

Problem 1

a. Identify which names below that are correct and incorrect for ionic compounds:

i. Potassium(I) chloride **(0.5%)**

ii. Calcium(II) nitrate **(0.5%)**

iii. Tin(IV) chloride **(0.5%)**

iv. Silver sulfide **(0.5%)**

v. Zinc(II) sulfide **(0.5%)**

b. Identify the oxidation numbers for each atom in the following compounds:

i. IO_4^- **(0.5%)**

ii. ClO_3^- **(0.5%)**

iii. H_2S **(0.5%)**

iv. $\text{C}_{16}\text{H}_{33}\text{Br}$ **(0.5%)**

v. $\text{C}_{12}\text{H}_{22}\text{O}_{11}$ **(0.5%)**

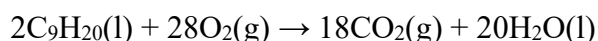
c. Balance the following reactions:

i. $\text{Sn}^{4+} + \text{Al} \rightarrow \text{Sn} + \text{Al}^{3+}$ **(1%)**

ii. $\text{C}_2\text{H}_6 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$ **(1%)**

iii. $\text{C}_{42}\text{H}_{70}\text{O}_{35} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$ **(2%)**

d. C_9H_{20} reacts with O_2 according to the following reaction equation:



Calculate the mass C_9H_{20} required to generate 1.00 kg H_2O . **(3.5%)**

Solution

a.

i. Potassium(I) chloride (**Incorrect**)

ii. Calcium(II) nitrate (**Incorrect**)

iii. Tin(IV) chloride (**Correct**)

iv. Silver sulfide (**Correct**)

v. Zinc(II) sulfide (**Incorrect**)

b.

i. Oxidation number: $\overset{-2}{\text{I}}\text{O}_4^-$? + 4(-2) = -1 gives ? = +7

Oxidation numbers

O: -2
I: +7

ii. Oxidation number: $\overset{-2}{\text{Cl}}\text{O}_3^-$? + 3(-2) = -1 gives ? = +5

Cl: +5
O: -2

iii. Oxidation number: $\overset{+1}{\text{H}}_2\overset{?}{\text{S}}$ 2(+1) + ? = 0 gives ? = -2

H: +1
S: -2

iv. Oxidation number: $\overset{?}{\text{C}}_{16}\overset{+1}{\text{H}}_{33}\overset{-1}{\text{Br}}$ 16(?) + 33(+1) + 1(-1) = 0 gives ? = -2

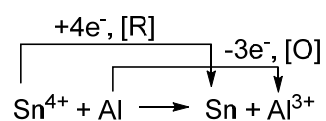
C: -2
H: +1
Br: -1

v. Oxidation number: $\overset{?}{\text{C}}_{12}\overset{+1}{\text{H}}_{22}\overset{-2}{\text{O}}_{11}$ 12(?) + 22(+1) + 11(-2) = 0 gives ? = 0

C: 0
H: +1
O: -2

c.

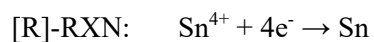
i. **Step 1.** Decide the which species that are oxidized ([O]) and reduced ([R]):



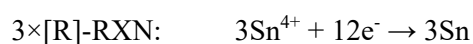
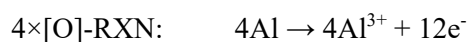
Step 2. Divide the reaction into an oxidation reaction ([O]-RXN) and reduction reaction ([R]-RXN):



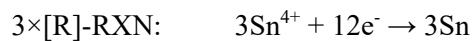
Step 3. Balance the charge by adding electrons (e^-):



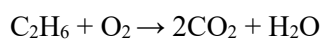
Step 4. Equalize the number of electrons lost in the oxidation reaction by the number of electrons gained in the reduction reaction by multiplying each reaction by a suitable integer:



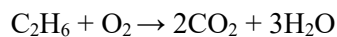
Step 5. Add the two half-reaction together to get the balanced reaction equation:



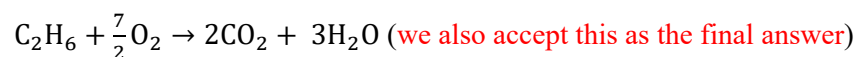
ii. **Step 1.** Balance the C-atoms:



Step 2. Balance the H-atoms:



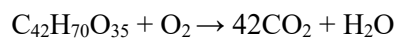
Step 3. Balance the O-atoms:



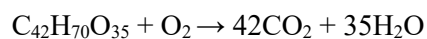
Step 4. Multiply the reaction by 2 in order clear the fraction:



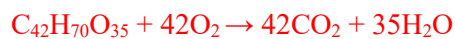
iii. **Step 1.** Balance the C-atoms:



