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Physics and Chemistry

preparing students for exams

Ana Oliveira | June 4, 2023

Integrated Masters in Medicine
Model Exam | Access for International Students | 2023/2024

1. On Earth, virtually all nitrogen atoms have a mass number of 14 or 15. The mass of a nitrogen atom will, on average, be _____ times greater than the mass of a carbon-12 atom, the most abundant isotope of nitrogen or _____.

(A) 1,17 ... ^{14}N
(B) 1,17 ... ^{15}N
(C) 14,01 ... ^{14}N
(D) 14,01 ... ^{15}N

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(D) 14,01 ... ^{15}N

$$\frac{N}{C} = \frac{14.01}{12.01} = 1.17$$

1																	18
1 H 1,01	2											13	14	15	16	17	2 He 4,00
3 Li 6,94	4 Be 9,01	Número atómico Elemento Massa atómica relativa										5 B 10,81	6 C 12,01	7 N 14,01	8 O 16,00	9 F 19,00	10 Ne 20,18
11 Na 22,99	12 Mg 24,31	3	4	5	6	7	8	9	10	11	12	13 Aℓ 26,98	14 Si 28,09	15 P 30,97	16 S 32,07	17 Cℓ 35,45	18 Ar 39,95
19 K 39,10	20 Ca 40,08	21 Sc 44,96	22 Ti 47,87	23 V 50,94	24 Cr 52,00	25 Mn 54,94	26 Fe 55,85	27 Co 58,93	28 Ni 58,69	29 Cu 63,55	30 Zn 65,41	31 Ga 69,72	32 Ge 72,64	33 As 74,92	34 Se 78,96	35 Br 79,90	36 Kr 83,80
37 Rb 85,47	38 Sr 87,62	39 Y 88,91	40 Zr 91,22	41 Nb 92,91	42 Mo 95,94	43 Tc 97,91	44 Ru 101,07	45 Rh 102,91	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 132,91	56 Ba 137,33	57-71 Lantanídeos	72 Hf 178,49	73 Ta 180,95	74 W 183,84	75 Re 186,21	76 Os 190,23	77 Ir 192,22	78 Pt 195,08	79 Au 196,97	80 Hg 200,59	81 Tℓ 204,38	82 Pb 207,21	83 Bi 208,98	84 Po [208,98]	85 At [209,99]	86 Rn [222,02]
87 Fr [223]	88 Ra [226]	89-103 Actinídeos	104 Rf [261]	105 Db [262]	106 Sg [266]	107 Bh [264]	108 Hs [277]	109 Mt [268]	110 Ds [271]	111 Rg [272]							

2. What is the name of the represented compound, according to IUPAC nomenclature?

(A) 2-propyl-1-butene
(B) 2-propyl-1-butane
(C) 4-ethyl-4-pentane
(D) 2-ethyl-1-pentene

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Resolution steps:

1) Identify the family of the organic compound

2) Identify the main chain

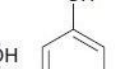
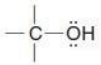
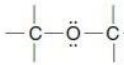
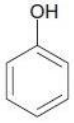
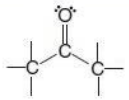
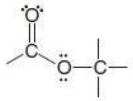
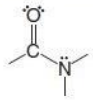
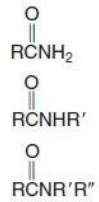
3) Name the compound

Learn more

https://www.angelo.edu/faculty/kboudrea/organic/IUPAC_Handout.pdf

To know

Important families of ORGANIC COMPOUNDS

	Family							
	Alkane	**Alkene**	**Alkyne**	**Aromatic**	**Haloalkane**	**Alcohol**	**Phenol**	**Ether**
Functional group	C—H and C—C bonds			Aromatic ring				
General formula	RH	$RCH=CH_2$ $RCH=CHR$ $R_2C=CHR$ $R_2C=CR_2$	$RC\equiv CH$ $RC\equiv CR$	ArH	RX	ROH	ArOH	ROR
Specific example	CH_3CH_3	$CH_2=CH_2$	$HC\equiv CH$		CH_3CH_2Cl	CH_3CH_2OH		CH_3OCH_3
IUPAC name	Ethane	Ethene	Ethyne	Benzene	Chloroethane	Ethanol	Phenol	Methoxymethane
Common name[a]	Ethane	Ethylene	Acetylene	Benzene	Ethyl chloride	Ethyl alcohol	Phenol	Dimethyl ether
	Amine	**Aldehyde**	**Ketone**	**Carboxylic Acid**	**Ester**	**Amide**		**Nitrile**
Functional group								
General formula	RNH_2 R_2NH R_3N							RCN
Specific example	CH_3NH_2							$CH_3C\equiv N$
IUPAC name	Methana-mine	Ethanal	Propanone	Ethanoic acid	Methyl ethanoate	Ethanamide		Ethanenitrile
Common name	Methyl-amine	Acetaldehyde	Acetone	Acetic acid	Methyl acetate	Acetamide		Acetonitrile

[a]These names are also accepted by the IUPAC.

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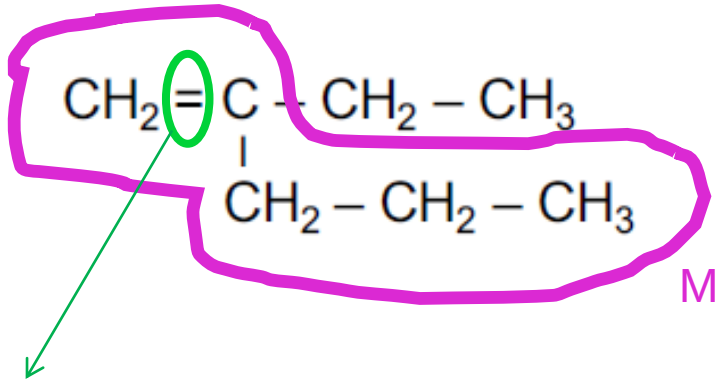
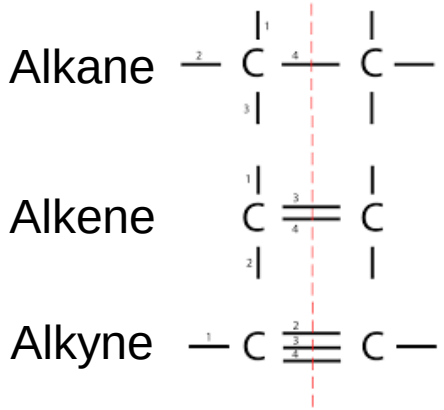


Main chain - highest number of carbons

Alkene family - ending in ene



Hydrocarbons "families":

- **Alkanes** (single bond) C_nH_{2n+2}
- **Alkenes** (double bond) C_nH_{2n}
- **Alkynes** (triple bond) C_nH_{2n-2}

3. A diprotic base ($X(OH)_2$), existing in an aqueous solution, has a concentration of $2.05x10^{-3}$ mol L^{-1} at 25°C. Assuming that the ionization of the base is complete, the pH of the base is:

