Solution Pathway

SECTION A- Multiple-choice questions

1. **Correct Answer B.** If the same energy is supplied to a greater volume of water then the temperature change would be lower resulting in a higher CF; if CF is higher then, $E = CF \times \Delta T$ will increase and the ΔH will increase.

2. **Correct Answer C.** The surface of a catalyst bonds with the reacting molecules to weaken the existing bonds within those reacting molecules lowering the activation energy of the reaction which then proceeds by a different pathway.

3. **Correct Answer A.** As $V\downarrow$, $P\uparrow$ so according to LCP the overall P must decrease to restore equilibrium. To do this there must be a net reaction to produce fewer particles so the reaction moves to the R to increase the concentration of N_2O_4 and decrease the concentration of NO_2.

4. **Correct Answer B.** Ag+ decreases in oxidation number from +1 to 0 and is therefore reduced. The silver oxide must gain electrons to be reduced to silver so it is the positive electrode (cathode) in an electrochemical/galvanic cell.

5. **Correct Answer A.**

    $n(Ba(OH)_2) = 1.139/113.9 = 0.01$ mol, $c(Ba(OH_2)$ n/v $0.01/1 = 0.01$M $c(OH-) = 2c(Ba(OH_2) = 0.01 \times 2 = 0.02$M, $[OH^-] = 0.02M = 10^{-1.69}$M, $[H_3O^+] = 10^{-14}/10^{-1.69} = 10^{-12.31}$M, pH $= -\log 10 [H_3O^+] = 12.31$. Alternative A has the correct order.

6. **Correct Answer C.** The $E^o{}_{cell} = E^o{}_{ox} - E^o{}_{red}$, Cu^{2+} is the oxidant in this cell so

    $E^0{}_{cell} = 0.34 - (-2.34) = 0.34 + 2.34 = 2.68$V

7. **Correct Answer C.** $Cu^{2+} + 2e^- \rightarrow Cu$; $Al^{3+} + 3e^- \rightarrow Al$

    For the same number of mol. of electrons passing through the cell

    $n(Cu) = 1.5$ $n(Al) = 1.0$
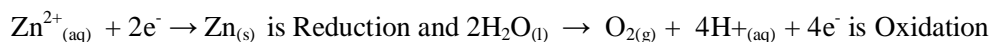
    $m(Cu) = n \times M = 1.5 \times 63.6 = 95.4$g $m(Al) = n \times M$ $1.0 \times 27.0 = 27.0$g

    $m(Cu)/m(Al) = 95.4/27.0$ 3.53 Ratio = 7:2

8. **Correct Answer C.** Particles gain KE with an increase in temperature. This means that more of the reacting particles have sufficient energy greater than the E_A of the reaction. This increases the probability of more successful collisions and so increases the rate of reaction.

9. **Correct Answer D.** Photosynthesis is an endothermic process as it requires energy from the sun so the total energy of the products will be greater than the total energy of the reactants.

10. **Correct Answer B.** Lactic Acid has the highest Acidity constant, K_a of the four acids. This means it is the strongest and so will undergo the greatest percentage ionization.

11. **Correct Answer C.** 1 mol. of Mg on reaction releases 600 kJ, $n(Mg) = 8000/600 = 13.33$,

    $m(Mg) = n \times M = 13.33 \times 24.3 = 324$g.

©2011   Ser1CHEMU4EA

12. **Correct Answer B.** The reactions that are occurring are:

$Zn^{2+}_{(aq)} + 2e^- \rightarrow Zn_{(s)}$ is Reduction and $2H_2O_{(l)} \rightarrow O_{2(g)} + 4H^+_{(aq)} + 4e^-$ is Oxidation

Water is both a solvent and a reductant.

13. **Correct Answer D.** Air is a mixture that contains approximately 20% oxygen so using air would decrease the concentration of oxygen and so decreasing the number of particles available to react therefore decreasing the rate.

14. **Correct Answer A.** For the endothermic self-ionisation reaction, an increase in temperature will move the position of equilibrium to the right in an attempt to lower the temperature. The concentration of the hydronium ion will increase, and so the pH will decrease. At 30^0C the pH will be less than 7 (although the water is still neutral as the hydroxide concentration has also increased by the same amount).

15. **Correct Answer C.** Referring to the electrochemical series, $Cu^{2+,}$ $Sn^{2}+$ and Ni^{2+} are all stronger oxidants than water and will be preferentially reduced. H_2O is a stronger oxidant than K^+ and will be preferentially reduced.

