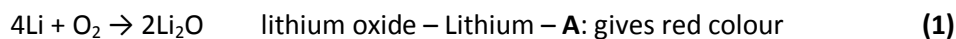
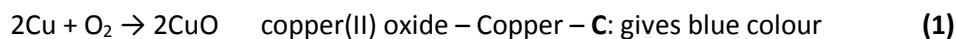
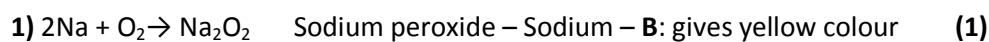




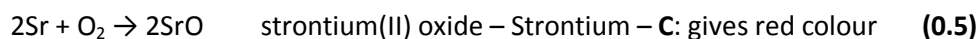
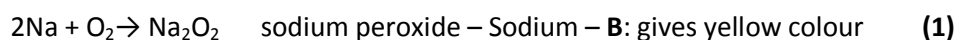
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1. FIREWORKS (10 points)



Alternative solution:

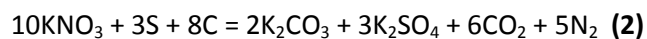
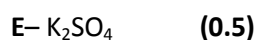
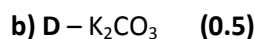


2) a)

$$x_C = \frac{\frac{2 \text{ g}}{12 \text{ g/mol}}}{\frac{2 \text{ g}}{12 \text{ g/mol}} + \frac{2 \text{ g}}{32 \text{ g/mol}} + \frac{21 \text{ g}}{101 \text{ g/mol}}} = 0.381 \quad (1)$$

$$x_S = \frac{\frac{2 \text{ g}}{32 \text{ g/mol}}}{\frac{2 \text{ g}}{12 \text{ g/mol}} + \frac{2 \text{ g}}{32 \text{ g/mol}} + \frac{21 \text{ g}}{101 \text{ g/mol}}} = 0.143 \quad (1)$$

$$x_{\text{KNO}_3} = \frac{\frac{21 \text{ g}}{101 \text{ g/mol}}}{\frac{2 \text{ g}}{12 \text{ g/mol}} + \frac{2 \text{ g}}{32 \text{ g/mol}} + \frac{21 \text{ g}}{101 \text{ g/mol}}} = 0.476 \quad (1)$$

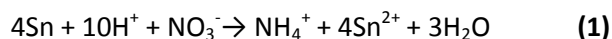
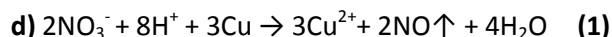
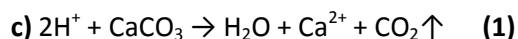
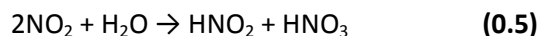
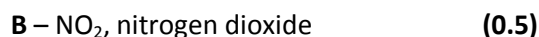
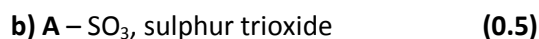




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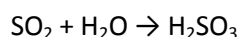
2. ACID RAIN (10 points)



Reducing nitrogen to oxidation states 0, 1 and 2 can also be considered right, reducing nitrogen to oxidation state 4 resulting in NO_2 being a product is not correct since acid rain is not concentrated HNO_3 .

2)

$$M(\text{SO}_2) = 32 \frac{\text{g}}{\text{mol}} + 2 * 16 \frac{\text{g}}{\text{mol}} = 64 \frac{\text{g}}{\text{mol}}$$



$$n(\text{H}_2\text{SO}_3) = n(\text{SO}_2) = \frac{m(\text{SO}_2)}{M(\text{SO}_2)} = \frac{2.5 * 10^{10} \text{g}}{64 \frac{\text{g}}{\text{mol}}} = 3.9 * 10^8 \text{ mol} \quad (1)$$

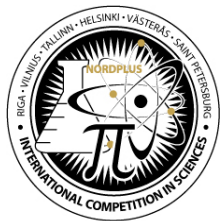
$$c(\text{H}_2\text{SO}_3) = \frac{n(\text{H}_2\text{SO}_3)}{V} = \frac{3.9 * 10^8 \text{ mol}}{2.4 * 10^{10} \text{ l}} = 1.6 * 10^{-2} \text{ M} \quad (1)$$

$$K_{a1} = \frac{[\text{H}^+][\text{HSO}_3^-]}{[\text{H}_2\text{SO}_3]} \quad (\text{equation 1})$$