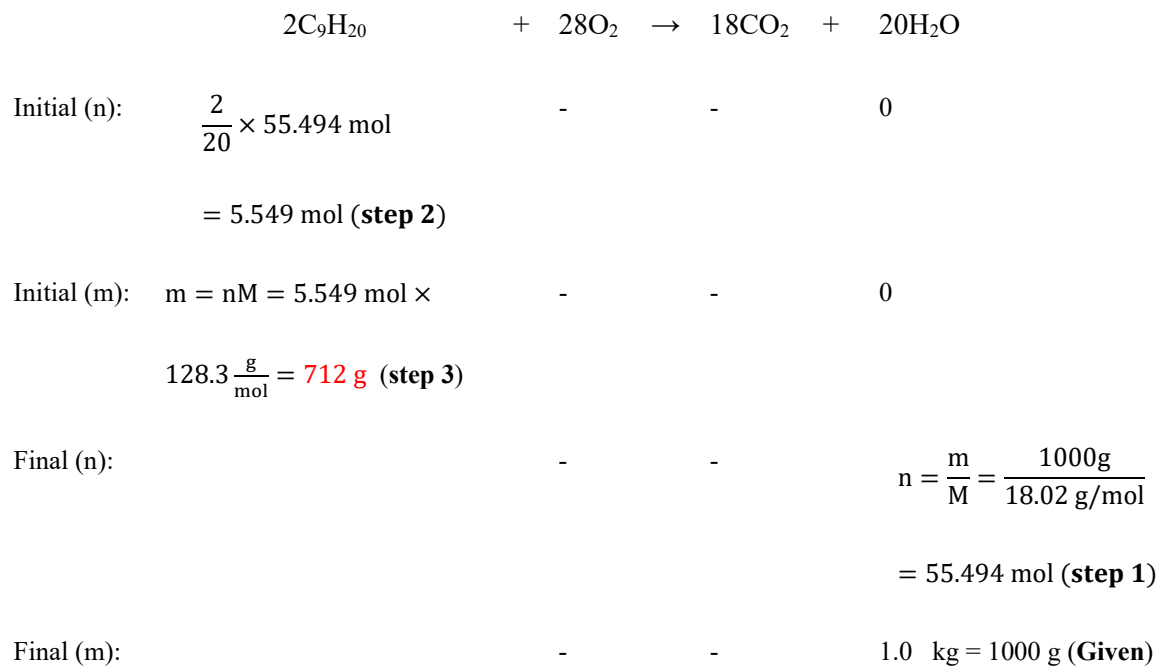
Step 2. Balance the H-atoms:



Step 3. Balance the O-atoms:



d.



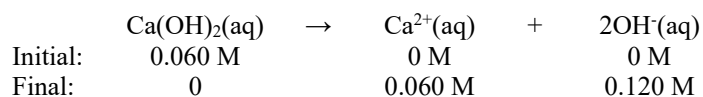
Problem 2

- a. At 25 °C, calculate the pH for:
- a 0.060 M $\text{Ca(OH)}_2(\text{aq})$ solution. (2%)
 - a 0.070 M $\text{HI}(\text{aq})$ solution. (1.5%)
- b. The pH of a 0.075 M $\text{HA}(\text{aq})$ solution is 2.75 at 25 °C. Calculate the acid constant, K_a , for acid HA and the base constant, K_b , for its conjugate base. (3.5%)
- c. How many grams ammonia (NH_3) is required in order to prepare a 1.00 L NH_3 solution in water with a pH of 12.00 at 25 °C ($K_b = 1.8 \times 10^{-5}$ for NH_3). (3.5%)
- d. Arrange the following acids after increasing acidity from left to right (2%):
- $\text{CH}_3\text{CH}_2\text{CH}_2\text{CO}_2\text{H}$ ($K_a = 1.5 \times 10^{-5}$)
 - HCO_3^- ($K_a = 4.8 \times 10^{-11}$)
 - HCO_2H ($K_a = 1.8 \times 10^{-4}$)
 - HIO_3 ($K_a = 1.6 \times 10^{-1}$)

Solution

a.

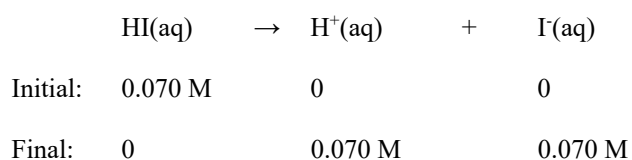
i.



$$\text{pOH} = -\log[\text{OH}^{-}] = -\log(0.120) = 0.92$$

$$\text{pH} + \text{pOH} = \text{pH} + 0.92 = 14.00 \text{ gives } \text{pH} = 13.08$$

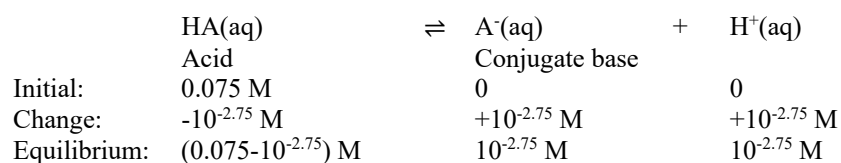
ii.



$$\text{pH} = -\log[\text{H}^{+}] = -\log 0.070 = 1.15$$

b.

