Chemistry olympiad – answers

Form 10

1. $C + O_2$ ----- CO_2 $1\ O_2$
   $1.8/2\ H_2 + 0.9/2\ O_2$ ------ $0.9\ H_2O$ $0.45\ O_2$
   $0.05\ S + 0.05\ O_2$ ----- $0.05\ SO_2$ $0.05\ O_2$
   $0.1\ N + 0.1\ O_2$ ----- $0.1\ NO_2$ $0.1\ O_2$
   The total amount of O_2 required = 1+0.45 + 0.05 + 0.1 = 1.6 mol O_2
   There is available 1.1 O or 0.55 O_2 which means that we must supply 1.6 – 0.55 = 1.05 O_2.
   This also means that we require 1.05/0.21 mol N_2 and that the amount of air will be 1.05 + 1.05/0.21 mol.

2. a)
   $S + O_2 \rightarrow SO_2$
   $SO_2 + 2O_2 \rightarrow 2\ SO_3$
   $SO_3 + H_2O \rightarrow H_2SO_4$
   $H_2SO_4 \rightarrow 2H^+ + SO_4^{2-}$

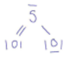
   $N_2 + O_2 \rightarrow NO_x$
   $NO_x + H_2O \rightarrow HNO_3$
   $HNO_3 \rightarrow H^+ + NO_3^-$

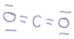
   b)
   Carbonates
   $CaCO_3 (s) \leftrightarrow Ca^{2+} + CO_3^{2-}$
   $CO_3^{2-} + H^+ \leftrightarrow HCO_3^-$
   $HCO_3^- + H^+ \leftrightarrow H_2CO_3$
   $H_2CO_3 \leftrightarrow CO_2 + H_2O$

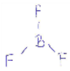
   c) The greenhouse effect is linked to No 2.

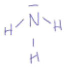
3. Assume that we have 100 g lead sulphide, which gives 13,4 g S = 0,417 mol and 86,6 g Pb = 0,418 mol. This gives the molar relationship 1:1, and the formula is thus PbS.

4.

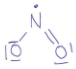
a.  dipole

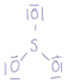
b.  no dipole

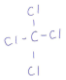
c.  no dipole

d.  dipole

e.  dipole

f.  dipole

g.  no dipole

h.  no dipole

5.

a. I_2 Covalent bondning, van der Waal

b. Na Metallic bondning

c. NaCl Ionic bondning

d. Kr van der Waal

e. CsF Ionic bondning

f. Si Covalent bondning

g. CH_4 Covalent bondning, van der Waal

h. NH_4Cl Ionic bondning, Covalent bondning

Form 11

1.

   a. We can expect to obtain H_2S and NH_3 from S and N in a reducing atmosphere as in a gasifier.

   b. The total quantity of oxygen:

$0.9\ C + 0.9\ O_2$ ------ $0.9\ CO_2$		$0.9\ O_2$
$1.7/2\ H_2 + 0.85/2\ O_2$ ------- $0.85\ H_2O$	$0.425\ O_2$	
$0.05\ S + 0.05\ O_2$ ------ $0.05\ SO_2$	$0.05\ O_2$	
$0.1\ N + 0.1\ O_2$ ----- $0.1\ NO_2$		$0.1\ O_2$
The total requirement is:	$1.475\ O_2$	
The amount in the compound is: 1.1 O or $0.55\ O_2$	- 0.55	
The amount of oxygen required is:	$1.475 – 0.55 = 0.925\ O_2$	

   c. Methane, hydrogen

2.

   a. $CO_2 + H_2O \longleftrightarrow H_2CO_3$

   $H_2CO_3 \longleftrightarrow HCO_3^- + H^+$

   $HCO_3^- \longleftrightarrow CO_3^{2-} + H^+$

   b. $H^+ + OH^- \longleftrightarrow H_2O$

$V(sjö) = 3{,}2 \text{ x } 10^6\ m^2 \text{ X } 2{,}5\ m = 8 \text{ X } 10^6\ m^3 = 8 \text{ X } 10^9\ L$

The pH is raised from 4,5 till 6,5 and that corresponds to an increase in the concentration of H^+ according to:

$pH = 6{,}5 = (H^+)= 10^{-pH}= 10^{-6{,}5} = 3{,}2X10^{-7}$ mol H^+ /L

$pH = 4{,}5 = (H^+)= 10^{-pH}= 10^{-4{,}5} = 3{,}2X10^{-5}$ mol H^+ /L

The concentration (H^+) shall thus be lowered from $3{,}2X10^{-5}$ mol H^+ /L to $3{,}2X10^{-7}$ mol H^+ /L, and the total amount of substance H^+ to be neutralised in the lake is

