1. D

[1]

2. B

[1]

3. A

[1]

4. D

[1]

5. (a) (i) (10 % 1000 g =) 100 g ethanol **and** (90 % 1000 g =) 900 g octane; 1

(ii) *n*(ethanol) = 2.17 mol **and** *n*(octane) = 7.88 mol; 1

(iii) $E_{\text{released from ethanol}} = (2.17 \times 1367) = 2966$ (kJ);
$E_{\text{released from octane}} = (7.88 \times 5470) = 43104$ (kJ);

total energy released = $(2966 + 43104) = 4.61 \times 10^4$ (kJ); 3
*Award **[3]** for correct final answer.*
Accept answers using whole numbers for molar masses and rounding.

(b) greater;
fewer intermolecular bonds/forces to break / vaporization is endothermic / gaseous fuel has greater enthalpy than liquid fuel / *OWTTE*; 2
M2 cannot be scored if M1 is incorrect.

[7]

6. D

[1]

7. (a) argon has a greater proportion of heavier isotopes / *OWTTE* /
argon has a greater number of neutrons; 1

(b) 19 protons **and** 18 electrons; 1

(c) 2, 8, 8; 1

Accept $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$.

[3]

8. $63x + 65(1 - x) = 63.55$;

(or some other mathematical expression).

$^{63}Cu = 72.5\ \%$ **and** $^{65}Cu = 27.5\ \%$;

Allow $^{63}Cu = 0.725$ ***and*** $^{65}Cu = 0.275$.

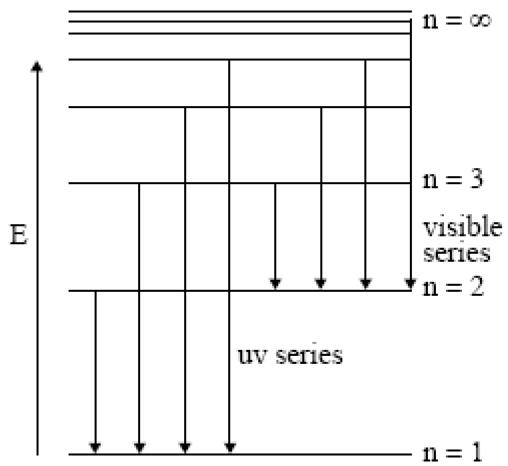
*Award **[2]** for correct final answer.* 2

[2]

9. B

[1]

10.



showing *y*-axis labelled as energy/E / labelling at least two energy levels;
showing a minimum of four energy levels/lines with convergence;
showing jumps to n = 1 for ultraviolet series;
showing jumps to n = 2 for visible light series;
Must show at least two vertical lines per series to score third and fourth mark but penalize once only.
For third and fourth marks if transition not shown from higher to lower energy level penalize only once. 4

[4]

11. C

[1]

12. (i) the amount of energy required to remove one (mole of) electron(s);
from (one mole of) an atom(s) in the <u>gaseous</u> state; 2

(ii) greater positive charge on nucleus / greater number of protons /
greater core charge;
greater attraction by Mg nucleus for electrons (in the same shell) /
smaller atomic radius; 2

[4]

13. A

[1]

14. A

[1]

15. (a) $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$ /
$Na(s) + H_2O(l) \rightarrow NaOH(aq) + \frac{1}{2} H_2(g)$

*Award **[1]** for correct balanced equation.*
*Award **[1]** for correct state symbols for sodium, water, sodium hydroxide and hydrogen.*
Second mark is not dependent on equation being correctly balanced. 2

(b) (Rb more reactive because) electron lost further from nucleus so less tightly held;
Rb electron is in 5th energy level **and** (Na less reactive) as electron lost in 3^{rd} energy level / *OWTTE*;
*Allow **[1 max]** for electron arrangements of Na (e.g. 2,8,1) and Rb if second mark is not scored.* 2

[4]

16. C

[1]

17. D

[1]

18. A

[1]

19. C

[1]

20. *Award **[2 max]** for three of the following features:*

Bonding

*Graphite **and** C_{60} fullerene:* covalent bonds **and** van der Waals'/London/ dispersion forces;
Diamond: covalent bonds (and van der Waals'/London/dispersion forces);