- $\text{pH} = -\log[\text{H}^{+}] = 3.00$ gives $[\text{H}^{+}] = 10^{-2.75}\text{M}$ (at equilibrium)
- $K_a \times K_b = 1.00 \times 10^{-14}$ (1)



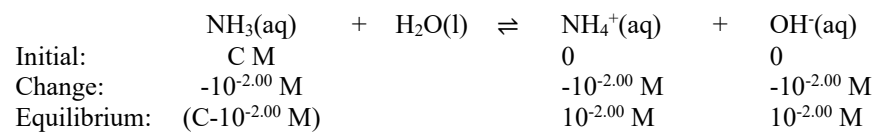
$$K_a = \frac{[\text{A}^{-}][\text{H}^{+}]}{[\text{HA}]} = \frac{(10^{-2.75}) \times (10^{-2.75})}{(0.075 - 10^{-2.75})} = 4.3 \times 10^{-5}$$

Use equation 1 to find the base constant, K_b , for the conjugate base, A^{-} :

$$K_b \times 4.3 \times 10^{-5} = 1.00 \times 10^{-14} \text{ gives } K_b = 2.3 \times 10^{-10}$$

c. $\text{pH} + \text{pOH} = 12 + \text{pOH} = 14.00$ gives $\text{pOH} = -\log[\text{OH}^-] =$

2.00 and therefore $[\text{OH}^-] = 10^{-2.00} \text{ M}$ (at equilibrium)



$$K_b = \frac{[\text{NH}_4^+][\text{OH}^-]}{[\text{NH}_3]} = \frac{(10^{-2.00}) \times (10^{-2.00})}{(\text{C} - 10^{-2.00})} = 1.8 \times 10^{-5} \text{ gives } \text{C} = 5.566 \text{ M}$$

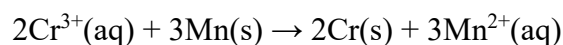
$$n = \text{C} \times V = \left(5.566 \frac{\text{mol}}{\text{L}} \right) \times (1.00 \text{ L}) = 5.566 \text{ mol}$$

$$m = n \times M = (5.566 \text{ mol}) \times \left(17.03 \frac{\text{g}}{\text{mol}} \right) = 94.8 \text{ g}$$

d. $\text{HCO}_3^- (K_a = 4.8 \times 10^{-11}) < \text{CH}_3\text{CH}_2\text{CH}_2\text{CO}_2\text{H} (K_a = 1.5 \times 10^{-5}) < \text{HCO}_2\text{H} (K_a = 1.8 \times 10^{-4}) < \text{HIO}_3 (K_a = 1.6 \times 10^{-1})$ (strongest acid)

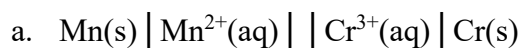
Problem 3

- a. Write the cell-diagram for the galvanic cell using the following cell reaction (**2.5%**):



- b. When the cell reaction in **Problem 3a** is at chemical equilibrium, the molar concentration of Cr^{3+} ions is 1.00×10^{-21} M. Calculate the molar concentration of the Mn^{2+} ions at chemical equilibrium. (**3%**)
- c. Explain whether you expect the pH to increase, decrease or remains unaffected when a $\text{HBr}(\text{aq})$ solution undergoes electrolysis using inert platinum electrodes (motivate your answer). (**4%**)
- d. Identify which of the following redox reactions that can be used to generate electrical current at standard conditions (motivate your answer) (**3%**):
- $\text{Zn}^{2+}(\text{aq}) + \text{Cu}(\text{s}) \rightarrow \text{Zn}(\text{s}) + \text{Cu}^{2+}(\text{aq})$
 - $\text{Ni}^{2+}(\text{aq}) + \text{Fe}(\text{s}) \rightarrow \text{Ni}(\text{s}) + \text{Fe}^{2+}(\text{aq})$
 - $2\text{Ag}^{+}(\text{aq}) + \text{Fe}(\text{s}) \rightarrow 2\text{Ag}(\text{s}) + \text{Fe}^{2+}(\text{aq})$
 - $2\text{Cr}^{3+}(\text{aq}) + 3\text{Cu}(\text{s}) \rightarrow 2\text{Cr}(\text{s}) + 3\text{Cu}^{2+}(\text{aq})$

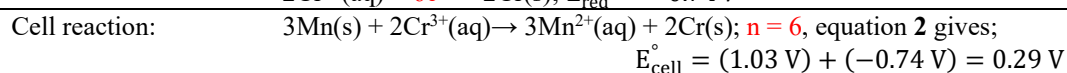
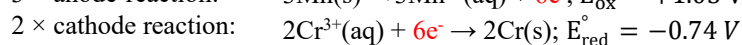
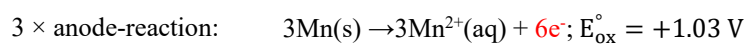
Solution



b.

