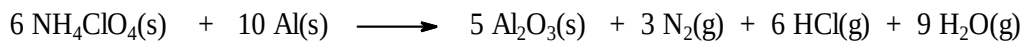
1. The fuel in the buster rockets of the Space Shuttle is constituted of a mixture of ammonium perchlorate, NH_4ClO_4, and aluminum powder. One of the reactions taking place during taking off is given by



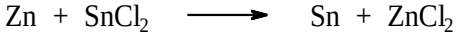
$$6\ NH_4ClO_4(s) + 10\ Al(s) \longrightarrow 5\ Al_2O_3(s) + 3\ N_2(g) + 6\ HCl(g) + 9\ H_2O(g)$$

The indication (s) and (g) signify solid and gaseous phase. Suppose that these rockets are loaded with 11.75 tons of ammonium perchlorate and 2.70 tons of aluminum. Calculate the volume of nitrogen gas produced during taking off under normal conditions (0°C and atmospheric pressure, so that 1 L corresponds to 22.4 moles of gas)

(A) $6.72\ 10^2$ L
(B) $1.12\ 10^3$ L
(C) $7.47\ 10^4$ L
(D) $6.72\ 10^5$ L
(E) $1.12\ 10^6$ L

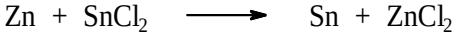
Correct answer: D
% correct answers: 24%

2. If a small zinc rod is put into a solution of tin(II)chloride, $SnCl_2$, tin will precipitate on the zinc rod and zinc will go into solution as Zn^{2+} ions.



$$Zn + SnCl_2 \longrightarrow Sn + ZnCl_2$$

If a lead rod is put into the same tin(II)chloride solution, no precipitation is observed.



$$Zn + SnCl_2 \longrightarrow Sn + ZnCl_2$$

What is your conclusion?

(A) Lead is a stronger reductor than zinc
(B) Tin is a stronger reductor than zinc
(C) Zinc is a stronger reductor than lead
(D) Tin is a stronger oxidator than zinc
(E) Zn^{2+} ions are a stronger oxidator than Pb^{2+} ions

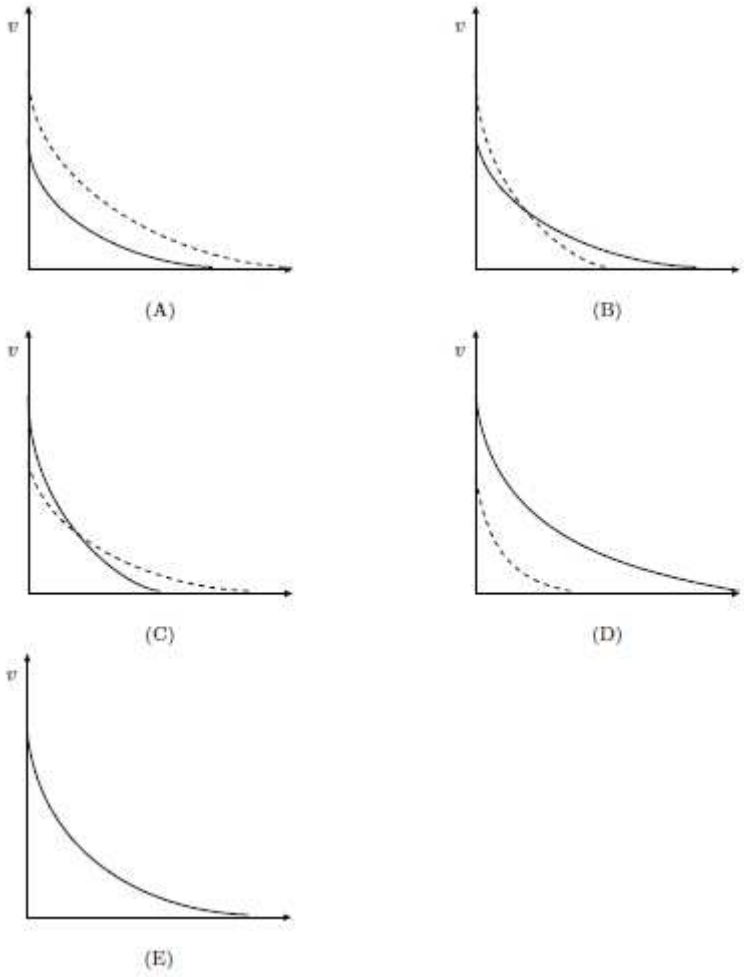
Correct answer: C
% correct answers: 52%

