Ocean exploration and studies of water

IJSO MCQ mock test

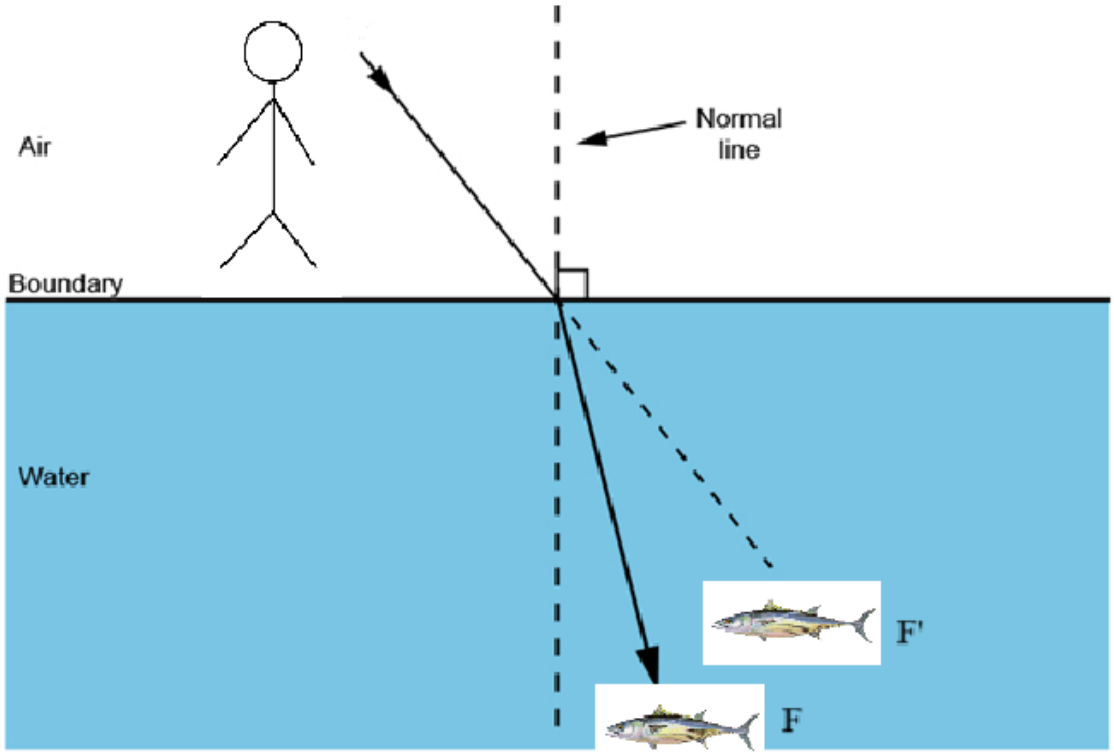
Solutions

Question Number	Option			
1	~~A~~	B	C	D
2	A	B	~~C~~	D
3	A	~~B~~	C	D
4	~~A~~	B	C	D
5	~~A~~	B	C	D
6	A	B	~~C~~	D
7	A	~~B~~	C	D
8	A	B	C	~~D~~
9	A	B	~~C~~	D
10	A	~~B~~	C	D
11	A	B	C	~~D~~
12	~~A~~	B	C	D
13	A	B	~~C~~	D
14	~~A~~	B	C	D
15	A	B	~~C~~	D

Question Number	Option			
16	A	~~B~~	C	D
17	~~A~~	B	C	D
18	~~A~~	B	C	D
19	A	B	C	~~D~~
20	A	B	~~C~~	D
21	A	B	~~C~~	D
22	A	~~B~~	C	D
23	A	~~B~~	C	D
24	A	~~B~~	C	D
25	A	B	C	~~D~~
26	A	B	~~C~~	D
27	~~A~~	B	C	D
28	A	B	~~C~~	D
29	~~A~~	B	C	D
30	A	~~B~~	C	D

Question 1 – Little Timmy in the waters

Because water has a higher index of refraction, when refracting from air to water light rays bend closer to the normal line. So, we have the following picture:



The fish is at point F, but Little Timmy sees it at point F', somewhere along the line of the ray coming from his eyes. The actual fish (F) is closer to Little Timmy than the image (F'), so that's where he should aim the spear.

The correct answer is **A**.

