T3 *[183 marks]*

1. *[1 mark]*

Markscheme

B

Examiners report

[N/A]

2. *[1 mark]*

Markscheme

B

Examiners report

[N/A]

3. *[1 mark]*

Markscheme

D

Examiners report

[N/A]

4. *[1 mark]*

Markscheme

A

Examiners report

[N/A]

5. *[1 mark]*

Markscheme

D

Examiners report

[N/A]

6.

[1 mark]

Markscheme

B

Examiners report

[N/A]

7.

[1 mark]

Markscheme

C

Examiners report

[N/A]

8.

[1 mark]

Markscheme

A

Examiners report

[N/A]

9.

[1 mark]

Markscheme

D

Examiners report

[N/A]

10.

[1 mark]

Markscheme

C

Examiners report

[N/A]

11a.

[3 marks]

Markscheme

energy supplied/bonds broken/heat absorbed;

increases potential energy;

no change in kinetic energy (so no change in temperature);

Examiners report

[N/A]

11b. *[4 marks]*

Markscheme

use of $M \times 4.2 \times 10^3 \times \Delta\theta$
$ml = 75 \times 10^{-3} \times 3.3 \times 10^5$ / 24750 J;
recognition that melted ice warms and water cools to common final temperature;
3.4ºC;

Examiners report

[N/A]

12. *[4 marks]*

Markscheme

(i) mass lost in 300 s=(1.880-1.580)=0.3 (kg);
(energy supplied=750 kJ) (do not award credit for this line)
L=2.5 MJ kg^{-1}; *(unit must appear correctly here)*
*Award **[2]** for a bald correct answer.*

(ii) energy will be transferred to surroundings; } *(accept energy is lost by/from kettle to surroundings)*
so calculated energy to water is too large / change in mass too large;
(hence overestimate)
*Award **[0]** for a bald correct answer.*
Treat references to energy gained by kettle as neutral; the kettle is at a constant temperature.

Examiners report

[N/A]

13. *[1 mark]*

Markscheme

D

Examiners report

14. *[1 mark]*

Markscheme

C

Examiners report

15. *[1 mark]*

Markscheme

A

Examiners report

[N/A]

16. *[1 mark]*

Markscheme

D

Examiners report

Candidates are required to learn definitions. There are conditions (such as changing pressure) where the temperature of a body changing phase may alter. If this is the case then the specific latent heat does not apply.

17. *[1 mark]*

Markscheme

B

Examiners report

The weaker candidates were opting for D. But D does not answer the question which asks for an explanation for the temperature rise.

18. *[1 mark]*

Markscheme

A

Examiners report

There are two changes that are made in going from X to Y. A simple sketch, done while reading the stem, should show which way the proportionality works. As there are no squares in pV = nRT, the answer must be A.

19a. *[2 marks]*

Markscheme

one twelfth of the mass of a carbon-12 atom/
${}^{12}_{6}\mathrm{C}$;
Do not allow nucleus.

$255.09 \times 931.5 = 237600(\mathrm{MeVc^{-2}})$;
*Award **[1]** for a bald correct answer.*

Examiners report

i) The definition of the unified atomic mass unit relates to the mass of the carbon 12 atom. Few candidates made this reference.

ii) Almost all were able to convert the mass unit into $MeVc^{-2}$.

19b. *[6 marks]*

Markscheme

(i) neutron/$^1_0\mathrm{n}$;

(ii) the (rest) mass of the products is greater than that of the reactants;
energy must be given to supply this extra mass;

(iii) $\Delta m = [37216.560 + 938.272] - [37214.694 + 939.565] = 0.573 \left(\mathrm{MeVc}^{-2}\right)$;
energy required for reaction=0.573(MeV);
kinetic energy=(8.326-0.573=)7.753(MeV);
*Award **[3]** for a bald correct answer.*

Examiners report

i) This was well answered with the majority of candidates identifying the neutron.

ii) Few could relate the mass defect to the energy required to initiate the reaction.