3. Hydrogen peroxide, H_2O_2, spontaneously decomposes in water and oxygen gas

$$2\ H_2O_2 \longrightarrow 2\ H_2O + O_2$$

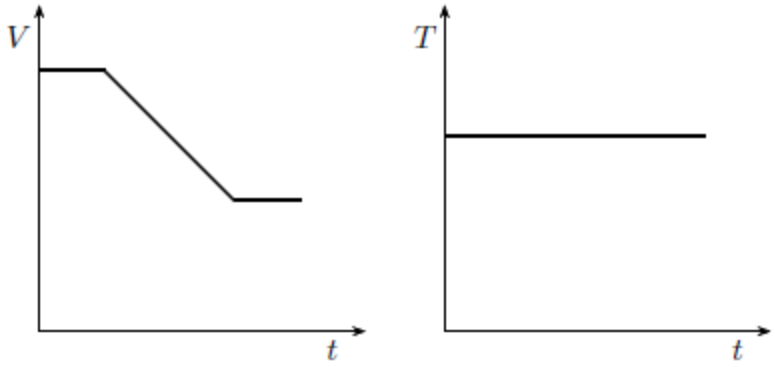
The reaction is one time performed without catalyst (full line) and one time in the presence of a catalyst (dashed line), starting from the same initial amount of hydrogen peroxide.

Which of the diagrams gives the correct reaction rate (v) as function of time (horizontal axis)?

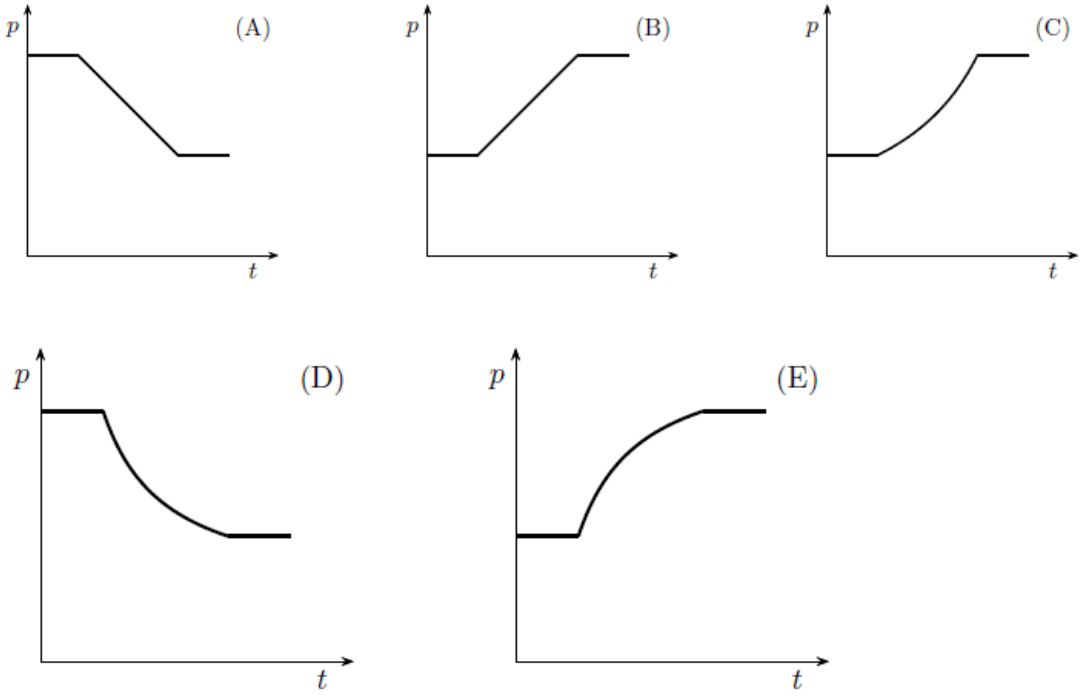


Correct answer: B
% correct answers: 52%

4. A cylinder with movable piston is filled with an ideal gas. Hence, the relation pV = nRT holds (n is the number of moles). Next figures show the relation of the volume (V) and the temperature (T) as function of time.



Which graph represents the correct pressure p as function of time?