Delocalized electrons

*Graphite **and** C_{60} fullerene:* delocalized electrons;
Diamond: no delocalized electrons;

Structure

Diamond: network/giant structure / macromolecular / three-dimensional structure **and** *Graphite:* layered structure / two-dimensional structure / planar;
C_{60} fullerene: consists of molecules / spheres made of atoms arranged in hexagons/pentagons;

Bond angles

Graphite: 120° **and** *Diamond:* 109°;
C_{60} fullerene: bond angles between 109–120°;
*Allow Graphite: sp^2 **and** Diamond: sp^3.*
*Allow C_{60} fullerene: sp^2 **and** sp^3.*

Number of atoms each carbon is bonded to

*Graphite **and** C_{60} fullerene:* each C atom attached to 3 others;
Diamond: each C atom attached to 4 atoms / tetrahedral arrangement of C (atoms); 6 max

[6]

21. C

[1]

22. A

[1]

23. D

[1]

24. C

[1]

25. B

[1]

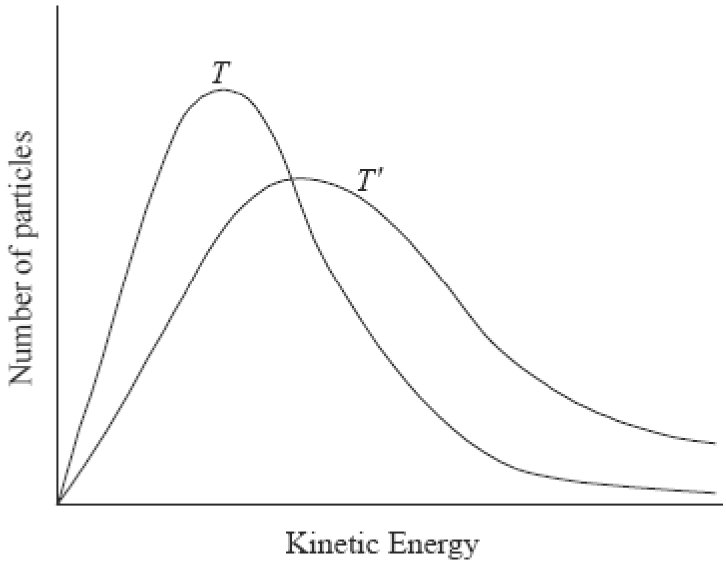
26. (i) increase in concentration of product per unit time / decrease in concentration of reactant per unit time; 1

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]

27.



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]

28. B

[1]

29. C

[1]

30. (a) $(K_c =) \frac{[CH_3OH]}{[CO][H_2]^2}$; 1

Do not award mark if incorrect brackets are used or brackets are missing.

(b) (i) amount (of methanol)/product decreases / less methanol;
(forward reaction) exothermic / reverse reaction endothermic / *OWTTE*; 2

(ii) amount (of methanol)/product increases / more methanol;
3 gas molecules/mol → 1 / decrease in volume / fewer gas molecules on right hand side/products / more gas molecules on left hand side/reactants; 2

(c) high pressure expensive / greater cost of operating at high pressure;
lower temperature – lower (reaction) rate; 2

(d) increases rate of forward and reverse reactions (equally) / lowers activation energy/E_a (of both the forward and reverse reaction equally) / provides alternative path with lower activation energy/E_a; 1
Accept reactants adsorb onto the catalyst surface and bonds weaken resulting in a decrease in the activation energy.

[8]

31. C

[1]

32. D

[1]

33. D

[1]

34. (a) ester; 1

(b) amount of oil = $\frac{1013.0}{885.6}$ = 1.144 mol;

amount of methanol = $\frac{200.0}{32.05}$ = 6.240 mol;

since three mol of methanol react with one mol of vegetable oil the amount of excess methanol = 6.204 – (3 × 1.144) = 2.808 mol; 3

(c) (i) rate of the forward reaction is equal to the rate of the reverse reaction / forward and reverse reactions occur and the concentrations of the reactants and products do not change / OWTTE; 1

(ii) $K_c = \frac{[\text{glycerol}]\times[\text{biodiesel}]^3}{[\text{vegetable oil}]\times[\text{methanol}]^3}$; 1

(iii) to move the position of equilibrium to the right/product side / increase the yield of biodiesel; 1