16. **Correct Answer D.** All industrial processes should be minimising energy use during each stage of every process.

17. **Correct Answer D.** All 3 answers are correct.

18. **Correct Answer C.** The second equation is the reverse of the first equation and all the coefficients are doubled. Reversing an equation produces the reciprocal of the equilibrium constant of the first equation i.e. 1/K. Raising all the concentrations in the equilibrium expression to the power of two causes the equilibrium constant to be squared i.e. $(1/K)^2$ or $1/K^2$.

19. **Correct Answer B.** Mg^{2+}/Mg half- cell is the weaker oxidant or stronger reductant and so will undergo oxidation; so the Mg^{2+}/Mg half- cell is the anode and has a negative polarity in a galvanic cell.

20. **Correct Answer B.** K^+ ions migrate to the cathode. This is the Ag electrode in this case; here Ag^+ ions are converted to Ag so positive charge is lost. K^+ ions migrate to the cathode to balance the positive charges at that electrode.

Ser1CHEMU4EA

SECTION B- Short answer questions

 Question 1
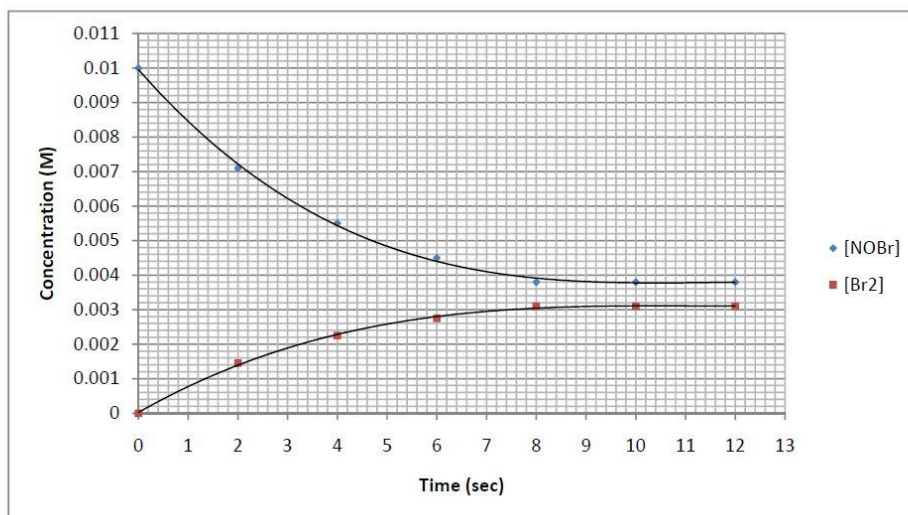
a)   Initial Rate = Gradient (at the beginning) = rise/run = 0.0016/1 = -1.6 x 10^{-3} [NOBr]Ms^{-1} (1)

All rates are negative as the [NOBr] is decreasing.

b)   Av. Rate over 8s = 0.0039-0.010/8-0 = -7.6 x 10^{-4} Ms^{-1} (1)

c)   The initial rate > the rate over the first 8s since [reactants] is higher at the start. (½) As the reaction proceeds [reactants] ↓ leading to fewer successful collisions. (½)

d)   Bromine formation graph below.

Time (s)	[NOBr]	[Br$_2$]
0	0.01	0
2	0.0071	0.00145
4	0.0055	0.00225
6	0.0045	0.00275
8	0.0038	0.0031
10	0.0038	0.0031
12	0.0038	0.0031

For every 2 mol of NOBr reacting only 1 mol of Br$_2$ forms. [Br$_2$]$\uparrow$ at half the rate [NOBr]$\downarrow$.

At t = 8s [NOBr] remains constant indicating that the reaction has come to completion. Here the [Br$_2$] also remains constant.

[Br$_2$] $= \frac{1}{2}\Delta$[NOBr] e.g. at 6s [Br$_2$] $= \frac{1}{2}\Delta$[NOBr] $= (0.01 - 0.0042)\frac{1}{2} = 0.00275$M

e) As P$\uparrow$, V$\downarrow$ $\rightarrow$ an increase in the [reactants] (1). This leads to more successful collisions between two NOBr particles over a period of time and so the reaction rate increases.

f) In this reaction only one reactant decomposes to form products. How many particles having enough energy to overcome E$_A$ and decompose is the crucial fact affecting the reaction rate. (1) $\downarrow$P has no effect on reaction rate. The number of moles reacting is equal to the number of moles produced.