Correct answer: C
% correct answers: 26%

5. Sulfuric acid has a molar mass of 98 g/mol. In the laboratory there is 100 mL of a 0.10 M sulfuric acid solution. How much water needs to be added to this volume to prepare a solution containing 4.9 g/L of sulfuric acid?
   (A) 10 mL
   (B) 50 mL
   (C) 100 mL
   (D) 150 mL
   (E) 200 mL

Correct answer: C
% correct answers: 44%

6. The ion-electron equations for a redox reaction are given by

$$2\,I^- \rightarrow I_2(aq) + 2\,e^-$$

$$MnO_4^- + 8\,H^+ + 5\,e^- \rightarrow Mn^{2+}(aq) + 4\,H_2O$$

How many moles of iodide ions are oxidised by one mole of permanganate ions?

(A) 0.2
(B) 0.4
(C) 1
(D) 2
(E) 5

Correct answer: E
% correct answers: 39%

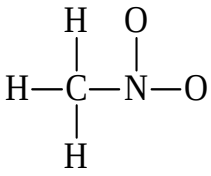
7. If the atomic number of an atom is represented by X and the mass number is represented by Y, the number of neutrons in an atom of this element is
(A) Y – X
(B) X – Y
(C) X + Y
(D) Y

Correct answer: A
% correct answers: 79%

8. Which of the following is the correct arrangement of electrons in a phosphorus atom (atomic number 15) ?
(A) 2, 8, 4, 1
(B) 2, 8, 5
(C) 5, 8, 2
(D) 2, 5, 8
(E) 2, 4, 8, 1

Correct answer: B
% correct answers: 82%

9. In the CH_3NO_2 molecule, shown below, what hybrid orbital set is used by the nitrogen atom for bonding? Be sure to check the Lewis structure to make sure it is correct?



(A) sp
(B) sp^2
(C) sp^3
(D) sp^3d
(E) sp^3d^2

Correct answer: B
% correct answers: 34%

10. Which of the following temperatures has an equal value expressed in °C and °F?
(A) -40
(B) -22.2
(C) 0
(D) 22.2
(E) +40

Correct answer: A
% correct answers: 42%

GHENT UNIVERSITY GLOBAL CAMPUS

[Chem²ath Contest Mathematics Questions]

June 20 (Sat), 2015

11. Consider the function $f: \mathbb{R} \to \mathbb{R}: x \mapsto x\cos(x^2)$. Evaluate the derivative of f at the point $\sqrt{2\pi}/2$.

    (A) $f'\left(\sqrt{2\pi}/2\right) = -\pi$

    (B) $f'\left(\sqrt{2\pi}/2\right) = -\sqrt{2\pi}$

    (C) $f'\left(\sqrt{2\pi}/2\right) = \sqrt{2\,\pi}$

    (D) $f'\left(\sqrt{2\pi}/2\right) = 0$

    (E) $f'\left(\sqrt{2\pi}/2\right) = 1 - \sqrt{2\pi}$

Correct answer: A
% of correct answers: 56%

12. Consider a natural number $m \neq 0$. Evaluate $\lim_{n \to \infty} \frac{nm}{m-n}$.

    (A) $\frac{m}{m-1}$
    (B) m
    (C) 1
    (D) -1
    (E) $-m$

Correct answer: E
% of correct answers: 56%

13. Consider the circle with equation $y^2 - 2y + x^2 + 6x - 15 = 0$. If $M = (a, b)$ is its center and R its radius, then $2a + b + R^2$ is equal to

    (A) 10
    (B) 14
    (C) 20
    (D) 24
    (E) 30

Correct answer: C
% of correct answers: 69%

14. Evaluate $\int \frac{e^{\sqrt{x}}}{\sqrt{x}} dx$.
    (A) $e^{\sqrt{x}} +$ constant
    (B) $2e^{\sqrt{x}} +$ constant
    (C) $e^{-\sqrt{x}} +$ constant
    (D) $\sqrt{x}e^{\sqrt{x}} +$ constant
    (E) $\frac{1}{2}e^{\sqrt{x}} +$ constant

Correct answer: B
% of correct answers: 61%

15. The trigonometric expression $\frac{1}{\cos x \tan x} - \sin x$ equals
    (A) $\frac{1}{\sin x}$
    (B) $\frac{\sin x}{\tan x}$
    (C) $\frac{(\sin x)^2}{\cos x}$
    (D) $\frac{\cos x}{\sin x}$
    (E) $\frac{(\cos x)^2}{\sin x}$

