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Trial Examination 2014

VCE Chemistry Units 3&4

Written Examination

Suggested Solutions

SECTION A: MULTIPLE-CHOICE QUESTIONS

Q	Answer		Q	Answer		Q	Answer
1	C		11	C		21	A
2	D		12	B		22	B
3	A		13	D		23	C
4	B		14	D		24	A
5	C		15	B		25	D
6	D		16	D		26	B
7	C		17	C		27	A
8	B		18	A		28	A
9	C		19	A		29	D
10	B		20	C		30	B

Question 1   C

For the same TLC plate with the same solvent, the R_f value of each component is fixed irrespective of how long the plate is run. **A** is not correct. A different solvent will have a different molecular structure and will interact with a component that is being analysed in a way which is different to other solvents. So the R_f value is specific to a particular solvent. **B** is also incorrect. The process of adsorption-desorption will continue for as long as the plate is run and thus the spots will continue to move up the plate, each at a particular rate. **C** is correct and the required answer. Using an organic solvent, the most polar food dye will be more attracted to the plate than the solvent, and so will move the shortest distance during the analysis. **D** is incorrect.

Question 2   D

The equation for the redox reaction is:

$MnO_4^-(aq) + 8H^+(aq) + 5Fe^{2+}(aq) \rightarrow Mn^{2+}(aq) + 5Fe^{3+}(aq) + 4H_2O(l)$
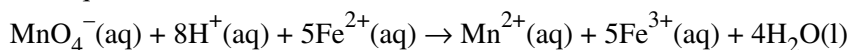
If 10 mol of Fe^{3+} ions are produced, 2 mol of MnO_4^- are required and 8 mol of H_2O are formed.

Question 3   A

Fe^{2+} is oxidised to Fe^{3+} and thus it is the reductant. Statement I is correct. As the oxidation number of Mn changes from +7 in MnO_4^- to +2 in Mn^{2+}, it is reduced and so must be the oxidant. Statement II is correct. Statement IV is incorrect. The oxidation number of Fe increases from +2 to +3. This is an oxidation. Statement III is incorrect.

Question 4   B

10 C and 12 H atoms give a relative mass of 132. This represents 75% of the relative molecular mass (RMM), which is numerically equal to the molar mass (M).

Hence, $M = 132 \times \dfrac{100}{75}$, so $M = 176$ g mol^{-1}.

Question 5   C

A weak acid/weak base titration does not produce the sharp change in pH shown on the graph. **A** is incorrect. The equivalence point occurs at pH < 7, indicating the presence of a weak acid in the solution at the equivalence point. Thus the titration was performed using a weak base.

Question 6   D

A suitable indicator must have a useful pH range with a midpoint as close as possible to the equivalence point of the titration, i.e. about 5.5. Phenolphthalein (8.3–10.0), thymol blue (1.2–2.8) and phenol red (6.8–8.4) are all not suitable. Methyl red (4.2–6.3) is the best choice.

Question 7   C
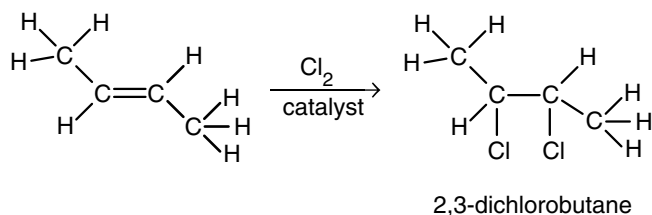
2,3-dichlorobutane

In reaction **C**, chlorine is added across the double bond of the alkene, and so the product must be 2,3-dichlorobutane, and cannot be 2,2-dichlorobutane. Thus the reaction described in alternative **C** is incorrect, and so **C** is the required response. The reactions described in **A**, **B** and **D** are correct.

Question 8   B

The retention times are $P < Q < R < S$ and so **A** is correct. As P travelled through the column at a faster rate than R, it must have less attraction to the stationary phase, and so alternative **B** is incorrect and is the required answer. Unless components have the same retention time, the rate of travel through the column must be different. **C** is correct. Component Q moved through the column faster as it spent less time adsorbed to the stationary phase. **D** is also correct.