Question 2 – Little Timmy's carps

In rows 3 and 4, phenotypes are not different despite the change in sex of the organisms expressing the phenotypes, hence eliminating the possibility of it being X linked or Y linked.

In row 1 all the offspring of common carp are common and row 3 expresses standard ratios of crosses between heterozygous and homozygous individuals.

In row 2, common phenotype emerges seemingly unrelated from the parents suggesting the common trait is recessive.

If the carps had alleles N and n which expressed the pattern. The 'line' carps carry one 'N' allele and one 'n' allele (Nn), while the common carps have the genotype nn.

So, when considering a cross between line carps (Nn) the offspring genotype ratio should be NN:Nn:nn ,1:2:1 but the actual phenotypic ratio is 2:1 suggesting that offspring carrying NN genotypes aren't viable in nature.

So, option **C** is the correct answer.

Question 3 – Litle Timmy on the island

Sea grass being a monocot will have most of the structures in a typical monocot. But since the main habitat of Sea Grass is underwater, it doesn't need a well developed xylem as it can obtain water readily from its surroundings. As a result, the Xylem in Sea Grass is vestigial (since its unnecessary it is reduced to a low functioning organ).

So the main difference between a Sea Grass and a Monocot plant is its xylem.

In conclusion, option **B** is the most suitable.

Question 4 – Heat in the Holmes signal

The balance combustion reaction of acetylene is:

$$C_2H_2 + \frac{5}{2}O_2 \rightarrow 2CO_2 + H_2O$$

The enthalpy change of the reaction is $\Delta_r H = \sum_{products} \nu \Delta_f H - \sum_{reactants} \nu \Delta_f H = 2\Delta_f H_{CO_2} + \Delta_f H_{H_2O} - \frac{5}{2}\Delta_f H_{O_2} - \Delta_f H_{C_2H_2}$

The enthalpy of formation of simple substances (like O_2) is zero, so the reaction enthalpy for acetylene combustion is $\Delta_r H = 2\Delta_f H_{CO_2} + \Delta_f H_{H_2O} - \Delta_f H_{C_2H_2} = -1305\ \text{kJ mol}^{-1}$

So the correct answer is **A**.

Question 5 – Phosphine and its analogue ammonia

A. Nitrogen is significantly more electronegative than phosphorus → leads to more polar N–H bonds than P–H. NH_3 can form hydrogen bonds with water, increasing solubility. PH_3 has weak intermolecular forces (no real H-bonding), so it's less soluble. So, option A is correct.
B. While both molecules have a trigonal pyramidal shape, their polarity depends not just on shape but also on the electronegativity of the central atom. Nitrogen is more electronegative than phosphorus, so NH_3 is more polar than PH_3, and thus more soluble in water. So, option B is wrong.
C. Phosphorus does not form stronger bonds with hydrogen than nitrogen does. In fact, P–H bonds are weaker. That is because the P-H bond is made by the overlap of lower energy 3p orbital of phosphorus and a higher energy 1s orbital of hydrogen, unlike in the N-H bond where N 2p orbitals are closer in energy to H 1s orbitals. This higher difference in energy leads to a weaker bond (observation fully explained by the molecular orbital theory). Also, P-H bonds are less polar than N–H bonds because of the lower electronegativity difference. This makes PH_3 less polar than NH_3, not more. So, option C is wrong.
D. Solubility in water depends on polarity and hydrogen bonding, not atomic size or electron count. Despite phosphorus being larger and having more electrons, PH_3 is less polar and does not hydrogen bond effectively with water, making it less soluble than NH_3. So, option D is wrong.

So, option **A** is correct

Question 6 – Limits of the human body

The following table is depicting the states of the atria and the ventricles during a cardiac cycle:

A	----------systole----------|----------diastole----------
V	----------diastole—---------|----------systole----------

We can see that the total diastole (time period during which the whole heart is relaxed) is equal to the overlap between the atrial and the ventricular diastole. From the picture, we can easily see the duration of the total diastole is the difference between the ventricular diastole and the atrial systole. We get total diastole = 0.239 - 0.047 = 0.192s.

Without the picture we can also figure out that the time interval in which the whole heart is in diastole is the time interval in which the ventricles are in diastole minus the time interval in which the atria are not in diastole (they are in systole).

The duration of the whole cardiac cycle is double the total diastole - 20.192 = 0.384s.

