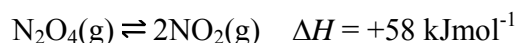


Sample Exam 2 – 2008 Sample Solutions

The answers provided are suggestions only and do not represent directly or otherwise official VCAA answers.

Section A

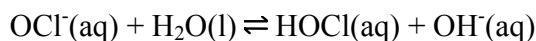
Question 1: Answer D



Increasing pressure means according to Le Chatelier the equilibrium will move in the direction of the least number of particles, hence toward the reactants, so the equilibrium yield of NO_2 will decrease.

Endothermic reaction, so an increase in temperature would drive the reaction forward.

Question 2: Answer B



Adding two drops of 5.0 M NaOH will not significantly affect the volume of the equilibrium mixture. When two drops of 5.0 M NaOH are added to an equilibrium mixture of OCl^- in water at constant temperature, some, but not all of the added OH^- ions are used up as the equilibrium shifts to the LHS. So the net effect is an increase in the $[\text{OH}^-]$

Question 3: Answer A

Only alternative I is correct because:

- I. increasing the proportion of a reactant in the reaction mixture results in an equilibrium shift to favour products.
- II. The effect of increasing temperature will depend on whether the reaction is exothermic or endothermic
- III. The effect of decreasing pressure will depend on the stoichiometry of the reaction and whether the pressure increase is due to increase in partial pressure of components of equilibrium mixture or to the addition of an inert gas
- IV. adding a catalyst has no effect of equilibrium yield

Question 4: Answer A

As the pH is the same in both beakers, the concentration of $\text{H}^+(\text{aq})$ in both beakers must be the same. (so III is not correct). The concentration of HY is less than that of HX, yet it ionises to form the same concentration of $\text{H}^+(\text{aq})$. So a greater proportion of acid molecules must be ionised in HY and HY must be the stronger acid and must have the higher K_a value (so I correct and II incorrect)

Question 5: Answer C

From Data Booklet: K_a for benzoic acid is 6.4×10^{-5}

$500 \text{ mg} = 0.500 \text{ g}$

$n(\text{C}_6\text{H}_5\text{COOH}) = 0.500 / 122 = 4.10 \times 10^{-3}$

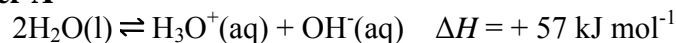
$c(\text{C}_6\text{H}_5\text{COOH}) = 4.10 \times 10^{-3} / 0.200 = 0.0205 \text{ M}$

Let $x = [\text{C}_6\text{H}_5\text{COOH}] = [\text{H}_3\text{O}^+]$

$6.4 \times 10^{-5} = x^2 / 0.0205$

So $x = 0.00115$

$\text{pH} = 2.9$

Question 6: Answer A

Pure water is neutral and has a pH of 7 at 25°C and the $[\text{H}_3\text{O}^+] = 10^{-7} \text{ M}$

The reaction is endothermic so increase in temperature favours the forward reaction and increase the amount of products. At 90°C , the concentration of $\text{H}^+(\text{aq})$ is greater than 10^{-7} M , so the pH becomes less than 7. Since the concentration of $\text{OH}^-(\text{aq})$ increases by the same amount as the $[\text{H}^+]$, pure water is still neutral at 90°C .

Question 7: Answer D

The relationship between pH and $[\text{H}_3\text{O}^+]$ is $\text{pH} = -\log_{10}[\text{H}_3\text{O}^+]$.

The combination of the 'log' function and the '-' sign means that a change in pH of 1 is caused by change in the $[\text{H}_3\text{O}^+]$ by a factor of 10 and that the pH will increase when the $[\text{H}_3\text{O}^+]$ decreases.

So because there are 3 pH units difference between distilled water and soap, and soap is at the higher pH, the $[\text{H}_3\text{O}^+]$ in distilled water is 1000 ($10 \times 10 \times 10$) times greater than the $[\text{H}_3\text{O}^+]$ in soap.

B is incorrect because the negative aspect of pH has been ignored.