(A) 2.4
(B) 3.0
(C) 11.0
(D) 11.6

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Resolution steps:

1) Write the equilibrium reaction: if ionization is complete, the reaction is complete and, therefore, irreversible

2) Calculate OH^- concentration: establish the relationship between the concentration of OH^-, $[OH^-]$, and the concentration of $X(OH)_2$, $[X(OH)_2]$

3) Calculate pOH

4) Calculate pH

To know

$$pOH = -log[OH^-] \Leftrightarrow [OH^-] = 10^{-pOH}$$

$$pH = -log[H^+] \Leftrightarrow [H^+] = 10^{-pH}$$

or

$$pH = -log[H_3O^+] \Leftrightarrow [H_3O^+] = 10^{-pH}$$

$$at\ 25°C: \quad pH + pOH = 14$$

3. A diprotic base ($X(OH)_2$), existing in an aqueous solution, has a concentration of 2.05×10^{-3} mol L^{-1} at 25°C. Assuming that the ionization of the base is complete, the pH of the base is:

(A) 2.4
(B) 3.0
(C) 11.0
(D) 11.6

ionization is complete (strong base), the reaction is irreversible

stoichiometric coefficient

$$X(OH)_2\ (aq) \rightarrow X^{2+}\ (aq) + 2OH^-(aq)$$

	$X(OH)_2\ (aq)$	$X^{2+}\ (aq)$	$2OH^-(aq)$
beginning:	y	0	0
equilibrium:	0	y	**2** y

$$[OH^-] = 2 \times [X(OH)_2] = 2 \times (2.05 \times 10^{-3}) = 4.1 \times 10^{-3}\ mol\ L^{-1}$$

$$pOH = -log[OH^-] = -log(4.1 \times 10^{-3}) = 2.39$$

$$pH + pOH = 14 \Leftrightarrow pH + 2.39 = 14 \Leftrightarrow pH = 11.61$$

4. Dimethylsulfoxide [$(CH_3)_2SO$] is an important solvent that penetrates the skin allowing its use as a delivery agent for topical medications. What volume of dimethylsulfoxide is needed to prepare 250 mL of a 0.150 mol L^{-1} solution? Consider the density of dimethylsulfoxide of 1.013 g mL^{-1} and the molar mass of 78 g mol^{-1}.

(A) $V = \frac{0.150\text{mol/L} \times 250\text{mL} \times 78\text{g/mol}}{1000 \times 1.013\text{g/mL}}\ mL$

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Resolution steps:

1) Calculate the number of moles - from the concentration

2) Calculate the mass - from the molar mass

3) Calculate the volume - from the density

To know

$$Concentration\ (mol\ L^{-1}):\ [X] = \frac{n}{V}$$

$$Molar\ mass\ (g\ mol^{-1}):\ M = \frac{m}{n}$$

$$Density\ (g\ cm^{-3}):\ \rho = \frac{m}{V}$$

Learn more

https://chem.libretexts.org/Courses/Prince_Georges_Community_College/CHEM_2000%3A_Chemistry_for_Engineers_(Sinex)/Unit_4%3A_Nomenclature_and_Reactions/Chapter_12%3A_Aqueous_Reactions/Chapter_12.1%3A_Preparing_Solutions

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Exercise data:

$V = 250\ mL = 250 \times 10^{-3}\ L$

$[(CH_3)_2SO] = 0.150\ mol\ L^{-1}$

$M = 78\ g\ mol^{-1}$

$\rho = 1.013\ g\ mL^{-1}$

$$[(CH_3)_2SO] = \frac{n}{V} \Leftrightarrow \boldsymbol{n} = [(CH_3)_2SO] \times V = 0.150 \times (250 \times 10^{-3}) = \frac{0.150 \times 250}{1000}\ mol$$

$$M = \frac{m}{n} \Leftrightarrow \boldsymbol{m} = M \times n = 78 \times \frac{0.150 \times 250}{1000}\ g$$

$$\rho = \frac{m}{V} \Leftrightarrow \boldsymbol{V} = \frac{m}{\rho} = \frac{78 \times \frac{0.150 \times 250}{1000}}{1.013} = \frac{78 \times 0.150 \times 250}{1000 \times 1.013}\ mL$$

5. The formation of H_2SO_4 (aq) from SO_2 (g) can be broadly translated by $2\,SO_2(g) + 2\,H_2O(l) + O_2(g) \rightarrow 2\,H_2SO_4(aq)$

In this reaction, sulfur:

(A) is reduced, and its oxidation number decreases.

(B) it oxidizes, and its oxidation number increases.

(C) it oxidizes, and its oxidation number decreases.

(D) is reduced, and its oxidation number increases.

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(C) it oxidizes, and its oxidation number decreases.

(D) is reduced, and its oxidation number increases.

Resolution steps:

1) Calculate the oxidation number (nox) of sulfur

2) Check the variation of nox and conclude about the oxidation or reduction of sulfur

Learn more

https://www.youtube.com/watch?v=iSAwDJTLIKY

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(D) is reduced, and its oxidation number increases.

$$2SO_2\ (g) + 2H_2O\ (l) + O_2\ (g) \rightarrow 2H_2SO_4\ (aq)$$

$x + (-2) \times 2 = 0$

$x = 4 \rightarrow nox = +4$

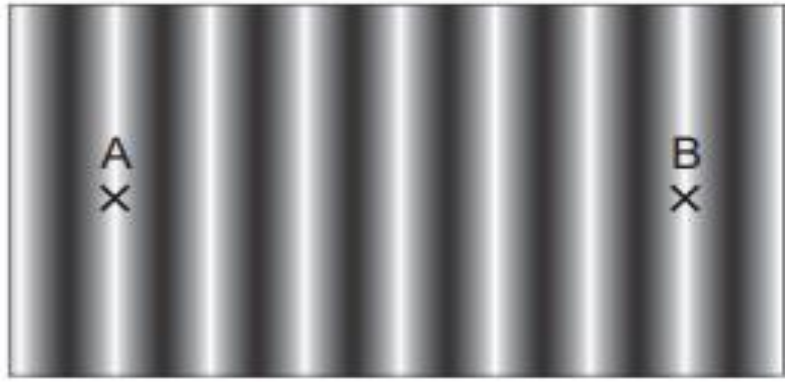
$1 \times 2 + x + (-2) \times 4 = 0$

$x = 6 \rightarrow nox = +6$

nox increases, thus undergoes oxidation

6. The Figure presents an image of the waves obtained in a wave trough, in a given experiment. The figure also shows two points, A and B, on the surface of the water.

Assume that the wave generator is set to 5.0 Hz and that the image is obtained at time t. How much time will elapse, at least, between time t and a time when point A is in a valley?