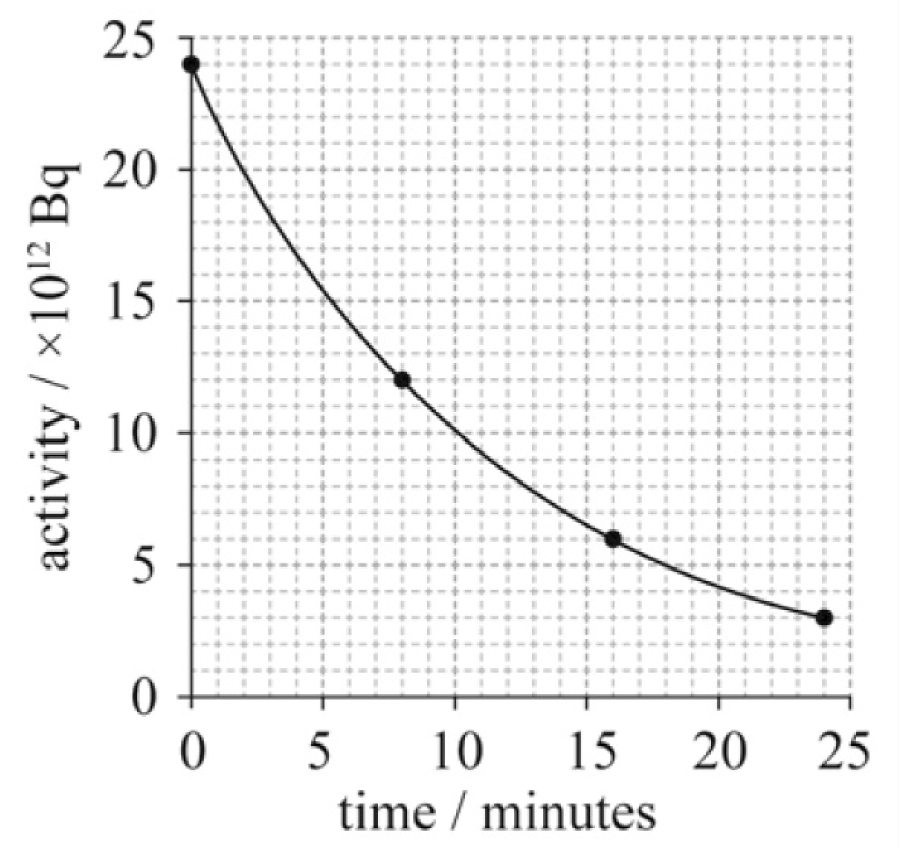
iii) Many were able to calculate the mass defect but did not realize that in this reaction it is the energy needed to initiate the reaction. This is why the products have more combined mass than the reactants.

19c. *[5 marks]*

Markscheme

(i) time for the activity of a sample to halve / time for half the radioactive nuclei to decay;

(ii) four data points (0, 24) (8, 12) (16, 6) (24, 3) correct;
smooth curve through points;



(iii) 2 hours (=120 minutes)=15 half-lives;
activity=$\frac{24\times10^{12}}{2^{15}} = 7.3 \times 10^8 \text{ (Bq)}$;
or
$\lambda = \frac{\ln 2}{8}$; $\left(A = A_0 e^{-\lambda t} \text{method}\right)$;
=7.3×10^8(Bq)
*Award **[2]** for a bald correct answer.*

Examiners report

i) The definition of radioactive half-life was often poorly done with few appreciating that half the radioactive nuclei decay into a more stable form. Those that explained that the activity of the sample would halve were more successful.

ii) Almost all were able to draw the decay curve.

iii) This was well answered with responses split between those that successfully found the number of half-lives elapsed in 2 hours and going on to find the activity of the sample and those that took the decay constant route. At SL, most successfully found the number of half lives elapsed in 2 hours and were able to find the corresponding activity of the sample.

19d. *[5 marks]*

Markscheme

(i) the energy (absorbed/released) when a unit mass/one kg;
of liquid freezes (to become solid) at constant temperature / of solid melts (to become liquid) at constant temperature;

(ii) potential energy changes during changes of state / bonds are weakened/broken during changes of state;
potential energy change is greater for vaporization than fusion / more energy is required to break bonds than to weaken them;
SLH vaporization is greater than SLH fusion;
Only award third marking point if first marking point or second marking point is awarded.