- $E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{0.059}{n} \log Q = 0$ at equilibrium (1)

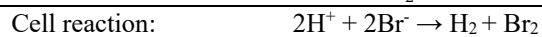
- $E_{\text{cell}}^{\circ} = E_{\text{ox}}^{\circ} + E_{\text{red}}^{\circ}$ (2)



Calculate $[\text{Mn}^{2+}]$ by using equation 1:

$$0.29 - \frac{0.059}{6} \log \frac{[\text{Mn}^{2+}]^3}{(1.00 \times 10^{-21})^2} = 0 \text{ gives } [\text{Mn}^{2+}] = 6.77 \times 10^{-5} \text{ M}$$

c.

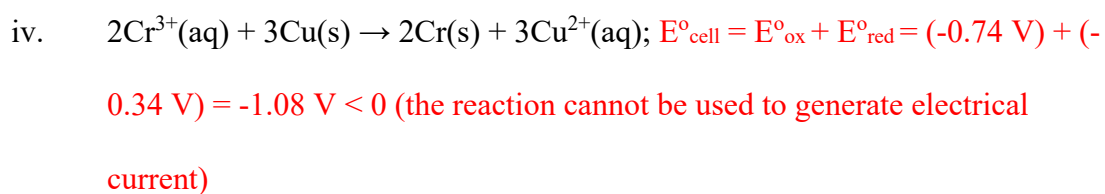
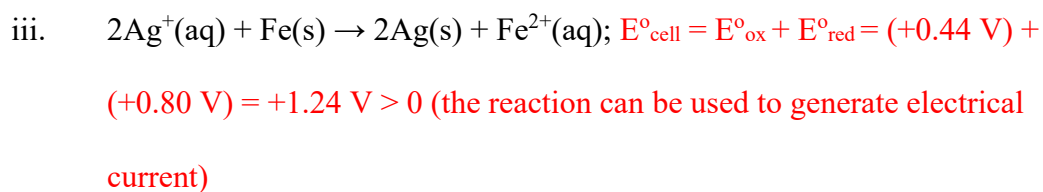
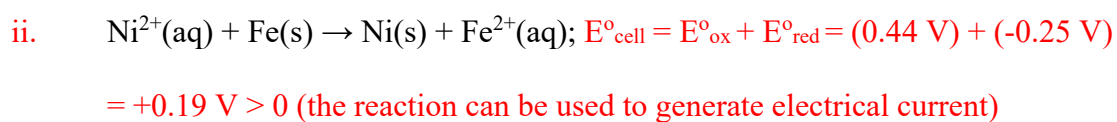
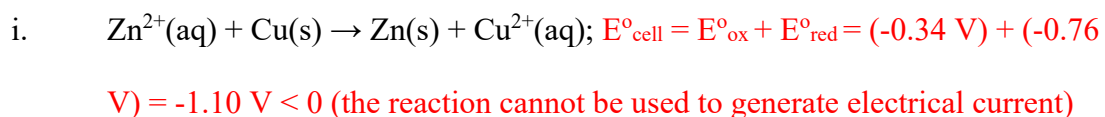


Thus, because the cell reaction consumes hydronium ions (H^{+}), the pH of the HBr(aq)

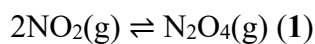
solution increases:

$$\uparrow \text{pH} = -\log[\text{H}^{+}] \downarrow$$

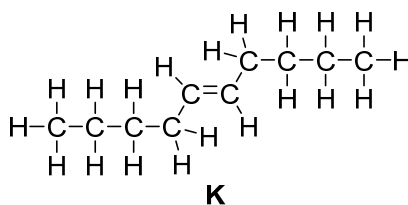
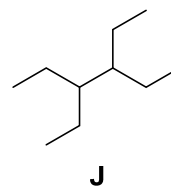
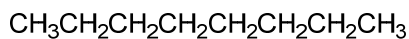
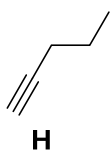
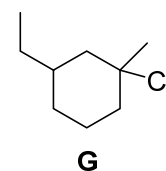
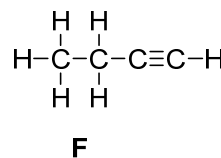
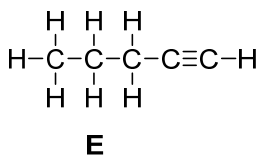
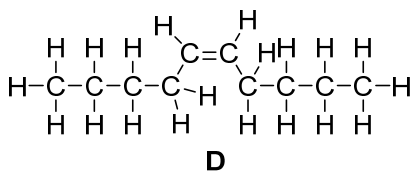
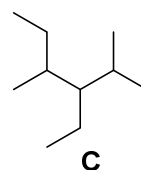
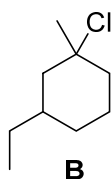
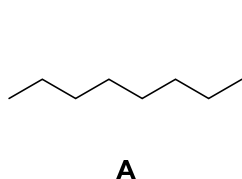
d.