Question 8: Answer A

The equations for the electrode half-reactions are

anode $\text{Na}(\text{l}) \rightarrow \text{Na}^+(\text{l}) + \text{e}^-$

cathode $3\text{S}(\text{l}) + 2\text{e}^- \rightarrow \text{S}_3^{2-}(\text{l})$

$\text{Na}(\text{l})$ is the reductant in this galvanic cell and hence it undergoes oxidation. Oxidation occurs at the anode and oxidation produces electrons that move toward the more positive cathode. Consequently Na is at the anode which is negative.

Question 9: Answer D

A: is the oxidation half-reaction for discharge

B: is the reduction half-reaction for discharge

C: is the overall cell reaction for discharge

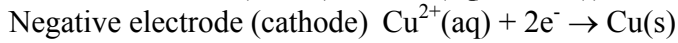
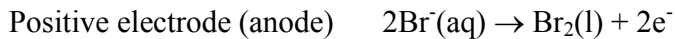
D: is the overall cell reaction for recharge

Because Li metal is the anode and it is being oxidized.

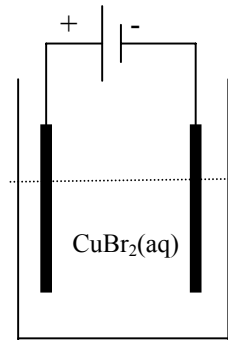
D is the only reaction where Li is being reduced and therefore this reaction cannot occur at the anode.

Question 10: Answer C

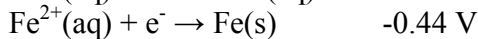
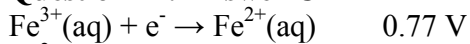
Electrode half-reactions are



No gas is produced at the cathode



Examination of the Electrochemical Series indicates that, although present, water will be a weaker oxidant Cu^{2+} ions and weaker reductant than Br^- ions. Being positive the Cu^{2+} ions are attracted toward the negative electrode and undergo reduction (always occurs at the cathode) producing a copper coating on the cathode. Also the Br^- ions being negative are attracted toward the positive anode and oxidized here producing coloured liquid bromine.

Question 11: Answer C

Fe^{2+} ions can act as either an oxidant (forming $\text{Fe}(\text{s})$) or as a reductant (forming $\text{Fe}^{3+}(\text{aq})$) depending on what is present.

Question 12: Answer C

From the Data Booklet, ΔH for ethanol = $-1364 \text{ kJ mol}^{-1}$.

$$n(\text{C}_2\text{H}_5\text{OH}) = 5.0 / 46 = 0.1087 \text{ mol}$$

Hence heat released by the amount of ethanol = $0.1087 \times 1364 = 148.3 \text{ kJ}$

$$\text{Since } CF = E / \Delta T$$

$$\Delta T = E / CF$$

$$= 148 / 3.34$$

$$= 44.3 \text{ }^\circ\text{C}$$

So temperature change is closest to 44°C

Question 13: Answer B

Water is a stronger oxidant than Ca^{2+} ions so no calcium metal will be produced in the first cell; hence A and C are incorrect.

Ag^+ ions require 1 mol electrons to be reduced to silver while nickel requires 2 mol electrons so for the same amount of charge, so twice as much nickel will be produced.

Question 14: Answer A

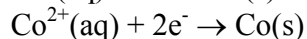
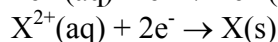
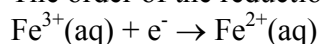
Anions always flow toward the half-cell containing the anode and oxidation always occurs at the anode. Because all the cells listed are acting as galvanic cells when discharging, B, C and D are incorrect.

Question 15: Answer C

When half cells 1 and 3 are joined to form a galvanic cell, the cobalt electrode is the negative electrode, which is the anode in a galvanic cell. Co must be oxidised by $X^{2+}(aq)$, so $X^{2+}(aq)$ ions are stronger oxidants than $Co^{2+}(aq)$ ions.

When half cells 2 and 3 are joined to form a galvanic cell, the electrode of metal X is the negative electrode. X must be oxidised by $Fe^{3+}(aq)$, so $Fe^{3+}(aq)$ ions are stronger oxidants than $X^{2+}(aq)$ ions

The order of the reduction on the electrochemical series is



Hence $Fe^{3+}(aq)$ is the strongest oxidant.