(iv) no effect (on position of equilibrium);
increases the rate of the forward and the reverse reactions equally (so equilibrium reached quicker) / it lowers E_a for both the forward and reverse reactions by the same amount / *OWTTE*;
No ECF for explanation. 2

(d) vegetable oil is mainly non-polar **and** methanol is polar / *OWTTE*;
stirring brings them into more contact with each other / increase the frequency of collisions / *OWTTE*;
Do not allow simply mixing. 2

(e) (relative molecular mass of biodiesel, $C_9H_{36}O_2$ = 296.55)
maximum yield of biodiesel = 3.432 mol / 1018 g;
percentage yield = $\frac{811.0}{1018} \times 100 = 79.67\ \%$;
Allow 80 % for percentage yield. 2

(f) the carbon dioxide was absorbed by plants initially so there is no net increase / vegetable oil is not a fossil fuel / vegetable oil is formed from (atmospheric) carbon dioxide / *OWTTE*; 1

[14]

35. (a) (i) correct substitution of values and numbers of bonds broken / (1 × 945) + (3 × 436)/2253;
correct substitution of values and numbers of bonds made / (6×391)/2346;
ΔH = (sum of energies of bonds broken) – (sum of energies of bonds formed) = (2253–2346) = –93 (kJ);
Ignore units.
*Award **[3]** for correct final answer.*
*Award **[2 max]** for +93 or 93.* 3

(ii) entropy of products = 2 × 192 = 384;
entropy of reactants = 193 + (3 × 131) = 586;
$\Delta S^{\ominus}$ (= sum of entropies of products) – (sum of entropies of reactants) / (384 – 586) = –202 (J K^{-1} mol^{-1});
*Award **[3]** for correct final answer.*
*Award **[2 max]** for +202 or 202.*
Ignore units.

negative as more ordered/less disordered / four moles become two moles / fewer molecules of gas; 4

(iii) ($\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$ = –93 – 298(–0.202)) = –32.8 (kJ mol^{-1}); 1

(iv) reaction becomes less spontaneous;
ΔG becomes more positive/less negative /TΔS becomes larger; 2

(b) macroscopic properties remain constant / concentrations remain constant / no change to copper solution seen;
rate of reverse/backwards reaction = rate of forward reaction; 2

(c) $(K_c =) \frac{[NH_3]}{[N_2][H_2]^3}$

Do not award mark if [ ] missing or round brackets used. 1

(d) (i) $[H_2]$ = 0.11 / 0.11 (mol dm^{-3});
$[N_2]$ = 0.17 / 0.17 (mol dm^{-3});
K_c = 16;
Ignore units.
Allow ECF from incorrect equilibrium expression and incorrect concentrations for third mark. 3

(ii) decrease;
heat is a product/reaction is exothermic so equilibrium moves to left / *OWTTE*; 2

(e) yield increases / equilibrium moves to the right / more ammonia;
4 gas molecules → 2 / decrease in volume / fewer gas molecules on right hand side; 2

(f) high pressure expensive / greater cost of operating at high pressure / reinforced pipes *etc*. needed;
Do not accept "high pressure is dangerous" without further explanation.

lower temperature – greater yield, but lowers rate;
Do not award a mark just for the word "compromise". 2

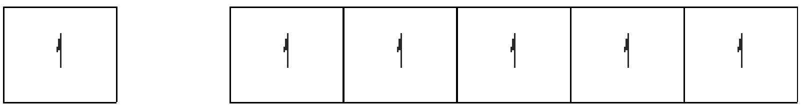
(g) K_c unaffected;
position of equilibrium unaffected;
rate of forward and reverse reactions are increased (equally); 3

[25]

36. (i) the electron configuration (of argon) / $1s^2 2s^2 2p^6 3s^2 3p^6$; 1

(ii) $x = 1$ **and** $y = 5$; 1

(iii)


;

4s 3d

Accept all six arrows pointing down rather than up. 1

[3]

37. B

[1]

38. A

[1]

39. C

[1]

40. B

[1]

41. A

[1]

42. C

[1]

43. C

[1]

44. (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 × 0.200 = 0.180 (mol dm^{-3});

rate = $(0.244 \times (0.180)^2 =)$ 7.91×10^{-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]