent to R1
- E. In all the above locations.

Part B (8 credits each)

B1. The density of water (H_2O) is about 1 g/mL. Consider a spoonful of water (5 mL). Imagine that you have 1 mole of water for every water molecule in that spoonful. The volume of water that you would have is enough to fill:

- A. A tanker truck
- B. An olympic-sized swimming pool
- C. The Great Lakes
- D. The oceans of the Earth
- E. A hollow sphere the size of the Earth

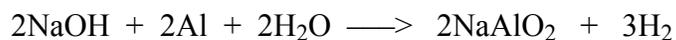
B2. A CF-18 jet aircraft has two engines each capable of producing 80 kN of thrust. The mass of the aircraft is 10,000 kg. What is the maximum possible vertical (upwards) acceleration?

- A 16 m/s²
- B 8 m/s²
- C 6 m/s²
- D 3 m/s²
- E -2 m/s² i.e. it cannot accelerate vertically upwards

B3. The angular diameter of the Sun is 0.48 degrees. How long does it take the Sun to set (from first touching the horizon to total disappearance), when observed from the west coast of Ecuador (on the equator) at the spring equinox? Ignore refraction effects.

- A 0
- B 2 seconds
- C 30 seconds
- D 1 minute
- E 2 minutes

B4. When aluminum dissolves in an aqueous solution of NaOH the reaction is:



When 84.1 g NaOH (in aqueous solution) and 51.0 g Al react, one of the reagents is completely consumed (i.e. is the 'limiting reagent'). After the reaction is finished, the mass of the OTHER reagent that remains is:

- A. 84.1 g
- B. 16.0 g
- C. 8.52 g
- D. 3.17 g
- E. 17.7 g

B5. A large population of beetles is thought to be in Hardy-Weinberg Equilibrium for a gene with two alleles, a dominant allele for black colour, and a recessive allele for brown colour. If 4% of the animals are found to be brown, what percent are expected to be heterozygotes?

- A. 8%
- B. 16%
- C. 32%
- D. 64%
- E. 96%