The man's heart rate is 60s/0.384 = 156 BPM.

This is 80% of the maximum possible heart rate so the maximum possible heart rate is 156/80% = 195 BPM.

Constant C is the max BPM plus the man's age, C = 195 + 25 = 220.

So, the correct answer is **C**.

Question 7 – More about divers

When a diver stays at depth, inert gases like nitrogen dissolve into their body fluids and tissues. The amount dissolved depends on the depth (ambient pressure) and the time spent there. During a slow, controlled ascent with decompression stops, the pressure decreases gradually, allowing this dissolved nitrogen to safely diffuse out of blood to the lungs, where it's exhaled.

However, if the ascent is too rapid (sudden decompression), the pressure drops quickly. The dissolved nitrogen can no longer stay in solution and comes out rapidly, forming tiny gas bubbles within the bloodstream and tissues. These bubbles can:

- Blocks small blood vessels (gas embolism), cutting off blood supply and oxygen to tissues.
- Cause mechanical damage to tissues and nerves.
- Trigger inflammatory responses.
- Accumulate in joints, causing pain.

As a result of this the diver may experience dizziness, joint pain and paralysis which are symptoms of Decompression Sickness (DCS).

So, the most suitable answer is option **B**.

Question 8 – Deep-sea exploration in a submarine

The pressure on the outside of the bubble is approximately constant (r<<h) and it is given by the formula $P = P_0 + \rho gh = 5.12 \cdot 10^6$ Pa.

Because surface tension is neglected, the inner pressure of the air inside the bubble is also equal to P.

The surface area of the bubble is $S = 4\pi r^2 = 5.02 \cdot 10^{-5} m^2$.

The force acting outward on the inside of the bubble is the force due to the air pressure inside. It is given by $F = P \cdot S = 257.0 N$.

So the correct answer is **D**.

Question 9 – Experiment in the submarine

The molar mass of UDMH is 60.12 g/mol, so 5.00g of UDMH corresponds to 0.0832mol.

The balanced equation of the decomposition reaction:

$$H_2NN(CH_3)_2 \rightarrow N_2 + 2CH_4$$

So one mole of UDMH generates one mole of nitrogen gas and two moles of methane. This means the 5.00g of UDMH will generate 0.0832mol of nitrogen and 0.166mol of methane. In total that's approximately 0.250mol of gas.

Using the ideal gas law $pV = nRT$, we get $P = 3.03 \cdot 10^5$ Pa. Using 1 atm = 101 000 Pa we get the pressure to be exactly 3atm.

So the right answer is **C**.

Question 10 – Titan submersible accident

We can write Hooke's law as $\sigma = E\varepsilon$, where σ is the tensile stress, E is the Young's modulus, while ε is the relative elongation. The relative elongation is equal to $\varepsilon = \frac{\Delta l}{l_0}$, where l_0 is the length in an undeformed state.

$$l_1 - l_2 = \Delta l_1 - \Delta l_2 = l_0(\varepsilon_1 - \varepsilon_2) = l_0\left(\frac{\sigma}{E_1} - \frac{\sigma}{E_2}\right) = l_0\sigma\left(\frac{1}{E_1} - \frac{1}{E_2}\right) = 6.3\text{cm}$$

So the answer is **B.**

Question 11 – Breathing in the submarine

The reactions taking place:

$$NaClO_3 \rightarrow NaCl + 1.5O_2$$

$$BaO_2 \rightarrow BaO + 0.5O_2$$

The volume of oxygen required is 2 people · 2 hours · 15 L/h/person = 60L. The number of moles of oxygen is n = 60/22.4 = 2.68mol.

Adding the 20% safety margin, we get n = 2.68 · 120% = 3.21mol.

Let m be the mass of the mixture. Using the given composition, the mass of sodium chlorate is 0.95m and the mass of barium peroxide is 0.05m.

The molar masses of the two compounds are BaO_2 - 169.33 g/mol and $NaClO_3$ - 106.45 g/mol.

The number of moles of oxygen resulted from the reaction is $n = 1.5n_{NaClO_3} + 0.5n_{BaO_2} = \frac{1.5 \cdot 0.95m}{106.45} + \frac{0.5 \cdot 0.05m}{169.33} = m\left(\frac{1.5 \cdot 0.95}{106.45} + \frac{0.5 \cdot 0.05}{169.33}\right)$

From this we get $m = \frac{n}{\frac{1.5 \cdot 0.95}{106.45} + \frac{0.5 \cdot 0.05}{169.33}}$

Using n = 3.21 mol, we get m = 237g.