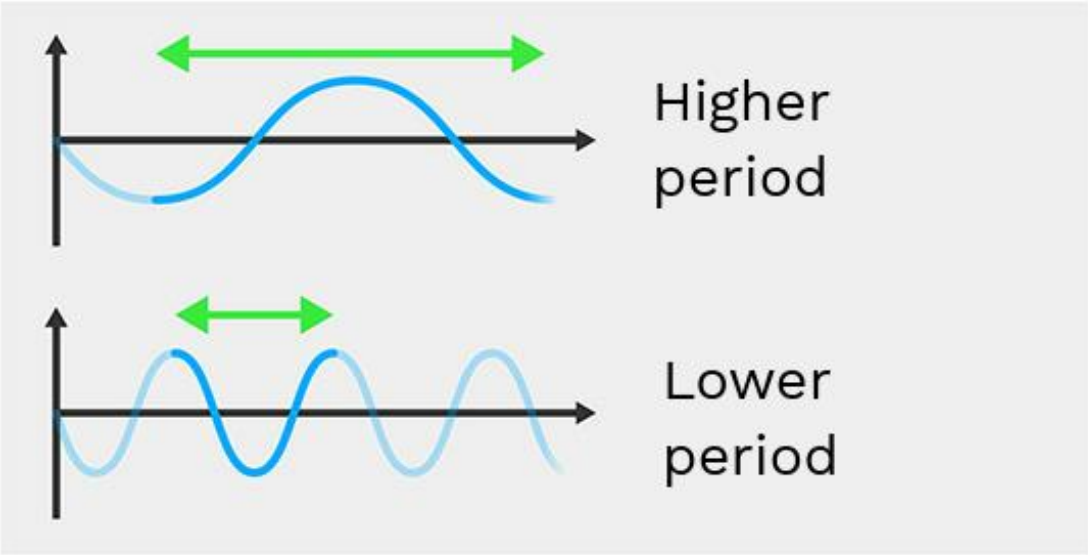
(A) 0.15 s.

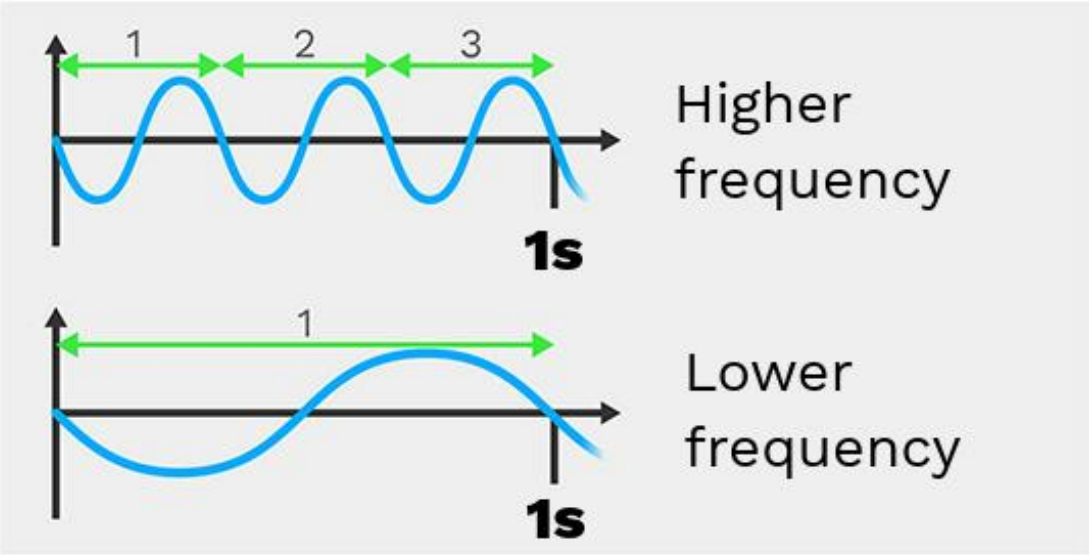
(B) 0.20 s.

(C) 0.10 s.

(D) 0.05 s.

To know





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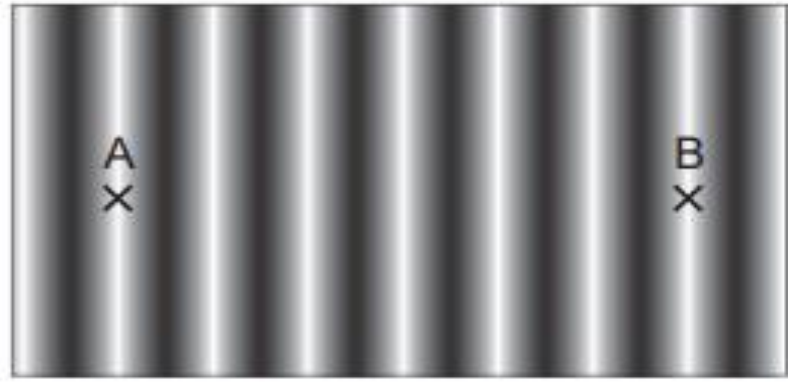


(A) 0.15 s.

(B) 0.20 s.

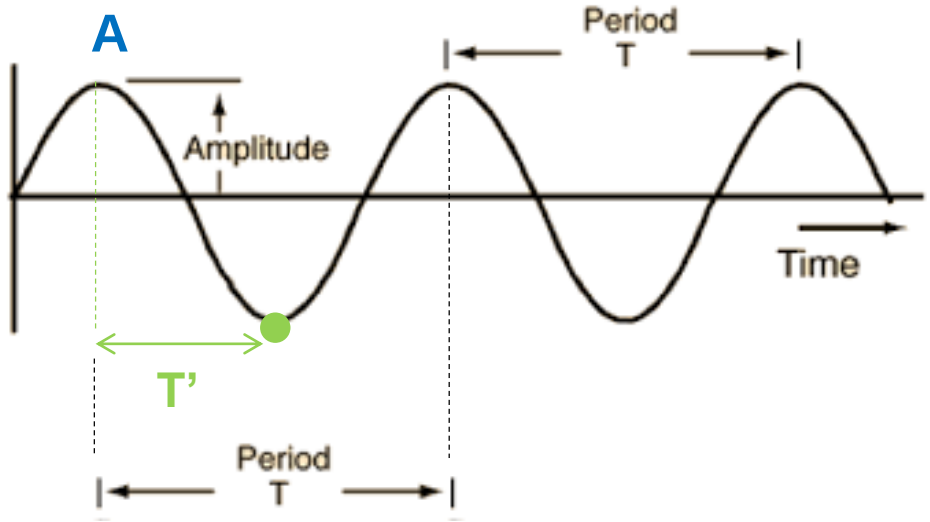
(C) 0.10 s.

(D) 0.05 s.

$$f = 5.0\ Hz$$

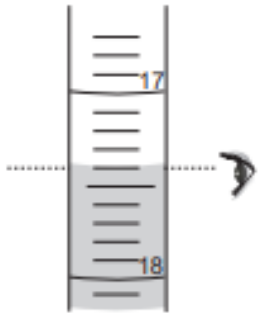
$$f = \frac{1}{T} \Leftrightarrow T = \frac{1}{f} = \frac{1}{5.0} = 0.2\ s$$

$$T' = \frac{T}{2} = \frac{0.2}{2} = 0.1\ s$$



T = 0.2 s

7. Assume that, to carry out a titration of a solution of an acid, a 50 mL burette was first filled with a standard solution of NaOH, the liquid level being checked with zero on the scale. The figure shows the level of titrant in the burette at a given point in the titration.



