

2 Calculate the change in Gibb's free energy for melting of ice at (i) -18 °C, (ii) +5 °C and (iii) 13 °C. Predict the temperatures at which the process will be spontaneous (Note: Change in enthalpy = 6.01 kJ mol⁻¹ & change in entropy = 0.022 kJ mol⁻¹ for melting of ice).

Key:

$$\Delta G = \Delta H - T\Delta S \text{ (Formula 1 marks)}$$

$$\Delta G = 0.4 \text{ (+ve at -18 °C)}$$

$$\Delta G = -0.106 \text{ (-ve at 5 °C)}$$

$$\Delta G = -0.282 \text{ (-ve at 13 °C)}$$

Spontaneous at 5 and 13 and non-spontaneous at -18 C

b) Derive the rate expression for conversion methyl isonitrile to acetonitrile. How can we calculate the rate constant for this reaction using graphical method?

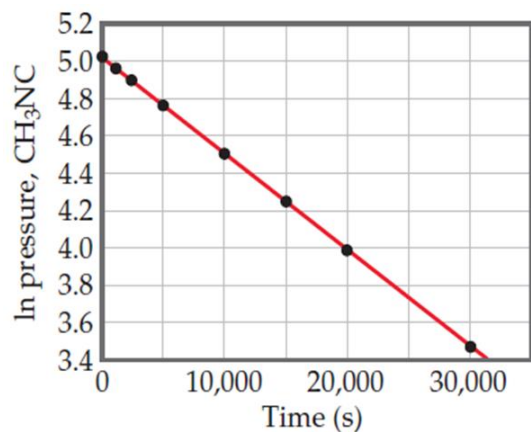
Key:

Identifying the conversion of methyl isonitrile to acetonitrile as First order reaction

Derivation of the rate equation:

$$\ln[\text{CH}_3\text{NC}]_t = -kt + \ln[\text{CH}_3\text{NC}]_0$$

Model graph for calculation of rate constant:



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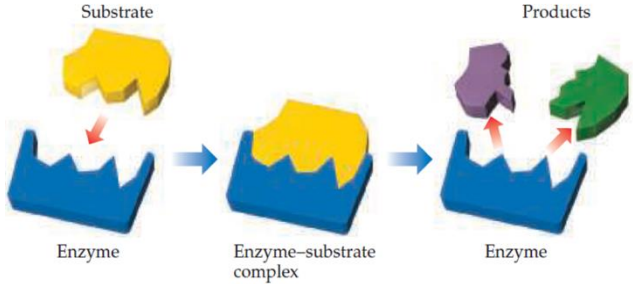
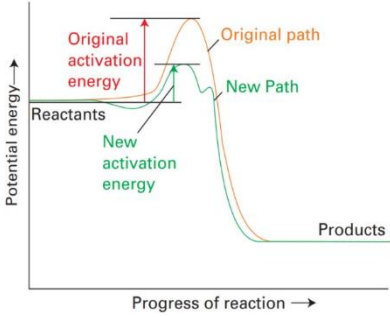
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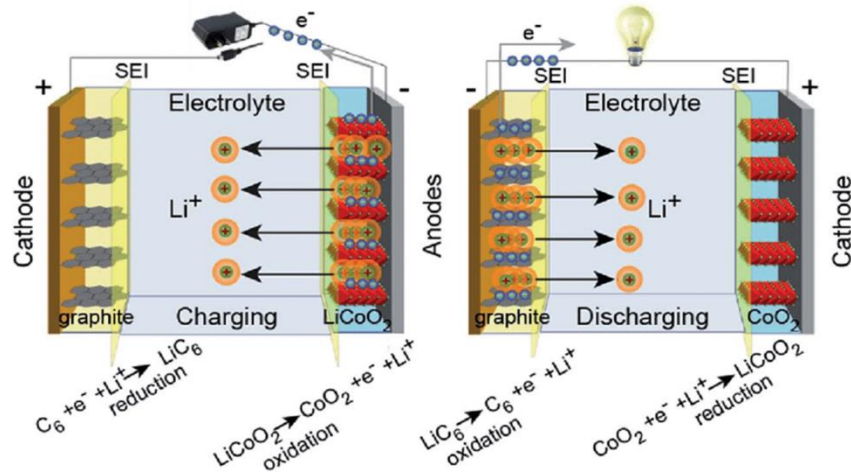
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<p>3</p>	<p>a) Describe why are enzyme catalysed reactions preferred in few cases despite the high cost, stability and other issues associated with enzymes.</p> <p>Key:</p> <p>(i) High selectivity due to the lock and key mechanism</p>  <p>(ii) High reaction rates using enzymes as catalysts as they minimize the activation energy due to different reaction path.</p>  <p>b) Briefly discuss on the concept of storing energy using electrostatics. How porous materials could help in enhancing the performance of these devices?</p> <p>Key:</p> <p>Concept of storing energy using electrostatics: A brief note on capacitors with diagram</p> <p>Role of porous materials in enhancing the performance: A note on supercapacitors with diagram</p>	<p>2.5</p> <p>2.5</p> <p>2</p> <p>3</p>
<p>4</p>	<p>a) Elucidate the working principle of a light weight, rechargeable battery system with neat sketch.</p> <p>Key:</p> <p>Identifying as Lithium ion battery and listing the anode, cathode, electrolyte and separator</p> <ul style="list-style-type: none"> ▪ Cathode: This is the positive electrode and it is typically layers of lithium-metal oxide (LiCoO_2, LiNiO_2, LiMn_2O_4, LiNiMnCoO_2) and lithium metal polyanionic materials (LiFePO_4, LiMnPO_4, LiFeSO_4F, etc.). ▪ Anode: The negative electrode is made from graphite, usually with composition $\text{Li}_{0.5}\text{C}_6$. ▪ Electrolyte: Mixture of organic carbonates such as ethylene carbonate, diethyl carbonate. 	<p>2</p>