Question 16: Answer D

$$n(PCl_5) = 6.49 / 268.47 = 0.0311 \text{ mol}$$

There are 4 mol PCl_5 in the equation, so the ΔH value must be the energy released when 4 mol PCl_5 is formed.

If 0.0311 mol releases 11.7 kJ, then 4 mol will release x kJ:

$$x = (4 \times 11.7) / 0.0311 = 1500 \text{ kJ}$$

Question 17: Answer A

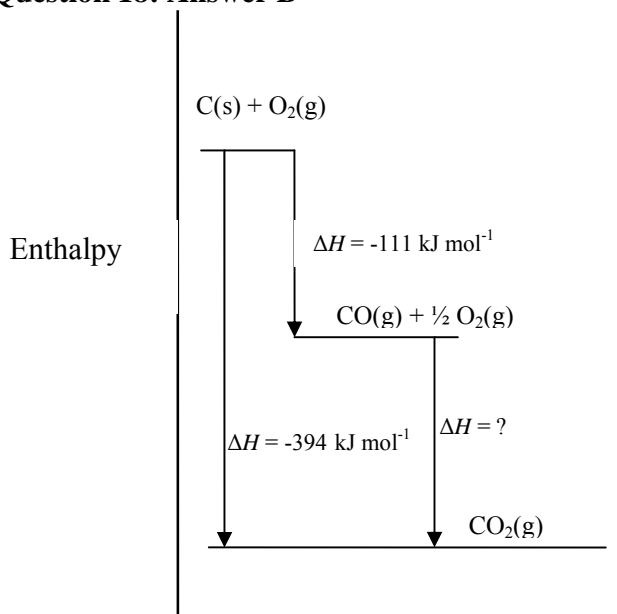
From the data Booklet:

Methane: 889 kJ for 1 mol CO_2 produced so 889 kJ for 1 mol CO_2 produced

Butane: 2874 kJ for 4 mol CO_2 produced so 719 kJ for 1 mol CO_2 produced

Octane: 5464 kJ for 8 mol CO_2 produced so 683 kJ for 1 mol CO_2 produced

Ethanol: 1364 kJ for 2 mol CO_2 produced so 682 kJ for 1 mol CO_2 produced

Question 18: Answer B

The energy profile clearly shows that ΔH for $C(s) + O_2(g) \rightarrow CO_2(g)$ is equal to the sum of ΔH for $C(s) + \frac{1}{2}O_2(g) \rightarrow CO_2$ and ΔH for $CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)$, i.e.

$$\begin{aligned}
 -111 + \Delta H(CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)) &= -394 \\
 \Delta H(CO(g) + \frac{1}{2}O_2(g) \rightarrow CO_2(g)) &= -394 - (-111) \\
 &= -283 \text{ kJ mol}^{-1}
 \end{aligned}$$

Question 19 Answer B

$CO_2(g)$ is an acidic gas and so could be effectively trapped by the basic solution $NaOH(aq)$
 $CO_2(g) + 2NaOH(aq) \rightarrow Na_2CO_3(aq) + 2H_2O(l)$.

Question 20: Answer C

The definition of a catalyst is that it lowers the activation energy of both the forward and backward reactions to the same extent, by providing an alternative reaction pathway.

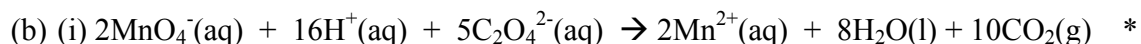
Section B

Question 1

(Total 5 marks)

- (a) Large clumps would have a smaller surface area in total than the powdered form so the number of collisions per second with the surface of the catalyst would be smaller and hence the rate would decrease*

1 mark



- (ii) As the concentration of reactants decrease, the likelihood of collisions becomes less and hence the rate decreases*

- (iii) The $\text{Mn}^{2+}(\text{aq})$ ions produced* by the reaction act as a catalyst* (*accept also that the reaction may be exothermic* and so the temperature increase causes a higher proportion of successful collisions and hence a rate increase**)

1+1+2 = 4 marks

Question 2

(Total 14 marks)

(a) $K = [\text{CH}_3\text{OH}] / [\text{CO}][\text{H}_2]^2$ *

1 mark

- (b) (i) In both cases an increased temperature will increase the rate of reaction due to an increased proportion of successful collisions.*

