CHEMISTRY 3.4 Paper 1

Describe properties of particles and thermochemical principles

Credits: Five

INSTRUCTIONS

Answer **ALL** questions

You may refer to a copy of the periodic table when answering these questions.

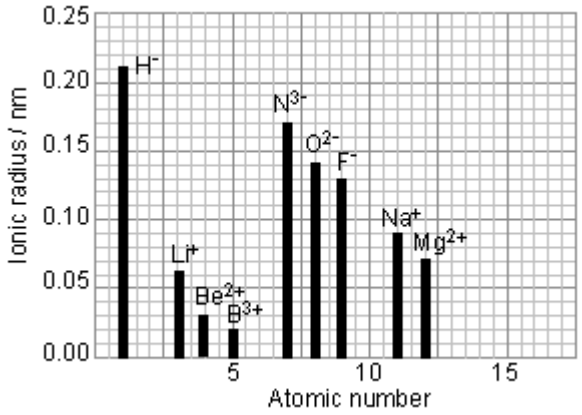
You are advised to spend about 50 minutes answering these questions.

Question One (Bursary 2003 Question 4: modified)

a **i** Describe the trend in electronegativity down Group 17 of the periodic table. A

ii A bond between Cl and Br is a polar bond. State what a polar bond is, and explain why the Cl–Br bond is polar. A M

b The relative size of the ions of some elements are shown below.



i Estimate the size of the ions of elements 13 (Al^{3+}) and 15 (P^{3-}) and plot these on the graph above. A

ii Explain why there is a large increase in size between B^{3+} and N^{3-}. A M

iii H^- and Li^+ have the same number of electrons.

Give ONE reason why H^- is bigger than Li^+. A

c The element tellurium, Te, is added to steel to improve its 'machinability'. Tellurium is in the same group of the periodic table as sulfur.

i State the number of electrons in the valence shell of a tellurium atom. A

ii Tellurium forms a compound with hydrogen. Write the formula for this compound. A

d The first ionisation energy of sulfur is 1000 kJ mol^{-1}. Circle the phrase that best describes the first ionisation energy of tellurium.

Greater than 1000 kJ mol^{-1} Less than 1000 kJ mol^{-1} Equal to 1000 kJ mol^{-1}

Give a reason for your answer. A M

Question Two (Bursary 2003 Question 1: modified)

a The electron configuration for iron can be written as $[Ar]3d^64s^2$.

i Explain what is meant by the abbreviation [Ar]. A M

ii Write the electron configuration for Fe^{2+}, using *s, p, d* notation. A

b Write balanced equations to represent the changes occurring in each of the following statements:

i The enthalpy of combustion of ethene is –1409 kJ mol^{-1}. A

ii The first ionisation energy of calcium is 596 kJ mol^{-1}. A

Question Three (Bursary 2003 Question 3: modified)

Properties of Organic Compounds

Name	Formula	*M* / g mol^{-1}	Density / g mL^{-1}	Melting point / °C	Boiling point / °C	$\Delta_f H°$ / kJ mol^{-1}	$\Delta_c H°$ / kJ mol^{-1}
Alkanes							
methane	CH_4	16.0	0.423	–182.5	–161.5	–74.0	–890
ethane	CH_3CH_3	30.1	0.545	–182.8	–88.6	–84.0	–1560
propane	$CH_3CH_2CH_3$	44.1	0.585	–187.7	–42.1	–105.0	–2220
butane	$CH_3(CH_2)_2CH_3$	58.0	0.601	–138.3	–0.5	–126.0	–2877
pentane	$CH_3(CH_2)_3CH_3$	72.1	0.621	–129.7	36.1	–147.0	–3509
hexane	$CH_3(CH_2)_4CH_3$	86.1	0.655	–95.3	68.7	–167.0	–4163
heptane	$CH_3(CH_2)_5CH_3$	100.2	0.680	–90.6	98.4	–188.0	–4817
octane	$CH_3(CH_2)_6CH_3$	114.2	0.698	–56.8	125.7	–209.0	–5470
Alkenes							
ethene	$CH_2=CH_2$	28.1	0.568	–169.1	–103.7	52.0	–1411
propene	$CH_3CH=CH_2$	42.1	0.610	–185.2	–47.7	20.0	–2058
but-1-ene	$CH_3CH_2CH=CH_2$	56.1	0.579	–185.3	–6.3	0.1	–2718
but-2-ene (*cis)*	$CH_3CH=CHCH_3$	56.1	0.595	–138.9	2.7	–7.0	–2710
but-2-ene (*trans*)	$CH_3CH=CHCH_3$	56.1	0.578	–105.6	0.88	–11.0	–2706
pent-1-ene	$CH_3(CH_2)_2CH=CH_2$	70.1	0.635	–165.2	30.0	–21.0	–3350
pent-2-ene (*cis)*	$CH_3CH_2CH=CHCH_3$	70.1	0.650	–151.4	36.9	–28.0	–3343
pent-2-ene (*trans*)	$CH_3CH_2CH=CHCH_3$	70.1	0.643	–140.2	36.4	–32.0	–3338
Alcohols							
methanol	CH_3OH	32.0	0.787	-97.7	64.7	-201.0	-726
ethanol	CH_3CH_2OH	46.1	0.785	-114.1	78.3	-235.0	-1267
propan-1-ol	$CH_3(CH_2)_2OH$	60.1	0.800	-126.2	97.2	-255.0	-2021
propan-2-ol	$CH_3CH(OH)CH_3$	60.1	0.781	-89.5	82.3	-273.0	-2006
butan-1-ol	$CH_3(CH_2)_3OH$	74.1	0.806	-89.8	117.7	-275.0	-2676
butan-2-ol	$CH_3CH_2CH(OH)CH_3$	74.1	0.802	-114.7	99.5	-293.0	-2661
2-methyl propan-1-ol	$CH_3CH(CH_3)CH_2OH$	74.1	0.798	-108.0	107.9	-283.0	-2668
2-methyl propan-2-ol	$CH_3C(CH_3)(OH)CH_3$	74.1	0.781	25.7	82.6	-313.0	-2644
pentan-1 -ol	$CH_3(CH_2)_4OH$	88.2	0.816	-78.9	138.0	-295.0	-3331
pentan-2 -ol	$CH_3(CH_2)_2CH(OH)CH_3$	88.2	0.805	-73.0	119.0	-313.0	-3317

