IB Chemistry – HL
Topic 6 Answers

1. C

2. D

3. D
4. D

5. B
6. B

7. C

8. C

9. A

10. C

11. A

12. D

13. B

14. D

15. C

16. (a) (order with respect to) NO = 2;
(order with respect to) H_2 = 1;
rate increases×4 when [NO] doubles/*OWTTE*; 3

(b) rate = $k[NO]^2[H_2]$; 1
ECF from (a).

(c) (2.53×10^{-6} mol dm^{-3} s^{-1} = k (0.100 mol dm^{-3})^2(0.100 mol dm^{-3}))
$k = 2.53\times10^{-3}$; 1

mol^{-2} dm^{6} s^{-1}; 1
ECF from (b).

(d) agrees/yes;
slow step depends on X and NO;
X depends on H_2 and NO;
(so) NO is involved twice and H_2 once;
Overall equation matches the stoichiometric equation;
*Award **[1]** each for any three of the four above.*
OWTTE
ECF for "no", depending on answer for (b).

Or agrees/yes;

and $\frac{[X]}{[H_2][NO]}$ = constant;

rate of slow step = k [X][NO]

= $k\ [H_2][NO]^2$; 4

ECF for "no", depending on answer for (b).

(e) reaction involves <u>four</u> molecules;
statistically/geometrically unlikely; 2

(f) the rate of formation of $H_2O(g)$ = 2×rate for $N_2(g)$;
because 2 moles H_2O formed with 1 mole N_2/*OWTTE*; 2

[14]

17. (a) first order (with respect to O_2); 1

(b) second order (with respect to NO); 1

(c) rate = $k[NO]^2[O_2]$; 1

Allow ECF from parts (a) and (b).

(d) $k = \frac{3.75\times10^{-3}}{(3.50\times10^{-2})^2(1.75\times10^{-2})} = 1.75\times10^2$;

$dm^6\ mol^{-2}\ s^{-1}$; 2

*Award **[1]** mark for the answer and **[1]** mark for units.*

Allow ECF from part (c).

(e) $NO + NO \rightleftharpoons N_2O_2$;

$N_2O_2 + O_2 \rightarrow 2NO_2$;

second step is rate determining step;

Allow ECF from part (c).

OR

$NO + O_2 \rightleftharpoons NO_3$;

$NO_3 + NO \rightarrow 2NO_2$;

second step is rate determining step; 3

Allow ECF from part (c).

[8]

18. (a) time for reactant concentration to halve/*OWTTE*; 1

Accept "time for mass to halve".

(b) 1000 s;
1000 s; 2

Accept 900-1100 s.

(c) first order;
constant half-life;
rate = k[A]; 3

Allow ECF for rate expression from stated order.

(d) $k = \frac{\text{rate}}{[\text{D}]^2[\text{E}]} / \frac{3.75\times10^{-5}}{(1.35\times10^{-2})^3}$;

= 15.2;

Accept answer in range 15.2 to 15.3.

$\text{mol}^{-2}\ \text{dm}^{6}\ \text{min}^{-1}$; 3

[9]

19. (a) first order;
constant half-life; 2

(b) rate = $k[\text{HI}][\text{H}_2\text{O}_2]$; 1

ECF from(a).

(c) 47 sec;

Accept answer in range 45 to 49.

$\left(t_{\frac{1}{2}} = \frac{0.693}{k}\right) = 0.015$; 2

Accept answer in range 0.014-0.015.

ECF from half-life.

[5]

20. (a) (i) (C) first order;
doubling [C] doubles rate/*OWTTE*;

(D) zero order;
changing [D] has no effect on rate/*OWTTE*; 4

(ii) rate = k[C]/rate = $k[\text{C}]^1[\text{D}]^0$; 1

Apply ECF from (a)(i).

(iii) $k = \frac{rate}{[C]} / \frac{1.0\times10^{-6}}{2.0\times10^{-3}}$;

= 5.0×10^{-4};

min^{-1}; 3

Apply ECF from (a)(ii).

(b) time for half of (amount/concentration of) reactant to react/disappear;

$t_{\frac{1}{2}}$ (= 0.693÷0.033) = 21 min; 2

Units needed for second mark.