Step 1: because it is endothermic, the equilibrium yield of products increases with increased temperature. *

Step 2: because it is exothermic, an increase in temperature decreases the equilibrium yield of products, so a compromise lower temperature than that in Step 1 is used to obtain an optimal yield in a reasonable time*

- (ii) Rate is faster at higher pressures than atmospheric for both steps (greater chance of collisions between reactants). *

Step 1: Le Chatelier indicates that higher pressure favours backward reaction (2 mole of gas reactants and 4 mole of gas products), so a compromise pressure will be used to obtain an optimal yield in a reasonable time. *

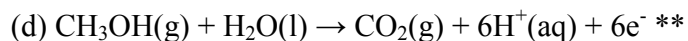
Step 2: The higher pressure increase the equilibrium yield of product (3 moles of gas reactants and 1 mole of gas products) so an increased pressure favours an increased rate as well as increased equilibrium yield*

- (iii) A catalyst will increase the rate in both steps to increase reaction rate, so more moderate temperature and pressures may be used. *

3+3+1=7 marks

- (c) Collect heat released in Step 2 and use it to maintain required temperatures in Step 1. *

1 mark



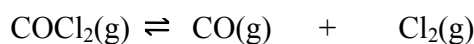
2 marks

- (e) (i) Hydrogen removal from the equilibrium mixture as it forms, drives the reaction forward. *
- (ii) It requires energy that is possibly supplied by fossil fuels and therefore increases greenhouse emissions; cost of palladium; cost of catalyst. *
- (iii) $2\text{H}_2\text{O}(\text{l}) \rightarrow \text{O}_2(\text{g}) + 2\text{H}_2(\text{g})$ *

1+1+1=3 marks

Question 3

(Total 11 marks)



(a) (i)

	$\text{COCl}_2(\text{g})$	$\text{CO}(\text{g})$	$\text{Cl}_2(\text{g})$
n initially (mol)	0.30	0.20	0.00
Change in n according to equation (mol)	0.10 reacted	0.10 produced	0.10 produced
n at equilibrium (mol)	0.20	0.30	0.10
c at equilibrium (mol L^{-1})	0.040	0.060	0.020

**

$$\text{Value of } K = 0.020 \times 0.060 / 0.040 = 0.030^*$$

(ii) $1/K = 1/0.030 = 33 \text{ M}^{-1}$ *

3 + 1 = 4 marks

(b) When the reaction is moving forward or backward there will be a change in pressure due to the change in moles of particles. If the pressure is constant, this indicates that the forward and backward reactions are occurring at the same rate; hence the system is at equilibrium. *

1 mark

(c) (i)

change	colour of mixture (unchanged, deeper green or lighter green)
1. increase in volume	Lighter green*
2. addition of more carbon monoxide	Lighter green*
3. addition of a non reacting gas	Unchanged*

(ii) none because the temperature is constant. *

3 + 1 = 4 marks

(d) Increase the temperature and see if it gets darker or lighter green. * If darker, this would indicate the reaction went forward, hence endothermic. *

(Alternatively: Place some $\text{COCl}_2(\text{g})$ in an empty container at a given temperature and measure any temperature changes as it reacts to form an equilibrium mixture*

If the temperature rises the reaction is exothermic* (if it drops it is endothermic))

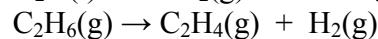
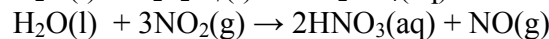
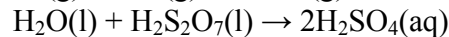
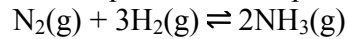
2 marks

Question 4

(Total 8 marks)

(a) (i) The chemical could be one of : NH_3 , H_2SO_4 , HNO_3 or C_2H_4 *

(ii) The chemical equation for the production of this chemical *



(b) $2\text{C}_8\text{H}_{18}(\text{l}) + 25\text{O}_2(\text{g}) \rightarrow 16\text{CO}_2(\text{g}) + 18\text{H}_2\text{O}(\text{g})$ * correctly balanced equation * states $\Delta H = -10928 \text{ kJ mol}^{-1}$ *