Examiners report

i) The majority related the latent heat to the energy required for a change of state but few successfully completed the definition by explaining that fusion is the change of state between a solid and liquid at constant temperature.

ii) This explanation was poorly done with few gaining full marks. Few could relate the change in potential energy during a change of state to fusion and vaporization.

19e. *[5 marks]*

Markscheme

(i) use of $\Delta Q = mc\Delta T$ and *mL*;
$0.020 \times 3.3 \times 10^5 + 0.020 \times 4200 \times (T - 0) = 0.25 \times 4200 \times (80 - T)$;
T=68(°C);
*Allow **[3]** for a bald correct answer.*
*Award **[2]** for an answer of T=74°(C) (missed melted ice changing temperature).*

(ii) no energy given off to the surroundings/environment;
no energy absorbed by beaker;
no evaporation of water;

Examiners report

i) Of those candidates that established a relevant energy transfer equation, many did not include the heat gained by the ice once it had melted.

ii) Few could state two sources of energy loss that were not included in their energy equation.

20. *[1 mark]*

Markscheme

D

Examiners report

[N/A]

21. *[1 mark]*

Markscheme

D

Examiners report

[N/A]

22. *[1 mark]*

Markscheme

D

Examiners report

[N/A]

23. *[1 mark]*

Markscheme

B

Examiners report

[N/A]

24. *[1 mark]*

Markscheme

C

Examiners report

[N/A]

25. *[1 mark]*

Markscheme

D

Examiners report

[N/A]

26a. *[2 marks]*

Markscheme

the force exerted per unit charge;
on a positive small/test charge;

Examiners report

[N/A]

26b. *[2 marks]*

Markscheme

$E = \frac{ke}{r^2} = \frac{9\times10^9\times1.6\times10^{-19}}{10^{-30}}$;
$= 1.4 \times 10^{21}\mathrm{NC}^{-1}$ ***or*** Vm^{-1};

Examiners report

[N/A]

26c. *[4 marks]*

Markscheme

(i) into the (plane of the) paper;
(ii) $Ee=Bev$ ***or*** $E=Bv$;
$=(2.3\times10^{-4}\times3.9\times10^{6}=)900/897$;
NC^{-1} ***or*** Vm^{-1};

Examiners report

[N/A]

26d. *[1 mark]*

Markscheme

proton number: 8
nucleon number: 17
(both needed)

Examiners report

[N/A]

26e. *[3 marks]*

Markscheme

16.9991u+1.0073u-[14.0031u+4.0026u];
$=-7.00\times10^{-4}$;
$7.000\times10^{-4}\times931.5=0.6521$MeV;
(~0.7MeV)

Examiners report

[N/A]

26f. *[5 marks]*

Markscheme

(i) *isotope:*

same proton number/element/number of protons ***and*** different number of neutrons/nucleon number/neutron number; } *(both needed)*

half-life:

time for the activity (of a radioactive sample) to fall by half its original value / time for half the radioactive/unstable nuclei/atoms (in a sample) to decay;

(ii)

(approximately) exponential shape;

minimum of three half lives shown;

graph correct at $\left[T_{\frac{1}{2}}, \frac{N_0}{2}\right], \left[2T_{\frac{1}{2}}, \frac{N_0}{4}\right], \left[3T_{\frac{1}{2}}, \frac{N_0}{8}\right]$;

Examiners report

[N/A]

26g. *[2 marks]*

Markscheme

temperature is a measure of the (average) kinetic energy of the molecules;

at the boiling point, energy supplied (does not increase the kinetic energy) but (only) increases the potential energy of the molecules/goes into increasing the separation of the molecules/breaking one molecule from another / *OWTTE*;