Correct answer: E
% of correct answers: 73%

16. A function $f: A \to B: x \mapsto f(x)$ is a one-to-one function is for all $x, y \in A$ it holds that: if $x \neq y$, then $f(x) \neq f(y)$. Determine which of the following functions is one-to-one.
    (A) $f: \mathbb{N} \times \mathbb{N} \to \mathbb{N}: (n, m) \mapsto m + n$
    (B) $f: \mathbb{N} \times \mathbb{N} \to \mathbb{N}: (n, m) \mapsto mn$
    (C) $f: \mathbb{N} \times \mathbb{N} \to \mathbb{N}: (n, m) \mapsto 3^m 5^n$
    (D) $f: \mathbb{N} \times \mathbb{N} \to \mathbb{N}: (n, m) \mapsto m^n$
    (E) $f: \mathbb{N} \times \mathbb{N} \to \mathbb{N}: (n, m) \mapsto 2^{m+n}$

Correct answer: C
% of correct answers: 44%

17. Consider the function $f: \mathbb{R} \longrightarrow \mathbb{R}: x \mapsto x - \sqrt{x^2 + 5x}$. Which of the following statements is true?
    (A) f is increasing on its domain.
    (B) f is decreasing on its domain.
    (C) f has two distinct zeros.
    (D) $f(x) \leq 0$ for all x in its domain.
    (E) f has both negative as positive values on its domain

Correct answer: D
% of correct answers: 37%

18. Suppose a, b, c and d are real numbers such that $ab < cd$ and $0 < a < c$. Which of the following statements is definitely true?
    (A) $a < cd$
    (B) $b < d$
    (C) $a < \frac{cd}{b}$
    (D) If $d < 0$, then $b < 0$.
    (E) If $b < 0$, then $d < 0$.

Correct answer: D
% of correct answers: 60%

19. The function sgn is defined as follows: $sgn(x) = \begin{cases} \frac{x}{|x|}, & x \neq 0 \\ 0, & x = 0 \end{cases}$. Evaluate $\int_0^4 x\, sgn(2 - x)\, dx$.
    (A) 8
    (B) 4
    (C) 0
    (D) -4
    (E) -8

Correct answer: D
% of correct answers: 34%

20. Suppose $f: \mathbb{R} \longrightarrow \mathbb{R}$ is a differentiable function such that $f(x) \geq 0$ for all $x \in \mathbb{R}$ and $P(5,9)$ is a point on the graph of f. The tangent line to the curve of f at P intersects the x-axis at the point $Q(1,0)$. If a function h is defined as $h: \mathbb{R} \longrightarrow \mathbb{R}: x \mapsto \sqrt{f(x)}$, then $h'(5)$ equals:
    (A) $\frac{3}{8}$
    (B) $\frac{3}{2}$
    (C) $\frac{1}{6}$
    (D) $\frac{9}{8\sqrt{5}}$
    (E) $\frac{2}{27}$

Correct answer: A
% of correct answers: 42%

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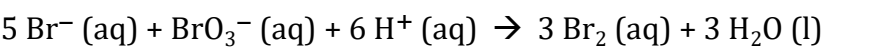
[Chem²ath Contest – Type A]

June 25 (Sat), 2016

1) Consider the following reaction:



$5\ Br^-\ (aq) + BrO_3^-\ (aq) + 6\ H^+\ (aq) \rightarrow 3\ Br_2\ (aq) + 3\ H_2O\ (l)$

The rate expression for this reaction is: $r = k * [Br^-]*[BrO_3^-]*[H^+]^2$

Which statement is correct?

(A) The overall order of the reaction is 12.

(B) Doubling the concentration of all reactants at the same time would increase the rate of the reaction by a factor 16.

(C) The units of the rate coefficient, k, are mol dm^{-3} s^{-1}.

(D) A change in concentration of Br^- does not affect the reaction rate.

2) Which quantity will <u>not</u> change for a sample of gas in a sealed rigid container when it is cooled from 100 °C to 50 °C at constant volume?

