Diplomi-insinöörien ja arkkitehtien yhteisvalinta – dia-valinta 2008

Insinöörivalinnan kemian koe 28.05.2008

1. Räjähdysaineet ovat tehokkaita, jos ne tuottavat paljon kaasumolekyylejä räjähtäessään. Nitroglyseriini räjähtää seuraavan reaktioyhtälön mukaisesti:

   $4\ C_3H_5N_3O_9\ (s) \rightarrow 12\ CO_2\ (g) + 6\ N_2\ (g) + 10\ H_2O\ (g) + O_2\ (g)$

   Laske räjähdyksessä syntyvien kaasujen kokonaispaine lämpötilassa 500 ^oC, kun 25,0 g nitroglyseriiniä räjähtää kestävässä astiassa, jonka tilavuus on 1,00 dm^3. Oletetaan ideaalikaasutilanne, vaikka kaasut eivät ole ideaalikaasuja korkeassa paineessa. (Pa = N/m^2 ja J = Nm).

2. Orgaanisen yhdisteen koostumus massaprosentteina on seuraava: 59,98 % C, 13,42 % H ja 26,60 % O.
   a) Mikä on yhdisteen empiirinen kaava?
   b) Mikä on yhdisteen molekyylikaava, jos sen moolimassa on noin 60 g/mol?
   c) Piirrä kaikki mahdolliset rakennekaavat yhdisteelle ja nimeä ne.

3. a) Piirrä rakennekaavat seuraaville yhdisteille.
      1) 2-klooributaani
      2) 2-penteeni (pent-2-eeni)
      3) etyylisykloheksaani
      4) 2-metyyli-3-butenaali (2-metyylibut-3-enaali)
      5) metyyliamiini
   b) Alla on esitetty kolme kemiallista ominaisuutta, joihin yksi tai useampi a) kohdan yhdisteistä voidaan liittää. Yhdistä yhdisteet ja ominaisuudet.
      1) yhdiste liukenee veteen muodostaen emäksisen liuoksen
      2) yhdiste on optisesti aktiivinen
      3) yhdisteellä esiintyy *cis*-*trans*-isomeriaa.
      Perustele vastauksesi.

4. Yhdenarvoinen orgaaninen happo tunnistettiin harjoitustyössä siten, että sen happovahvuutta verrattiin tunnettujen happojen vahvuuksiin. Tuntemattoman hapon 0,100 mol/dm^3 vesiliuoksen pH:n arvoksi mitattiin 2,60.

   a) Laske mittaustuloksen perusteella happovakio K_a ja vertaa sitä alla olevan taulukon arvoihin. Mikä happo on kyseessä?

Happo	Happovakio
Muurahaishappo	$1{,}8 \cdot 10^{-4}\ mol/dm^3$
Etikkahappo	$1{,}8 \cdot 10^{-5}\ mol/dm^3$
Propionihappo	$1{,}3 \cdot 10^{-5}\ mol/dm^3$
Bentsoehappo	$6{,}5 \cdot 10^{-5}\ mol/dm^3$

   b) Kirjoita reaktioyhtälö reaktiolle, joka tapahtuu kun a) kohdan liuokseen lisätään natriumhydroksidia. Nimeä tuotteet.
   c) Jos a) kohdan liuokseen lisätään ekvivalentti määrä natriumhydroksidia, onko muodostunut liuos hapan, emäksinen vai neutraali? Vastaa sanallisesti ja perustele vastauksesi.

5. Virtalähteenä käytetään sähkökemiallista kennoa (paristo), jossa kuparimetallielektrodi on upotettu 1,00 mol/dm^3 Cu^{2+}-liuokseen ja nikkelimetallielektrodi on upotettu 1,00 mol/dm^3 Ni^{2+}-liuokseen. Liuoksia yhdistää suolasilta. Kennon lämpötila on 25 °C. Tunnetaan seuraavat normaalipotentiaalit (25 °C):

$Ni^{2+} + 2\ e^- \rightarrow Ni \qquad E^o = -0{,}25$ V

$Cu^{2+} + 2\ e^- \rightarrow Cu \qquad E^o = +0{,}34$ V

a) Kirjoita anodi- ja katodireaktiot sekä kokonaisreaktio (kennoreaktio).
b) Laske kennon lähdejännite.
c) Kun kennosta otetaan virtaa, muuttuvat elektrodien massat. Kumman elektrodin massa pienenee ja kumman kasvaa? Perustele vastauksesi.
d) Laske, mitkä ovat elektrodien massat, kun paristosta on otettu virtaa 5,0 A 4 tunnin ajan. Kummankin elektrodin alkumassat ovat 200 g. Liuostilavuudet voidaan olettaa vakioiksi.