26h. *[4 marks]*

Markscheme

(energy gained by cold water is) 0.300×4180×[34.6-15.2] / 24327;
(energy lost by cooling water is) 0.012×4180×[100-34.6] / 3280;
(energy lost by condensing steam is) 0.012*L*;
1.75×10^{6}(Jkg^{-1})/
$\frac{[\text{theirenergygainedbycoldwater} - \text{theirenergylostbycoolingwater}]}{0.012}$;

*Award **[4]** for 1.75×10^{6}(Jkg^{-1}).*
*Award **[2 max]** for an answer that ignores cooling of condensed steam.*

Examiners report

[N/A]

26i. *[2 marks]*

Markscheme

some of the energy (of the condensing steam) is lost to the surroundings;
so less energy available to be absorbed by water / rise in temperature of the water would be greater if no energy lost;

Examiners report

[N/A]

27a. *[2 marks]*

Markscheme

defined from the equation of state of an ideal gas *PV=nRT*;
all symbols (*PVnT*) correctly identified;

Examiners report

[N/A]

27b. *[1 mark]*

Markscheme

390/391 K;

Examiners report

[N/A]

27c. *[2 marks]*

$$= \left(P\Delta V = 2.32 \times 10^{5} \times 2.20 \times 10^{-3} = \right) 510\text{J}$$
$$= (760 + 510 =)\, 1.27 \times 10^{3}\text{J}$$

-3

Examiners report

[N/A]

27d.

[2 marks]

Markscheme

an adiabatic change is one in which no (thermal/heat) energy is transferred between system and surroundings / no energy enters/leaves system;
a rapid compression means that there is insufficient time (for energy transfer) / *OWTTE*;

Examiners report

[N/A]

28.

[1 mark]

Markscheme

B

Examiners report

[N/A]

29.

[1 mark]

Markscheme

C

Examiners report

[N/A]

30.

[1 mark]

Markscheme

D

Examiners report

[N/A]

31.

[1 mark]

Markscheme

A

Examiners report

[N/A]

32.

[1 mark]

Markscheme

B

Examiners report

[N/A]

33.

[1 mark]

Markscheme

D

Examiners report

[N/A]

34.

[1 mark]

Markscheme

C

Examiners report

[N/A]

35.

[1 mark]

Markscheme

A

Examiners report

A minority of candidates at both levels opted for response C believing that internal energy is only the kinetic energy of any substance; this is only true for ideal gases.

36.

[1 mark]

Markscheme

B

Examiners report

37.

[1 mark]

Markscheme

B

Examiners report

38. *[1 mark]*

Markscheme

B

Examiners report

This is a question straight from the Guide which states that internal energy consists of the intermolecular potential energy of the molecules of a substance plus their random kinetic energy.

39. *[1 mark]*

Markscheme

C

Examiners report

[N/A]

40. *[1 mark]*

Markscheme

A

Examiners report

41a. *[2 marks]*

Markscheme

(Q) energy transferred between two objects (at different temperatures);
(U) (total) potential energy and (random) kinetic energy of the molecules/particles (of the gas);

Examiners report

Few candidates were able to explain thermal energy was the energy transfer between two objects at different temperatures. Many knew the definition of internal energy but a high percentage omitted to mention the potential energy (probably assuming that the gas was ideal).

41b. *[10 marks]*

Markscheme

(i) use of area within cycle;
each large square has work value of 250 (J);
estimate (16 x 250=)4000 (J); (allow 3600 − 4100)
*Award **[3]** for same outcome with small squares of area 10 (J).*

(ii) (work is done by the gas because) area under expansion is greater than that under compression/pressure during expansion is greater than during compression;

(iii) clear attempt to compare two *PV* values;
evaluate two *PV* values correctly *eg* 75 x 80= 6000 and 200 x 30= 6000;

(iv) use of *PV* =*nRT* or equivalent;
1350/1330 (K);

(v) both changes are isochoric/isovolumetric/constant volume changes;
B: temperature/internal energy increases, D: temperature/internal energy decreases;
B: thermal energy/heat input (to system), D: thermal energy/heat output (from system);
B: pressure increases, D: pressure decreases;

Examiners report

(i) Many candidates appeared to attempt to calculate area without actually saying what they were doing; although this was obvious when they referred to the area of a square, in many case it was not obvious and marks were lost when the candidates technique produced an answer out of tolerance. In examples like this there will be a reasonable tolerance for the area and it is not expected that candidates will waste considerable time in counting the small squares.