(Data booklet gives $\Delta H_c(\text{C}_8\text{H}_{18}) = -5464 \text{ kJ mol}^{-1}$, however the equation shows 2 mol C_8H_{18} hence $\Delta H = 2 \times -5464 \text{ kJ mol}^{-1}$)

[Alternatively

$\text{C}_8\text{H}_{18}(\text{l}) + 12\frac{1}{2}\text{O}_2(\text{g}) \rightarrow 8\text{CO}_2(\text{g}) + 9\text{H}_2\text{O}(\text{g})$ * products * states* $\Delta H = -5464 \text{ kJ mol}^{-1}$ *]

3 marks

(c) (i) $\text{Li} \rightarrow \text{Li}^+ + \text{e}^-$ *

(ii) $2\text{SOCl}_2 + 4\text{Li} \rightarrow 4\text{Cl}^- + \text{SO}_2 + \text{S} + 4\text{Li}^+$

(iii) to avoid pressure build up as gas accumulates in the cell* and possible explosion

3 marks

Question 5

(Total 7 marks)

(a) $E = c \times m(\text{H}_2\text{O}) \times \Delta T = 4.18 \times 200 \times (85.6 - 22.7) = 52\,584 \text{ J} = 52.6 \text{ kJ}$ *

2 marks

(b) $m(\text{C}_3\text{H}_8\text{O}) = (125.62 - 122.89) = 2.73 \text{ g}$

$n(\text{C}_3\text{H}_8\text{O}) = 2.73 / 60.0 = 0.0455$ *

Enthalpy of combustion = $52.8 / 0.0455 = -1156 \text{ kJ mol}^{-1}$ *

2 marks

(c) % of chemical energy into water = (calculated enthalpy / theoretical enthalpy) $\times 100$
= $(1156 / 2016) \times 100 = 57.3 \%$ *

1 mark

- (d) less heat loss to surroundings due to the insulated container*
 more complete combustion of 1-propanol in pure oxygen*
 we have assumed that all heat has gone into the water only*
 (any 2 of these 3)

2 marks

Question 6

(Total 4 marks)

- (a) The electrochemical series only predicts possible reaction; it gives no indication of the rate of reaction. In this case the rate may have been too slow. *

1 mark

- (b) More energy lost as heat in a power station* (Lower efficiency of the power station compared to fuel cells.)

1 mark

- (c) Water is a stronger oxidant than Mg^{2+} ions and would be reduced preferentially.*

1 mark

- (d) $Mg^{2+} + 2e^- \rightarrow Mg$ and $K^+ + e^- \rightarrow K$

The equations show that 2 moles of electrons, and hence $2 \times 96500C$, are needed to deposit 1 mole of Mg from Mg^{2+} ions but only 1 mole of electrons.

Hence $1 \times 96500C$, is needed to deposit 1 mole of K from K^+ . *

1 mark

Question 7

(Total 10 marks)

- (a) In a fuel cell the reactants are continuously supplied, whereas they are already present in a dry cell or lead-acid battery. *

1 mark

- (b) (i) Cathode (+) left , anode (-) right *
 (ii) From B to A (right to left) *

2 marks

- (c) (i) $2H_2 + O_2 \rightarrow 2H_2O$ *
 (ii) $O_2 + 4e^- \rightarrow 2O^{2-}$ *

2 marks

(d) (i) $E = Vit = 0.600 \times 0.500 \times 10.0 \times 60 = 180 \text{ J}^*$

(ii) $Q = It = 0.500 \times 10.0 \times 60$
 $= 300 \text{ C}^*$

(iii) $n(e^-) = Q / F = 300 / 96500^*$
 $= 3.11 \times 10^{-3} \text{ mol}$

$n(\text{H}_2) \text{ required} = \frac{1}{2} \times n(e^-)^*$
 $= \frac{1}{2} \times 3.11 \times 10^{-3} = 1.55 \times 10^{-3} \text{ mol}$

Since cell is 60.0 % efficient

$1.55 \times 10^{-3} = 60.0 \% \text{ of } n(\text{H}_2) \text{ consumed}$

$n(\text{H}_2) \text{ consumed} = 1.55 \times 10^{-3} / 0.600^*$
 $= 2.59 \times 10^{-3} \text{ mol}$

5 marks