(A) The average energy of the molecules

(B) The average speed of the molecules

(C) The pressure of the gas

(D) The density of the gas

3) An oxide of lead contains 90.65% Pb, by weight (M_{Pb} = 207.2 g mol^{-1}). The empirical formula is:

(A) Pb

(B) PbO

(C) Pb_3O_4

(D) Pb_2O_3

(E) PbO_2

4) Calculate the mass of hydrogen gas formed when 25 grams of aluminum reacts with an excess hydrochloric acid in the reaction: $2Al + 6HCl \rightarrow Al_2Cl_6 + 3H_2$ (M_{Al} = 26.98 g mol^{-1}):
   (A) 0.41 g
   (B) 1.2 g
   (C) 1.8 g
   (D) 2.8 g
   (E) 0.92 g

5) Silicon carbide is made by the reaction of silicon dioxide with graphite according to the reaction: $SiO_2 + 3C \rightarrow SiC + 2CO$. If 100 g of SiO_2 and 100 g of C are reacted as far as possible, which one of the following statements will be correct (M_{Si} = 28.085 g mol^{-1})?
   (A) 11 g of SiO_2 will be left over.
   (B) 44 g of SiO_2 will be left over.
   (C) 80 g of C will be left over.
   (D) 40 g of C will be left over.
   (E) Both reactants will be consumed completely, with none of either left over.

6) How many mL of 17 M NH_3 must be diluted to 500.0 mL to make a 0.75 M solution?
   (A) 13 mL
   (B) 23 mL
   (C) 39 mL
   (D) 73 mL
   (E) none of these

7) Balance the molecular equation for the given redox reaction. What is the sum of the coefficients? Don't forget coefficients of one (=1). Use the smallest whole number coefficients possible.

$$H_2SO_4\ (aq) + HI\ (aq) \rightarrow I_2\ (s) + SO_2\ (g)$$

(A) 7
(B) 9
(C) 11
(D) 13
(E) 5

8) For mercury we have the following properties:

Melting point = -39 °C
Boiling point = 357 °C
Heat of fusion = 11.6 J/g at -39 °C
Heat of vaporization = 292 J/g @ 357 °C
Specific Heat (solid) = 0.141 J/g °C
Specific Heat (liquid) = 0.138 J/g °C
Specific Heat (gas) = 0.104 J/g °C

Calculate the amount of heat that must be released to convert 20.0 g of mercury vapor at 387 °C to liquid mercury at 307 °C (in kJ):

(A) 61.9
(B) 6.56
(C) 6.04
(D) 5.69
(E) 5.10

9) The heat of vaporization of freon, CCl_2F_2, is 17.2 kJ mol^{-1} at 25 °C. What is the change of entropy for one mole of liquid freon when it vaporizes at 25 °C?

(A) 57.7 J K^{-1}

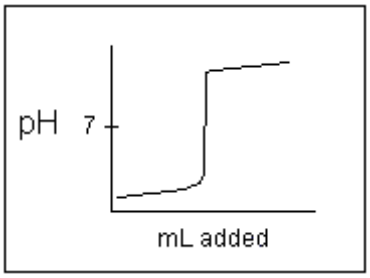
(B) 0.688 J K^{-1}

(C) 5.13 x 10^3 kJ K^{-1}

(D) 3.16 J K^{-1}

(E) 239 J K^{-1}

10) The following titration curve is the kind of curve expected for the titration of a ___ acid with a ___ base.



(A) strong, strong

(B) weak, strong

(C) strong, weak

(D) weak, weak

(E) none of these

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[Chem²ath Contest – Type A]

June 25 (Sat), 2016

11) What is the derivative of the function $f(x) = \frac{\sin(x)}{\cos(x)-\sin(x)}$?

(A) $\frac{1}{1-\sin(2x)}$
(B) $\frac{\cos(2x)}{1-\sin(2x)}$
(C) 1
(D) $\frac{-\cos(x)}{\sin(x)+\cos(x)}$
(E) $\frac{\cos(x)}{\sin(x)-\cos(x)}$

12) Given a circle with radius 5. Starting from the X-axis, we travel along the circumference of the circle. What is the length of the arc that encloses an angle $\theta = \frac{1}{5}$ rad.

(A) 2π
(B) $\frac{2\pi}{5}$
(C) 1
(D) 5π
(E) 5

13) Determine the equation of the tangent to the circle with center $(-2,0)$ and radius $\sqrt{5}$ in the point $(-4,1)$.

(A) $2x + y = -8$
(B) $-2x - y = 7$
(C) $\frac{1}{2}x + y = -1$
(D) $-2x + y = 9$
(E) $-\frac{1}{2}x + y = 3$

14) If $x^4 + 4x^3 + 6px^2 + 4qx + r$ is divisible by $x^3 + 3x^2 + 9x + 3$, then $p(q + r)$ is equal to

(A) 12
(B) 15
(C) 18
(D) 21
(E) 24

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[Chem²ath Contest – Type A]

June 25 (Sat), 2016

15) Calculate, if possible, the limit $\lim_{x\to 1/2} \frac{4x^3-3x+1}{4x^3-4x^2+x}$.