a Give the state of butane at room temperature (25 °C). A

b When ethanol and hexane are mixed, two layers will separate out.

Name the compound that is the top layer in this mixture and give a reason for your answer. A M

c Explain the trend in the boiling points of the alkanes. A M

d Pent-1-ene and butan-1-ol have similar molar masses but different melting points. Account for the different melting points by discussing the forces of attraction between the molecules. A M E

e Use the data from the table on page 3 to calculate whether butane or octane will generate more energy per gram of compound when burnt in oxygen. A M

f Use the data from the table ($\Delta_f H°$) to calculate the energy change for the following reaction. A M

$$CH_2{=}CH_2(g) + H_2(g) \rightarrow CH_3CH_3(g)$$

Question Four (Bursary 2003 Question 6: modified)

The following article appeared in the media in 2003.

A dozen grains can kill

A dozen grains of cyanide swallowed or inhaled can kill humans. Cyanide poison (sodium cyanide) looks like salt crystals and is odourless. It is difficult to make. Hydrogen cyanide (HCN) is produced by adding a catalyst to natural gas and ammonia and heating to 1000 °C under pressure. The poison is made from this raw material. The antidote to cyanide poisoning is cobalt ethanoate.

a The reaction for the production of hydrogen cyanide is:

$$CH_4(g) + NH_3(g) \rightarrow HCN(g) + 3H_2(g) \qquad \Delta_r H^\circ = 247 \text{ kJ mol}-1$$

Calculate the bond enthalpy for the C≡N bond using the equation above and the data given below.

A M E

Bond	Bond enthalpy/kJ mol^{-1}
N — H	391
H — H	436
C — H	414

b The reaction for the production of hydrogen cyanide needs a catalyst.

Explain the role of a catalyst in a reaction. A M

Question Five (Bursary 2003 Question 7: modified)

Elements in Group 18 are very unreactive so they are sometimes called ‘inert gases’. However, compounds of Group 18 elements were first prepared in 1962, one of the first being XeF_4.

a Draw the Lewis diagrams for CF_4 and XeF_4. A M

CF_4

XeF_4

b Discuss the shapes and polarities of CF_4 and XeF_4. A M E

Question Six (Bursary 2003 Question 10: modified)

Urea, $CO(NH_2)_2$, is widely used as a fertiliser. It is manufactured by reacting carbon dioxide with ammonia. In New Zealand, these reactants are synthesised from natural gas in Taranaki.

The equation for which the enthalpy change is the enthalpy of formation of urea, $\Delta_f H°$(urea), is:

$$C(s) + \tfrac{1}{2}O_2(g) + N_2(g) + 2H_2(g) \rightarrow CO(NH_2)_2(s)$$

a Calculate the enthalpy of formation, $\Delta_f H°$, for urea, using the following information: A M E

$2NH_3(g) + CO_2(g) \rightarrow CO(NH_2)_2(s) + H_2O(g)$ $\quad \Delta_r H° = +5 \text{ kJ mol}^{-1}$

$CO(g) + H_2O(g) \rightarrow CO_2(g) + H_2(g)$ $\quad \Delta_r H° = -41 \text{ kJ mol}^{-1}$

$\tfrac{1}{2}N_2(g) + {}^3/_2H_2(g) \rightarrow NH_3(g)$ $\quad \Delta_f H° = -46 \text{ kJ mol}^{-1}$

$C(s) + \tfrac{1}{2}O_2(g) \rightarrow CO(g)$ $\quad \Delta_f H° = -111 \text{ kJ mol}^{-1}$