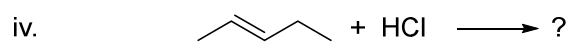
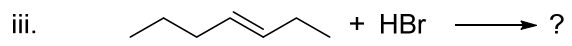
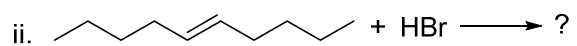
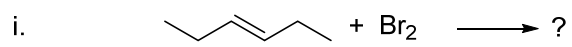
Problem 4



- a. When reaction **1** is at chemical equilibrium in a 2.00 L reaction vessel, the reaction vessel contains 0.35 mol of NO_2 and 10.00 mol of N_2O_4 . Calculate the equilibrium constant (K_c) for reaction **1**. (2%)
- b. Reaction **1** is forced away from its first equilibrium described in **Problem 4a** by increasing the volume of the reaction vessel from 2.00 L to 4.00 L. Calculate the molar concentrations for NO_2 and N_2O_4 when the new chemical equilibrium is established. (4%)
- c. Identify which of the compounds below that are identical, constitutional isomers, and geometric isomers (2.5%):

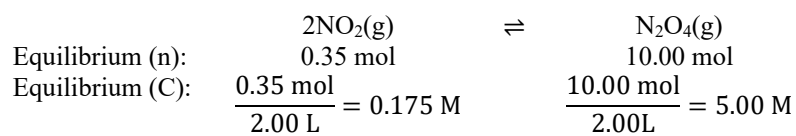


d. Show product or products by structure and name that are formed in each of the following reactions: (4%)



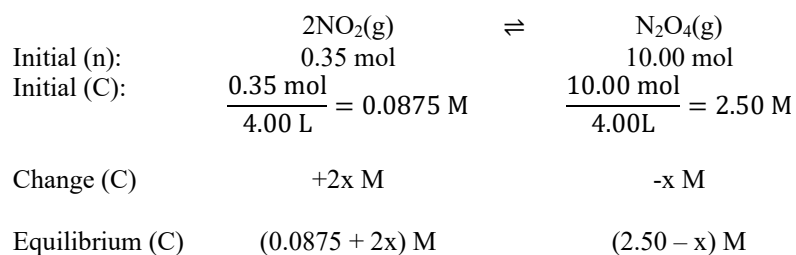
Solution

a.



$$K_c = \frac{[\text{N}_2\text{O}_4]}{[\text{NO}_2]^2} = \frac{5.00}{0.175^2} = 163.27$$

- b. According to the Le Chatelier's principle, when the volume of the reaction vessel increases, the reaction re-establishes its chemical equilibrium by moving in the direction that increases the total gas concentration in the reaction vessel, which is towards NO_2 in the current case.