Question 9   C

The area under a peak is a measure of the amount of the component in the sample injected into the column. Changing the concentration of the sample (for example, by removing solvent) will increase the area under each peak. Statement III is correct. Using a different mobile phase is likely to produce different retention times for the components, and increasing the temperature of operation will decrease retention times. Neither of these actions will affect the area under each peak.

Question 10   B

The relevant equation with structural formulas is shown below. Dehydration (removal of water) will result in the formation of a double carbon–carbon bond, giving the formula C_5H_{10}.

1-pentanol   1-pentene
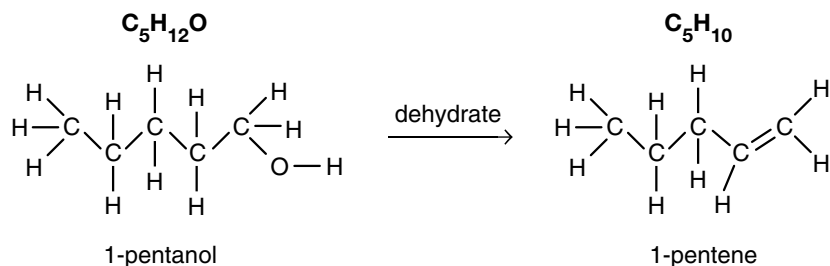
Question 11   C

The melting temperature occurs halfway through the separation process, which starts at about 75°C and ends at about 100°C (by extrapolation). Halfway is approximately 87°C.

Question 12   B

The primary structure of DNA involves the covalent bonding of components to make a single strand. The secondary structure involves the interactions between complementary bases on separate strands. This occurs by hydrogen bonding. At the temperatures which cause separation of the DNA strands, hydrogen bonding will be disrupted, but covalent bonds will not.

Question 13   D

Adenine and thymine are bonded by two hydrogen bonds, whereas guanine and cytosine are bonded by three hydrogen bonds. A greater number of hydrogen bonds between the DNA strands will cause a higher melting temperature of a DNA sample.

Question 14   D

The enzyme activity at X is low because the temperature is low and thus the substrate molecules are not coming into contact with the active site of the enzyme very often. The enzyme structure and active site are not compromised at this temperature. At Y, the higher temperature has caused destruction of the active site of many enzyme molecules, disruption of the weak bonding which is responsible for the secondary structure and, in part, the tertiary structure of the protein. Denaturation has occurred. So Statements I and II can be used to explain the level of enzyme activity at Y, but not at X.

Question 15   B

Approaching equilibrium the rate of the forward reaction is decreasing, while the rate of the backward reaction is increasing. This occurs as a result of the decreasing concentration of reactants and increasing concentration of products. Thus **A** and **D** are increasing, and so are not the correct responses. The reaction is exothermic, and so temperature will increase as the forward reaction moves towards equilibrium. **C** is not the correct answer. With 5 mole of gaseous reactants and only 4 mole of gaseous products, the forward reaction will result in a decrease in pressure. **B** is the required response.

Question 16   D

	4HCl	**O$_2$**	**2H$_2$O**	**2Cl$_2$**
n_i	3.60	2.00		
change	-0.600×2	$\dfrac{-0.600}{2}$	+0.600	+0.600
n_{eq}	2.40	1.70	0.600	0.600
$c_{eq} = \dfrac{n}{2.5}$	0.96 M	0.68 M		

Question 17   C

Relevant calculations:

For a strong, monoprotic acid; $[H_3O^+] = [HCl] = 0.00030$ M, pH $= -\log(0.00030) = 3.5$

For a weak, monoprotic acid, K_a must be considered:

$$K_a = \frac{[OCl^-][H_3O^+]}{[HOCl]} = 2.9 \times 10^{-8}$$

$$[H_3O^+]^2 = 0.30 \times 2.9 \times 10^{-8}$$

$$[H_3O^+] = 9.33 \times 10^{-5}$$

$$pH = -\log(9.33 \times 10^{-5}) = 4.0$$

Methyl red is red below pH 4.2, so both acid solutions will be red.