- Separator: Prevents touching two electrodes. This absorbs the electrolyte, and enables the passage of ions, but prevents the direct contact of the two electrodes within the lithium in cell. Polyethylene (PE), polypropylene (PP), and PE/PP separators with pore sizes are used.

Cell reactions during charging and discharging with neat sketch

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b) A futuristic fuel produces H_2O as by-product after being used. Explain the working principle involved in this electrochemical energy conversion system.

Key:

Identifying as Hydrogen-oxygen fuel cell and listing the electrode and electrolyte materials

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- Both half cells have porous graphite electrode with a catalyst (platinum, silver or a metal oxide).
- The electrodes are placed in the aqueous solution of NaOH or KOH (alkaline fuel cells-AFC) or H_2SO_4 (acidic fuel cell) which acts as an electrolyte.

Working principle and cell reactions:

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- Hydrogen fuel is processed at the anode where electrons are separated from protons on the surface of a platinum-based catalyst.
 - The protons pass through the membrane to the cathode side of the cell while the electrons travel in an external circuit, generating the electrical output of the cell.
 - On the cathode side, another Pt electrode combines the protons and electrons with oxygen to produce water.
- At anode: $\text{H}_2 (\text{g}) \rightarrow 2 \text{H}^+ + 2 \text{e}^-$
 - At cathode: $\text{O}_2 (\text{g}) + 4 \text{H}^+ + 4 \text{e}^- \rightarrow 2 \text{H}_2\text{O}$
 - Net reaction: $\text{O}_2 (\text{g}) + 2 \text{H}_2 (\text{g}) \rightarrow 2 \text{H}_2\text{O} (\text{l}) \quad E_{\text{Cell}}^\circ = 1.23 \text{ V}$

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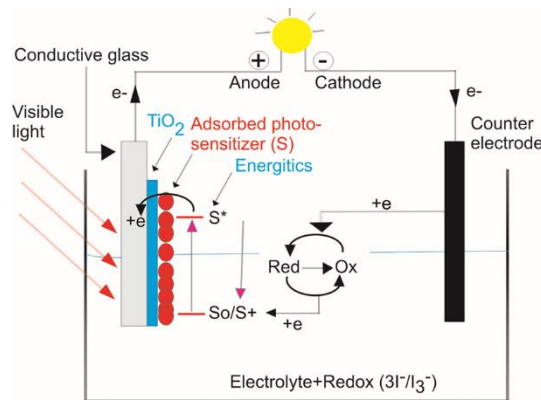
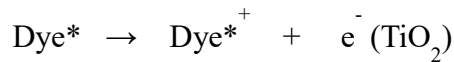
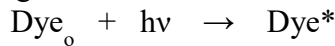
Elaborate the process of electricity generation using naturally occurring dyes including its construction, working mechanism, merits and demerits.

Dye sensitized solar cells using any one naturally occurring dye as example.

- (i) Construction – electrodes, substrate, electrolyte
- (ii) Working mechanism – Reactions with diagram

The working principle of DSSC involves four basic steps: light absorption, electron injection, transportation of carrier, and collection of current.

- Sunlight energy (photon of light) passes through the titanium dioxide layer and absorbed by the photosensitizer
- Due to the photon absorption, electrons get promoted from the ground state (Dye) to the excited state (Dye*) of the dye
- Excited electrons with a lifetime of nanosecond range are injected into the conduction band of nano-porous TiO₂ electrode which lies below the excited state of the dye.
- As a result, the dye gets oxidized.



(iii) Merits and demerits

Advantages	Disadvantages
<ul style="list-style-type: none"> □ Ability to Work at Wider Angles and in Low Light □ Long Life □ Good Price/Performance Ratio □ Low Cost □ Mechanical Robustness □ Ability to Operate at Lower Internal Temperatures □ Lowering the electricity bills 	<ul style="list-style-type: none"> □ DSSC design is the use of the liquid electrolyte □ which has temperature stability problems □ costly ruthenium (dye), platinum(catalyst) □ the electrolyte solution contains volatile organic compounds (or VOC's),

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Q. No.	Answer <u>ALL</u> the questions (5 X 10 = 50 Marks)	Marks	CO	BL
1	Module-1	10	CO1	2
2	a) Numerical from Module-1 b) Module-1	(5 + 5)	CO2	3
3	a) Module-1 b) Module-4	(5 + 5)	CO3	4
4	a) Module-4 b) Module-4	(5 + 5)	CO3	3
5	Module-4	10	CO5	2