Neap

Diagnostic Topic Test 2024

VCE Chemistry Units 3&4

Suggested Solutions

Test 3: How can the rate and yield of chemical reactions be optimised?

- Rates of chemical reactions
- Extent of chemical reactions

SECTION A – MULTIPLE-CHOICE QUESTIONS

Question 1 B

B is correct. Catalysts provide an alternate reaction pathway, lowering activation energy and so increasing reaction rate.

A and **D** are incorrect. Catalysts do not alter equilibrium position or the value of the equilibrium constant.

C is incorrect. Catalysts do no alter enthalpy values.

Question 2 D

D is correct. The equilibrium system responds to oppose the change made. The response only partially overcomes the imposed change.

A and **B** are incorrect. Concentrations do not return to their former values and, if the imposed change is a change in temperature, the equilibrium constant will alter.

C is incorrect. An equilibrium system in a closed, fixed-volume vessel will not be able to alter the 'volume of the reaction vessel'.

Question 3 D

$$Q_c = \frac{[Y][Z]}{[X]} = \frac{1.0 \times 1.0}{1.0} = 1.0 \text{ M}$$

The equilibrium constant, K, is 1.70 M.

$Q < K$, hence the reaction moves to the right to reach equilibrium.

Therefore, temperature decreases (endothermic reaction) and the mass of X decreases.

Question 4 B

The reaction is exothermic, hence heating will favour the reverse, temperature-decreasing reaction.

The amount of NH_3 will decrease, while the amount of H_2 will increase. The changes must occur in the mole ratio given in the equation; that is, $n(H_2) : n(NH_3) = 3 : 2 = 0.243 : 0.162$.

Question 5 A

A is correct, and **C** and **D** are incorrect. The yield decreases with increasing temperature, indicating that this is an exothermic reaction.

B is incorrect. The yield increases with increasing pressure, indicating that the forward reaction is pressure-reducing; that is, there are more moles of gaseous reactants than products.

Question 6 B

B is correct. The dilemma occurs for exothermic equilibrium reactions (reaction II), where a high temperature favours the rate but a low temperature favours the yield.

A, **C** and **D** are incorrect. For endothermic equilibrium reactions, high temperatures favour both the rate and the yield, so there is no dilemma. In practice, although high temperature could be used for reaction I, the use of a catalyst might lower the required temperature and so lower the operating costs.

Question 7 A

A is correct. The relative rates of formation and disappearance are given by the coefficients in the equation. Thus for every 1.0 mole (per minute) of Q that reacts, 0.25 mole (per minute) of R will be formed.

B is incorrect. The rate of disappearance of Q is twice the rate of disappearance of P.

C is incorrect. The rate of formation of S is half the rate of the disappearance of Q.

D is incorrect. The rates for P and S are equal.

Question 8 C

C is correct and **D** is incorrect. Catalysts increase the rate of reaction and have no effect on the equilibrium yield of a product (other than to produce the yield more quickly).

A and **B** are incorrect. These incorrectly show a change in the amount of R formed.

Question 9 A

A is correct. The concentration of H_2 has decreased from 0.09 to 0.08, a drop of 0.01, or $\frac{0.01}{0.09} \times 100 = 11\%$

B is incorrect. It shows too large an increase in volume.

C and **D** are incorrect. They show a volume decrease.

Question 10 C

The maintenance of a constant temperature during the first 200 seconds required the removal of heat, hence the forward reaction is exothermic. After the change at 400 seconds, the reaction moved backwards, in the temperature-reducing direction, thus the change made was a temperature increase. The concentration of hydrogen iodide, HI, will decrease by approximately twice the value of the increase in H_2 concentration; that is, by approximately $2 \times 0.009 = 0.018$ M. The final HI concentration will be $0.036 - 0.018 = 0.018$ M.

SECTION B

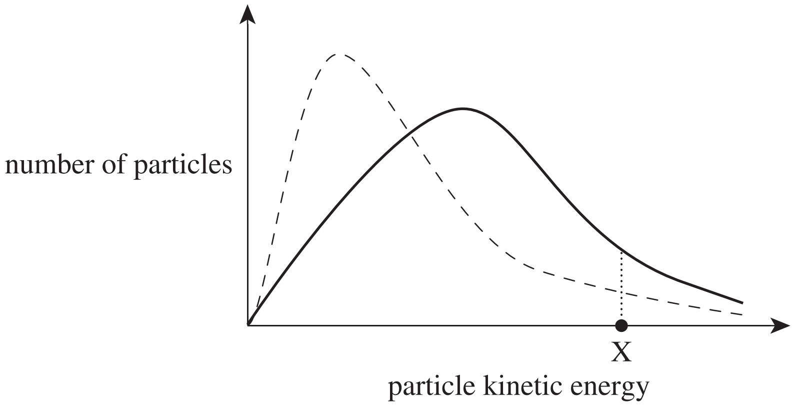
Question 1 (9 marks)

a. **i.** the minimum amount of energy required for the reaction to proceed

OR

the energy required to break bonds in the reactants to allow reaction to proceed — 1 mark

ii.



