

## Survey of Materials

### Homework 3, due date is set in Canvas LMS

**Notes:** In multiple choice problems explain your answer. Add references if needed. Your solution must be uploaded as a single file “YourName.pdf” or “YourName.zip”.

1. List at least three important performance degradation mechanisms in Li-ion batteries.
2. Estimate the specific energy of the battery based on  $\text{LiFePO}_4$  cathode and graphite anode (excluding battery case, electrolyte, current collectors etc.). Hint: electrode potential of  $\text{LiFePO}_4$  is 3.4 V, of graphite is 0.3 V with up to one Li per six carbon atoms.
3. Rank the following cathode materials according to their electrode potential:  $\text{LiVPO}_4\text{F}$ ,  $\text{LiTiO}_2$ ,  $\text{Li}_3\text{V}_2(\text{PO}_4)_3$ ,  $\text{Li}_2\text{NiPO}_4\text{F}$ ,  $\text{LiTi}_2(\text{PO}_4)_3$ ,  $\text{LiCoPO}_4$ . *Hint:* look into tables of standard electrode potentials.
4. List materials requirements for membrane in redox flow batteries.
5. What is the main reason behind a nanosize core-shell architecture for surface catalysts?
6. Why the catalytic activity for oxygen reduction reaction of perovskite oxides correlates with the orbital filling of  $e_g$  orbital of surface transition metal atoms? At what filling the largest catalytic activity is observed? *Hint:* [http://zhugayevych.me/edu/Materials/res/Rev\\_Suntivich11.pdf](http://zhugayevych.me/edu/Materials/res/Rev_Suntivich11.pdf).
7. Which of the following applications of carbon nanotubes (as pure material) is the least practical: A) high-endurance mechanical cable; B) conducting wire; C) mechanical deformation sensor; D) gas sensor; E) metal-ion battery electrode.
8. What is the main reason to add amorphous carbon to metal-ion batteries: A) to improve mechanical stability of electrode; B) to improve chemical stability of electrode; C) to improve electronic conductivity of electrode; D) to improve ionic conductivity of electrode.
9. In your opinion, what are the three most critical threats to the sustainability of the human civilization and how advances in materials science can help to mitigate them?
10. In five sentences review a contributed presentation from MIT-Skoltech Conference including: 1) motivation; 2) approach; 3) results; 4) their significance; 5) outlook (your proposal of follow-up research).