[10]

21. (a) (order with respect to) H_2 = 1;

(order with respect to) NO = 2; 2

(b) rate = $k[H_2][NO]^2$; 1

ECF from (a).

(c) (2.53×10^{-6} mol dm^{-3} s^{-1} = k(0.100 mol dm^{-3})(0.100 mol dm^{-3})^2)

$k = 2.53\times10^{-3}$;

mol^{-2} dm^{6} s^{-1}; 2

ECF from (b).

(d) agrees/yes;

slow step depends on X and NO;

(so) NO is involved twice and H_2 once;

overall equation matches the stoichiometric equation/*OWTTE*;

ECF for "no", depending on answer for (b).

OR

agrees/yes;

and $\frac{[X]}{[H_2][NO]}$ = constant;

rate of slow step = k[X][NO];

but X depends on H_2 and NO;

rate of slow step = $k[H_2][NO]^2$; 4

max

Award ***[1]*** *each for any three of the four above.*

ECF for "no", depending on answer for (b).

(e) reaction involves <u>four</u> molecules;

statistically/geometrically unlikely; 2

(f) the rate of formation of H_2O = 2×rate for N_2;

because 2 moles H_2O formed with 1 mole N_2/*OWTTE*; 2

[13]

(i) the power of a reactant's concentration in the rate equation/sum of powers of concentration/rate = $k[X]^n$, where n = order of reaction; 1

Must be in terms of powers of concentration.

(ii) experiment 1—2 : [X] doubles and rate×4;
2nd order for X;
experiment 2—3 : [Y] doubles and rate×2;
1st order for Y; 4

(iii) rate = $k[X]^2[Y]$(*ECF from (ii)*)
for experiment 1, $1.0\times10^{-2} = k\,(0.25)^2(0.25)$;
k = 0.64;
$mol^{-2}\,dm^6\,s^{-1}$; 4

Allow ECF from rate expression.

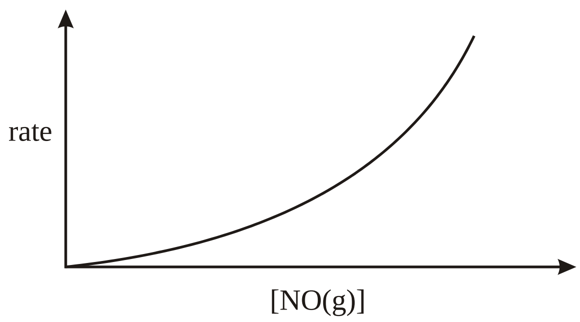
(iv) rate = $0.64[0.40]^2[0.60]$;
= 0.061; 2

Final answer to 2 sig figs only.
Allow ECF from (iii).

[11]

23. (a) 1/first order;
rate is (directly) proportional to concentration of oxygen/*OWTTE*; 2

(b)



correct axes;
correct shape curve; 2

(c) 3/third order; 1

Allow ECF from (a) and (b).

(d) overall effect on rate = $4\times\frac{1}{2}$ /doubled/×2;
[NO(g)] doubled, rate =×4/quadrupled;
$[O_2(g)]$ halved, rate =×1/halved; 3

Allow ECF from (a) and (b).

(e) rate = $k[NO(g)]^2\,[O_2(g)]$;

$$k = \frac{rate}{[NO(g)]^2[O_2(g)]} = \frac{6.3\times10^{-4}}{(3.0\times10^{-2})^2(1.0\times10^{-2})};$$

= 70;

$mol^{-2}\ dm^6\ s^{-1}$; 4

Allow ECF.

State symbols not needed.

[12]

24. (i) $2ICl + H_2 \rightarrow I_2 + 2HCl$; 1

(ii) *ICl order*

1;

because doubling [ICl] doubles rate (when $[H_2]$ constant);

H_2 order

2;

because halving $[H_2]$ quarters rate (when [ICl] constant);

or doubling $[H_2]$ quadruples rate (when [ICl] constant); 4

(iii) rate = $k\,[ICl][H_2]^2$; 1

ECF from (ii).

(iv) $k = 5.00\times10^{-3} \div 0.100\times0.0500^2 = 20$;

$mol^{-2}\ dm^6\ s^{-1}$; 2

ECF from (iii).