So, the correct answer is **D**.

Question 12 – Algae also breathe

In the given experiment, the initial concentration of dissolved oxygen is given as 8 mg/l/h. The factors which could have affected the concentration in the clear bottle are photosynthesis and respiration, while only respiration could have affected oxygen concentration in the opaque bottle. Hence the amount of oxygen produced by algae during that time could be calculated by subtracting the Oxygen concentration of the opaque bottle from the clear bottle which gives us 7 mg/l and since this is after an hour, the rate of photosynthesis (GPP) is equal to 7 mg/l/h. The excess O2 produced can be found by subtracting the concentration of O2 of initial solution from the clear bottle sample, which comes out to be 4mg/l/h. The respiration rate is the value in initial solution - the value in opaque bottle. The respiration rate is 3 mg/l/h.

So the correct option is option **A**.

Question 13 – And marine animals also breathe

Compound Z stops ATP production while oxygen consumption remains normal, indicating the electron transport chain (ETC) is still pumping protons. This builds a proton gradient across the mitochondrial membrane. Since ATP synthesis is halted despite the gradient, Compound Z likely interferes with ATP synthase's ability to use this gradient.

So, out of the given options, option **C** best explains the probable reason.

Question 14 – Sphere on the ocean surface

Because the density of the sphere is half that of the water, the sphere can be submerged up to half its volume without any force acting on it. This means that for $0 < y/R < 1$, $F = 0$, so option A or B.

$$F = F_A - W = \rho g V_{submerged} - mg$$

The dependence is $F = AV_{submerged} + B$, with A and B being constants. Because the section area of a sphere is not constant, the dependence of $V_{submerged}(y)$ is not linear, so F(y) is not linear, so F(y/R) is not linear. This means the correct option is option **A**.

Question 15 – Carbon dioxide in the ocean

A. In setup B, the reaction is faster and the acid is produced faster. Lower pH values are more acidic, so the pH drops faster in setup B - option A is wrong

B. Carbonic anhydrase speeds up carbonic acid formation, so carbon dioxide consumption. This means that in setup B the concentration of carbon dioxide decreases faster, so option B is wrong

C. In setup B, the forward reaction is faster, so the rate of carbonic acid production is faster. So, the concentration of carbonic acid increases faster - option C is correct

D. Catalysts speed up both the forward and reverse reaction, providing a faster more energy efficient mechanism for both. So, catalysts do not change the equilibrium position - option D is wrong

In conclusion, the answer is **C**.

Question 16 – More on carbon dioxide

$[H_2CO_3] = [CO_{2(aq)}] = K_H \cdot p_{CO_2} = 2.5 \cdot 10^{-4}\ M$

Using the Henderson-Hasselbach equation:

$$pH = pK_{a1} + \log\frac{[HCO_3^-]}{[H_2CO_3]} = 6.8$$

So, option **B** is correct.

Question 17 – Oceanic temperature gradient

The speed of sound increases with temperature. Because the pulse moves downwards in the thermocline, the temperature decreases so its speed decreases.

However, the sound pulse won't be affected by refraction. That is because it moves vertically downwards, so perpendicular to the surface of separation between two different mediums. Waves at normal incidence (perpendicular to the surface of separation) are not affected by refraction or phenomena like total internal reflection (which would also happen because of refraction).

So, in conclusion, the only correct answer among the four options is option **A** - the sound pulse moves slower but doesn't change its direction.

Question 18 – Using the temperature gradient

T_H and T_C are absolute temperatures so $T_H = 30 + 273 = 303K$, and $T_C = 5 + 273 = 278K$.

The efficiency of the Carnot engine calculated by the formula is $\eta = 8.25\%$

The energy supplied to the turbine by the OTEC is $8.25\% \cdot 90\,000J = 7425J$.

The energy supplied by the turbine to the oil rig is $Q = 45\% \cdot 7425J = 3341J$

The water has to be heated from 30°C to 100°C ($\Delta t = 70°C = 70K$) and then boiled.

$Q = cm\Delta t + Lm$, so $m = \frac{Q}{c\Delta t + L} = 1.29g$

So the correct answer is **A**.