Select the only option that displays the measurement result of the volume of titrant spent up to that point in the titration.

(A) (18.60 ± 0.05) cm^3

(B) (17.40 ± 0.05) cm^3

(C) (17.4 ± 0.1) cm^3

(D) (18.6 ± 0.1) cm^3

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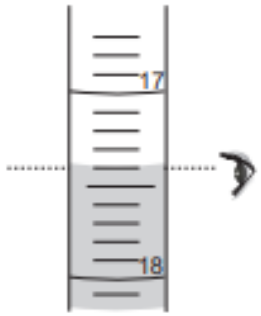

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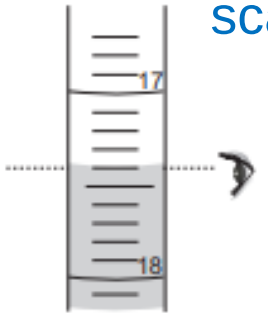


scale = 0.1 mL = 0.1 cm^3

17.4 mL = 17.4 cm^3

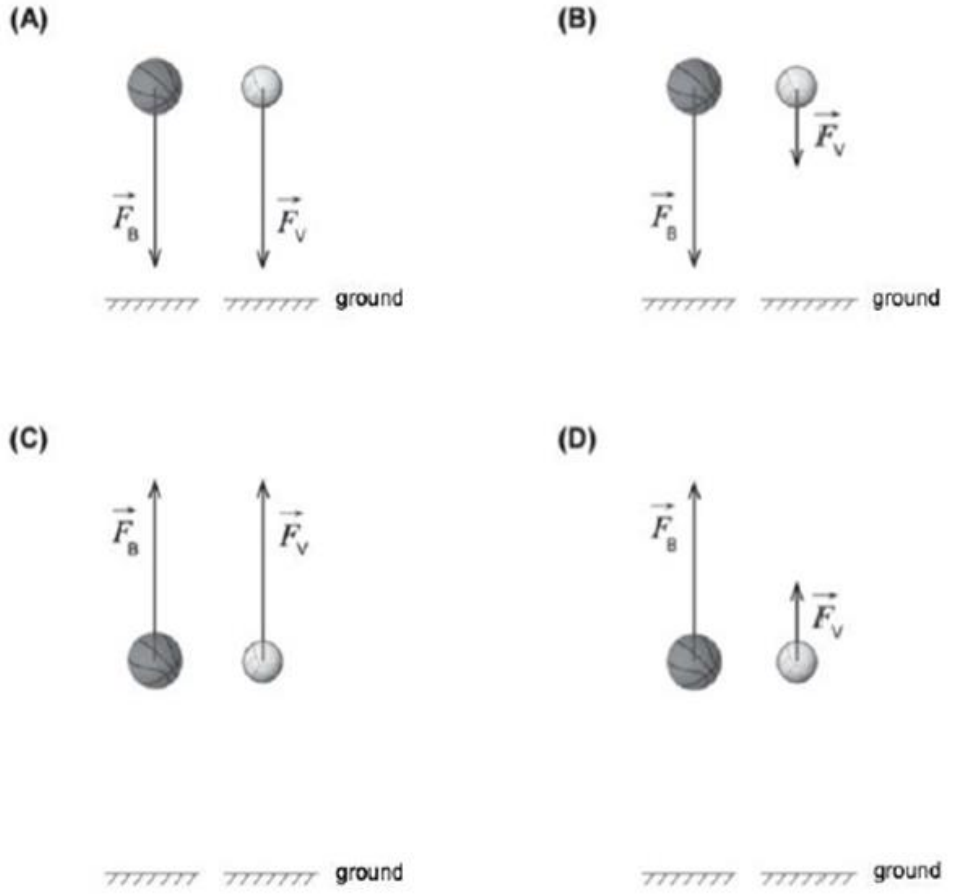
$$Precision = \frac{scale}{2} = \frac{0.1}{2} = 0.05$$

burette

8. A basketball, B, and a volleyball, V, were launched vertically, from the bottom up, with the mass of ball B greater than the mass of ball V. The launches were repeated, changing the initial conditions.

Consider negligible air resistance and assume that the balls can be represented by their center of mass (material particle model).

8.1. Consider the upward motion of the balls after the release. Which of the options can represent, on the same scale, the resultant of the forces acting on the basketball, $\vec{F}_B$, and the resultant of the forces acting on the volleyball, $\vec{F}_V$?