Question 18   **A**

At the anode, H_2O and Cu are present but the stronger reductant (Cu) will be oxidised. At the cathode, H_2O and Ni^{2+} ions are present but the stronger oxidant (Ni^{2+}) will be reduced.

Question 19   **A**

For the self-ionisation reaction of water, $K_w = K \times [H_2O]^2 = [H_3O^+] \times [OH^-]$.

In pure water $[H_3O^+] = [OH^-]$ and so $K_w = [H_3O^+]^2$. Statement I is correct.

$[H_3O^+] = 10^{-pH}$ and so $K_w = 10^{-pH} \times [OH^-]$. Statement II is correct.

As the concentration of water should be squared in Statement III, it is not correct.

Question 20   **C**

At 0°C, 1.0 mol of ice requires 6.00 kJ to convert it to liquid water.

To heat 1.0 mol (18.0 g) of water from 0°C to 100°C requires $18.0 \times 4.18 \times 100 = 7524$ J $= 7.52$ kJ.

At 100°C, 1.0 mol of water requires 44.0 kJ to convert it to steam.

Total energy required $= 6.00 + 7.52 + 44.0 = 57.5$ kJ, closest to 60 kJ, therefore alternative **C**.

Question 21   **A**

Br_2 is the oxidant, undergoing reduction at the positively charged cathode (electrode II) to produce Br^-.

SO_2 is the reductant, undergoing oxidation at the negatively charged anode (electrode I) to produce SO_4^{2-}.

Question 22   **B**

The reaction occurring at electrode I is $SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^+ + 2e^-$.

As reaction proceeds, $4H^+$ is produced, and so the pH will decrease.

Question 23   **C**

Self-ionisation of water is represented by the equation $2H_2O(l) \rightleftharpoons H_3O^+(aq) + OH^-(aq)$.

For this endothermic reaction, as temperature is decreased, the value of K decreases, the backwards reaction is favoured and the $[H_3O^+]$ decreases (so pH increases).

Question 24   **A**

Reduction occurs at the cathode in both types of cells, but the cathode is positive in galvanic cells and negative in electrolytic cells. **A** is correct and is the required answer. Oxidation and reduction occur simultaneously at the electrodes in both types of cells. Thus **B** is not the required response. In a galvanic cell, cations travel towards the cathode (+). In an electrolytic cell, cations travel towards the cathode (–) where reduction occurs. **C** is incorrect for both types of cells. If electrodes are reactive, mass loss will equal mass gain at the electrodes if they are made of the same metal. In most other circumstances, **D** is incorrect.

Question 25   **D**

A catalyst will increase the rate of the forward and reverse reactions equally. If the system is at equilibrium, the concentration of the reactants and products will not change on the introduction of a catalyst. Therefore the graph should continue with the concentration of Z unchanged.

Question 26   B

Fuel cells are highly efficient at converting chemical energy to electrical energy. Power stations are inefficient due to the number of conversions involved and the poor efficiency of the transformation of thermal energy to mechanical energy in the turbine. However, fuel cells are expensive due to the developing nature of the technology, expensive catalytic electrodes and, in some cases, the expensive electrolytes.

Question 27   A

Electrodes are catalytic in fuel cells but not in other cell types. The statement in **A** is incorrect, and so **A** is the required response. The statements in **B**, **C** and **D** are correct.

Question 28   A

The half-reaction with the highest E^o value will have the strongest oxidant. The half-reaction with the lowest E^o value will have the strongest reductant. Thus MnO_2 is the strongest oxidant and Cd is the strongest reductant.