(A) This limit exists and is equal to 0
(B) This limit exists and is equal to1
(C) This limit exists and lies in the interval [2, 2016]
(D) This limit exists and is equal to $+\infty$
(E) This limit does not exist

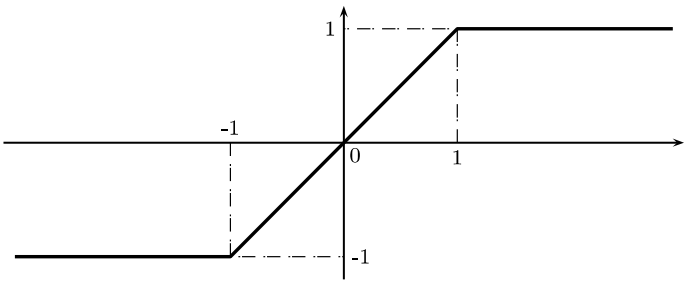
16) Which of the following integrals is strictly positive?

(A) $\int_{-\pi}^{\pi} \frac{\sin x}{1+x^2}\,dx$
(B) $\int_{-\pi}^{\pi} \frac{\cos x}{1+x^2}\,dx$
(C) $\int_{-\pi}^{\pi} x^4 \sin x\,dx$
(D) $\int_{-\pi}^{\pi} x^4 \cos x\,dx$
(E) $\int_{0}^{\pi} \left(x-\frac{\pi}{2}\right)^2 \cos x\,dx$

17) Consider the curve with equation $y = x^{3/2}$. Which point on this curve has the smallest distance to the point (1/2,0)?

(A) $(0,0)$
(B) $(\frac{1}{2}, \frac{1}{2^{3/2}})$
(C) $(\frac{1}{3}, \frac{1}{3^{3/2}})$
(D) $(\frac{1}{4}, \frac{1}{4^{3/2}})$
(E) $(1,1)$

18) Consider the function $f: \mathbb{R} \to \mathbb{R}$ with the following graph



Let $g: \mathbb{R} \to \mathbb{R}$ be an arbitrary function. Which of the following statements is true?

(A) If $g(x) = g(1-x)$ for all $x \in \mathbb{R}$, then $f\big(g(x)\big) = g(x)$ for all $x \in \mathbb{R}$
(B) If $g(x) = g(1-x)$ for all $x \in \mathbb{R}$, then $g\big(f(x)\big) = g(x)$ for all $x \in \mathbb{R}$
(C) If $-1 \leq g(x) \leq 1$ for all $x \in \mathbb{R}$, then $f\big(g(x)\big) = g(x)$ for all $x \in \mathbb{R}$
(D) If $-1 \leq g(x) \leq 1$ for all $x \in \mathbb{R}$, then $g\big(f(x)\big) = g(x)$ for all $x \in \mathbb{R}$
(E) If $g(x) = g(1-x)$ and $-1 \leq g(x) \leq 1$ for all $x \in \mathbb{R}$, then $g\big(f(x)\big) = g(x)$ for all $x \in \mathbb{R}$

19) Order the following real numbers from small to large:

$$a = \int_0^1 e^{-(x-1)^2}\,dx$$

$$b = \int_0^1 e^{-x^2}\,dx$$

$$c = \int_0^1 e^{-(x+1)^2}\,dx$$

(A) $a < b < c$
(B) $a = b < c$
(C) $c < b < a$
(D) $c < b = a$
(E) $a = b = c$

20) Given the function

$$f: \mathbb{R} \to \mathbb{R}: x \mapsto f(x) = \int_0^{x+2\pi} \frac{2t}{1+\sin^2 t}\,dt$$

What is the value of f' in $\frac{\pi}{2}$?

(A) 0
(B) $\frac{\pi}{2}$
(C) $\frac{5\pi}{2}$
(D) 5π
(E) 2

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[Chem²ath Contest – Type A]

June 25 (Sat), 2016

Answers:

1	B
2	D
3	C
4	D
5	D
6	B
7	A
8	C
9	A
10	A
11	A
12	C
13	D
14	A
15	C
16	B
17	C
18	C
19	D
20	C