(ii) Although some candidates were aware that a clockwise cycle applies to net work done by the gas, this does not explain the choice. Simply saying that the area under the expansion was greater than the area under the compression was all that was needed.

(iii) This part was mostly well done by candidates. It is accepted, in line with SL A1, that showing constancy of two PV values does not prove that the change is isothermal; however in terms of deducing that the change is isothermal this technique is fine – that is, the candidates are told that it is isothermal and they are simply illustrating that this is the case. Often examiners will expect three values to be taken in questions such as this.

(iv) This part was well done by those many candidates who used any appropriate variant of the ideal gas equation to calculate the temperature.

(v) The large majority of candidates did well here although a minority were deducted marks when they used contradictory statements such as isochoric and compression or expansion.

42a. *[2 marks]*

Markscheme

internal energy:

the sum of the potential and the (random) kinetic energy of the molecules/particles of a substance;

Allow “potential and kinetic” for “sum”.

thermal energy:

the (non-mechanical) transfer of energy between two different bodies as a result of a temperature difference between them;

Examiners report

There was a widespread failure to respond to the command term. “Distinguish” implies some type of comparison but often candidates simply gave definitions (which could in this mark scheme attract full credit). However, only a few received two marks. Explanations of the meaning for thermal energy were weak and usually failed to make clear the need for a temperature difference in the transfer of the energy.

42b. *[4 marks]*

Markscheme

(i) (ΔU)=0.25×4.2×10^3×27(=2.835×10^4J);
=2.8×10^4(J);
*Award **[2]** for a bald correct final answer of 28 (kJ)*
*Award **[1 max]** if correct energy calculated but the answer goes on to work out a further quantity, for example power.*

(ii) energy transfer=[300×120] – [2.835×10^4]=7.65×10^3 (J);
rate of transfer=$\frac{7.650\times10^3}{120} = 64\,(\mathrm{W})$;
Allow ECF from (b)(i).

*Award **[1 max]** for*
$\frac{(b)(i)answer}{120}$ *where answer omits 300×120 term, however only allow this if 120 is seen. Award **[0]** for other numerators and denominators.*
Accept rounded value from (b)(i) to give 67 (W).

Examiners report

(i) Many were able to access both marks, but some lost credit by then inserting an extra final step and going part way to the solution to (ii). As these candidates did not fully understand what was meant by “change in internal energy” they could not achieve full marks for this part question.

(ii) This part question was more poorly done than (i). Incorrect solutions included: failures to subtract the 28 kJ arrived at in (b)(i), and incorrect arithmetic.

43a. *[2 marks]*

Markscheme

point molecules / negligible volume;
no forces between molecules except during contact;
motion/distribution is random;
elastic collisions / no energy lost;
obey Newton’s laws of motion;
collision in zero time;
gravity is ignored;

Examiners report

Many could only give one sensible assumption of the ideal gas kinetic model. It was very common to see the bald statement that there are no interatomic forces between the molecules. Candidates failed to give the proviso that this is not true during the collisions between molecules and with the walls of the container. Some candidates tried unsuccessfully to convince examiners that the empirical gas laws are in themselves assumptions.

43b. *[4 marks]*

Markscheme

(i) the molecular weight of argon in grams / 6.02×10^{23} argon
atoms / same number of particles as in 12 g of C-12;
(allow atoms or molecules for particles)

(ii) mass of gas = 0.040kg ;
specific heat = $\frac{Q}{m\Delta T}$ ***or*** 620 = 0.04×*c*×50;
(i.e. correctly aligns substitution with equation)
$= \left(\frac{620}{0.040\times50} =\right) 310\mathrm{Jkg^{-1}K^{-1}}$;

Examiners report

(i) Many could either define the mole of argon in terms of 12 g of carbon-12 or in terms of a correctly stated Avogadro number. Either was acceptable if clear.