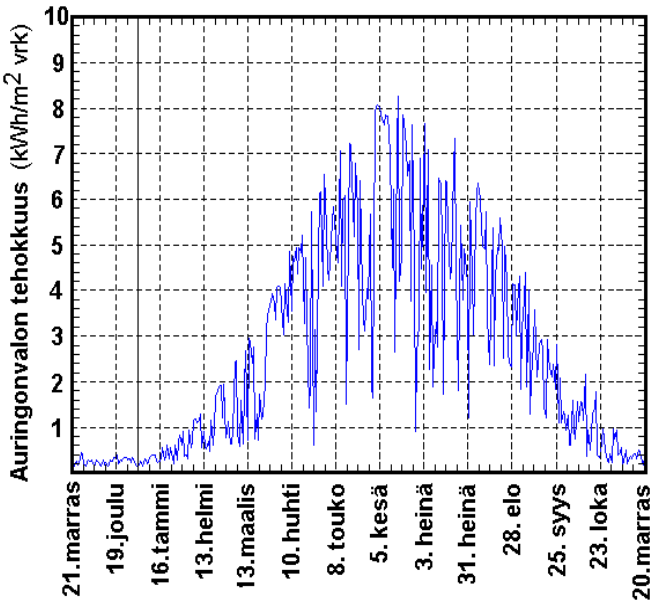
6. Auringon valon vaikutuksesta pellon taimet (biomassa) tuottavat sakkaroosia ($C_{12}H_{22}O_{11}$) seuraavalla fotosynteesireaktiolla:

$12\ CO_2\ (g) + 11\ H_2O\ (l) \rightarrow C_{12}H_{22}O_{11}\ (s) + 12\ O_2\ (g) \qquad \Delta H = 5640$ kJ/mol sakkaroosi

Viereinen diagrammi kuvaa auringonvalon tehokkuutta yksiköissä kWh energiaa neliömetriä ja vuorokautta kohden Turussa vuonna 2007. (Ws = J)

Laske mikä prosenttiosuus kesäkuun 5. päivän auringon energiasta kului sakkaroosin tuottamiseen eli varastoitui biomassaan, kun hehtaaria (1 ha = 10 000 m^2) kohden syntyi 200 kg sakkaroosia vuorokaudessa.

Tämä ei ole fotosynteesin kokonaishyötysuhde, sillä kasvit kuluttavat energiaa soluhengitykseen.



Alkuaineiden moolimassoja:

Alkuaine:	H	C	N	O	Ni	Cu
M / g mol^{-1}	1,008	12,01	14,01	16,00	58,70	63,55

Vakiot:

$R = 8{,}314$ J K^{-1} mol^{-1} $\qquad F = 96485$ A s mol^{-1}

Diplomingenjörs- och arkitektutbildningens gemensamma antagning – dia-antagning 2008

Ingenjörsantagningens prov i kemi 28.05.2008

1. Sprängämnen är effektiva om de producerar många gasmolekyler vid detonationen. Nitroglycerin detonerar enligt följande reaktionslikhet:

   $4\ C_3H_5N_3O_9(s) \rightarrow 12\ CO_2(g) + 6\ N_2(g) + 10\ H_2O(g) + O_2(g)$

   Beräkna det totala trycket av reaktionsgaserna efter en explosion vid temperaturen 500 °C, då 25,0 g nitroglycerin exploderar i en hård behållare vars volym är 1,00 dm^3. Antag ideal gas även om gaserna är icke-ideala vid högt tryck. (Pa = N/m^2 och J = Nm).

2. En organisk förenings sammansättning i massprocent är följande: 59,98 % C, 13,42 % H och 26,60 % O.
   a) Vilken är föreningens empiriska formel?
   b) Vilken är föreningens molekylformel, då dess molmassa är ca 60 g/mol.
   c) Rita alla möjliga strukturformler för föreningen och namnge dem.

3. a) Rita strukturformler för följande föreningar
      1) 2-klorbutan
      2) 2-penten (pent-2-en)
      3) etylcyklohexan
      4) 2-metyl-3-butenal (2-metylbut-3-enal)
      5) metylamin
   b) De tre nedanstående kemiska egenskaperna hör ihop med en eller flera av föreningarna i punkt a). Kombinera föreningar och egenskaper.
      1) föreningen löser sig i vatten varvid en basisk lösning bildas
      2) föreningen är optiskt aktiv
      3) föreningen har *cis-trans*-isomeri
      Motivera ditt svar.

4. En okänd envärd organisk syra identifierades i ett övningsarbete genom att syrans styrka jämfördes med kända syrors styrka. För en 0,100 mol/dm^3 vattenlösning av den okända syran uppmättes pH-värdet 2,60.

   a) Räkna, på basen av mätningsresultatet, syrakonstanten K_a och jämför den med värdena i nedanstående tabell. Vilken syra är det fråga om?

Syra	Syrakonstant
Myrsyra	$1{,}8 \cdot 10^{-4}$ mol/dm^3
Ättiksyra	$1{,}8 \cdot 10^{-5}$ mol/dm^3
Propionsyra	$1{,}3 \cdot 10^{-5}$ mol/dm^3
Bensoesyra	$6{,}5 \cdot 10^{-5}$ mol/dm^3

   b) Skriv reaktionslikhet för den reaktion som sker då natriumhydroxid sätts till lösningen i punkt a). Namnge produkterna.
   c) Om man till lösningen i punkt a) sätter en ekvivalent mängd natriumhydroxid, bildas det då en sur, basisk eller neutral lösning? Besvara frågan med ord och motivera ditt svar.

