Q1.

1 **(a)** Atoms which have the same number of protons (or same element) but different numbers of neutrons (1) **[1]**

(b) **(i)** ^{35}Cl (1)

(ii) $H^{37}Cl$ (1) **[2]**

(c) H Cl line at 36 has rel. abundance of 90 } (1)
38 30

These show ^{35}Cl and ^{37}Cl in ratio 3:1 (1)
[or use of 35 and 37] **[2]**

(d) Mean of the two isotopes $\frac{3 \times 35 + 1 \times 37}{4} = 35.5$ (1) **[1]**

[Total: 6]

Q2.

1 **(a)** same proton no./atomic no./no. of protons **(1)**
different mass no./nucleon no./no. of neutrons **(1)** **[2]**

(b)

	number of		
isotope	protons	neutrons	electrons
^{56}Fe	**26**	**30**	**26**
^{59}Co	**27**	**32**	**27**
	(1)	**(1)**	**(1)**

give one mark for each correct column
allow **(1)** if no column is correct but one row is correct **[3]**

(c) (i) weighted mean/average mass
of an atom (not element) **(1)**
compared with ^{12}C **(1)**
one atom of ^{12}C has a mass of exactly 12 **(1)**
[relative to $^{1}/_{12}^{th}$ the mass of a ^{12}C atom would get 2]

or

mass of 1 mol of atoms **(1)**
compared with ^{12}C **(1)**
1 mol of ^{12}C has a mass of 12 g **(1)**

(ii) $A_r = \frac{54 \times 5.84 + 56 \times 91.68 + 57 \times 2.17}{100}$ **(1)**

$= \frac{5573.13}{100} = 55.7$ to 3 sf **(1)**

allow 55.9 if A_r is calculated using 99.69 instead of 100 **[5]**

[Total: 10]

Q3.

(e) (i) an acid that is partially dissociated into ions **(1)**

(ii) $H_2S(g) + H_2O(l) \rightarrow H_3O^+(aq) + HS^-(aq)$

or

$H_2S(g) + aq \rightarrow H^+(aq) + HS^-(aq)$

or

$H_2S(aq) \rightarrow H^+(aq) + HS^-(aq)$
equation **(1)** state symbols **(1)** **[3]**

Q4.

3 (a)

	1s	2s	2p	3s	3p	3d	4s	4p	4d	
Ca	2	2	6	2	6	0	2	0	0	[1]
Sr^{2+}	2	2	6	2	6	10	2	6		[1]

[2]

(b) (i) more shells of electrons [1]

(ii) outermost shell has been removed [1]

(iii) outermost electrons are further from nucleus/there are more shells [1]
increased shielding [1] **[4]**

Q5.

2 (a) $F(g) \rightarrow F^+(g) + e^-$

correct equation (1)

correct state symbols (1) [2]

(b) from Na to Ar, electrons

are added to the same shell/have same shielding (1)

are subject to increasing nuclear charge/proton number (1)

are closer to the nucleus **or** atom gets smaller (1) [3]

(c) (i) Al and Mg

in Al outermost electron is in 3p rather than 3s (1)

3p electron is at higher energy
or is further away/is more shielded from nucleus (1)

(ii) P and S

for P 3p sub-shell is singly filled
and for S one 3p orbital has paired electrons (1)

paired electrons repel (1) [4]

Q6.

1 (a) Al $1s^2\ 2s^2 2p^6\ 3s^2 3p^1$ (1)

Ti $1s^2\ 2s^2 2p^6\ 3s^2\ 3p^6\ 3d^2\ 4s^2$ **or**

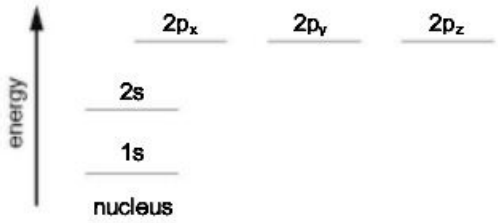
$1s^2\ 2s^2 2p^6\ 3s^2\ 3p^6\ 4s^2 3d^2$ penalise any error (1) [2]

(a) (i) $Ca^{+}(g) \rightarrow Ca^{2+}(g) + e^{-}$ equation (1)
state symbols (1)

(ii) 590 + 1150 = +1740 kJ mol^{-1} (1) [3]

Q7.