Question 19 – Water in the oceans

The O-H bonds in water are polar, but due to water's bent structure, the net dipole moment is non-zero. So, option A is wrong.

Water is a very common solvent that dissolves a huge number of compounds such as $NaCl$, $FeSO_4$, $Al(NO_3)_3$, NH_3, $CuCl_2$, $FeCl_2$. But water does NOT dissolve iodine. So, option B is wrong.

Water is an acid-base ampholyte, its conjugate acid being the hydronium ion (chemical species that can give up a proton), while the conjugate base is the hydroxide ion (chemical species that can accept a proton). So, option C is wrong.

The water molecule has 4 sigma electrons (two single bonds each having a pair of electrons) and no pi bonds. Hydrogen atoms do not have any non-bonding electrons. Oxygen has a total of 8 electrons and 2 of them are bonded with the two hydrogen atoms. So, there are 6 electrons not participating in chemical bonds. So, option D is correct.

In conclusion, the answer is option **D**.

Question 20 – Sodium in oceanic waters

The ionization energy of alkali metals decreases down the group. This is because when we go down the group, the distance between the outermost electron shell layer and the nucleus is high. So, the coulomb attraction is lower. Due to this and the inner shielding effects, the ionization energy decreases down the group. So, sodium's ionization energy should be the second highest ionization energy, which is 496kJ/mol.

$H = H_{sub} + H_{hyd} + IE_1$

H = +108 kJ/mol -406 kJ/mol +496 kJ/mol

H = +198 kJ/mol

This means 1 mol of sodium absorbs 198 kJ of energy, so $N_A = 6.022 \cdot 10^{23}$ sodium atoms release 198kJ of energy, so the energy absorbed by the oxidation of one sodium atom is $\frac{198kJ}{N_A} = 3.29 \cdot 10^{-19}J$

1eV is the energy of an electron accelerated by one volt. So, we can write

$1eV = e \cdot 1V = 1.6 \cdot 10^{-19}J$

H = 198 kJ/mol = $\frac{3.29}{1.6}$ = 2.05 eV.

So, the correct answer is **C**.

Question 21 – Sodium and magnesium in oceanic waters

A. Na^+ and Mg^{2+} are isoelectronic. Since Mg has a higher nuclear charge, electrons experience a stronger attraction from the nucleus which leads to a higher electron shell contraction so a smaller ionic radius. Even if Mg^{2+} had a larger ionic radius, that would've resulted in a weaker electric field so, by this logic (if distance were the relevant factor), in less hydration -so option A is wrong

B. Magnesium is indeed more electronegative than sodium. But when ions are hydrated the water - cation bond is not a covalent one, so not electronegativity is the factor influencing hydration - so option B is wrong

C. Mg^{2+} having double the charge of Na^+ and a smaller ionic radius, the charge density is higher in magnesium, resulting in a stronger electric field. This results in a greater attraction of the negative pole of water, resulting in a higher hydration - option C is correct

D. Mg^{2+} is a main group metal with a relatively strong electropositive (metallic) character and does not as a non-metal in aqueous solutions - option D is wrong

In conclusion, option **C** is correct

Question 22 – More about sodium and magnesium

Consider a current generated by particles with charge q moving in an area of section S with velocity v, the concentration of the particles being n. Using common notations, we can prove the following formula:

$I = \frac{\Delta Q}{\Delta t} = \frac{q\Delta N}{\Delta t} = \frac{qn\Delta V}{\Delta t} = \frac{qnS\Delta x}{\Delta t} = qnSv$, a well-known formula in electrokinetics.

For the sodium ions (monovalent), $I_{Na} = en_{Na}Sv_{Na} = en_{Na}S\mu_{Na}E$.

For the magnesium ions (divalent), $I_{Mg} = 2en_{Mg}Sv_{Mg} = en_{Mg}S\mu_{Mg}E$

The ratio is $\frac{I_{Mg}}{I_{Na}} = \frac{2n_{Mg}\mu_{Mg}}{n_{Na}\mu_{Na}} = 2 \cdot \frac{n_{Mg}}{n_{Na}} \cdot \frac{\mu_{Mg}}{\mu_{Na}} = 2 \cdot \frac{1}{3} \cdot \frac{\mu_{Mg}}{\mu_{Na}} = 0.71$

So the correct option is **B**.