5. Som strömkälla används en elektrokemisk cell (ett batteri), där en elektrod av kopparmetall är nedsänkt i en 1,00 mol/dm^3 Cu^{2+}-lösning och en elektrod av nickelmetall är nedsänkt i en 1,00 mol/dm^3 Ni^{2+}-lösning. Lösningarna förenas av en saltbrygga. Temperaturen i cellen är 25 ^{o}C. Man känner följande normalpotentialer (25 ^{o}C):

   $Ni^{2+} + 2\ e^- \rightarrow Ni$ $\quad E^o = -0{,}25$ V

   $Cu^{2+} + 2\ e^- \rightarrow Cu$ $\quad E^o = +0{,}34$ V

   a) Skriv anod- och katodreaktionerna samt totalreaktionen (cellreaktionen).
   b) Beräkna cellens elektromotoriska kraft.
   c) Då ström tas ur cellen förändras elektrodernas massor. Vilkendera elektrodens mass minskar och vilkendera ökar? Motivera ditt svar.
   d) Beräkna elektrodernas massor då en ström på 5,0 A tagits ur batteriet under 4 timmar. Utgångsmassan för vardera elektroden är 200 g. Lösningsvolymerna kan antas vara konstanta.

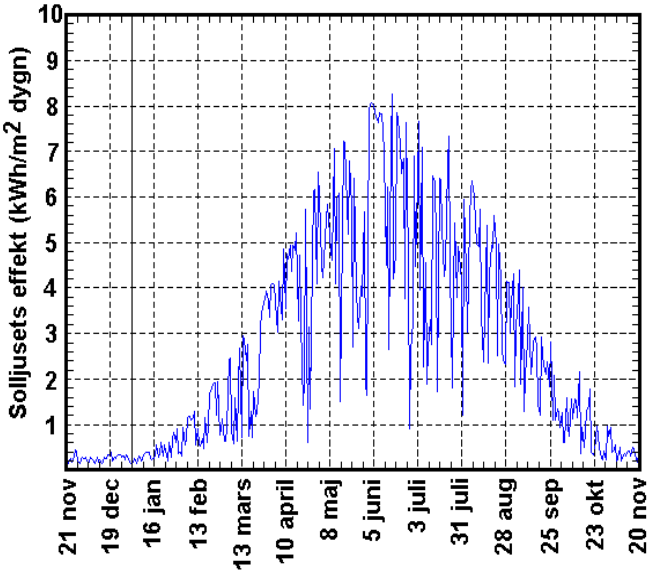
6. Under soliga sommardagar producerar plantorna på en åker sackaros ($C_{12}H_{22}O_{11}$) enligt följande fotosyntesreaktion:

   $12\ CO_2\ (g) + 11\ H_2O\ (l) \rightarrow C_{12}H_{22}O_{11}\ (s) + 12\ O_2\ (g)$ $\quad \Delta H = 5640$ kJ/mol sackaros

   Vidstående diagram visar solljusets effekt i enheten kWh energi per kvadratmeter och dygn uppmätt i Åbo år 2007. (Ws = J)

   Beräkna den procentuella andelen av solljusenergin den 5 juni som gick åt till produktion av sackaros dvs. lagrades i biomassan (plantorna), då 200 kg sackaros bildades per dygn och hektar.
   (1 ha = 10 000 m^2)

   Detta är inte den totala verkningsgraden för fotosyntesen då växterna förbrukar energi i cellandningen.



Grundämnenas molmassor:

Grundämne:	H	C	N	O	Ni	Cu
M / g mol^{-1}	1,008	12,01	14,01	16,00	58,70	63,55

Konstanter:

$R = 8{,}314$ J K^{-1} mol^{-1} $\quad F = 96485$ A s mol^{-1}

Entrance Examination at the Universities of Technology in Finland

Engineering programs, Chemistry 28 May 2008

1. Explosives are effective if they produce a large number of gaseous molecules when they explode. Nitroglycerin explodes according to the following equation:

   $4\ C_3H_5N_3O_9\ (s) \rightarrow 12\ CO_2\ (g) + 6\ N_2\ (g) + 10\ H_2O\ (g) + O_2\ (g)$

   Calculate the total pressure of gases formed in the explosion at 500 ^oC when 25.0 g of nitroglycerin explodes in a 1.00 dm^3 rigid container. Assume ideal gas behavior although gases are not ideal gases at high pressure. (Pa = N/m^2 ja J = Nm).

2. The composition of an organic compound as mass percent is following: 59.98 % C, 13.42 % H and 26.60 % O.
   a) What is the empirical formula of the compound?
   b) What is the molecular formula of the compound if its molar mass is about 60 g/mol?
   c) Draw all the possible structural formulas for the compound and name them.