(ii) Although almost all were able to identify the starting point for the calculation of the specific heat capacity of argon, a very common error was to forget that the molar mass is quoted in grams not kilograms. It was therefore common to see answers that were 1000 times too small.

43c. *[3 marks]*

Markscheme

temperature is a measure of the average kinetic energy of the molecules;
(must see "average kinetic" for the mark)

energy/momentum to move piston is provided by energy/momentum of molecules that collide with it;
the (average) kinetic energy of the gas therefore decreases;
Do not allow arguments in terms of loss of speed as a result of collision with a moving piston.

Examiners report

Explanations for the decrease in temperature of the gas on expansion were weak. The key to the explanation is that, at the molecular level, temperature is a measure of the average kinetic energy of the particles. This was often missing from the answers..

44. *[1 mark]*

Markscheme

B

Examiners report

[N/A]

45a. *[2 marks]*

Markscheme

the energy required to change the temperature (of a substance) by 1K/°C/unit degree;
of mass 1 kg / per unit mass;

Examiners report

[N/A]

45b. *[5 marks]*

Markscheme

(i) use of $mc\Delta T$;
$0.58\times c\times[180-44]=0.35\times4200\times[44-20]$;
$c=447 \text{Jkg}^{-1}\text{K}^{-1}\approx450 \text{Jkg}^{-1}\text{K}^{-1}$;

(ii) energy would be given off to surroundings/environment / energy would be absorbed by container / energy would be given off through vaporization of water;
hence final temperature would be less;
hence measured value of (specific) heat capacity (of iron) would be higher;

Examiners report

[N/A]

46a. *[3 marks]*

Markscheme

internal energy:
total energy of component particles (in the human);
comprises potential energy + (random) kinetic energy;

temperature:
measure of average kinetic energy of particles;
indicates direction of (natural) flow of thermal energy;
internal energy measured in J and temperature measured in K/°C ; *(both needed)*
(accept alternative suitable units)

Examiners report

[N/A]

46b. *[2 marks]*

Markscheme

total energy lost$=2.3\times10^{6}\times1.8(=4.14\times10^{6}\text{J})$;
1.2 kW;

Examiners report

[N/A]

47. *[3 marks]*

Markscheme

internal energy:
total energy of component particles (in the human);
comprises potential energy + (random) kinetic energy;

temperature:
measure of average kinetic energy of particles;
indicates direction of (natural) flow of thermal energy;
internal energy measured in J and temperature measured in K/°C ; *(both needed)* {*(accept alternative suitable units)*

Examiners report

[N/A]

48a. *[8 marks]*

Markscheme

(i) in water, molecules are able to move relative to other molecules, less movement possible in ice / in water, vibration and translation of molecules possible, in ice only vibration;
in liquid there is sufficient energy/vibration (from latent heat) to break and re-form inter-molecular bonds;

(ii) mass of ice$=70000\times35000\times240\times920(=5.4\times10^{14}$kg);
energy to raise ice temperature to 0°C$=5.4\times10^{14}\times2.1\times10^{3}\times35(=3.98\times10^{19}$J);
energy to melt ice$=5.4\times10^{14}\times3.3\times10^{5}(=1.8\times10^{20}$J);
total$=2.2\times10^{20}$J

(iii) energy incident$=450\times70000\times35000(=1.1\times10^{12}$Js^{-1}m^{-2});
energy available for melting$=1.1\times10^{12}\times0.2(=2.2\times10^{11}$J);
time $=\left(\frac{2.2\times10^{20}}{2.2\times10^{11}}=\right)9.9\times10^{8}\text{s}$ ***or*** 32 years;

Examiners report

[N/A]

48b. *[2 marks]*

Markscheme

average albedo of ocean much smaller than (snow and) ice;
so average albedo (of Earth) is reduced;

Examiners report

[N/A]

49. *[1 mark]*

Markscheme

A

Examiners report

[N/A]

50. *[1 mark]*

Markscheme

D

Examiners report

Many candidates opted for C. It should be stressed that the molecules of an ideal gas are regarded as having zero potential energy. This caught out many candidates in paper two as well and clearly needs to be reiterated to the candidates.