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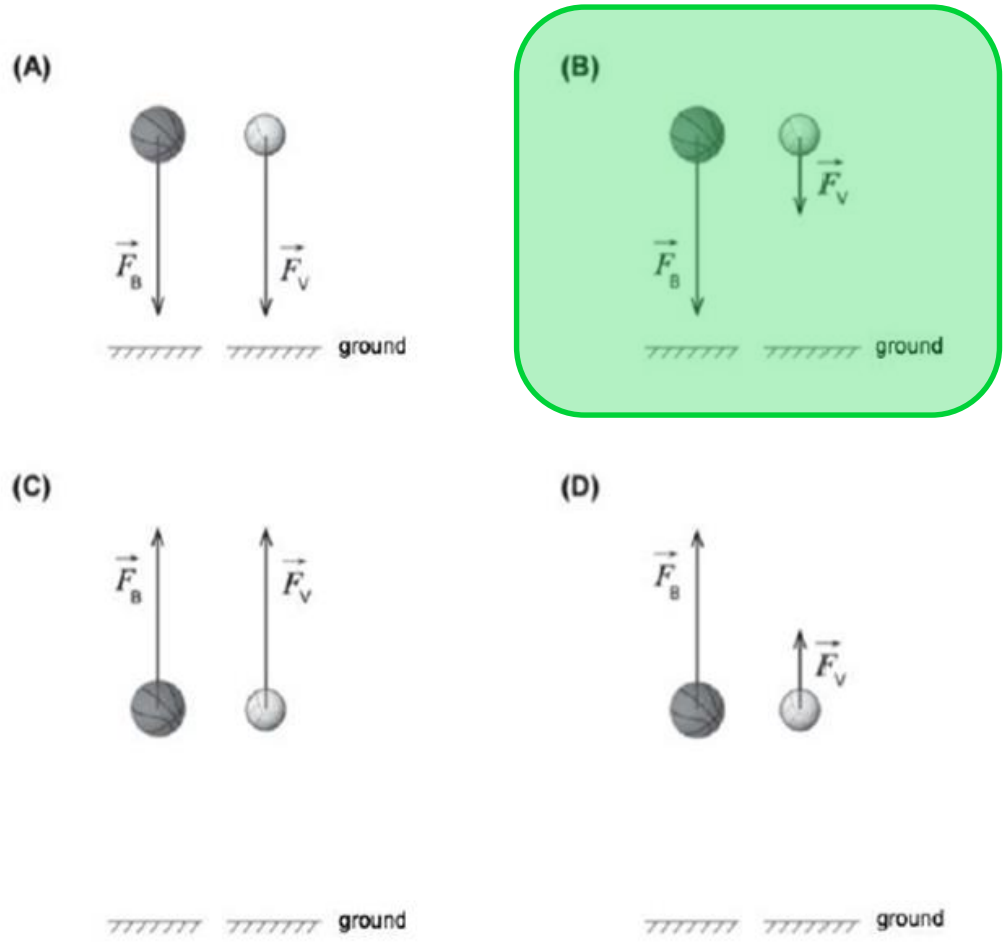
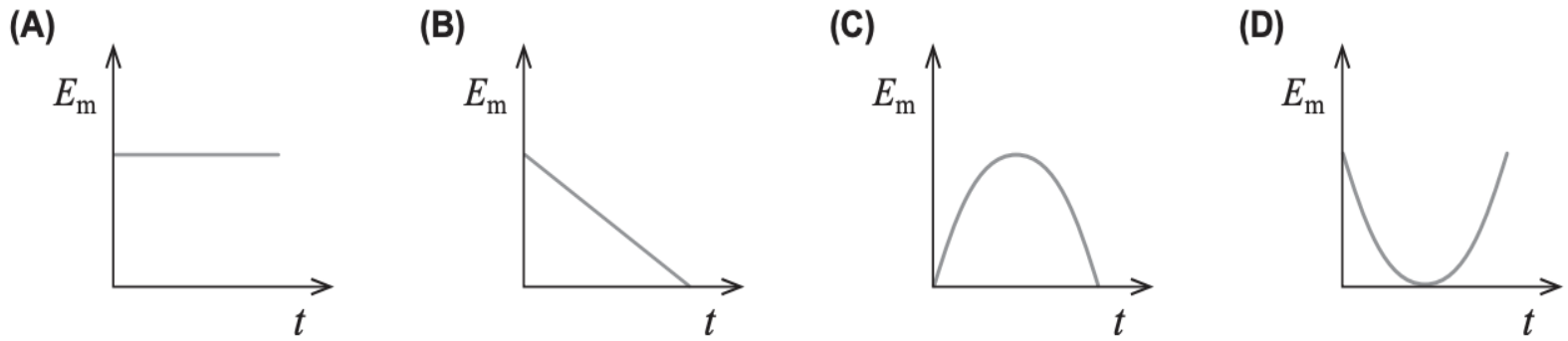


$m_B > m_A$ therefore $F_B > F_A$

Considering the upward motion of the balls,
the force acting on the balls is gravity

8.2. Consider the motion of the basketball from the instant immediately after the first collision with the ground to the instant just before the second collision with the ground. Which of the following sketches of graph can represent the mechanical energy, E_m, of the basketball + Earth system, as a function of time, t, in the considered motion?



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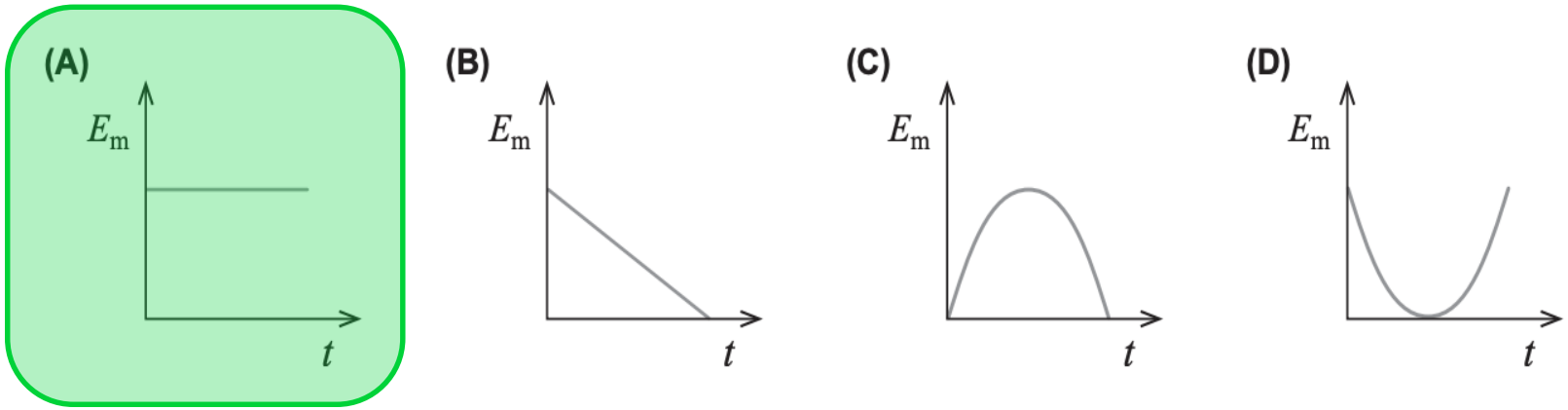

E_m of the system is constant with time

9. Through single-glazed windows, energy is transferred between the outside and the inside of a house, in the form of heat, by conduction.

The living room of a house has a single-glazed window that looks out onto the house. The glass of this window, of thermal conductivity 0.8 Wm, measures 1.5 m high, 1.2 m wide and 5.0 mm thick.

Which of the following expressions allows you to calculate the energy transferred, in the form of heat, through the glass of this window, in each second, if the temperature difference between the outside of the house and the inside of the room is 10°C?

(A) $\left(0.8 \times \frac{1.5 \times 1.2}{5.00 \times 10^{-3}} \times (10 + 273)\right)\text{J}$

(B) $\left(0.8 \times \frac{1.2 \times 5.00 \times 10^{-3}}{1.5} \times (10 + 273)\right)\text{J}$

(C) $\left(0.8 \times \frac{1.5 \times 1{,}2}{5.00 \times 10^{-3}} \times 10\right)\text{J}$

(D) $\left(0.8 \times \frac{1.2 \times 5.00 \times 10^{-3}}{1.5} \times 10\right)\text{J}$

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(D) $\left(0.8 \times \frac{1.2 \times 5.00 \times 10^{-3}}{1.5} \times 10\right) \text{J}$

Exercise data:

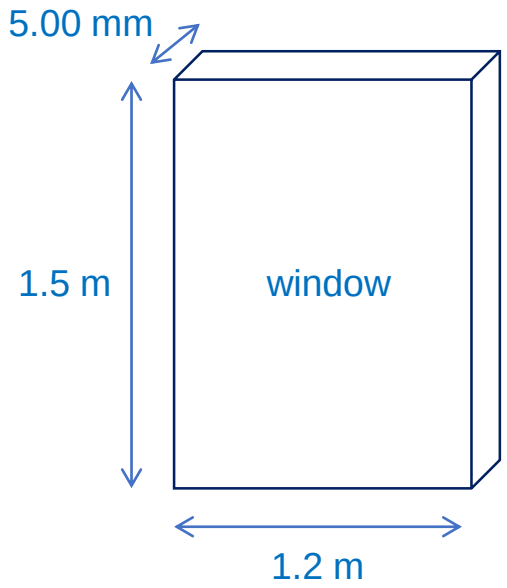
$k = 0.8\ Wm$

$high = 1.5\ m$

$wide = 1.2\ m$

$thick(l) = 5.0\ mm = 5.0 \times 10^{-3}\ m$

$T = 10°C$



$$A\ (window\ area) = high\ \times\ wide = 1.5 \times 1.2\ m^2$$

Temporal rate of energy transfer in the form of heat, by conduction *(the formula is in the form of the exam):*

$$\frac{Q}{\Delta t} = k \cdot \frac{A}{l} \cdot \Delta T$$

$$\frac{Q}{\Delta t} = k \cdot \frac{A}{l} \cdot \Delta T \Leftrightarrow \frac{Q}{\Delta t} = 0.8 \times \frac{(1.5 \times 1.2)}{5.00 \times 10^{-3}} \times 10$$

10. Iodine, I_2 (g), reacts with hydrogen, H_2 (g), in the gas phase to form hydrogen iodide, HI (g). The reaction can be translated as: $I_2(g) + H_2(g) \rightleftharpoons 2\,HI(g)$

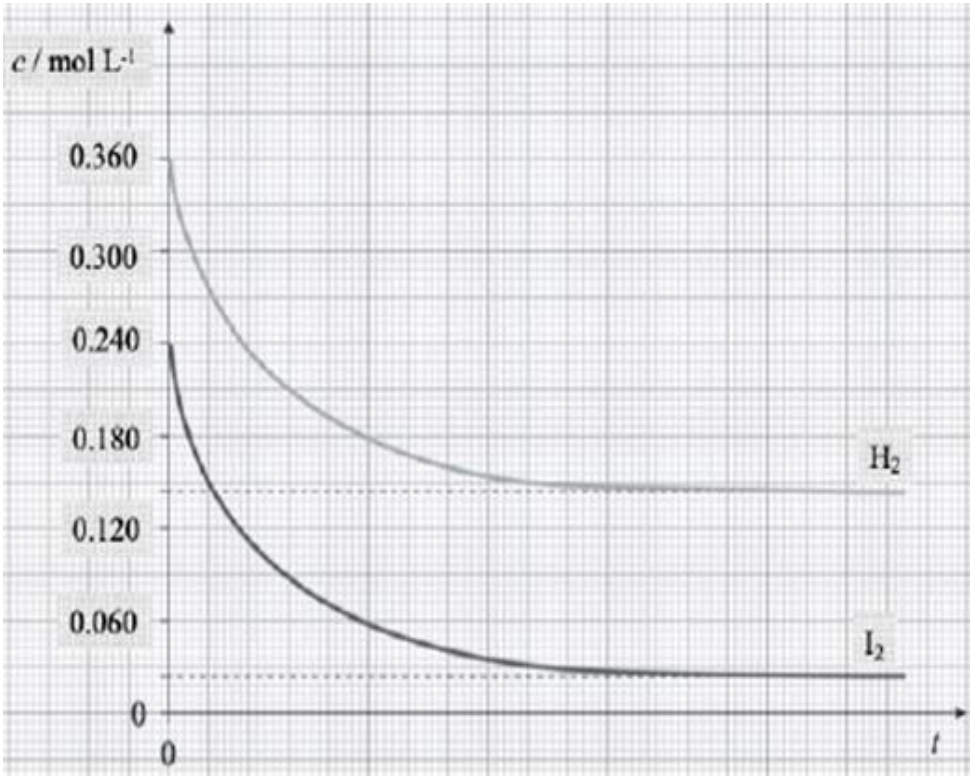
In this reaction, the enthalpy change associated with the formation of 2 mol of HI (g) as a value of -9.2 kJ.

10.1. Consider that, at temperature T, a mixture of H_2 (g) and I_2 (g) in different concentrations was introduced into a reactor with a capacity of 1.00 L, initially there being no HI (g) in the reactor.

The graph in the figure shows the evolution, over time, t, of the concentrations, c, of the reactants.

Calculate the equilibrium constant, K_c, of the considered reaction at temperature T.

Present all stages of resolution.



Resolution steps:

1) Interpret the graph:

- identify the reactants (concentration decreases until equilibrium) and the products (initial concentration is zero and increases until equilibrium)

- identify initial and equilibrium concentrations

2) Elaborate the balance sheet

3) Determine the amount of reactants that reacted

4) Determine the equilibrium concentrations of the products

5) Calculate the equilibrium constant (K_c)

Learn more

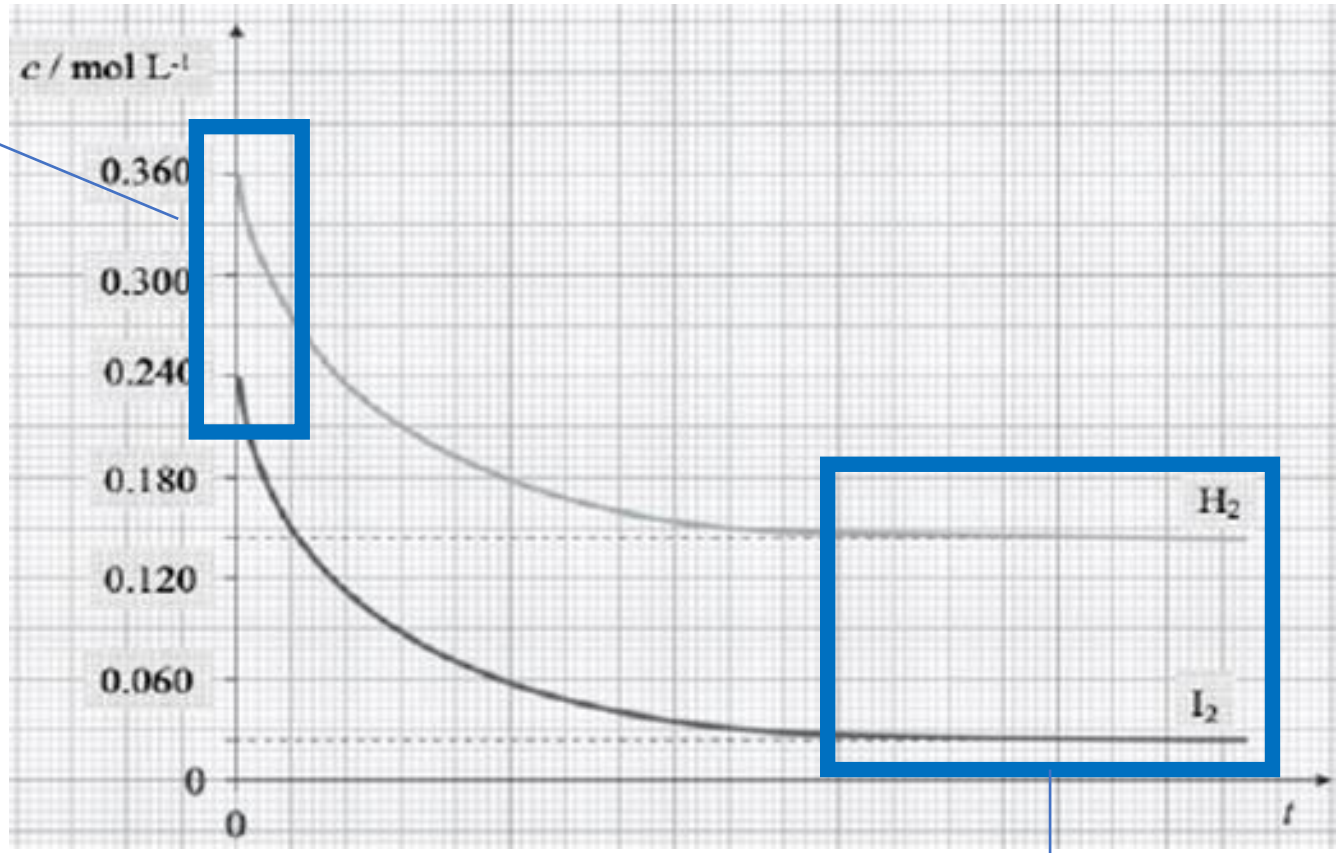
https://chem.libretexts.org/Bookshelves/Introductory_Chemistry/Chemistry_for_Allied_Health_(Soult)/08%3A_Properties_of_Solutions/8.02%3A_Chemical_Equilibrium