3. a) Draw structural formulas for the following compounds.
      1) 2-chlorobutane
      2) 2-pentene (pent-2-ene)
      3) ethylcyclohexane
      4) 2-methyl-3-butenal (2-methylbut-3-enal)
      5) methylamine
   b) Three chemical properties which can be connected to one or several compounds in part a) are given below. Combine the compounds and properties.
      1) compound dissolves in water forming basic solution
      2) compound is optically active
      3) compound exhibits *cis-trans* isomerism.
      Justify your answer.

4. A monoprotic organic acid was identified in a practical work so that its acid strength was compared to the strengths of known acids. The pH value of 0.100 mol/dm^3 water solution of an unknown acid was measured to be 2.60.

   a) On the basis of the measuring result calculate the acid dissociation constant K_a and compare it to the values in the table below. What is the acid in question?

Acid	Acid dissociation constant
Formic acid	$1.8 \cdot 10^{-4}$ mol/dm^3
Acetic acid	$1.8 \cdot 10^{-5}$ mol/dm^3
Propionic acid	$1.3 \cdot 10^{-5}$ mol/dm^3
Benzoic acid	$6.5 \cdot 10^{-5}$ mol/dm^3

   b) Write the reaction equation for reaction which takes place when sodium hydroxide is added to the solution of part a). Name the products.
   c) If an equivalent amount of sodium hydroxide is added to the solution of part a), is the solution formed acidic, basic or neutral? Answer verbally and justify your answer.

5. An electrochemical cell (battery), used as a power source, consists of a copper metal electrode immersed in a 1.00 mol/dm^3 Cu^{2+}-solution and nickel metal electrode immersed in a 1.00 mol/dm^3 Ni^{2+}-solution. The solutions are connected with a salt bridge. The temperature of the cell is 25 ^oC. The following standard reduction potentials at 25 ^oC are known:

$Ni^{2+} + 2\ e^- \rightarrow Ni \qquad E^o = -0.25\ V$

$Cu^{2+} + 2\ e^- \rightarrow Cu \qquad E^o = +0.34\ V$

a) Write the anode and cathode reactions as well as the total reaction (cell reaction).
b) Calculate the cell potential.
c) The masses of the electrodes will change when current is taken from the cell. Which one of the electrodes loses weight and which one gains weight? Justify your answer.
d) Calculate the masses of electrodes after a current of 5.0 A has been taken from the battery during 4 hours. At the beginning the mass of each electrode is 200 g. The volumes of the solutions can be assumed constant.

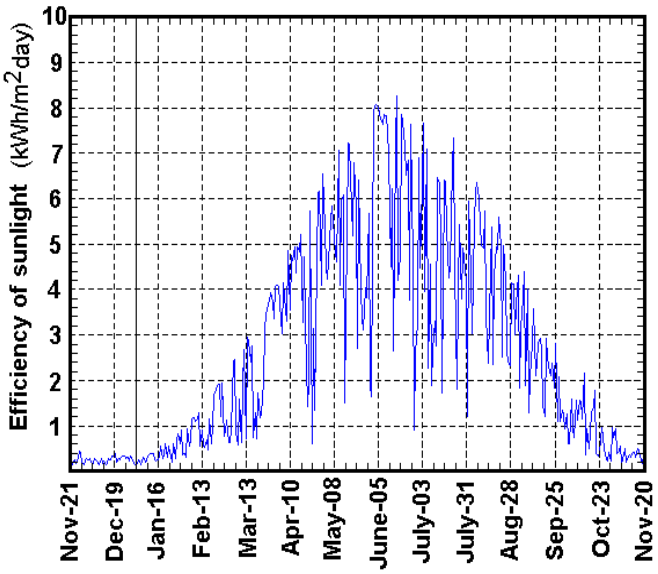
6. Due to the sunlight the plants of the field (biomass) produce saccharose ($C_{12}H_{22}O_{11}$) according to following photosynthesis reaction:

$12\ CO_2\ (g) + 11\ H_2O\ (l) \rightarrow C_{12}H_{22}O_{11}\ (s) + 12\ O_2\ (g) \qquad \Delta H = 5640\ kJ/mol\ saccharose$

The adjacent diagram illustrates the efficiency of sunlight in units of kWh of energy per square meter and day in the city of Turku in the year 2007. (Ws = J)

Calculate which percentage of the solar energy of June 5th was consumed in producing saccharose, e.g. was stored in biomass, when 200 kg saccharose was produced per hectare (1 ha = 10 000 m^2) in one day.

This is not the total efficiency of photosynthesis, because plants consume energy in cell respiration.