51. *[1 mark]*

Markscheme

A

Examiners report

52. *[1 mark]*

Markscheme

B

Examiners report

As many teachers noted there was no correct answer to this question as the word ‘average’ was omitted from the stem leading a significant number of candidates to opt for D. This question was, therefore, discounted from both SL and HL.

53a. *[3 marks]*

Markscheme

internal energy is the total kinetic and potential energy <u>of the molecules</u> of a body;
thermal energy is a (net) amount of energy transferred between two bodies;
at different temperatures;

Examiners report

Few could repeat the Subject Guide definition of internal energy and relate it to that of the molecules or atoms of the substance under discussion. Understanding of thermal energy was very limited with a widespread failure to describe it in terms of transferred energy. Candidates evidently struggle with this concept.

53b. *[2 marks]*

Markscheme

the internal energy of the iron is equal to the total KE plus PE of the molecules; the molecules of an ideal gas have only KE so internal energy is the total KE of the molecules;

Examiners report

The distinction between internal energy of a solid and an ideal gas is not well understood by candidates. The emphasis is on the word “ideal” where no potential energy issues arise. Candidates were poor in their descriptions and explanations.

53c. *[4 marks]*

Markscheme

(i) $60 \times [\theta - 45]$;

(ii) $(2.0 \times 10^3 \times 29) = 5.8 \times 10^4$ J;

(iii) $60 \times [\theta - 45] = 5.8 \times 10^4$;
$\theta = 1000$°C; (*allow 1010°C to 3 sig fig*)

Examiners report

The three sub-sections of this question led towards a determination of the final energy when iron at high temperature is added to cold water in a container. There was confusion over both units and ideas. In (i) both K and °C appeared, in (ii) many answers of 29°C were presented for the increase in the internal energy of the water, and in (iii) there were further errors in temperature units and significant errors. Only about half the candidates were able to work towards a full answer in (iii).

54.

[1 mark]

Markscheme

A

Examiners report

[N/A]

55.

[1 mark]

Markscheme

A

Examiners report

[N/A]

56a.

[1 mark]

Markscheme

the area under the curve;

Examiners report

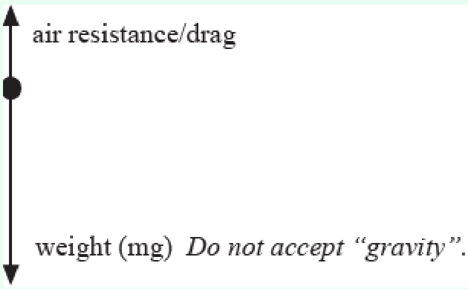
[N/A]

56b.

[7 marks]

Markscheme

(i) arrows as shown, with up arrow shorter;



(ii) drawing of tangent to curve at t = 2.0 s;
calculation of slope of tangent in range 3.6 − 4.4ms^{-2} ;
*Award **[0]** for calculations without a tangent but do not be particular about size of triangle.*

(iii) calculation of F = ma = 0.50 × 4 = 2N
R(= mg −ma = 0.50×9.81− 0.50× 4) ≈ 3N;

(iv) the acceleration is decreasing;
and so R is greater;
or
air resistance forces increase with speed;
since speed at 5.0 s is greater so is resistance force;

Examiners report

[N/A]

56c. *[6 marks]*

Markscheme

(i) loss of potential energy is $mg\Delta h$=0.50×9.81×190=932J;
gain in kinetic energy is $\frac{1}{2}mv^2 = \frac{1}{2}0.50 \times 25^2 = 156\text{J}$;
loss of mechanical energy is 932–156;
≈780J

(ii) $mc\Delta\theta$=780J;
$\Delta\theta = \left(\frac{780}{0.5 \times 480}\right) \approx 3\text{K}/3^\circ\text{C}$;

(iii) all the lost energy went into heating just the ball / no energy transferred to surroundings / the ball was heated uniformly;

Examiners report

[N/A]