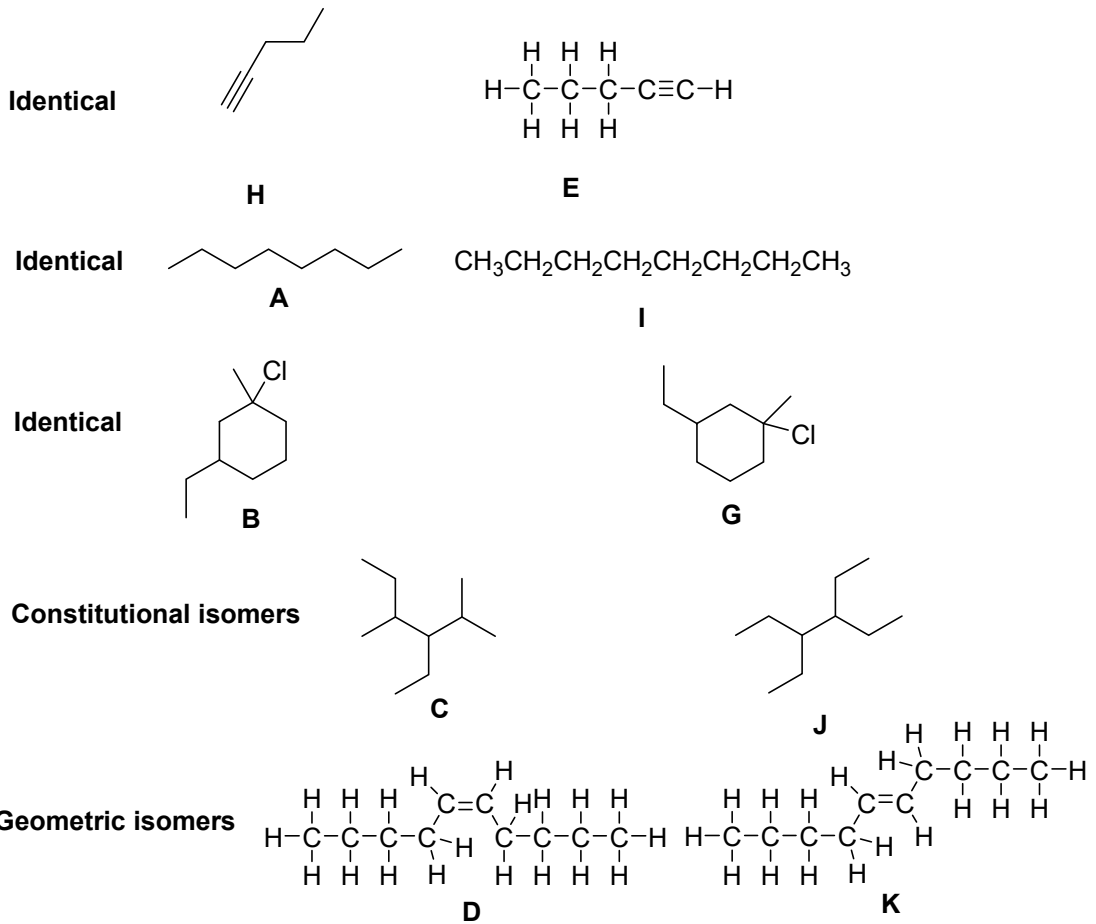


$$K_c = \frac{[\text{N}_2\text{O}_4]}{[\text{NO}_2]^2} = \frac{(2.50 - x)}{(0.0875 + 2x)^2} = 163.27 \text{ gives } x = 0.0178991 \text{ M}$$

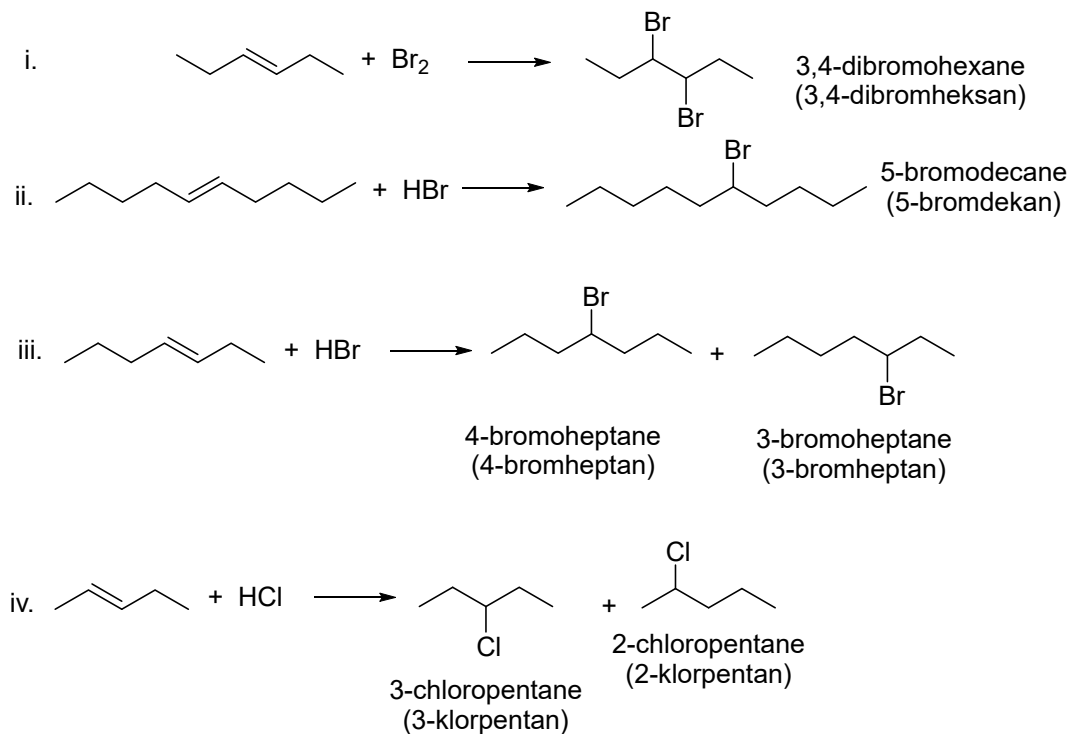
$$[\text{NO}_2] = 0.0875 + 2x = (0.0875 + 2 \times 0.0178991) \text{ M} = 0.123 \text{ M}$$

$$[\text{N}_2\text{O}_4] = 2.50 - x = (2.50 - 0.0178991) \text{ M} = 2.48 \text{ M}$$

c.



d.



Problem 5

- a. Use balanced reaction equations to explain how sulfur dioxide contributes to acid rain.
(4%)

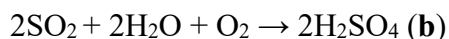
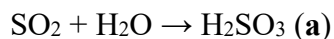
- b. Show the balanced reaction equations for the removal of sulfur dioxide from flue air using limestone and point out which atoms that are reduced and oxidized. (6%)

- c. Explain:
 - i. which type of air pollutions that can be removed by electrostatic filters (2%)

 - ii. graphically and fill in by words how electrostatic filters work. (4%)

Solution

- a. **Step 1.** When sulfur dioxide in the atmosphere together with O₂ is dissolved in the water droplets in the clouds, chemical reactions occur that generates sulfurous acid (**a**) and sulfuric acid (**b**):



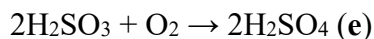
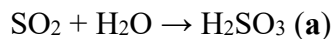
Comment 1.