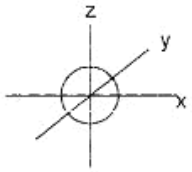
1 (a) (i)



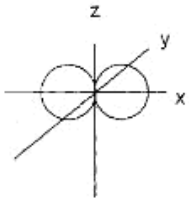
correct 1s and 2s (1)

correct $2p_x$, $2p_y$ and $2p_z$ (1)

(ii)



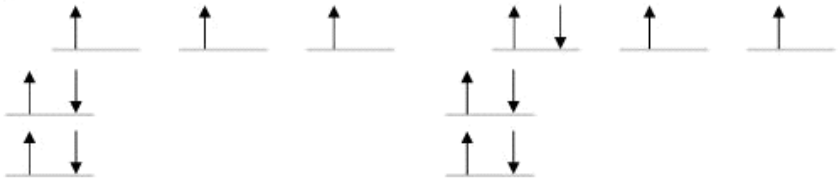
spherical s orbital (1)



double lobed p orbital along one axis (1)

both orbitals correctly labelled (1)

(iii)



nitrogen oxygen

both correct (1) [6]

(b) (i) N 1400 kJ mol^{-1} O 1310 kJ mol^{-1} **both** (1)

(ii) N is all singly filled 2p orbitals **or** O has one filled/paired 2p orbital (1)
these paired 2p electrons in the O atom repel one another (1) [3]

[Total: 9]

Q8.

2 **(a)** the energy required to remove one electron from each atom (1)
in one mole of gaseous atoms (1)
or
the enthalpy change in kJ mol^{-1} for (1)
$M(g) \rightarrow M^+(g) + e^-$ (1) [2]

(b) **(i)** first ionisation energy decreases down Group 1 (1)
outermost electron is further from nucleus
or has greater shielding (1)

(ii) outermost electron experiences less attraction
or formation of M^+ cation becomes easier down Group 1 (1) [3]

(c) **(i)** $n(Li) = \frac{0.83}{6.9} = 0.12$ (1)

(ii) 2 mol Li $\rightarrow$ 1 mol H_2
0.12 mol Li $\rightarrow \frac{1 \times 0.12}{2} = 0.06$ mol H_2 (1)
volume of $H_2 = 0.06 \times 24.0 = 1.44 dm^3$ (1)

(iii) 2 mol Li $\rightarrow$ 2 mol LiOH
0.12 mol Li $\rightarrow$ 0.12 mol LiOH in 0.50 dm^3 (1)
$[LiOH] = \frac{0.12 \times 1}{0.50} = 0.24$ mol dm^{-3} (1) [5]

(d) sodium burns with a yellow flame
or white solid formed
or colour of chlorine disappears (1)

$2Na + Cl_2 \rightarrow 2NaCl$ (1) [2]

[Total: 12]

Q9.

1	(a)	Energy required to remove one electron from each atom		(1)	
		in one mole of		(1)	
		gaseous atoms of an element		(1)	
		('Energy change when one mole of gaseous atoms loses one mole of electrons' would score all three marks.)			[3]
	(b)	$X^+(g) \rightarrow X^{2+}(g) + e^-$	equation	(1)	
			state symbols	(1)	[2]
	(c)	Group 5		(1)	
		sharp rise in successive ionisation energies between 5th and 6th IEs		(1)	
		indicating change to a different shell/energy level **or** outer shell contains 5 electrons		(1)	[3]
	(d)	down the Group			
		atomic radii increase/ outer electrons are increasingly further away		(1)	
		electrons are added to new shells/more shells		(1)	
		more shielding		(1)	
		despite increase in nuclear charge		(1)	[4]
					[Total: 12]

Q10.