Molar masses of the elements:

Element:	H	C	N	O	Ni	Cu
M / g mol^{-1}	1.008	12.01	14.01	16.00	58.70	63.55

Constants:

$R = 8.314\ J\ K^{-1}\ mol^{-1} \qquad F = 96485\ A\ s\ mol^{-1}$

Diplomi-insinöörien ja arkkitehtien yhteisvalinta – dia-valinta 2008

Insinöörivalinnan kemian koe 2008 malliratkaisut

1. $4\ C_3H_5N_3O_9(s) \rightarrow 12\ CO_2(g) + 6\ N_2(g) + 10\ H_2O(g) + O_2(g)$

   $M(C_3H_5N_3O_9) = 227{,}10$ g/mol, $m(C_3H_5N_3O_9) = 25{,}0$ g

   $$n(C_3H_5N_3O_9) = \frac{m(C_3H_5N_3O_9)}{M(C_3H_5N_3O_9)} = \frac{25{,}0\,g}{227{,}10\,g/mol} = 0{,}110084\ mol$$

   $n(CO_2) = 3 \cdot n(C_3H_5N_3O_9) = 0{,}330252$ mol

   $n(N_2) = 3/2 \cdot n(C_3H_5N_3O_9) = 0{,}165126$ mol

   $n(H_2O) = 5/2 \cdot n(C_3H_5N_3O_9) = 0{,}27521$ mol

   $n(O_2) = ¼ \cdot n(C_3H_5N_3O_9) = 0{,}027521$ mol

   $\Sigma n = 0{,}798109$ mol

   $T = (273{,}15 + 500)$ K $= 773{,}15$ K

   $pV = \Sigma nRT$, $p = \Sigma nRT / V$

   $$p = \frac{0{,}798109\ mol \cdot 8{,}314\ J\,mol^{-1}\,K^{-1} \cdot 773{,}15\,K}{1{,}00 \cdot 10^{-3}\,m^3} = 5130219{,}99\ Pa \approx \underline{\mathbf{5130\ kPa}}$$

2. a) Oletetaan, että yhdistettä on 100 g → sisältää 59,98 g C, 13,42 g H ja 26,60 g O

   $$n_C = \frac{m}{M} = \frac{59{,}98\,g}{12{,}01\,g/mol} = 4{,}99417\ mol : 1{,}66250\ mol = 3{,}004 \sim 3$$

   $$n_H = \frac{m}{M} = \frac{13{,}42\,g}{1{,}008\,g/mol} = 13{,}31349\ mol : 1{,}66250\ mol = 8{,}008 \sim 8$$

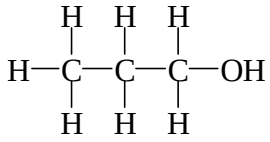
   $$n_O = \frac{m}{M} = \frac{26{,}60\,g}{16{,}00\,g/mol} = 1{,}66250\ mol : 1{,}66250\ mol = 1$$

   → **empiirinen kaava = $(C_3H_8O)_n$**

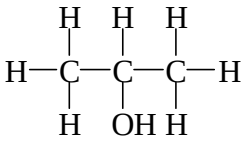
   b) jos n = 1: $M(C_3H_8O) = (3 \cdot 12{,}01 + 8 \cdot 1{,}008 + 16)$ g/mol $= 60{,}09$ g/mol

   → n = 1, **molekyylikaava = C_3H_8O**

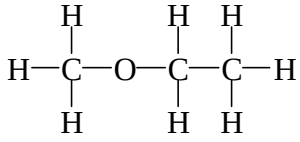
c)



1-propanoli



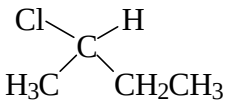
2-propanoli



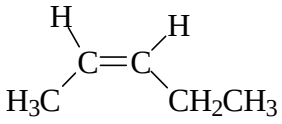
etyylimetyylieetteri

3.a)

1)



2)



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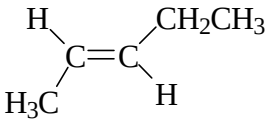

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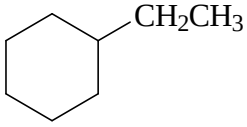
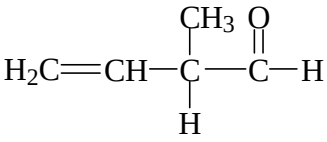


4)



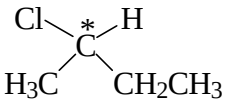
5) CH_3NH_2

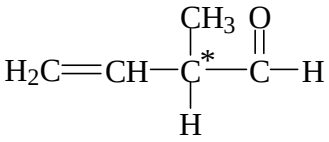
b)

1) **Yhdiste 5** (**metyyliamiini, CH_3NH_2)** on orgaaninen emäs, joka liuetessaan veteen muodostaa emäksisen liuoksen:

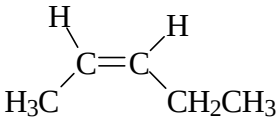
$$CH_3NH_2 + H_2O \Leftrightarrow CH_3NH_3^+ + OH^-$$

2) Yhdisteet **1 (2-klooributaani) ja 4 (2-metyyli-3-butenaali)** ovat optisesti aktiivisia, sillä ne sisältävät hiiliatomin (asymmetrinen hiili, *), johon on kiinnittynyt neljä erilaista atomia tai atomiryhmää. Tällainen yhdiste on optisesti aktiivinen.