(v) rate = $20\times0.200\times0.100^2 = 4.00\times10^{-2}$ ($mol\ dm^{-3}\ s^{-1}$); 1

ECF from (iii).

[9]

25. (a) (i) it relates to the geometric requirements of the reaction/orientation of reactants on collision/*OWTTE*; 1

(ii) minimum energy needed for reactants to react (on collision)/*OWTTE*; 1

(iii) k measured at different values of temperature;

graph plotted of ln k against $1/T$;

intercept on y-axis is ln A;

$A = e^{intercept}$;

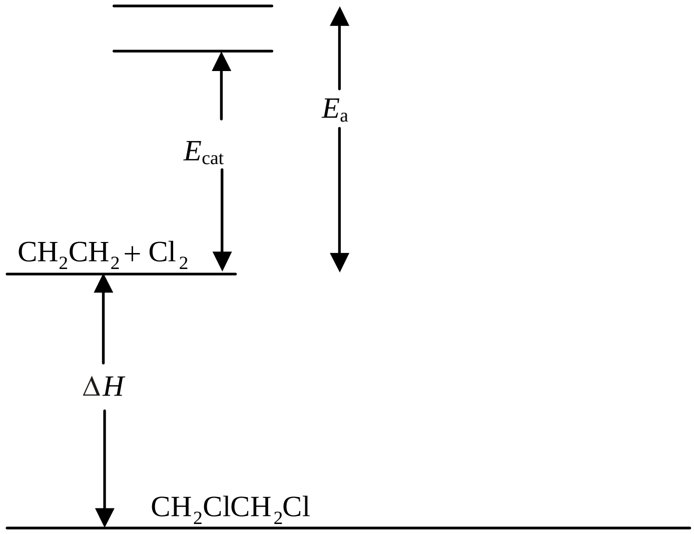
measured slope of graph = $-E_a/R$;

$E_a = -R\times$gradient; 5

*Award **[1]** each for any five.*

(b) (i) homogeneous catalyst is in same phase as reactants and heterogeneous catalyst is in different phase from reactants; 1

(ii) 4



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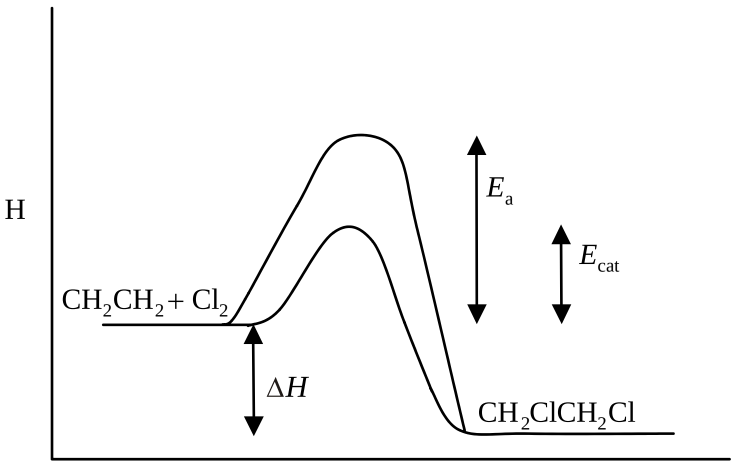


reactants line higher than product line *(labels not needed)*;
ΔH label;
E_a label;
E_{cat} label;

[12]

26. (a) *order of NO*: second/2 - [NO] doubled, rate×4/*OWTTE*;
order of Br_2: first/1 - as [Br_2] doubled, rate of reaction doubled/*OWTTE*; 2
Reason needed for each mark.

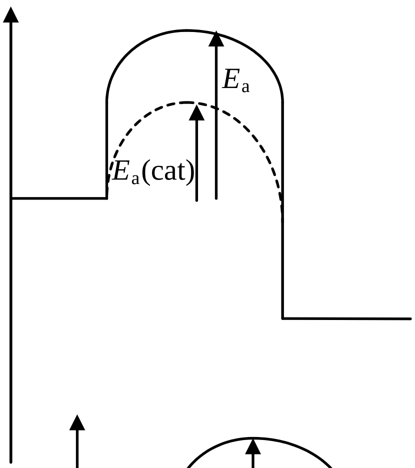
(b) rate = $k\,[NO]^2[Br_2]$; 1
Allow ECF from (a).

