1. B

[1]

2. A

[1]

3. B

[1]

4. C

[1]

5. D

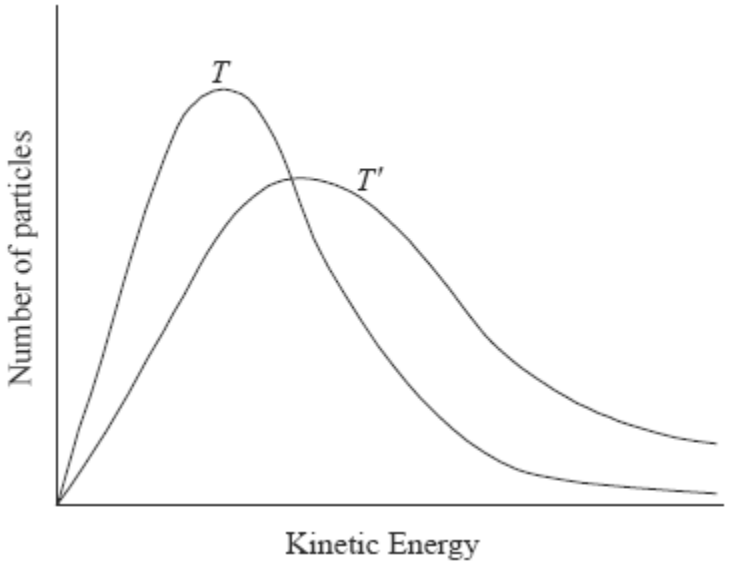
[1]

6. (i) increase in concentration of product per unit time / decrease in concentration of reactant per unit time; 1
Accept change instead of increase/decrease and mass/amount/ volume instead of concentration.

(ii) frequency of collisions;
kinetic energy/speed of reactant particles;
collision geometry/orientation; 3

[4]

7.



correctly labelled axes showing number of particles/frequency against (kinetic) energy;
correctly shaped graph for *T* (curve must not touch or cross *x* axes);
T′ curve to the right of *T* and with a peak lower than *T*;
increasing the temperature increases the (kinetic) energy of the particles / more particles will possess the necessary activation energy;
there will be more collisions per unit time / the frequency of collisions increases / there are more successful collisions; 5

[5]

8. D

[1]

9. C

[1]

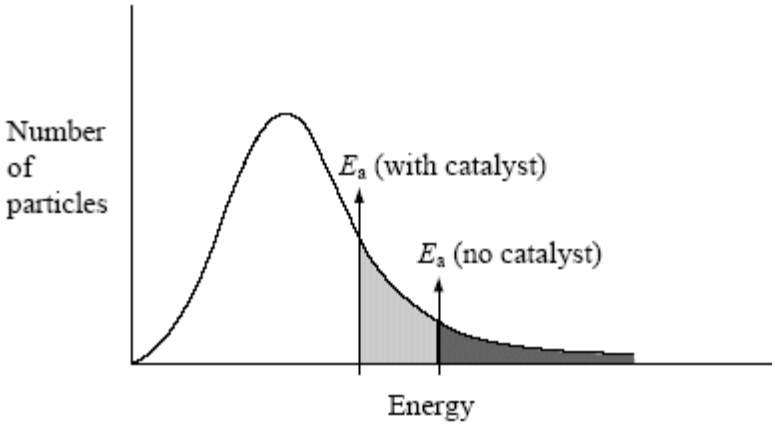
10. C

[1]

11. (a) $[I_2]$ does not affect rate / *OWTTE*;
neither correct/both partially correct with explanation as to how; 2

(b) more particles/molecules have sufficient energy to overcome activation energy / *OWTTE*;
more frequent collisions; 2

(c) (i)



axes correctly labelled *x* = energy/velocity/speed, *y* = number/% of molecules/particles/probability;
graph showing correct curve for Maxwell-Boltzmann distribution;
If two curves are drawn, first and second mark can still be scored, but not third.
Curve(s) must begin at origin and not go up at high energy.

two activation energies shown with E_{cat} shown lower;
Award the mark for the final point if shown on an enthalpy level diagram. 3

(ii) catalyst provides an alternative pathway of lower energy / *OWTTE*;
Accept catalyst lowers activation energy (of reaction). 1

[8]

12. C

[1]

13. C

[1]

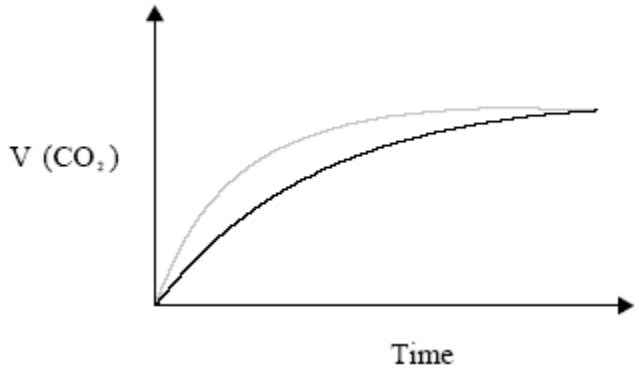
14. D

[1]