Question 23 – Coral reefs

The initial coral population, which was used for the experiment, was found to be tolerant to ocean acidification up to a certain degree. The samples were gradually exposed to more and more acidic conditions, effectively killing the weaker traits and allowing the more tolerant ones to reproduce. Since, a trait is favourable due to human intervention, it's an example for Artificial Selection.

So, option **B** is the most suitable.

Question 24 – More species in coral reefs

In terrestrial ecosystems, the biomass pyramid is usually upright:

Most biomass is in plants, and it decreases at higher levels.

But in marine ecosystems, the pyramid is often inverted because:

Phytoplankton reproduce and are eaten so fast that their standing biomass is small. Zooplankton and larger consumers like tuna and sharks have more accumulated biomass at any given moment.

So, the most suitable option out of the given options is **B**.

Question 25 – One more marine ecosystem

The entire energy captured by the ecosystem (GPP) is given as 20000 J and the percentage of this energy which was used by the primary producers (plants) for their own metabolic activities is given as 25%. So, the energy stored in the biomass of 1st trophic level is 20000·75% = 15000 J. According to the 10% efficiency in energy transfer between trophic levels:

The energy stored in the 2nd trophic level will be 1500 J.

The energy stored in the 3rd trophic level is 150 J.

The energy stored in 4th trophic level is 15 J.

So, option **D** is the most suitable one.

Question 26 – The swimmer

Swimmer's ear is a bacterial/fungal infection in ear canal. Normally Ear wax (Cerumen) inhibits infections. So, the skin and ear wax forms a protective mechanism against infections. But the frequent use of cotton swabs pushes ear wax further into the ear, furthermore it may cause micro abrasions which may increasing the likelihood of infection.

So, the correct option is **C**.

Question 27 – Oceanic measurements

The two buoys are 100m apart. The fact that the wavefront hits the two buoys with a gap of 20.0 seconds means the wavefront travels at a speed of $v = \frac{s}{t} = 5\ m \cdot s^{-1}$

The distance between two successive wavefronts is defined as the wavelength. So, the wavelength is $\lambda = 12m$.

$v = f\lambda$

$f = \frac{v}{\lambda} = 0.42\ Hz$

So the correct option is **A**

Question 28 – Another oceanic measurement

A. Density is a mechanical property which does not have any influence over electromagnetic fields (like bending field lines) - option A is wrong

B. The temperature in oceanic waters does not change drastically (the change is around 5 degrees celsius) so the variation due to temperature of magnetic permeability of water would not lead to measurable fluctuations - option B is wrong

C. Moving charged ions in water experience Lorenz forces. Even though the Lorenz force does not alter the magnitude of the velocities, it makes the ionic movement more ordered (unlike the previous disordered Brownian motion) which makes the induced secondary magnetic fields not cancel out, but add up to a measurable fluctuation in the value indicated by the magnetometer - option C is correct

D. Just like in option A, the pressure difference exists, but it is a mechanical property not influencing electromagnetic fields - option D is wrong

In conclusion, option **C** is the correct option.

Question 29 – Optic measurements

The glass vessel is equivalent to a plane-concave lens. Its first radius of curvature is that of the plane surface, $R_1 = \infty$, while the second radius is $R_2 = R$ (positive because the curvature is towards the positive direction of the axis - the direction of the light).

The water is also equivalent to a lens, with the first radius of curvature $R_1 = R$, and the second radius of the curvature is infinite, $R_2 = \infty$.

Using the lens maker's formula, the convergence of the glass vessel is given by:

$$C_1 = (n_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = -\frac{n_g - 1}{R}$$

For the water we get:

$$C_2 = \frac{n_w - 1}{R}$$

The equivalent convergence of the system is the sum $C = C_1 + C_2 = \frac{n_w - 1 - n_g + 1}{R} = \frac{n_w - n_g}{R} = -0.4\ m^{-1}$

So, the correct answer is **A**.

Question 30 – Ship hulls corrosion

$E_{cell} = E_{cathode} + E_{anode}$

$E_{cell} = +0.44\ V + 0.40\ V = +0.84\ V$

A Fe atom takes 2 electrons to reach Fe (II). 96500 C is 1 mol of electrons (Faraday's constant). 1 mol of electrons can oxidize 0.5 mol of Fe. So, the correct answer is **B**.