$\uparrow$T would $\uparrow$ reaction rate by providing more particles with enough energy to overcome E$_A$ (1)

Using a catalyst would $\uparrow$ reaction rate by providing an alternative pathway with $\downarrow$ E$_A \rightarrow \uparrow$ no. of particles reacting.

Question 2

a) A weak acid undergoes partial ionisation to produce H_3O^+ ions. It ionises to a small extent (1)

b) HCOOH is a weak acid and therefore the [HCOO$^-$] cannot be directly calculated from the [HCOOH]

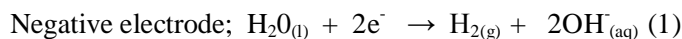K_a (HCOOH) $= 1.8 \times 10^{-4}$

$K_a = [H_3O^+][HCOO^-]/[HCOOH]$ (1)

$[HCOO^-] = [H_3O^+]$ (1)

$[HCOO^-]^2 = K_a[HCOOH] = 1.8 \times 10^{-4} \times 0.0500 = 9 \times 10^{-6}$ (1)

$[HCOO^-] = \sqrt{9 \times 10^{-6}} = 0.003M$ (1)

c) $HCOO^-_{(aq)} + H_2O_{(l)} \rightleftharpoons OH^-_{(aq)} + HCOOH_{(aq)}$ Equilibrium arrows must be included (1) along with reactants and products states (1)

d) $K_b = [OH^-][HCOOH]/[HCOO^-]$ (1)

Question 3

a) Positive electrode : $2Cl^-_{(aq)} \rightarrow Cl_{2(g)} + 2e^-$ (1)

Negative electrode; $H_2O_{(l)} + 2e^- \rightarrow H_{2(g)} + 2OH^-_{(aq)}$ (1)

b) i) $2Cl^-_{(aq)} \rightarrow Cl_{2(g)} + 2e^-$

n(NaCl) = n(Cl$^-$) = cV = 1.00 x 10.00 = 10.0 mol.

n(Cl$_2$) = ½ n(Cl$^-$) = ½ x 10.0 = 5.00 mol (1)

n(Cl$_2$) = V/24.5, so V = 5.00 x 24.5 = 122.5 L = 123 L (1)

ii) Q = n(e$^-$) x F = 10.0 x 96 500 = 965,000C (1)

Q = It, so t = Q/I = 965,000/20 = 48250 s (1), t = 48250/3600 = 13.4 hrs. (1)

c) Electrical energy $\rightarrow$ Chemical energy (1)


Ser1CHEMU4EA

Question 4

a) 240V power supply: non-renewable, (1) 12V car battery: renewable(1)

b) **Advantage: 240V power supply**; inexpensive, (1) constant voltage (1),
           continuous supply under heavy load (1), widespread (1), a reliable source (1)

       12V car battery: mobile (1), rechargeable (1), readily replaceable (1),
       commonly available (1)

   Disadvantage: **240V power supply**: need for a connection to the electricity grid, (1), not
           available to cover remote areas (1), cost of hiring a powered site (1),
           can't use when mobile (1)

        12V car battery: eventually goes flat with loss of power (1), under load the
        voltage decreases (1), eventually must be replaced (1),
        is only recharged when the car is mobile (1)

Question 5

a) $E = CF \times \Delta T = 1076 \times 5.84 = 6283.84 \text{ J} = 6.28 \times 10^3 \text{ J}$ (1)

b) $E = 6283.84/0.503 \text{g}$ (1) $= 6283.84/0.01863 \text{ mol}$ $n(Al) = 0.503/27 = 0.01863$ mol

   $= 337.3 \text{ kJ mol}^{-1}$ (1), $\Delta H = 2 \text{ x} - 337.3 = -675 \text{ kJ mol}^{-1}$ (1)

c) $n(Fe) = m/M = 0.651/55.9 = 0.0100$ mol (1)

           2 mol $\rightarrow$ 828kJ

           0.01 mol $\rightarrow$ x kJ, x $= -4.155$ kJ (1)

      $\Delta T = E/CF = 4155/1076 = 3.86 \,^0\text{C}$ (1)

d) Iron (1) as the ΔH for the reverse reaction (the extraction of the metal from its ore) is higher than
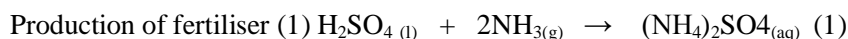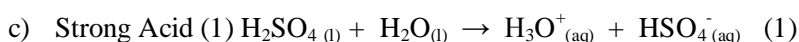   that of aluminium (1)