Question 29   D

A spontaneous reaction will occur between the stronger oxidant and the stronger reductant of the chemical species in two half-reactions. **A** and **B** involve mixing the weaker oxidant and weaker reductant of the species available in the half-reactions and so neither alternative would be likely to produce a reaction. In alternative **C**, the stronger oxidant ($AuCl_4^-$) is mixed with the stronger reductant (NO), but the E^o values for the respective half-reactions are almost identical. Thus a significant reaction would not be expected. **D** is the required answer, as the stronger oxidant and reductant are mixed and the E^o values differ significantly.

Question 30   B

Even though alternative **A** is a correct statement, it is not relevant to the context and does not explain the discrepancy. If conditions of the galvanic cell replicate standard conditions under which the electrochemical series was formulated, predictions should be accurate. Thus **C** is incorrect, while **B** explains the reason for the discrepancy and is therefore the required answer. The Zn^{2+}/Zn standard half-cell would use pure zinc and so **D** is not a correct explanation.

SECTION B: SHORT-ANSWER QUESTIONS

Question 1 (11 marks)

a. **i.**
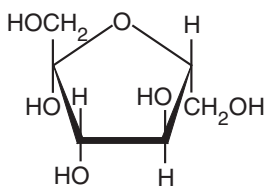
fructose

1 mark

ii. To produce the molecule, 1999 water molecules are formed when the ether linkages are made. 1 mark

M(starch) = $2000 \times 180 - 1999 \times 18 = 324\,018 = 3.24 \times 10^5$ g mol^{-1} 1 mark
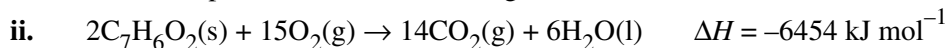
b. **i.** To achieve accurate results, the energy released or absorbed in the reaction chamber must be related only to the change in temperature of the water bath without any possibility of heat loss or gain through the outer walls of the calorimeter – the insulation prevents this heat loss or gain. 1 mark

ii. $2C_7H_6O_2(s) + 15O_2(g) \rightarrow 14CO_2(g) + 6H_2O(l)$ $\Delta H = -6454$ kJ mol^{-1} 2 marks

1 mark for reactants, products and balancing
1 mark for correct enthalpy change

iii. the heating coil 1 mark

This is used to heat the water when the calorimeter is calibrated electrically. It is not needed for chemical calibration. 1 mark

iv. energy = CF $\times \Delta T$ = $1.387 \times (23.41 - 21.73) = 2.330$ kJ 1 mark

$n(\text{sucrose}) = \dfrac{m}{M} = \dfrac{0.142}{342} = 4.152 \times 10^{-4}$ mol 1 mark

energy released for 1 mol of sucrose = $\dfrac{E}{n} = \dfrac{2.330}{4.152 \times 10^{-4}} = 5.61$ MJ 1 mark

Question 2 (15 marks)

a. The bacteria which produce biogas function only in the absence of oxygen *(other products would be formed if oxygen-dependent bacteria were involved in the decomposition).* 1 mark

b. Natural gas is a fossil fuel which was formed over millions of years and therefore is a limited resource, whereas biogas is a sustainable energy source which can be generated almost limitlessly. 1 mark

c. molar enthalpy of CH_4 = –889 kJ mol^{-1} and molar enthalpy of CO = –233 kJ mol^{-1} 1 mark

In 1.0 L of biogas at SLC there is 0.65 L CH_4 and 0.050 L CO. 1 mark

$$n(\text{gas}) = \frac{V}{V_M} = \frac{V}{24.5} \text{ mol}$$

In 1.0 L of biogas at SLC there is $\dfrac{0.65}{24.5}$ mol of CH_4 and $\dfrac{0.050}{24.5}$ mol of CO. 1 mark