https://www.youtube.com/watch?v=1GiZzCzmO5Q

$$I_2(g) + H_2(g) \rightleftharpoons 2\,HI(g)$$

Beginning: initial concentrations

At the beginning the concentration of HI is zero because tehe reaction haven´t started



Equilibrium: concentration is constant with time

stoichiometric coefficient

$$I_2\,(aq) + H_2\,(aq) \rightleftarrows 2HI\,(aq)$$

	$I_2\,(aq)$	$H_2\,(aq)$	$2HI\,(aq)$
beginning:	0.240	0.360	0
reacted:	x	x	**2** x
equilibrium:	0.024	0.144	

values from the graph

what reacted:

$$x = [I_2] = 0.240 - 0.024 = 0.216\ mol\ L^{-1}$$

$$x = [H_2] = 0.360 - 0.144 = 0.216\ mol\ L^{-1}$$

equilibrium: $[HI]_{eq} = 2x = 2 \times 0.216 = 0.432\ mol\ L^{-1}$

stoichiometric coefficient

$$I_2\,(aq) + H_2\,(aq) \rightleftarrows 2HI\,(aq)$$

Equilibrium constant (K_c):

$$K_c = \frac{[HI]_{eq}^2}{[I_2]_{eq} \times [H_2]_{eq}} = \frac{(0.432)^2}{0.024 \times 0.144} = 54$$

10.2. Conclude how the composition of the system will change if the temperature decreases at constant volume. Present in a text the reasons for the requested conclusion.

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Resolution steps:

1) Identify whether the reaction is exothermic ($\Delta H < 0$ kJ) or endothermic ($\Delta H > 0$ kJ)

2) Check the number of moles of reactants and products (just add the stoichiometric coefficients of reactants and products)

3) Predict in which direction the system will evolve, according to the Principle of le Cahtelier

Learn more

https://chem.libretexts.org/Bookshelves/Physical_and_Theoretical_Chemistry_Textbook_Maps/Supplemental_Modules_(Physical_and_Theoretical_Chemistry)/Equilibria/Le_Chateliers_Principle

https://www.youtube.com/watch?v=XmgRRmxS3is

$$I_2\,(aq) + H_2\,(aq) \rightleftarrows 2HI\,(aq) \qquad \Delta H = -9.2\,kJ$$

$$\Delta H < 0 \Longrightarrow Exothermic\ reaction$$

According to Le Chatelier's Principle the system will evolve in the direct direction of the reaction.

Thus, the I_2 and H_2 concentrations will decrease and the HI concentration will increase.

11. Hydrofluoric acid, HF (aq), is a weak acid whose ionization reaction in water can be translated as:

$$HF(aq) + H_2O(l) \rightleftharpoons F^-(aq) + H_3O^+(aq)$$

The pH of a 0.020 mol L^{-1} hydrofluoric acid solution is 2.45 at 25°C. calculate the percentage of unionized acid in this solution. Write the expression for the basicity constant, K_b, of the conjugate base of hydrofluoric acid. Present all stages of resolution.

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Learn more

https://www.youtube.com/watch?v=pkqDTi2K-5g

Exercise data:

$pH = 2.45$

$[HF] = 0.020\ mol\ L^{-1}$

$$HF(aq) + H_2O(l) \rightleftharpoons F^-(aq) + H_3O^+(aq)$$

$$pH = -log[H_3O^+] \Leftrightarrow [H_3O^+] = 10^{-pH} = 10^{-2.45} = 0.0035\ mol\ L^{-1}$$

$$\%_{ionized} = \frac{reacted}{initial} \times 100 = \frac{0.0035}{0.020} \times 100 = 17.74\%$$

$$\%_{unionized} = 100 - \%_{ionized} = 100 - 17.74 = 82.26\%$$

ACID: $HF(aq) + H_2O(l) \rightleftharpoons F^-(aq) + H_3O^+(aq)$

$$K_a = \frac{[F^-] \times [H_3O^+]}{[HF]}$$

Attention: the concentration of water, in the liquid state, is never included in the equilibrium constant

BASE: $F^-(aq) + H_2O(l) \rightleftarrows HF(aq) + OH^-(aq)$

$$K_b = \frac{[HF] \times [OH^-]}{[F^-]}$$

12. For an irradiance of 1000 W m^{-2} and at 25°C, a photovoltaic panel, with an area of 1.63 m^2, provides maximum electrical power when the potential difference across its terminals as a value of 28.5 V and the electrical current is 7.6 A.

Determine the maximum efficiency of the panel, under the considered conditions.

Present all the resolution steps, explaining all the calculations performed.

12. For an irradiance of 1000 W m^{-2} and at 25°C, a photovoltaic panel, with an area of 1.63 m^2, provides maximum electrical power when the potential difference across its terminals as a value of 28.5 V and the electrical current is 7.6 A.

Determine the maximum efficiency of the panel, under the considered conditions.

Present all the resolution steps, explaining all the calculations performed.