1 **(a)** **(i)** electron (1)

(ii) towards the positive pole (1)

(iii) electron has negative charge (1)

electron has very small mass (1) **[4]**

(b) **(i)** the number of protons in the nucleus of an atom (1)

(ii) the nucleus usually contain protons and neutrons (1) **[2]**

(c) neutrons are uncharged (1)

and are not repelled by protons in the nuclei of atoms (1) **[2]**

(d) no change (1)

new atom/isotope formed has the same electronic configuration as the original element (1) **[2]**

[Total: 10]

Q11.

1 **(a)** same proton number/atomic number (1)
different mass number/nucleon number (1) [2]

(b) $A_r = \frac{(24 \times 78.60) + (25 \times 10.11) + (26 \times 11.29)}{100}$ (1)

$= \frac{1886.4 + 252.75 + 293.54}{100} = \frac{2432.69}{100}$

which gives A_r = 24.33 (1)
penalise (–1) for misuse of significant figures [2]

(c)

isotopes	number of		
	protons	neutrons	electrons
^{226}Ra	88	138	88
^{238}U	92	146	92

allow **one mark** for each correct column (3 × 1)
if there are no correct columns,
allow **maximum one mark** for a correct row [3]

(d) (i) Ra^{2+} (1)

(ii) less than (502 + 966)
allow answers in the range 1000–1400 kJ mol^{-1} (1)

ionisation energies decrease down the Group
or must be less than IE for Ba → Ba^{2+}
or size of atom increases down Group/
electrons are further away from nucleus
or there is increased shielding down Group (1)

allow ecf on answer to **(i)** [3]

[Total: 10]

Q12.

1 (a) atoms of the same element / with same proton (atomic) number / same number of protons (1)
different numbers of neutrons / nucleon number / mass number (1) [2]

(b)

isotope	no. of protons	no. of neutrons	no. of electrons
^{24}Mg	12	12	12
^{26}Mg	12	14	12

each correct row (1) [2]

(c) $A_r = \frac{24 \times 78.60 + 25 \times 10.11 + 26 \times 11.29}{100}$ (1)

$= \frac{1886.40 + 252.75 + 293.54}{100}$

gives 24.33 to 4 sig fig (same as data in question)

do not credit wrong number of sig figs **or** incorrect rounding up/down (1) [2]

(d) $Mg + Cl_2 \rightarrow MgCl_2$ (1) [1]

(e) **(i)** $n(Sb) = \frac{2.45}{122} = 0.020$ (1)

(ii) mass of Cl in **A** = 4.57 – 2.45 = 2.12 g (1)

$n(Cl) = \frac{4.57 - 2.45}{35.5} = \frac{2.12}{35.5} = 0.06$

allow ecf as appropriate (1)

(iii) Sb : Cl = 0.02 : 0.06 = 1:3
empirical formula of **A** is $SbCl_3$ (1)

(iv) $2Sb + 3Cl_2 \rightarrow 2SbCl_3$ (1) [5]

(f) **(i)** ionic (1)

(ii) covalent (1)
not van der Waals' forces [2]

[Total: 14]

Q13.

2 **(a)** $S(g) \rightarrow S^+(g) + e^-$
correct equation (1)
correct state symbols (1) [2]

(b) **from Na to Ar,**
electrons are added to the same shell/have same shielding (1)
electrons are subject to increasing nuclear charge/proton number (1)
electrons are closer to the nucleus **or** atom gets smaller (1) [3]

(c) **(i)** **Mg and Al**
in Mg outermost electron is in 3s **and**
in Al outermost electron is in 3p (1)

3p electron is at higher energy **or**
is further away from the nucleus **or**
is more shielded from the nucleus (1)

(ii) **S and P**
for S one 3p orbital has paired electrons **and**
for P 3p sub-shell is singly filled (1)

paired electrons repel (1) [4]

Q14.