Burning 1.0 L of biogas at SLC releases $\left(\dfrac{0.65}{24.5} \times 889\right) + \left(\dfrac{0.050}{24.5} \times 233\right) = 24.1$ kJ. 1 mark

d. **i.** Combustion releases sulfur dioxide which is involved in 'acid rain' formation. 1 mark

ii. Ensure there is adequate ventilation to limit inhalation of hydrogen sulfide gas. 1 mark

iii. $K_{a2} = \dfrac{[S^{2-}][H_3O^+]}{[HS^-]}$ 1 mark

iv. Ammonia is a weak base which will react with the H_3O^+ ions and thus remove them from the equilibrium reaction. 1 mark

By Le Chatelier's principle, the equilibrium will shift to the right to oppose the change, producing a higher concentration of sulfide ions. 1 mark
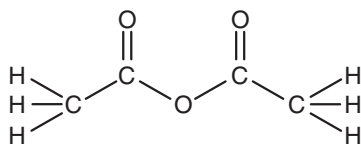
v. $n(H_2S) = n(Ag_2S) = \dfrac{m}{M} = \dfrac{1.540}{247.9} = 6.2122 \times 10^{-3}$ mol 1 mark

$V = \dfrac{nRT}{p} = 6.2122 \times 10^{-3} \times 8.31 \times \dfrac{290}{101.3} = 0.1478$ L 2 marks

% by volume $= \dfrac{0.1478}{10.0} \times 100 = 1.48\%$ 1 mark

Question 3 (10 marks)

a.

1 mark

b. **i.** A solution of salicylic acid (in $Fe(NO_3)_3$ solution) would be scanned using a full range of wavelengths of light. 1 mark

The wavelength of light which shows maximum absorbance is chosen to be used in the experiment. 1 mark

**ii.** $c_1V_1 = c_2V_2$ and so $V_1 = \dfrac{c_2V_2}{c_1}$

$$= \dfrac{1.60 \times 10^{-4} \times 50.0}{0.00200} = 4.00 \text{ mL}$$

1 mark

iii. Absorbance of 0.15 gives a concentration of 1.25×10^{-4} M. 1 mark

n(salicylic acid) in 50 mL $= 1.25 \times 10^{-4} \times 0.050 = 6.25 \times 10^{-6}$ mol

This is the n(salicylic acid) in the 5.00 mL aliquot. 1 mark

n(salicylic acid) in 100.0 mL solution of impure aspirin $= 6.25 \times 10^{-6} \times \dfrac{100.0}{5.00}$

$$= 1.25 \times 10^{-4} \text{ mol}$$ 1 mark

m(salicylic acid) $= n \times M = 1.25 \times 10^{-4} \times 138 = 0.01725$ g 1 mark

iv. m(aspirin) in impure sample $= 0.298 - 0.01725 = 0.2807$ g 1 mark

% aspirin in impure sample $= \dfrac{0.2807}{0.298} \times 100 = 94.2\%$ 1 mark

Question 4 (14 marks)

a. propan-2-ol (*as there are only two carbon environments. For propan-1-ol, there are three C environments and so three peaks would be expected.*) 1 mark

b. **i.** $CH_3CH_2CH_3 + Cl_2 \rightarrow CH_3CH_2CH_2Cl + HCl$ 1 mark

$CH_3CH_2CH_2Cl + OH^- \rightarrow CH_3CH_2CH_2OH + Cl^-$ 1 mark

ii.
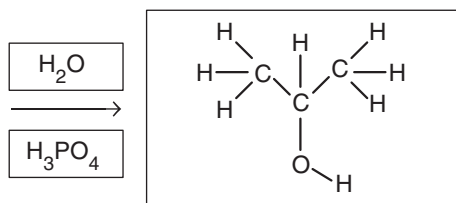
3 marks
1 mark for each box filled in correctly

c. **i.** Three peaks indicate that there are three H environments and therefore it is not compound I, as it has only two H environments. 1 mark

The area under the peaks shows that the hydrogens in the separate environments are in the ratio of 2 : 3 : 3 and so it cannot be compound III (ratio 2 : 3 : 1). 1 mark