Reaction **b** can be replaced by the following reaction sequence:

1. $2\text{SO}_2 + \text{O}_2 \rightarrow 2\text{SO}_3$ (**c**)
2. $\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4$ (**d**)

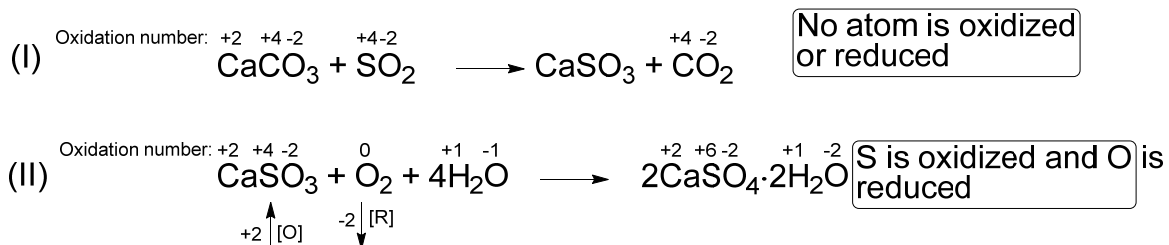
Comment 2.

Reaction **b** can also be replaced by the following reaction sequence:



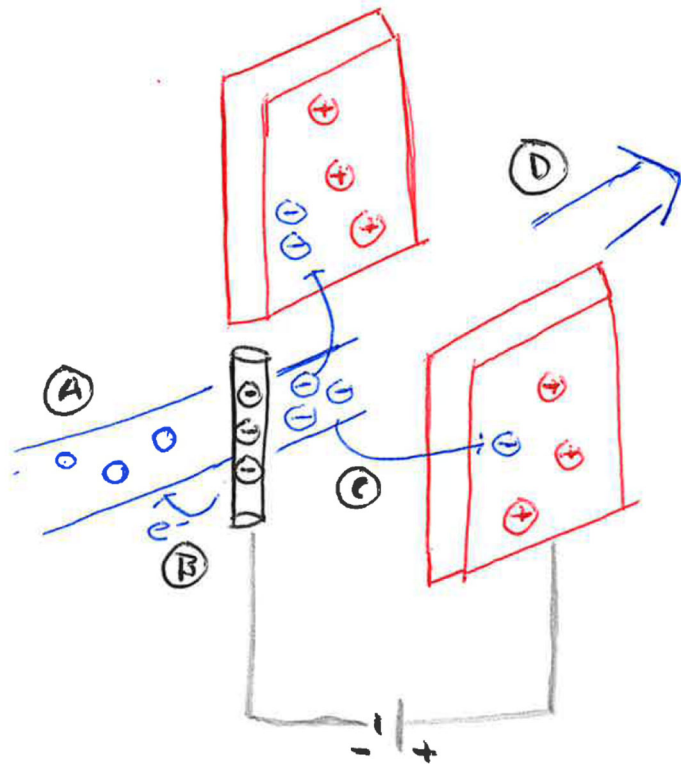
Step 2. The acidic water droplets in the clouds fall as acidic rain.

b.



c. i. Particles (dust) from dirty air

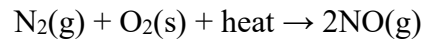
ii. When dirty air containing particles is entering the electrostatic filter (A), the particles get ionized (B). The ionized particles get attracted to the electrode by opposite charge (C), which allows the pure air to pass through the electrostatic filter (D).



Problem 6

a. Explain how carbon dioxide is released to the atmosphere and absorbed from the atmosphere when biomass is used as energy source. **(5%)**

b. For the reaction:



i. Explain whether it occurs endothermically or exothermically. **(2%)**

ii. Explain what happens to the heat that is absorbed by the reaction. **(3%)**

c. Explain:

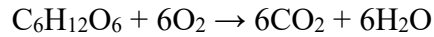
i. The difference between high quality energy and low quality energy. **(2%)**

ii. How the energy quality is affected when one type of energy is converted to another type of energy. **(4%)**

Solution

a.

- Carbon dioxide is released to the atmosphere when biomass is combusted:



- Biomass absorbs CO_2 from the atmosphere as it is growing.

b.

i. Endothermically

ii. The absorbed heat is held as chemical bound energy (potential energy) in the product (NO).

c.

i. High quality energy can carry out many tasks whereas low quality energy is only able to perform a few tasks.

ii. When one energy form is converted to another, we always end up with lower-quality or less usable energy than we started with.