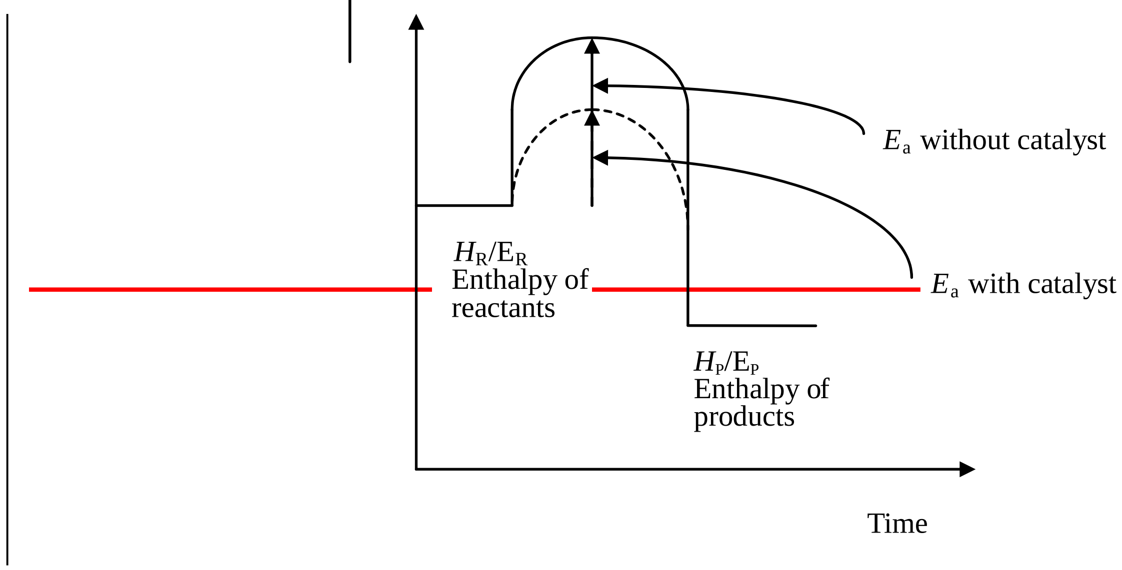
(c) $3.20\times10^{-3} = k(2.00\times10^{-2})^2\times5.00\times10^{-3}$
$k = 1.60\times10^3$;
$dm^6\ mol^{-2}\ s^{-1}$; 2
Allow ECF from (b).

(d) (i) no effect/K changes only with temperature/OWTTE; 1

(ii) decrease (by a factor of 2); 1

(e)





curve clearly showing E_a without catalyst (E_a);
curve clearly showing E_a with catalyst (E_a(cat));

labelling for x axis; 3

Accept time/progress of reaction/course of reaction/OWTTE.

Award ***[2 max]*** *if an enthalpy level diagram for an endothermic reaction has been correctly drawn.*

[10]

27. (i) rate = k[CH_3COCH_3][H^+];

rate = k[CH_3COCH_3]^2;

rate = k[H^+]^2; 3

(ii) [CH_3COCH_3] doubles, rate doubles **and** [H^+] doubles, rate doubles;
[Br_2] double, no effect on rate;

OR

[CH_3COCH_3] doubles, rate quadruples;
[Br_2] doubles/[H^+] □doubles, no effect on rate;

OR

[H^+] □doubles, rate quadruples;
[Br_2] doubles/[CH_3COCH_3] doubles, no effect on rate; 2

The answer given must correspond to the selected expression in (i).

(iii) constant half-life;
at least two sets of data to justify statement; 2

e.g. [ ] from 1.6 to 0.8 mol dm^{-3}, 10s; 0.8 to 0.4, 10s; 0.4 to 0.2, 10s.

(iv) decrease in the colour of the bromine/*OWTTE*;
catalyst;
increases rate/speeds up reaction;
by lowering E_a/activation energy (by providing an alternate pathway); 4

[11]