Question 6

a) $K_c = [Z]^2/[X]^2[Y]$ (1)

b) Concentration fraction $= 3^2/(2^2 \text{ x } (1) \neq 3$ so therefore the system is not at equilibrium (1)

c) An increase in V results in an overall decrease in concentration. In this system there would be a
    net back reaction to partially oppose the change (LCP) by creating more particles to increase the
    overall number (1). This causes the number of mole of Y to increase(1) but the overall
    concentration of Y decreases because of the initial dilution (1)

Question 7

Production of Sulphuric Acid (Contact Process)

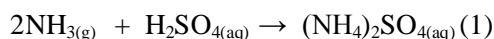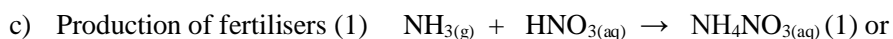a) $2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)}$ (1) ΔH is negative (1)
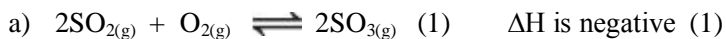
b) Use of Vanadium pentoxide as a catalyst in the converter-reduces activation energy and also quickens rate (energy efficiency) (1)

Any SO_2 not initially converted is recycled back into the catalytic converter to increase percentage yield (reaction mixture is passed over the catalyst beds several times). This reduces SO_2 emissions into the atmosphere.(1)

c) Strong Acid (1) $H_2SO_{4\,(l)} + H_2O_{(l)} \rightarrow H_3O^+_{(aq)} + HSO_4^-_{(aq)}$ (1)

Production of fertiliser (1) $H_2SO_{4\,(l)} + 2NH_{3(g)} \rightarrow (NH_4)_2SO4_{(aq)}$ (1)

Production of Ammonia (Haber-Bosch Synthesis)

a) $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$ (1) ΔH is negative (1)

b) Use of an Fe catalyst with K, Ca and Al promoters to reduce activation energy (1)
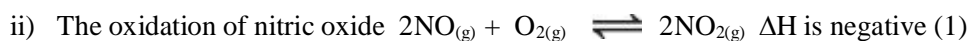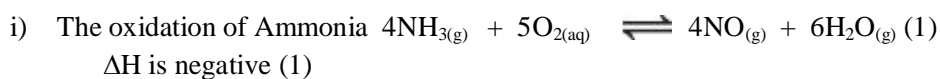
A reaction temperature of 450^0C is a compromise between yield and rate. A higher temperature will increase the yield and the rate but will require more energy (1)

c) Production of fertilisers (1) $NH_{3(g)} + HNO_{3(aq)} \rightarrow NH_4NO_{3(aq)}$ (1) or

$2NH_{3(g)} + H_2SO_{4(aq)} \rightarrow (NH_4)_2SO_{4(aq)}$ (1)

The oxidation of Ammonia in the first step of the production of Nitric Acid (1)

$4NH_{3(g)} + 5O_{2(aq)} \rightleftharpoons 4NO_{(g)} + 6H_2O_{(g)}$ ΔH is negative (1)
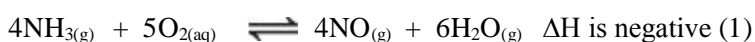
Production of Nitric Acid (Ostwald Process)

a) The process involves 3 steps:

i)   The oxidation of Ammonia $4NH_{3(g)} + 5O_{2(aq)} \rightleftharpoons 4NO_{(g)} + 6H_2O_{(g)}$ (1)
     ΔH is negative (1)

ii) The oxidation of nitric oxide $2NO_{(g)} + O_{2(g)} \rightleftharpoons 2NO_{2(g)}$ ΔH is negative (1)

iii) The hydrolysis of nitrogen oxide

$\rightarrow$

b) In step 1 the control of the production of NO is achieved by using a fine-wire gauze catalyst of an alloy of Platinum (90%) and Rhodium (10%) and suitable reaction conditions. The contact time with the catalyst is crucial, less than 0.003s, or the NO would decompose to N_2. This reaction is one of the most efficient catalytic reactions known with a percentage yield of approx. 96% (1)

The heat produced in this step is recovered and is enough to supply most of the energy demands of the process providing huge savings, e.g. boiling water to produce steam to turn a turbine to produce electricity(1)

c) Production of Fertilisers (1) $NH_{3(g)} + HNO_{3(aq)} \rightarrow NH_4NO_{3(aq)}$ (1)

A strong oxidant (1) $Cu_{(s)} + 4HNO_{3(aq)} \rightarrow Cu(NO_3)_{(aq)} + 2NO_{2(g)} + 2H_2O_{(l)}$ (1)