Problem 7 (Answers in red color)

Oppdrett og eksport av atlantisk laks (*Salmo Salar*) er et sentralt satsingsområde for norsk økonomi. Etter etablering av industrien på 70 tallet og vekst-problemer med fiskehelse på 80 og 90-tallet er næringen vokst til en årlig produksjon på 1.5 mill. tonn/år. Oppdrett medfører flere miljøproblemer, både av kjemisk, biologisk og fysisk art.

- a. Hva er de viktigste miljøproblemene som oppstår ved merd-basert oppdrett av laks i sjø (marint miljø)?

Her bør studenten kunne nevne minst fire potensielle problemer. De trenger ikke eksemplifisere, men jeg tar med noen og man kan godt gi ekstrascoring for disse:

- Overgjødning/eutrofiering på grunn av økt tilførsel av næringssalter (spesielt PO_4^{3-} og NH_4^+).
- Saprobiering (eller hypoxia) forårsaket av utslipp av bionedbrytbart organisk stoff
- Genetisk innblanding i lokale ville laksestammer ved rømming
- Spredning og oppblomstring av lakselus (*Gyrodactylus salaris*)
- Bruk av desinfiserende kjemikalier ved avlusing (H_2O_2)
- Spredning av fiskesykdommer (ILA, etc.)

Produksjonen nevnt over (fra 2019) medførte utslipp av ca. 900.000 tonn organisk stoff i form av fôrspill og feces (fiskeavføring).

- b. Hvorfor er utslipp av organisk stoff til akvatiske miljø et problem?

Vel, her gir vi jo bort en av svarene over... Problemet her er det man i økologien kaller saprobiering eller hypoxia; dvs. redusert konsentrasjon av løst O_2 på grunn av økt mikrobielt forbruk ved aerob nedbrytning av tilført bionedbrytbart organisk materiale. Definisjonen er ikke veldig stram, men elementene knyttet til økt tilførsel av oksiderbart organisk materiale, og mikroorganismers forbruk knyttet til denne prosessen bør være med (i en eller annen form). Mens saprobiering betegner alle situasjoner av redusert O_2 (fra redusert oxia til komplett anoxia) betegner hypoxia et miljø der løst O_2 har falt til nivåer der høyere organismer får signifikant redusert «fitness» (som regel rundt 2 mg/l).

Sammen med det organiske utslippet følger ca. 60.000 tonn nitrogen (i hovedsak aminosyrer/protein og ammonium) og 12.500 tonn fosfor.

- c. Hvilken konsekvens vil utslipp av disse næringssaltene ha på det akvatiske miljø, og hva kaller vi denne effekten?

Og her gir vi den andre... 😊, men det er ok (man må være både kunnskapsrik og våken for å koble disse spørsmålene). Svaret her er eutrofiering (det andre) og definisjonen på dette (og dermed virkningen) er at økt tilførsel av begrensende næringssalt for primærproduksjonen (ofte begrenset til den fotosyntetiske) vil gi økt primærproduksjon (algevekst), noe som har flere negative miljøkonsekvenser (algetettheten alene (siktedyb), potensielle algetoksiner, oksygensvikt ved nattrespirasjon, m.fl.). Her er det nok om studenten definerer eller viser at de forstår begrepet (eutrofiering) og kan sette navnet på begrepet...

- d. Konsekvensen av økt utslipp av organisk stoff og utslipp av næringssalter er koplet (dvs. at den ene ofte følger den andre). Hvorfor er det slik?

Dette er «A» spørsmålet som tester studentens forståelse. Svaret er at ved eutrofiering vil den økte algebiomassen fikse store mengder CO₂ (danne organisk reduserte forbindelser) som seinere i vekstsesongen (men også under) vil synke og dekomponere under forbruk av løst oksygen (saprobieering). Noen kaller denne effekten for autogen saprobieering (men dette er ikke forelest). Vice versa vil økt utslipp av organisk stoff føre til det samme. Koplingen tilbake til eutrofiering går gjennom anoksiske sedimentmekanismer der innlagret næringsstoffer (spesielt fosfater) frigjøres ved anoksiske respirasjon av spesielt jernreduserende bakterier (men også andre di- og trivalente metaller som bakterielt kan reduseres (fungerer som mikrobiell elektronakseptor)). Løselighetsproduktet er betydelig høyere for reduserte metall-fosfater, og fosfat mobiliseres og lekker ut av sedimentene. Dersom vannmassene ikke er sjikta (dvs. rimelig homogen tetthet) vil frigjort fosfat i dypvannet transporteres til fototrofisk (eufotisk eller fotisk) sone (overflaten) og re-stimulere eutrofiering. Denne effekten kalles også for sekundær-eutrofiering.

Jeg forventer ikke at studentene har alle detaljer i mekanismene med her, men det man må ha med (for 100% uttelling) er at organisk stoff (tilført eller autogent) reduserer/fjerner løst O₂ i dypvannet, noe som fører til metallreduksjon (holder å peke på tre-verdig jern) og frigjøring av fosfat, som ved transport til overflaten stimulerer algeveksten. Gi litt slakk her, og tolk i beste mening...