$(3{,}2X10^{-5} - 3{,}2X10^{-7})$ mol H^+ /L X $(8 \text{ X } 10^9\ L) = 2{,}53 \text{ X } 10^5$ mol H^+

and according to $2H^+ + Ca(OH)_2$, the amount required is ½ $2{,}53 \text{ X } 10^5$ mol $OH^- = 1{,}27 \text{ X } 10^5$ mol OH^-

The molar mass of $Ca(OH)_2$= 74 g/mol

The amount of $Ca(OH)_2$ required is: $9{,}36 \text{ x} 10^6$ g =9,36 t

3. Assume that we have 100 g, which means that we have x g Pb, 2x g Zn och 100-3x S.

   x/207,2 + 2x/65,4 = (100-3x)/32,1

   0,0048x + 0,0306x = 3,1153 – 0,0935x

   0,1289x = 3,1153

   x= 24,2

   24,2 g

   24,2 g Pb + (x/207,2)*32,1 g S =27,9 g totally which gives 28 weight-% Pb

4. m(NaOH)=10 g, V=200 ml,
n=10/40 = 0,25 mol NaOH
c=0,25/0,2 = 1,25M
In the titration, 54,1 ml NaOH-solution is used =1,25 x 0,0541 mol NaOH
0,0676 mol NaOH is equivalent to 0,0676 mol salicylic acid which gives a molar mass of 138,4 g/mol

5.

a. $4\ Ag(s) + 2\ H_2S(g) + O_2(g) \rightarrow 2\ Ag_2S(s) + 2\ H_2O(l)$
silver **hydrogen sulphide** **oxygen** **silver sulphide** **water**

b.
oxidation $2\ Al(s) \rightarrow 2\ Al^{3+} + 6\ e^-$
aluminium **Aluminium ions** **electrons**
reduction $6\ Ag^+ + 6\ e^- \rightarrow 6\ Ag(s)$
silver ions **electrons** **Pure silver**

c. They have a very low reducing ability. Far to the right in the electrochemical series. Noble metals.
d. It is a mixture of HNO_3 + HCl, where the combination of an oxidising agent and another strong acid has been shown to be able to dissolve gold.
e. Glass is not dissolved by strong acids. HF is a weak acid and SiO_2 is therefore affected by and dissolved by hydrofluoric acid.
f. SiO_2 is also soluble in alkaline solutions, such as NaOH. Glass therefore develops a roughened surface if strong alkaline agents are used as washing-up agents.

Form 12

1. M(ethanol) =46 g/mol,
   energy/mass: 1367/46 = 29,7 kJ/g,
   Energy/ml: 29,7x0,79 = 23,5 kJ/mol

   M(octane) = 114 g/mol
   energy/mass: 4902/114 = 43 kJ/mol
   Energy/ml: 43x0,7= 30,1 kJ/mol

   Octane is ca 30% more effective as a propellant fuel than ethanol. But now one must naturally take into consideration the environmental effects of the two fuels and this can lead to completely different conclusions.

2.
   a. 10 L 5 M HAc gives 50 mol HAc
      The raw acid contains 1057,5x0,50/60 = 8,81 mol HAc   M(HAc) = 60g/mol
      Take 50/8,8 L = 5,67 of the raw acid and dilute it to 10 L
   b. $K_a = ([CH_3COO^-]\,[H_3O^+]) / [CH_3COOH]$ = mol/dm^3
   c. $CH_3COOH + H_2O \rightleftarrows CH_3COO^- + H_3O^+$

Before	-	-	-	10^{-7} = negligible
After	(5-x)/801	-	x/801	x/801

   gives $(x/801)^2/((5-x)/801)=1{,}8*10^{-5}$ which gives x=0,261
   $[H_3O^+]=3{,}258*10^{-4}$ gives   pH=3,48635

3. Theoretical models of oscillating reactions have been studied by chemists, physicists and mathematicians. In an oscillating system, the reactions which are thermo-dynamically the most favourable can follow at least two paths and the reactions oscillate between these two paths. One of the reaction paths produces an intermediate product which the other reaction path consumes. The concentration of this intermediate product determines which reaction path predominates. When the concentration of the intermediate product is low, the reaction follows the path which produces the intermediate product. When the concentration of the intermediate product increases, the second reaction path takes over

   In this chemical clock, the cerium (IV) ions are reduced by the malonic acid to cerium (III) ions which are oxidised back to cerium (IV) by the bromate (V) ions.

4.

a. 69 °C n-hexane (weak van der Waals bonds between molecules)
103 °C pentanal (dipole-dipole bonds between molecules)
137 °C 1-pentanol (hydrogen bonding between molecules)
164 °C butanoic acid (two polar groups – carbonyl and hydroxyl groups – hydrogen bonding between molecules)

b. Nos. 3) and 6) are correct

5.

a. No. 2 is correct
b. No. 3 is correct
c. No. 1 is correct
d. No. 3 is correct