3) Yhdisteellä **2 (2-penteeni)** esiintyy *cis*-*trans*-isomeriaa:



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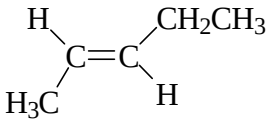


cis *trans*

4. a) pH (HA) = 2,60 → $[H_3O^+] = 10^{-2,60} = 2,511886 \cdot 10^{-3}$ mol/dm^3

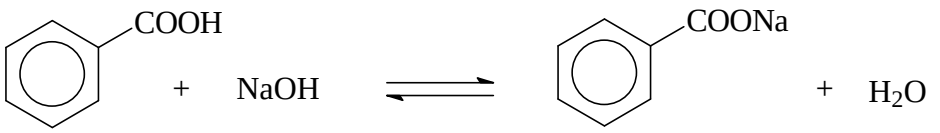
$[HA] = 0,100$ mol/dm^3

	HA	+ H_2O	↔	A^- +	H_3O^+
Alussa (mol/dm^3)	0,100			0	0
Tasapainossa (mol/dm^3)	0,100 - x			x	x

$$K_a = \frac{[A^-]\,[H_3O^+]}{[HA]} = \frac{x^2}{0,100 - x}, \quad x = 2,511886 \cdot 10^{-3} \text{ mol/dm}^3 \rightarrow$$

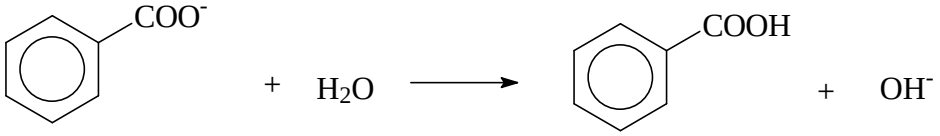
$$K_a = \frac{(2,511886 \cdot 10^{-3} \text{ mol/dm}^3)^2}{(0,100 - 2,511886 \cdot 10^{-3}) \text{ mol/dm}^3} = \underline{\mathbf{6,47 \cdot 10^{-5} \text{ mol/dm}^3}} \rightarrow \underline{\textbf{Bentsoehappo}}$$

b)



natriumbentsoaatti vesi

c) Kyseessä on neutralointireaktio. Natriumhydroksidi on vahva emäs ja bentsoehappo on heikko happo. Muodostuneen suolan, natriumbentsoaatin, vesiliuos on emäksinen (heikkoa happoa vastaava emäs):



5. a) Katodi: $Cu^{2+} + 2\ e^- \rightarrow Cu$ $E° = + 0{,}34$ V
Anodi: $Ni \rightarrow Ni^{2+} + 2\ e^-$ $E° = + 0{,}25$ V
Kenno: $Cu^{2+} + Ni \rightarrow Cu + Ni^{2+}$

b) $E°(\text{kenno}) = E°(\text{katodi}) + E°(\text{anodi}) =$ **0,59 V**

c) Kun kennosta otetaan virtaa, Ni-elektrodi hapettuu (liukenee), ts. sen massa pienenee ja kuparia saostuu liuoksesta (kuparia pelkistyy), ts. Cu-elektrodin massa kasvaa.

d) $It = znF$ $I = 5{,}0$ A
$t = 4$ h
$z = 2$

$$\rightarrow n = \frac{I \cdot t}{Z \cdot F} = \frac{5{,}0\ \text{A} \cdot 4 \cdot 60 \cdot 60\ \text{s}}{2 \cdot 96485\ \text{A s mol}^{-1}} = 0{,}3731\ \text{mol}$$

Ni-elektrodin massa pienenee: $m = n \cdot M = 0{,}3731\ \text{mol} \cdot 58{,}70\ \text{g/mol} = 21{,}90$ g

Cu-elektrodin massa kasvaa: $m = n \cdot M = 0{,}3731\ \text{mol}\ 63{,}55\ \text{g/mol} = 23{,}71$ g

→ **m(Ni-elektrodi)** = 200 g – 21,90 g = **178 g**

m(Cu-elektrodi) = 200 g + 23,71 g = **224 g**

6. Sakkaroosin tuotanto hehtaaria kohden vuorokaudessa:

m = 200 kg = 200000 g

M(sakkaroosi) = (12 · 12,01 + 22 · 1,008 + 11 · 16,00) g/mol = 342,296 g/mol

$$n(\text{sakkaroosi}) = \frac{m}{M} = \frac{200000\,g}{342{,}296\,g/mol} = 584{,}2896\ mol$$

Sakkaroosin tuottamiseen kuluva energia:
ΔH = 5640 kJ/mol sakkaroosia

→ energiankulutus = n · ΔH = 584,2896 mol · 5640 kJ/mol = 3295393 kJ

Auringonvalon tehokkuus 5. kesäkuuta diagrammin mukaan = 8 kWh/m^2 vuorokaudessa.