The compound is II – the three environments are in the ratio 2 : 3 : 3. 1 mark

ii. The chemical shift data indicates that the cluster at 1.1 ppm is a R-CH_3 group. This is next to a CH_2 group and thus the peak will have (2 + 1) subpeaks, 1 mark
i.e. it will be a triplet. 1 mark

d. **i.** 2-hydroxypropanoic acid 1 mark

ii. O–H (alcohol) groups absorb in the 3200–3550 cm^{-1} range. O–H (acid) groups absorb in the 2500–3300 cm^{-1} range. 1 mark

With both these OH groups present in the molecule, a very broad trough will be seen between 2500 and 3500 cm^{-1}. 1 mark

Question 5 (15 marks)

a. **i.** $K_a = \dfrac{[HPO_4{}^{2-}][H_3O^+]}{[H_2PO_4{}^-]} = 6.4 \times 10^{-8}$ 1 mark

As $[HPO_4{}^{2-}] = [H_2PO_4{}^-]$, then $[H_3O^+] = 6.4 \times 10^{-8}$ M   1 mark

pH $= -\log[H_3O^+] = -\log(6.4 \times 10^{-8}) = 7.2$ 1 mark

ii. $n(H_2PO_4{}^-) = 0.250 + 0.005 = 0.255$ mol and $c(H_2PO_4{}^-) = \dfrac{0.255}{0.50} = 0.51$ M   1 mark

$n(HPO_4{}^{2-}) = 0.250 - 0.005 = 0.245$ mol and $c(HPO_4{}^{2-}) = \dfrac{0.245}{0.50} = 0.49$ M   1 mark

iii. $K_a = \dfrac{[HPO_4^{2-}][H_3O^+]}{[H_2PO_4^-]} = \dfrac{0.49 \times [H_3O^+]}{0.51} = 6.4 \times 10^{-8}$ 1 mark

$[H_3O^+] = 6.66 \times 10^{-8}$ M and so pH $= -\log(6.66 \times 10^{-8}) = 7.18$ 1 mark

iv. The pH of pure water at 25°C is 7.

0.005 mol in 500 mL is 0.010 M.

$[H_3O^+] = 0.010$ M $= 10^{-2}$ M and so pH $= 2$ 1 mark

The change is 5 pH units.   1 mark

v. When a small amount of acid (0.005 mol) was added to the buffered solution, almost no change occurred in pH. Adding the same amount of acid to an unbuffered solution (i.e. to water) changed the pH drastically. The natural buffer in the body is very effective at keeping the pH within a narrow range.   1 mark

b. **i.** high temperature   1 mark

For an endothermic reaction at high temperature, the forward reaction is favoured to partly oppose the heat added (by absorbing some of the heat).   1 mark

ii. The manufacturer will choose the most economically beneficial method which produces the maximum yield at the best rate.   1 mark

High temperatures will produce a high rate of reaction, but the cost of the energy source will be considered when deciding the temperature of operation.   1 mark

iii. *Statement 4 should be ticked.*   1 mark

Question 6 (10 marks)

a. **i.** addition reaction   1 mark

ii. $n(I_2) = c \times V = 0.591 \times 0.0500 = 0.02955$ mol   1 mark

iii. $n(S_2O_3{}^{2-}) = c \times V = 0.224 \times 0.01785$ mol   1 mark

$n(I_2) = \dfrac{1}{2} \times n(S_2O_3{}^{2-}) = \dfrac{1}{2} \times 0.224 \times 0.01785 = 0.001999$ mol   1 mark

iv. $n(I_2)$ in excess in 50 mL $= \dfrac{50.0}{10.0} \times 0.001999 = 0.009996$ mol   1 mark

$n(I_2)$ reacting with acid sample $= 0.02955 - 0.009996 = 0.01955$ mol   1 mark

v. $n(ROOCH) = \dfrac{m}{M} = \dfrac{1.069}{328} = 0.003259$ mol   1 mark

$n(I_2) : n(RCOOH) = 0.01955 : 0.003259 = 6 : 1$, i.e. there are six double bonds.   1 mark

b.