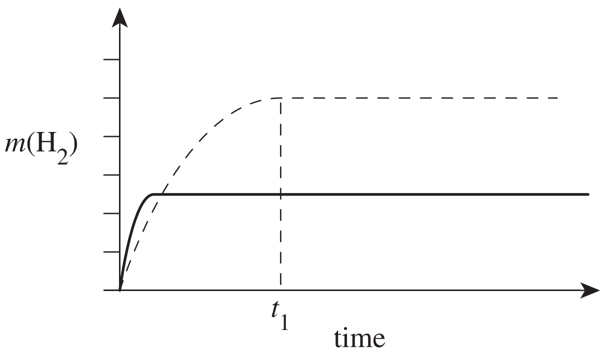
1 mark

iii. From the shape of the graph for the elevated temperature, it can be seen that a significantly greater proportion of particles now have sufficient energy to initiate the reaction. — 1 mark

Graphically, the area under the graph to the right of X is much larger at the higher temperature. — 1 mark

b. **i.** One of the reactants (the limiting one, in this case Mg) has been completely reacted and so no further reaction occurred. — 1 mark

ii.



(Powdered magnesium is used and so the rate of the reaction is much faster, and the reaction reaches completion more quickly. In this case, only 1.0 g of magnesium is reacted and so the volume of hydrogen gas evolved is only half that of the initial experiment. HCl is in excess in both cases.)

2 marks

1 mark for graphing a greater rate of reaction.

1 mark for graphing half the volume of hydrogen evolved.

iii. At higher concentrations there are more H^+ ions in a given volume of HCl solution. — 1 mark

Frequency of collisions between H^+ and Mg is increased and so reaction rate increases. — 1 mark

Question 2 (5 marks)

a. **i.** $K = \dfrac{[\text{ClF}_3]^2}{[\text{Cl}_2][\text{F}_2]^3}$ 1 mark

ii. $K = \dfrac{[\text{ClF}_3]^2}{[\text{Cl}_2][\text{F}_2]^3} = \dfrac{(1.059)^2}{(0.173)(0.419)^3} = 88.1\ \text{M}^{\ 2}$ 1 mark

b. **i.** $E_\text{a} = 40 + 160 = 200\ \text{kJ mol}^{-1}$ 1 mark

ii. Reverse reaction:

$\Delta H = +160\ \text{kJ mol}^{-1}$ 1 mark

iii. Reverse and halve reaction:

$K' = \dfrac{1}{\sqrt{K}} = \dfrac{1}{\sqrt{88.1}} = 0.107\ \text{M}$ 1 mark

Question 3 (7 marks)

a. **i.**

	Reactants		Products
Mole ratio in the equation	PCl_3	Cl_2	PCl_5
$\boldsymbol{n}_\textbf{i}$	0.533	0.291	0
Change	–0.213	–0.213	+0.213
$\boldsymbol{n}_\textbf{eq}$	0.320*	0.078	0.213
[ ]eq, V = 4.00 L	0.0800	0.0195	0.0533

*60% of 0.533 = 0.320

$[PCl_3] = 0.0800$ M, $[Cl_2] = 0.0195$ M, $[PCl_5] = 0.0533$ M 3 marks

1 mark for each correct concentration.

Note: Award only one mark for recognising that the reactants decrease and the products increase in concentration.

ii. $K = \dfrac{[\text{PCl}_5]}{[\text{PCl}_3][\text{Cl}_2]}$ 1 mark

$= \dfrac{0.0533}{0.0800 \times 0.0195} = 34.2\ \text{M}^{-1}$ (which is greater than $0.041\ \text{M}^{-1}$) 1 mark

Note: Consequential on answer to ***Question 3a.i.***

b. lower 1 mark

A decrease in temperature favours the forward reaction for an exothermic process, resulting in the larger equilibrium constant. 1 mark

Question 4 (4 marks)

Reaction condition	Advantage	Disadvantage
high temperature	There is a faster rate of reaction, producing products rapidly. **OR** There is a higher yield of products as it is an endothermic reaction.	High energy costs are required to produce and maintain this temperature.
low pressure	There are two reactant molecules and four product molecules. If low pressures are used, the forward reaction would be favoured, giving a higher yield. **OR** Energy would be saved by not using expensive high-pressure equipment.	Low pressure for a gaseous equilibrium will produce a slow rate of reaction as frequency of collisions of reactant particles is low.

4 marks
1 mark for each correctly filled box.