1 kWh = 1000 Wh → 8 kWh/m^2 = 8000 Wh/m^2 = 8000 · 3600 Ws/m^2 = 28800000 Ws/m^2 = 28800000 J/m^2 = 28800 kJ/m^2

1 ha = 10000 m^2 → Auringon energia hehtaaria kohden vuorokaudessa =

28800 kJ/m^2 · 10000 m^2 = 288000000 kJ

<u>Biomassaan varastoidun energian määrä (%)</u>:

(sakkaroosin tuotanto / auringon energia) ·100%

$$= \frac{3295393\,kJ}{288000000\,kJ} \cdot 100\% = \mathbf{\underline{1{,}14\ \%}}$$

Entrance Examination at the Universities of Technology in Finland

Engineering programs, Chemistry 28 May 2008

Model Solutions

1. $4\ C_3H_5N_3O_9(s) \rightarrow 12\ CO_2(g) + 6\ N_2(g) + 10\ H_2O(g) + O_2(g)$

   $M(C_3H_5N_3O_9) = 227.10$ g/mol, $m(C_3H_5N_3O_9) = 25.0$ g

   $$n(C_3H_5N_3O_9) = \frac{m(C_3H_5N_3O_9)}{M(C_3H_5N_3O_9)} = \frac{25.0\,g}{227.10\,g/mol} = 0.110084\ mol$$

   $n(CO_2) = 3 \cdot n(C_3H_5N_3O_9) = 0.330252$ mol

   $n(N_2) = 3/2 \cdot n(C_3H_5N_3O_9) = 0.165126$ mol

   $n(H_2O) = 5/2 \cdot n(C_3H_5N_3O_9) = 0.27521$ mol

   $n(O_2) = ¼ \cdot n(C_3H_5N_3O_9) = 0.027521$ mol

   $\Sigma n = 0.798109$ mol

   $T = (273.15 + 500)$ K $= 773.15$ K

   $pV = \Sigma nRT$, $p = \Sigma nRT / V$

   $$p = \frac{0.798109\ mol \cdot 8.314\ J\,mol^{-1}\,K^{-1} \cdot 773.15\,K}{1.00 \cdot 10^{-3}\,m^3} = 5130219.99\ Pa \approx \underline{\mathbf{5130\ kPa}}$$

2. a) The mass of the compound is assumed to be 100 g → it contains 59.98 g C, 13.42 g H and 26.60 g O

   $$n_C = \frac{m}{M} = \frac{59.98\,g}{12.01\,g/mol} = 4.99417\ mol : 1.66250\ mol = 3.004 \sim 3$$

   $$n_H = \frac{m}{M} = \frac{13.42\,g}{1.008\,g/mol} = 13.31349\ mol : 1.66250\ mol = 8.008 \sim 8$$

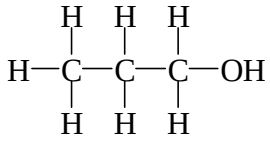
   $$n_O = \frac{m}{M} = \frac{26.60\,g}{16.00\,g/mol} = 1.66250\ mol : 1.66250\ mol = 1$$

   → **<u>empirical formula = $(C_3H_8O)_n$</u>**

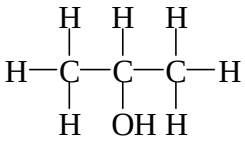
   b) if n = 1: $M(C_3H_8O) = (3 \cdot 12.01 + 8 \cdot 1.008 + 16)$ g/mol $= 60.09$ g/mol

   → n = 1, **<u>molecular formula = C_3H_8O</u>**

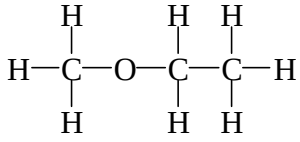
c)



1-propanol



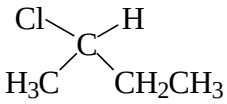
2-propanol



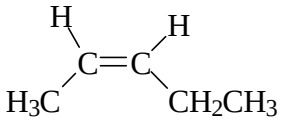
ethyl methyl ether

3.a)

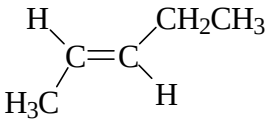
1)



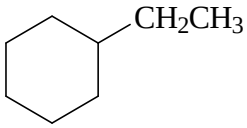
2)



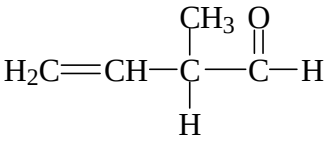
or



3)



4)



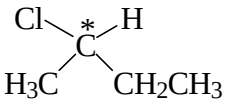
5) CH_3NH_2

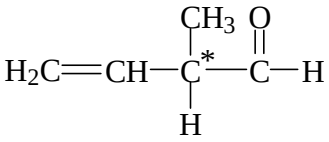
b)

1) **Compound 5 (methylamine, CH_3NH_2)** is an organic base, which dissolves in water forming basic solution:

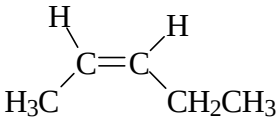
$$CH_3NH_2 + H_2O \Leftrightarrow CH_3NH_3^+ + OH^-$$

2) Compounds **1 (2-chlorobutane) and 4 (2-methyl-3-butenal)** are optically active, since they have a carbon (an asymmetric carbon*) that has four different groups attached to it. This kind of compound is optically active.