15. (i) rate = increase in $\frac{\text{volume}}{\text{time}}$ = slope of graph;

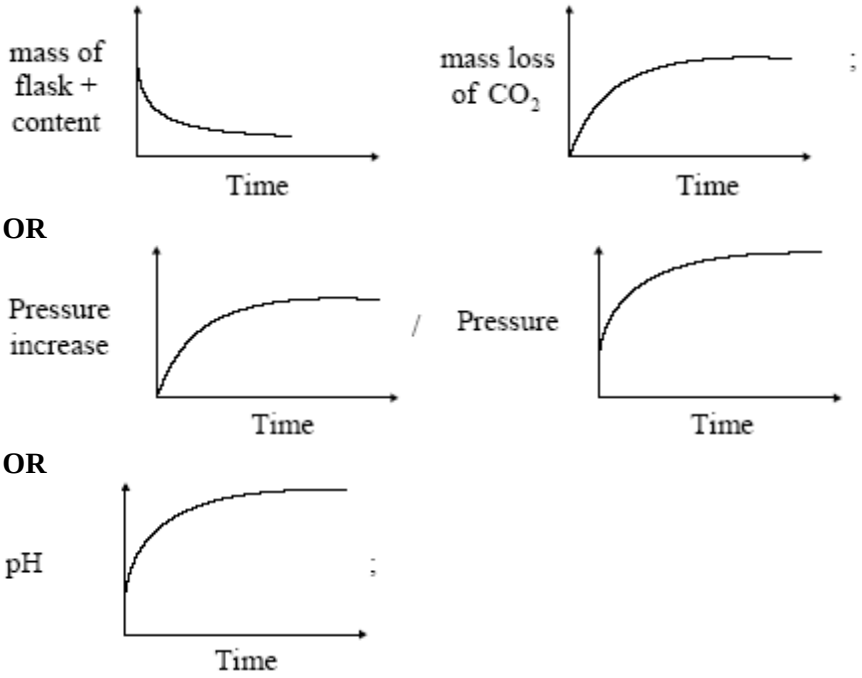
initially/to begin with steeper slope / fastest rate / volume of gas/CO_2 produced faster/quickly as concentration of HCl highest / *OWTTE*;
as reaction progresses/with time, less steep slope / volume of gas production slows / rate decreases due to less frequent collisions as concentration (of HCl) decreases / *OWTTE*;
curve flattens/becomes horizontal when HCl used up/consumed (as there are no more H^+ ions to collide with the $CaCO_3$ particles);
Each mark requires explanation. 3 max

(ii)



less steep curve;
same maximum volume at later time;
half/lower H^+ /acid concentration less frequent collisions/slower rate;
same amount of HCl, same volume CO_2 produced; 4

(iii) mass loss/of CO_2 / mass of flask + content;



Do not penalize for missing x-axis label or for missing units on y-axis.
Accept if line meets time axis. 2

(iv) minimum energy (of colliding particles) for a reaction to occur / *OWTTE*;
lower E_a / greater surface area/contact between $CaCO_3$ and HCl / higher HCl concentration / (sufficient) particles/molecules have activation energy; 2

[11]

16. C

[1]

17. (a) *k* increases with increase in *T* / *k* decreases with decrease in *T*; 1
Do not allow answers giving just the Arrhenius equation or involving ln k relationships.

(b) gradient = $-E_a/R$;
-30000 (K) = $-E_a/R$;
Allow value in range –28800–31300 (K).

E_a =(30000 × 8.31=) 2.49×10^5 J mol^{-1} /249 kJ mol^{-1}; 3
Allow value in range 240–260 kJ mol^{-1}.
*Allow **[3]** for correct final answer.*

(c) $0.9 \times 0.200 = 0.180$ (mol dm^{-3});

rate = $(0.244 \times (0.180)^2 =) 7.91 \times 10^{-3}$ mol dm^{-3} s^{-1}; 2

*Award **[2]** for correct final answer.*

*Award **[1 max]** for either 9.76×10^{-3} mol dm^{-3} s^{-1} or 9.76×10^{-5} mol dm^{-3} s^{-1}.*

[6]

18. A

[1]

19. (i) the concentration (of nitrogen(II) oxide); 1

*Award **[0]** if reference made to equilibrium.*

(ii) mol^{-2} dm^6 s^{-1} / dm^6 mol^{-2} s^{-1}; 1

Accept $(mol^{-1}\ dm^3)^2\ s^{-1}$.

[2]

20. B

[1]

21. D

[1]