Resolution steps:

1) Calculate the electrical power

2) Calculate the radiation power

3) Calculate efficiency

Learn more

https://www.youtube.com/watch?v=IxFIewx54Ok

Exercise data:

$A = 1.63\ m^2$

$E = 1000\ Wm^{-2}$

$U = 28.5\ V$

$I = 7.6\ A5$

Resolution:

$$P_{eletric} = U \cdot I = 28.5 \times 7.6 = 216.6\ W$$

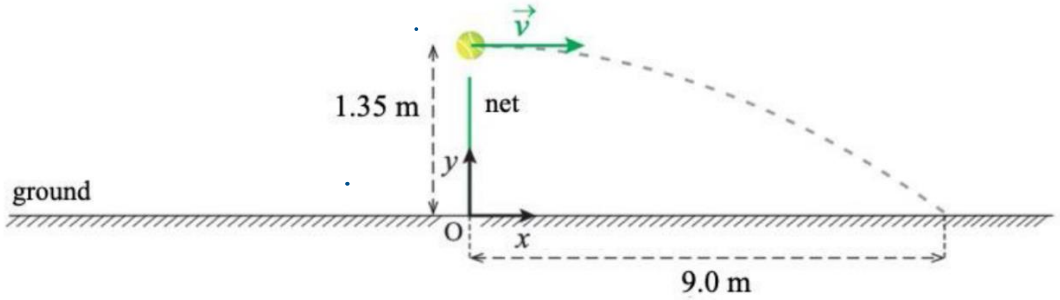
$$P_{radiation} = A \cdot E = 1.63 \times 1000 = 1630\ W$$

$$\eta = \frac{P_{eletric}}{P_{radiation}} \times 100 = \frac{216.6}{1630} \times 100 = 13.3\%$$

13. The figure (not to scale) represents a tennis ball that passes over the net of a tennis court with horizontal velocity, $\vec{v}$, describing a parabolic trajectory until it hits the ground.

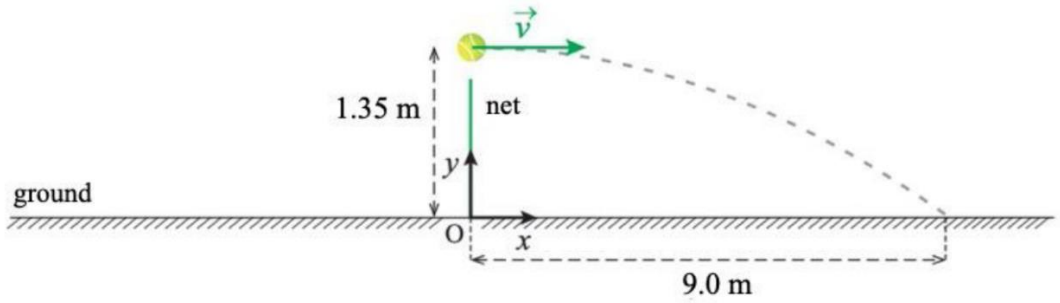
Assume that the air resistance force is negligible and assume that the ball can be represented by its center of mass (material particle model).

Consider the two-dimensional frame of reference shown in the figure.



The ball passes over the net at 1.35 m from the ground and hits the ground at 9.0 m from the net, as shown in the figure. Calculate the magnitude of the speed with which the ball hits the ground.

Present all stages of resolution.



Exercise data:

$y_0 = 1.35\ m$ $\quad y_F = 0\ m$

$x_0 = 0\ m$ $\quad x_F = 9\ m$

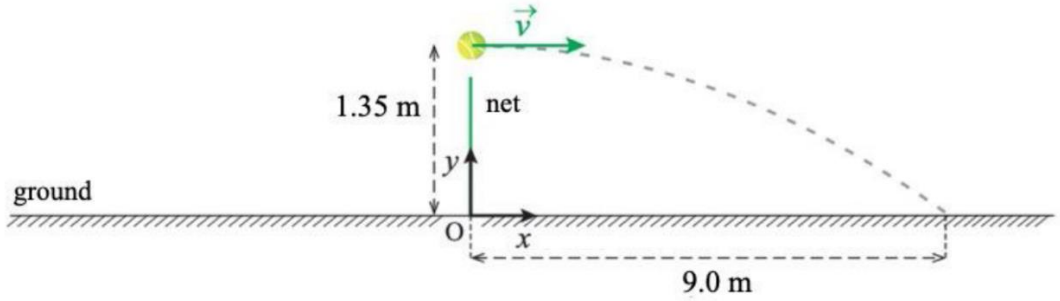
Resolution:

1) Calculate the time

$$\Delta y = v_{0y}t - \frac{1}{2}gt^2 \Leftrightarrow y_F - y_0 = 0 - \frac{1}{2}gt^2$$

$$0 - 1.35 = 0 - \frac{1}{2} \times 9.8 \times t^2 \Leftrightarrow t = \sqrt{\frac{1.35 \times 2}{9.8}}$$

$$t = 0.525\ s$$



Exercise data:

$y_0 = 1.35\ m$ $\quad y_F = 0\ m$

$x_0 = 0\ m$ $\quad x_F = 9\ m$

Resolution:

2) Calculate the velocity in X

$$\Delta x = v_{0x}t + \frac{1}{2}at^2 \Leftrightarrow x_F - x_0 = v_{0x}t + 0$$

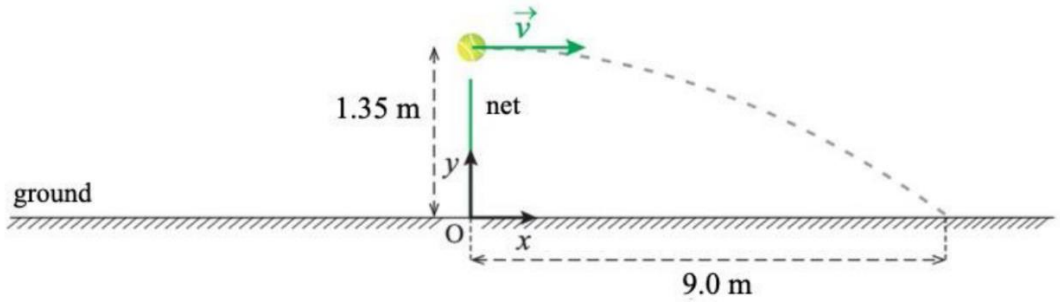
$$9 - 0 = v_{0x} \times 0.525 \Leftrightarrow v_{0x} = 17.1\ m\ s^{-1}$$

3) Calculate the velocity in Y

$$v_y^2 = v_{0y}^2 - 2g\Delta y$$

$$v_y^2 = 0 - 2 \times 9.8 \times (0 - 1.35)$$

$$v_y = 5.14\ m\ s^{-1}$$



Exercise data:

$y_0 = 1.35\ m$ $\quad$ $y_F = 0\ m$

$x_0 = 0\ m$ $\quad$ $x_F = 9\ m$

Resolution:

4) Calculate the velocity

$$v^2 = v_x^2 + v_x^2$$

$$v = \sqrt{17.1^2 + 5.14^2}$$

$$v = 17.9\ m\ s^{-1}$$