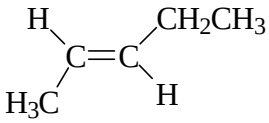




3) Compound **2 (2-pentene)** exhibits *cis*-*trans*-isomerism:



or



cis *trans*

4. a) pH (HA) = 2.60 → $[H_3O^+] = 10^{-2.60} = 2.511886 \cdot 10^{-3}$ mol/dm^3

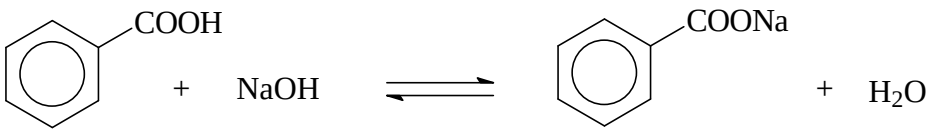
$[HA] = 0.100$ mol/dm^3

	HA + H_2O ↔	A^- +	H_3O^+
At the beginning (mol/dm^3)	0.100	0	0
At equilibrium (mol/dm^3)	0.100 - x	x	x

$$K_a = \frac{[A^-]\,[H_3O^+]}{[HA]} = \frac{x^2}{0.100 - x}, \quad x = 2.511886 \cdot 10^{-3} \text{ mol/dm}^3 \rightarrow$$

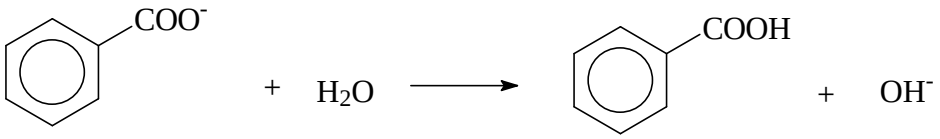
$$K_a = \frac{(2.511886 \cdot 10^{-3} \text{ mol/dm}^3)^2}{(0.100 - 2.511886 \cdot 10^{-3}) \text{ mol/dm}^3} = \underline{\mathbf{6.47 \cdot 10^{-5} \text{ mol/dm}^3}} \rightarrow \underline{\textbf{Benzoic acid}}$$

b)



Sodium benzoate water

c) The reaction in question is a neutralization reaction. Sodium hydroxide is a strong base and benzoic acid is a weak acid. The water solution of a salt formed, sodium benzoate, is basic (a base that corresponds to a weak acid):



5. a)

Cathode:	$Cu^{2+} + 2\ e^-$	$\rightarrow$	Cu	E° = + 0.34 V
Anode:	Ni	$\rightarrow$	$Ni^{2+} + 2\ e^-$	E° = + 0.25 V
Cell:	Cu^{2+} + Ni	$\rightarrow$	Cu + Ni^{2+}	

b) E°(cell) = E°(cathode) + E°(anode) = **0.59 V**

c) When current is taken from the cell, Ni electrode oxidizes (dissolves), that is, its mass decreases and copper deposits from the solution (copper ions reduce), that is, the mass of Cu electrode increases.

d) It = znF I = 5.0 A
t = 4 h
z = 2

$$\rightarrow n = \frac{I \cdot t}{Z \cdot F} = \frac{5.0\,A \cdot 4 \cdot 60 \cdot 60\,s}{2 \cdot 96485\,A\,s\,mol^{-1}} = 0.3731\ mol$$

The mass of Ni electrode decreases: m = n·M = 0.3731 mol · 58.70 g/mol = 21.90 g

The mass of Cu electrode increases: m = n·M = 0.3731 mol 63.55 g/mol = 23.71 g

→ **m(Ni electrode)** = 200 g – 21.90 g = **178 g**

m(Cu electrode) = 200 g + 23.71 g = **224 g**

6. The production of saccharose per hectare in one day:

m = 200 kg = 200000 g

M(saccharose) = (12 · 12.01 + 22 · 1.008 + 11 · 1600) g/mol = 342.296 g/mol

$$n(\text{saccharose}) = \frac{m}{M} = \frac{200000\,g}{342.296\,g/mol} = 584.2896\ mol$$

The energy consumed in producing saccharose:
ΔH = 5640 kJ/mol saccharose

→ energy consumption = n · ΔH = 584.2896 mol · 5640 kJ/mol = 3295393 kJ

The efficiency of sunlight in June 5th according to the diagram = 8 kWh/m^2 in one day.

1 kWh = 1000 Wh → 8 kWh/m^2 = 8000 Wh/m^2 = 8000 · 3600 Ws/m^2 = 28800000 Ws/m^2 = 28800000 J/m^2 = 28800 kJ/m^2

1 ha = 10000 m^2 → the solar energy per hectare in one day =

28800 kJ/m^2 · 10000 m^2 = 288000000 kJ

The amount of energy stored in biomass (%):

(production of saccharose / solar energy) ·100%

$$= \frac{3295393\,kJ}{288000000\,kJ} \cdot 100\% = \mathbf{1.14\ \%}$$