Assume that pH is low enough that 2nd order dissociation can be ignored.

$$[\text{H}^+] = [\text{HSO}_3^-] \quad (\text{equation 2})$$

$$[\text{H}_2\text{SO}_3] = c(\text{H}_2\text{SO}_3) - [\text{HSO}_3^-] \quad (\text{equation 3})$$



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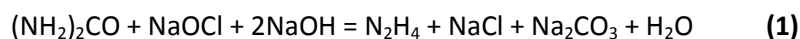
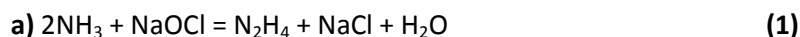


Replace $[\text{HSO}_3^-]$ and $[\text{H}_2\text{SO}_3]$ from equations 2 and 3 to equation 1 and solve the quadratic equation for $[\text{H}^+]$.

$$[\text{H}^+]^2 + K_{a1} * [\text{H}^+] - K_{a1} * c = 0$$

The positive solution for this equation is $[\text{H}^+] = 1.0 * 10^{-2} \text{ M}$ and $\text{pH} = 2.00$. **(2)**

3. QUANTITATIVE RELATIONS IN CHEMISTRY (8 points)



b) $M(\text{N}_2\text{H}_4) = 32 \text{ g/mol}$, $M(\text{NH}_3) = 17 \text{ g/mol}$

$m = 34 \text{ g} / (2 \cdot 17 \text{ g/mol}) \cdot 32 \text{ g/mol} = \mathbf{32 \text{ g}}$ **(1)**

c) $M(\text{NaOCl}) = 74.5 \text{ g/mol}$, $M(\text{NaOH}) = 40 \text{ g/mol}$, $M((\text{NH}_2)_2\text{CO}) = 60 \text{ g/mol}$

$\text{EA}(\text{Olin Raschig}) = 32 \text{ g/mol} / (74.5 \text{ g/mol} + 2 \cdot 17 \text{ g/mol}) = 29\%$ **(1)**

$\text{EA}(\text{peroxide}) = 32 \text{ g/mol} / (34 \text{ g/mol} + 2 \cdot 17 \text{ g/mol}) = 47\%$ **(1)**

$\text{EA}(\text{urea}) = 32 \text{ g/mol} / (60 \text{ g/mol} + 74.5 \text{ g/mol} + 40 \text{ g/mol}) = 18\%$ **(1)**

d) Peroxide process is the greenest in terms of atom economy and because by-products (waste) such as sodium chloride are not produced. **(1)**

4. CONDUCTOMETRY (10 points)

1) a) point A – $\text{H}^+ < \text{Na}^+ = \text{OH}^-$ **(0.5)**

point B – $\text{H}^+ = \text{OH}^- < \text{Na}^+ = \text{Cl}^-$ **(0.5)**

point C – $\text{OH}^- < \text{H}^+ = \text{Na}^+ < \text{Cl}^-$ **(0.5)**

b) 5 ml **(0.5)**

c) $c = \frac{\kappa}{\lambda_{\text{Na}^+} + \lambda_{\text{Cl}^-}} = \frac{0.125 \frac{1}{\Omega \cdot \text{m}}}{5.01 \frac{1}{\Omega \cdot \text{m} \cdot \text{M}} + 7.64 \frac{1}{\Omega \cdot \text{m} \cdot \text{M}}} = 0.01 \text{ M}$ **(3)**



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d) $c(\text{NaOH, original}) = c(\text{NaCl, pH=7}) = 0.01\text{M}$ $pOH = -\log(c(\text{NaOH})) = -\log(0.01) = 2$

$pH = 14 - pOH = 14 - 2 = 12$ (2)

2) (0.5 points for each correct cell that was not filled in before)

Volume of HCl added	Conductance of the solution	pH of the solution
7 ml	$3 \cdot 10^{-4} / (\Omega \cdot m)$	2.4
8 ml	$4 \cdot 10^{-4} / (\Omega \cdot m)$	2.2
~5 ml	$1.25 \cdot 10^{-4} / (\Omega \cdot m)$	9

5. OXIDATION AND REDUCTION (10 points)