1 **(a)** same proton number/atomic number (1)
different mass number/nucleon number (1) [2]

(b) $A_r = \frac{(32 \times 95.00) + (33 \times 0.77) + (34 \times 4.23)}{100}$ (1)

$= \frac{3040 + 25.41 + 143.82}{100} = \frac{3209.23}{100}$

which gives $A_r = 32.09$ (1) [2]

(c)

	number of		
isotopes	protons	neutrons	electrons
^{213}Po	84	129	84
^{232}Th	90	142	90

allow **one mark** for each correct column
if there are no 'column' marks,
allow **maximum one mark** for a correct row (3 × 1) [3]

(d) **(i)** nucleon no. is 228 (1)
proton no. is 88 (1)

(ii) Ra **not** radium (1) [3]

[Total: 10]

Q15.

3 **(a)** $C(g) \rightarrow C^+(g) + e^-$
correct equation (1)
correct state symbols (1) [2]

(b) **(i)** **Na and Mg**
Mg has greater nuclear charge/more protons than Na (1)

in both atoms, the 3s electrons are in the same orbital/
same energy level/same shell (1)

(ii) **Mg and Al**
in Al outermost electron is in 3p rather than 3s (1)

3p electron is at higher energy **or**
is further away/is more shielded from nucleus (1)

(iii) **He and Ne**
both He and Ne have the highest nuclear charges in their Period (1)

(iv) **He, Ne, and Ar**
going down the group,

valence/outer shell electrons are farther from the nucleus (1)

there is greater shielding (1)

attraction between valence electrons and nucleus is less **or**
effective nuclear charge is less (1) [8]

(c) **(i)** **from Na to Cl**
increased nuclear charge/nuclear attraction (1)

(ii) cation has fewer electrons than atom **or**
cation has lost outer electrons **or**
cation has fewer shells (1)

but cation has same nuclear charge as atom **or**
proton number is the same (1) [3]

3 **(d)** ignore any state symbols

$MgO(s)$	+	$NaOH(aq)$			→	NO REACTION	(1)	
$MgO(s)$	+	$2HCl(aq)$			→	$MgCl_2 + H_2O$	(1)	
$Al_2O_3(s)$	+	$2NaOH(aq)$	+	$3H_2O(l)$	→	$2NaAl(OH)_4$ **or**	(1)	
$Al_2O_3(s)$	+	$2NaOH(aq)$	+	$H_2O(l)$	→	$2NaAlO_2 + 2H_2O$ **or**		
$Al_2O_3(s)$	+	$6NaOH(aq)$	+	$3H_2O(l)$	→	$2Na_3Al(OH)_6$		
$Al_2O_3(s)$	+	$6HCl(aq)$			→	$2AlCl_3 + 3H_2O$ **or**	(1)	
$Al_2O_3(s)$	+	$6HCl(aq)$			→	$Al_2Cl_6 + 3H_2O$		
$SO_2(g)$	+	$NaOH(aq)$			→	$NaHSO_3$ **or**	(1)	
$SO_2(g)$	+	$2NaOH(aq)$			→	$Na_2SO_3 + H_2O$		
$SO_2(g)$	+	$HCl(aq)$			→	NO REACTION	(1)	[6]

[Total: 19]

Q16.

1 (a) (i) from Na to Cl

nuclear charge increases (1)
electrons are in the same shell/have the same shielding (1)
nuclear attraction increases (1)

(ii) argon does not form any bonds/compounds **or**
argon exists as single atoms/is monatomic (1) [4]

(b) (i)

radius of cation/nm			radius of anion/nm		
Na^+	Mg^{2+}	Al^{3+}	P^{3-}	S^{2-}	Cl^-
0.095	0.065	0.050	0.212	0.184	0.181

(1)

(ii) cations contain fewer electrons than the corresponding atoms **or**
cations contain fewer electrons than they do protons (1)
nucleus has a greater attraction (1)

(iii) anions contain more electrons than the corresponding atoms **or**
anions contain more electrons than they do protons (1)
nucleus has a smaller attraction (1) [5]