$$CH_3OH$$
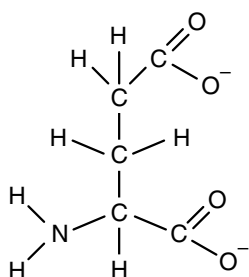
$$\longrightarrow \quad C_{15}H_{31}COOCH_3$$
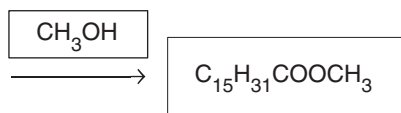
2 marks
1 mark for each box filled in correctly

Question 7 (6 marks)

a. $n(NC(CH_2)_4CN) = \dfrac{m}{M} = \dfrac{2000 \times 10^3}{108} = 1.852 \times 10^4$ mol   1 mark

$n(e^-) = 2 \times n(NC(CH_2)_4CN) = 2 \times 1.852 \times 10^4$ mol   1 mark

$I = \dfrac{n(e^-) \times F}{t} = \dfrac{2 \times 1.852 \times 10^4 \times 96\,500}{24 \times 60 \times 60} = 4.1 \times 10^4$ amperes   1 mark
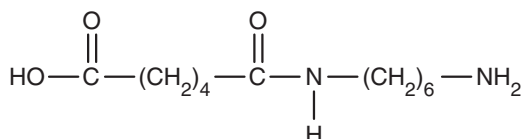
b.

2 marks
1 mark for structure
1 mark for correct charges

c.

1 mark

Question 8 (9 marks)

a. $n(HCl)$ initially added $= c \times V = 0.15 \times 50.0 \times 10^{-3}$ mol   1 mark
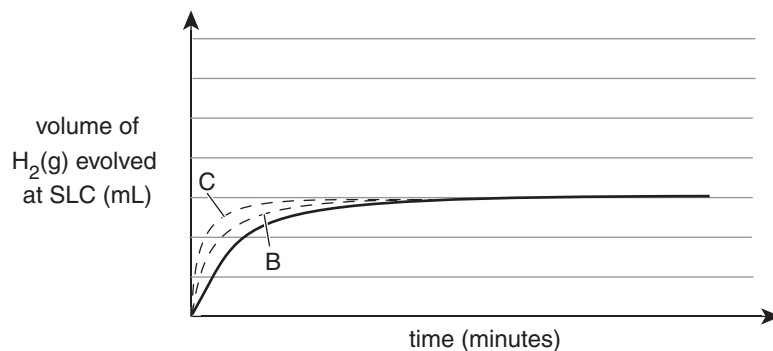
$n(Mg) = \dfrac{m}{M} = \dfrac{0.080}{24.3}$ mol

$n(HCl\ reacting) = 2 \times n(Mg) = 2 \times \dfrac{0.080}{24.3}$ mol   1 mark

$n(H_3O^+) = n(HCl\ in\ excess/remaining) = n(HCl\ initially\ added) - n(HCl\ reacting)$

$$= (0.15 \times 50.0 \times 10^{-3}) - \left(2 \times \dfrac{0.080}{24.3}\right)$$

$$= 0.00092 = 9.2 \times 10^{-4} \text{ mol} \qquad \text{1 mark}$$

b.   **i.** and **ii.**

$$1 + 1 = 2 \text{ marks}$$

Note: HCl is in excess in each of flasks A to D. In flask B and C, increasing HCl concentration increases rate, but does not increase maximum volume of H_2 evolved. Higher temperature in flask C gives a greater rate of reaction.

c.   flask E   1 mark

To obtain valid results, the conditions used for the experiment must differ from another flask by only one factor. Flask E uses the same conditions as flask D apart from the surface area of the magnesium.   1 mark

d.   To produce a successful collision, the reactants particles must collide in the correct orientation and with at least the energy equivalent to the activation energy.   1 mark

The reactant particles have an enormous range of energies, with only a small fraction having the energy required, and then these particles must collide in the orientation so that bonds are broken and new bonds can reform.   1 mark